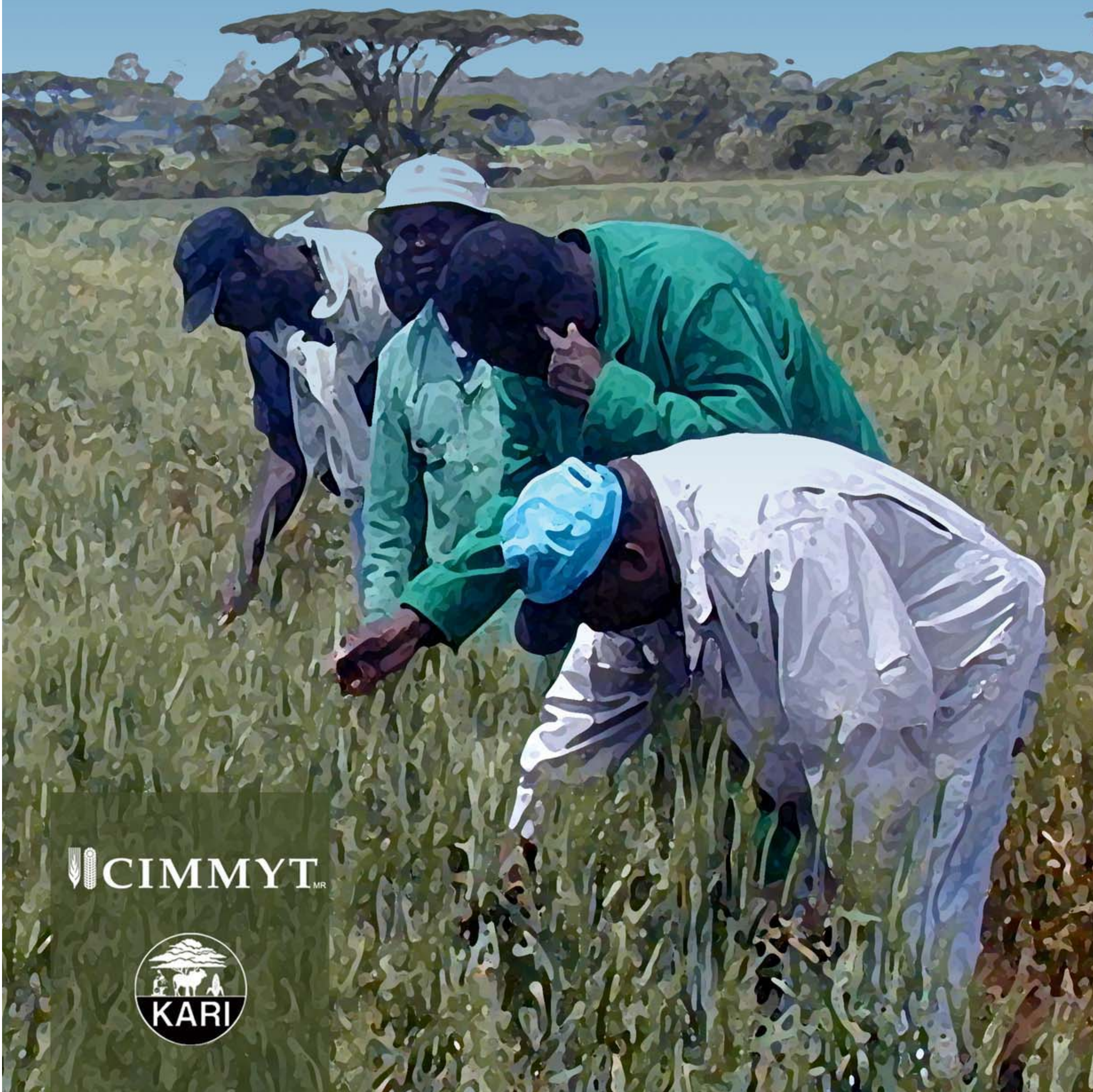
PROCEEDINGS

of the 12th Regional Wheat Workshop for Eastern, Central and Southern Africa

Nakuru, Kenya, 22–26 November 2004



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Correct citation: M.G. Kinyua, J. Kamwaga, J.O. Owuoche, A. C.Ndiema, P.N. Njau, D. K. Friesen, D. Ouya (Editors) 2006. Proceedings of the 12th Regional Wheat Workshop for Eastern, Central, and Southern Africa. Nakuru, Kenya, 22–26 November 2004. Mexico, D.F.; CIMMYT and KARI

ISBN:	970-648-135-4
AGROVOC Descriptors	Triticum durum; Triticum aestivum; Varieties; Plant breeding; Breeding methods; Plant production; Production increase; Plant diseases; Food production; Food security; Production factors; Economic policies; Pests of plants; Pest resistance; Yield increases; Kenya; Ethiopia; Tanzania; Sudan; Africa
Additional Keywords	CIMMYT; KARI
AGRIS Category Codes	F30 Plant Genetics and Breeding
	E14 Development Economics and Policies
	H20 Plant Diseases
Dewey Decimal Classification	633.116

Introduction

Like its predecessors, the 12th Regional Wheat Workshop for Eastern, Central and Southern Africa, held at Merica Hotel in Nakuru, Kenya , 22–26 November 2004 provided a forum where wheat scientists from the region could come together to exchange their results, views, and ideas on the way forward in securing this important food crop.

Ethiopia has an annual production of 1,600,000 metric tons, of both bread and durum wheats, produced mainly on small scale farms. A large gap exists between wheat production and demand in Ethiopia, and the country relies heavily on imports of nearly 800,000 metric tons each year. Kenya’s domestic bread wheat requirement, which currently stands at 720,000 tons p.a., is projected to reach 1 million tons by 2010. Like Ethiopia, Kenya produces less wheat than she needs, importing some 400,000 tons each year. Clearly therefore, increased wheat production in the region—through approaches such as breeding, agronomy, crop protection and improved economic policies, is not just desirable, but essential for the food security of millions of people.

This proceedings presents valuable new information from research conducted in Kenya (11 articles), Ethiopia (9), The Sudan (2), and Tanzania (1), and is organized into four sections, namely Agronomy, Breeding, Protection, And Economics.

The Agronomy section contains 6 papers, ranging in subject mater from water and fertilizer use efficiency in wheat varieties, to a comparison of field pea and barley as break crops in wheat farming. Breeding is the largest section, with 14 articles, including results from a three-year survey of the wheat stem rust situation in Kenya. The Protection section, with 3 articles, reports on the chemical management of weeds, and the Russian wheat aphid *Diuraphis noxia*—a new and damaging pest in the region. Results from a survey of the natural enemies of *D. noxia* are also presented, as the starting point for designing a biological control strategy for the aphid. In his economics article, Professor Abbas Elsir M. Elamin deals with the financial and economic profitability of wheat production in The Sudan, and its international competitiveness. The comprehensive analysis discusses government reform policies in the 1990s, and their role in wheat production, consumption and input use from that time to the present.

We believe that this volume represents an important contribution to the regional and global knowledge bases on wheat production and economics, and that a better understanding of the subject matter will contribute to the ultimate goal of improved livelihoods for the people of Africa.

Romano Kiome, PhD
Permanent Secretary, Ministry of Agriculture

Acknowledgments

The Workshop organizers would like to acknowledge the contributions of several institutions and individuals towards the success of the workshop, and the publication of this proceedings.

We thank Monsanto, Bayer Crop science, and Osho chemicals, for funding the workshop; KARI and CIMMYT for technical and administrative support; and all the workshop participants, for their cooperation during all stages, starting with the preparation and presentation of the papers, to their review/revision for publication.

CIMMYT reviewers Karim Ammar, Hans-Joachim Braun, Jose Crossa, Hugo De Groote, Etienne Duveiller, Augustine Langyintuo, Ivan Monasterio, Wilfred Mwangi, Tom Payne, Javier Pena, Matthew Reynolds, Ken Sayre, Ravi Singh, Richard Trethowan, and Pat Wall, provided thorough and constructive comments on the manuscripts, including suggestions for improvement. This was a valuable contribution towards seeing the proceedings to completion, for which we are very grateful.

Dr. Miriam Kinyua
Chair, Organizing Committee

Contents

Part 1. AGRONOMY

Effect of Nitrogen Fertilizer Levels and Varieties on Gluten Content and Some Rheological Characteristics of Durum Wheat Flour

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Abstract—Improved gluten and rheological characteristics of durum wheat (*Triticum durum* Desf) have recently received increased attention due to their positive effect on the quality of pasta products. An experiment was conducted at Debre Zeit and Akaki in the Central Highlands of Ethiopia, during the 2000/01 cropping season, to study the influence of nitrogen fertilization levels (0, 30, 60, 90 and 120 $KgNha^{-1}$) on gluten content and some rheological characteristics (dough resistance, expansion and extensibility) of five durum wheat varieties at Akaki and Debre Zeit. At Debre Zeit, gluten content significantly varied ($P<0.05$) depending on wheat genotype (variety) and nitrogen fertilizer levels, but at Akaki only varietal differences were significant. Nitrogen level increment consistently increased wet gluten content of varieties at Debre Ziet and; the highest nitrogen level, 120 $Kgha^{-1}$, gave significantly higher wet gluten percent 29.5 % than all other treatment levels, except 90 $Kgha^{-1}$ (27.3%). Tob 66 (30.8%) had the highest wet gluten content followed by Foka (27.5%). At Akaki, Tob 66 was the highest (24.9%), followed by Boohai (22.4%). The studied rheological characteristics at Debre Zeit showed that nitrogen fertilizer application had no effect on either of the traits (dough resistance and extensibility), but varietal differences were observed in dough resistance. Therefore, durum wheat quality improvement should concentrate both on selection of appropriate varieties and management practices such as nitrogen fertilizer application. Further study on input-responsive semi dwarf varieties is recommended.

Introduction

Durum wheat is used for pasta production because of its hard grain texture, amber color, and other grain quality traits related to endosperm protein. Increasing grain protein concentration and improving other grain quality traits have been the major objectives in most varietal development processes (Metho, Hammes and Beer, 1997). This is because the processing quality of wheat is largely dependent on the amount and quality of endosperm protein. Grain protein content affects milling and other industrial qualities of wheat. As a result, premiums are commonly paid for protein levels above base line (Woolfolk *et al.*, 2002).

Gluten is an important endosperm protein that affects pasta quality. It is a visco-elastic component of wheat dough responsible for physical dough properties (C'uric *et al.*, 2001). Due to its strong relation with greater cooked firmness and increased tolerance to overcooking, strong gluten varieties are preferred (Josephides *et al.*, 1987). Besides gluten content, rheological characteristics that measure gluten quality are also important criteria of selection for quality durum wheat. D'Egidio *et al.* (1990) have shown that Alveogrphic parameters are excellent indicator of durum wheat gluten properties.

Quality durum wheat grain used for production of pasta is achieved by selection of appropriate variety, environment and management practices (Rharrabti *et al.*, 2001). Under high rainfall and low soil fertility conditions grain protein production is limited (Simmonds, 1989). The effect of environment and management methods, especially availability of nitrogen in the soil during ripening, on vitreousness of durum wheat has been reported (Mosconi and Bozzini, 1973; Ottman *et al.*, 2000). Numerous authors have obtained improved grain protein upon intensive nitrogen fertilization (Geleto *et al.*, 1996; Gashawbebeza *et al.*, 2002; Virga *et al.*, 2003). The work of Hadjichristodoulou (1979) showed significant effects of nitrogen fertilization, genotype and location on vitreousness, a physical grain quality correlated with protein content, of durum wheat. Dexter *et al.* (1982) also found significant difference between varieties for several quality traits at different nitrogen fertilizer levels.

Durum wheat is a traditional crop for the Ethiopian farmers. Its production however has been limited to locally made foods. The current increasing of food processing industries and importance of pasta products by the urban people of the country has increased the importance of quality durum wheat production.

The objective of this experiment was, therefore, to evaluate the effect of nitrogen fertilizer and varieties on gluten content and some rheological properties of durum wheat flour.

Materials and Methods

A field experiment was conducted during the 2000/01 cropping season under rain-fed conditions at two locations in the Central Highlands of Ethiopia (Debre Zeit and Akaki). Debre Zeit (8^o 44'N, 39^o 02'E) is mid-highland (1900 m.a.s.l.) characterized by moderate rainfall (851mm average annual rainfall); 17.9^{o}C average mean temperature and Pellic Vertisol soil; and Akaki (8^o52'N, 38^o47'E) mid altitude area (2100masl) characterized by average annual rainfall of 1086mm and 15.6^{o}C average mean temperature. Five medium tall to tall durum wheat varieties viz (Kilinto, Tob66, Foka, Assasa and Boohai) that were selected for their industrial quality by the local pasta industries were planted at five different nitrogen levels (0, 30, 60, 90 and 120 kgha^{-1} N) with uniform basal application of 10kgha^{-1} phosphorus in the form of Triple Super Phosphate (TSP). The experiment was laid out in Randomized Complete Block (RCB) in factorial arrangement with three replications. The plot size was 3m x 4m (12m^2) and data was recorded from 10.4m^2. Seeding rate was 150 kgha^{-1}. Nitrogen was split applied half at planting and the remaining half at full tillering. Wet gluten content was determined from flour and was determined by gluten wash method (ICC standard No. 106/2) while rheological characteristics viz. extensibility (L in mm) and dough resistance (P=height X 1.1 in mm) were measured using Chopin Alveograph (ICC No.121) (ICC, 2000). Rheological data was taken for Debre Zeit only. Data was analyzed by ANOVA using MSTATC.

Results

Wet gluten. ANOVA showed that wet gluen content significantly varied depending on varieties, locations and; location X nitrogen level interaction was significant ($P<0.05$) but no marked difference between the nitrogen levels in the combined analysis. However, the difference between varieties and fertilizer levels were significant ($P<0.05$) at Debre Zeit. At Debre Zeit, the highest nitrogen level (120 Kgha^{-1}) had significantly higher wet gluten percent than all other treatment levels except 90 Kgha^{-1}. At Akaki, on the other hand, only varietal differences were significant (Table 1).

Varietal differences were evident at both locations. In the combined analysis Tob 66 gave the highest wet gluten content (27.9%) while the lowest was Kilinto (21.18%). The response to applied nitrogen was higher at Debre Zeit and Tob 66 also gave the highest wet gluten percent (30.8) while the least was Kilinto (22.55%). But no significant difference was observed between Boohai, Foka and Assassa.

Dough resistance. Varietal difference was significant for Dough resistance. But no marked difference between nitrogen levels was observed. Boohai (113.9) gave the highest dough resistance followed by Foka (101.5) while the least was Assassa.

Dough extensibility. This trait was not affected by the applied nitrogen fertilizer levels (Table 2). Besides, there was no statistically significant difference between varieties.

Table 1. Nitrogen fertilizer level effects on wet gluten (%) of durum wheat varieties at two locations (2000/01)

Treatment		Wet gluten		
		Debre Zeit	Akaki	Mean
Nitrogen (Kg ha^{-1})	0	24.4c	22.2	23.3
	30	26.5bc	21.8	24.2
	60	26.5bc	22.8	24.6
	90	27.3ab	21.29	24.3
	120	29.5a	20.95	25.2
	LSD (0.05)	2.543	NS	NS
	CV (%)	12.91	15.57	14.1
Variety	Boohai	27.02b	22.4ab	24.73b
	Foka	27.5b	20.65b	24.11b
	Kilinto	22.5c	19.8b	21.18c
	Tob 66	30.8a	24.93a	27.9a
	Assassa	26.2b	21.29b	21.29b

Means within a column with similar letters are not significantly different at P<0.05 by DMRT. NS = no statistically significant difference

Table 2. Effect of nitrogen levels on rheological characteristics of durum wheat flour at Debre Zeit (2000/01)

Treatment		Dough resistance (P)	Expansion (G)	Extensibility (L)	P/L
Nitrogen	0	95.6	19.35	78.8	1.1
	30	97.8	18.09	68.6	1.4
	60	93.7	19.1	76.9	1.2
	90	88.8	18.5	73.4	1.2
	120	101.7	19.27	70.1	1.4
Variety	Boohai	113.9a	20.3	78.8	1.4
	Foka	101.5ab	18.7	73.3	1.4
	Kilinto	92.5bc	18.8	74.6	1.2
	Tob66	91.8bc	18.0	68.7	1.3
	Assassa	78.1c	18.6	72.1	1.1
	LSD(0.05)	15.8	NS	NS	
CV(%)		22.59	11.6	18.64	

Means within a column with similar letters are not significantly different at P<0.05 by DMRT. NS = no statistically significant difference

Generally, nitrogen level increment increased wet gluten contents of durum wheat varieties at Debre Zeit but not on rheological characteristics (dough resistance and extensibility). The response of gluten contents was linear with the respective applications of 0, 30, 60, 90, and 120 $kgha^{-1}$. In similar studies, the positive effect of nitrogen increment on grain protein (Prima *et al.*, 1982 and Geleto *et al.*, 1996) and also on gluten content of wheat (Prima *et al.*, 1982 and Varga *et al.*, 2003) was reported.

At Akaki, on the other hand, the response to the applied nitrogen was not consistent. The work of Campbell *et al.* (1993) also showed significant contribution of environmental factors on grain nitrogen content of wheat in addition to nitrogen application. As in most grain quality traits in wheat, protein content is known to be affected by genetic and environment mainly location, fertilizer application and other management practices. The effect of nitrogen fertilizer on whole meal protein content of durum wheat was reported (Gashawbeza *et al.*, 2002). Thus this difference could be ascribed to the difference between the two locations in air temperature and degree of water-logging. Akaki is more waterlogged than Debre Zeit and could have inhibited efficient utilization of the applied nitrogen (Gashawbeza *et al.*, 2002). According to Spiertz and Devos (1983), under high temperature especially during grain filling period protein synthesis is favored. Therefore, the environment at Debre Zeit could favor protein synthesis due to its relatively higher mean temperature and less water-logging stress. Besides, no correlation between gluten content and grain yield at Debre Zeit (r=0.15) suggesting improving gluten content couldn't risk grain yield. From the result of the study, for high rainfall and waterlogged environments like Akaki, it appears that other crop management practices such as drainage of excess water and adjustment of planting dates should be studied, in addition to nitrogen application, to increase gluten content of durum wheat.

Gluten content of varieties was significant at both locations and Tob 66 had the highest while kilinto had the lowest (Table 1). As shown in Fig.1, at Debre Zeit, there is a general linear increasing trend of gluten content of varieties with increasing nitrogen level. However, the increase was sharp beyond 90 N kg/ha for Tob 66, which gave 37 % gluten content at the highest nitrogen fertilizer level. Besides, Tob 66 had consistently high wet gluten starting from the nil nitrogen treatment to the highest level and, this could suggest the efficiency of the variety in converting assimilates to protein. At Akaki on the other hand, there is no definite trend for the applied nitrogen levels and gluten content (Fig.2).

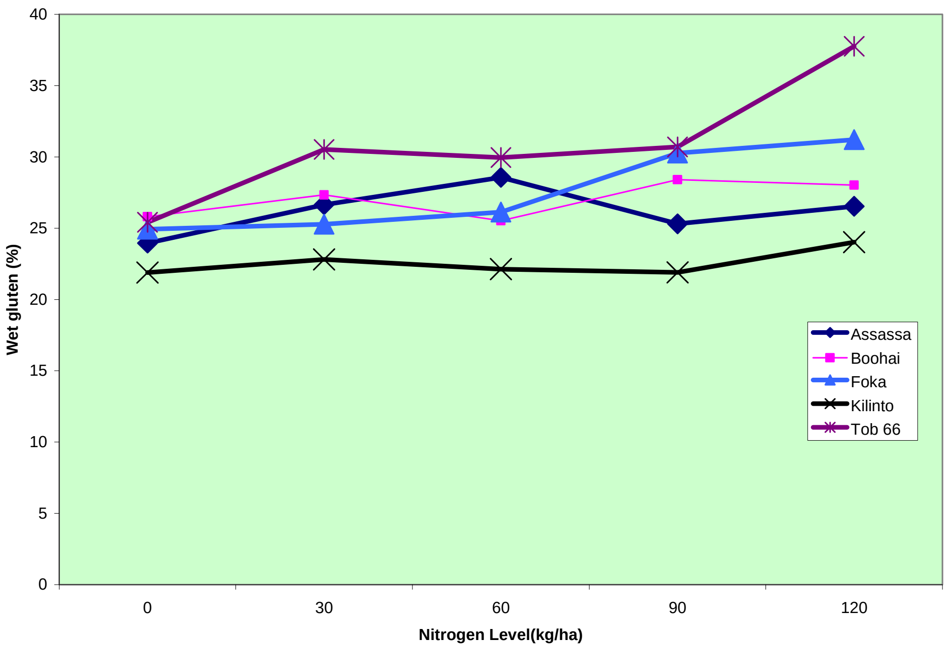

Fig. 1. Gluten Content of durum wheat varieties at different nitrogen levels at Debre Zeit

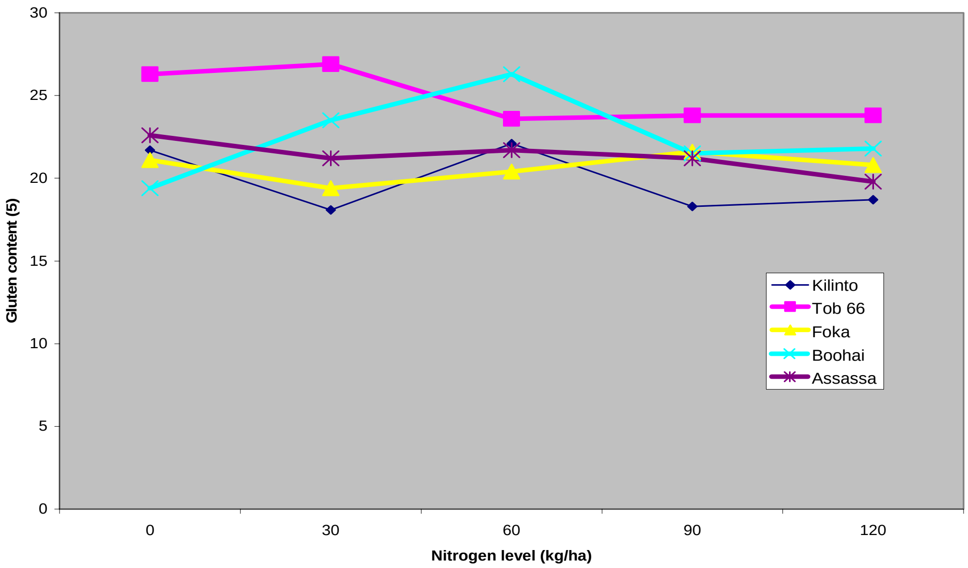

Fig. 2. Gluten Content of durum wheat varieties at different nitrogen levels at Akaki

According to ICC (2001), the rheological characteristics of a dough are expressed as the resistance of the dough to stretching and its extensibility until it begins to rupture. (Curic *et al.*, 2001) measured the physical properties of the dough of wheat flour, which primarily depend on the gluten quality. In this study, the observed non-significant difference in rheological properties due to increasing application of nitrogen fertilizer could suggest that the traits are affected more by genotype rather than by environment in which varieties are grown. Unlike this, however, Virga *et al.* (2003) reported the use of the intensive production system in bread wheat resulted in a significant improvement in dough resistance. Curic *et al.* (2001) reported gluten quality of wheat to be dependent on location and region of cultivation. In this study, varietal differences were observed in dough resistance. Assassa showed the least performance in dough resistance but it was within the acceptable range for pasta industry use. From the alveograph curve, the resistance to stretching is taken from the maximum height reached by the curve (P) while extensibility is taken from the total length (L) in the horizontal direction of the curve. Alveograph strength is taken from the area under the alveogram (W) X 10^{-3} ergs and the greater the reference area shows the higher the value of W. Alveograph strength (W X 10^{-3} ergs) and the ratio of dough resistance to extensibility (P/L) are the two commonly used indicators of quality of durum wheat rheological characteristics. When W is greater or equal to 250 and P/L ratio is greater than 0.8, the flour is considered to be obtained from strong grains (Professional pasta website, 1999). Considering P/L ratio, all varieties fall under strong gluten category.

Discussion

Increasing grain protein, especially that of gluten content of durum wheat and its strength has recently received higher attention due to the premium product produced out of it. In Ethiopia, growing selected varieties like Boohai, Foka and Tob 66 with high gluten content and acceptable dough characteristics under appropriate growing environment and; could be a good option for durum wheat growers to produce high quality durum wheat. Considering the varied agro-climatic conditions of the country, which varies within a short distance, the durum wheat growing environments should be characterized for suitability to produce industrial quality durum wheat. Regarding the studied rheological properties, the observed non-significant difference between nitrogen fertilizer levels could show selection of appropriate varieties could be more important factor than the growing environment. Although early to conclude, the observed significant differences in gluten content between 60kgha^{-1}, recommended for grain yield at Debre Zeit, and 120Kg ha^{-1} N levels in this study could suggest the need to consider economically important quality traits besides grain yield in fertilizer rate recommendations. The durum wheat breeding program should also concentrate on development of varieties with desirable chemical grain quality as well as physical dough properties required by Pasta industries. Such type of study on input responsive semi dwarf durum wheat varieties is recommended.

Acknowledgments—The authors are thankful to the technical staff of Durum Wheat Research Project of the Debre Zeit Agricultural Research Center. The authors would like to acknowledge Kality Food Share Company for quality analysis.

References

Campbell, C.A., Selles. F., Zentner, R.P. and MacConkey B.G. 1993. Nitrogen management for zero till spring wheat: disposition in plant and utilization efficiency. Commun. Soil Sci. Plant Anal 24:2223-2239

Curic, D., Karlovic, D., Tusak, D., Petrovic,B.and Dugum, J.2001. Gluten as a standard of wheat flour quality. Biotechnol.39: 353-361

D'Egidio,M.G., Mariani, B.M., Nardi,S., Novaro,P. and Cubadda,R.(1990). Chemical and technological variables and their relationships: A predictive equation for pasta cooking quality. Cereal Chem., 67,275-281

Dexter, J.E., Crowle, W.C. Matsuo, R.R. and Kosmulax, F.G. 1982. Effect of N fertilization on quality characteristics of five North American amber durum wheat varietys. 1. Can.J. Plant Sci. (Canada), 62: 90-902

Gashawbeza, B., Mekuria, B., Yaekob, A., Mitiku, D., Tadesse, T., and Kifetew, J. 2002. Effect of nitrogen fertilization on grain protein content of durum wheat varietys. Proceedings of 6th Annual Conference of Ethiopian Soil Science Society. (in press)

Geleto, T.,Tanner, D.G., Mamo, T. and Gebeyehu, G.,. 1996. Response of rainfed bread and durum wheat to source, level and timing of nitrogen fertilizer on two Ethiopian Vertisols: II. N uptake, recovery and efficiency.

Hadjichristodoulou, A. 1979. Genetic and environmental effects on vitreousness of durum wheat. Euphytica 28:711-716

International Association for Cereal Science and Technology. 2000. ICC Standards 106/2,Viena, Austria

Josephides, C.M.; Joppa, L.R. and Youngs, V.L. 1987. Effect of chromosome 1 B on gluten strength and other characteristics of durum wheat. Crop Sci. 27:212-216

Metho, A.L, Hammes, P.S. and De Beer,J.M. 1997. Effect of cultivar and soil fertility on grain yield, yield components and grain nitrogen content of wheat. African Crop Science Proceedings, Vol. 3: 695-709

Mosconi, G and Bozzini, A. 1973. Effects of application of late nitrogen fertilizer to durum wheat. Revista di Agronomia:75 (Cited in Field Crop Abstr. (1975) 4226)

Ottman, M.J., Doerge, T.A. and Edward, E.M. 2000. Durum grain quality as affected by nitrogen fertilization near anthesis and irrigation during grain fill. Agron. J. 92:1035-1041.

Prima, G.Di., Sarrino, R. and Stringi, L. 1982. Nitrogen, its role in controlling yield and quality of durum wheat in the warm arid zone of Sicily. Inst. Agron. Gen. Erbace, Italy (Cited in An Annoted Bibliography in Durum Wheat 1972-1984, ICARDA)

Rharrabti,Y., Villegas,D., Moral,L.F.G., Aparicio, N., Elhani, S. and Royo, C. 2001. Environmental and genetic determination of protein content and grain yield in durum wheat under Mediterranean conditions. Plant Breeding 120,381-388

Simmonds, D.H. 1989. Inherent quality factors in wheat. Wheat and wheat quality in Australia. CSIRO, Australia, P31-61

Spiertz, J.H.J. and Devos, N.M. 1983. Agronomical and physiological aspects of the role of nitrogen in yield formation of cereals. Plant and soil 75:379-391

Woolfolk, C.W., Raun, W.R. Johnson. G.V. Thomason, W.E., Mullen, R. W., Wynn, K. J. and K.W.freeman.2002. Influence of late-season foliar nitrogen application on yield and grain nitrogen in winter wheat. Agron.J. Agron.J. 94:429-434

Impact of Irrigation Frequency and Farmyard Manure on Wheat Productivity on a Saline-Sodic Soil in Dongola, Sudan

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Abstract—A field experiment was conducted in January 2001 and December 2002, at Dongola University Farm to investigate the effects of irrigation frequency and farmyard manure application on salt leaching and on wheat (*Triticum aestivum* L.) growth on a saline–sodic sandy loam soil classified as fine loam, mixed, hyperthermic, sodic haplocalcids. Each experiment consisted of three irrigation frequencies: 7, 14, and 21 days, and three levels of farm yard manure (F.Y.M): 0, 4.8 and 9.7 ton/fed. The quantity of water applied was proportional to the irrigation frequency and estimated from knowledge of reference evapotranspiration as predicted by Jensen and Haise equation, a crop factor and an irrigation efficiency value. Each treatment was replicated thrice in a split-plot design. Irrigation treatments accommodated main plots (7 × 18m) and manure application sub-plots (7 x 6m). Data, collected at harvest, showed that all irrigation treatments caused salt leaching, which decreased with increase of soil depth. The data did not reflect the salt distribution between irrigation intervals. The 'irrigated weekly' (F1) was the superior treatment; all forage and grain yields and their components increased with irrigation frequency.

INTRODUCTION

Northern Sudan is dominated by hyper-arid, arid and semiarid ecological zones that favor the formation of salt-affected soils (Nachtergaele, 1976; Mustafa, 1986). Dongola, in the Northern State, has two main soil orders: Entisols in the first terrace and Aridisols in the upper second and third terraces. Entisols, at the close proximity of the Nile, are fertile, non-saline, non-sodic and highly productive soils. However, they are endangered by gully erosion at the riverside and sand encroachment from the adjacent desert. Furthermore, the land is intensively cultivated and fractionated due to land tenure laws. The accessibility of good quality Nile water (Mustafa, 1973) and Nubian aquifer water prompted horizontal expansion of agriculture in salt-affected soils of the upper terraces (Aridisols). The productivity of these soils is constrained by osmotic and specific ion effects and nutritional imbalance.

Wheat (*Triticum aestivum*) is a strategic field crop in Sudan, since it constitutes the main staple food for most of the urban population. It is grown in Northern and Central Sudan. However, the new trend is to restrict its production to the northern State because of its favorable climatic environment and consequent higher yield as compared to Central Sudan. The national need for more wheat production necessitated the expansion of wheat production to salt-affected areas. The proper use of these soils requires appropriate soil and water management.

The share of the Nile water of Sudan is limited because of the large expansion of irrigated agriculture in the arid and semi-arid regions. Thus, there is need to economize on water use by increasing its efficiency.

The present research was undertaken to investigate the effect of irrigation frequency and farm yard manure on salt leaching and wheat growth on a saline–sodic Aridisol in Dongola.

Materials and Methods

A field experiment was conducted in two successive seasons (Jan. 2001 - April 2001 and Dec. 2001- April 2002) on an old alluvium saline-sodic sandy loam soil classified as fine loam, mixed, hyperthermic, sodic Haplocalcids (Soil Survey Staff 1996) at Dongola (19 N′ 29° 30′ E), 228 above sea level. The characteristics of this soil are presented in Table 1.

The treatments consisted of three irrigation frequencies:7 (F1), 14 (F2) and 21 (F3) days, and three levels of farm yard manure: 0 (M0), 4.8 (M1) and 9.7 (M3) ton/feddan (1 feddan = 0.42 ha).Each treatment was replicated three times in a split-plot design. Irrigation frequencies were designated to main plots and farmyard manure levels were accommodated in subplots. The main plots were arranged in completely randomized block design. The land was disc ploughed to 20-cm depth, and leveled using a long-span blade leveler. Nine main plots (7 × 18 m), each subdivided into three sub-plots (7 x 6 m) were constructed using earth embankments. The main plots were 1-meter apart to check lateral water movement. In the second season, the experiment was repeated in the same plots, which were harrowed before seeding.

Wheat (Wadi El Niel variety) was sown on 1st January 2001 in the first season and on 27th December 2001 in the second season. Seeds were hand dibbled in rows 20 cm apart in each subplot with a seed rate of 60-kg/ feddan. The quantity of water applied per irrigation (Q, mm) was estimated by the following relationship:

$$Q = kc \times ETp \times F \times Ei$$

Where: kc = a crop coefficient, ETp = potential evapotranspiration (mm/day), F = irrigation frequency (days) and Ei = efficiency of irrigation water application (0.7). kc was estimated using the FAO (1984) procedure, ETp was estimated using the following Jensen and Haise (1963) equations:

$$ETp = C_T (T - T_x) Rs$$

$$C_T = 1/ (C_1+7.6 C_H)$$

$$C1 = 38 - 2E/ 305$$

$$C_H= 50 mb/ (e_2-e_1)$$

$$T_x = - 2.5 - 0.14(e_2-e_1) - E/550$$

Where: T= mean air temperature (°C), E = the site elevation (m), e_1 and e_2 = the saturation vapor pressure of water (mb) at the mean monthly minimum and maximum air temperature of the warmest month in the year, respectively, Rs = short wave incoming solar radiation. Thus, the water applied at each irrigation event was proportional to the irrigation frequency and varied with the month. However all treatments received the same total amount (seasonal) of water by the time of harvest. These amounts were 856.6 and 774.7 mm in the two successive seasons. The estimated irrigation water requirement (IWR) in each month expressed in mm/day is presented in Table 2. The quantity of water applied per irrigation, Q is the product of IWR and F. Thus using Table 2, a predetermined quantity of water was applied to each subplot using Parshall flume. Three irrigations at 7-day frequency were applied to all subplots for establishing the crop before subjecting it to different irrigation regimes. The FYM was heaped, mixed with water, and composted for one month before application. The average EC of the composted FYM was 20.7 dS/m. It was applied at a predetermined rate at the third irrigation. In all treatments, P fertilizer (Triple super phosphate) was applied before sowing in the order of 80 kg/feddan. Twenty-one and 63 days after sowing, urea at the rate of 20 kg N/ feddan was applied to all treatments. Fertilizers were applied at the same rate and stage in both seasons. Manual weeding was done whenever needed.

Soil samples were collected, before sowing and at harvest, by an auger from each subplot at an increment of 0.2 m from the surface to a depth of one meter. Gravimetric moisture content, electrical conductivity (ECe) and sodium adsorption ratio (SAR) of the saturation extract were determined using standard procedures (Richards, 1954, Black, 1962).

At harvest, ten plants were selected at random from each subplot and their height, head length and leaf area index were determined. One-meter square was taken at random and the number of heads was counted. Ten heads were selected at random and threshed collectively and the number of seeds per head was counted. Thousand grains were taken randomly from each treatment and weighed. The total biomass enclosed in an area of 5 x 6 m^2 in each subplot was cut at ground level and the weight was measured and expressed in ton/feddan. The harvested crop was left to dry for a week threshed and the total gain yield was determined in ton/feddan. The crop water use (CWU) was determined by the following water balance equation:

$$CWU = I + P + \Delta M$$

where: I = Amount of irrigation water (mm), P = Amount of rainfall (mm) and ΔM = The difference between cumulative water content before sowing minus that at harvest in one meter depth (mm). The crop water use efficiency (CWUE) was calculated by dividing grain yield by crop water use (kg/m^3)

Table 1. Seedling and adult plant reactions (0-4 scale) of wheat varieties when tested with to *P. graminis* isolates from Ambo

		Isolate 1		Isolate 2	
No.	Variety	Seedling reaction	Adult plant reaction	Seedling reaction	Adult plant reaction
	Durum wheat				
1	Assassa	2	3	2	2
2	Tob-66	1	1	1	1
3	Kilinto	1	3	2	2
4	Foka	3	2	1	1
5	Gerardo	1	1	2	2
6	DZ1640	2	1	2	2
7	DY1050	2	2	2	2
8	Cocorit-71	1	3	1	3
9	Yielma	2	1	1	1
10	DZ1928-2	1	1	1	2
11	DZ 1691	2	2	2	2
12	DZ 1695-5	2	2	3	2
13	DZ1543	1	2	1	3
14	Boohai	2	2	2	2
15	Bichena	3	2	1	3
	Susceptible check	4	4	4	4
	Bread wheat				
1	Kubsa	2	4	2	3
2	Wabe	3	3	0	1
3	Galama	2	2	2	2
4	Tuse	3	3	0	1
5	Katar	3	2	2	;
6	Shina	3	3	0	2
7	Hawi	0	;	0	0
8	Simba	0	;	0	0
9	Wetera	0	0	0	;
10	HAR 2192	1	2	0	2
11	HAR 2508	3	1	;	1
12	F-H-6-1-7	1	3	;	1
13	Abola	;	2	0	0
14	Tura	2	1	0	;
	Susceptible check	4	4	4	4

Table 2. Estimated irrigation water requirements (IWR) of wheat for the two seasons in Dongola.*

Month	ETp (mm/day)	kc	ETcrop (mm/day)	IWR (mm/day)
		First season (2001)		
January	3.50	0.70	2.45	3.50
February	4.48	1.2	5.38	7.70
March	6.70	1.2	8.04	11.4
April	8.69	0.70	6.08	8.70
		Second season (2001-2002)		
December	3.64	0.60	2.18	3.10
January	3.50	0.70	2.45	3.50
February	4.48	1.10	4.93	7.00
March	6.70	1.10	7.37	10.5

* ETp = Potential evapotranspiration estimated by Jensen and Haise equation, kc = crop factor, ETcrop = Crop (actual) evapotranspiration

Results and Discussion

The results of the two seasons showed that irrigation *per se* caused significant salt leaching. Furthermore, salt leaching was not significantly affected by irrigation frequency (IF), farmyard manure (FYM) or by their interaction. Thus, the ECe data of each season were averaged over the three levels of FYM and plotted to reflect the main effects of irrigation frequency (Fig.1a and Fig.1c), and averaged over the three levels of irrigation frequency and plotted to reflect the main effects of FYM (Fig.1b and Fig.1d). In general, the effectiveness of salt leaching decreased with increase in the depth of the soil layer. It may be cautioned that this data was collected at harvest. It indicates the overall effect of treatments at harvest, but it does not reflect the salt distribution between irrigation intervals.

For the first season, the ECe redistribution profiles depicted a top desalinized zone (0 – 60 cm) and a salt accumulation zone (60-100 cm). The main effect data of IF showed that F_1, F_2 and F_3 reduced the initial ECe of the 0 – 20 cm by 89, 90 and 79 %, respectively (Fig. 1a). The reductions of the initial ECe (20-40 cm) by the same treatments in sequence were 56, 50 and 59 %, respectively. The reductions of the initial ECe (40-60 cm) by the same treatments in sequence were 22, 36 and 19 %, respectively. Irrigation with good quality Nile water (Mustafa, 1973) caused desalinization of these layers. It is evident that the efficiency of salt leaching decreased with increasing soil depth. This may be attributed partly to the gradual decrease of water available for salt leaching and consequent decrease in downward water movement with increase in soil depth, and partly due to the rise of salt by capillarity during the drying cycle.

The initial ECe (0-20 cm) was reduced by 85, 84 and 88% due to the application of M_0, M_1 and M_3, respectively (Fig.1 b). The same treatments in sequence reduced the initial ECe (20-40 cm) by 53, 58 and 54 %, respectively. At the 40 –60 cm depth, the initial ECe was reduced by 28, 26 and 23, respectively. The reductions of the initial ECe in the successive depths due to FYM were of nearly similar order of magnitude as that due to IF. The effect is conceivably an indirect effect of irrigation. FYM is expected to promote water movement, enhance root development and ramification, and thereby enhance salt leaching. However, its effect was not significant. Although, the FYM was washed before its application, its residual salinity limited its effectiveness in salt leaching. Furthermore, vaporization during composting reduced its potential as a nitrogen source.

For the second season, irrigation reduced the salinity throughout the profile (0 – 100 cm) (Fig.1c and Fig.1d). Treatments F_1, F_2 and F_3 reduced the initial ECe (0-20 cm) by 59, 80 or 84 %, respectively. M_0, M_1 and M_3 reduced the initial ECe (0-20 cm) by59, 81 and 84 %, respectively. It seems that the reduction of salinity was due mainly to irrigation and not to the application of farmyard manure. This is because the top layer is permeable and did not need FYM to promote water movement. It is evident that salt leaching was greater in the first season because of the initial higher salt level in the virgin uncultivated soil. However, trends of salt leaching were similar.

Fig. 1a indicates that F_2 was relatively more efficient in salt leaching than F_1 or F_3, since it desalinized the top 70 cm whereas F_1 and F_3 desalinized the top 60 cm. However, the effect was not significant.

The second season data showed that irrigation reduced the initial ECe throughout the soil profile (0-100 cm). This was a cumulative effect, since the experimental plots of the first season were irrigated in the second season. Treatments F_1, F_2 and F_3 reduced the initial ECe (0-20 cm) by 59, 80 and 84 %, respectively. M_0, M_1 and M_3 reduced the initial ECe at the same depth by 59, 81 and 84%, respectively. The results indicate that the effect of FYM was an indirect effect of IF. FYM did not enhance salt leaching by water because the inherent salt content of the manure was not reduced greatly and it was not incorporated in the soil. Furthermore, salt leaching indicated, as percentage decrease of the initial ECe, was greater in the first season. This is because the initial ECe in the first season was greater than in the second season.

SAR redistribution

The main effects of treatments on SAR are presented on Figs. 2a, b, c, d. Irrigation per se significantly reduced the initial SAR in the top 50 cm in the first season and through out the whole profile in the second season. In the first season, F_1 and F_2 reduced the initial SAR throughout the profile; however, the percentage decrease in SAR was minimal below 50 cm depth. F_3 increased the initial SAR in the third layer. In general, the effectiveness of dealkalization decreased with increase in soil depth. This trend was similar to desalinization and could be explained on the same manner. Dealkalization was due to dissolution of ca-bearing compounds, replacement of Na^+ by Ca^{++} ions on the exchange complex and leaching of the more mobile Na^+ ions (Mustafa and Abdelmagid, 1981). It is evident that the initial SAR of the top layer was rapidly and markedly reduced merely by leaching with water, this may attributed to the low SAR of the irrigation water and decrease in soil solution SAR values during leaching because of dilution and faster leaching of sodium compared with calcium and magnesium. Similar results were obtained in India (Leffellar and Sharma, 1977; Dahiya *et al*., 1981,1982).

For the first season, the initial SAR of the 0-20 cm was reduced by 72, 80 and 64 % by F_1, F_2 and F_3, respectively. The reductions in the second layer caused by the same frequencies in sequence were 35, 27 and 39 %, respectively. The initial SAR values of the third layer were reduced by 6 and 7 and increased by 12 % by the same frequencies in sequence. The differences between treatments were not significant. The effect of FYM on SAR redistribution profile was qualitatively similar to that of irrigation frequency. The trend of FYM effect on SAR profile was similar to that of salt leaching and it may be explained in the same manner.

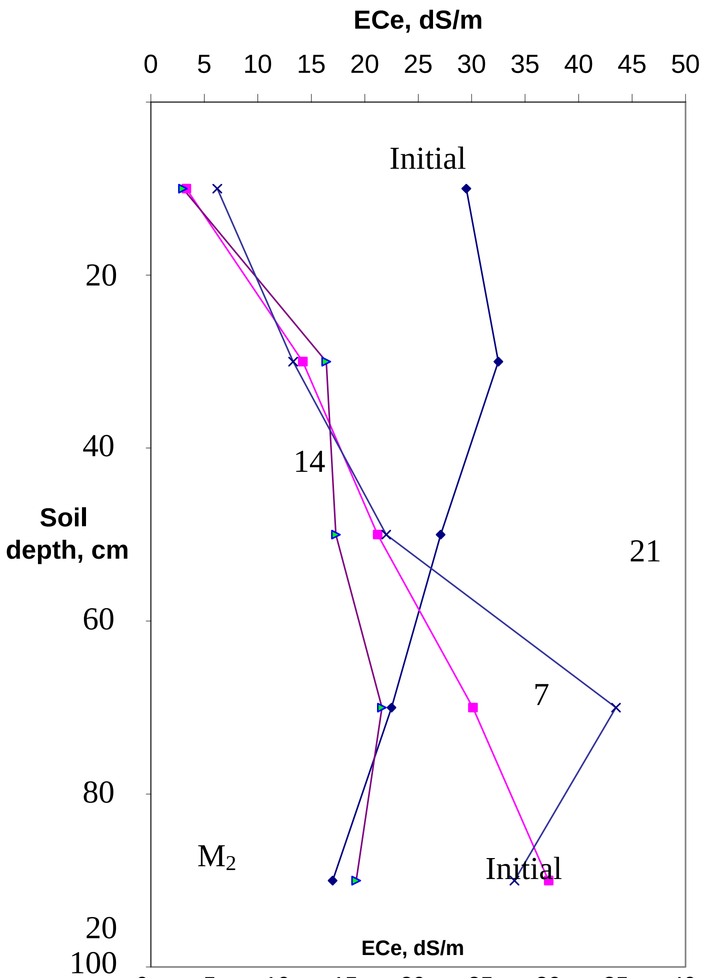

Fig. (1a) Mean electrical conductivity (dS/m) profile as affected by irrigation frequency (days) at the end of the first season (Dec. 2000- April 2001)

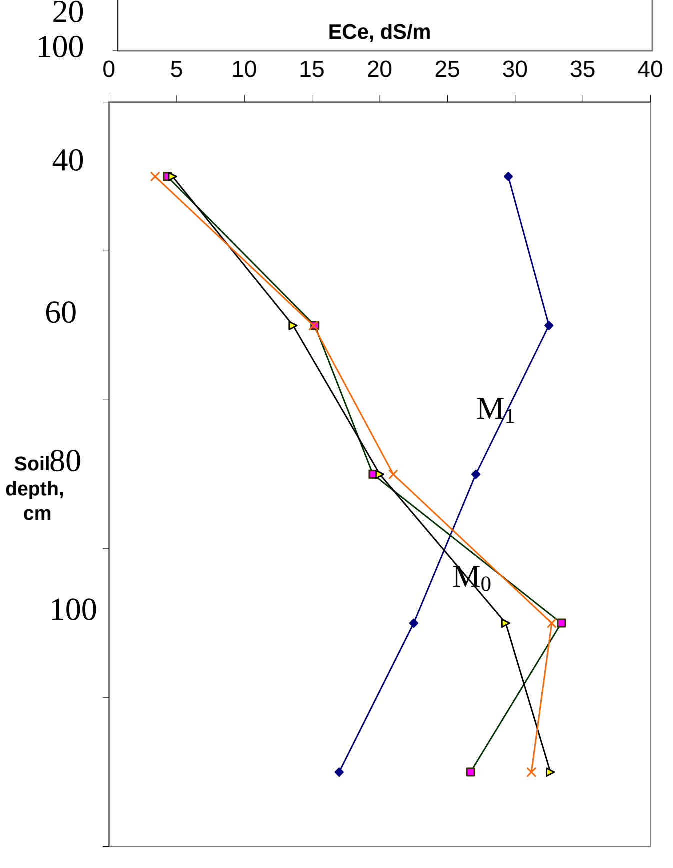

Fig. (1b) Mean electrical conductivity (dS/m) profile as affected by farm yard manure (ton) at the end of the first season (Dec. 2000- April 2001)

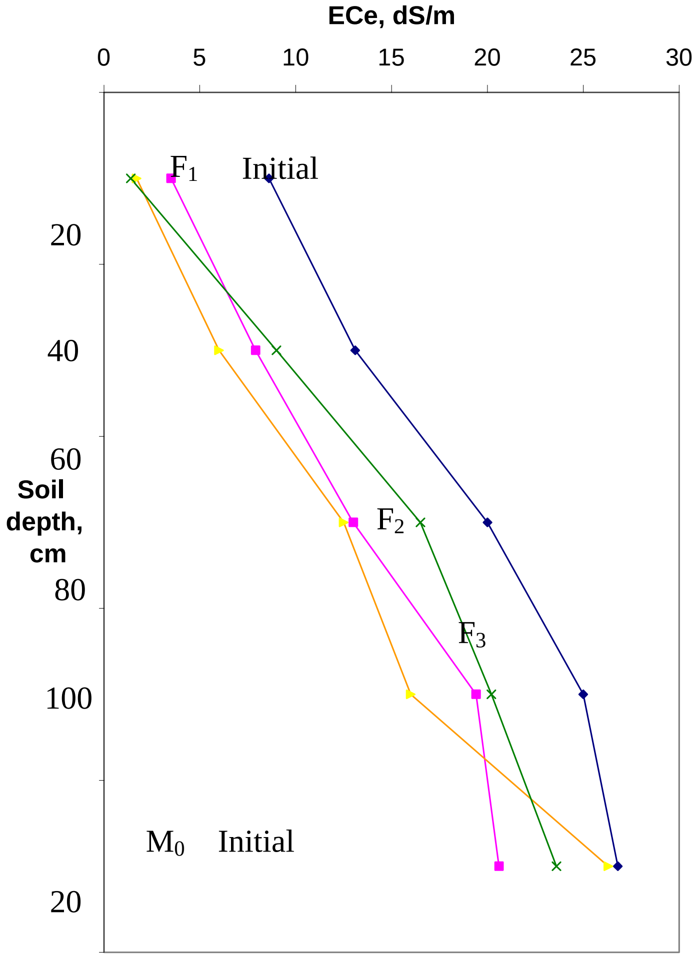

Fig. (1c) Mean electrical conductivity (dS/m) profile as affected by irrigation frequency (days) at the end of the second season (Dec. 2001- April 2002)

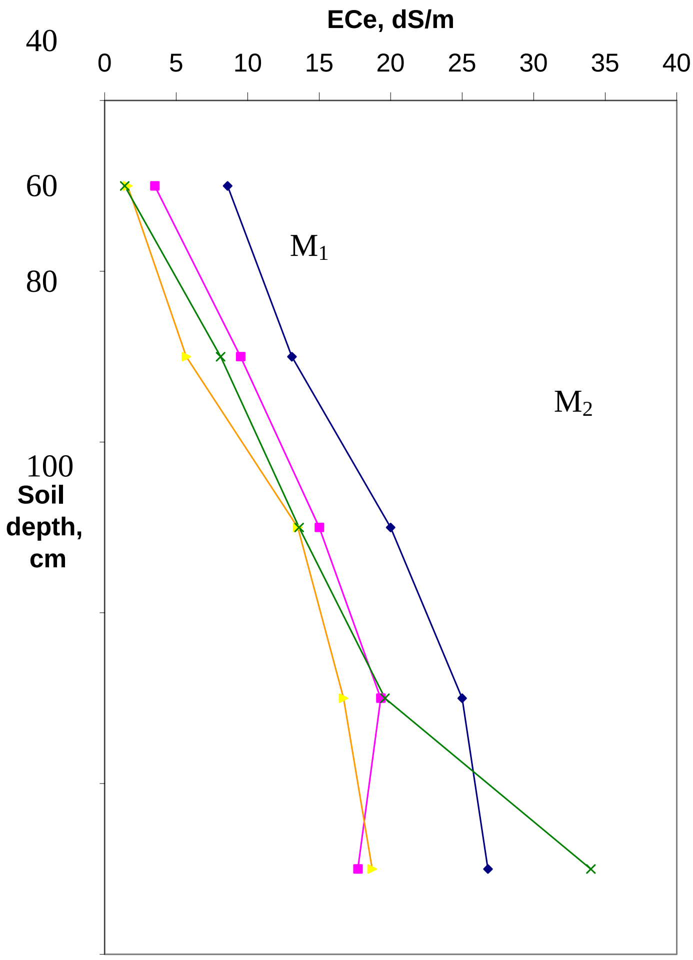

Fig. (1d) Mean electrical conductivity (dS/m) profile as affected by farm yard manure (ton) at the end of the second season (Dec. 2001- April 2002)

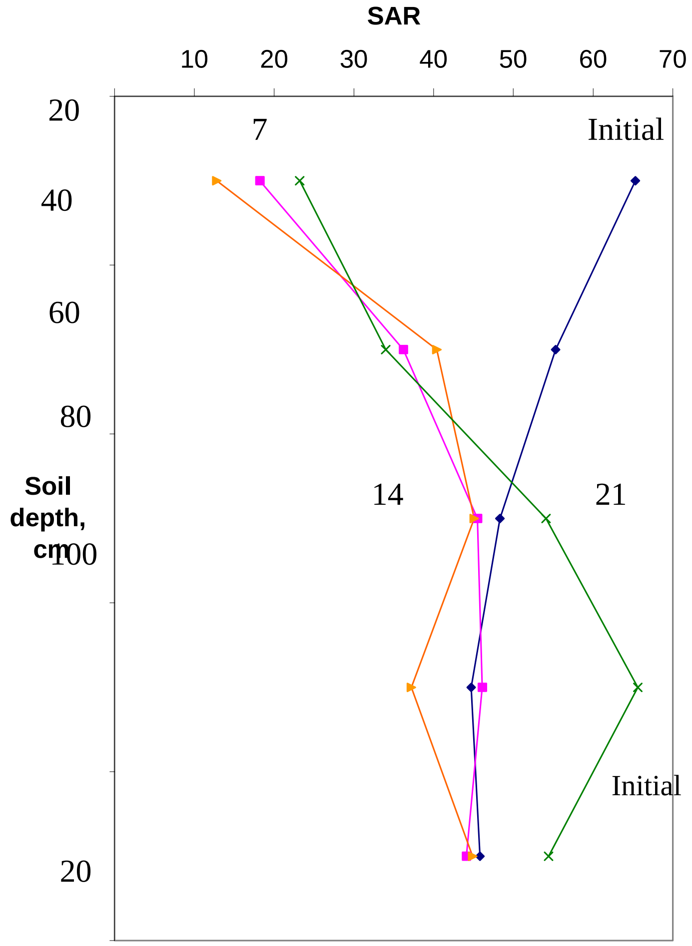

Fig. (2a) Mean sodium adsorption ratio (SAR) profile as affected by irrigation frequency (days) at the end of the first season (Dec. 2000- April 2001)

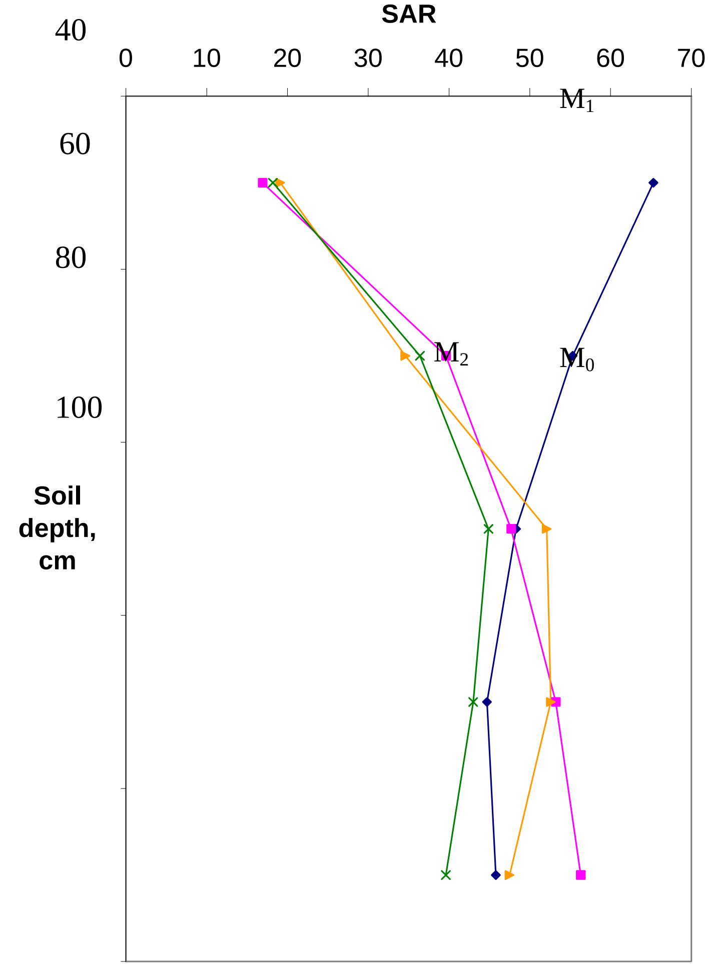

Fig. (2b) Mean sodium adsorption ratio (SAR) profile as affected by farm yard manure (ton) at the end of the first season (Dec. 2000- April 2001)

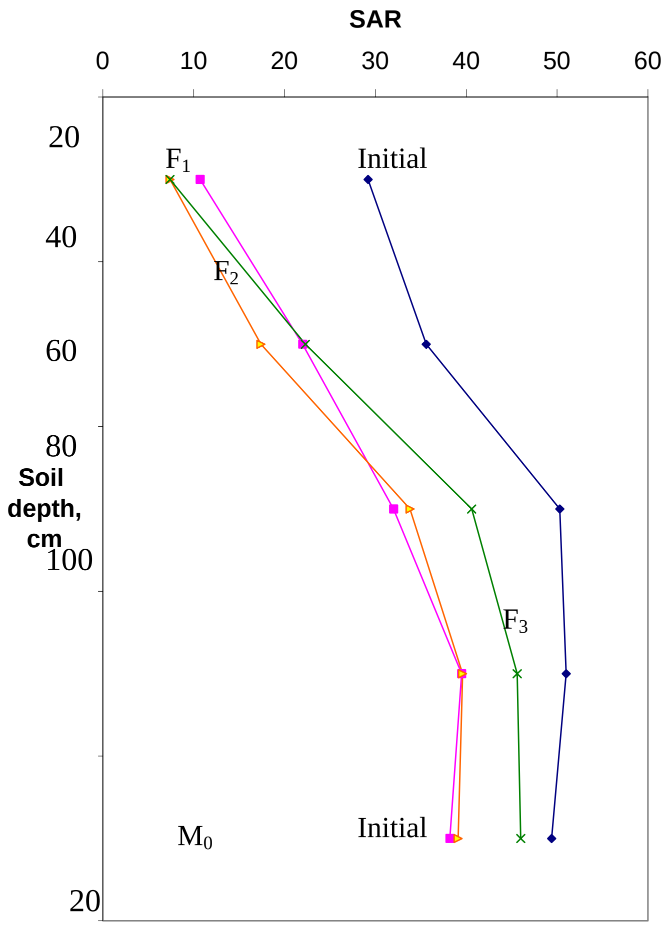

Fig. (2c) Mean sodium adsorption ratio (SAR) profile as affected by irrigation frequency (days) at the end of the second season (Dec. 2001- April 2002)

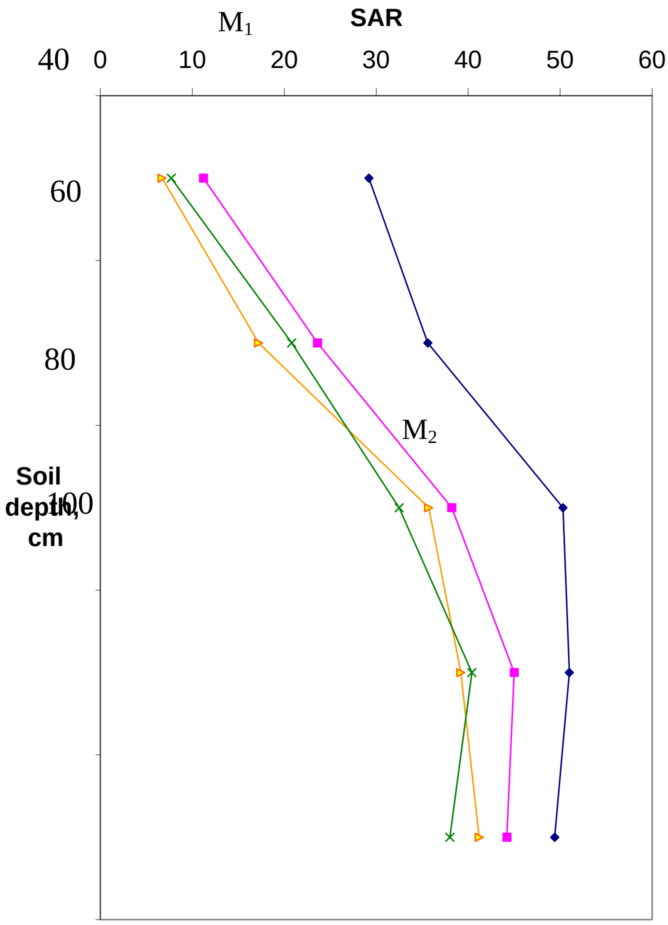

Fig. (2d) Mean sodium adsorption ratio (SAR) profile as affected by farm yard manure (ton) at the end of the second season (Dec. 2001- April 2002)

Yield components and total grain yield

Since irrigation had the predominant impact on growth and yield of wheat, only the main effects of irrigation frequency are reported in Table 3. In general, all variables increased with increase in FYM, but the effect in many cases was not significant. In the first seasons, LAI, head length, number of grains per head, and total biomass increased with increase of irrigation frequency; but the difference was only significant between F_1 and F_3;. Plant height, 1000 grains weight total grain yield and water use efficiency increased significantly with increase of irrigation frequency. The number of heads/m^2 increased with increase of irrigation frequency but the effect was not significant. In all cases, F_1 was the superior treatment. In the second season, all forage and grain yields and their components increased with increase in irrigation frequency but the effects were only significant in the case of LAI and number of grains per head.

For the first season, the impact of irrigation frequency and FYM on grain yield, and consumptive water use efficiency, which were significant, is presented in Table 4. It is evident that treatment F_1M_2 was the superior treatment and treatment F_3M_0 was the inferior treatment. In comparison to the inferior treatment, the total grain yield was significantly increased by 170 % and the CWUE was increased by 100 %. Increasing the irrigation interval would prolong both osmotic and water stress, reduce cell elongation and decrease plant growth and grain yield (Heyn, 1940; Mustafa and Abdelmagid, 1981). Irrigating weekly will increase the water potential between irrigation and alleviate both stresses. Treatment F_1M_2 was also superior in the second season, but the effect was not significant. In comparison to the inferior treatment, the total grain yield was significantly increased by 46 % and the CWUE was increased by 31 %. The beneficial impact of the superior treatment was reduced in the second season because was relatively ameliorated in the first season.

It is recommended that in these higher terrace saline-sodic sandy loam Aridisols, wheat should irrigated weekly at a rate equivalent to the potential evapotranspiration. Farm Yard manure may be washed first properly composted and incorporated into the plough layer after the first month.

Table 3. Main irrigation effect (means at harvest for the three levels of F.Y.M) on the growth and yield of wheat in two successive season (2000/01- 2001/02)

Type of data	Irrigation frequency /day			LSD
	F_1	F_2	F_3	
First season (April 2001)				
LAI	1.6	1.2	1.0	$LSD_{0.0108} = 0.30$
Plant height (cm)	65.7	56.1	49.5	$LSD_{0.0022} = 5.06$
Head length (cm)	6.8	6.2	6.0	$LSD_{0.0042} = 0.41$
No. of heads /m^2	378.6	339.7	307.1	NS
No. of grains / head	30.6	25.6	20.3	$LSD_{0.0185} = 5.63$
1000 grains weight (gm)	33.3	30.7	29.7	$LSD_{0.0002} = 0.64$
Total biomass ton/fed	2.9392	2.2050	1.5563	$LSD_{0.0225} = 0.8073$
Total grain yield ton/fed	1.0834	0.8220	0.5220	$LSD_{0.0045} = 0.20963$
Water use efficiency kg/m^3	0.301	0.228	0.145	$LSD_{0.0046} = 0.06$
Second season (April 2002)				
LAI	1.5	1.4	1.1	$LSD_{0.041} = 0.29$
Plant height (cm)	61.7	58.8	56.4	NS
Head length (cm)	6.30	6.00	5.70	NS
No. of heads /m^2	422.9	398.1	391.6	NS
No. of grains / head	31.3	26.0	24.1	$LSD_{0.0076} = 3.2$
1000 grains weight (gm)	34.0	33.1	31.9	NS
Total biomass ton/fed	2.3092	2.0549	1.9795	NS
Total grain yield ton/fed	0.9303	0.7966	0.7060	NS
Water use efficiency Kg/m^3	0.285	0.244	0.217	NS

F_1, F_2 and F_3 mean 7, 14 and 21 days respectively.

Table 4.Mean grain yield (ton/feddan) and consumptive water use efficiency of wheat (kg/m^3) as affected by irrigation frequency and farm yard manure.*

Frequency (day)	M0	M1	M2	Mean
		Grain yield		
7	0.828	1.121	1.302	1.083 a
14	0.622	0.929	0.915	0.822 b
21	0.482	0.511	0.573	0.522 c
Mean	0.644 a	0.854 b	0.930 b	
		Water use efficiency		
7	0.230	0.311	0.361	0.301 a
14	0.172	0.258	0.254	0.228 b
21	0.134	0.141	0.159	0.145 c
Mean	0.179 a	0.237 b	0.258 b	

* M_0 = Zero farm yard manure, M_1= 4.8 ton / feddan farmyard manure, M_2 = 9.7 ton/feddan.

Main frequency effect (F) LSD $_{0.0045}$ = 0.20963

Main farmyard manure effect (M) LSD $_{0.0003}$ = 0.11100

Main frequency effect (F) LSD $_{0.0046}$ = 0.06

Main farmyard manure (M) LSD $_{0.0003}$ = 0.03

References

Black, C. A. (1962). Methods of Soil Analysis. Part I. Agronomy Monograph No. 9. American Society of Agronomy, Inc., Publisher, Madison, Wisconsin, USA.

Dahiya, I.S., Malik, R.S. and Singh, M. (1981). Field studies on leaching behaviour of a highly saline sodic soil under two methods of water application in the presence of crops. J. of Agric. Sci. Cambridge. 97: 383-389.

Dahiya, I.S., Malik, R.S. and Singh, M. (1982). Reclaiming a saline –sodic, sandy loam soil under rice production. Agricultural water management. 5: 61-72.

FAO (1984). Irrigation and drainage in crop water requirements. Paper No. 24. Rome, P. 35-44.

Heyn, A.N.F. (1940). The physiology of cell elongation. Bot. Rev. 6: 515.

Jensen, M. E. and Haise, H. R. (1963). Estimating Evapotranspiration from Solar Radiation. Proc. Am. Soc. CN. Engr., J. 89:5-41.

Leffellaar, P.A. and Sharma, R.P. (1977). Leaching of a highly saline – sodic soil J. of hydrology. 32: 203-219.

Mustafa, M. A. (1973). Appraisal of the water quality of the Blue and the White Niles for irrigation use. African Soils. 18: 113-124.

Mustafa, M.A. (1986). Salt affected soils in the Sudan their distribution, properties and management. Reclamation and revegetation research. 5 : 115 – 124.

Mustafa, M.A. and Abdelmagid, E.A. (1981). The effect of irrigation interval, urea –N, and gypsum on salt redistribution on a highly saline-sodic montmorillonitic clay soil under forage sorghum. Soil Sci. 132 4th: 308-315.

Nachtergaele, F.O.F. (1976). Studies on saline and sodic soils in Sudan. FAO/ UNDP project for strengthening the soil survey administration: SUD/71/553. Technical Bulletin N. 24. May 1976. Wad Medani, Sudan.

Richards, L. A. (1954). Diagnosis and improvement of saline and alkali soils. Hand book 60., USDA.

Soil Survey Staff (1996). Soil Taxonomy (key). Seventh Edition.

Consumptive Use of Water and Water Use Efficiency by Wheat (*Triticum aestivum*) in Relation to Irrigation and Nitrogen

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Abstract—A field experiment was carried out on a sandy loam soil to study the use relationships to yields of a late sown wheat cultivar, HD-2285 under limited and adequate water and nitrogen regimes. The experiment was laid out in a split-plot design with four irrigation levels (I_0, no post-sowing irrigation; I_1, one irrigation at CRI; I_2, two irrigations, each at CRI and flowering; I_3, four irrigations each given at CRI, jointing, flowering and dough stages) in main plots and a combination of three N levels, viz. N_0, N_{50} and N_{100} and two zinc levels, Z_0 and Z_5 in sub-plots, (subscript numbers signifying N and Zn quantities in kg/ha), in three replicates. The consumptive use of water (CU) by wheat increased with every additional irrigation level to a maximum of 328.4 mm and 301.7mm. Water use efficiency (WUE) was maximum (1.38 kg grain/m^3 water use) with two irrigation treatments given at the crown root initiation (CRI) and flowering stages. This did not correspond with the above ground biomass and grain yield production, which were highest under four irrigation treatments (I_3). The moisture use rate increased with increase in irrigation water to a maximum of 2.74 and 2.51 mm/day in the first and second seasons, respectively. Moisture extraction was maximum (59.4% - 65.8%) from the 0-30 cm soil layer. Water use efficiency increased markedly with increase in nitrogen application attaining a maximum (1.42 and 1.52 kg grain/m^3 water use) under 100 kg N/ha application. Maximum WUE did not correspond to the highest grain yield. The rate of increase in both grain yield and WUE started to decline as ET further increased beyond 270 mm.

Introduction

The importance of irrigation water to wheat is to provide the water for enhanced transpiration. This permits higher leaf area indices and stomatal apertures and therefore, a greater rate of biomass production – which often lead to higher yields (Davis, 1994). Improving water use efficiency (WUE) in crop production and sustainable use of water resources are the need of the day. Fully satisfying crop water requirements may be prohibitive in terms of sustainable utilization of limited water. The solution therefore, is to limit water application to specific stages thereby minimizing loss of yield from water stress. Thus, it is imperative to study and know which critical growth stages of wheat; a small amount of water application would results in optimal WUE and minimum loss of yield.

Apart from water, other factors such as essential nutrients play important roles in optimizing growth and yield of wheat. Major wheat growing regions of the world are poor in available nitrogen. Nitrogen fertilization is essential for obtaining reasonable yields. Improvement of plant nutrition often leads to increased leaf area index (LAI). As the LAI increases, transpiration increases and evaporation from the soil surface declines because of shading and canopy closure. Nitrogen fertilization can enhance new leaf growth (increased LAI and CGR) and delay plant senescence (increased leaf area duration), resulting in increased transpiration demand. Nutrient deficiencies however often lead to more rapid senescence (Davis, 1994). Thus, a better understanding of the response and relationship of wheat growth (i.e., dry mater accumulation and LAI) to nutrient and water inputs is necessary in our assessment of a cultivar. This will also enable us make appropriate decisions for purposes of optimizing the productivity of wheat under various environments.

Seasonal consumptive use of water by wheat is universally acknowledged to increase with increasing available soil moisture. This is commensurate with the increase in growth and yield of wheat. Water use efficiency is however, known to decrease with increase in irrigation water applied beyond an optimum (Zhang, *et al*. 1999). The quantities of moisture used and the efficiency of it's utilization differs however, as influenced by factors such as the environment, cultivars, duration of the cultivars on the land and the rooting pattern of the crop.

The effects of irrigation on crop production are usually quantified using crop production functions that relate crop yield to the amount of water applied (English and Raja, 1996). These functions are used to optimize on-farm irrigation and economic evaluation of irrigation water application. Water production functions are mathematical equations relating crop response in terms of biomass or grain yield with water availability or its uptake by the crop. These functions can be used in managing water resource for achieving maximum returns with minimum amount of water application as irrigation. The use of water-yield relationships has been employed in the development of models that are used for prediction purposes. This type of work has mostly been done successfully in the developed countries. There is a need for more work in the developing countries, where water is limited, for purposes of determining the optimum amounts of water required in producing appreciable and sustainable crop yields.

In light of the considerations mentioned above, the present investigation was undertaken at the Water Technology Center, Indian Agricultural Research Institute, New Delhi during the winter seasons of 1999-2000 and 2000-2001 with the following objectives:

1. To determine the influence of irrigation, nitrogen and zinc on the growth of wheat
2. To determine the seasonal consumptive water use, water use efficiency and moisture use rate of wheat under varying irrigation and nutrient levels
3. To compute production functions for wheat under varying water supply conditions.

Materials and Methods

Four irrigation levels (I_0, no post-sowing irrigation; I_1, one irrigation at CRI; I_2, two irrigations, each at CRI and flowering; I_3, four irrigations each given at CRI, jointing, flowering and dough stages) were allotted to main plots and six fertilizer levels (N_0Z_0, no nitrogen and zinc; N_0Z_5, no nitrogen and 5 kg Zn/ha; $N_{50}Z_0$, 50 kg N/ha and no Zinc; $N_{50}Z_5$, 50 kg N/ha and 5 kg Zn/ha; $N_{100}Z_0$, 100 kg N/ha and no zinc; $N_{100}Z_5$, 100 kg N/ha and 5 kg Zn/ha) were allotted to the sub-plots of a split plot design replicated thrice.

Dry matter production (DMP), Leaf Area Index (LAI), grain and straw yield data was recorded. Periodic soil samples from 0-120 cm soil depth were collected layer-wise to compute water use by crop as described by Dastane (1972). Crop evapo-transpiration to yield relationships was determined through regression analysis.

Soil samples were taken from plots at depth intervals of 0-15, 15-30, 30-60, 60-90,and 90-120 cm soil profiles and dried to, respectively, to determine the soil moisture. Samples were taken at sowing time; 48 hours before; and after irrigating; and at harvest, with the help of a tube auger. Samples were dried in the oven at 105^0 C for over 24hr till constant dry weight. The moisture content was measured thermo-gravimetrically. Seasonal consumptive water use (CU) and the water use efficiency (WUE) of the crop, daily moisture use rate

(MUR) and soil moisture extraction pattern of the crop were computed from the periodic soil moisture content data.

The seasonal consumptive water use by the crop under different treatments was worked out using the formula described by Dastane (1972):

$$CU = \sum_{1}^{N} (E_{p} \times 0.6) + \sum_{i=1}^{n} \frac{(M_{1I} - M_{2I})}{100} \times Asi \times Di + ER + GWC$$

where

CU = Consumptive use of water (mm)

E_p= Pan evaporation value from the USWB class A open pan evaporimeter for the period from the date of irrigation to the date of soil sampling after each irrigation (mm)

A = constant used for obtaining ET value from E_p value for the given period of time

M_{1i} = Per cent soil moisture (w/w) of the i^{th} layer of the soil at the time of sampling after each irrigation

M_{2i} = Per cent soil moisture (w/w) of the i^{th} layer of the soil at the time of sampling before each irrigation

Asi = Apparent specific gravity of the i^{th} layer of the soil

Di = Depth of i^{th} layer of soil (mm)

ER = Effective rainfall, if any , during the period under consideration, mm

GWC =Ground water contribution to the root zone moisture during the given period of time (mm)

n = Number of soil layers

N = Number of days between pre-irrigation and post-irrigation soil moisture samplings

The ground water contribution (GWC) was considered negligible as the ground water table during crop growth periods remained below 4.0 from soil surface during in both the seasons. Crop water use efficiency was computed using the following formula and was expressed as kg grain /m^3 water used.

$$WUE = \frac{\text{Grain yield (Economic yield)}}{\text{Consumptive Water Use (Seasonal)}}$$

Leaf area index was measured using the leaf area to dry leaf weight relationship. At each dry mater sampling date, a sub sample of fresh leaves from the main sample (1m row length) was taken from one replication and leaf area was recorded with the help of LI-3100 Area Meter, LI-COR, Inc. The leaves were then dried at 60 °C for about 24 hr until a constant weight was obtained. Specific leaf area (SLA) was calculated as the ratio of leaf area (cm^2) to leaf weight (g). This SLA value for each treatment at each sampling time was multiplied by the corresponding dry leaf weight values, to get leaf area index. Leaf area index is expressed as total leaf area of the crop (one side only) per unit ground area occupied by the crop. The area occupied by the plants under consideration in the field was taken as 0.25 m x 1.00 m.
The experimental data pertaining to each character was analyzed statistically by using Analyses of Variance technique (ANOVA) for split plot. Standard error of mean difference and significant difference (LSD) at 5% level of significance were worked out for each character. Pooled analysis of the two years data was done only for grain and straw yield. The

computed parameters such as data on soil moisture studies were explained on the basis of comparative performance.

Results and Discussion

Growth of Wheat (Dry matter and Leaf area index)

The four irrigation treatment applied at CRI, jointing, flowering and dough stages along with one pre-sowing irrigation increased the dry matter production of wheat at harvest significantly over other irrigation treatments in both the 1999-00 and 2000-01 seasons.

Total above ground dry matter (yields) production (TDMP) at 30, 60 and 90 days after sowing was significantly more with added irrigation, compared to the no post-sowing irrigated TDMP production in second season (Table 1). In the first season however, only the 90 days after sowing (DAS) above ground DM showed significant differences due to irrigation treatments. This was attributed to the 68.2mm rainfall (Fig. 1) during the initial part of the first season that mitigated irrigation effects on DMP up to the 60 DAS. Similarly, application of irrigation increased the leaf area index (LAI) of wheat significantly over the non-irrigated control treatment at 60 and 90 DAS, in the second year (Table 2).

Table 1: Influence of I, N and Z on total dry matter production (g/m2), at different growth stages

Treatment	30 DAS		60 DAS		90 DAS		Harvest	
	1999-00	2000-01	1999-00	2000-01	1999-00	2000-01	1999-00	2000-01
I0	304.9	222.5	1299.2	999.4	5711.8	5192.3	7061.0	6852.5
I1	316.5	218.9	1306.5	1082.9	6966.1	6181.1	8739.2	8354.4
I2	316.6	224.4	1309.6	1139.9	7518.3	6695.2	9876.2	9553.1
I3	317.8	236.0	1308.0	1238.7	7915.8	7300.5	10454.2	10524.1
SEm±	4.34	1.77	10.37	7.57	54.56	42.77	89.60	75.26
CD(p=0.05)	NS	5.3	NS	22.8	164.3	128.9	269.9	226.8
N0	292.2	202.9	1086.3	929.5	5423.3	5174.9	7998.4	7744.8
N50	306.6	224.2	1295.2	1085.9	7098.1	6228.7	9029.8	8889.2
N100	343.1	246.4	1536.0	1330.3	8562.6	7623.2	10069.7	9829.6
SEm±	2.11	2.2	12.34	8.64	65.24	52.89	97.7	87.2
CD(p=0.05)	15.4	6.6	37.2	26.1	196.6	159.4	300.5	262.2
Z0	313.5	225.2	1303.9	1114.6	7018.6	6331.7	8982.2	8800.3
Z5	314.5	225.7	1307.9	1115.9	7037.4	6352.8	9083.1	8842.0
SEm±	4.17	1.79	10.05	53.26	43.18	85.4	81.4	71.2
CD(p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

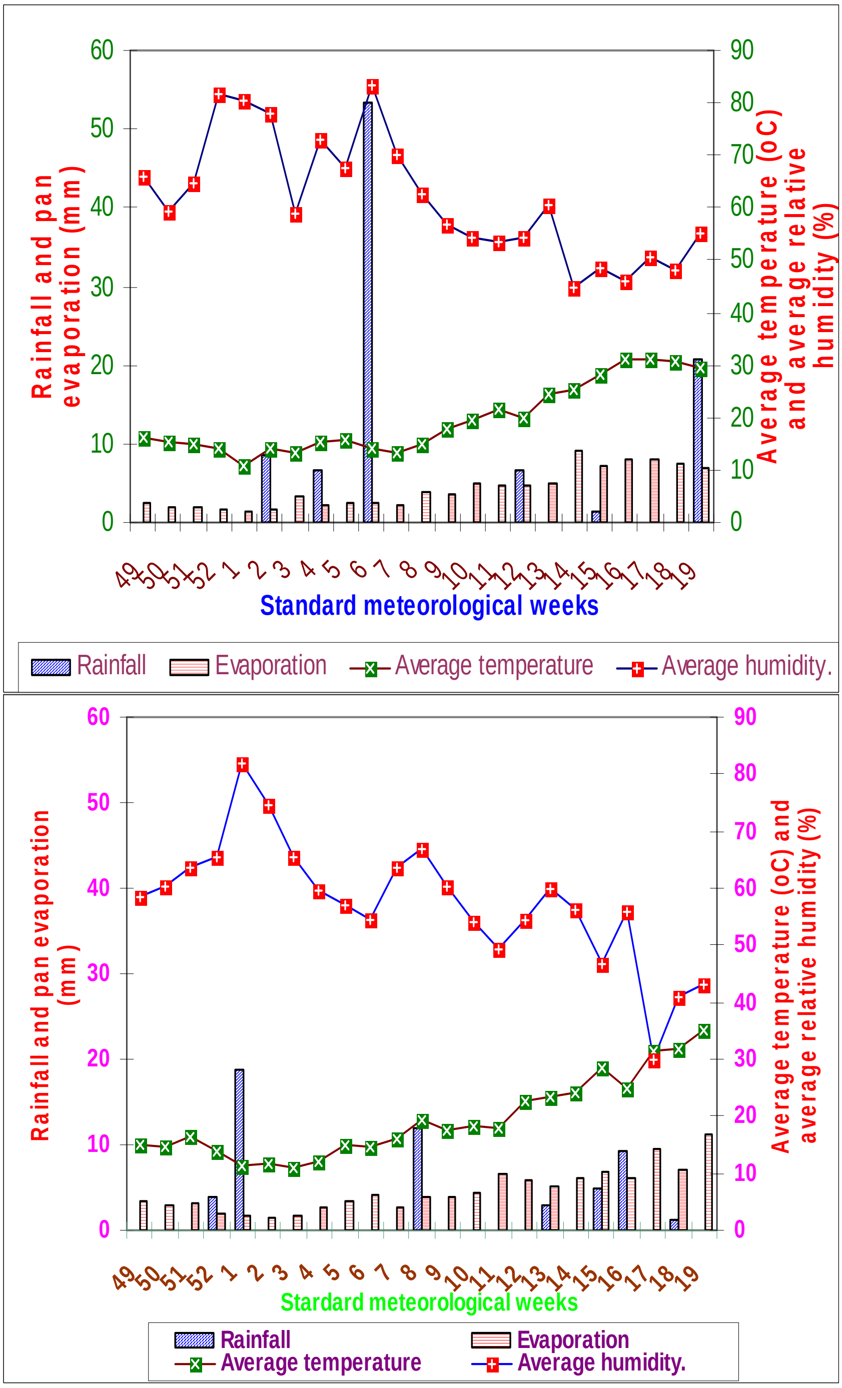


Fig 1:Pattern of rainfall, evaporation, average temperature and average relative humidity during Late sown wheat growth periods of 1999-00 and 2000-01

Table 2 :Influence of irrigation, Nitrogen and Zinc on the LAI of late sown wheat at 30, 60 and 90 DAS

Treatment	30 DAS		60 DAS		90 DAS	
	1999-00	2000-01	1999-00	2000-01	1999-00	2000-01
I0	0.164	0.291	0.595	0.561	2.349	2.007
I1	0.163	0.289	0.614	0.564	3.178	2.697
I2	0.163	0.293	0.607	0.566	3.467	2.922
I3	0.162	0.292	0.613	0.576	3.603	3.11
SEm±	0.01	0.05	0.007	0.008	0.036	0.028
CD(p=0.05)	NS	NS	NS	NS	0.01	0.09
N0	0.14	0.226	0.519	0.493	2.696	2.314
N50	0.159	0.278	0.616	0.525	3.272	2.77
N100	0.19	0.368	0.687	0.682	3.48	2.963
SEm±	0.001	0.005	0.008	0.008	0.047	0.034
CD(p=0.05)	0.003	0.014	0.024	0.025	0.141	0.103
Z0	0.163	0.291	0.606	0.566	3.142	2.676
Z5	0.163	0.291	0.608	0.568	3.157	2.693
SEm±	0.001	0.004	0.006	0.007	0.038	0.028
CD(p=0.05)	NS	NS	NS	NS	NS	NS

Grain and Straw yield of Wheat

The maximum average grain yield of 4.0 tons in first season and 3.9 tons per hectare (t/ha) in the second season was obtained with the four irrigation treatment (I_3) given at CRI, jointing, flowering and dough stages of the crop (Fig. 2). Minimum yields of 2.3 t/ha in both the seasons were obtained with no post sowing irrigation (I_0). The per cent increase in grain yield due to one (I_1), two (I_2) and four irrigation levels over the no irrigation treatment was 36.2, 58.0 and 71.5 in 1999-2000, and the corresponding per cent increase in 2000-2001 was 32.0, 57.8 and 73.9, respectively. Each and every addition of either irrigation or nitrogen resulted in a progressive and significant increase in grain yield up to I_3N_{100} level in first and second year of experimentation, respectively (Table 3). The minimum grain yield of 2.00 t/ha and 1.96 t/ha were obtained with I_0N_0 in the respective seasons.

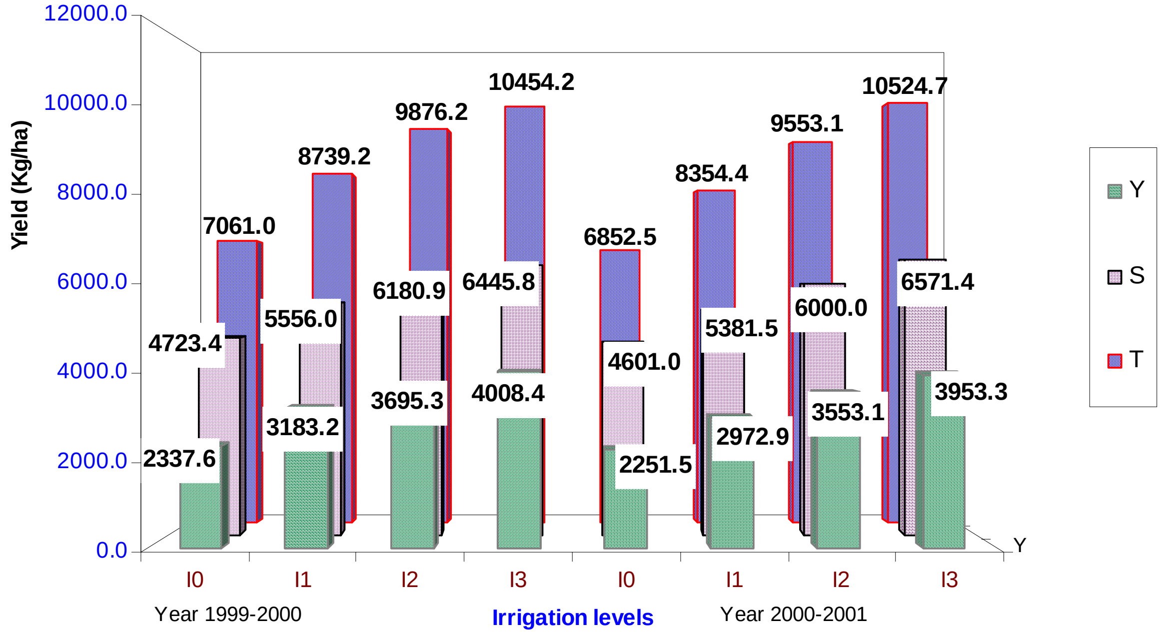
Straw yield increased significantly with addition of irrigation attaining a maximum of 6.4 t/ha with four irrigations in 1999-2000 and 6.6 t/ha in 2000-2001 (Fig. 2). Application of one and two irrigations, resulted in a percentage increase of the straw yield by, 17.6 and 30.9 in the first season and 17.0 and 30.4 increase in the second season, over the control (I_0), respectively.

Table 3:Interactive effects of I and N on the grain yield (kg/ha) of late sown wheat at harvest

IxN effects on grain yield

	I0	I1	I2	I3	I0	I1	I2	I3
N0	2038.8	2649.9	3013.0	3301.2	1959.8	2407.8	288505	3271.7
N50	2337.1	3199.9	3713.1	4108.7	2259.8	3011.0	3587.9	4042.1
N100	2637.1	3699.9	4359.7	4615.4	2535.1	3499.9	4186.9	4436.1
	N within I		**I within N**		**N within I**		**I within N**	-
SEm±	144.3		149.52		130.49		136.2	
CD(p=0.05)	298.1		302.2		268.9		275.2	

Fig. 2. Straw yield increase with additional irrigation



Consumptive Use of Water (CU) by Wheat

Increasing frequency of irrigation increased the CU progressively and markedly in both the seasons (Fig 3 and Table 4). The maximum consumptive use of 328.6 mm in 1999 – 2000 and 302.0 mm in 2000–2001 was attained with the four irrigation treatments, given at CRI, jointing, flowering and dough stages of the crop growth. The minimum CU was obtained with no post – sowing irrigation, i.e., control (191.5 mm and 178.2 mm) in corresponding seasons, respectively. The percent increase in CU values due to I_1, I_2 and I_3 over I_0 treatment was 21.5, 44.5, and 71.5, in 1999 – 2000 and 25.5, 39.8, and 69.3 in 2000 – 2001 seasons, respectively. Moisture use rate of wheat increased with the increase in the number of irrigation levels given. The increase in moisture use rate of wheat due to I_1, I_2 and I_3 levels over the no irrigation treatment (I_0), was in the order of 21.3%, 39.6%, and 68.5% in 2000-2001 season, respectively.

Water Use Efficiency by Wheat

The pooled average water use efficiency (kg grain/m^3 water use) of I_1 (1.35) and I_2 (1.38) were higher than those of I_0 (1.24) and I_3 (1.27) treatments in both the seasons (Table 4). Highest WUE for the first season crop was recorded with I_1 (1.37), while it was with I_2 (1.42) in the second season (Fig 3 and Table 4). Minimum water use efficiency was recorded with I_0 (1.22 and 1.26 kg grain/m^3 water use) in both the respective seasons.

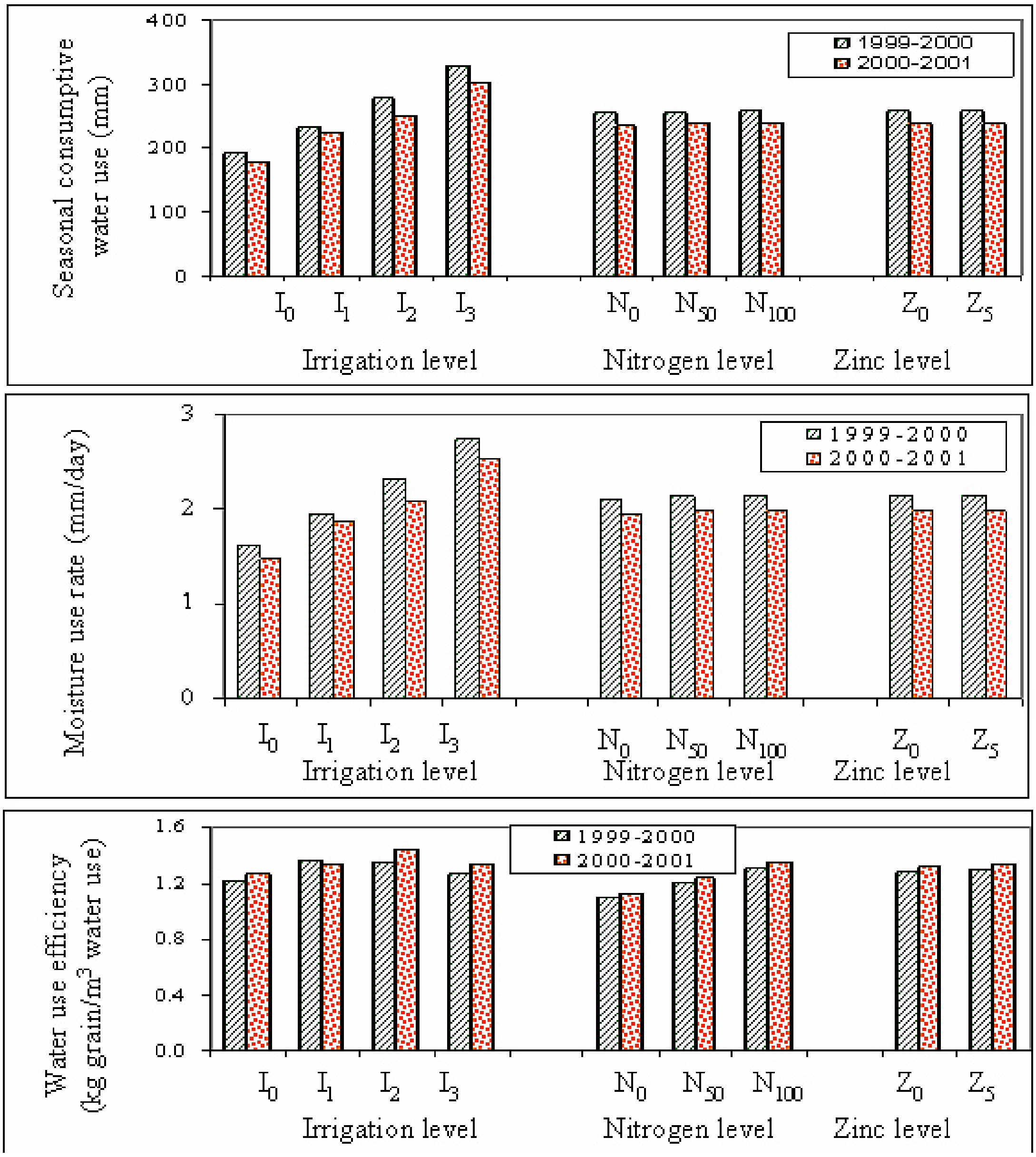


Figure 3. Influence of irrigation, nitrogen and zinc on the consumptive use of water, moisture use rate and water use efficiency by late sown wheat

Table 4:Influence of I, N and z on seasonal consumptive water use, moisture use rate and WUE of late sown wheat

	CU (mm)		WUE(kg grain/m3 water)		Moisture use rate (mm/day)	
	1999-00	2000-01	1999-2000	2000-2001	1999-2000	2000-2001
I_0	191.52	178.20	1.22	1.26	1.60	1.49
I_1	232.67	223.66	1.37	1.33	1.94	1.86
I_2	276.10	249.10	1.34	1.42	2.30	2.08
I_3	328.39	301.66	1.22	1.31	2.74	2.51
N_0	253.14	234.36	1.09	1.12	2.11	1.95
N_{50}	257.08	237.95	1.30	1.35	2.14	1.98
N_{100}	261.28	242.16	1.46	1.52	2.18	2.02
Z_0	257.11	238.15	1.27	1.32	2.14	1.98
Z_5	257.23	238.16	1.30	1.34	2.14	1.98

Nutrient Nitrogen and Zinc Effects on Water Use

Application of nitrogen did not enhance the CU appreciably as in case of irrigation application. With application of nitrogen fertilizer at the rate of 50 and 100 kg /ha, the percent increase in CU of wheat over no nitrogen (N_0) application was marginal i.e. 1.56 and 3.22 in the first season and 1.53 and 3.32 in the second season respectively (Table 4). Similarly Zinc application did not have much influence on the consumptive use of wheat. Application of nitrogen had very little effect on the daily moisture use rate of wheat, while zinc application had practically no effect at all, in both the cropping seasons (Table 4).

Nitrogen application increased water use efficiency of the crop progressively up to 100 kg / ha (1.46 and 1.52 kg grain/m^3 water use) during both the years of experimentation. Zinc application however, induced negligible influence in WUE of wheat in both the seasons (Fig. 3 and Table).

Nitrogen application up to 100 kg/ha did not bring any noticeable change in seasonal consumptive use and daily moisture use rate of the crop (Table 4). Water use efficiency increased progressively with N application and the mean maximum WUE recorded with 100 kg N/ha was 1.46 and 1.52 kg grain/m^3 water use, in first and second seasons, respectively.

Moisture Extraction

The influence of irrigation and fertility (N and Z) interactive effects on the soil moisture extraction patterns is depicted in Table 5. Maximum (58.6 % to 66.8 %) soil moisture was extracted from within the 0- 30cm soil profile layer with the highest being under the four irrigation regime (64.7 to 66.8 %) and lowest under the no post-sowing irrigation treatment (58.2 to 60.1 %). This trend of declining soil moisture extraction percentages with increasing irrigation frequency was evident at the 60-90 cm and 90–120 cm depth soil layer profiles also. The ranges were 9.6 – 11.7 % and 6.4 – 8.0 % in the 60–90 cm and 90–120 cm soil profiles, respectively.

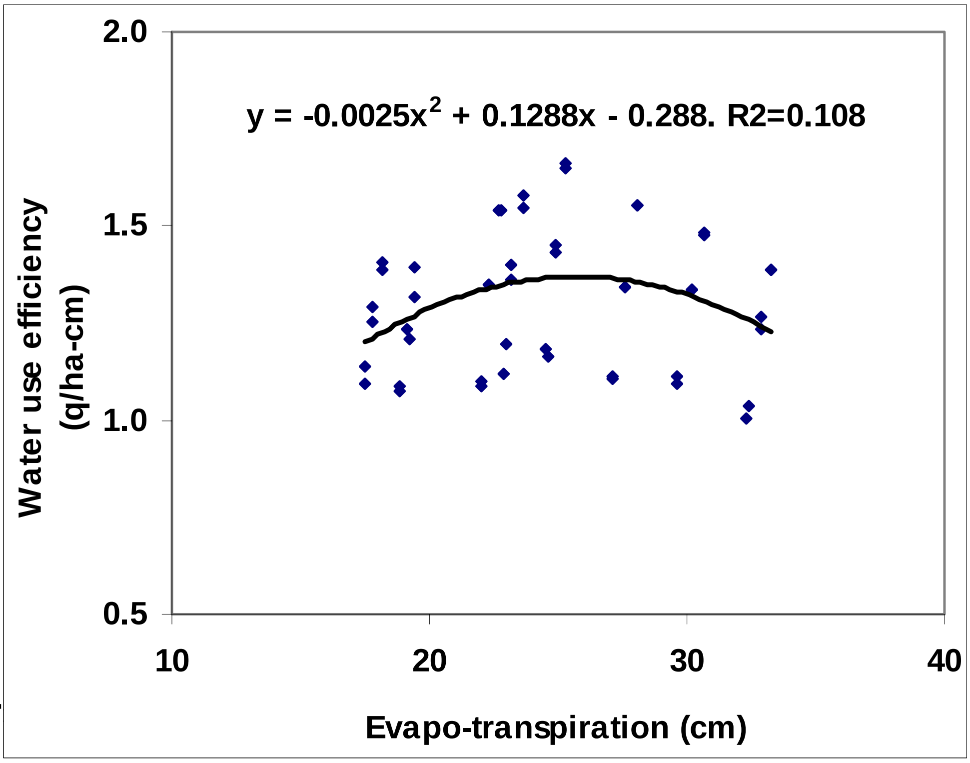
Application of nitrogen induced the plants to extract proportionately greater amount of soil moisture from 60-120 cm layers as compared to the non- fertilized ones. Zinc application on the other hand, caused negligible increase in moisture extraction pattern at different soil profiles that followed the similar effect as in the case of irrigation effects.

Table 5: Influence of irrigation, nitrogen and zinc on soil moisture extraction pattern (%)

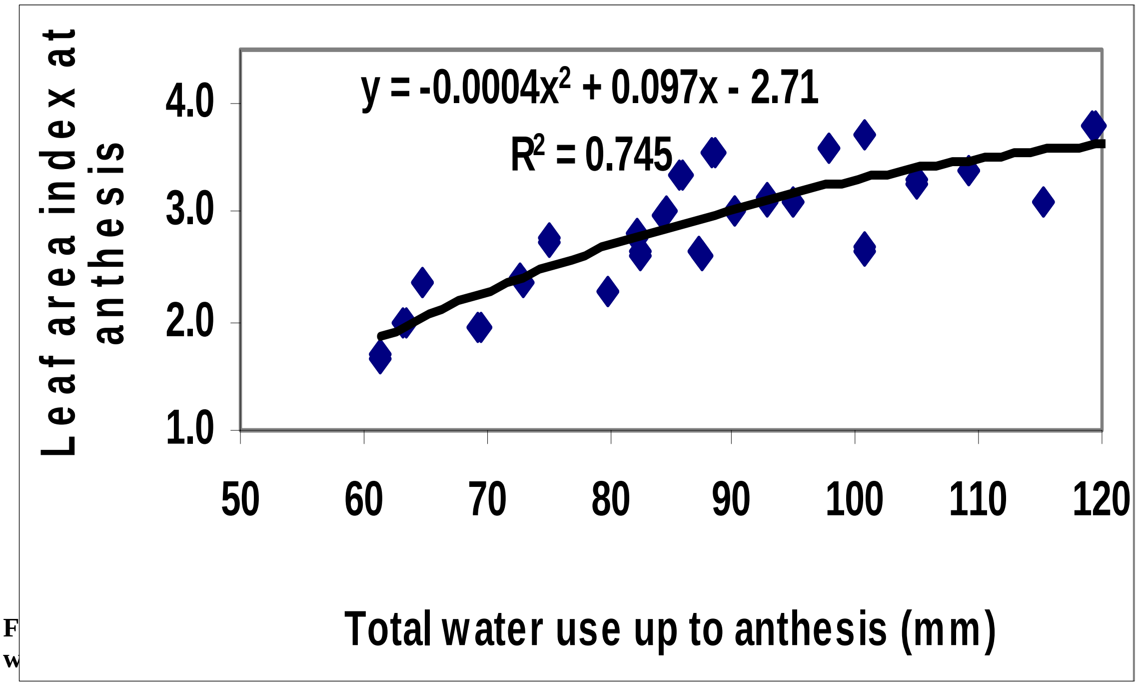
	1999-2000				2000-2001			
	Seasonal moisture extracton patern				Seasonal moisture extracton patern			
Treatment	0-30 cm	30-60 cm	60-90 cm	90-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
Irrrigation								
I_0	59.35	21.90	11.65	7.10	58.10	21.62	12.53	7.75
I_1	61.50	20.98	11.12	6.40	60.15	21.00	12.05	6.80
I_2	64.32	20.05	10.00	5.63	61.62	20.25	11.65	6.48
I_3	65.80	19.30	9.58	5.32	64.68	19.72	10.13	5.47
Nitrogen								
N_0	63.56	20.70	10.58	5.16	61.43	20.54	11.78	6.26
N_{50}	62.94	20.53	10.60	5.94	61.13	20.63	11.60	6.65
N_{100}	61.73	20.45	10.59	7.24	60.86	20.78	11.40	6.96
Zinc								
Z_0	62.69	20.54	10.56	6.21	61.10	20.62	11.56	6.73
Z_5	62.79	20.58	10.62	6.02	61.18	20.68	11.63	6.53

Production Function for Wheat

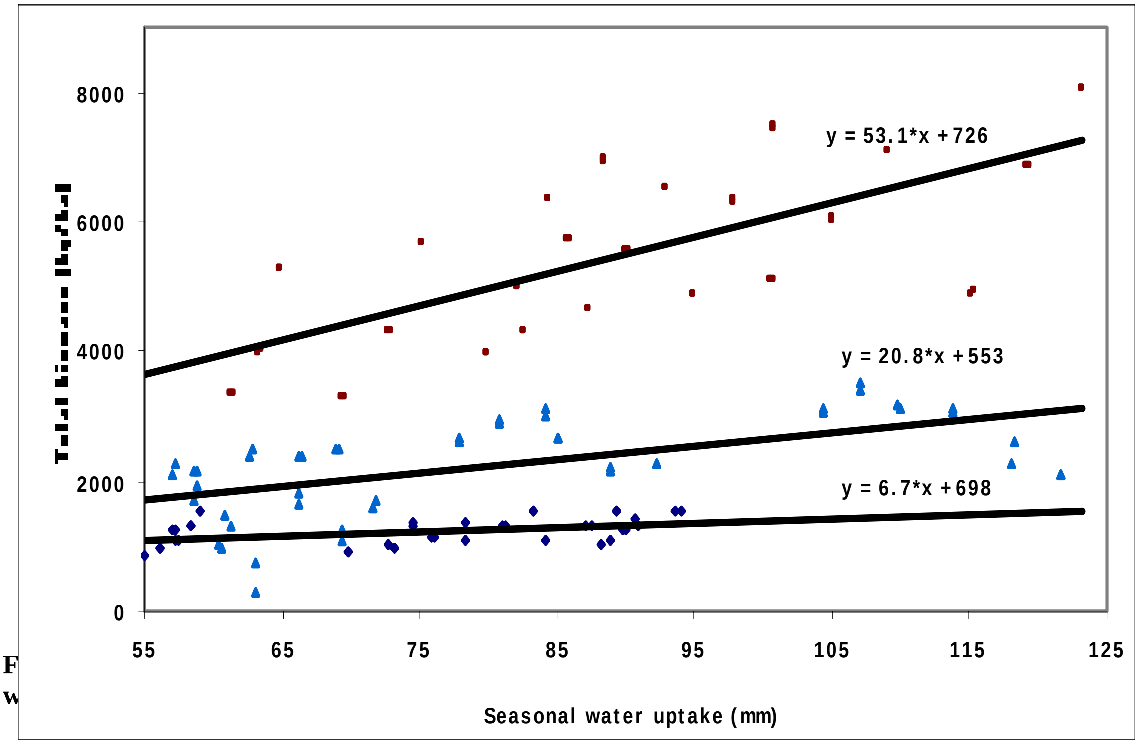
Water yield relationships depicted as production functions are considered as useful tools in the management of water and nitrogen application for the purposes of optimizing crop productivity. Crop production functions that relate water-yield relationships, are mathematical equations relating crop response in terms of biomass or grain yield with water availability and it’s uptake by the crop.


y = -0.0025x2 + 0.1288x - 0.288. R2=0.108
Water use efficiency
(q/ha-cm)
2.0
1.5
1.0
0.5
10
20
30
40
Evapo-transpiration (cm)

F


y = -0.0004x2 + 0.097x - 2.71
R2 = 0.745
Leaf area index at
anthesis
4.0
3.0
2.0
1.0
50
60
70
80
90
100
110
120
Total water use up to anthesis (mm)

F
w



Water use efficiency is generally considered as a conservative term and is expressed as the ratio of DMP or Y to water supply or water use, expressed in terms of evapotranspiration (ET) or transpiration (Tr) on daily or seasonal basis (Sinclair et al, 1984). Water use efficiency generally ranged from 1.22 to 1.42 kg/m^3 (Table 4), with the highest WUE observed at one and two irrigation levels of the first and second season crop, respectively. The values of WUE were higher than those reported from the Mediterranean region by Zhang and Oweis (1999) that ranged from 1.08 to 1.19 kg/m^3 and close to those (1.23-1.46 kg/m^3) of the Loess plateau in China (Kang *et al.*, 2002).

Regression analysis indicated a quadratic relationship between WUE and seasonal evapo-transpiration (Fig. 5), which was reflected in a poor correlation of 11%. WUE reached its maximum value at an evapo-transpiration of approximately 260-270 mm then started a decrease with evapo-transpiration. Maximum WUE did not correspond to the highest grain yield (Fig 2 and 3). When ET is relatively low, water availability is the limiting factor for grain yield and an increase in ET results in significant increase in both grain yield and WUE. However, the rate of increase in both grain yield and WUE starts to decrease as ET further increases. Once WUE reaches its maximum value, an increase in total crop water use could still lead to a marginal increase in grain yield. Thus, WUE would decrease (Figure 5). This was in agreement with the findings of Singh (1977) and Kang *et al.*(2002). This means that relatively high crop yield and WUE can be maintained while substantially reducing irrigation volume under limited-irrigation management (Singh *et al.*1991; Zhang and Oweis, 1999; Kang *et al.*2002).

When evaluating dry matter production, expansive growth deserves special attention, since it is the means for developing leaf area for intercepting light and carrying out photosynthesis. The sensitivity of expansive growth to small water deficits is marked by reduction in leaf area (Hsiao *et al.*, 1976b; Vaux and Pruitt, 1983). Maximum LAI for wheat is generally noticed at anthesis. LAI at flowering is mainly used for forecasting wheat yields, with the prime assumption that there is no stress in the subsequent stages of crop growth. The LAI estimates based on water use (Fig 8) accounted for 75% of the variations only.

It can be concluded that wheat grown under lower levels of irrigation water results in lower consumptive use of water (Fig 3 and Table 4). This further influences the production of less leaf area indices (Table 3 and Fig 6), that ultimately causes the decline in the total above ground biomass and grain yield production (Fig 2).

Final biomass and grain yield of wheat depends upon the sensitivity of various stages towards moisture availability that scheduling of irrigation is carried out. Dated production functions take care of the crop stage sensitivity and thus gives better predictability for biomass and yield estimates (Kalra, 1986; Singh *et al.*, 1987). The highest rate of biomass gains of 53.1 kg/ha-mm was obtained over the 60–90 day period, a period that falls within the maximum growth phase of wheat, followed by 28.3 and 6.7 kg/ha-mm during the 90-120 and 0-60 DAS periods (Fig 7). This is in agreement with the findings for semi arid regions of Hisar in India (Singh *et al.*, 1987) and China (Zhang *et al.*, 1999). Therefore, scheduling of water application ought to consider providing less quantities of water during the 0-60 DAS period as compared to the 90-120 and 60-90 DAS periods, respectively. This should be aimed at providing just sufficient amounts of water and nitrogen for the necessary developmental processes to take place. Further research aimed at optimizing growth and production of wheat through the application of minimum quantities of water and nitrogen, at various stages of wheat growth, is therefore recommended.

References

Dastane, N.G., Singh, M. Hukkeri, S.B. and Vasudevan, V.k. 1970. Review of work done on water requirement of crops in India. *New Bharat Prakashan*, Poona, India.

Davis, G.J. 1994. Managing plant nutrients for optimum water use efficiency. *Advances in Agronomy* 53 : 85-110.

English, M., Raja, S.N. (1997). Perspectives on deficit irrigation. *Agricultural Water Management*, 32 (1) : 1-14.

Hsiao, T.C., Feres, E., Acevedo, E. and Henderson, D.W. 1976b. Water stress and dynamics of growth and yield of crop plants. Ecological Studies, 19: 281-305.

Jackson, M. L. 1958. Soil Chemical analysis. Prentice Hall of India. (Pvt.) Ltd. New Delhi 1973, India.

Kalra, N. 1986. Evakuation of soil water status, plant growt and canopy environment in relation to variable water supply to wheat. P.hD. Theses. P.G. School, I.A.R.I., New Delhi: 103pp.

Kang, S.Z. and Dang, Y.H. 1987. Research on crop water production functions and optimal irrigation scheduling. *Water Resource Hydraulic Eng*. 1: 1-12.

Khang, S., Zhang, L., Liang, Y., Hu, X., Cai, H. and Gu, B. 2002. Effects of limited irrigation on yield and water use efficiency of winter wheat in the Loess plateau of China. *Agric. Water Manage*. 55 : 203-216.

Novoa, R and Loomis, S.S. 1981. Nitrogen in plant production. *Plant and Soil*. 58 (1) : 177-204.

Sinclair, T. R., Tanner, C. B. and Bennet, J. M. 1984. Water use efficiency in crop production. *Bioscience* 34 : 46- 40.

Singh N.T., Vig A.C., Rachhpal Singh, Chaudhary M. R., Singh R., (1977). Influence of different levels of irrigation and nitrogen on yield and nutrient uptake by wheat, *Agronomy Journal*, 71 (3) : 401-404.

Singh, A.K. 1991. Response of irrigated wheat (*Triticum aestivum*) to nitrogen and phosphorus in farmers' fields in Ganga diara of Bihar, *Indian J. Agron*., 41 (1) 157-159.

Singh, P., Wolkewitz, H. and Kumar, R. 1987. Comparative performance of different crop production functions for wheat (*Triticum aestivum*). *Irrigation Sci*. 8 (4) : 273-290.

Stewart, J. I., Cuerca, R. H., Prutt, W.O., Hagon, R.M. and Tosso, J. 1977a. Determination and utilizationof water production functions for principal California crops, *W-67 Calif Contri. Proj. Rep*. University of California, Davis.

Tandon H.L.S. (Ed.) 1998. Methods of analysis of soils, plants, waters and fertilizers. Fertilizer Development and Consultations Organization, New Delhi, India. Pp. 144+vi.

Vaux, H.J. and Pruitt, W.O. 1983. Crop water production functions. In: D. Hillel (Editor), *Adv. in Irrigation*, 2. Academic Press, New York, pp 257-272.

Watson, D.J. 1952. *Adv. Agron.* 4 : 101-145.
Zhang H., Wang X., You M. and Liu C., (1999). Water-yield relations and water-use efficiency of winter wheat in the North China Plain, *Irrigation Science*, 19 (1) : 37-45.
Zhang H.P, and Oweis T., (1999). Water-yield relations and water-use efficiency of winter wheat in the North China Plain, *Agricultural Water Management*, 38 (3) : 195-211.

Agronomic and Economic Evaluation of Break Crops and Management Practices on Grain Yield of Wheat at Shambo, Western Oromiya, Ethiopia

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Abstract—Sustainable production of wheat (*Triticum aestivum*) may be limited by a number of crop management practices, including crop rotation and cultural practices. A field experiment was conducted for three years at Shambo, Ethiopia, to evaluate the agronomic and economic effects of break crops and management practices on the grain yield of wheat. After a field pea break crop wheat grain yield was 32% higher than after a barley crop. Management practices gave significant effects on the mean grain yield of wheat. Wheat performed better after the field pea break crop with both farmer's management practices and the recommended practices. Both local and improved varieties gave greater yield with intensive management and fertilizer application. The highest economic benefits came from the use of field pea break crop with improved management practices and fertilizer application and the extension program under way in the area should consider this recommendation for sustainable production of wheat.

Introduction

Wheat is one of the major cereal crops produced in the Ethiopian highlands (1,500 to 3,000 m.a.s.l) (Hailu *et al.*, 1991), and in the highlands of Shambo, wheat ranks fourth among the cultivated crops in terms of production (Asfaw *et al.*, 1997). Both biotic and abiotic factors limit agricultural productivity in the country. Human degradation on the natural resource base is generally very swift, but interventions to amend the decline are very slow. Lal (1989) indicated that conservation tillage and crop rotation are considered the major means of sustaining agricultural productivity at the global scale. Soil fertility can, in many cases, be maintained through the combined use of suitable legumes in a suitable crop rotation and modern artificial fertilizers capable of correcting nutrient deficiencies (Whyte *et al.*, 1969).

Practical cropping systems options with appropriate management practices for wheat in western parts of Ethiopia have not been clearly identified. However, making use of their indigenous knowledge, most farmers practice crop rotation based on short-term agronomic benefits break crops, and most studies in the past focused on the short-term agronomic benefits of break crops for wheat production (Hailu *et al.*, 1989).

The application of chemical fertilizer has been recommended for wheat production in eastern and southern Africa (ESA) without considering the sustainability of continuous application (Tanner, 1997). Demonstration and extension of fertilizer and improved seeds along with all the recommended practices were started in Ethiopia with the introduction of the Minimum Package Program (MPP) (1967 - 78). In this Program, based on multi-locational trials and demonstration results, "blanket fertilizer recommendations" were made for major cereal crops in the country. The "blanket" fertilizer rate recommendations of EPID during the 1970s are still used for wheat production (Asnakew *et al.*, 1991), and there are no reports available on the long-term effects of these recommended fertilizer rates on wheat production in the Shambo highlands. However, increasing productivity and system sustainability through crop rotation has been suggested to be a sound management options for small-scale farmers in the Ethiopian highlands. Hailu *et al.* (1989) reported that faba bean as a break crop increased wheat grain yield by 1,100 kg ha^{-1} or 69 % cf. the yield of second-year continuously cropped wheat, while the study of Asefa *et al.* (1992) indicated that a faba bean crop increased the yield of the following wheat crop by 982 kg ha^{-1}, or 44 %, compared to that of continuously cropped wheat. However, studies have not been conducted in the highlands of Shambo in relation to these agronomic interventions. Furthermore, the agronomic results of "multi-optional and local input inclusive trials" are important to obtain useful information on break crops for wheat production in the area. Therefore, the objective of this study was to evaluate the effects of pulse and cereal break crops along with management practices on wheat productivity in the Shambo highlands.

Materials and Methods

The experiment was conducted during the1997, 1998 and 1999 cropping seasons at Shambo: 9°34'N latitude and 37°06'E longitude at an altitude of 2400 meters above sea level. Mean annual rainfall is 1,695 mm (NMSA, 2003). It has a cool humid climate with the mean minimum, mean maximum, and average air temperatures of 8.15°C, 15.72°C, and 11.94°C, respectively. The soils are nitisols.

The experiment was laid out as split plot in a randomized complete block design with precursor crops as main plots and management practices as sub-plots. The precursor crops were field pea (*Pisum sativum)* variety (G-22763-2c) and barley (*Hordeum vulgar)* variety (Shege) and were sown in the 1997 cropping season. Wheat was sown on these plots in six management sub-treatments in the 1998 and 1999 seasons The wheat management practices included wheat variety, cultural practices and fertilizer level, arranged as follows:

- Farmer's variety and farmer's traditional practices without fertilizer (FVFP-FE)
- Improved variety and farmer's traditional practices without fertilizer (IVFP-FE)
- Farmer's variety with improved practices without chemical fertilizer (FVIP-FE)
- Improved variety with improved agronomic practices without chemical fertilizer (IVIP-FE)
- Farmer's variety with all improved agronomic practices with chemical fertilizer (FVIP + FE)
- Improved variety with all improved agronomic practices with chemical fertilize (IVIP + FE).

The wheat varieties used were the local variety "*Molgo"* (awnless wheat) and HAR-604 (Galama), an improved variety. The improved cultural practices were the recommendation practices as for wheat. For the improved cultural practices, the herbicide 2,4-D was applied 30 to 45 days after planting to control weeds while in plots with the farmer's cultural practices, hand weeding was done once at 25 days after sowing. The recommended fertilizer rates of 100 kg ha^{-1} each for DAP and Urea were applied at planting n the plots receiving fertilizers.

The plot size was 10 m x 10 m. The seed rates were 150 kg ha^{-1} for field pea, barley and the improved wheat variety, whereas the normal farmer practice of 160 kg ha^{-1} was used for the local variety. Sowing dates were between mid June and early July.

The data were analyzed using MSTAT-C Computer Software Program. Selected orthogonal contrasts were used to separate the effects of the two levels of the three factors: management practices, fertilizer effects, and variety.

Economic evaluation was conducted using the partial budget, values to cost ratio (VCR) and marginal analyses methods. Wheat grain yield was valued at the average open market price over the last five years of Ethiopian Bihr (EB) 143.00/100 kg. Plot grain yields were reduced by 10 % to reflect actual production environments (CIMMYT, 1988). The wheat seed cost used was EB 2.40/kg for the improved variety and EB 1.43/kg for the local variety. Urea and DAP were valued at the official prices of EB 192.00 and 256/100 kg respectively. The cost utilized for labour for weeding was EB 3.50/day. The average rental price of a sprayer was EB 10.00 ha^{-1}, and the cost of 2,4-D herbicide was EB 0.42/liter.

Results and Discussion

The yields of the precursor crops sown in the 1997 cropping season are shown in Table 1.

Table 1. Mean grain yield of break crops, field pea and barley in 1997.

Crop	Grain yield (kg ha^{-1})*
Field pea	556
Barley	1549

* Statistically significant t-value at P=0.01

With all management practices, the grain yield of wheat was significantly greater ($P<0.05$) following field peas than following barly in both cropping seasons (Tables 2 and 3). The mean grain yield of wheat was increased by 39% and 25% following field pea compared to barley in the 1998 and 1999 cropping seasons respectively, and on average by 32%. This benefit of the field pea break crop has also been shown by Tanner *et al.* (1991), who reported that wheat after barley break crop was not significantly different from continuous wheat production, and Tilahun *et al.* (2000). Tanner *et al.* (1999) showed that wheat grain yield was consistently higher in rotation with dicotyledonous crops than with cereal crops, exhibiting grain yield increments ranging from 22 to 54 %. In addition, in their studies, wheat grain yield was higher in rotation with faba bean than with rapeseed, with grain yield increases ranging from 8 to 31 %. This is likely due to the fixing of free atmospheric nitrogen by Rhizobium bacteria in association with

Table 2. Effects of break crops and management practices on grain yield of wheat (kg ha-1) at Shambo in 1998.

Treatment	Management practices						Mean
Break crop	FVFP -FE	IVFP -FE	FVIP -FE	IVIP -FE	FVFP +FE	IVIP +FE	
Barley	1093	1563	1300	1400	1590	1763	1451
Field pea	1510	2250	1650	2390	1970	2373	2024
Mean	1302	1906	1475	1895	1780	2068	1718
Yield change (%) (Pea/barley)	38	44	27	71	24	35	39

	Break crop	Mgmt practices	Break crop x Mgmt practices
LSD (5%)	206	480	NS
CV %	8.25	22.94	

Table 3. Effects of break crops and management practices on grain yield of wheat (kg ha^{-1}) at Shambo in 1999.

Treatment	Management practices						Mean
Break crop	FVFP -FE	IVFP -FE	FVIP -FE	IVIP -FE	FVFP +FE	IVIP +FE	
Barley	1087	1800	1400	1210	1767	1947	1535
Field pea	1567	2033	1633	2133	1933	2200	1917
Mean	1327	1917	1517	1672	1850	2073	1726
Yield change (%) (Pea/barley)	44	13	17	76	9	13	25

	Break crop	Mgmt practices	Break crop x Mgmt practices
LSD (5%)	155	NS	NS
CV %	6.26	25.40	

Table 4. Effects of break crops and management practices on mean grain yield of wheat (kg ha^{-1}) at Shambo (combined over two years), 1998-1999.

Treatment	Management practices						Mean
Break crops	FVFP -FE	IVFP -FE	FVIP -FE	IVIP -FE	FVFP +FE	IVIP +FE	
Barley	1090	1681	1350	1305	1678	1855	1493
Field pea	1538	2142	1642	2262	1952	2287	1970
Mean	1314	1911	1496	1783	1815	2071	
Yield change (%)	41	27	22	73	16	24	32

	Break crop	Mgmt practices	Break crop x Mgmt practices
LSD (5%)	83.02	345.7	NS
CV %	7.33	24.19	

the legume break crops, as the amount of nitrogen left in the soil by a crop may influence the yield of the crop that follows it (Martin *et al.*, 1976).

The yield increment of local variety was lesser in field pea break as compared to barley in two consecutive years as the management practices increased. This might be due to the more nitrogen left in the soil from legume break crop. Tanner *et al*. (1991) reported that for most of the characteristics, the effect of faba bean break crop was similar to that of N-fertilizer. The mean grain yield increment ranged from 24 of 71 % was observed from the FVFP+FE and IVIP-FE following field pea as compared to barely in 1998 (Table 2). Mean grain yield advantage of 9 to 76 % was recorded from FVFP+FE and IVIP-FE following field pea as compared to barely in 1998 (Table 3). The result argues that with improved agronomic managements both fields gave similar yields.

Management practices had significant ($P<0.05$) effects for grain yield in 1998 and when combined over the two years, but differences were not significant in 1999 (Tables 2, 3 and 4). There was no significant interaction bewteen previous crop and management practices on grain yield of wheat in either year, nor in the combined data (Tables 2, 3 and 4).

Orthogonal contrasts of all three factors (variety, cultural practices and fertilizer use) showed highly significant mean grain yield difference ($P< 0.01$) (Table 5). The improved variety gave a mean grain yield increases of 191 kg ha^{-1}, the improved management practices a yield advantage of 78 kg ha^{-1}, fertilizer application a mean wheat grain yield increase of 115 kg ha^{-1}. Thus improved agronomic practices are very advantageous for wheat production in the Shambo highlands.

Table 5. Statistical significance of orthogonal comparisons in the wheat management trial at Shambo, 1998-1999.

Contrast[a]	Mean grain yield
Farmers vs. improved management practices	**
Local vs. improved variety	**
With fertilizer vs. without fertilizer application	**

** Significant at 1% level of probability.

[a] See materials and methods for complete description of orthogonal contrasts used

Economic analysis of the management practices indicated that the highest net benefit of EB 1554.23 ha^{-1} and a cost:benefit ratio of EB 1.26 profit per unit of investment were obtained from the treatment with the improved variety, improved management practices and fertilizer application (IVIP+FE)(Table 6). The second highest net benefit of EB 1537.83 ha^{-1}, and a cost:benefit ratio of EB 3.03 profit per unit investment, was achieved with the farmers' variety, improved agronomic management practices without fertilizer application (FVIP-FE). However, the marginal rate of return of IVIP+FE over FVIP-FE was only 2.2%, far too low to warrant the recommendation of this treatment. The cost:benefit ratios of the other management practices were EB 1.29, 1.19, 1.30 and 1.08 profit per unit investment, from IVFP-FE, IVIP-FE, FVIP+FE and FVFP-FE respectively.

Table 6. Partial budget and marginal rate of return (MRR) analyses for the effects of management practices on the grain yield of wheat at Shambo, 1998-1999.

Item	Management practices					
	FVIP -FE	FVFP -FE	FVIP +FE	IVIP -FE	IVFP -FE	IVIP +FE
Average yield (kg ha^{-1}) of wheat	1496	1314	1815	1783	1911	2071
Adjusted yield (kg ha^{-1}) Wheat	1346	1183	1634	1605	1720	1864
Gross field benefit of Wheat grain	1925	1691	2336	2294	2459	2665
Average straw yield (kg ha^{-1})	2400	1947	2850	2003	1870	2457
Gross field benefit of wheat straw	120	97	143	100	94	123
Total field benefit (EB ha^{-1})	2045	1788	2478	2395	2553	2788
Costs that vary (EB ha^{-1})						
Wheat seed cost (EB ha^{-1}	215	215	215	360	360	360
Urea	-	-	192	-	-	192
DAP	-	-	256	-	-	256
Rental price of sprayer (EB ha^{-1})	10	-	10	10	-	10
Herbicide cost (EB ha^{-1})	42	-	42	42	-	42
Fertilizer application cost (EB ha^{-1})	-	-	11	-	-	10.5
Total labour cost (EB ha^{-1})	241	645	350	683	756	364
Total costs that vary (EB ha^{-1})	508	860	1075	1095	1117	1234
Net benefit	1538	929^{D}	1403^{D}	1300^{D}	1436^{D}	1554
Value to cost ratio	3.03	1.08	1.30	1.19	1.29	1.26
Marginal rate of return (MRR)						2.20%

Note: D= dominated treatment, Urea= EB 1.92/kg, DAP= EB 2.56/kg, Labour cost =EB 3.5/day, 2,4-D= EB 0.42/litter, Grain price= EB 1.37/kg, Local seed = EB 1.43/kg, Improved seed= EB 2.40/kg, Straw cost= EB 0.05/kg, Rental price of sprayer= EB 10.00 ha^{-1}, Fertilizer application cost= EB 10.50 ha^{-1}, Yield was down adjusted with 10 % coefficient

It is noteworthy that the farmers’ common practice (FVFP-FE) was dominated in the partial budget analysis, because the best treatment (FVIP-FE) gave higher net benefits with lower costs that vary. In the current study the low cost of seed of the farmers’ variety resulted in this variety dominating the treatments with the improved variety. However, it should be noted that the full cost of buying new seed of the improved variety was used, whereas this can probably be discounted as usually the farmer will use this seed for several years. The high cost of commercial fertilizer and improved seed made the improved agronomic practices for wheat production costly, and reduced prices of improved seed and commercial fertilizer will benefit wheat producers of the area. However, with the average current prices of inputs, use of farmers' variety with improved technology without fertilizer or the improved variety with improved practices and fertilizer application were economically viable and profitable. Both the local and improved varieties gave better grain yield under intensive management practices with fertilizer application (Table 4). The least profitable management option of wheat is farmer's variety with farmer's management practices and without fertilizer application. However, the escalating price of chemical fertilizer and improved seed, together with the reduced market price of grain drastically decrease the profitability of wheat production with improved packages.

Conclusion

A previous field pea crop significantly increased the grain yield of wheat compared to a previous barley crop. Both the local variety and the improved variety gave the greatest yields under improved agronomic management with chemical fertilizer application when following after a field pea break crop. The economic analysis indicates that optimum market prices should be determined by the policy makers for producers of wheat in order to get the potential benefit of the recommended package. Alternative technologies should be developed on the integration of inorganic and organic fertilizer use for profitable wheat production. Long term investigation on the economic benefit of rotation effects with intensive management practices and the extension of the results to the farmers is essential for sustainable wheat production in the Shambo highlands.

Acknowledgment—The authors thank Oromiya Agricultural Research Institute for funding the project. We are most grateful to our senior researchers Mr. Abdissa Gemeda and Mr. Abubeker Mussa for their priceless contributions to us in executing this experiment. We are also grateful to Mr. Asefa Mijena, Tesema Tesso and Yosef kenea for their assistance in carrying out the experiment and efficiently collecting the data. Bako Research Center Management is also thanked for facilitating the execution of the field trial.

References

Asefa Taa, Tanner, D G. and Amanuel Gorfu. 1992. The effects of tillage practices on bread wheat in three different cropping sequences in Ethiopia. pp. 376-386. *In:* Tanner, D. G. and Mwangi, W. (eds.). Seventh Regional Wheat Workshop for Eastern, Central and Southern Africa. CIMMYT, Nakuru, Kenya.

Asfaw Negassa, Abdissa Gemeda, Tesfaye Kumsa and Gemechu Gedeno. 1997. Agro ecological and Socioeconomical Circumstances of farmers in East Wallagga Zone of Oromiya Region, Ethiopia. Research Report No. 32. Institute of Agricultural Research, Addis Ababa, Ethiopia.

Asnakew Woldeab, Tekaligne Mamo, Mengesha Bekele and Tefera Ajema. 1991. Soil fertility management studies on wheat in Ethiopia. pp.137-172. *In:* Hailu Gebre-Mariam, Tanner, D.G. and Mengistu Hulluka (eds.). Wheat Research in Ethiopia: A Historical Perspective. Addis Ababa, IAR/CIMMYT.

CIMMYT. 1998. From Agronomic Data to Farmer Recommendations. An Economics Training Manual. Completely Revised Edition. CIMMYT, Mexico, D.F., Mexico. 79 pp

Hailu Gebre, Amsal Tarekegne and Endale Asmare. 1989. Beneficial break crops for wheat production. Ethiopian Journal of Agricultural Sciences Vol. 11: 15-24.

Hailu Gebre-Mariam, Tanner, D.G. and Mengistu Hulluka. 1991 Wheat Research in Ethiopia: A Historical Perspective. Addis Ababa, IAR/CIMMYT.

Martin, J. H., Leonard, W. H., and Stamp, D. L. 1976. Principles of Field Crop Production (3rd ed.). Collier Macmillan Publishing. London, UK.

Lal, R. 1989. Conservation tillage for sustainable agriculture: Tropics versus temperate environment. Advances in Agronomy 42:85-197.

NMSA (National Meteorological Service Agency). 2003. Meteorological data of Shambo area for 1969-2002. NMSA, Addis Ababa, Ethiopia.

Tanner, D. G., Amanuel Gorfu and Kassahun Zewdie. 1991. Wheat agronomy research in Ethiopia. pp. 95-135. *In*: Hailu Gebre-Mariam, Tanner, D.G. and Mengistu Hulluka (eds.). Wheat Research in Ethiopia: A Historical Perspective. Addis Ababa: IAR/CIMMYT.

Tanner, D.G. 1997. Sustainable wheat production: global perspectives and local initiatives. pp. 10-41 *In:* Woldeyesus Sinebo (ed.). Crop Management Research for Sustainable Production: Status and Potentials. Proceedings of the Second Annual Conference of the Agronomy and Crop Physiology Society of Ethiopia. ACPSE, Addis Ababa, Ethiopia.

Tanner, D.G., Verkuij, H., Asefa Taa and Regassa Ensermu. 1999. An agronomic and economic analysis of long-term wheat based crop rotation trial in Ethiopia. pp. 213-248. *In:* The Tenth Regional Wheat Workshop for Eastern, Centeral and Southern Africa. Addis Ababa, Ethiopia: CIMMYT.

Tilahun Geleto, Kedir Nefo and Feyissa Tadesse. 2000. Crop rotation effects on grain yield and yield components of bread wheat in the Bale highlands of southeastern Ethiopia. pp. 316-324. *In:* The Eleventh Regional Wheat Workshop for Eastern, Central and Southern Africa. Addis Ababa, Ethiopia: CIMMYT.

Whyte, R.O., Neisser, G. N. and Trumble, H.C. 1969. Legumes in Agriculture. Food and Agricultural Organization of the United Nations, Rome, Italy.

Response of Bread Wheat to Nitrogen and Phosphorous Fertilizers at Different Agro-ecologies of Northwestern Ethiopia

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Abstract—Wheat is one of the major cereal crops grown in northwestern Ethiopia, though its productivity in farmers' fields is very low. In northwestern Ethiopia, N and P deficiencies are among the major biophysical constraints. Wheat fertilizer response trials were conducted at different agro-ecologies on farmers' field during 1999, 2000 and 2001. The objective of the trial was to determine economically optimum rates of N and P fertilizer for the high-yielding semi-dwarf bread wheat cultivars HAR 1868 and HAR 604 at Farta and Laie-Gaient areas, respectively. Four rates of N (0, 46, 92 & 138 kg/ha for Farta where as 0, 41, 82 & 123 kg/ha for Laie-Gaient) and four rates of P_2O_5 (0, 23, 46 & 69 kg/ha for both localities) were laid out in a factorial arrangement in RCB design with three replications. The results indicated highly significant differences on grain yield, plant height, tiller and spike density and thousand-kernel weight amongst the fertilizer rates in the two locations. There was a linear increase in grain yield of bread wheat as the rates of N and P increased. The increase in grain yield is significant for nitrogen, P and N by P interaction. The highest grain yield, 3025 kg/ha at Farta and 2610 kg/ha at Laie-Gaient were obtained at the highest fertilizer rates of 138/69 kg N/ P_2O_5 ha^{-1} and 123/69 kg N/ P_2O_5 ha^{-1}, respectively. Fertilizer rates of 138/46 kg N/P_2O_5 ha^{-1} at Farta and 123/46 kg N/ P_2O_5 ha^{-1} at Laie-Gaient were found economically feasible with net benefit (NB) of Ethiopian Birr 3538 and 3062, respectively.

Introduction

Wheat ranks fifth in production and area and fourth in mean-yield among the principal cereal crops grown in the country. The national mean yield is low ranging from about 1.1 t/ha for peasant farmers to about 2 t/ha for state farms (Hailu *et al.*, 1991). Soil degradation is a serious problem in many parts of the country, largely as a result of mismanagement of natural resources. Erosion and farmers' practice of continuous cultivation without fallow aggravate the soil fertility problem. Northwestern Ethiopia is accompanied with diversified agro ecologies. Poor soil fertility particularly N and P deficiencies are among the major biophysical constraints in those agro ecologies (Hailu *et al.*1991, UNDP 1996, Aleligne *et al.*1992, ANRS BOPED 2000, Aleligne & Regassa 1992). Previous experiments conducted at the different agro ecologies of the region indicated variations in yield responses of the wheat crop to fertilizer application. Therefore, this wheat fertilizer response trial was conducted at the two agro ecologically different localities on farmers' field during 1999, 2000 and 2001. The objective was to determine economically optimum rates of N and P fertilizer for the high-yielding semi-dwarf bread wheat cultivars HAR 1868 and HAR 604 at Farta and Laie-Gaient areas, respectively.

Materials and Methods

The experiment was carried out on luvisols at Farta and Laie-Gaient region on farmers' fields for three consecutive years (1999-2001) on a total of five sites at Farta and seven sites at Laie-Gaient. Laie-Gaient and Farta at an altitude of 2860 and 2630 m.a.s.l., respectively are located on the same zone (south Gondar) of northwestern Ethiopia but represent different agro ecologies. Laie-Gaient is characterized by erratic rainfall, short rainy season (late onset and early cease) and low temperature compared to Farta area. The soil fertility status of Farta area is total N 0.08%, available P 3.70%, OC 3.20, C/N 40 and pH of the soil 5.17.

The experiment consisted of 16 factorial combinations of four N rates 0,46,92 and 138 kg/ha for Farta, 0,41,82 and 123 kg/ha for Laie-Gaient and four P_2O_5 rates (0, 23, 46 & 69 kg/ha) at both sites. The design was a complete factorial arrangement within an RCB with three replications. The improved varieties HAR-1868 (shina) at Farta and HAR-604 (Galema) at Laie-Gaient were used. Seeds were broadcasted at the recommended seed rate of 175 kg/ha. DAP, urea and TSP were the sources of N and P_2O_5. All P and half of the N were applied at sowing, and the remaining N was top dressed at early to mid-tillering stage of the crop. The gross and net plot sizes were $20m^2$ and $12m^2$, respectively. Data were collected on grain yield, tiller and spike density at maturity, plant height and thousand-kernel weight. All data were subjected to analysis of variance (ANOVA) using the MSTATC microcomputer software.

The mean grain yield data over sites for each location was adjusted down by 10% and subjected to partial budget and sensitivity analysis (CIMMYT, 1988). Total costs that varied (fertilizer cost) for each treatments was calculated and treatments were ranked in order of ascending total variable cost (TVC) and dominance analysis was used to eliminate those treatments costing more but producing a lower net benefit than the next lowest cost treatment. The marginal rate of return (MRR) was calculated for each non-dominated treatment and a minimum acceptable MRR of 100% was assumed. Sensitivity analysis was made through the assumption that cost of fertilizer and price grain increased by 10%, respectively.

Results and Discussion

Analysis on mean grain yield of the individual sites indicated significant responses for N application in all sites. At Farta, all sites except one showed significant response to P application where as at Laie-Gaient only one site showed significant responses to P (Table 1). Fertilizer application increased grain yield ranging from 1554 to 2602 $kgha^{-1}$ at Farta and 1208 to 2447 $kgha^{-1}$ at Laie-Gaient compared to the unfertilized control.

Results on combined analysis indicated significant response for N application in all traits except thousand kernel weight at Laie-Gaient. The response for P application was significant on grain yield, plant height and thousand kernel weight at Farta. At Laie-Gaient all traits showed significant response except thousand kernel weight. Most of the traits showed a significant responses to NxP interaction (Table 2). Generally there was linear increase in all the parameters as the N and P rates increased. This is in line with previous findings that at most sites of northwestern Ethiopia, wheat grain yield responds positively to increasing fertilizer rates (Minale et al. 1999; Ammanuel et al. 1990). The responses were relatively larger for N than P in all parameter considered. Biologically the highest grain yield 3052 $kgha^{-1}$ at Farta and 2610 $kgha^{-1}$ at Laie-Gaient were obtained at the highest fertilizer rates in both of the locations (Table 3 & 4). An increase in grain yield, 175.70 and 106.50%, over the control was recorded at Farta and Laie-Gaient areas, respectively.

Table 1: Results of ANOVA and mean grain yield of bread wheat on the individual sites of the two regions

	Farta region					Laie-Gaient region						
Source of variation	Site-1	Site-2	Site-3	Site-4	Site-5	Site-1	Site-2	Site-3	Site-4	Site-5	Site-6	Site-7
N	**	*	**	**	**	**	**	*	**	**	**	**
P_2O_5	**	**	NS	**	*	NS	NS	NS	NS	NS	*	NS
N X P_2O_5	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mean yield ($kgha^{-1}$) of 0/0 N/ P_2O_5	495	1663	1510	490	1376	1689	1311	1134	889	1483	1381	961
Highest mean yield ($kgha^{-1}$)	2816	3453	3603	3092	2930	4136	3038	2342	2337	2925	2768	2218
N/ P_2O_5 comb. for highest yield	138/69	92/69	92/23	138/46	138/46	92/46	123/69	123/69	123/69	123/46	123/23	123/69
CV(%)	20.02	25.10	18.40	37.54	21.45	35.24	28.00	37.66	28.28	29.56	20.27	31.42

*,** Indicate significance at the 5 &1% levels, respectively.
NS Indicate non-significance

Table 2: Results of combined analysis of variance over sites of the two locations

	Farta area					Laie-Gaient area				
Source of variation	Grain yield (kg/ha)	plant height (cm)	Tiller /m^2 at maturity	Fertile spike/m^2	1000 kernel wt.(g)	Grain yield (kg/ha)	plant height (cm)	Tiller /m^2 at maturity	Fertile spike/m^2	1000 kernel wt.(g)
Site (S)	**	**	**	**	**	**	**	**	**	**
N	**	**	*	*	**	**	**	**	**	NS
NxS	*	NS	**	**	**	*	NS	NS	NS	**
P_2O_5	**	**	NS	NS	**	**	**	*	*	NS
P_2O_5 x S	*	*	NS	NS	**	NS	NS	NS	NS	*
N x P_2O_5	*	*	NS	*	*	*	*	*	NS	NS
Mean value of 0/0 N/P_2O_5	1107	63.1	319	304	26.8	1264	71.2	245	234	41.3
Highest mean value	3052	82.3	391	381	32.8	2610	95.3	308	300	43.5
N/P_2O_5 comb. for highest value	138/69	138/69	138/0	138/0	138/69	123/69	123/69	123/69	123/23	41/46

*,** Indicate significance at the 5 &1% levels, respectively.
NS Indicate non-significance

Table 3: Effect of nitrogen (N) and phosphorus (P_2O_5) on the grain yield (kg/ha) of bread wheat (Shina variety) at Farta area

N levels (kg/ha)	P_2O_5 levels (kg/ha)				**Mean**
	0	**23**	**46**	**69**	
0	1107	1429	1570	1802	1477
46	1535	1832	2115	1990	1868
92	2033	2359	2696	2426	2379
138	2116	2833	3025	3052	2757
Mean	1698	2113	2352	2318	

C.V(%)	24.8		
	N	P	N x P
LSD (5%)	190	190	380

Table 4: Effect of N and P on the grain yield (kg/ha) of bread wheat (Galema variety) at Laie-Gaient area

N rates (kg/ha)	P_2O_5 rates kg/ha				Mean
	0	**23**	**46**	**69**	
0	1264	1103	1280	1355	1251
41	1630	1413	1754	1605	1601
82	1817	2206	2237	2297	2139
123	1890	2457	2599	2610	2389
Mean	1650	1795	1967	1967	

C.V(%)	31.2		
	N	**P**	**N x P**
LSD (5%)	174.8	174.8	349.6

The economic analysis indicated 138/46 kg N/P_2O_5 ha^{-1} was more profitable with net benefit (NB) of birr 3538.4 and an acceptable marginal rate of return (MRR) of 171.9% at Farta area (Table 5). The NB increased by birr 1958.6 over the unfertilized one through the application of 138/46 kg N/P_2O_5 ha^{-1}. The sensitivity analysis revealed the same recommendation as to the current situations.

Table 5: Results of the economic analysis of N and P_2O_5 fertilizers rate on grain yield of bread wheat at Farta area

	At current cost and price			Scenario (cost of fertilizer & price of grain increased and decreased, respectively by 10%)		
N/P_2O_5 ($kgha^{-1}$)	TVC (Eth. birr)	NB (Eth. birr)	MRR (%)	TVC (Eth. birr)	NB (Eth. birr)	MRR (%)
0/0	0	1579.8		0	1421.8	
0/23	138.8	1900.5	231.0	152.7	1682.7	170.8
46/0	192.7	1998.7	182.4	211.9	1760.3	131.1
46/23	293.8	2321.5	319.2	323.2	2030.6	243.0
92/0	385.3	2516.0	212.5	423.9	2187.4	155.7
46/46	395.0	2624.5	1128.4	434.4	2283.0	905.3
92/23	486.5	2881.6	280.9	535.1	2496.1	211.6
92/46	587.6	3261.2	375.3	646.4	2817.5	288.9
138/23	679.1	3364.5	112.9	747.1	2892.2	74.2
138/46	780.3	3538.4	172.0	858.3	3028.5	122.5

Note: Cost of DAP = Birr 2.77/kg
Cost of Urea = Birr 1.92/kg
Price of wheat grain = Birr 1.58/kg

The highest NB of birr 3213.2 with acceptable MRR (122.51%) was obtained at fertilizer rates of 138/46 kg N/P_2O_5 ha^{-1}. At Laie-Gaient, 123/46 kg N/P_2O_5 ha^{-1} was more profitable with a NB of birr 3061.7 and MRR 117.5% (Table 6). The sensitivity analysis showed 123/46 kg N/P_2O_5 ha^{-1} gave the highest NB, however, the MRR is below the acceptable level. Therefore, with the assumption that price of grain and fertilizers decreased and increased, respectively by 10%, fertilizer rate of 82/23 kg N/P_2O_5 ha^{-1} will be the optimum rate to be recommended.

Table 6 Results of the economic analysis of N and P_2O_5 fertilizers rate on grain yield of bread wheat at Laie-Gaient area

	At current cost and price			Scenario (cost of fertilizer & price of grain increased and decreased, respectively by 10%)		
N/P_2O_5 ($kgha^{-1}$)	TVC (Eth. birr)	NB (Eth. birr)	MRR (%)	TVC (Eth. birr)	NB (Eth. birr)	MRR (%)
0/0	0	1846.7		0	1662	
41/0	181.5	2200.5	194.9	199.7	1944.1	141.3
82/0	363.3	2290.7	49.6	399.6	1989.0	22.5
82/23	458.6	2764.0	496.5	504.4	2395.9	388.2
123/23	640.1	2949.4	102.2	704.1	2526.4	65.3
123/46	735.6	3061.7	117.5	809.2	2608.4	78.1

Note: Cost of DAP = Birr 2.70/kg
Cost of Urea = Birr 2.03/kg
Price of wheat grain = Birr 1.62/kg

References

Aleligne Kefyalew, and Regassa Ensermu. 1992. Bahir-Dar Mixed Farming Zone: Diagnostic Survey Report. Research Report No 18. Institute of Agricultural Research, Addis Ababa, Ethiopia Amahara National Regional State Bureau of Planning and Economic Development (ANRS BOPED). 2000. Annual Statistical Bulletin , Bahir Dar Ethiopia.

CIMMYT. 1988. From agronomic data to farmer recommendations: An economics training manual. Completely revised edition. Mexico, D.F.

Hailu Gebre-Mariam, Tanner, D.G., and Mengistu Hulluka, (eds.). 1991. *Wheat Research in Ethiopia: A historical perspective*. Addis Ababa: IAR/CIMMYT.

UNDP. 1996. Sustainable Agricultural and Environmental Rehabilitation Program (SAERP). House Hold Level Socio-Economic Survey of the Amhara Region. V.l Produced by the Cooperative Endeavors of the Amhara Regional Council. Bahir Dar, Ethiopia.

Ammanuel G, D.G. Tanner, Lemma Z, Tilahun G, Zewdu Y. and Eyasu E. 1990. Derivation of Economic fertilizer recommendations for bread wheat in the Ethiopian highlands: On-Farm trial in the peasant sector. PP. 63-72. In; Tanner, D.G., M. van Ginkel, and W. Mwangi, eds. Sixth Regional Wheat Workshop for Eastern, Central and Southern Africa. Mexico, D.F; CIMMYT.

Minale Liben, Alemayehu Assefa, D.G. Tanner and Tilahun Tadesse. 1999. The response of bread wheat to N and P application under improved drainage on Bichena Vertisols in northwestern Ethiopia. The Tenth Regional Wheat Workshop for Eastern, Central and Southern Africa. Addis Ababa, Ethiopia: CIMMYT.

Grain Yield, Water Use and Water Use Efficiency as Affected by Moisture Level Under Rain-Out Shelter

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Abstract—About one-third of the developing world's wheat area is located in environments that are regarded as marginal for wheat production, because of drought, heat, and soil problems. Nearly one-third of the area planted to bread wheat and about three-quarters of the area planted to durum wheat suffer from drought stress during the growing seasons. Despite these limitations, the world's dry and difficult cropping environments are increasingly crucial to food security in the developing world. Gains in wheat productivity in marginal environments are important because it is unlikely that increased productivity in the favourable environments will be sufficient to meet the projected growth in demand for wheat from the present to 2020. This study was aimed at evaluating wheat genotypes' water use efficiency (WUE) as affected by moisture regime. An experiment was conducted under rain shelter for two seasons (2001-2002) with six cultivars (Duma, Ngamia, Chozi, Kwale, Mbuni and Pasa) tested under two moisture regimes (High and low moisture regimes). The experiment was a randomized complete block design (RCBD) with split arrangement of the treatments. Moisture regime was assigned as the main plot and cultivars as the sub-plot. An analysis of variance was carried out on combined season using SAS computer package. The genotypes tested were significantly different in their water use efficiency (WUE) under both low and high moisture conditions. The drought-tolerant cultivars (DTC)—Duma, Ngamia and Chozi—had significantly higher WUE under moisture stress than the drought-susceptible cultivars (DSC)—Kwale, Mbuni and Pasa. Under high moisture the WUE of the DTC was decreased by 10-19% and in the DSC, it increased by 26-29.

Introduction

Cereals contribute significantly to food security in Kenya (Wanjama *et al,* 1993). Among cereals, wheat has been ranked second to maize (KARI, 1991) and is grown on an estimated area of 105,000 ha (representing about 6% of the total area under cereal production in Kenya) giving an annual production of about 350,000 metric tones (Ekboir, 2002). The crop is mainly grown in the Rift Valley province with Nakuru, Uasin Gishu and Narok districts contributing about 85% of the total national production (Wanjama *et al*, 1993). The national wheat production has varied over time. For example, in the period 1988 - 2000, wheat production declined annually by about 1.5% (Aquino *et al.*, 2002).

Due to the reduction in wheat area, Kenya produces only 40% of the national demand of approximately 720,000 tonnes, and importing about 60% of its wheat requirement (Aquino *et al.*, 2002). For example, between 1997-1999, wheat imports stood at 484,900 tonnes (5.4 million 90-kg bags), costing about 5.85 billion Kenya shillings (US$ 84 million). Kenya is bound to remain a net importer of wheat and wheat products unless domestic wheat production is significantly stepped up. Thus for wheat production to be increased to meet the increasing demand in Kenya, among other technologies, wheat growing has to be expanded to the marginal rainfall areas which consist of 83% of the total land area with unused arable potential of approximately 200,000 hectares (World Bank, 1989).

Furthermore, it has been reported that 32% of the 99 million hectares of wheat grown in developing countries experiences varying levels of drought stress (Rajaram *et al.*, 1996). In Kenya, for example, marginal rainfall areas have been able to achieve wheat yields of between one third and one half of those from high rainfall areas (Kinyua *et al.*, 1989). Promotion of wheat farming in the dry lands of Kenya can be done through several ways. These include use of irrigation and/or drought resistant wheat varieties. Irrigation would require steady supply of water and due to scarcity of water in the marginal areas and large capital required, irrigation is not easily achievable. Thus development of appropriate varieties for marginal areas may be the most effective alternative for utilizing these areas for crop production. Therefore, the main objective of this study was to evaluate WUE as an indirect method for selecting drought tolerant wheat cultivars.

Materials and Methods

An experiment was conducted in the rain shelter for two seasons between August, 2001 and May, 2002 at the National Plant Breeding Research Centre (NPBRC), Kenya (0^o 20' S and 35^o56'E and altitude 2185 metres) [NPBRC Meteorological Station No. 9035021, 1999]. The site lies within the Agro-ecological zone LH3 (AEZ LH3) with a bi-modal rainfall pattern (Jaetzold and Schmidt, 1983). The site receives an annual rainfall of about 960 mm with an average maximum and minimum temperatures of 24 ^{o} C and 8 ^{o} C, respectively (NPBRC, Njoro Meteorological station No.9035021, 1999).

The soil at the is site well drained, deep to very deep, dark reddish brown, friable and smeary, silt clay, with humic topsoil classified as mollic Andosols (Jaetzold and Schmidt, 1983). The site was under fallow for two seasons before this study was carried out. The experiment was carried out under a mobile rain-out shelter (which is an open ended structure measuring 30 m long and 7 m wide constructed at NPBRC) to exclude rain and consequently induce drought stress. The shelter consists of a roof mounted on wheels that allows it to roll on two parallel-elevated concrete tracks. Translucent sheets (which allow up to 90% photosynthetic photon flux density) covered the roof. The sides had metal frame, which was covered by foldable polythene sheets, with open-end 0.5 m above the ground. A concrete barrier had also been constructed to a depth of 0.6 m below the ground level and 0.15 m above the ground level along the two longer sides of the shade from a rail. The length of the rail was 30 m but the shelter rested on half the length. The barrier also helped to prevent the rainwater from flooding the shade. The mobile rainout shelter used is similar to that described by Legg *et al.* (1978) and Upchurch *et al.* (1983).

Six bread wheat genotypes Duma, Chozi, Ngamia, Kwale, Mbuni and Pasa were grown under two watering regimes (High and low watering regimes) for two seasons. The experiment was laid out in a randomized complete block design (RCBD) with split plot arrangement with the watering regime being the main plot and cultivar as sub-plot.

Thirty-six (36) access tubes (PVC in nature) with 39.4 mm and 41.4 mm as internal and outside diameters, respectively, were installed in the field before planting. In each sub-plot, an access tube was installed in holes drilled by hand using a soil auger. The tubes were cut to a depth of 1.7 m out of which 1.1 m was driven into the holes and 0.6 m was left above the soil surface. Moisture readings were taken by use a Troxler moisture meter (Neutron probe). In the process of moisture reading a standard count was at the beginning of each moisture regime.

Hydrogen ions, standard counts and moisture percentage by volume readings were taken through the access tubes at an interval of 7 days at an interval of 10 cm in the upper 40 cm and 20 cm below 40 cm. The hydrogen counts were divided by the standard counts to derive the count ratio that was later fitted in the calibration equations, for different soil levels within the profile, to calculate the actual soil water content.

The seeds of the wheat varieties used in the trial were tested for germination before planting and the seed-rate was adjusted according to the germination percentage. The recommended seed-rate of 125 kg ha^{-1} was used.

The six cultivars were planted in plots of 0.8 metres length and 2 metres wide with ten rows. The rows were 20 cm a part and planting was done by hand. The seeds were drilled continuously on the furrows (5 cm deep) made by hand. Triple super-phosphate (0-46-0) was applied in the furrows at 60 kg P_2O_5 ha^{-1} planting and calcium ammonium nitrate (CAN) at 40 kg N ha^{-1} (recommended rate) was top-dressed at early tillering stage to supply Water was supplied through a drip irrigation at a constant pressure as per the treatments. One drip lateral was laid between two wheat rows.

Watering was done once weekly and a day before watering was done moisture reading were taken by use of neutron probe. Watering was done when the moisture level had come to 50% field capacity and watering done according to treatments. The high moisture treatment received 14.5 mm and the low moisture regime received 7.5 mm once weekly. The total amount of water applied during each season was 217 mm and 113 mm for the high and low moisture regimes, respectively.

Weed control was done by the use of Buctril Mc at the rate of 1.4 L ha^{-1} at the 3-4-leaf stage of crop. The chemical was used to take care of broad-leaved weeds but for the grasses, hand weeding was done. Six innermost rows were hand harvested for biomass and grain yield determination.

Evapo-transpiration (ET) included both transpiration and direct evaporation of water from the soil surface (E_{sc}). Evapo-transpiration (ET) was determined by using the soil water balance equation given below:

$$ET = -\Delta S + I - D - R \qquad (3.1)$$

where $-\Delta S$ is the change in storage (obtained by the difference in volumetric moisture content of the entire profile at the beginning and end of the season), I is irrigation water applied, D is the drainage and R is the run-off. Drainage and run-off were assumed to be negligible hence total crop water use for the whole season obtained by summing total irrigation where applicable) and changes in storage for the entire profile (Ogola, 1999). Pilbeam *et al*., (1995) suggested that significant drainage is considered to have occurred where the soil water at the base of the profile was increased above its initial value. Drip irrigation was used hence drainage was assumed to be zero and thus not included in the water balance equation.
For the purposes of this study, water use efficiency (WUE) was defined as a ratio of grain yield (GY) to evapo-transpiration (ET). Thus WUE was determined as follows:

$$WUE = GY/ET. \qquad (3.2)$$

where GY is the grain yield.

Grain yield (GY) was determined by harvesting one metre length of the two inner-most rows. Harvesting was done by hand and threshed by the use of laboratory single head thresher and grain yield was standardized at 12.5% moisture content.
Thousand-kernel weight (TKW) was determined after grain weight had been recorded from both experiments. A thousand seeds were picked randomly and weighed to determine TKW.

Neutron probe calibration procedure

The soil profile of the site (NPBRC field 1) was described and the soil depth of the site determined and the pumice was realized to start immediately after 60-cm depth. For calibration, two access tubes were installed each at a depth of 110 cm. One of the tubes was used to get wettest point of the calibration curve whereas the other one was for the drier points of the curve (Ooro *et al.*, 2001).

The place surrounding the tube for the wettest point was flooded with water and left to settle for 24 hours and then soil samples for gravimetric moisture determination were taken at 10, 20, 30, 40, 60, 80 and 100 cm depths. At the corresponding depths, neutron probe readings were taken for the hydrogen ion counts and hence volumetric water content. The same approach was used around the access tube for the lower points of the calibration curve (Manual of operation and Instruction, 1996).

The data generated from the neutron probe readings (from the wet and dry calibration spots) were used to calculate count ratios (H^+/Standard count) plotted on the x-axis of the calibration curves and two equations were then developed for the top soil (upper 20 cm) and below 20 cm depths. The two calibrations were developed due to the variations between the readings of depths up to 20 cm and those below 20 cm. Hydrogen ions readings up to 20 cm depth were relatively lower due to scatter effect while this effect did affect readings below 20 cm. Plotting gravimetric moisture readings on the y-axis and the count ratios on the x-axis developed the equations. The equations were as follows:

0 - 20 cm depth: $$Y = 0.0661n + 0.001615 \quad (3.3)$$

30 - 100 cm depth: $$Y = 0.20960n + 0.001132 \quad (3.4)$$

where Y is the actual moisture (volumetric moisture), n = count ratios (H^+/standard counts) [H+ was read from the neutron probe].

The data read by neutron probe in the rain-shade experiment was fitted on the calibration curve to give the actual moisture content.

Data from all the parameters, combined over two seasons (2001 and 2002), were subjected to an analysis of variance (ANOVA) using SAS (SAS User's guide, 1985). Least significant difference procedure (Lsd) was used to carry out mean separations. The data was also subjected to correlation and path coefficient analysis was done to separate the direct and indirect between the agronomic traits and water use efficiency.

Results

The interaction between genotype and moisture regime affected final grain yield. High watering regime increased grain yield of both the drought tolerant and drought susceptible varieties but the increase in yield due to high watering regime was greater in susceptible (110%-134%) than in tolerant (55-64%) varieties. The drought tolerant varieties produced greater yield than the drought susceptible ones under low watering regime. Under high moisture regime, in contrast, the drought sensitive varieties produced greater yields than the tolerant ones. Significant genotypic differences in grain yield were detected. Averaged over the low watering regimes, the drought tolerant cultivars had higher yield (1274 kg ha^{-1}) while the drought susceptible ones had relatively lower yield (972 kg ha^{-1}). Moreover, drought tolerant varieties produced greater (by 39%) yield than the drought susceptible varieties under low watering regime. Averaged over all the genotypes, high watering regime increased grain yield by 89% (from 1123.2 kg ha^{-1} to 2119.0 kg ha^{-1}).

There was significant effect of the interaction between moisture regime and cultivar on crop water use, such that the increase in water use due to high watering regime was greater for drought sensitive (96%) than for drought tolerant (93%) varieties. Also, under low moisture conditions Kwale used more water (by 10%) than all the other cultivars tested while under high moisture, Chozi had significantly lower (by 3%) water use value than the rest of the cultivars. Significant genotypic differences on water use were detected. Averaged over the watering regimes, Kwale had the highest water use (139 mm) while Pasa had the lowest water use (132 mm) as compared to the other varieties tested. High watering regime increased water use (averaged over all varieties) by 95% (from 91 to 177 mm).

The interaction between variety and moisture regime affected water use efficiency (WUE) significantly (Table 1). High moisture regime decreased (by 10%-19%) WUE of drought tolerant varieties (Duma, Ngamia and Chozi) but increased (by 26%-29%) WUE of drought sensitive varieties (Kwale, Mbuni and Pasa). Under low moisture regime, drought tolerant varieties had higher WUE values than the drought sensitive varieties while the converse was true under high moisture level (Table 1). No significant effects of cultivar on WUE were detected. However, high watering regime increased WUE (averaged over all wheat varieties) by 4% (from 9.6 to 9.9 kg ha^{-1} mm^{-1}) (Table 1).

Table 1a. Grain yield, water use and water use efficiency of six wheat genotypes under two watering regimes

Treatment Moisture regime	Cultivar	Grain Yield (kg ha^{-1})	Water Use (mm)	Water Use Efficiency (kg ha^{-1} mm^{-1})
Low				
	Duma	1213.ab	90.b	10.7ab
	Ngamia	1286.a	91.b	10.9a
	Chozi	1324.a	91.b	11.1a
	Kwale	1152.abc	98.a	9.0b
	Mbuni	902.bc	88.b	7.9c
	Pasa	862.c	87.0b	7.7c
High				
	Duma	1886.b	177.a	8.7b
	Ngamia	2097.b	177. a	9.8ab
	Chozi	2173.ab	171. b	9.6b
	Kwale	2424.a	179. a	11.3a
	Mbuni	2114.ab	177.a	10.1ab
	Pasa	2020. b	177.a	9.9ab
SE		11	3	0.58
F-test probabilities				
Irrigation (I)		P<0.001	P<0.001	P<0.05
Cultivar (C)		P<0.05	P<0.05	ns
Interaction (CXI)		P<0.05	P<0.001	P<0.001

Figures followed by the same letter within the same moisture regime in the same column are not significantly different at Lsd 5%.

Table 1b. Varietal differences in yield components of wheat at two moisture levels

Treatment Moisture regime	Cultivar	No. of tillers/plant	Plant height (cm)	TKW (g/1000seeds)	No. of seeds/spike	
Low						
	Duma	4.5ab	53.b	43.b	26.c	
	Ngamia	2.7c	52. b	39.c	40.a	
	Chozi	3.7bc	58.a	46.a	27.bc	
	Kwale	3.5bc	55.ab	45.ab	25.c	
	Mbuni	4.0b	55.ab	46.a	35.abc	
	Pasa	5.7a	58.a	43. b	36.ab	
High						
	Duma	3.8bc	69.bcd	44.bc	33.b	
	Ngamia	3.7bc	66.cd	41.d	36.ab	
	Chozi	5.7a	81.a	49.a	28.b	
	Kwale	4.7ab	70. bc	46.b	34.ab	
	Mbuni	3.3c	73.bc	42.cd	35.ab	
	Pasa	4.5abc	65.d	40.d	43.a	
SE		0.63	2.	1	9	
F-test probabilities						
Irrigation (I)		P<0.001	P<0.05	ns	P<0.001	
Cultivar (C)		P<0.001 ns	P<0.05	P<0.05		
Interaction (CXI)		P<0.05	P<0.001	P<0.001	P<0.001	

Figures followed by the same letter within the same moisture regime in the same column are not significantly different at Lsd 5%.

Discussion

Improving drought tolerant of wheat has long been a major objective of most breeding program because water deficits during some parts of growing period are common in most regions of the world where wheat is produced under rain-fed conditions. Therefore in this study the cultivars tested were evaluated with an aim of understanding their reactions under low and high moisture regimes. Significant interactions were observed between moisture level and water use efficiency (WUE) of wheat cultivars. The WUE of drought tolerant wheat cultivars (Duma, Ngamia and Chozi) was decreased (by 14%) under high moisture but increased (by 30%) WUE of drought sensitive varieties (Kwale, Mbuni and Pasa). This behaviour of drought tolerant cultivars under low moisture was probably due to the fact they had less tiller number per plant compared to the susceptible varieties. Fewer tillers of drought tolerant wheat have been reported from studies by Ehlig and Lemert (1976) and Singh *et al.,*(1979). Low tiller number per plant under low moisture could be a mechanism that drought tolerant used reducing the demand for water. In a study involving the evaluation of the effects of moisture stress, reduced maximum tiller number of *Triticum tauschii* (wild relative of wheat) were reported to be strongly reduced by low moisture. Those findings were similar to those reported for cultivated wheat (Cone *et al.*, 1995).

The significantly high WUE of a cultivar such as Chozi might have been due to therelatively taller plants under low moisture which probably converted into higher biomass and relatively higher grain yield. Drought tolerant cultivars (Duma and Ngamia) maintained shorter plant stature under low moisture, which is another mechanism of economizing on moisture hence, increased WUE. The findings of this study are in disagreement with those reported by Rezgui *et al.*, (1999) from their study involving evaluation of 61 durum wheat genotypes in a moisture stressed environment at Mograne in Tunisia. From their study it came out that taller plants were associated with increased WUE.

The thousand-kernel weight (TKW) for the drought tolerant cultivars (Chozi, Duma and Ngamia) was higher under both low and high moisture. Less tillers per plant under low moisture observed on the drought tolerant cultivars was boosted by the higher TKW value. The high TKW value resulted in heavy individual seeds which in turn culminated in higher grain yield which appeared to increas WUE mainly due to higher harvest index (HI). The fact that the drought tolerant cultivars (Chozi, Duma and Ngamia) were shorter in stature HI was inversely related to plant height resulting into higher WUE under both low and high moisture conditions. Ehdaie (1995) reported higher WUE of shorter wheat cultivars under both low and high moisture regimes in a study conducted on bread wheat to evaluate seasonal WUE and its components in Spring wheat.

Lower seed number per spike was observed on drought tolerant cultivars (Duma and Chozi) a part from Ngamia under low moisture. The low seed number per spike translated into increased seed size and therefore increased TKW. Rebetzke *et al.*, (2001) reported increased kernel size due to die back of wasteful tillers in wheat under drought in Australia. A study carried out to evaluate the stability of grain yield and its components under moisture stress also revealed that the overall moisture deficit induced reduction in yield of specific wheat cultivars were largely due to similar effects on kernels per spike (Guttieri *et al.*, 2001).

Drought tolerant cultivars (Chozi, Duma and Ngamia) maintained high TKW even under low moisture. Despite the fact that these cultivars had fewer tillers per plant under low moisture, they had relatively higher WUE value. The high WUE value may be attributed to high TKW, which helped to maintain higher grain yield resulting into increased WUE. The drought tolerant cultivars (Duma and Chozi) a part from Ngamia had relatively lower seed number per spike under low moisture. The high seed number per spike translated into increased TKW which may be because the low seed number per spike resulted into less competition giving rise to increased kernel size. Rebetzke *et al.*, (2001) reported that wheat cultivars that had tiller inhibition genes had increased kernel size. Correlation study confirmed that tiller number per plant had a high negative ($P<0.05$) correlation with WUE of Duma under low moisture. However, under the same moisture regime, Ngamia and Chozi were not significantly correlated to tiller number per plant. This showed that tiller number controlled WUE positively on Duma but not Ngamia and Chozi under low moisture regime.

Conclusion and Recommendation

Moisture affected the grain yield and water use efficiency (WUE) of the genotypes tested significantly. Drought tolerant wheat cultivars (Duma, Ngamia and Chozi) under moisture stress used moisture more efficiently than the drought susceptible cultivars (Kwale, Mbuni and Pasa). The increased WUE of drought tolerant wheat cultivars (Duma, Ngamia and Chozi) was the basis of their drought tolerance. This has an implication on the drought tolerance selection in wheat research.

In view of the aforementioned results, the understanding of the traits that contributed to the increased WUE of the drought tolerant wheat genotypes under moisture stressed environment was addressed in the second part of this study. However, the results of that section of the study have not been included in this paper.

References

Aquino, P., Carrion, F., and Calvo, R. 2002. Selected Wheat Statistics. In Ekboir J.(ed.) 2002. CIMMYT 2000 - 2001 World Wheat over-view and outlook: Developing no - till packages for small-scale farmers. *Mexico, D.F.:CIMMYT.*

Cone, A. E., Stafer, G.A., and Halloran, G.M. 1995. Effects of moisture stress on leaf appearance, tillering and other aspects of development in *Triticum tauschii*.Euphytica. 86 (1): 56-64.

Ehdaie,B. 1995. Variation in water-use efficiency and its components in wheat: II. Well-watered pot experiment. *Crop Science.* 1995. 35 (6). 1617-1626.

Ehlig, C.F., and LeMert, R.D. 1976. Water use and productivity of wheat under five irrigation treatments. *Soil Sci. Soc. Am. J.* 40:750-755.

Ekboir, J. (ed.) .2002. CIMMYT 2000-2001World Wheat Overview and Outlook: Developing No-Till Packages for Small-Scale Farmers*. Mexico, DF:CIMMYT.*

Guttieri, M.J., Stark, J.C., O'Brien, K., and Souza, E. 2001. Relative sensitivity of Spring wheat grain and quality parameters to moisture deficit. *Crop Science.* 41 (2): 327- 335.

Jaetzold, R., and Schmidt, H. 1983. Farm Management Handbook of Kenya, Vol IIB, Central Kenya (Rift Valley and Central Provinces). *Ministry of Agriculture in Cooperation with the German Agric. Team (GAT) of the German Agency for Technical Cooperation (GTZ).* Printed by Typo-druck, Rossdorf, W. Germany. 381-416pp.

KARI. 1991. KARI agricultural research priorities to the year 2000. *KARI, Nairobi, Kenya*.

Kinyua, M.G., Wanjama, J.K., Kamwaga, J., and Migwi, S. 1989. The situation in wheat production in Kenya. *Kenya Agricultural Research Institute (KARI) Report.*

Legg, B.J., Day, W., Brown, N.J., and Smith, G.J. 1978. Small plots and automatic rain shelter. A field appraisal. *Journal of Agricultural Science* 91: 321 – 326.

Manual of Operation and Instruction, 1996. Calibration of Depth moisture gauge (Model 4300), pp.C-24. *Troxler Electronic Laboratories, Inc. and subsidiary Troxler International, Ltd, North Carolina, USA.*

National Plant Breeding Research Centre (NPBRC). 1999. Weather Data. Meteorological Station No. 9035021.

Ooro, P.A., Kinyua, M.G., Ogola, B.O., Owido, S.O., Kimurto, P.K., and Mwangi, S.K. 2001. Soil Profile characterization and Moisture meter (Neutron Probe) calibration. *Report, National Plant Breeding Research Centre (NPBRC), Njoro.*

Rajaram, S., Braun, H.J., and Ginkel, M. van. 1996. CIMMYT's approach to breed for drought tolerance. *Eupytica*. 92, (1/2), 147-153.

Rebetzke, G.J., Bonnett, D.G., Richards, R.A., Condon, A.G., and Herwaarden van, A. 2001. Breeding for high water use efficiency increases grain yield. *CSIRO, Plant Industry.*

Rezgui, S., Yahyaoui, A., Amara, H., and Daaloul, A. 1999. Relationships between water use efficiency and agronomic traits of selected durum wheat cultivars. *Revue de l'INAT.* 14 (1): 143-153.

SAS Institute Inc. 1985. SAS user’s guide: Statistics, Version 5 Edition. *SAS Inst. Inc.* Carry, NC.

Singh, N.T., Singh, R., Mahajan, P.S. and Vig, A.C. 1979. Influence of supplemenatary irrigation and pre-sowing soil water storage on wheat. *Agron.J.* 71:483-486.

Upchurch, D.R., Ritchie, J.T., and Foale, M.A. 1983. Design of a large dual-structure rainout shelter. *Agronomy Journal* 75: 845 –848.

Wanjama, J.K., Macharia, M., Karanja, D.D., Pinto, J.M., Maina, M.P.D., Kinyua, M.G., Wanyera, R., Faraj, A., and Gitari, J.N. 1993. Strategic Planning For Wheat Research To The Year 2013. *National Plant Breeding Research Centre, Njoro,* pp.2-28.

World Bank. 1989. Kenya Agricultural growth and strategy options. *Unpublished Sector* Report. Nairobi, Kenya.

Part 2. BREEDING

Current Status of Stem Rust in Wheat Production in Kenya

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Abstract—Stem rust *Puccinia graminis* f. sp *tritici* is among the three rusts currently threatening wheat (*Triticum aestivum* L) production in Kenya. A three-year survey (2002-2004) was carried out to determine the distribution of stem rust on the wheat varieties in the country, and to study the reaction of wheat varieties/lines to stem rust inocula from different sources. Fifty-three (53) Stem Rust Parental Collections (SRPC) were also screened in the experimental cage at Njoro whereas 16 commercial wheat varieties were screened in the field in Njoro, Mau-Narok and Eldoret arranged in a RCBD with 3 and 2 replications respectively. Fourteen (14), 9 and 11 sets of breeders F_3, stem rust differentials from Mexico and Australia were also screened in the greenhouse. The survey results indicated that stem rust has reched the high altitude areas where maximum and minimum temperatures range from 22 to 26^{o} C and 6 to14^{o}C respectively. Out of 53 SRPC screened, 79.3% were susceptible, while 20.7% showed resistance. The 16 commercial varieties were susceptible. Varieties Ngamia, Duma, Yombi, Heroe were most susceptible with a mean score of 63%, 48%, 46%, and 43% respectively. Kenya Fahari, K. Paka and Njrbw1 were least susceptible (5%, 4%, and 14%). The infection types of stem rust spores from different sources were different on the stem differentials from Australia. These preliminary data indicate the possibility of more than one stem rust race attacking the wheat crop. Joint effort is required to utilize the current biotechnology tools to identify and breed for resistance to the new race(s).

Introduction

Stem rust (*Puccinia graminis f p.tritici*) is among the cereal rusts that cause severe losses throughout the world. The rust range can cause losses ranging from slight to complete destruction of a wheat crop. Losses of 50-70-% have been reported in the field. Infected grain is shriveled, light in weight and of low quality **(**Stubbs *et all*, 1986; Agrios, 1988; Wiese, 1991; Minzenmayer, 2000; Cereal Disease Laboratory, 2004). In addition to reducing grain yield, rusts lower the crop's forage value and predispose plants to other diseases. Rusted wheat plants are less palatable and are toxic to livestock (Wiese, 1991). *Puccinia graminis* commonly attacks wheat; other hosts include barley, rye, oats, wild barley and goat grass.

Wheat production in Kenya is highly affected by stem rust and other rusts like yellow and leaf rusts. Under favorable environmental conditions, infection of the wheat crop with stem rust disease reduces both the quantity and quality of the grain (KARI annual reports 2000, 2001, 2002, and 2003). At the beginning of the wheat breeding efforts in Kenya in 1927 up to the early 1980s, stem rust was the most serious of the three rusts. This was given a high priority by the breeding team and due to wide resistance breeding, this problem disappeared for some time and subsequently many resistant commercial wheat varieties were developed and released to farmers. Since 1992, severe epidemics have continued to occur on commercial bread wheat and introductions (Danial *et al*, 1994; KARI annual reports 1999, 2002, and 2003). In 1996 the disease was recorded on some commercial wheat varieties in Mau-Narok and Molo. By 2000, all the varieties had succumbed to the disease, and at present, they are susceptible. Stem rust outbreak is now widespread in all the wheat growing areas in the country in low, medium and high altitude areas (KARI annual reports 2000-2003). The resurgence of this disease even in the high altitude areas (2700-2900 masl) has necessitated the need to revive work on this pathogen to incorporate genetic resistance to the prevalent race(s) within the commercial varieties to work on this pathogen. Therefore, the objective of this study was to determine the distribution of stem rust on wheat varieties around the country and also to study the reaction of wheat varieties/ lines to rust inocula collected from different sources.

Materials and Methods

1. Survey and collection of stem rust spore from the fields

The survey was carried out on farmers' commercial fields and also experimental plots in some parts of Uasin-Gishu, Nakuru, Meru, Nyeri, Nyandarua and Narok districts between years 2002-2004. Farms were picked along routes at random, stopping at every 3- 5 kilometers or whenever the nearest farm was, especially in areas with sparsely distributed farms. In every farm, plants were examined randomly by walking across the field. When sampling, a two meter distance from the edge was left to avoid border effect. Disease severities were taken using modified Cobb's scale (Peterson, *et al*.,1948) and coefficient of infection calculated by multiplying the disease severity and host response. Growth stage was entered in the field data form. The stem rust (sr) spores (uredospores) were then collected using a suction pump and some were scrapped from the leaves and stems using sterile scalpel blades. In the laboratory the spores were dried using Silica gel in the dessicator, vacuumed , sealed in vials and stored for further work.

2. Screening of Stem Rust Parental Collection (SRPC)

Fifty-three SRPC were planted by hand in the cage at Kari-Njoro and evaluated for stem rust infection. Variety Morocco, the universal suscept was used as the check. Each collection was planted in a hill at 2-3 seeds/hill. Diammonium phosphate (DAP) fertilizer was applied at the recommended rate of 130kg/ha.The plants were sprayed with Metasystox insecticide at the rate of 0.5L/ha to control the Russian wheat aphid (RWA) and other aphid vectors for the barley yellow dwarf disease. No fungicide was applied and the plants were monitored for the appearance of stem rust. Disease severity scores were taken twice at the heading stage using Cobb's modified scale **(**Peterson *et al*.,1948**).** The scores were then transformed using square root (x+1) and the means transformed back to original scores. These were statistically analysed using analysis of variance and least significance difference used to separate the means.

3 .Screening of wheat commercial varieties against stem rust in the field

Sixteen wheat commercial varieties were planted in Njoro (2185 m asl) and Eldoret – Chepkoilel campus (2150 m asl) while 14 varieties were planted in Mau-Narok-Purko ranch (2900 m asl) and evaluated for resistance against stem rust. In Njoro and Mau-Narok the varieties were planted in a randomized complete block design with three replications. Plots were 8 rows by 2 meters per variety. In Eldoret , two replicates of the same were planted. Furrows were made using the seed drill and both seed and fertilizer placed by hand. Immediately, after planting the experiment was sprayed with Stomp 500E a pre-emergent herbicide at the rate of 3.0L/ha to control grass weeds. At the tillering stage **,** the experiment was sprayed with Buctril MC at the rate of 1.25L/ha to control broad leaved weeds. The Russian wheat aphid and other insect pests were controlled as above. Disease severity readings were taken at the heading stage and data were analysed as above.

4. Screening of breeders F_3 lines and stem rust differential lines for resistance against stem rust

Seventy-eight F3 lines and 50 and 40 stem rust differential lines from Cimmyt-Mexico and Australia respectively were planted in 14,8 and 11 sets respectively. Each set was planted in 4 inch plastic pots filled with soil and placed in the green-house. The pots were placed on trays with gravel filled with water. In every pot there were four lines/varieties. The uredospores collected from : Njbw2, ISR5RA(SR5), ISR9DRA, F_1 material , Chozi, Ngamia Duma, Heroe/Rwa8**,** Heroe/Rwa9, K7892/Rwa9**,** differentials Yalta, Anautka, Timboroa (Matharu), Eldoret and National Dryland Wheat Preliminary Trial (NDWPT) . The rust spores were tested for viability and suspended in distilled water. A drop of Tween 20 was added to each collection and sprayed on 7 day old seedlings. The seedlings had been treated at emergence with Maleic hydrazide 0.01 g in 30 mls of water to enhance spore production. The plants were incubated for 24 hrs in a polythene chamber kept moist by frequent spraying with water under high relative humidity of 80-100%, and temperature of 18-22^{o}C. They were removed and placed on the benches in the green house for 14 days and infection types recorded using 0-4 scale proposed by Stakman *et al.*(McIntosh *et al*, 1995) for stem rust: **0-** Immune, ;(fleck)-Very resistant,**1**-Resistant, **2-**Resistant to moderately resistant,**3-**Moderately resistant/moderately susceptible,**4-** Susceptible. Data on infection types was compiled and analyzed using SAS system and means separated using least significance difference.

Results

1. Survey and collection of stem rust spore from the fields

The total number of commercial farms sampled between 2002 and 2004 were 61, from which 46 (75.4%) of the farms had stem rust infection(Table 1). In some farms the wheat crop had dried but the stem rust infection spores (basidiospores) were obvious. The farmers were in most cases not able to identify the varieties because they bought planting seed from fellow farmers. Those who kept their own seed were growing old varieties.

2. Screening of Stem Rust Parental Collection (SRPC)

Disease evaluation was based on 29 lines out of the 53 SRPC and Morocco the susceptible check. Twenty-three of these (79.3%) and Morocco were susceptible while six (20.7%) were resistant. There were significance ($P \leq 0.05$) differences among the line in disease infection. Table 2 shows that SRPC1(b), SRPC4(b), SRPC 25, SRPC 38(b) and SRPC 204 were highly susceptible while SRPC10, SRPC 27(a), SRPC (b), SRPC 29, SRPC 166 and 245 were resistant.

3. Screening of wheat commercial varieties in the field

There were significance ($P \leq 0.05$) differences among the varieties in stem rust infection (Table3). The16 commercial wheat varieties were all infected with stem rust and the level of infection varied from variety to variety in all the three sites. In Njoro (2185 m asl), the most infected varieties were: Duma and Ngamia (56.7%, K.Tembo (46.7%) Yombi and Chozi (43.3%) Heroe and K. Kongoni (40%), Kwale (30%) and Chiriku, Mbega, Mbuni. K. Fahari, K.Paka. and Njrbw1 were least infected. In Eldoret(2150 m asl), the most affected varieties were: Ngamia and Duma (70%), Chozi, Kwale, Heroe and K. Kongoni(50%), Yombi (45%), while Chiriku, K.Nyangumi, K. Fahari, K.Paka K. Tembo and Njrbw1 were less infected. In Mau-Narok (2900 m asl), the most infected were: Yombi (50%), K. Nyangumi (30%) and Heroe (40%) wheras, Chiriku, Kwale, K. Nyangumi, Mbuni, K. Fahari and K. Kongoni were less infected. Varieties Ngamia, Duma, Yombi, Heroe and Chozi were most susceptible across the three sites with a mean disease score of 63.4%, 48.3%,46.1%, 43.3% and 40.0% respectively.

Table 1: Stem rust scores and coefficient of infection on commecial wheat varieties year 2002-2004

Year	District	Place/Area	Sr score/ reactions	Coefficient of infection	District	Place/Area	Sr score/ reactions	Coefficient of infection
2002	UasinGishu	Ainabkoi	20 MR	8	Nyeri	Bagati	40S	40
		Ainabkoi	40S	24		Bagati	60MS	36
		Plateau	30MS	18		Naromoru	50MR	20
		Plateau	60MS	36		Mweiga	5MS	3
		Plateau	5MR	2		Mweiga	30MS	18
		Plateau	70S	70		Kieni	40MS	24
		Lembus	10S	10		Nairutia	20S	20
		Lembus	5MR	2	Narok	Olokurto	70S	70
		Timboroa	5MR	2		Olokurto	20S	20
		Timboroa	10S	10		Olokurto	50S	50
		Timboroa	40S	24		Olokurto	30MS	30
		Timboroa	20MR	8		Lopito	80S	80
		Timboroa	5S	5		Elmasharani	80MS	32
2002	Nyeri	Mbogo	5MR	2		Elmasharani	20S	20
		Mbogo	20S	20		Ilipson	90S	90
		Mbogo	10MR	4		Ntulele	60S	60
2003	Nakuru	Lare	20S	20		Ntulele	5MR	1
2004	Nakuru	M/Narok	80S	80		Navasha	40S	40
		M/Narok	70S	70		Navasha	30MS	18
		M/Narok	40S	40		Navasha	20S	20
		M/Narok	15S	15				
2004	Meru	W/Embori	20S	20				
		Magara	30S	30				
		Kararu	10S	10				
		Mwireri	30S	30				

M/Narok=Mau-Narok, W/Embori=Wangu Embori

Table2 : Mean Stem Rust Disease Infection score and relative ranking (Lsd) on the Stem Rust Parental Collection (SRPC) in the Cage Kari-Njoro, 2002

SRPC	Pedigree	Mean disease score	SRPC N0.	Pedigree	Mean Disease score
SRPC 1(b)	Africaxmayo 3529-1y-4m-3c-1t	45ab	SRPC 36	E.Na480(Pilotxmd, CII2316)xGza 139^2 ,1289-2196	0.5 hij
SRPC1(c)	Africa/mayo	15 def	SRPC 38(a)	-	17.5 cde
SRPC 2	Africa/mayo 3529-1y-4m-3y-1m	0.5 ij	SRPC 38(b)	-	45 ab
SRPC 2(a)	-	30 bcd	SRPC 41	(FederationxHope) xBolim, PI124830	5 fghij
SRPC 4(b)	Bza sibx(CI 12633,WIS245)	35 bc	SRPC 71	Gbx(fn-K58/N,II-50-17), II-53-649	5 ghij
SRPC 8(b)	Chinca-A-ElongatumxRd,K.Sel.A	10 efgh	SRPC 140	MbxSR, LM-72-14-57	10 efghi
SRPC 10	Chinca-A-ElongatumxRd)x(cl 12633xIdaed	0 j	SRPC 148	My54XL1266-61,1448-4603	10 efgh
SRPC 12	CI 8154xfr^2 III-1009-2t-3b-1t-2b-1t	10 efgh	SRPC 153	Mt-KxN-M,(fr-fn /y^2),15224-5b-1t-1b-4t	10efgh
SRPC 15	C1.12632xCeres R6421198.A.2.1	3 hij	SRPC 166	ND 463	0 j
SRPC 25	-	30 bcd	SRPC 204	Sandos No63x CI12633-Idaed^2) Gb 56xVeranopolis, 5134.B.3.B2.A	40 ab
SRPC 27(a)	(CI 12633,Wis245)^2 –s51x(fr-fn /y)III-113-6-6b-3t-2b.K.sel .1	0 j	SRPC 238(a)	-	57.5a
SRPC 27(b)	(CII2633, WIS245)/(for-fn/y)^2	0 j	SRPC 245	-	0 j
SRPC 28(b)	-	3 hij	SRPC 250	-	5 ghij
SRPC 29	-	0 j	SRPC 263	-	2.5 hij
SRPC 32	Desc-CI7800 /Bza3,14951-9b-1t	5 ghij	Morocco		12.5 efg
Lsd $P \leq 0.05$		1.7	Lsd $P \leq 0.05$		1.7
Cv		26.4	Cv		26.4

Means in the same column followed by the same letter do not differ significantly using Lsd $P \leq 0.05$

-Pedigree to be traced

Table 3: Mean % stem rust disease infection and relative ranking (Lsd) on commercial wheat varieties in Njoro, Eldoret and Mau-Narok 2003

Variety	Site/ Mean disease score						% mean score across the sites
	Njoro	Reaction type	Mau-Narok	Reaction type	Eldoret	Reaction type	
Yombi	43.3 b	S	50.0 a	S	45.0 b	MR	46.1
Duma	56.7 a	S	18.3 abcd	S	70.0a	S	48.3
Chiriku	5.0 g	MR	6.6 cd	MR	5.0 f	MR	5.5
Chozi	43.3 b	S	26.6 bcd	S	50.0b	S	40.0
Ngamia	56.7 a	S	-	-	70.0a	MS	63.4
Njrbw2	20.0 def	MR	11.6 bcd	MR	25.0cd	MS	18.9
Mbega	13.3 efg	MS	23.2 abcd	S	30.0c	MS	22.2
Kwale	30.0 cd	S	1.6 d	MS	50.0b	S	27.2
K.Nyangumi	21.7 de	MS	30.3 abc	MS	5.0 f	MS	19.0
Mbuni	5.0 g	MR	10.0 cd	MS	20.0de	S	11.7
K.Fahari	10.0 efg	MR	5.0 cd	MR	0.0f	R	7.5
K.Paka	8.3 fg	MR	-	-	5.0f	MR	4.4
Heroe	40.0 bc	S	40.0 ab	S	50.0b	S	43.3
K.Kongoni	40.0 bc	MR	5.3 cd	MR	50.0b	MS	31.8
K.Tembo	46.7 ab	S	17.0 bcd	MR	5.0f	MS	22.9
Njrbw1	11.7 efg	MR	16.6 abcd	MR	15.0f	MR	14.4
$P \leq 0.05$	12.3		3.092		9.482		-
Cv	26.16%		48.3%		14.38%		-

Means in the same column followed by the same letter do not differ significantly using Lsd $P \leq 0.05$

4. Screening of breeders F3 lines and stem rust differential lines for resistance against stem rust

Significant differences were observed in sources of stem rust inocula on sr differential lines acquired from Australia (table 4a). Stem rust spores collected from sr differential Anautika, ISR5RA(SR) and K 7892/Rwa9 had the highest mean infection (reaction) type while Heroe/Rwa9, Timboroa (Matharu), Eldoret, and NDLWPT had the lowest mean infection (reaction) type. This was not significant on breeders F_3 material and also on sr differential lines acquired from Mexico. Test lines, the lines x source of inocula did not differ significantly for all the breeders F_3 and sr differential lines. The analysis of variance (Table 4b) showed significant differences among the sources of sr inocula for the differentials acquired from Australia (F=0.001**) were significant.

Table 4a :Mean disease score of stem rust inocula from different sources on sr differential lines from Australia 2003

Source of inocula	Mean disease score
Variety Chozi	0.82 def
ISR5RA(SR)	2.14 ab
Timboroa(Matharu)	0.31 f
ISRDRA	1.27 cde
Heroe/Rwa8	1.42 bcd
Heroe/Rwa9	0.30 f
K7892/Rwa9	2.01 abc
Yalta	0.52 ef
Anautika	2.69 a
Eldoret	0.36 f
NDLWPT	0.36 f
Lsd ($P \leq 0.05$)	0.825

Means in the same column followed by the same letter do not differ significantly using Lsd P≤0.05

Table 4b: Analysis of variance for sources of stem rust inocula

Source	DF	SS	F
Set	10	359.514	0.001**
Variety	39	183.086	0.4709
Set x Variety	288	1475.120	0.1133
Error	219	960.833	

Discussion

Levels of stem rust infection varied with environment as well as varieties/lines. This could have been due to the temperature and rain distribution which varies from place to place with some areas experiencing drought while others were wet. In Kenya, wheat is grown in many agro- ecological zones that have different planting dates (Ralph and Schmit,1983). This staggered planting provides a green crop most part of the year allowing stem rust spores to move by wind from one area to another and that way spreads to different areas. It is therefore, a problem to reduce the disease infection in susceptible varieties. Almost all the wheat fields had stem rust infection and the problem is advancing and becoming more serious in high altitude areas where maximum and minimum temperatures range from 22^{o}C- 26^{o} C and 6^{o}C-14^{o}C respectively. The varied infection (reaction) types of stem rust inocula from different sources on differential lines from Australia probably showed that there could be more new races attacking the wheat varieties. Although, Ngamia was not among the varieties screened in Mau-Narok (2900m ASL), the records from a different study (data not shown) showed that the infection of stem rust was very high (Kari annual report, 2003).

Conclusion

The survey of stem rust revealed that the disease is on the increase in Kenya. Apparently all the wheat growing areas are prone to this disease. There is therefore, an urgent need to have more work done to determine the isolates so that the breeding programme can be effectively sustained. Commercial varieties like K. Fahari, K.Paka, Chiriku and some of the old varieties which have remained resistant/ moderately resistant to stem rust can be utilized in the breeding programme. It is evident that stem rust is widely distributed in the wheat growing areas and joint effort is required to utilize the current biotechnology tools to identify and breed for resistance to the apparently new race(s).

Acknowledgement-The authors wish to acknowledge funds from CIMMYT for the implementation of this study; Dr. Ravi Singh (CIMMYT, Mexico) for technical discussions and germplasm; Drs.C.R. Wellings and Robert Park (Australia) for the differentials; Mr. D. Onyango for maintaining the stem rust spores; and colleagues in pathology section for cooperation and technical support.

References

Agrios, G.N. 1988. Plant Pathology.3 rd edition. Academic Press. ISBN 0-12-044563-8

Cereal Disease Laboratory .(2004). Wheat Stem Rust (*Puccinia graminis* f.sp. *tritici*) at http://www.cdl.umn.edu

Danial, D.L., 1994. Aspects of Durable Resistance in Wheat to yellow rust. PhD Thesis. Wagenigen Agricultural University, The Nertherlands, 144pp.

Kenya Agricultural Research Institute.1999-2003.Annual reports. Kenya Agricultural Research Institute.2002-2003.Annual reports.

McIntosh,R. A.,C.R. Wellings and R.F.Park. 1995. Wheat Rusts: An Atlas of resistance Genes. CSIRO, Australia.

Minzenmayer Richard (2000). Pest Management News at http:// www.tpma.org

Peterson,R.F., A.B. Campell and A.E. Hannah. 1948. A diagrammatic Scale for estimating Rust Severity on leaves and stems of cereals. Can.J. Res; 26:496-500.

Ralph Jaetzold and Helmut Schmidt. 1993. Farm Management Handbook Agriculture Vol.II , Part B. Ministry of of Kenya in cooperation with German Agricultural Team (GAT) of Germany Agency for Technical for Technical Cooperation (GTZ).

Stubbs, R.W., J.M. Prescott, E.E. Saari and H.J.Dubin. Cereal Disease Methodology Manual. Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), Mexico.1986.

Wiese, M.V.1991. Compedium of Wheat Diseases 2nd Edition. APS Press.

Genotype-by-Nutrient Interaction in Wheat Grown in a Marginal Environment in Kenya

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Abstract—Six wheat (*Triticum aestivum* L.) cultivars (Chozi, Ngamia, Duma, Njoro BW1, K.Heroe, and Chiriku) were grown in a marginal environment at two levels of fertilizer; 0:0:0, 30:60:0 kg ha^{-1} ($N:P_2O_5:K$).and at a seed rate of 125 kg. ha^{-1} to assess their response to fertilizer application and nutrient use efficiencies. Grain yield, spike numbers, harvest index (HI), nitrogen (N) uptake, N concentration and nitrogen use efficiency (NUE) were recorded. There were no significant differences in grain yield or spikes m^{-2} among varieties when averaged across fertilizer levels. Differences in HI between varieties were significant, with cv. Duma, a variety recommended for marginal environments, having a higher HI than cv. K.Heroe. Fertilizer did not affect the HI. There were no significant differences among varieties in N acquisition, indicating similar nutrient uptake abilities, or in NUE, although this was reduced by fertilizer application, probably because the increased N uptake did not translate into a corresponding grain yield increase due to the poor growing conditions. Grain N content ranged between 2.2% in the fertilized plots and 1.8% in the unfertilized plots (meaned across cultivars) and 2.2% in Njoro BW1 and 1.9% in Ngamia.

Introduction

Genotypic differences in nutrient utilization have been documented in wheat. These differences have been attributed to both differences in the acquisition and the efficiency of use of nutrients between cultivars (Inthapanya *et al.*, 2000). One reason for differences in efficiency has been attributed to the development of different root systems between wheat cultivars. Nitrogen (N) and phosphorous (P) deficiencies limit the yield of wheat in most wheat growing areas of Kenya. A number of approaches have been used to enhance productivity of wheat in such environments: principally the development of site-specific fertilizer recommendations for various areas. Inorganic fertilizers are expensive and not affordable to most wheat growers, while. Organic sources of nutrients are not easily available in the quantities and qualities that would give adequate yields in farmers' fields. The use of nitrogen fixing crops also has its limitations. Another approach would be to identify cultivars that do well in low soil fertility conditions but that also respond well to applied fertilizer. These would be the preferred cultivars because they would be useful to both farmers with fertilizer inputs and resource-poor farmers. This type of cultivar usually has a high harvest index (El Bassam 1998)

The efficiency of utilization of both N and P determines grain and dry matter yields. Variety by fertilizer level interactions will be very important: researchers need to find varieties that have low yield interactions with fertilizer level, and that, therefore, respond in in a similar manner in low and high fertility environments. This is especially important as varieties widely adapted to diverse soil fertility status will be preferable.

Cultivars grown in the marginal environments of Kenya have not been evaluated for their nutrient use efficiency, yet this is an important factor determining yield of wheat in such areas. Identification of cultivars that do well under low nutrient and moisture conditions will improve wheat production in such areas and the the breeding program will be enhanced by incorporation of characters associated with nutrient use efficiency. Improved cultivar response to nutrients will help reduce inputs and hence protect the environment (El Bassam 1998).

The objectives of this project were to:
I. Determine genotypic variation in nitrogen uptake between cultivars recommended for the arid and semi arid areas (ASALs) of Kenya.
ii. Determine the efficiency of utilization of N in recommended cultivars.
Materials and Methods
The trial was established in Kajiado, Kenya, on a moderately fertile vertisol with P ststus above the critical levels (Table 1). The treatments were arranged in a split plot design with three replications, with fertilizer levels as the main treatments and varieties as sub-treatments. The two fertilizer levels used were 0:0:0, and 30:60:0 kg ha^{-1} ($N:P_2O_5:K$), and the cultivars assessed for nutrient use efficiency were: Ngamia, Chozi, Duma, Njoro BW1, Chiriku and K. Heroe. Sub-plot size was 6m x 3m.

Seed was dribbled by hand into furrows spaced at 20 cm apart at a rate of 125 kg. ha^{-1}, and fertilizer dribbled into the same furrows. At four weeks after seeding, Buctril MC. (*a.i. Bromoxynil +MCPA*) was applied at 1.2 l ha^{-1} to control weeds. At harvest, a 1 m^2 quadrat was harvested by cutting the plants at ground level. Parameters evaluated were total biomass (Total Dry Matter), grain yield and nitrogen (N) concentration in grain and straw, determined using the kjeldahl method. N uptake, nitrogen use efficiency (NUE) and harvest index (HI) were calculated from the evaluated parameters.

Table 1 Soil chemical and physical characteristics of the trial site

Depth (cm)	pH	% N	P (ppm)	% O.M.
0-15	5.8	0.15	33	2.4
15-30	6.5	0.09	30	2.0
30-60	6.9	0.07	31	1.7
60-90	6.9	0.08	31	0.8

Results and Discussion

There were no significant effects of genotype on grain yield, harvest index, nitrogen uptake, use efficiency or grain N concentration, nor were there fertizer by genotype interactions with respect to these variables (Table 2), indicating that the varieties responded similarly to fertilizer application. However there were differences between varieties with respect to thousand kernel weight (TKW): Chozi had significantly higher TKW than all the other varieties (Table 3). Fertilizer application significantly increased grain yield, total N uptake and grain N concentration, but reduced nitrogen use efficiency, and had no significant effect on HI nor TKW. (Table 2 and Table 4).

Table 2. Degrees of freedom , F ratio and level of significance for grain yield, Harvest Index (HI), Total N uptake, Grain N concentration and Nitrogen Use Efficiency.

Source of variation	DF	Grain yield	HI	Total N Uptake	Grain N (%)	NUE	TKW
Genotype	5	0.94	1.46	0.69	1.49	0.95	6.49**
Fertilizer	1	12.75**	0.68	65.6**	19.65**	18.51**	2.94
Genotype*Fertilizer	5	0.85	0.51	0.97	0.42	0.46	1.12

** Significant at ($p<0.01$)

Table 3. Variety yield parameters measured across fertilizer levels at Kajiado

Variety	Spikes/m2	Grain yield kg ha^{-1}	Harvest index (HI)	TKW
Duma	182	1853	0.40 A	38.9 B
Ngamia	179	1751	0.38 AB	35.6 BC
Njoro bw1	173	1491	0.37 AB	37.9 BC
Chiriku	170	1642	0.37 AB	34.6 C
Heroe	163	1417	0.31 B	39.0 B
Chozi	150	1522	0.37 AB	44.0 A
LSD 5%	NS	NS	0.06	3.8
C.V %	24	26.2	15.7	8.3

Table 4. Fertilizer effects on yield parameters measured across varieties at Kajiado

Fertilizer level	Grain yield kg ha^{-1}	Harvest index	TKW	NUE g grain g^{-1} N	Total N Uptake g m^{-2}	Grain N Concentration (%)
O	1361 B	0.37 A	39.2	41.8 a	330 a	0.38 a
N X P	1864 A	0.36 A	37.4	31.9 b	600 b	0.36 b
LSD 5%	29.4	NS	NS	0.05	69.6	0.04

There were no significant differences between genotypes in either nitrogen uptake (acquisition) or utilization of the absorbed N: there were no significant differences in NUE (grain production per unit of the total N) (Table 5) However, cv. Njoro BW1 had a significantly higher N concentration than c.v Ngamia. It has been shown that grain yield is a function of NUE, total N uptake and HI as in the equation of Inthapanya *et al*. (2000).

Y=NUE X Total N uptake x HI

Where NUE= Nitrogen Use Efficiency
Hi=Harvest Index.

The results from this study show that of the three variables, the tested cultivars only differed in HI, suggesting that the only potential for increasing yields in the wheat cultivars would be in improving the HI of the cultivars.

Table 5. Total N uptake, grain nitrogen concentration and nitrogen use efficiency (NUE) meaned over two fertilizer levels in wheat at Kajiado

Variety	Total Nitrogen Uptake g m^{-2}	Grain N Concentration (%)		Nitrogen Use Efficiency (NUE) g grain g^{-1} N
Duma	5.22	2.08	Ab	38
Njoro BW1	4.72	2.17	A	33
Chiriku	4.67	1.96	Ab	37
Ngamia	4.60	1.87	B	40
K. Heroe	4.50	1.93	Ab	34
Chozi	4.18	2.00	Ab	39
LSD	NS	0.26		NS
C.V	2.15	10.8		18.8

Means followed by the same letter are not significantly different at p>0.05

References

Inthapanya P., Sipaseuth, Sihavong P., Sihathep V., Chanphengsay M., Fukai S., Basnayake J. 2000. Genotype differences in nutrient uptake and utilization for grain yield production of rainfed lowland rice under fertilized and non-fertilized conditions. Field Crops Research 65 (2000) 57-68.

El Bassam N. 1998. A concept of selection of low input wheat varieties. Euphytica 100 (1/3) 95-100.Improvement of Wheat

Improving Wheat Productivity for the Drought Prone Areas of Kenya Using the Doubled Haploid Technique

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Abstract- Various breeding methods have been applied in an effort to develop superior wheat varieties for the marginal areas of Kenya. These include germplasm introductions, mutation breeding and doubled haploid (DH) production. .The application of DH in breeding for drought tolerance has proved to be very effective and efficient. This study was aimed at evaluating and validating DH lines that were developed in 2000 using the chromosome elimination technique. The resulting lines were compared with other lines introduced from CIMMYT and two mutants developed in Njoro. The lines were tested in multi-locational trials in 2002 and 2003. The sites included were Lanet, Mogotio, Naivasha, Mweiga, Kajiado and Katumani. The results show that the DHs were as good as the conventionally developed lines and yielded more than the check varieties Chozi and Duma. One of the DHs had average yielded 1.7tonsHa^{-1}, which was not significantly different from Chozi. . The DH technique has proved to be applicable in saving time of breeding without compromising the output.

Introduction

Wheat is the second most important cereal crop in Kenya (FAO, 2002) but Kenya's current national wheat production (approximately 300,000 tons per annum) meets only about 50% of the national demand. Moreover, increasing population and changing eating habits is expected to have a bigger impact on wheat demand; estimated to reach 850,000 tons p.a. in the year 2020 (FAO 2003). Land area currently suitable for wheat production in the high potential areas is less than 2% and hence expansion of wheat production in these regions is limited. In recent years wheat production has expanded in the marginal rainfall areas (such as lower Narok, Naivasha, Laikipia and Machakos) which were hitherto considered unsuitable for wheat growing. Introduction of wheat in the non-traditional areas began in 1992. Over this period 4 varieties (Duma, Ngamia, Chozi and Njoro BW1) have been released (Kinyua *et al*, 2002). However, varieties with greater yields are still needed to meet the farmers' needs. Future production increases must come largely from vertical expansion (i.e., greater production per unit area), which will require more intensive research to further improve yield potential and cultural technology. Wheat improvement in Kenya has been directed into developing broadly adapted, high yielding germplasm with high yield stability, durable disease resistance and acceptable end use quality (CIMMYT 2002). Resistance to biotic stress and tolerance to abiotic stress can be critically important in maintaining high yield and adaptation over time and locations. Over the last decade wheat breeding has been enhanced by the application of various biotechnological approaches; these have been used to accelerate the breeding process and also complemented the conventional breeding methods. The DH technique and mutation breeding have been used to improve stress tolerance in wheat. These include breeding for drought tolerance, tolerance to soil acidity, lodging tolerance and resistance to Russian wheat aphid.

Drought is a multidimensional stress affecting plants at various levels of their organisation (Blum, 1996). Improvement of yield under stress must combine a reasonably high yield potential with specific plant factors which would buffer yield against severe reduction due to drought (Blum, 1983). Measurement of plant response to drought at the whole-plant level is complex because it reflects the integration of stress effects and responses at all underlying levels of organisation, over space and time (Blum, 1996). Conventional breeding (which involves multi-location testing and hence gauges spatial adaptation of genotypes) is used extensively by the Kenya bread wheat program to identify temporally stable, drought tolerant germplasm (Maarten, 1994 – this does not appear in the reference list). However, practical breeding programs for self-pollinated crops (such as wheat) must include a process of genetic fixation (for uniformity of agronomic traits) after genetic recombination to increase variability (Inagaki, 1996). Repeated selection of heterozygous material can increase uniformity but many generation cycles are required to reach homozygosity in loci associated with agronomic traits. Haploid production followed by chromosome doubling offers a quick method for developing homozygous breeding lines (Bentolila *et al*, 1992, Murignaux *et al.*1993, Beanziger *et al.*, 1989a, Baenziger, 1996). The DH lines derived from hybrid progenies can be used as recombinant inbred lines with favourable gene combinations (Inagaki, 1996). This technique could thus complement the conventional breeding programs to accelerate the release of new varieties.

Since the double haploids are completely homozygous, all stocks are identical and no purification process is required. In contrast, in the conventional system stocks are usually derived from a single plant of an advanced generation (Baenziger, 1996) hence several generations are required to build up sufficient quantities of seeds for release. Compared to selection during the early generations , a DH system increases the efficiency of selection for both qualitative and quantitative characters. This study aimed to evaluate and validate DH lines and compare them with conventionally bred materials. It was hypothesised that the DH technique is superior to conventional breeding when dealing with complex factors like drought.

Materials and Methods

Introduction

Two experiments were carried out. Experiment I involved development of the double haploids (including embryo rescue, regeneration of haploid plantlets and chromosome doubling of haploids) and preliminary evaluation of the DHs. Experiment II was a field evaluation of the performance of the DHs as compared with the conventionally developed lines

Development of doubled haploids

Six F_1 hybrids were produced by crossing three drought tolerant lines (Duma, K. Mbweha and Ngamia) as females with two high yielding commercial varieties (Kwale and Kenya Chiriku) as males. The F_1 plants were emasculated at anthesis. The glumes and awns were not clipped, as is the case with normal-crossing emasculation. The emasculated spikes were then covered with polyethylene bags to maintain high humidity. One day before (predicted) anthesis, emasculated spikes were pollinated with freshly collected maize pollen. The pollen was collected by picking mature anthers and placing them on petri-dishes. Once the anthers burst to release the pollen, a soft brush was used to brush the emasculated spikelets with the pollen. Extreme care was taken not to damage the stigma. After pollination, the uppermost internodes of wheat culms (with pollinated spikes) were injected with a 100mg l^{-1} 2, 4-D solution daily (for two consecutive days) to increase the rate of fertilisation and embryo formation.

After about 14 days of spike growth, wheat caryopses were removed from spikes and sterilized (in 2% sodium hypochlorite) for 15 minutes. After rinsing with sterilized water (under laminar flow bench), embryos were aseptically excised and transferred onto half strength Murashige and Skoog medium supplemented with 20g L^{-1} sucrose and 8g L^{-1} agarose in petri dishes (Inagaki 1996). These were then placed in the fridge (at 4 ^oC) for three days after which they were incubated (at 25 ^oC) in the dark until embryos germinated (5-7 days).

The germinated embryos were transferred to a lighted growth room with controlled temperature of 24 ^oC and 16 hours day length. The light intensity was Ca 5000 Lax. Cultured plants with fully developed roots and leaves were transplanted to potted soil for further growth. The temperature was maintained at 21 ^oC -25 ^oC using 24 hours day length. The size of the stomata was used to determine the ploidy level of the plants. This is because haploid plants have stomata half the size of diploid plants. At the third tillering stage, a leaf from each plant was cut and coated with clear nail varnish. The varnish was pealed off (upon drying) and mounted on high power objective of light microscope; the size of the stomata was then compared with that of known diploid plants.

In addition, at the third tillering stage the plants were watered and then removed from the pots. The roots were trimmed to about 2 cm below the crown (to increase solution absorption). The plants were then immersed in colchicine solution (0.2% colchicine, 2% dimethyl sulfoxide and 15 drops of tween-20) for 3 hours at room temperature. The plants were then washed thoroughly with running tap water for 3 hours after which they were planted in pots (using forest soil enriched with copper dust) at a temperature of 20^o C-25 ^{o} C under high humidity (90-100%).

Preliminary evaluation of the doubled haploids

Twenty DH lines were selected (based on the amount of seed available). These selections and their five parents were initially screened in the rain-shelter at the National Plant Breeding Research Centre (NPBRC) Njoro in 2000 and later evaluated in the field (in Njoro and Katumani) through observation trials in 2001. They were planted in a randomized complete block design (RCBD) with three replications. Each plot was 1 metre long with two rows 20 cm apart. Five seeds were planted per row. DAP (18-46-0) fertilizer was applied at planting at the rate of 150 kg ha^{-1}. Drip irrigation was used to water the plots (Chapin Watermatics, 1999). Water was applied at the rate of 20 mm every fortnight (up to grain filling stage), giving a total of 200 mm water during the crop season. The amount and frequency of water application simulates the amount and nature of rainfall pattern usually received in most marginal areas during the cropping season (Mugo *et al.*, 1998; Jaetzold and Smith, 1983). The following parameters were measured (both in the rain shelter and in the field): Ear length (measured from the base of the spike to the tip of the apical spikelet, excluding the awns); number of spikes per plant, sterile spikelets per head; number of grains per head counted on 10 spikes selected randomly in each experimental at maturity; and weight of 10-kernels (g). All the data was subjected to analysis of variance using the general linear model (SAS, 1996).

Field performance of the double haploids

Eight DH lines (DH4, DH5, DH6, DH7, DH9, DH12, DH15, DH16) and 2 mutants (BM1 and BM3) were selected in a preliminary yield trial in 2001. The selection was on the basis of drought tolerance. These lines, together with Chozi and Njoro BW1 (checks), were entered in the National Performance Trial (NPT) in 2002 and consequently planted at three sites (i.e., Naivasha, Katumani, and Lanet). The design was a RCBD replicated 3 times. The seeds were drilled in plots of four rows that were 6 metres long and 20 cm apart.

Seven DHs (DH4, DH5, DH6, DH7, DH9, DH12 and DH16) were selected form the first year of NPT and entered into the second year of National Performance Trial (in 2003) alongside 7

conventionally developed lines (R840, R960, R962, R963, R965, R966 and K7872) and the check varieties (Njoro BW1 and Chozi). These were evaluated at Katumani, Naivasha, Mweiga, Lanet and Ravine. The Design was a RCBD replicated three times. The plots were 4 rows, 20 cm apart and 6 m long.
The following parameters were measured in both the first and second year NPT: grain yield, Kernel weight, plant height and reaction to rust diseases.
ANOVA was used for data analysis and means were separated using LSD

Results and Discussion

Development of Doubled Haploids
A total of 1800 florets were cross pollinated out of which 890 F1 seeds were harvested and the embryos excised and planted *in-vitro*. This shortened the F_1 seed production by over four months compared to the *in-vivo* method where the seed is left to dry in the field. The *in-vitro* F_1 plants grew faster due to the conducive environment and reached heading stage one month earlier than in the conventional method.

Over 2,880 florets of F_1 plants were cross pollinated with maize. 413 of these developed seeds from which 57 embryos were rescued (Table 2). Out of the 57 embryos rescued 46 were haploid. When treated with colchicine 24 of the 40 survived. The time taken for pollination to colchicine treatment was 8 weeks and the DHs were ready for harvesting in 20 weeks.

Performance of doubled haploids
There was high variability among the DHs in the rainout shelter for the yield components measured (Table 1). These results are comparable to those reported by Baenziger (1996); whilst there was variation among doubled haploid lines, there was little variation within individual haploid lines. This increased the efficiency of selecting lines with superior characteristics (Njau *et al*, 2000) because the response to selection is indicated by the variability between the treatments. Such variation can be used to select lines with the required characteristics (Njau 2001).

There were significant differences in yield and other growth parameters between the DHs and their respective parents (Table 1) and some DHs showed heterosis for drought tolerance over their better parent or the mean of the two parents (Table 4). For example, one of the DHs ($DH_1$7) developed from the cross between Kenya Mbweha and Kenya Chiriku had greater number of spikes (6.1) than the parents (2.0 and 5.0, respectively for Kenya Chiriku and Kenya Mbweha). $DH_1$7 also had more grains per head (43) than the mean of the parents (27.5). $DH_1$12 (developed from Duma/Kenya Chiriku cross) had more grains (%) than either of the parents. The expression of heterosis in DH lines (Njau 2002) makes the DH technique superior to that of conventional breeding. This is because heterosis is lost in conventional breeding due to repeated selfing of the hybrids. Similar results have been reported elsewhere (Ba-Bong and Swaminathan, 1995).

Over 26% of the cost of developing a fixed line using conventional selection was saved in the production of the DHs (data not provided). This saving was attributed to the fewer number of generations required to produce homozygous lines when using haploids. Similar findings have been reported in rice (Sunint, 1993).

Table 1. Mean performance for various parameters of 20 DHs as compared to their parents tested for drought tolerance under the rainshelter at Njoro. Kenya.

Parents	DH lines	No. of tillers at booting	Effective Heads	Spikelets/Head	Sterile Spikelets	Grains/ head	weight of 10 grains
K. Mbweha		5.00	5.0	15.333	2.000	24.333	0.367
Kwale		4.21	2.16	14.533	3.994	27.936	0.306
(K.mbweha x	DH$_1$1	5.33	4.00♦	16.000**	2.00*	34.00	0.301
Kwale)	DH$_1$8	5.71	3.67♦	17.533**	2.494*	35.936	0.317**
	DH$_1$19	3.71♦♦	3.66	15.533	1.494*	32.936	0.27♦
K. Chiriku		4.33	2.00	15.333	3.000	30.667	0.312
(K. Chiriku x	DH$_1$7	7.39**	6.11**	19.301	2.009	43.489***	0.282
K Mbeha)	DH$_1$14	2.67♦♦	2.33	17.333	1.333*	36.667**	0.343
Ngamia		3.67	3.00	10.00	1.667*	41.667	0.349
(Ngamia x	DH$_1$2	4.39	4.11	19.301**	1.009*	41.489**	0.336
Kwale)	DH$_1$3	5.21	3.66	16.033**	1.995*	24.94♦	0.21♦
	DH$_1$10	4.33	2.00♦	13.333	1.006*	27.67♦	0.346
	DH$_1$13	4.30	3.95	15.349**	1.996*	41.755**	0.304
	DH$_1$15	3.33♦	3.33	15.333**	0.67***	30.00*	0.367
	DH$_1$16	8.39**	6.1***	19.301**	0.09***	28.489	0.304
(Ngamia	DH$_1$17	0.803♦♦	0.45♦♦	13.765	4.980♦♦	4.33♦♦	0.12♦♦
xK.Chiriku)	DH$_1$20	5.00	4.33	14.000**	1.667**	28.67♦	0.19♦♦
Duma		6.33	3.00	15.000	2.000	28.333	0.467
	DH$_1$4	2.80♦♦	2.45	13.349	2.996	19.255	0.305♦
(Duma x	DH$_1$5	3.39	3.11	19.301	2.009**	35.489	0.310♦
Kwale)	DH$_1$6	7.39	2.89	14.617	1.510**	33.308	0.367♦
	DH$_1$9	7.00	4.00	11.333	2.333**	29.333	0.266♦
	DH$_1$18	4.30	2.45	12.349	1.996**	32.255	0.326♦
(Duma x	DH$_1$11	3.71♦	2.16	14.533	0.995	40.936*	0.307*
K.Chiriku)	DH$_1$12	5.67	3.67	17.333	2.000	44.00**	0.421**

* Significantly better at 5% level than the poorer parent .
** Significantly better than the mean of the parent at $P \leq 0.5$
*** Significantly better than the better parent at 5 % level
♦Significantly poorer than the better parent at 5 % level.
♦♦ Significantly poorer than the poor parents at 5 % level.

Preliminary performance of the double haploids

Significant differences **in yield** Among genotypes were noted in Katumani and Naivasha while no differences were noted in Lanet. Two lines DH6 and DH4 performed quite well at all the sites. DH6 was better than all the other entries in Naivasha and it was better than the checks at all the sites. DH7 and DH9 also performed well at all the sites

Table 2. Grain yield of the test lines (DHs, mutants and check varieties) at 3 different sites (t ha^{-1})

LINE	YIELD (t ha^{-1})		
	KATUMANI	NAIVASHA	LANET
DH4	.9AB	1.0BC	1.4AB
DH5	.3E	.3D	1.1B
DH6	.9AB	1.5A	1.5AB
DH7	1.0A	1.3AB	1.1B
DH9	.7BCD	1.4AB	1.6A
DH12	.7ABCD	.9C	1.2AB
DH15	.7CD	.7C	1.3AB
DH16	.8ABC	.8C	1.2AB
BM1	.6CD	.8C	1.0B
BM3	.7BCD	.7C	1.3AB
NJORO BW1	.8ABC	.9C	1.3AB
CHOZI	.5DE.	.9C	1.1B
LSD	.27	.37	0.56
SE		0.22	0.11
P(F-ratio)	<0.05	<0.05	<0.05

Values followed by the same letter are not significantly different at p = 0.05

Genotype did not affect 1000-kernel weight in Katumani and Naivasha but did affect 1000-kernel weight in Lanet (Table 3). The double haploids had greater 1000-kernel weight (16% on average) than the check varieties and the mutant BM3 in Lanet (Table 3). Also, the mutant BM1 had 9% - 13% greater 1000-kernel weight than the double haploids in Lanet (Table 3).

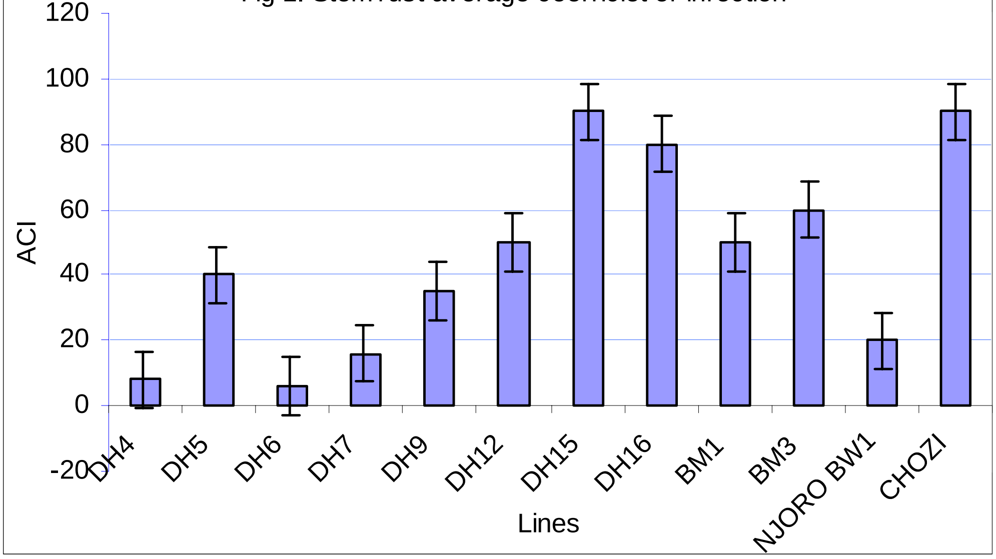
Table 3. 1000 kernel weight of the entries in the three sites during the year 2002

Line	1000-Kernel weight (g)		
	Katumani	Naivasha	Lanet
DH4	76.6	73.4	83.1A
DH5	72.0	78.8	81.0AB
DH6	72.4	76.7	78.7AB
DH7	72.4	72.4	78.4AB
DH9	70.7	71.2	78.0AB
DH12	77.4	78.3	78.0AB
DH15	75.9	75.8	77.9AB
DH16	76.6	76.4	77.4AB
BM1	73.9	72.7	75.6AB
BM3	72.9	68.2	69.7CD
NJORO BW1	74.2	76.1	69.4CD
CHOZI	75.3	78.6	66.9D
Lsd	-	-	10.85
P (F-ratio)	ns	ns	<0.05
SED	4.1	3.2	4.04

Values followed by the same letter are not significantly different at p = 0.05

Genotype affected the average coefficient of infection (ACI) by stem rust in 2002 (Fig 1). Chozi (check variety) was more susceptible to stem rust than the double haploids (except DH15 and DH16) and the mutants (Figure 1). NjoroBW1 (check variety) had lower stem rust infection than the mutants and most double haploids (DH5, DH9, DH12, DH15, DH16) (Figure 1).

Fig 1. Stem rust average coefficiet of infection



Performance of the DHs as compared to the conventionally developed lines

There was a significant effect of site on variety in terms of grain yield and hectolitre weight in 2003 (Table 4). Katumani had lower yields than Lanet (by 80%), Mogotio (by 70%), Naivasha (by 70%), Mweiga (by 30%) and Kajiado (by 30%). Kajiado and Mweiga also had lower yields compared with Lanet (38%), Mogotio (31%) and Naivasha (31%) (Table 4). The lower yield in Katumani (compared with other sites) could be due to the low rainfall (100 mm) recorded in Katumani during the growing period of the crop.

Lanet had lower hectolitre weight (by 20%, 19%, 10%, 13% and 7% for Mogotio, Naivasha, Mweiga, Kajiado and Katumani, respectively) compared with the other sites (Table 4). Katumani had 12%, 11% and 5% lower hectolitre weight than Mogotio, Naivasha and Kajiado, respectively. Also, Mweiga had lower hectolitre weight compared with Mogotio (9%), Naivasha (8%) and Kajiado (2%). Moreover, Kajiado had 6% lower hectolitre weight compared with Lanet and Mogotio (Table 4).

Table 4. Average yield in tons per hectare and hectolitre weight in the six sites

Site	Yield (t ha^{-1})	Hectolitre weight (g)
Lanet	1.8a	67.3d
Mogotio	1.7a	80.9a
Naivasha	1.7a	80.2a
Mweiga	1.3b	74.3c
Kajiado	1.3b	76.0b
Katumani	1.0c	72.1c
Mean	1.5	75.1
LSD	0.18	1.70
SED	0.21	4.21
P (F-ratio)	<0.01	<0.01
CV (%)	29.7	5.6

The yields and hectolitre weight for the lines averaged across the sites are shown in Table 5. Genotype affected grain yield and hectolitre weight (Table 5). Chozi (check variety) had 55% greater yield than DH6 and DH16 and 113% greater yield compared with DH12. NJOROBW1 (check variety) also had greater yield (by 88%) than DH12 (Table 5).

Chozi had greater hectolitre weight compared with R960, R962 and R966 (9%), K7872 (12%), R965 (10%), which are lines developed through conventional breeding (Table 5).

Chozi also had greater hectolitre weight (by 8% - 13%; average 11%) compared with a number of double haploid lines (DH4, DH9, DH5, DH7, DH16, DH12) (Table 5). The check variety NJOROBW1 had 7% greater hectolitre weight than DH12 (Table 5). These results show that in addition to being reducing the breeding time, lines developed using the DH technique, compete well with conventionally developed lines which have taken over 13 years to develop.

Table 5. Yield and hectolitre weight of the sixteen lines averaged over the sites

Line	Yield (t ha-1)	Hectolitre weight (g)
R960	1.9a	74.5bcd
DH4	1.7a	73.0cd
R840	1.7a	78.1ab
Chozi	1.7a	81.3a
R966	1.6ab	74.3bcd
R963	1.6ab	76.6abcd
K7872	1.5abc	72.3cd
DH9	1.5abc	75.0bcd
NJBW1	1.5abc	77.0abc
DH5	1.5abc	73.5bcd
R965	1.5abc	73.9bcd
DH7	1.4abc	74.7bcd
R962	1.4abc	74.6bcd
DH16	1.1bcd	72.9cd
DH6	1.1cd	78.0ab
DH12	0.8d	72.0d
Mean	1.5	75.1
LSD	.29	2.77
SED	0.09	17.7
P (F-ratio)	<0.01	0.01

Conclusion

The DH technique proved to be quite useful in breeding for complex characters such as drought and compares well with the conventional methods. The time saved in DH development makes the methodsuperior to the other methods. It is important to note that the multiloctional testing increases the efficiency of measuring yield stability. The two lines (DH4 and R960) are recommended for release as they both out yielded the check varieties at almost all sites.

References

Ba Bong B. and M.S. Swaminathan 1995. Magnitude of hybrid vigour retained in double haploid lines of some heterotic rice hybrids. *Theo. Appl. Genet. 90*:253-257.

Baenziger P.S. C.J Peterson, M.R Morris and P.J Mattern 1989a. Quantifying gametoclonal variation in wheat doubled haploids. M. Muluszynski (Ed). Current Options for cereal improvement pp. 1-9. Kluwer Academic Publishers. Boston.

Baenziger S.P. 1996. Reflections on doubled haploids in plant breeding. S.M. Jains, S.K Sopory and R.E Veilleus (Ed). In vitro Haploid production in Higher plants 1: 35-48. Klumer Academic Publishers. Netherlands.

Bentolila S, T. Hardy, C. Guitton and G. Freyssient 1992. Comparative genetic analysis of F2 plants and anther culture derived plants of maize. Genome 35: 575-582.

Bitch C., G. Sabine and J. Lelley 1998. Effect of parental genotypes on haploid embryo and plantlet formation in wheat x maize crosses. *Euphytica 103:* 319-323.

Blum A. 1996. Crop responses to drought and the interpretation of adaptation. Plant Growth Regulation 20:135-148.

FAO, 1986. Production yearbook. Vol. 40. FAO ROME.

Inagaki M.N. (1990). Wheat Haploid through *Bulbosum* technique. Biotechnology in Agriculture and Forestry 13:448-58.

Inagaki M.N. (1996). Technical advances in wheat haploid production using ultra-wide crosses. IIRCAS Journal 4:51-62.

Jaetzold R. and H. Schmidt, 1983. Farm management Handbook of Kenya. MOA and GTZ.

Kinyua M.G.1997. Transfer of genes of resistance to yellow rust (*Puccinia stiifarmis* L.) from wild emmer *Triticum dicoccoides* into Kenyan wheat commercial varieties. PhD Thesis. Nairobi University.

Kinyua, M.G,., Karanja, L., and Njau, P.N. 2002. Drought tolerant wheat varieties developed through mutation breeding technique. Workshop on Dryland Farming January 2002. Paper submitted and accepted.

Kinyua, M.G., J.K. Wanjama, J. Kamwaga, M. Migui 1989. The situation of wheat production in Kenya KARI Report.

Lefebure D. and P. Devaux 1996. Doubled Haploid of wheat from wheat x maize crosses: genotypic influence, fertility and inheritance of the IBL-IRS chromosomes. Theor. Appl. Genet. 93: 1267-1273.

Murignaux A., D. Barloy, P, Leray and M. Beckont 1993. Molecular and morphological evaluation of doubled haploid lines in maize, Homogeneity within DH lines. Theor. Appl. Genet. 86:837-842.

Njau P. N. 2001. Development of drought tolerant wheat lines through chromosome elimination technique. Msc. Thesis. Egerton University.

Njau P.N., M.G. Kinyua and R.S. Pathak.2000. Drought Tolerant Doubled Haploid (DH) of Bread Wheat for Kenya. Proceedings of the 7th Biennial KARI Scientific Conference Paper No.40.KARI Headquarters. Nairobi.

Sunint L.R., C.P. Martinez, A. Ramirez and Z. Lentini, 1993. Rice anther culture versus conventional breeding: A cost/benefit analysis. Trends in CIAT commodities working document NO.128. Contro International De Agricultura Tropical, Call.

Grain Yield Stability of Bread Wheat Genotypes in Favorable and Stressed Environments

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Abstract—A multilocational trial consisting of 18 bread wheat genotypes including standard and local checks was conducted in 39 locations between 1999 and 2001 across the diverse wheat agro-ecologies of Ethiopia. Yield stability of the genotypes was assessed in high potential, moisture stress and waterlogged growing environments using the AMMI (Additive Main Effects and Multiplicative Interaction) model. The results showed highly significant genotypic and G x E interaction affects in all three environmental categories. Genotypes FH 8-2, HAR 3354, ETBWC 037 showed low positive interaction while HAR 3116, and FH 6-1-7 showed low negative IPCA axis 1 scores indicating stable performance in the high potential wheat growing areas. In the low moisture areas FH 8-1, ETBWC026, HAR 3224 and HAR 2870 showed low positive IPCA axis 1 scores. Among these genotypes, HAR 2818 gave the highest mean grain yield and is better suited to moisture stressed areas. The analysis of waterlogged areas showed that HAR 3354, FH 4-2-11 and ETBWC037 had high mean grain yield performance and low G x E interaction. From the results we concluded that FH 8-2, HAR 3354, ETBWC 037, HAR 3116 and FH 6-1-7 are widely adaptable; FH 8-1, ETBWC026, HAR 3224 and HAR 2870 perform better in the moisture stressed areas while FH 4-2-11 and ETBWC037 are tolerant to waterlogged vertisols.

Introduction

In developing crop varieties with high and stable yields, data from multi-environments, representing spatial and temporal target domains, play an important role in estimating and predicting yield and yield stability. The pattern of response of genotypes to different environments is used by the plant breeder to select the best varieties for any particular region. Yield response of genotypes tested in different environments is almost always subject to genotype x environment interaction (GxE). To estimate the level of interaction of genotypes to environments and eliminate as much as possible the unexplainable and extraneous variability contained in the data, several statistical techniques have been developed to describe G x E and measure the stability of genotypes. These techniques include conventional analysis of variance (Yates and Cochran, 1938; Cochran and Cox, 1957); the joint regression method proposed by Yates and Cochran (1938),modified by Finlay and Wilkinson (1963) and further improved by Eberhart and Russell (1966); combined analysis of variance for each pair of genotypes (Plaised and Peterson, 1959); ecovalence (Wrickle, 1962;1964); stability variance (Shuka, 1972); cluster analysis (Lin *et al.*, 1986); and cultivar superiority measure (Lin and Binns, 1988).

Furthermore, the additive main effect and multiplicative interaction method, widely known as AMMI model, has recently been developed and used to analyze multienvironmental trials (Gauch and Zobel, 1988; Zobel *et al*., 1988; Crossa *et al.*, 1990). It is a unified approach that fits the additive main effects of genotypes and environments by the usual analysis of variance and then describes the non-additive part by principal components analysis fitted to the AMMI model according to the following equation:

$$Yge = \mu + \alpha g + \beta e + \sum_{n=1}^{ù} \lambda n\ \gamma gn\ \delta en + \Theta ge,$$

where Yge is the yield of genotype g in environment e; μ is the grand mean;
αg are the genotype mean deviations (the genotype means minus the grand mean);
βe are the environment mean deviations; λn is the eigenvalue of principal components analysis (PCA) axis n; γgn and γgn are the genotype and environment PCA scores for PCA axis n; ù is the number of PCA axes retained in the model; Θge is the residual.

Wheat is a widely grown crop in the world, produced under a wide range of environments (Hanson *et al*., 1982). In Ethiopia, wheat is grown between 6 and 14^{o} N latitudes; and between 35 and 42^{o}E longitude at altitudes from 1500 m to 3200 m. The current total area of production of both durum (*Triticum turgidum* var. *durum*) and bread wheat (*Triticum aestivum*) is estimated to be between 1.2 to 1.5 million hectares. The environmental variation within the wheat growing range is noticeable over short distances. This type of environment obviously affects the adaptation of a particular crop variety and complicates the process of plant breeding.

To counterbalance this problem, categorizing environments and conducting multi-environment variety evaluation and stability analysis are imperative. In the last two decades, a considerable number of bread wheat varieties were released in Ethiopia; all were assessed for adaptation and stability over different environmental categories before release (Desalegn *et al*., 1996; Debebe *et al*., 2000; Bedada *et al*., 1999; Desalegn *et* al., 2001). The purpose of this paper is to report on the stability of yield performance and yield potential of advanced bread wheat genotypes in different environments in Ethiopia.

Materials and Methods

A national variety trial consisting of 18 bread wheat genotypes was conducted from 1999 to 2001 across the wheat growing agro-ecologies in Ethiopia. The genotypes included advanced materials from a breeding program and selections from introductions. The entries were established on six rows of 2.5m plots with a distance of 20cm between rows. The seeds were drilled into the row at the rate of 150kg ha^{-1}. A randomized complete block design with four replications was used at all locations. Site-specific agronomic practices were applied. The central 4 rows were harvested to determine the yield potential of each genotype.

The testing sites included nine high potential locations, two waterlogged sites (Ginchi and Arsi-Robe) and three moisture stress sites (Alemaya, Asasa and Dhera) as described in Table 1.

For the three environmental categories, analysis of variance was performed on yield data of individual trials and AMMI analysis was carried out separately on pooled data using Agrobase 99 (Agronomix Software, Inc., 1999).

Table 1. Environmental characteristics of national bread wheat testing sites in Ethiopia.

Location	Altitude (masl)	Long-term Annual Rainfall (mm)	Major production constraint(s)
Kulumsa	2200	830	SR
Bekoji	2780	1098	YR, STB
Adet	2240	1250	SR
Holetta	2400	1078	STB
Arsi-Negele	1800	763	SR
Sinana	2400	1023	YR, SR, STB
Hossana	2450		YR, SR
Kokate	2150		SR, YR
Alemaya	1900	638	SR, drought
Ginchi	2100	1093	Waterlogging
Arsi-Robe	2400	873	Waterlogging
Asasa	2360	644	Terminal drought
Dhera	1680	617	Intermittent drought

SR= Stem rust; YR=yellow rust; STB=Septoria blotch

Results and Discussion

In high potential wheat growing areas, the AMMI analysis showed that environments, genotypes and G x E interaction were highly significant. . In this set of environment, IPCA1 explained 33 per cent of the G x E interaction sum of squares and IPCA2 explained 23 per cent of the interaction. The first principal component explained more of the interaction variation and this could be interpreted in terms of morphological, phenological, agronomic or disease factors that may affect the performance the genotypes (Table 2).

In the drought stressed sites, the environments, genotypes and G x E were highly significantly different. About 41 per cent of the interaction sum of squares was explained by IPCA1. IPCA2 and IPCA3 explained 17% and 14% of the interaction, respectively. The first principal component factor has a high contribution to the interaction sum of squares while the IPCA2 and IPCA3 are small. This indicates that one primary factor is influencing the G x E interaction in this set of environment (Table 2).

Likewise, in the waterlogged areas the environments, genotypes and G x E interaction were significantly different (Table 2). IPCA1 explained 42% of sum of squares of the interaction, while IPCA2 and IPCA3 were responsible for 24% and 17 % of the interaction sum of squares, respectively. This indicates that one fundamental factor affects G x E interaction; this could be either genotypic or environmental in nature.

In AMMI analysis, IPCA scores of genotypes are stability indicators. IPCA scores closer to zero (0), either from a positive or negative direction, indicate stable performance of genotypes over sampled environments for the particular trait under consideration.

Accordingly, in high potential wheat growing environments, FH 8-2, which had IPCA score nearest to zero (Table 3), was the most stable variety although it was low yielding. FH 8-2 was developed from a cross between Ethiopian and Germany materials for multiple diseases resistance. Moreover, genotypes HAR 3316, HAR 3354, FH 6-1-7 and ETBWC 037 showed stable and predictable yield performance across the different environments (Figure 1).

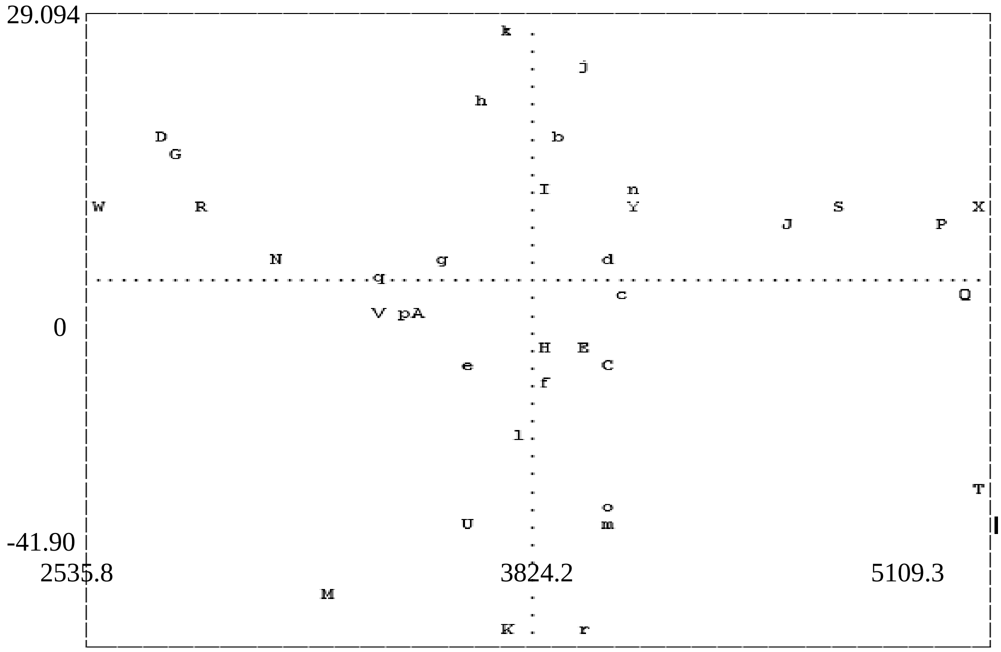
TABLE 2. Analysis of variance for multi-environment bread wheat trial over the period of 1999 to 2001.

Source	Favorable Environment			Low moisture environment			Water logged environment		
	df	MS	Prob.	df	MS	Prob.	df	MS	Prob.
Total	1799			575			431		
Environments	24	43510329.0	**	7	98028937.3	**	5	160558072.6	**
Genotype	17	5002302.5	**	17	2974331.8	**	17	6143106.4	**
G x E.	408	1279672.6	**	119	585980.1	**	85	1158614.0	**
IPCA 1	40	4251121.2	**	23	1234844.4	**	21	1969767.6	**
IPCA 2	38	3222205.7	**	21	565213.7	**	19	1258203.6	**
IPCA 3	36	1396068.3	**	19	499430.6	*	17	1023044.6	*
IPCA 4	34	1234018.4	**						
IPCA 5	32	969418.0	**						
IPCA 6	30	979453.2	**						
IPCA 7	28	779923.7	**						
Residual	1275	414285.4		408	284442.936		306	433747.8	

*, ** =significant at 0.05 and 0.01 levels respectively

TABLE 3. Genotype IPCA Axis 1 Scores for High potential environment

No		Genotype	Score	Mean	No	Genotype	Score
1	a	HAR 1522	20.5423	3688.48 |	11	11 HAR 2870	29.0941
2	b	HAR 3224	16.4640	3908.44 |	10	10 HAR 2818	26.0322
3	c	HAR 3116	-2.0432	4091.36 |	8	8 HAR 2812	20.8600
4	d	HAR 3354	2.1311	4036.38 |	1	1 HAR 1522	20.5423
5	e	ETBWC026	-10.4608	3621.87 |	2	2 HAR 3224	16.4640
6	f	ETBWC028	-10.5972	3872.90 |	14	14 FH 9-3-4	10.7835
7	g	ETBWC037	2.7556	3560.85 |	9	9 HAR 2814	7.7190
8	h	HAR 2812	20.8600	3691.62 |	7	7 ETBWC037	2.7556
9	i	HAR 2814	7.7190	3832.50 |	4	4 HAR 3354	2.1311
10	j	HAR 2818	26.0322	3963.50 |	17	17 FH 8-2	1.1397
11	k	HAR 2870	29.0941	3746.58 |	3	3 HAR 3116	-2.0432
12	l	FH 4-2-11	-17.3445	3787.62 |	16	16 FH 6-1-7	-2.5637
13	m	FH 81	-27.9384	4039.08 |	5	5 ETBWC026	-10.4608
14	n	FH 9-3-4	10.7835	4117.90 |	6	6 ETBWC028	-10.5972
15	o	FH 7-1-5	-24.6687	4059.52 |	12	12 FH 4-2-11	-17.3445
16	p	FH 6-1-7	-2.5637	3459.06 |	15	15 FH 7-1-5	-24.6687
17	q	FH 8-2	1.1397	3372.47 |	13	13 FH 81	-27.9384
18	r	L.CHECK	-41.9050	3986.09 |	18	18 L.CHECK	-41.9050



<u>key for the letters in the AMMI biplot</u>

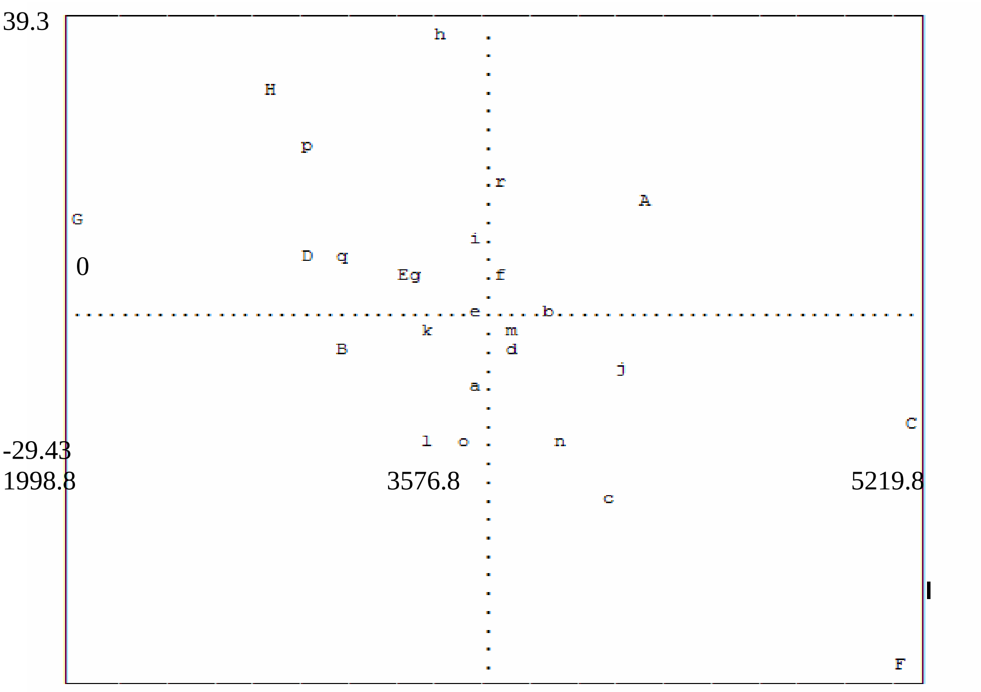
A= A-NEGELLE 01, B=ADET 01, C=BEKOJI 01, D=DEBRE-ZEIT 01, E=HOLETTA 01, F=KOKATE01, G= KULUMSA 01, H=SINANA01, I=A-NEGELLE 00, J= ADET 00, K= BEKOJI 00, L=D-ZEIT 00, M= HOLETTA 00, N=HOSSAENA 00, O=KOKATE 00, P=KULUMSA 00, Q=SINANA 00, R=A-NEGELLE 99, S=ADET 99, T=BEKOJI 99, U=HOLETTA 99, V=HOSSAENA 99, W= KOKATE 99, X=KULUMSA 99, Y= SINANA 99; a=HAR 1522, b=HAR 3224, c=HAR 3116, d=HAR 3354,e=ETBWC026, f=ETBWC028, g=ETBWC037, h=HAR 2812, I=HAR 2814, j=HAR 2818, k=HAR 2870, l=FH 4-2-11, m=FH 81, n=FH 9-3-4, o=FH 7-1-5, p=FH 6-1-7, q=FH 8-2, r=L.CHECK

Figure 1. AMMI biplot for bread wheat variety trial consisting 18 genotypes and 25 environments (high potential) over the period of 1999 to 2001. (Note: 1 genotype and 3 environments in place of others with similar means and not shown)

On the other hand, FH 8-1 and FH 7-1-5 showed high negative IPCA1 scores, which is evidence of their specific adaptability to favorable environments. It was noted that the genotypes have considerably high variation around the mean grain yield of 3824 kg ha^{-1}. The test sites also showed year-to-year variation in mean grain yield and were evenly distributed in all four quadrants indicating the importance of seasonal climatic variation. Clearly, two or more seasons of testing are better than a single year.

High seasonal variation was observed among the drought stressed environments (Figure 2). This is probably attributable to seasonal rainfall variation both in amount and distribution. The genotypes tended to vary widely in grain yield around the grand mean (3576.8 kg ha^{-1}). Among these genotypes, HAR 2818 gave the highest mean grain yield indicating that it could be an ideal variety for low moisture stress areas; while ETBWC026 was the most stable genotype in this environment (Table 4).

For water logged environment, genotypes like ETBWC037 and FH 4-2-11, which had IPCA score close to zero, were found to perform stably and may be used in such areas as Arsi Robe and Ginchi (Table 5)



key for the letters in the AMMI biplot
A=AS01, B=DH01, D=AS00, E=DH00, F=AS99, G=DH99, H=AL99, I=AL01; a=HAR 1522, b=HAR 3224, c=HAR 3116, d=HAR 3354,e=ETBWC026, f=ETBWC028, g=ETBWC037, h=HAR 2812, I=HAR 2814, j=HAR 2818, k=HAR 2870, l=FH 4-2-11, m=FH 81, n=FH 9-3-4, o=FH 7-1-5, p=FH 6-1-7, q=FH 8-2, r=L.CHECK

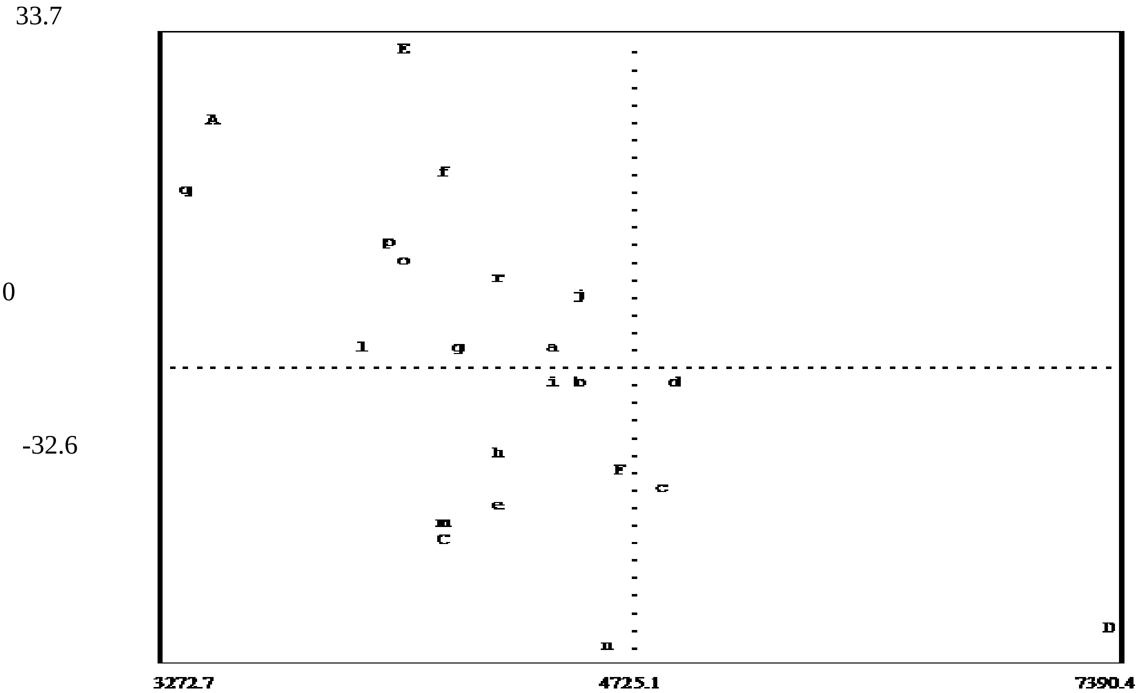
Figure 2. AMMI biplot for bread wheat variety trial consisting 18 genotypes and 9 environments (moisture stress areas) over the period of 1999 to 2001.

TABLE 4. Genotype IPCA Axis 1 Scores for Moisture stress environment

No		**Genotype**	**Score**	**Mean**	**No**	**Genotype**	**Score**
1	a	HAR 1522	-8.4258	3571.91	8	HAR 2812	30.0680
2	b	HAR 3224	-0.9773	3829.22	16	FH 6-1-7	18.7863
3	c	HAR 3116	-19.9266	4065.53	18	L.CHECK	14.0816
4	d	HAR 3354	-4.8353	3701.38	9	HAR 2814	8.0520
5	e	ETBWC026	0.2994	3561.94	17	FH 8-2	5.5885
6	f	ETBWC028	4.4483	3638.34	6	ETBWC028	4.4483
7	g	ETBWC037	3.9407	3348.19	7	ETBWC037	3.9407
8	h	HAR 2812	30.0680	3445.28	5	ETBWC026	0.2994
9	i	HAR 2814	8.0520	3545.06	2	HAR 3224	-0.9773
10	j	HAR 2818	-5.8004	4134.16	13	FH 81	-2.1974
11	k	HAR 2870	-2.9071	3390.59	11	HAR 2870	-2.9071
12	l	FH 4-2-11	-13.4219	3373.72	4	HAR 3354	-4.8353
13	m	FH 81	-2.1974	3680.75	10	HAR 2818	-5.8004
14	n	FH 9-3-4	-13.3237	3891.50	1	HAR 1522	-8.4258
15	o	FH 7-1-5	-13.4493	3535.34	14	FH 9-3-4	-13.3237
16	p	FH 6-1-7	18.7863	2938.75	12	FH 4-2-11	-13.4219
17	q	FH 8-2	5.5885	3054.97	15	FH 7-1-5	-13.4493
18	r	L.CHECK	14.0816	3676.22	3	HAR 3116	-19.9266

TABLE 5. Genotype IPCA Axis 1 Scores for water-logged environment

No		Genotype	Score	Mean	No	Genotype	Score
1	a	HAR 1522	1.0963	4994.58	6	ETBWC028	21.1901
2	b	HAR 3224	-3.0194	5094.63	17	FH 8-2	18.9806
3	c	HAR 3116	-12.8362	5441.63	16	FH 6-1-7	12.4562
4	d	HAR 3354	-1.9025	5489.25	15	FH 7-1-5	11.3533
5	e	ETBWC026	-15.6519	4746.42	11	HAR 2870	9.9798
6	f	ETBWC028	21.1901	4486.79	18	L.CHECK	9.9606
7	g	ETBWC037	1.8652	4576.63	10	HAR 2818	6.9080
8	h	HAR 2812	-9.4631	4733.50	7	ETBWC037	1.8652
9	i	HAR 2814	-3.0989	4962.17	12	FH 4-2-11	1.6042
10	j	HAR 2818	6.9080	5120.92	1	HAR 1522	1.0963
11	k	HAR 2870	9.9798	4760.33	4	HAR 3354	-1.9025
12	l	FH 4-2-11	1.6042	4129.79	2	HAR 3224	-3.0194
13	m	FH 81	-16.7825	4533.42	9	HAR 2814	-3.0989
14	n	FH 9-3-4	-32.6399	5225.58	8	HAR 2812	-9.4631
15	o	FH 7-1-5	11.3533	4313.71	3	HAR 3116	-12.8362
16	p	FH 6-1-7	12.4562	4298.67	5	ETBWC026	-15.6519
17	q	FH 8-2	18.9806	3399.08	13	FH 81	-16.7825
18	r	L.CHECK	9.9606	4744.17	14	FH 9-3-4	-32.6399



Key for the letters in the AMMI biplot

A=Arsi-Robe 01, B=Ginchi 01, C=Arsi-Robe 00, D=Ginchi 00, E=Arsi-Robe 99, F=Ginchi 99; a=HAR1522,b=HAR3224,c=HAR3116, d=HAR3354,e=ETBWC026,f=ETBWC028,g=ETBWC037,h=HAR2812,I=HAR2814,j=HAR2818, k=HAR2870,l=FH4-2-11,m=FH81, n=FH9-3-4,o=FH7-1-5, p=FH6-1-7,q=FH8-2,r=L.CHECK

Figure 3. AMMI biplot for bread wheat variety trial consisting 18 genotypes and 6 environments (water logging stress) over the period of 1999 to 2001. (Note: one environments in place of other with similar means and not shown)

The genotypes were ranked for their yield stability in the favorable environments according to each genotype by environment interaction statistical analysis procedure used.(Table 6). Spearman's rank correlation coefficient was computed for each of the possible pairs of the G x E statistics (Table 7). Student's *t* test for the Spearman's rank correlation coefficients showed no significant correlation with AMMI, but was highly significantly associated with the other procedures. A similar trend was noted for the two extreme moisture stress environments (data not presented). Clearly, the stability analysis procedures do not conform to AMMI analysis.

From the results, we can conclude that HAR 3116 and HAR 3354 are high yielding and stable across high potential environments; HAR 3224 and HAR 2818 perform better in the drought stress environment while FH 4-2-11 and ETBWC037 are tolerant to waterlogged vertisols.

TABLE 6. Estimates of various G x E statistics and stability parameters for 18 bread wheat genotypes grown at 25 environments during 1999 to 2001.

No	Genotypes	Cultivar Superiority Measure, Lin and Binns	Ecovalence, Wricke	Stability Variance		Beta	Deviation from Linearity
				Shukla	Finlay and Wilkinson		
1	HAR 1522	996717	5817426	1010788	1011008	0.873	121138
2	HAR 3224	735159	4445462	753545	784681	1.035	70843
3	HAR 3116	525681	5887418	1023911	978553	1.180	113926
4	HAR 3354	530726	5952597	1036132	993175	1.178	117176
5	ETBWC026	973059	5052679	867398	835330	0.841	82099
6	ETBWC028	716908	9040414	1615098	1681013	1.047	270028
7	ETBWC037	1024086	2243215	340623	300359	0.858	-36784
8	HAR 2812	1086634	7680015	1360023	1308673	0.801	187286
9	HAR 2814	767383	6031427	1050913	1057356	1.120	131438
10	HAR 2818	828490	7437071	1314471	1372687	0.983	201512
11	HAR 2870	1084103	9258608	1656010	1724961	0.958	279795
12	FH 4-2-11	743175	7003698	1233214	1282976	0.955	181576
13	FH 81	463092	8720217	1555061	1593398	1.105	250558
14	FH 9-3-4	555071	7247264	1278882	1336333	0.995	193433
15	FH 7-1-5	422436	6374056	1115156	1140053	1.095	149815
16	FH 6-1-7	1279747	10782393	1941719	2027627	0.988	347054
17	FH 8-2	1288069	2611873	409747	429482	1.001	-8090
18	L.CHECK	708448	18940766	3471414	3623810	0.987	701761

TABLE 7. Spearman's rank correlation for various stability parameters

	Cultivar Superiority Measure	Ecovalence (Wricke)	Stability Variance (Shukla)	Stability Variance (Finlay & Wikinson)	Deviation from Linearity	AMMI
Cultivar Superiority Measure		0.88*	0.88*	0.88*	0.66*	0.36
Ecovalence (Wricke)			1.00*	0.99*	0.90*	0.13
Stability Variance Shukla)				0.99*	0.90*	0.13
Stability Variance Finlay & Wikinson)					0.90*	0.14
Deviation from Linearity						0.04

*Student's t test is significant at 0.01 level of significance

References

Bedada Girma, Desalegn Debelo and Bekele Geleta. 1999. Evaluation and characterization of some bread wheat genotypes for waterlogging tolerance in Ethiopia. African Crop Science Proceedings, vol.4.pp.113-116, Uganda.

Crossa, J. 1990. Statistical analysis of multilocation trials. *Advances in Agronomy* **44**: 55-86.

Cochran, W. G. and Cox, G. M. 1957. Experimental designs. John Wiley &Sons Inc., New york, 2nd Ed.

Debebe Masresha, Desalegn Debelo, Bedada Girma, Solomon Gelalcha and Balcha Yaie.2000. Bread wheat yield stability and environmental clustering of major wheat growing zones in Ethiopia. pp. 78-86. **In**: CIMMYT. 2000. The Eleventh Regional Wheat Workshop for Eastern, Central and Southern Africa. Addis Ababa, Ethiopia: CIMMYT.

Desalegn Debelo, Bekele Geleta, Balcha Yaie and Zewdie Alemayehu. Grain Yield Response of Some Bread Wheat Cultivars in Diverse Environments of Ethiopia. pp.382-86. **In**: Tanner, D. G., Payne, T. S., and Abdalla, O. S. Eds. 1996. The Ninth Regional Wheat Workshop for Eastern, Central and Southern Africa. Addis Ababa, Ethiopia: CIMMYT.

Desalegn Debelo, Bedada Girma, Zewdie Alemayehu and Solomon Gelalcha. 2001. Drought tolerance of some bread wheat genotypes in Ethiopia. *African Crop Sci. J.* **9(2):** 385-392.

Eberhart, S. A. and W. A. Russell. 1966. Stability parameters for comparing varieties. *Crop sci.***6**: 36-40.

Finlay, K. W. and G. N. Wilkinson. 1963. The analysis of adaptation in plant breeding programs. *Austral. J. Agri. Res.* **14:** 742-754.

Guach, H. G. 1988. Model selection and validation for yield trials with interaction. *Biometrics* **88:** 705-715.

Guach, H. G. and R. W. Zobel.1988. Predictive and postdictive successes of statistical analysis of yield trials. *Theor. Appl. Genet.***76**: 1-10.

Hanson, H., Borlaug, N. E. and Anderson, R. G. 1982. Wheat in the third world. Boulder, CO, USA, Westview Press.

Lin, C. S. and Binns, M. R. 1988. A superiority measure of cultivar performance for cultivar x location data. *Can. J. Plant Sci.* **68:** *193-198.*

Plaised, R. L. and Peterson, L. C. 1959. Atechnique for evaluating the ability of selection to yield consistently in different locations and seasons. *Amer. Potato J.* **36:** 381-385.

Shukla, G. K. 1972. Some statistical aspects of partitioning genotype-environmental components of variability. *Heredity* **28:** 237-245.

Wright, A. J. 1971. The analysis and prediction of some two factors interactions in grass breeding. *J. Agric. Sci***. 76:** 301-306.

Yates, E. and Cochran. 1938. The analysis of grouped experiments. *J. Agric. Sci***. 28:** 556-580.

Seedling and Adult Plant Resistance in Ethiopian Wheat Varieties to Local *Puccinia graminis* Isolates

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Abstract—Wheat entries showing resistance to stem rust at the seedling stage do not necessarily possess adult plant resistance, and vice-versa. This investigation was therefore undertaken to evaluate some wheat varieties from Ethiopia for their resistance to four virulent stem rust isolates collected from Ambo and Debre Zeit (two isolates from each locality) at seedling as well as adult plant stages. Out of 15 durum (*Triticum turgidum*) and 14 bread wheat (*T. aestivum*) varieties tested, 10 durum and 7 bread wheat varieties were found to be resistant both at the seedling and adult stages to the first Ambo isolate. Whereas 11 durum and 13 bread wheat varieties were resistant to the second isolate at both growth stages. Eight durum and 8 bread wheat varieties exhibited a resistant infection type to the two Debre Zeit isolates at both growth stages. Some materials, for instance durum wheat varieties Kilinto and Gerardo were resistant at the seedling stage but were susceptible at the adult stage, whereas variety DZ 169505 exhibited a susceptible and resistant reaction at the seedling and adult stages respectively to the first Debre Zeit isolate. Our results indicate that selection for resistance must involve rigorous field evaluation with a range of isolates to achieve effective resistance.

Introduction

Stem rust, caused by *Puccinia graminis* f. sp. *tritici*, occurs every year in the wheat growing regions of Ethiopia. For over 20 years, stem rust has been controlled through the use of resistant cultivars. Appearance of new races and conditions favorable for diffusion of the pathogen enhance the likelihood of epidemics that may significantly reduce wheat yield. Although host resistance is the best method to avoid epidemics and minimize yield losses, changes in pathogen virulence and the attendant loss of resistance complicates this control strategy. Goludan *et al.* (1928) reported that adult plant resistance was inherited independently of seedling resistance. Mutkekar *et al.* (1985) also reported similar results stating that entries showing resistance at the seedling stage do not necessarily posses adult plant resistance and vice-versa. The present investigation was undertaken to evaluate selected wheat varieties for their resistance to stem rust at seedling as well as adult plant stages. The resistant varieties are recommended as the best sources for breeding programs.

Materials and Methods

Stem rust field populations from Ambo and Debre Zeit were multiplied on the adult plants of the susceptible variety Morocco in a greenhouse under conditions favourable for the development of the pathogen. Two most virulent isolates from each location were selected for the present study.

Four sets of the seedlings and adult plants of 29 bread and durum wheat cultivars were grown in 4*4 cm size earthen pots in a glass house where they were maintained disease free. After inoculating seedlings at 2-leaf stage and adult plants at 5-leaf stage with individual races, each set were placed in a moist chamber for 24 hours for incubation and then transferred to glass house benches for the development of uredinia (pustules). Rust reactions were recorded about 14 days after inoculation by following the 0-4 scale (Stakman and Levine, 1922) where 0 - ; = immune, 1-2 = resistant, and 3 and 4 = susceptible.

Results

Seedling and adult plant reactions of the cultivars are given in Tables 1 and 2 for isolates from Ambo and Debre Zeit, respectively. Variety 2 exhibited highly resistant reactions to both isolates at both growth stages with Ambo isolates whereas varieties 5, 6, 7, 9, 10, 11, and 14 exhibited moderately resistant reactions and hence are suggested to be used as alternatives (Table 1).

Bread wheat varieties exhibited highly resistant reaction compared to durum wheats. Some varieties were immune to the pathogen isolates at either of the two growth stages. Varieties 8 and 9 were highly resistant with immune or resistant reactions to the Ambo isolates at both growth stages. Varieties 3, 7, 10, 13, 14 had a reaction type ranging from immune to moderately resistant (Table 1). Hence, these varieties could provide additional resistance sources. With Debre Zeit isolates varieties 8, 9, 13 had immune to highly resistant reaction type. As alternatives 2, 3, 10, 12 and 14 could be used as their reactions ranged from immune to moderately resistant to the two pathogen isolates (Table 2).

Some materials, for instance durum wheat varieties Kilinto and Gerardo were resistant at the seedling stage but were susceptible at the adult stage, whereas variety DZ 169505 exhibited a susceptible and resistant reaction at the seedling and adult stages, respectively to the first Debre Zeit isolate (Table 2). Resistance that could be to all isolates can be generated by carefully choosing the right parents based on the data we have presented here.

Table 1. Reaction of seedling and adult wheat plants to p.graminis isolate from Ambo

		Isolate 1		**Isolate 2**	
Plot no.	**Variety**	**Seedling infection type(0-4scale)**	**Adult infection type (0-4scale)**	**Seedling infection type(0-4scale)**	**Adult infection Type (0-4scale)**
	Durum				
1	Assassa	2	3	2	2
2	Tob-66	1	1	1	1
3	Kilinto	1	3	2	2
4	Foka	3	2	1	1
5	Gerardo	1	1	2	2
6	DZ1640	2	1	2	2
7	DY1050	2	2	2	2
8	Cocorit-71	1	3	1	3
9	Yielma	2	1	1	1
10	DZ1928-2	1	1	1	2
11	DZ 1691	2	2	2	2
12	DZ 1695-5	2	2	3	2
13	DZ1543	1	2	1	3
14	Boohai	2	2	2	2
15	Bichena	3	2	1	3

	Local check	4	4	4	4
	Bread Wheat				
1	Kubsa	2	4	2	3
2	Wabe	3	3	0	1
3	Galama	2	2	2	2
4	Tuse	3	3	0	1
5	Katar	3	2	2	;
6	Shina	3	3	0	2
7	Hawi	0	;	0	0
8	Simba	0	;	0	0
9	Wetera	0	0	0	;
10	HAR 2192	1	2	0	2
11	HAR 2508	3	1	;	1
12	F-H-6-1-7	1	3	;	1
13	Abola	;	2	0	0
14	Tura	2	1	0	;
	Local check	4	4	4	4

Table 2. Seedling and adult plant reactions (0-4 scale) of wheat varieties when tested with to *P. graminis* isolates from DebreZeit

		Isolate 1		Isolate 2	
No.	Variety	Seedling reaction	Adult plant reaction	Seedling reaction	Adult plant reaction
	Durum wheat				
1	Assassa	2	2	2	3
2	Tob-66	1	2	1	;
3	Kilinto	2	3	;	1
4	Foka	1	2	1	1
5	Gerardo	2	3	1	1
6	DZ1640	1	2	1	2
7	DY1050	2	2	2	2
8	Cocorit-71	;	1	1	2
9	Yielma	3	4	1	2
10	DZ1928-2	2	2	1	2
11	DZ 1691	1	2	2	2
12	DZ 1695-5	3	2	1	2
13	DZ1543	2	2	1	2
14	Boohai	3	3	3	1
15	Bichena	3	4	2	2
	Susceptible check	4	4	4	4
	Bread Wheat				
1	Kubsa	1	3	1	0
2	Wabe	2	2	1	0
3	Galama	2	2	;	2
4	Tuse	;	2	1	3
5	Katar	3	3	1	0
6	Shina	2	4	1	2
7	Hawi	3	0	;	0
8	Simba	;	0	0	0
9	Wetera	;	0	;	0
10	HAR 2192	1	2	1	0
11	HAR 2508	2	3	1	3
12	F-H-6-1-7	1	2	1	;
13	Abola	1	;	;	0
14	Tura	;	2	;	0
	Susceptible check	3	4	3	4

REFERENCES

Goluden, C.H., Neatby, K.W. and Welsh, J.N. (1928). The inheritance of resistance of *Puccinia graminis tritici* in a cross between two varieties of *Triticum vulgare*. Phytopathology 18:631-658.

Mutkekar, M.L., Bhangale, G.T., Patil, J.V. and Kalekar, A.R. (1985). Source of resistance to stem rust of wheat. Cereal Rust Bulletin 13:19-22.

Stakeman, E.C. and Levine, M.N. (1922). The determination of physiologic forms of *Puccinia graminis* on *Triticum* spp. Tech. Bull. 10 Univ. Minn. Agric. Exp. Stn. 1-10pp.

Evaluation of Kenyan Wheat (*Triticum aestivum* L.) Lines for Bread Making Quality

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Abstract—The grain composition and baking quality of wheat (*Triticum aestivum L.)* are important in determining end-use product acceptability, although some of these factors are influenced by environmental conditions. This study investigates the bread making quality and protein content of Kenyan wheat advanced lines. Eleven lines and one wheat variety (control) were planted in four locations in 2001 and 2002, and evaluated for flour extraction rate; protein content; farinographic dough water absorption and dough development time (DDT); and bread loaf volume, using official methods of the American Association of Cereal Chemists. There were significant ($p \leq 0.01$) effects associated with year of planting for protein, DDT; water absorption and loaf volume. Effects due to genotype were significant ($p \leq 0.01$) for flour yield and DDT. No significant ($P>0.05$) genotype × year interaction was observed. Genotype K7972-1 had 5.94% higher mean FY than the control K. Heroe. Lines 92B20 and R932 showed 4.5 and 2.67mins, respectively, longer DDT than K. Heroe. R899 had the highest mean flour Water Absorption (WA), 2.18% more than the control. R946 had the highest Loaf Volume (LV) of 619.38cm^3 (20.1% higher than K. Heroe). K. Heroe recorded the lowest loaf volume of 515.63 cm^3. 92B19, 92B24 and R946 had higher protein content, 19.2%, and 17.1% and 15.9%, respectively, than K. Heroe. Protein content and loaf volume correlated significantly ($r = 0.657^{**}$ and 0.707^{**}, respectively) with DDT. Protein content and loaf volume correlated significantly ($r= 0.642^{**}$) while flour yield correlated negatively ($r= 0.462^{**}$) with flour water absorption. From this study, we suggest that 92B9, 92B19 and R946 can be used in the breeding program to improve the quality of wheat.

Introduction

Grain and baking quality of wheat (*Triticum aestivum* L.) refers to its suitability for the type of processing or utilization for which the raw material is destined (Morris and Rose, 1996). Grain composition and baking quality are variable factors that depend on both genotype and the growing conditions. Environmental conditions such as weather-related factors, soil fertility, temperature, and soil moisture regimes have a major influence on grain and end use quality of wheat (Peterson et al, 1998). Therefore, there is genetic variation in wheat baking quality although some of the quality factors are influenced by the environment (Busch *et al.*, 1969; Baezinger *et al.*, 1985; Bassett *et al.*, 1989; Peterson *et al.*, 1992). Wheat strength is usually associated with flour protein. Both protein quantity and quality are considered to be primary factors in measuring the quality of flour in relation to bread making. The quantitative expression of crude protein is related to total organic nitrogen in the flour, whereas quality evaluations relate specially to physicochemical characteristics of the gluten-forming component. Protein quality criteria are related primarily to the gluten portion of the flour protein. Glutenins and gliadins are the major components of the storage protein in wheat and make a significant contribution to dough rheology and baking quality (Payne, 1987; Weegels *et al.* 1996). Quality is appraised largely by subjecting the flour to several physical testing devices, which measure various rheological characteristics. The tests are performed usually on flour-water dough. They characterize the dough as related to the properties of the gluten portion of the protein. Resistance to extension of dough at rest, hydration time, maximum development time and tolerance or resistance to breakdown at a predetermined consistency during mechanical mixing, are some of the most common dough parameters evaluated. Mixing characteristics are usually related to gluten quality, and can be reasonably well defined by the use of recording dough mixers such as the farinograph. Mixing requirements of bread dough correlate with some of the measurements obtained with recording dough mixers.

Performance of flour is evaluated experimentally under conditions that are similar to those applied by the millers and bakers. The evaluation of flour is carried out by test baking depending on intended use. Tests are performed under rigidly controlled and standardized condition (AACC methods).

Flour water absorption is an important factor in production of all types of baked goods. Usually high water absorption values are desirable, since they tend to increase unit yields of baked products. It is measured as the amount of water required to yield dough of predetermined consistency (Pratt, 1971).

In Kenya wheat is mainly used for *chapatti* and bread making but rarely used for pasta production. The increased demand for these products has prompted the breeding of more new varieties with good qualities. Although yield and resistance to diseases and pest have been the main objective of breeding work, recently, there has been an increasing emphasis on improvement of quality of the grain for milling and baking. The objective of this study was to investigate the bread making quality of advanced wheat lines, evaluated at four locations in Kenya.

Materials and Methods

Two wheat genotypes developed in Kenya (K7972-1 and K7872), five CIMMYT lines (R946, R891, R892, R932, R899) and four from Kenya Seed Company (92B9, 92B19, 92B20 and 92B24) were used in this experiment. *K. Heroe*, a variety was used as a control. The genotypes are described in Table 4.

The experiment was conducted at Lanet (0°4'S; 36°3'E), Naivasha (0°6'S; 36°5'E), Mau Narok (0°6'S; 35°8'E) in Rift Valley Province and at Katumani (1°6'S; 37°4'E) in the Eastern Province of Kenya. The cultural practices were followed according to the recommendations in all sites in order to sustain plant growth and production of grain. The seeding rate was maintained at 138 Kg ha^{-1}. Diammonium phosphate fertilizer was applied at the rate of 231 Kg ha^{-1} in order to supply 42 Kg N and 100g of DAP (18% N + 20% P) per plot during planting time. Pre-emergence herbicide STOMP^R (Pendimethalin 500g/litre) was applied at sowing time to restrict early weed growth. The experiment was laid out in a partially balanced lattice design, replicated three times and in each replicate, there were 4 blocks with 4 entries. At physiological maturity, the crop was harvested by Hege combine Model 140, seed cleaned and composited. Due to inadequate seed for entries, the sites were considered as replicates. About 800-1000g of wheat samples were sieved and cleaned, tempered to 15% moisture content (MC) and left overnight at room temperature about 20-21°C. These samples were then milled using a Buhler mill (Buhler Brothers Ltd., Switzerland) to determine flour extraction. The milled products were withdrawn and weights of all six flour streams (blended) and of shorts and bran were determined. Flour yield was calculated using equation:

$$FlourYield = \frac{Flour}{total\ recovered\ milled\ products} \times 100$$

Chemical, rheological, and baking tests were carried out to evaluate the baking quality of the wheat. The flour water absorption (WA) and dough development time (DDT) were analysed using a small bowl (50g) Brabender Farinograph (brabender OHG. Duisburg Germany) as described in the AACC method 54-21 (AACC, 1983). The amount of flour used was 50g (14% moisture basis). Flour water absorption is the amount of water required to centre the farinograph curve on the 500 brabender unit line.

Dough development time (DDT) is the duration required to develop dough visco elastic properties. It is the interval from first addition of water to that point of maximum consistency range immediately before first indication of weakening. This value has also been referred to as “peak” or “peak time”.

Bread making was performed using a modified basic straight dough method. The baking formula used included 100g flour at 14% moisture basis (mb), 1.2g yeast, 2.5g sugar, 1g salt, 3g dry milk powder, 3g fat and 1ml of bromate phosphate solution. Dough ingredients were mixed until optimum mixing time and then the dough was fermented (30°C and 80% relative humidity) for about four hours, with intervals of moulding the dough and finally proofing for 55minutes. This was then baked for 25 minutes in the oven at 220°C. Loaf volume (LV) was measured using the Rapeseed displacement method 10 minutes after the loaf was removed from the oven, using a Loaf Volumeter (National Mfg. Co., Lincohl, Nebraska.)

Crude flour protein (PC) analysis was done using the Kjeldahl method (N X 5.7) using a Tecator Kjeltec system.

SAS system was used to do statistical analysis using the General Linear Model. Analysis of variance for all the parameters, involving sites and years was done for each quality trait. Pearson correlation was done between some of the baking quality parameters.

Results

The mean year effects were significantly different ($p \leq 0.01$) for all the traits (Table 1). The effects due to genotype were also significant ($p \leq 0.05$) for FY and DDT. No significant ($P>0.05$) effects due to year × genotype interaction were observed.

A comparison of the genotypes for the two years showed much difference across the traits (Table 2). The means of the second year were lower for flour yield and higher for DDT, LV and PC than those of the first year.

Among the tested genotypes, K7972-1 produced 5.94% more FY than the control K. Heroe (Table 4). 92B20 and R932 showed longer differences of DDT of 4.5 and 2.67min, respectively, as compared to K. Heroe. R899, 92B19 and 92B24 showed higher water absorption than the control (Table 4).

The loaf volumes were generally low for all the genotypes (lower than the desirable 700cm^3 and above). The highest loaf volume was shown by R946 with 619.38 cm^3. This was higher than K. Heroe by 20.1%. Genotype 92B19, 92B24 and R946 exhibited protein ranging from 118.30 –115.01 g/kg. This was 19.2%, 17.1% and 15.9% than K. Heroe (Table 4).

Table 1: Mean Squares for flour yield, Dough Development, Flour Water absorption, loaf volume and protein content of the 12 wheat genotypes (*Triticum aestivum* L.)

Source	DF	FY (%)	DDT (min)	WA	LV (cm3)	PC g.Kg^{-1}
Year	1	343.01**	0.90**	32.67**	112951.40**	1889.08**
Genotype	11	29.68*	0.37**	3.92	9422.79	237.93
Rep	3	107.78	7.22	12.23	314602.39	8021.20
Gen*Year	11	29.19	0.13	9.14	7482.89	138.81
Error	64^k	12.86	0.10	4.14	5492.40	167.14
C.V		5.54	13.72	3.36	13.26	11.75

*, ** $P \leq 0.05$, $P \leq 0.01$

portion of the protein. Resistance to extension of dough at rest, hydration time, maximum development time and tolerance or resistance to breakdown at a predetermined consistency during mechanical mixing, are some of the most common dough parameters evaluated. Mixing characteristics are usually related to gluten quality, and can be reasonably well defined by the use of recording dough mixers such as the farinograph. Mixing requirements of bread dough correlate with some of the measurements obtained with recording dough mixers.

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$$FlourYield = \frac{Flour}{total\ recoveredmilledproducts} \times 100$$

Chemical, rheological, and baking tests were carried out to evaluate the baking quality of the wheat. The flour water absorption (WA) and dough development time (DDT) were analysed

Table 4. Pedigrees and grain characteristics (hardness and colour) of wheat (*Triticum aestivum* L.) genotypes evaluated for milling, grain and baking qualities and Ls means of the 12 wheat genotypes over the two years and four locations

Genotype	Pedigree	Grain Colour	Grain Hardness	FY (%)	DDT (min)	WA (%)	LV (cm^3)	PC (g/kg)
K7972-1	PASA/WED 186//K7837/WED365	Amber	Hard	69.13	4.07	60.10	603.75	110.58
K7872	K.CHIRIKU/WED354//BOUNTY	White	Soft	67.50	3.88	59.78	546.25	112.58
R946	OASIS/SKAUZ//4*BCN CMSS93Y04054M-2M-OY	Red	Hard	63.00	4.97	60.88	619.38	115.01
R891	ATTILA CM83836-5OY-OM-OY-3M-05Y	Red	Hard	62.88	3.56	60.10	520.63	103.96
R892	IL-75-2264/4/CAR//KAL/BB/3/NAC/5/GAA/CM112735-OTOPY-18M-020Y-010M-3Y-0101Y-OM	Amber	Hard	65.00	4.50	60.14	523.75	111.98
R932	PRL/SARA//TSI/VEE\50 CM103443-41M-030Y-020Y-010M-2Y-OM-OSY	Amber	Hard	62.88	8.09	59.51	570.85	103.87
R899	PGO/SARA CM95414-OM-IY-030M-020Y-010M-3Y-010Y-OM	Red	Hard	64.71	4.44	61.85	540.63	106.46
92B9	-	Red	Hard	64.93	5.62	59.89	591.47	113.37
92B19	-	Red	Hard	63.75	5.78	61.26	530.00	118.30
92B20	-	Red	Hard	64.97	6.26	60.29	572.21	110.91
92B24	-	White	Hard	62.80	4.71	61.39	576.27	116.24
K.Heroe	MBUNI/SRPC 64//YRPC1	Red	Hard	65.25	3.59	60.53	515.63	99.24
Mean				64.73	4.96	60.48	559.23	110.21
SEM				0.38	0.19	0.21	7.77	1.37

Discussion

Lill D Van (1995) in his study on multivariate assessment of environmental effects indicated that climatic factors contributed most to variation in yield and baking and milling quality characteristics. This explains the variation due to year effects, as the locations did not change. The change due to environmental effects also caused the differences in the parameters between the two years for all the genotypes. The correlation between loaf volume and DDT indicates that a longer dough development time is required to obtain large loaf volumes. It suggests that one can predict the volume of loaf from the dough development time obtained from a farinogram. The highly significant correlation between DDT and protein observed in this study concurs with findings of Bushuk *et al.* (1969). This suggests that there is a linear relationship between protein content and dough development time. As the protein content increases, there is increase in duration for development of dough. DDT relates to changes occurring in gluten proteins during mixing (Preston and Kilborn, 1984.) The dough of the two genotypes, R932 and 92B20, with long DDT started weakening after a long duration of time. They showed exceptionally strong dough thus the high dough development time. This was especially so for the Katumani site. Variation in loaf volume is mainly influenced by protein content (Pomeranz, 1971). In this experiment there is a linear relationship between protein content and loaf volume (Table 3). Lill D. Van (1993) found that loaf volume actually correlates significantly with gliadin and glutenin, the storage proteins in wheat. It can therefore be concluded that within a genotype, DDT and loaf volume both depend on the protein content. Flour yield is an essential parameter for milling profitability. Table 3 shows that there is negative correlation between flour yield and flour water absorption. Starch when damaged during milling takes up greater quantities of water than the 35% by intact starch. The quantity of additional water absorbed by dough as a result of starch damage depends on the degree and extent of starch damage (Sandstedt, 1955). Cultivars with a high proportion of starch damage (common in hard wheat) produce flours with high water absorption (Blackman and Payne, 1987). This would explain the negative correlation of flour yield (FY) to water absorption (WA). However, water absorption is also influenced by other factors as protein content and particle size of the flour. Flours with smaller average particle size would have higher absorption values because of greater specific surface. From the Dunnets means of squares, the cultivars were not significantly different for this parameter but were of desirable flour yield

Conclusion

Our aim was to evaluate the advanced lines in the wheat-breeding program for quality. We classified the 12 bread wheat cultivars for crude protein content and only 4 cultivars including the control had values below 12%. Genotypes 92B19, 92B24 and R946 had the highest values. These varieties showed high loaf volumes as compared to the others. 92B9 had high protein values as well as loaf volume. Protein content was used for classification as it correlates with most of the other parameters.

References

American Association of Cereal Chemists. 1983. Approved methods of the AACC. 8th Edition St Paul, MN.

Baezinger.P.S., R.L. Clements, M.S. McIntosh, W.T. Yamazaki, T.M. Starling, D.J. Sammons, and J.W. Johnson. 1985. Effect of cultivar, environment and their interaction and stability analyses on milling and baking quality of soft red winter wheat. Crop Sci 22: 5-8.

Bassett, L.M., R.E. Allan and G.L. Rubenthaler. 1989. Genotype x environment interactions on soft white winter wheat quality. Agronomy Journal 81:955-960.

Blackman, J.A. and P.I. Payne. 1987. Grain Quality. *In* Lupton F.G.H. (ed), Wheat Breeding. Chapman and Hall, London and New York, pp. 455-485

Busch, R.H., W.C. Shuey, and R.C. Frohberg. 1969. Response of hard red spring wheat (*Triticum aestivum L.*) to environments in relation to six quality characteristics. Crop Sci 9:813-817.

Bushuk, W. K.G. Briggs, and L.H. Shebeski. 1969. Protein quantity and quality as factors in the evaluation of bread wheats. Cereal Chem. 49:113-122

Finney, W.T., V.L. Yamazaki, and G.L. Rubenthaler. 1987. Quality of hard, soft and durum wheats. In Heyne, E.G. (Ed) Wheat and wheat improvement (2nd Edition), ASA, Madison, WI pp. 677-748.

Katunzi A.L., T.E. Maganga, and A. Mrema. 1991. The Effects of Genotype, Environment and their Interaction on Soft Bread Wheat Quality. In Proceedings of the. 7th Regional Wheat Workshop, Tanzania………, pp. 64-72

Lill D. van, J.L. Purchase, M.F.Smith, G.A Agenbag, and O.T. De Villiers. 1995. Multivariate assessment of environmental effects on hard red winter wheat. II. Canonical correlation and canonical variate analysis of yield, biochemical and bread-making characteristics. S. Afr. J. Plant Soil 12(4):164-169.

Morris,C.F. and S.P. Rose. 1996. Wheat. In: Henry, R.J.and P.S. Kettlewell, (eds) Cereal Grain Quality. Chapman and Hall, London. Pp. 3-54.

Peterson , C.J., R.A. Graybosch, P.S. Baezingger, and A.W. Grombacher. 1992. Genotype and environment effects on quality characteristics of hard red winter wheat. Crop Sci 32:98-103.

Peterson C.J., R.A.Graybosch , D.R. Shelton, and P.S. Baenziger. 1998. Baking quality of hard winter wheat: Response of cultivars to environment in the Great Plains. Euphytica 100:157-162.

Pomeranz Y. 1971. Wheat Chemistry and Technology: Compositional and functionality of wheat flour components Chapter 12: 602-603

Pratt Jr D.B. 1971. Wheat Chemistry and Technology: Criteria of Flour Quality. Chapter V:201-225

Preston, K.R., and R.H. Kilborn. 1984 The Farinograph handbook, B.L. D'Applonia, and W.H. Kunerth (ed.) 3rd ed. AACC. St.Paul, MN.)

Sandstedt, R.M. 1955 Photomicrographic studies of wheat starch. III. Enzymatic digestion and granule structure. Cereal Chem. 32 (incomplete reference)

Physiological Traits Associated with Drought Tolerance in Bread Wheat (*Triticum Aestivum* L.) under Tropical Conditions

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Abstract—Although it is generally accepted that drought tolerance is a critical agronomic trait, efficient and predictable improvement in drought tolerance in bread wheat (*Triticum aestivum* L.) has not yet been achieved. Evaluating the responses of physiological traits associated with drought tolerance in bread wheat varieties will enhance selection for tolerance in wheat varieties grown in marginal rainfall areas. This study assessed the drought responses of bread wheat using physiological traits associated with drought tolerance that may be used for selection. Two experiments (under the rain shelter and in the field) were carried out, each for two seasons (2001/2002). The rain shelter experiment simulated rains at three watering regimes: low (210mm), medium (240mm), and high (270mm). Significant genotypic variation ($P<0.01$) was observed for water use efficiency (WUE), harvest index (HI), stomatal conductance, transpiration rates, and CO_2 assimilation. Under dry conditions, these were identified as key control points in determining the drought resistance of tolerant genotypes. These traits could also be responsible for sustained survival and facilitated recovery after rewatering. Thus, their use as selection criterion in breeding for drought tolerance is promising. In these respects, the genetypes R960, KM14, R963, and R965 were the most promising candidates with superior physiological traits and high grain yield. All of the genotypes were compared with the commercial checks Duma and Chozi. A need exists to determine the heritability of these traits to realize their potential usefulness in a breeding program.

Introduction

Water scarcity is increasingly becoming a major limitation for agricultural production and food security in sub-Saharan Africa (Turner, 2001). In Kenya, for example, the major constraint limiting wheat production in marginal rainfall areas is inadequate and erratic rainfall (Jaetzold and Smith, 1983; Mugo *et al*., 1998). Development of wheat cultivars with improved adaptation to drought has thus been a major goal in most of national wheat breeding programmes. However, breeders have traditionally applied methods where grain yield comparison is used as the main selection criteria for drought tolerance. The approach has often succeeded in the absence of in-depth knowledge about physiological basis for superior performance of existing germplasm. The effectiveness of selection for grain yield *per se* is, however, low because of the large number of genes involved, hence low heritabilities (Acevedo, 1993) and large genotype × year, genotype × location and genotype × year × location interactions (Calhoun *et al*., 1994; Van *et al*., 1998). These make genetic progress for drought and heat tolerance extremely difficult and new varieties are released, for commercial production, after long periods (up to eight years). To improve genetic gains and realize production increases, more efficient screening and selection methodologies and tools need to be developed (Pfeiffer *et al*., 2000; Reynolds *et al*., 2001). Ludlow and Muchow (1990) noted that grain yield (under drought) is dependent upon many phenological, morphological, and physiological characters. Therefore, the use of physiological traits as an indirect selection would be important in augmenting yield-based selection procedures (Acevedo, 1993) and hence result in more precise targeting of factors limiting yield and consequently faster rates of yield improvement and broadening of genetic base (Richard *et al*. 2002). Physiological traits take less time to measure than grain yield and can be observed gradually at seedling stage before flowering. The breeder can thus eliminate susceptible lines from the crossing nursery and shorten the selection cycle time. By using physiological traits, it may be possible to provide an easy estimate of yield potential before the final harvest. (Edmeades *et al*., 1996). The objective of this study was to evaluate drought responses of physiological traits in bread wheat that control grain yield and hence may be used for selection in dry tropical environments.

Materials and Methods

Experimental sites

Two experiments (experiment I and experiment II) were undertaken in 2001 and 2002. Experiment I was carried out under field conditions at the National Dryland Research Centre, Katumani (1º35’S, 37º14’E, altitude 1560m). Katumani lies in the semi-arid zone low potential dryland area within Agro-Ecozone UM 4 in the Eastern Province of Kenya. The average annual rainfall is about 716mm, with mean minimum and maximum temperatures of 13.9°C and 24.7°C, respectively. Water loss through evaporation is about 1800mm per year, creating an annual water deficit of about 1048 mm (ICRAF, 1988). The soils are Ferral Chromic Luvisols, which are well-drained, deep sandy loam to clay loam (Jaetzold and Schimdt, 1983).

In contrast, experiment II was carried out under rain shelter, by simulating early season drought at seedling stage, at the National Plant Breeding Research Centre, Njoro (0° 20’S, 35° 56’E, altitude 2160 m). Njoro is in the Greater Rift Valley, Kenya, and it receives an average annual rainfall of 931mm. Mean maximum and minimum temperatures are 22.7°C and 7.90°C, respectively. The soils are well drained Mollic Andosols with sandy loam (Jaetzold and Schmidt, 1983). The shelter is similar to that described by Jefferies (1993) and Upchurch *et al*.(1983) and is 15.5m long × 7.5m wide. Translucent sheets (which allow up to 90% of photosynthetic photon flux density to pass through) covered the roof.

Wheat genotypes

Seventeen bread wheat genotypes were evaluated in the field in experiment I (Table 1). Of these, 12 genotypes (R963, R965, R962, R960, R966, R970, 94b01, R917, KM20, Chozi, Duma and Heroe) were evaluated in experiment II under the rain shelter (Table 1). Four of the genotypes originated from Kenya while thirteen were introductions from CIMMYT and other international nurseries showing resistance to drought and having different phenotypic traits, maturity periods, and yield potential (Table 1). Mutants were developed by irradiating the seeds of parents with different levels of radiation at International Atomic Energy Agency (IAEA), Vienna Austria (Table 1).

Table 1. The origin, pedigree, and drought tolerance level for the seventeen wheat genotypes used in the study.

Genotype	Origin	Pedigree	Drought tolerance response
1. Chozi	Kenya	F12.71/COC//GEN	Tolerant
2. Duma	Kenya	SW 53 = BUCK BUCK ‘S’	Tolerant check
3. Kenya Heroe	Kenya	MBUNI/SRPC 64//YRPC1	Susceptible check
4. R913	CIMMYT Mexico	KMN/BOW/OPATA	Unknown
5. R917	CIMMYT Mexico	URES/BOW/OPATA	Moderately tolerant
6. R920	CIMMYT Mexico	PJN/BOW//OPATA	Moderately tolerant
7. R960	CIMMYT Mexico	PASTOR	Moderately tolerant
8. R962	CIMMYT Mexico	KLEIN CHAMACO	Moderately tolerant
9. R963	CIMMYT Mexico	BOW//URES//KEA	Moderately tolerant
10. R965	CIMMYT Mexico	BOW//BUC/BUL/3/KAUZ	Moderately tolerant
11. R966	CIMMYT Mexico	FILIN	Moderately tolerant
12. R970	CIMMYT Mexico	PIPED/5PATIO/ALD//PAT	
		72300/3PUN/4/BOW/	
		6BAW 898	Moderately tolerant
13. R840	CIMMYT Mexico	PIPED/5PATIO/ALD// PAT 72300/3PUN	Moderately tolerant
14. KM14	Kenya	PASA MUTANT (BUC “S”/CHAT “S”	Tolerant
15. KM15	Kenya	PASA MUTANT	Moderately tolerant
16. KM20	Kenya	PASA MUTANT	Moderately tolerant
17. 94b01	Kenya	PUN// BOW/BAW	Moderately susceptible

Experimental design

Experiment I was sown on 25 October 2001 (season I) and 20th April 2002 (season II). The test germplasm was drilled in 4 rows (each 6m long) spaced 0.2m apart (at a seed rate of 125 kg ha^{-1}) in a randomized complete block design, replicated three times. Fertilizer was applied at the recommended rate (70 Kg P_20_5 ha^{-1} and 37 Kg N ha^{-1}) as Diammonium phosphate (46-18-0). Aphids were controlled by application of Metasystox at the rate of 1L ha^{-1}. The experiments were kept weed-free throughout the growing season by manual weeding. Physiological data was taken 26-31 Dec 2001 (61 DAE) and 27-30 June 2002 (65 DAE).

Experiment II was a split-plot design sown on 15 September 2001 (season I) and 5 January 2002 (season II) with water regime as main plots (size) replicated three times and the 12 wheat genotypes as sub-plots (size). Wheat seeds were drilled in rows 0.2m apart at the recommended seed rate of 125 kg ha^{-1}. Fertilizer rates were similar to those in experiment I. Plots were shielded from rainfall by covering with the rain shelter at all rainy times and at night. To ensure good germination and crop establishment before imposing irrigation treatments, all plots were watered to field capacity (30-32% moisture content) at planting. In addition, all the plots received 30mm of water at emergence and at 7 days after emergence (DAE). The watering regime treatments were imposed by withholding water supply for a period of 2, 4, and 6 weeks, respectively (up to 21, 35, and 49 DAE, respectively). In total, the “low” watering regime received 210 mm of moisture, “medium” received 240 mm, and “high” water regimes received 270 mm during the growing season. The amount and frequency of water application simulates the amount and nature of rainfall pattern usually received in most marginal areas during cropping season (Mugo *et al*., 1998; Jaetzold and Smith, 1983). Drip irrigation was the method used to water the plots (Chapin Watermatics, 1999).

Measurement of weather variables

An automatic weather station located 100m from the site of experiment I recorded rainfall (mm), maximum and minimum air temperatures (°C), solar radiation (MJ m^{-2} per day), and relative humidity (RH, %) each day during the experiment (Table 2). Also, instantaneous weather variables like atmospheric temperature, RH (%), and photosynthetically active radiation (PAR) were recorded in experiment I (Table 3).

Measurement of water use

Total crop water use was determined in experiment II by monitoring changes in volumetric moisture content throughout the season. Soil moisture content was measured at 7-day intervals using a neutron probe (Troxler Model 4300, New York). Measurements were taken between 7 and 91 DAE (season I) and 7 and 98 DAE (season II). Volumetric water content at each depth was calculated using calibration equations for this site (Ooro *et al*., 2001).

Table 2. Monthly total (rainfall and Epot) and daily mean of weather variables (temperature, solar radiation and relative humidity) during the 2001 and 2002 growing seasons at Katumani.

	Mean	Total	Maximum		Minimum		Mean *		Solar		Relative	
	Rainfall		E_{pot}.	Daily	Daily		Temperature		Radiation		Humidity	
(mm)	(mm)	Temperature (^{0} C)			Temperature (^{0} C)		(^{o} C)			(MJ m^{-2} d^{-1})		(%)
2001												
January		244.5	115.4	24.5		14.0		19.3		609.1		71.0
February		trace	161	26.4		14.3		20.4		694.4		60.0
March	113	158	26.7		14.3		21.5		658.1		60.0	
April	88.9	115.4	24.9		15.1		20.0		549.2		68.5	
May	15.3	123.8	25.0		14.0		19.5		533.9		63.5	
June	4.3	79.4	23.6		11.9		17.8		498.2		65.0	
July	4.3	100.3	21.2		10.9		16.2		490.7		66.0	
August	2.5	134.5	24.5		11.0		17.8		527.5		59.0	
September	trace	169.5	26.7		12.5		19.6		611.2		54.5	
October	73	180.3	27.1		13.6		20.4		630.0		51.5	
November	169	126.1	24.0		14.6		19.3		573.9		69.0	
December	43.6	127.6	24.2		14.4		19.3		552.7		72.5	
Mean/Total	758.4	1591.3	24.9		13.1		19.2		577.4		63.4	
2002												
January												
February		79.5	148.2	25.9		14.1		20.0		624.4		65.5
March	98.9	7.5	179.0	27.1		13.9		20.0		676.4		53.0
April	120.4	141.6	26.3		15.3		21.3		634.1		65.5	
May	125.6	151.9	25.8		15.8		20.3		572.4		67.0	
June	94.9	111.3	24.4		14.2		19.3		475.5		70.0	
July	trace	94.9	23.4		12.1		17.8		447.8		66.5	
August	0.2	101.3	23.9		13.2		18.6		445.6		65.0	
Mean/Total	527.0	120.3	24.1		12.0		18.1		435.6		64.5	
		1048.5	25.1		13.8		19.4		539.0		64.6	

* The mean of daily maximum and minimum temperature

Table 3. Diurnal variation in mean temperature, relative humidity (RH) and photosynthetically active radiation (PAR) at 61 (season I) and 65 (season II) DAE.

Time Of day (hours)	Atmospheric Temperature (^{0}C)	RH (%)	PAR (μE m^{-2}s^{-1})
0800	23.0	52.1	780.8
1000	28.1	39.8	1369.7
1200	31.3	37.1	1866.8
1300	34.0	36.7	1941.3
Mean	29.1	41.4	1489.7

Total crop evapotranspiration (ET) was estimated using the soil water balance equation:

$ET = -\Delta S + I – D - R.$ 1

where ΔS is the change in storage (the difference in volumetric water content of the entire profile between the start and the end of the experiment), I is irrigation, D the drainage, and R is the runoff. Drainage and runoff were assumed to be negligible. The soil moisture content of the deepest layer (1.0m) showed little change during the crop-growing season. There was no runoff because drip irrigation was used. W/ET

Water use efficiency (WUE); the ratio of the total above ground dry matter produced (DM) to the total amount of water used by the crop was determined using the equation:

WUE =DM/ET 2

Measurement of gas exchange parameters

Stomatal conductance (g) and instantaneous transpiration (T) rates were measured on both the upper and lower surfaces of the uppermost fully expanded leaves at two-hour intervals (between 1000 and 1300 hrs) on clear sunny days, at booting stage, using a steady-state porometer (LI-1600Lico Inc. Lincoln, NE, USA). Stomatal resistance (r_s) was calculated as inverse of stomatal conductance (Burrows and Milthorpe, 1976; Cowan, 1977). Net leaf CO_2 exchange rates (CER) was measured on selected leaves using a portable Infrared Gas Analyzer (IRGA), fitted with Parkinson Leaf chamber.

Statistical analysis

Analysis of variance (ANOVA) was used to evaluate the treatments using a general linear model (GLM) (SAS, 1996). Statistical differences for the watering regimes and means of all variables measured for wheat genotypes were separated using Fisher's least significance test (LSD) at $P<0.05$.

Results

Crop biomass, grain yield, and harvest index

The interaction between watering regimes and genotypes affected biomass such that the increase in biomass due to irrigation varied with genotypes (Table 4). The medium watering regime increased biomass of all genotypes, from a 15% increase in R963 to 122% in R965. On average, the increase in biomass due to medium watering regime was greater for drought susceptible (68%) and medium tolerant (59%) genotypes than drought tolerant ones (41%). Similarly, the increase in biomass due to high watering regime varied with genotypes (from 50% to 215%). The increase in biomass due to high watering regime was greater (on average) for drought susceptible (131%) and medium tolerant (121%) varieties than drought tolerant ones (95%). On average, irrigation increased crop biomass by 56% (medium watering regime) and 116% (high watering regime) (Table 4).

The interaction between moisture regimes and wheat genotypes affected grain yield such that medium watering regime decreased (by 14%) the grain yield of genotype R917 but increased the grain yield of the other varieties (by 11% - 113%, respectively for 94b01 and R970) (Table 4). The increase in grain yield due to the medium watering regime was greater for susceptible varieties (60%) than medium tolerant (55%) and drought tolerant (56%) ones (Table 4). In contrast, the high watering regime increased grain yield of all genotypes, but the magnitude of the increase varied by genotype. For example, the increase was greatest for R963 (157%) and lowest for R917 (13%). On average, the increase in grain yield due to the high watering regime was greater for susceptible varieties (121%) than drought tolerant (117%) and medium tolerant (104%) genotypes (Table 4).

Harvest index was not affected by the interaction between water regimes and genotypes (Table 4). Genotype affected harvest index under all moisture regimes (Table 4). Averaged over the moisture regimes, HI varied from 0.21 (R917) to 0.46 (R960). Drought tolerant varieties had greater (by 25%) HI than drought susceptible and medium tolerant varieties (Table 4). Irrigation increased HI by 26% (medium moisture) and 22% (high moisture regime) (Table 4).

Table 4. Response of grain yield, biomass, evapotranpiration (ET), water use efficiency of biomass production (q_d), and grain yield (q_g) and harvest index (HI) to three moisture regimes for two seasons (2001/2002)/

Genotype/	ET	Biomass	Grain yield	WUEg	WUEb	HI Irrigation
(mm)	(kg ha^{-1})	(kg ha^{-1})	(kg ha^{-1}mm^{-1})	(kg ha^{-1}mm^{-1})		
Low Moisture						
Chozi	97.4	2993.3	703.2	5.7	30.2	0.24
94b01	83.2	1199.2	605.6	7.2	14.1	0.40
Duma	93.9	1480.8	652.8	7.9	16.7	0.44
Heroe	86.0	2303.3	394.9	4.8	26.2	0.18
KM20	75.8	1420.0	494.4	4.5	24.4	0.34
R917	81.7	1454.2	622.7	4.1	16.3	0.40
R960	88.1	1230.8	661.9	7.5	13.8	0.51
R962	93.6	2311.3	570.6	5.7	23.8	0.22
R965	108.9	1470.8	650.1	4.8	14.7	0.45
R963	79.1	1630.0	682.9	8.1	20.2	0.41
R966	100.9	2171.3	598.1	5.6	21.3	0.36
R970	85.3	1407.5	447.7	5.8	15.0	0.34
Medium moisture						
Chozi	131.0	3831.3	1061.1	8.1	29.2	0.35
94B01	110.7	2125.8	783.3	7.7	23.0	0.37
Duma	107.7	2277.9	1049.1	9.6	22.2	0.46
Heroe	111.9	3142.9	820.4	6.4	30.0	0.23
KM20	117.2	2612.9	709.7	5.7	26.8	0.28
R917	120.9	1933.3	685.6	5.6	17.6	0.31
R960	104.9	2003.7	1089.4	10.5	22.2	0.54
R962	127.3	3342.5	1023.8	7.2	26.8	0.31
R963	115.4	2372.1	1043.0	9.1	21.7	0.43
R965	116.2	3261.3	946.3	7.6	28.8	0.31
R966	112.5	2582.9	861.6	7.0	24.9	0.32
R970	107.3	2650.0	952.3	8.0	22.1	0.33
High moisture						
Chozi	165.8	5337.9	1616.8	8.9	32.5	0.31
94B01	149.3	3057.5	1405.1	11.5	26.1	0.44
Duma	127.8	3143.3	1323.1	12.1	24.6	0.42
Heroe	157.1	4194.6	960.2	8.4	31.4	0.26
KM20	180.4	3502.9	1056.9	6.0	32.4	0.29
R917	131.0	3244.2	904.6	6.9	24.1	0.27
R960	134.4	2868.3	1505.7	11.4	21.2	0.53
R962	158.0	5060.4	1298.2	8.5	32.0	0.25
R963	179.5	3082.9	1346.1	8.4	17.2	0.44
R965	155.7	4638.7	1184.7	7.6	30.2	0.26
R966	158.8	3758.6	1229.2	7.7	30.7	0.35
R970	132.4	2855.0	995.7	7.5	21.0	0.34
S.E.D	146.1	1351.0	1072	0.93	11.5	0.003
Lsd	438.19	458.9	107.21	1.78	2.67	0.03
Variety	P<0.001	P<0.001	P<0.001	P<0.005	P<0.001	P<0.001
Water	P<0.001	P<0.005	P<0.001	P<0.05	P<0.001	P<0.001
W x G	P<0.05	P<0.05	P<0.05	ns	P<0.05	ns

W x G = water regime x genotype interaction, ns, not significant

Crop water use (ET)
The interaction between water regimes and genotypes affected total crop ET such that the increase in crop ET due to irrigation varied with varieties (Table 4). For example, the medium watering regime increased crop ET by 7% (R965) to 55% (KM20). Increase in crop ET due to the high watering regime ranged from 36% (Chozi) to 138% (KM20). Also, the increase in ET due to irrigation was greater for the drought susceptible (32% and 81%, respectively for the medium and high watering regimes) and medium tolerant (33% and 77%, respectively for the medium and high watering regimes) varieties than for drought tolerant varieties (25% and 53%, respectively for the medium and high watering regimes) (Table 4).

Water use efficiency (WUE)
The interaction between moisture regimes and wheat genotypes affects water use efficiency of biomass production (q_d, Howell *et al.*, 1998). The increase in q_d due to the medium moisture regime varied respectively from 14-17% (KM20 and R966) to 47-50% (R970 and R960). Similarly, the increase in q_d due to the high moisture regime varied with genotype (ranging from 4% to 94%, respectively for Heroe and R917) (Table 4). On average, the increase in q_d due to the medium moisture regime was greater (32%) for medium tolerant genotypes than for tolerant (28%) and susceptible (29%) genotypes (Table 4). Also, the increase in q_d due to high moisture regime was greater for medium tolerant (65%) and tolerant (36%) genotypes than drought susceptible ones (22%) (Table 4).

The interaction between watering regime and genotype did not affect water use efficiency of grain production (q_g, Howell *et al*., 1998; Ogola *et al*., 2002) (Table 4), but q_d varied with genotypes (from 5.4 kg $ha^{-1}mm^{-1}$ to 9.9 kg $ha^{-1}mm^{-1}$ respectively, for R917 and Duma) across the three moisture levels (Table 4). On average, the drought tolerant genotypes had a greater q_g (8.9 kg $ha^{-1}mm^{-1}$) than susceptible (7.9 kg $ha^{-1}mm^{-1}$) and medium tolerant (6.9 kg $ha^{-1}mm^{-1}$) genotypes (Table 4). Averaged over all genotypes, the medium watering regime increased q_g by 28% (from 5.8 to 7.4 kg $ha^{-1}mm^{-1}$), while the high watering regime increased q_g by 53% (from 5.8 to 8.9 kg $ha^{-1}mm^{-1}$).

Gas exchange parameters
Results showed similar trends in both seasons. Genotypes affected leaf temperature in field experiment I; Duma, R960, and Chozi had the lowest leaf temperature, and R920, R963, and KM20 the greatest (Table 5). This resulted in mean lowest and highest leaf temperature depressions, respectively for these genotypes. On average, leaf temperature was lower (by 3%) for drought tolerant genotypes (28.6°C) than medium tolerant (29.3°C) and susceptible (29.5°C) genotypes. The difference between the lowest and the greatest leaf temperature was 7%. The greatest leaf temperature depression was recorded in R920 and the lowest in Duma (Table 5). Leaf temperature depression was greater for drought tolerant genotypes (-0.6°C) than medium tolerant (0.4°C) and susceptible (0.2°C) genotypes.

Instantaneous transpiration (IT) differed by genotype; KM14, R963, Chozi, Duma, and R960 had the greatest IT (ranging 10.3-11.2 mmol m^{-2} s^{-1}) and R913, R840, R970, and KM20 the lowest (ranging from 7.0-7.7 mmol m^{-2} s^{-1}) (Table 5). On average, IT was greater (by 21% and 44%, respectively) for drought tolerant genotypes than medium tolerant and susceptible genotypes. Also, average IT was 20% greater for susceptible than medium tolerant genotypes.

There was variation among the genotypes in CER (from 7.9 to 15.1 μmol m^{-2} s^{-1}) with KM14, R960, R966, R965, and Duma having the lowest values (Table 5). Drought tolerant genotypes recorded 16% and 20% greater CER than medium tolerant and susceptible genotypes, respectively. The results of CER ranked susceptible genotypes (like R966) higher than tolerant genotypes (Duma).

Stomatal conductance (g) and resistance r_s were affected by genotypes; Chozi and Heroe had the greatest g and lowest r_s, respectively (1.3 μmol $cm^{-2} s^{-1}$ and 2.1 s cm^{-1}). KM20 the lowest g (0.6 μmol $cm^{-2} s^{-1}$) while R840 had highest r_s (4.9 s cm^{-1}) (Table 5). Stomatal conductance was greater in drought tolerant than susceptible genotypes by an average of 27% and non-significant with medium tolerant genotypes. The genotypes ranking based on g and r_s was inconsistent (Table 5).

Table 5. Gas exchange parameters of 17 wheat cultivars measured at Katumani for two seasons (2001/2002).

Cultivar	LT (^{0}C)	LTD (^{0}C)	g (μmol $cm^{-2} s^{-1}$)	TR (mmol $m^{-2} s^{-1}$)	r_s (s cm^{-1})	CER (μmol $m^{-2} s^{-1}$)	Yield Kg/ha
R963	30.0	0.4	0.9	10.0	3.5	10.5	1269
KM14	29.29	-0.2	1.1	11.2	3.2	15.1	1185
Heroe	29.2	-0.2	1.3	9.5	1.5	9.5	676
R920	30.0	0.8	0.7	8.6	3.9	10.1	1034
R840	29.8	0.6	0.7	7.1	4.9	12.3	1028
R966	29.2	0.4	1.0	9.8	2.9	13.0	1033
KM15	29.8	0.7	0.7	7.8	2.2	9.4	615
R960	28.7	-0.1	0.8	10.3	2.9	13.4	1315
R970	29.5	0.4	0.8	7.4	2.8	9.7	1059
94B01	29.6	0.5	0.8	9.0	3.4	12.9	676
R965	29.2	0.1	0.7	8.1	4.0	13.1	1364
Duma	28.1	-0.9	1.1	10.3	1.2	12.9	1258
KM20	29.7	0.7	0.6	7.7	3.9	10.1	776
Chozi	28.3	-0.6	1.3	10.4	2.1	12.3	1267
R917	29.6	0.8	0.9	8.2	1.5	8.4	719
R962	28.7	-0.4	1.0	8.6	1.9	11.4	848
R913	29.4	0.7	0.7	7.0	2.3	7.9	898
Mean	29.3	0.2	0.9	8.9	3.1	11.1	1003
P(F-ratios)	P<0.05	P<0.01	P<0.001	P<0.001	ns	P<0.001	P<0.001
Lsd	1.13	0.36	0.15	0.57	3.95	3.80	661.4

Discussion

The bread wheat genotypes used to examine variation in physiological responses to early season drought could be classified into three groups: relatively drought tolerant (Chozi, Duma, R960, R963, and KM14); moderately drought tolerant (R840, R970, R920, R965, and R966) and relatively drought susceptible (Heroe, KM20, KM15, R917, 94B01, R913, and R962) based on physiological changes and grain yields measured.

The production of biomass varied considerably among the genotypes across the moisture regimes. Chozi, R962, Heroe, and R965 produced the highest biomass, while Duma, 94B01, R960, and R970 had the lowest biomass. This variation was closely associated with the amount of water transpired (ET) by each genotype as expected (Sinclair *et al*., 1984 and Ogola *et al*., 2002). The response to increasing moisture among the former group of cultivars enabled them maintain high ET resulting in increased water use for dry matter production (q_d) at the expense of water use for grain yield production (q_d). These represent inherent ability of high yield potential by way of a good biomass source. These findings are in agreement with earlier findings (van Ginkel *et al*., 1998 and Kirigwi *et al*., 2004) that yield potential is a useful criterion in breeding for superior performance in drought environments. Ceccarelli *et al*., (1987) disagreed with these findings and concluded that yield potential is not a useful criterion in breeding for superior performance in drought environments. In semi-arid areas of Kenya where seedling stage drought stress has been found to cause serious yield losses

(Mugo *et al*., 1988 and Kimurto *et al*., 2003), the latter group of cultivars could be recommended as they sustained growth with initial moisture. Studies in winter wheat indicate the importance of early-season dry matter production in early-drought situations (Entz and Fowler (1990). They also tended to invest more water for grain yield production (high WUE) than biomass, which may be used as an indicator of drought tolerance, as earlier reported (Ehdaie, 1995). These cultivars could be grouped into those susceptible to early season drought stress which utilize more water extracted in biomass production, and those tolerant to drought with more water used efficiently for grain yield production The exception to this is Chozi, which possessed a relatively high yield and biomass. The former group of cultivars could do well in areas with high amounts of rainfall to support high ET and longer growth duration. The latter group of genotypes was short and early maturing with high HI, as a result of early growth rate and vigour, which allowed more efficient initial water use during the cooler part of growing season when vapor pressure deficits are low. This was clearly demonstrated by Duma and R963 in this study, suggesting that high seedling vigor and faster biomass accumulation enhance early-season drought survival.

ET was affected by an interaction between genotype and moisture regime such that the WUE decreased with decreasing irrigation. This is in agreement with earlier findings (Ehdaie and Waines, 1994 and Ehdaie, 1995) that drought significantly reduced mean WUE for near-isogenic lines of wheat.

Harvest index provides an estimate of the conversion efficiency of dry matter to grain yield. The interaction between water regimes and genotypes did not affect HI, but drought tolerant cultivars (Chozi, Duma, R960, and R963) had a higher mean HI (0.38) than susceptible genotypes (0.23) (Heroe, KM20, R962 and R917). These observations concur with earlier statement (Richards *et al*., 2002) that drought tolerant genotypes convert more of biomass into grain raising the HI and final yield. Siddique *et al.,* (1990) also reported that improved mechanisms of partition between straw and grain (improved HI) are the main causes of increased yield in a Mediterranean-type climate. Similarly, Donmez *et al*., (2001) noted that wheat grain yields have been associated with increases in harvest index as opposed to increases in biomass. These results further showed that while HI of the same cultivars (except Chozi which was tall and 94B01, a short cultivar) grown under the high moisture regime approached and sometimes exceeded 0.40, it was generally much less under drought conditions with the same cultivars. Therefore, it appears that the HI of the study cultivars is well below the potential, and perhaps the maximum grain yield is not being achieved. These findings are in disagreement with Edhaie (1995) who reported that mean HI for two cultivars were similar in well-watered and dry conditions.

Field data was taken during anthesis on flag leaf, which was expected to be the most active physiological growth stage. The results showed that despite the higher ambient temperatures, tolerant genotypes were able to create cooler conditions around the leaf, which was essential for photosynthesis. Similarly, Reynolds *et al.*(1994) reported that high stomatal conductance (g), which permits leaf cooling through evapotranspiration, was associated with heat tolerance in CIMMYT wheat.

For wheat plants to absorb carbon dioxide (CO_2) for photosynthesis, they must expose wet surfaces (stomata) to dry atmosphere and in consequence suffer evaporative water loss. The drought tolerant genotypes (R963, Duma, KM14, R960, and Chozi) had higher values of transpiration than susceptible genotypes. Drought tolerant varieties also exhibited a smaller stomatal resistance though not more significant than the second group, which was susceptible to drought stress. These findings are in agreement with those reported by El Hafid *et al*., (1998), that susceptible genotypes exhibit a higher stomatal resistance (r_s) than tolerant genotypes on exposure to stress. The resultant being higher transpiration rates, suggesting that the ability of a cultivar to keep its stomata open despite internal water stress and could therefore be considered a form of drought resistance and for possible use as selection trait, is promising. Similar observations have been reported earlier (Johson *et al.*, 1987). This is because greater transpiration rates may lead to lower leaf temperatures, creating ambient temperatures for $C0_2$ uptake, resulting in higher yield. Gummuluru *et al.*(1989) disagreed and reported that higher stomatal resistance has been related to greater drought resistance.

Although significant, cultivar differences in stomatal conductance (g) were quite small ranging from 0.6-1.1 μmol cm^{-2} s^{-1}. Similarly, Gutierrez *et al.*(1998) recorded stomatal conductance values ranging between 1.22-1.73 μmol cm^{-2} s^{-1} under water stress conditions in Tuxpeno maize population. CER differed among genotypes with drought tolerant group of genotypes exhibiting higher rates than susceptible genotypes. Gummuluru *et al.(*1989) reported similar findings and noted that leaf photosynthesis and stomatal conductance differed significantly between the drought tolerant and susceptible genotypes, where higher stomatal conductance was related with drought resistance. These results suggest that stomatal conductance and transpiration rates are traits used by tolerant genotypes to enhance high CER and final grain yield in stress conditions. These genotypes were among the highest yielding in the field and rain shelter conditions (Table 4 and 6). This is in agreement with results by Omanyin *et al.*(1996) in sorghum and Cornish *et al.*(1991) in Pima cotton, where drought resistant genotypes had higher yield as they suffered less yield reduction because they exhibited higher leaf stomatal conductance and relative water content with associated heat tolerance. Omanyin *et al.*(1996) reported that drought tolerant sorghum varieties exhibited higher leaf RWC and suffered less yield reduction because of maintenance of turgidity, hence high stomatal conductance led to continued photosynthesis. Further, enhanced productivity was expected because increased stomatal conductance increases CO_2 partial pressures within the leaf and therefore also increases assimilation rates and final yield (Jones, 1987).

The data was taken during a very dry period (at anthesis, in Dec 2001 and June 2002) when the crop had received low rainfall against high evapotranspiration (Table 2). Despite severe drought stress, high radiation, and low RH at the time of data taking (Table 3) the tolerant genotypes continued photosynthesising. These results are consistent with earlier findings (Chaves, 1991) that plant survival during and after drought stress is, in part, possibly due to the maintenance of photosynthesis during drought stress, which allows rapid recovery of the plant after dehydration.

The derived values of instantaneous CER to water loss (TR) ratio (A/E) (Table 5) showed that tolerant genotypes had higher ratios (1.1-1.59) as compared to susceptible genotypes. However, under drought stress conditions when survival is more important than optimal functioning, the A/E ratios may not remain consistent among drought tolerant genotypes. For example, R840 recorded the highest ratio (1.7), indicating that it was very efficient in fixing large quantities of CO_2 while loosing small quantities of water. Similar observations were reported earlier in durum and winter wheat (Van Resburg and Kruger, 1993 and El Hafid *et al.*, 1998). El Hafid *et al.*(1998) further noted that drought-resistant group of cultivars had a lower decrease in net photosynthetic rate to transpiration ratio (A/E), showing that they can continue with C-assimilation despite partial stomata closure. Richards *et al.*(2001) noted that power of CO_2 sucking by the leaf is determined by the amount of photosynthetic machinery per unit leaf area and leaf stomatal conductance. In same study, El Hafid *et al.*(1998) noted that under drought stress, drought tolerant wheat cultivars exhibited lower internal CO_2 concentration to ambient CO_2 concentration (C_i/C_a ratio), suggesting that they can create CO_2 diffusion gradient into the cells. The increase in stomatal conductance could have accounted for most of the increased carbon assimilation rate. Due to a strong correlation between A/E ratio and grain yield, aboveground drymatter, WUE_g, and WUE_{gm} under drought (Van Resburg and Kruger, 1993 and El Hafid *et al.*, 1998), the value of determining A/E ratio of wheat cultivars during stress for possible use as a selection trait is promising.

Higher stomatal conductance was not correlated with increased yield in cassava (Githunguri *et al.*, 1998), hence it may only be one of the drought mechanisms for drought tolerance and not necessarily for increased yield production. In contrast, Omanyin *et al.*(1996) reported that in sorghum drought resistant genotypes suffered less yield reduction because they exhibited higher leaf stomatal conductance and relative water content (RWC). Reynolds *et al.*(1994) reported that high stomatal conductance permits leaf cooling through evapotranspiration. These traits can therefore be used for selection in wheat.

Conclusion

The major hypothesis tested in this study was that high grain yield (under drought stress) of bread wheat is controlled by physiological factors and that genotypic differences in such traits exist in wheat. This hypothesis was based on the assumption that a drought ideotype would combine all traits controlling yield and thus once identified could be used to select for yield. The hypothesis has not been disapproved. Genotypes that had high WUE_g, HI, early biomass accumulation, stomatal conductance, concomitant high transpiration, and photosynthetic rate were the highest yielding under drought stress conditions during seedling stage. These factors were therefore identified as key control points in determining the drought resistance of bread wheat genotypes. These traits may have facilitated maintenance of survival and facilitated the recovery upon rewatering. In these respects, Duma, Chozi, R960, KM14, and R963 appeared to be the most promising genotypes. These traits can be used to separate susceptible and tolerant wheat germplasm, and their use as a possible selection tools is promising. There is need to determine the heritability of these traits to know the potential usefulness of these traits in a breeding program.

References

Calhoun, D.S., G. Gebeyehu., A. Miranda., S. Rajaram and M. van Ginkel. 1994. Choosing evaluation environments to increase wheat grain yield under drought conditions. *Crop Science 34:* 673-678.

Ceccarelli, S. 1987. Wide adaptation: How wide? *Euphtica 40*: 197-205.

Chaves, M.M. 1991. Effects of water deficits on carbon assimilation. *Journal of Experimental Botany 42*: 1-16.

Donmez, E., R.G. Sears, J.P. Shroyer and G.M. Paulsen. 2001. Genetic gain in yield attributes of winter wheat in the Great Plains. *Crop Science 41*: 1412-1419.

Edaie, B. 1995. Variation in water-use efficiency and its components in wheat II: Pot and field experiments. *Crop Science 35*: 1617-1626.

Edhaie, B., J.G. Waines and A.E. Hall. 1988. Differential responses of landrace and improved spring wheat genotypes to stress environments. *Crop Science 28*: 838-842.

Edmeades, G.O., J. Bolanos and S.C. Chapman. 1996. Value of secondary traits in selecting for drought tolerance in tropical maize In: G.O. Edmeades, M. Banzinger, H.R. Mickelson and C.B. Pena-Valdivia (Eds). 1997. Developing drought and low N tolerant maize. Proceedings of a symposium, March 25-29, 1996, CIMMYT, El Batan, Mexico, D.F: CIMMYT.

El Hafid, R., D.H. Smith., M. Karrow and K.Samir. 1998. Physiological attributes associated with early season drought resistance in spring durum wheat. *Canadian Journal of Plant Science 78*: 227-237.

Gummuluru, S., S.L.A. Hobbs and S. Jana. 1989. Genotypic variability in physiological characters and its relationship to drought tolerance in durum wheat. *Canadian Journal of Plant Science 69:* 703-711.

Howell, T.A., J.A. Tolk., A.D. Schneider, S.R. Evett. 1998. Evapotranspiration, yield, and water use efficiency of corn hybrids differing in maturity. *Agronomy Journal 90*: 3-9.

ICRAF. 1988. International Centre for Agro-foresrty (ICRAF) Field Station, Machakos, Part 1I. General Account, ICARF, Nairobi, Kenya

Jaetzold, R. and H. Schimdt. 1983. Farm management Handbook of Kenya. Natural conditions and farm management information Vol. II/B. Central and Western Kenya. Government Printers, Nairobi.KARI, 1984. Kenya Agricultural Research Institute Annual Report. KARI, Nairobi, Kenya.

Johnson, R.C., D.W. Morhinwerg, D.M. Ferris and J.J. Heitholt. 1987. Leaf photosthesis and conductance of selected *Triticum* spp at different water potentials. *Plant Physiology 83*: 1014-1017.

Kimurto, P.K. M.G. Kinyua and J.M. Njoroge. 2003. Response of bread wheat genotypes to drought simulation under a mobile rain shelter in Kenya. *African Crop Science Journal 11*:16-25.

Kirigwi, F.M., M. van Ginkel., R. Trethowan., R.G. Sears., S. Rajaram and G.M. Paulsen. 2004. Evaluation of selection strategies for wheat adaptation across water regimes. *Euphytica 135*: 361-371.

Ludlow, M.M. and R.C. Muchow. 1990. A critical evaluation of trait for improving crop yields in water-limited environments. *Advances of Agronomy 43:* 106-153.

Mugo, S., M. Smith, M. Banzinger and T. Setter. 1998. Performance of early maturing Katumani and Kito composites under drought at the seedling stage and flowering stages. *African Crop Science Journal 6(4):* 329-344.

Ogola, J.B.O., T.R. Wheeler., P.M. Harris. 2001. Water use of maize in response to planting density and irrigation. *European Journal of Agronomy. In Press.*

Pfeiffer, W.H., R.M. Trethowan and T.S. Payne. 2000. CIMMYT's approach to address production constraints in marginal areas-Global Project 5. In: The 11th Regional wheat workshop for Eastern, Central and Southern Africa. Addis Ababa, Ethiopia, CIMMYT.

Reynolds, M.P., Balota, M., Delgado, M.I.B., Amani, I., Fischer, R.A. 1994. Physiological and morphological traits associated with spring wheat yield under hot, irrigated conditions. Austrl. J. Plant Physiol. 21:717-30.

Reynolds, M.P., S. Nagarajan, M.A. Razzque and O.A.A. Ageeb. 2001.Heat tolerance In. M.P. Reynolds, J.I. Ortiz-Monasterio and A. McNabs (eds.). Application of Physiology in wheat Breeding. Mexico, D.F.: CIMMYT.

Richards, R.A., A.G. Condon and G.J. Rebetzke. 2001. Traits to improve yield in dry environments. In. M.P. Reynolds, J.I. Ortiz-Monasterio and A. McNabs (Es.). Application of Physiology in wheat Breeding. Mexico, D.F.: CIMMYT.

Skovmand, B. and M.P. Reynolds. 2000. Increasing yield potential for marginal areas by exploring genetic resources collections. The 11th Regional wheat workshop for Eastern, Central and Southern Africa. Addis Ababa, Ethiopia, CIMMYT.

Richards, R.A., G.J. Rebetzke., A.G. Condon and A.F. van Herwaarden. 2002. Breeding opportunities for increasing the efficiency of water use and crop yield in temperate cereals. *Crop Science 42*: 111-121.

Siddique, K.H.M., D. Tennant., M.W. Perry and R.K. Belford. 1990. Water use and water use efficiency of old and modern wheat cultivars in a Mediterranean environment. *Australian Journal of Agricultural Research 41*: 432-447.

Sinclair, T.R., C.B. Tanner and J.M. Bennett. 1984. Water use efficiency in crop production. *Bioscience 34*: 40-60.

Turner, N.C. 2001. Optimizing water use. In: J. Nosberger., H.H. Geiger and P.C. Struik (eds.). Crop Science Congress Proceedings, Australia. CAB International.

Van Ginkel, M., D.S. Calhoun., G. Gebeyehu., A. Miranda., C. Tian-you., R. Pargas Lara., R.M. Trethowan., K Sayre., J. Crossa and S. Rajaram. 1998. Plant traits related to yield of wheat in early, late or continuous drought conditions. *Euphytica 100*: 109-121.

Van Rensberg, L and G.H.L. Kruger. 1993. Comparative analysis of differential drought stress-induced suppression of and recovery in carbon dioxide fixation, stomatal and non-stomatal limitation in *Nicotiana tabacum* L. *Journal of Plant Physiology 142*: 296-306.

Allelism of Resistance Genes to *Phaeosphaeria nodorum* in Wheat

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Abstract—Disease reaction of the F_1, F_2 and F_3 populations of crosses made between six winter wheat cultivars with resistance to *Phaeosphaeria nodorum* showed that they possessed a major gene for resistance in common. Cultivars EE 8, Hadden, 821WWMN 2019 and Atlas 66 may carry two genes for resistance to *P. nodorum*. The second resistance gene in EE 8 is non-allelic to the second resistance gene in 821WWMN 2019 or Hadden.

Observations made on F_2 plants derived from single crosses or crosses in various combinations revealed the presence of minor resistance genes or modifier genes in the resistant cultivars. None of the F_3 families derived from susceptible F_2 plants were susceptible. These findings suggest that host resistance to *P. nodorum* in wheat is controlled by both major and minor.

Introduction

Septoria nodorum blotch caused by *Phaeosphaeria nodorum* (Müller) Hedjaroude anamorph *Stagonospora nodorum* (Berk.) Castellani and Germano has become an increasingly important disease of wheat. Recommendations for disease control include crop rotation, fungicide sprays and the use of resistant cultivars.

The most economical way of controlling the disease under Saskatchewan conditions is the use of resistant cultivars. However, very little success has been achieved in breeding for resistance to *P. nodorum* due to lack of information concerning its inheritance.

Monogenic and polygenic control, and recessive, dominant, epistatic, pleiotropic and additive gene action have been reported in studies of seedling resistance to *P. nodorum* in wheat (Eyal *et al.*, 1987; Frecha, 1973; Kleijer *et al.*, 1977; Nelson and Gates, 1982; Wong and Hughes, 1989). Most studies have indicated that resistance to *P. nodorum* is under polygenic control (Nelson, 1980; Nelson and Gates, 1982), but monogenic control has been reported (Frecha, 1973; Kleijer *et al.*, 1977; Wong and Hughes, 1989).

Wong and Hughes (1989) found that genetic control of resistance to *L. nodorum* in three winter wheat cultivars 811WWMN 2095, Coker 76-35 and Red Chief was due to a single recessive gene. Similar gene action but with dominant effect was reported by Frecha (1973) in Atlas 66. Kleijer *et al.*, (1997) located the resistance gene in Atlas 66 on chromosome 1B. Ma (1993) showed that the resistance genes to *P. nodorum* are located on chromosomes 2A and 3A in the common wheat cv. EE 8 and on chromosome 3A in cv. Red Chief.

Genes for resistance that are at different loci can be combined through breeding for increased levels of resistance. The main objective of this study was to determine the independence of genes controlling resistance to *P. nodorum* among selected resistant winter wheat cultivars.

Materials and Methods

Plant Material

Wheat plants used in this study were grown in a 3:1:1(v/v) sterilized soil, vermiculite and peat mixture in 15cm diameter pots in a walk-in growth room with a 16-h photoperiod and

$22^0C/16^0C$ day/night temperatures. They were fertilized with 20:20:20 (N:P:K) water-soluble fertilizer at weekly intervals. Crosses were made among six *P. nodorum* resistant parents (Table 1). Except for cv. Atlas 66, previous studies had indicated monogenic or oligogenic control of seedling resistance in these cultivars (Wong and Hughes, 1989; Ma 1993). Some F_1 plants were selfed to produce F_2 plants, others were inoculated and rated for disease reaction. After being rated for disease reaction, 50 randomly selected F_2 plants of the Red Chief x 831WWMN 2051, EE 8 X 831WWMN 2051, Atlas 66 x 821WWMN 2019 and Hadden x Red Chief crosses were selfed to produce F_3 families. The parental, F_1 and F_2 generations of a cross and the susceptible cv. Kenyon were included in each test. Reciprocal F_1 plants of certain crosses were also tested. Testing of the F_3 families of the selected crosses was done subsequently.

Inoculum Preparation
A single pycnidiospore of *P. nodorum* isolate KVTN, obtained from field-infected leaf material at Kelvington, Saskatchewan was used in all experiments. The isolate was increased on solid V8 juice agar containing 15g agar, 1.5g calcium carbonate, and 150 ml of V8 juice and 850 ml of water. The cultures, incubated for 14 d under continuous fluorescent light grew as the anamorph (*S.nodorum*).

Pycnidiospores were collected in distilled water by gently rubbing with a toothbrush. The mixture was then blended in an Oster blender for 1 min. This process was repeated once. The pycnidiospore suspension was then filtered through four layers of cheese cloth. Inoculum concentration was determined by a hemacytometer and adjusted to 1.5-3.0 x 10^6 mL^{-1}. Two drops of the surfactant Tween 20 were added per 100 mL inoculum.

Inoculation
Test plants were inoculated two weeks after planting, when the second leaf had completely unfolded. The inoculum was applied to the leaves of test plants by a hand sprayer until near runoff. In each experiment, un-inoculated plants were included to monitor natural senescence and physiological leaf spotting. Where these occurred, the data was discarded.

The inoculated plants were left in a humidity chamber at 90-100 RH for 48 h, after which they were removed and placed on a growth room bench with a 16 h photoperiod and $22^oC/16^oC$ day/night temperature.

Disease Assessment
Inoculated plants were rated for disease reaction seven days after inoculation on a 0-9 scale in which 0= highly resistant and 9= highly susceptible (complete necrosis of the leaves). This type of rating took into consideration the size of lesions and the amount of chlorotic tissue (Wong and Hughes, 1989). In situations where disease categories overlapped,, it was necessary to group the reactions into three broad classes, resistant (ratings 0-3), moderately resistant (ratings 4-5) and susceptible (ratings 6-9) for easier interpretation of the data.

Results and Discussion

The F_1 plants of all the crosses had disease ratings within the parental range. Some crosses produced F_2 populations that had all plants rated within that parental range while others had slight or obvious deviations, but in every case, most of the plants fell within the parental range.

Based on the disease ratings of the F_2 populations of these crosses, three types of segregation were became apparent. The first type involved the EE 8 x Red Chief and Hadden x 821WWMN 2019 crosses (Table 2). In both crosses, the ratings of plants in the F_2 populations fell within the parental range. This suggested that parents involved in these crosses possess genes that are allelic. These results support Ma's (1993) finding of a resistance gene common to both EE 8 and red Chief. Three F_2 plants of the EE 8 and Red Chief cross-rated outside the parental range. However, these plants had a rating of 3, which is within the resistant range. Occasionally, a few Red Chief plants were rated 3.

Table 1. Cultivars used in studies of allelism of resistance genes to *Leptosphaeria nodorum* and their disease reaction.

Cultivar	**Disease reaction**
Red Chief	**Resistant**
EE 8	**Resistant**
821WWMN 2019	**Resistant**
Hadden	**Resistant**
Atlas 66	**Resistant**
831WWMN 2051	**Resistant**
Kenyon	**Susceptible**

Table 2. Distribution of disease ratings of parental, F_1 and F_2 populations of crosses involving EE 8, Red Chief, Hadden and 821WWMN 2019 and the susceptible control cv. Kenyon using lesion type rating[a] for resistance to *Leptosphaeria nodorum* tested at second leaf stage under controlled environmental conditions.

Lesion Type Frequency [a]													
	0	1	2	3	4	5	6	7	8	9	Total plants	Mean	SD
EE8 X Red Chief													
EE8	17	15	16								48	0.97	0.83
F_1	2	3									5	0.60	0.54
F_2	20	23	29	3							75	1.20	0.88
Red Chief	38	5	7								50	0.38	0.72
RC(F_1)	2	2					1	1	3	3	4	0.50	0.52
Kenyon											8	0.80	1.06
Hadden X 821WWMN2019													
Hadden	3	6	23								32	1.62	0.65
F_1		15									15	2.00	0.00
F_2	8	42	66								116	1.50	0.62
821WWMN2019				9	19	2		2	19	12	30	1.76	0.56
Kenyon											33	8.30	0.58

[a] Rated on a 0-9 scale

The second type of segregation was observed in the F_2 populations of the Atlas 66 x Red Chief and Red Chief x 821WWMN 2019 crosses (Table 3). Most of the F_2 plants of these crosses had disease ratings within the parental range suggesting allelism between the Atlas 66 and Red Chief, and between Red Chief and 821WWMN 2019 resistance genes. A small proportion of moderately resistant or susceptible plants occurred in the F_2 populations of these crosses. However, the susceptible plants observed were never as susceptible as the susceptible control Kenyon and thus were not considered to represent susceptible genotypes. The observed deviations could have been caused by misclassification or environmental variability within the experiment resulting from e.g. non-uniform inoculation of the plants.

The third type of segregation involved F_2 plants of the Atlas 66 x 821WWMN 2019, Hadden x Red Chief and Red Chief x 831WWMN 2051 and EE 8 x 831WWMN 2051 crosses (Table 4 and 5). While most of the F_2 plants of these crosses had disease ratings within the parental range, the proportion of plants which had disease ratings outside the parental range was large enough for both allelism and modifier gene effects to be suggested. The distribution of plants outside the parental range was continuous and the susceptible plants in these populations were not as susceptible as Kenyon. The presence of modifier genes influencing the expression of resistance to S. *nodorum* has been reported by other workers (Laubscher *et al*., 1966; Kleijer *et al*., 1977; Ma, 1993).

Table 3. Distribution of disease ratings of parental, F_1 and F_2 populations of crosses involving Atlas 66, Red Chief and 821WWMN 2019 and susceptible control cv. Kenyon using lesion type rating for resistance to *L. nodorum* tested at second leaf stage under controlled environmental conditions

Lesion Type Frequency [a]													
	0	1	2	3	4	5	6	7	8	9	Total plants	Mean	SD
Atlas66 X Red Chief													
Atlas 66	7	14	2								23	1.78	0.59
F_1	3	6									9	0.66	0.50
F_2	5	19	32	43	4	4					107	2.32	1.07
Red Chief	12	6	6	3							27	1.00	1.07
Kenyon							2	7	15		24	8.54	0.65
Red Chief X 821WWMN2019													
Red Chief	10	4	5	4							23	1.13	1.17
F_1	2	7	2								11	1.00	0.63
F_2	22	11	22	42	2	2	1				102	1.96	1.28
821WWMN2019	1	8	9	2	1						21	1.71	0.90
Kenyon							2	7	15		24	8.54	0.65

[a] Rated on a 0-9 scale

Table 4. Distribution of disease ratings of parental, F_1 and F_2 populations of crosses involving Atlas 66, 821WWMN 2019, Hadden and Red Chief and the susceptible control cv. Kenyon using lesion type rating[a] for resistance to *L. nodorum* tested at second leaf stage under controlled environmental conditions.

Lesion Type Frequency [a]													
	0	1	2	3	4	5	6	7	8	9	Total plants	Mean	SD
Atlas66 X 821WWMN2019													
Atlas 66	7	14	2								23	0.78	
F_1	2	13									15	0.86	0.35
F_2	2	16	21	39	12	3	7				100	2.80	1.37
F_3	260	276	181	57	3	7	3	4			791	1.14	1.13
821WWMN2091	1	8	9	2	1			2	7	15	24	8.54	0.66
Kenyon													
Hadden X Red Chief													
Hadden	3	5	15	1							24	1.58	0.77
F_1	5	6	4								15	0.93	0.78
F_2	11	36	23	13	12	3	1	1			100	2.07	1.41
F_3	110	219	29	67	17	2	5	3			452	1.34	1.30
Red Chief	10	7	1	4							22	0.95	1.13
Kenyon								2	7	15	24	8.54	0.65

[a] Rated on a 0-9 scale

Table 5. Distribution of disease ratings of parental, F_1 and F_2 populations of crosses involving Red Chief, 831WWMN 2051 and EE 8, and the susceptible control cv. Kenyon using lesion type rating[a] for resistance to *L. nodorum* tested at second leaf stage under controlled environmental conditions.

Lesion Type Frequency [a]

	0	1	2	3	4	5	6	7	8	9	Total plants	Mean	SD
						Red Chief X 821WWMN2051							
Red Chief	22	4	4	1							22	1.66	0.70
F_{1b}			3								3	2.00	0.00
F_{2b}	12	2	36	12	6	4	4	2			78	2.46	1.68
F_3	93	236	279	73	15	29	19	9	2	0	755	1.86	1.45
821WWMN2091	6	10	14	7							37	1.59	0.98
RC (F_1)	7	4									11	1.36	0.58
Kenyon							3	15	14		32	8.34	0.65
						EE8 X 821WWMN2051							
EE8	15	15	4								34	0.67	0.68
F_{1b}			4								4	2.00	0.00
F2	9	3	60	9	10		4	2			97	2.30	1.40
F_{3b}	82	59	155	43	14	8	10	1			372	1.77	1.39
821WWMN2091	6	10	14	7							37	1.59	0.98
RC (F_1)	5	7	2								14	0.78	0.69
Kenyon								2	7	15	24	8.54	0.65

[a] Rated on a 0-9 scale. $_{b=}$Reciprocal cross progeny not included, RC= Reciprocal cross

F_2 plants with disease ratings outside the parental range did not occur in the EE 8 x Red Chief cross (Table 2), but were observed in the Red Chief x 831WWMN 2051 and EE 8 x 8311WWMN 2051 crosses (Table 5). However, even where such plants were observed, the ratings of the most F_2 plants were within the parental range. This suggested that EE 8, Red Chief and 831WWMN 2051 have a common resistance gene. Allelism of one resistance gene in these parents is further supported by the fact that the F1 disease ratings were within the parental range. In the Atlas 66 x 821WWMN 2019, Atlas 66 x Red Chief and Red Chief x 821WWMN 2019 crosses (Table 3 and 4) most of the F_2 plants were rated within parental range. However, there were more plants in the F_2 population of the Atlas 66 x 821WWMN 2019 that deviated from parental range than in the other crosses. This suggested the presence of modifying genes or other undetected resistance genes. There is a possibility that Atlas 66 also possesses other resistance gene(s) apart from the one reported by other workers (Frecha, 1973; Kleijer *et al*., 1977). Data from the Atlas 66 x Red Chief cross (Table 3) suggested that Atlas 66 possessed the Red Chief resistance gene which is located on chromosome 3A. The allelic relationship that was proved in this study, plus the fact that cultivars EE 8 and Red Chief each has a resistant gene located on chromosome 3A (Ma, 1993) suggests that the allelic gene in all the resistant cultivars is also located on chromosome 3A. Allelism has been implicated in other host-pathogen systems when resistant parents produced F_2 populations that did not segregate (Zink and Gubler, 1986; Hibberd *et al*., 1987; Sigh and McIntosh, 1988; Potts, 1990; Sykes and Bernier, 1991).

The F_3 generation of those crosses in which susceptible F_2 plants had occurred were tested. Although susceptible F_3 plants were observed (Table 6), none of the F3 families were susceptible (Table 7). These observations support the conclusions made from the F_1 and F_2

data that the resistance genes in the parents are allelic. If there was no allelism, susceptible F_3 families would have occurred.

Table 6. Distribution of disease ratings of parental, F_3 populations of crosses involving EE 8, 831WWMN 2051, Red Chief, Atlas 66, 821WWMN 2019, Hadden and Red Chief, and susceptible cv. Kenyon using lesion type rating[a] for a resistance to *L. nodorum* tested at the second leaf stage under controlled environmental conditions.

Lesion Type Frequency [a]													
	0	1	2	3	4	5	6	7	8	9	Total plants	Mean	SD
EE8 X 831WWMN2051													
F_3	82	59	155	43	14	8	10	1			372	1.77	1.39
831WWMN2051	1	0	6	2							9	2.00	0.86
EE8	6	2	1								9	0.44	0.72
Kenyon							2	7			9	7.77	0.44
Red Chief X 831WWMN2051													
F_3	93	236	279	73	15	29	19	9	2		755	1.86	1.45
Red Chief	4	6	1								11	0.72	0.64
831WWMN2051		7	7	1							15	1.60	0.63
Kenyon								3	5	9	17	8.30	0.78
Atlas 66 X 821WWMN2019													
F_3	260	276	181	57	3	7	3	4			791	1.14	1.13
Atlas 66	8	6	2								16	0.62	0.71
821WWMN2019	2	10	4	2							18	1.33	0.84
Kenyon								5	3	9	17	8.23	0.90
Hadden X Red Chief													
F_3	110	219	29	67	17	2	5	3			452	1.34	1.30
Hadden		5	6	1	3						15	2.13	1.12
Red Chief	3	12	4								19	1.05	0.62
Kenyon							2	4	8		14	8.42	0.75

[a] Rated on a 0-9 scale

Table 7. F3 family segregation for resistance[a] to *L. nodorum* in seedling tests of four crosses.

Cross Total	homozygous resistant	Segregation	Susceptible	Families
Red Chief x 831WWMN 2051	25	23	0	48
EE 8 x 831WWMN 2051	20	19	0	39
Atlas 66 x 831WWMN 2051	43	8		51
Hadden x Red Chief	28	17	0	45

[a] 0-3=Resistant; 4-5=Moderately resistant; s= Susceptible
esion Type Frequence [a]

One explanation for these observations is to hypothesize that all the parents have a common resistance gene. This hypothesis is supported by the fact that the various cross combinations of these parents produced F_1 plants with disease ratings within the parental range. Most or all of the F_2 generations of these crosses had plants rated within the parental range. Furthermore, no segregation was observed in the F_3 families (Table 7).

The occurrence of plants that rated outside the parental range in the F_2 population of the Hadden x Red Chief cross but not of the Hadden x 821WWMN 2019 cross suggested the presence of a second resistance gene in Hadden and 821WWMN 2019. A second resistance gene is suggested because the disease ratings of all F_2 plants of the Hadden x 821WWMN 2019 cross fell within the parental range (Table 2) and, except for three plants, the same was observed for the Red Chief x 821WWMN 2019 cross (Table 3). This gene(s) may be different from that in EE 8 because deviations from parental range were observed in the F_2 population of the Hadden x Red Chief cross (Table 4), but not in the EE 8 x Red Chief or Hadden x 821WWMN 2019 crosses (Table 2).

The implication of these results is that although it appears that there is a common resistance gene in all the resistant cultivars used in this study, other resistance genes may be present in certain cultivars. The existence of different genes for resistance provides the opportunity to combine resistance genes from different sources to enhance the level of resistance to septoria nodorum blotch in a breeding program.

References

Eyal, Z., Scharen, A.L., Prescott, J.M., and van Ginkel, M. 1987. The septoria diseases of wheat: Concepts and methods of disease management. CIMMYT, Mexico. 46pp.

Frecha, J.H., 1973. The inheritance of resistance to *Septoria nodorum* in wheat. Bol. Genet. Fitotec. Castelar 8: 29-30

Hibberd, A.M., Bassett, M.J., and Stall, R.E 1987. Allelism tests of three dominant genes for hypersensitive resistance to bacterial spot of pepper. Phytopathology 77:1304-1307

Kleijer, G., Bronnimann, A., and Fossati, A 1977. Chromosomal location of a dominant gene for resistance at the seedling stage to *Septoria nodorum* Berk. In the wheat variety ‘Atlas 66’. Z. Pflanzenzuichtg 78:170-173.

Laubscher, F.X., von Wechmar, B., and van Schalkwyk, D. 1966. Heritable resistance of wheat varieties for glume blotch (Septoria nodorum Berk.). Phytopathol. Z. 56:260-264.

Ma, H. 1993. Genetic and cytogenetic studies of resistance to *Septoria nodorum* in tetraploid and hexaploid wheat. Ph.D thesis. University of Saskatchewan, Saskatoon.

Nelson, L.R. 1980. Inheritance of resistance to *Septoria nodorum* in wheat. Crop Sci. 20:447-449.

Nelson, L.R., and Gates, C.E. 1982. Genetics of host plant resistance of wheat to *Septoria nodorum*. Crop. Sci. 27:771-773.

Potts, D.A. 1990. Expression and genetics of resistance to *Septoria tritici* in wheat. PhD Thesis. University of Saskatchewan, Saskatoon.

Primard, S.J., Morris, R., and Papa, C.M. 1991. Cytogenetic studies on a heterozygous reciprocal translocation in the wheat (*Triticum aestivum*) cultivar Atlas 66. Genome 34:313-316.

Singh, S.J., and McIntosh, R.A 1988. Allelism of two genes for stem rust resistance in triticale. Euphytica 38:185-189.

Sykes, E.E., and Bernier, C.C. 1991. Qualitative inheritance of tan spot resistance in hexaploid, tetraploid and diploid wheat. Can. J. plant Pathol. 13:38-44.

Wong, L.S.L. and Hughes, G.R. 1989. Genetic control of seedling resistance to *Leptosphaeria nodorum* in wheat. Pp 136-138, in:Fried, M.P., ed. Septoria of cereals. Proc. Workshop, July 4-7, 1989, Zurich, Switz. 189pp.

Zink, F.W., and Gubler, W.D. 1986. Inheritance of resistance to races 0 and 2 of Fusarium oxysporum f. sp melonis in gynoecious muskmelon. Plant Disease 70:676-678.

Evaluation of Kenyan Breadwheat (*Triticum aetivum* L.) Varieties for Resistance to Russian Wheat Aphid in Multi-location Trials

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Abstract—Russian wheat aphid (RWA, Diuraphis noxia: Kurdjumov) is a serious pest of wheat (Triticum aestivum L.) worldwide. The purpose of this investigation was to evaluate commercial bread wheat cultivars in different environments in Kenya to identify RWA resistance. Seven wheat cultivars (Pasa, Mbuni, Kenya Heroe, Kenya Fahari, Chozi, Duma and Kwale) were planted at five locations over two years in Kenya in a split plot RCBD experimental design. The main plot consisted of insecticide treatment at two levels (untreated and insecticide treated). The subplot was the varieties. Results showed significant ($P<0.05$) genotypic differences across location. Effects due to insecticide year × location, and genotype × year × location interaction were significant ($P< 0.05\%$) for thousand-kernel weight and grain weight. Positive correlation was observed between plant height and yield ($r = 0.935$ **), and thousand-kernel weight and yield ($r = 0.876$**). Significant negative correlations were recorded between RWA damage and plant height ($r = -0.662$**); and yield (-0.785**); and kernel weight -0.667**). No significant association was observed for percentage plant height reduction and RWA damage. The first two principal components accounted for 83% of the variability. The study shows that K. Fahari, which has been previously reported to be resistant to green bug may have some resistance to RWA.

Introduction

Russian wheat aphid (RWA), *Diuraphis noxia* (Kurdjumov), is a major pest of small grained cereals in the world (Liu *et al*., 2001). RWA is endemic to Eastern Europe, and has been invading other regions of the world after being identified in South Africa in 1978, (Walters, 1984; Marassas *et al*., 1995). It rapidly spread to Central, North and South America, and most parts of Europe. In Africa, it has maintained minor status in Egypt, Sudan and Ethiopia (Miller and Pike, 2002) but flared up in Kenya in 1995 where it remains the most important cereal pest of wheat and barley (Anon., 2002).

The pest is difficult to detect until symptoms occur on the plant. RWA may cause yield losses of up to 90% (Du Toit and Walters, 1984: Hewit, 1988), and in Kenya most wheat varieties appear to be susceptible. Farmers, even with the use of insecticide application, have reported high yield losses of upto 40% (Kinyua *et al*., 2002). Despite this, information on performance of wheat varieties infested by RWA is lacking. Preliminary greenhouse studies indicate that all Kenyan varieties are susceptible to RWA (Malinga *et al*., 2001). Despite the susceptibility of wheat varieties to RWA, it may be possible to identify low levels of RWA resistance that can be useful to farmers as they await the development of RWA resistant varieties.

Varieties previously thought to be susceptible have been found elsewhere to have low resistance (Hein, 1992; Smith *et al*., 1991). Low resistance also called tolerance has been defined as qualities that show less damage than the average crop (Thomas and Waage 1996; Butts and Pakendorf, 1984; Painter, 1951). Tolerance is identified on the ability of the crop to recover despite pest attack (Thomas and Waage, 1996).

Yield reduction is one of the measures that may indicate tolerance (Painter, 1951). However, although yield is highly correlated with tolerance it should be carefully treated, as it is the output of many other factors. Quantifying degree of yield reduction attributed to RWA in crop loss assessment studies is useful measures to aid identify varieties with resistance or tolerance to RWA. The quantification RWA damage on wheat varieties, across locations, would therefore be useful in the latter management of the pest. The objective of this study was to quantify reactions due to RWA infestation on selected varieties and identify those with low levels of RWA resistance.

Materials and Methods

Site descriptions

The experiment was conducted at five sits described below.

Njoro, Kenya (0 20'S; 35 56'E; 2166m above sea level (asl)) is located in the lower highlands with a mean annual rainfall of 936 mm (Kinyanjui, 1979) and temperatures of 7.9 ^{o}C to 21.9^{o} C and a mean of 14.9^{o}C. The soils are fertile *vitric mollic Andosols* that are well drained, deep to very deep, dark reddish brown in colour, consisting of heavy textured friable silty clay to clay humic top soils (Jaetzold and Schmidt, 1983a). These are well drained, deep to very deep dark reddish brown friable and silt clay to clay soils with humic topsoil.

Timau, Kenya (0 05'S; 37 20'E; 2640m asl) is located in the upper highlands in the pyrethrum-wheat zone. The site receives annual rainfall of 1170 mm with temperatures ranging from 7.5 to 18.36^{o} C. Absolute minimum temperatures of 0-2^{o} C are recorded. The soils are *chromi*c and *ferric Luvisols* with *Lithosols*. These soils are well-drained deep, dark reddish brown and red friable sandy clay, which are shallow to deep.

Eldoret, Kenya site was located at Chepkoilel Campus, Moi University (0 N; 35 W; 2133 m asl) with mean annual rainfall of 885 mm and maximum and minimum temperatures of 23.5 and 9.5 respectively.

Naivasha, Kenya is about 70 km from Nairobi, in Nakuru province, at an altitude of around 1800 m asl, with a warm and dry climate. and daytime temperatures are up to 30°C, with rainfall of 500-700mm per annum.

Katumani, Kenya (1 35’S; 37 14’E; 1575m asl) is located in the upper midland zones. The site receives 700mm of rainfall annually with mean temperatures of 19.3^{o} C. The soils are well drained, deep, dark reddish brown, friable sand clay, classified as *ferral chromic Luvisols* (Jaetzold and Schmidt, 1983b; FURP, 1988).

Rearing RWA aphid cultures

A total of three different colonies of RWA aphids were established one each from three key wheat-producing areas of Kenya (Njoro, Timau and Eldoret). Aphids collected from the specified locations were multiplied into colonies. Viviparous female RWA aphids were placed on clean and non-infested plant raised under aphid free conditions in the greenhouse. The females were caged inside low cost plexi cage (50cm x 55 cm x 48cm). The aphids were multiplied on wheat seedlings of the variety Mbega under greenhouse conditions. The aphids were harvested after one month of caging using a paintbrush into Petri dishes dusted with talcum powder. Aphids were used to infest test varieties in regions were there were collected.

Experimental design and field layout

The trial was planted in a randomized complete block in split plot arrangement replicated three times. Two factors were investigated: insecticide treatment (insecticide treated vs. un-treated) as main plots and seven wheat genotypes as sub plots. The genotypes tested were Kenya Fahari, Duma, Chozi, Kenya Heroe, Kwale, Pasa, and Mbuni (Table 1). The main plots (24m long x 3m wide) separated by 0.5 m alley were randomly allocated to insecticide treatment. Variety was allocated to the sub-plots measuring 3m x 1m and separated by 0.5m paths. Each subplot had 4 rows spaced 20 cm apart. Genotypes were manually drilled in hill plots spaced at 20cm seed rate of 125kg/ha and di-ammonium phosphate (DAP) 18: 46:0 (NPK) fertilizer applied at the rate of 60 kg/ha in them prior to planting of the seed. Hand weeding was carried out when plants reached growth stage 16 (Zadok *et al*., 1974). Foliar diseases were controlled at Njoro and Eldoret where the crop succumbed to rust infection by spraying with one fungicide spray.

Table 1: Wheat varieties, released in Kenya, used in this study.

Variety	Released by	Pedigree
Chozi	NPBRC	F12.7/COC//GEN
Duma	NPBRC	AU/VP/301//GLL/SX/3/PEW'/4/MAYA/PEW
Fahari	NPBRC	Tob66/SRPC527/CI8155/2*Fr
K. Heroe	NPBRC	Mbuni/SRPC64/YRPC1
Kwale	NPBRC	KINGLET
Mbuni	NPBRC	ZA75/LD357E-Tc^{3}xGU, CM30520-1B-1B-3Y-0Y
Pasa	NPBRC	FINK

Infestation procedure

At the two to three leaf stage (Zadok's 12-14) the test plots were infested with greenhouse reared aphids and aphids picked from surrounding crop using a paint brush. The purpose was to ensure infestation. Approximately three to five aphids were placed on plants at 30 cm intervals. The aphids were allowed to multiply freely. Un-infested plots were protected at planting with seed application of Gaucho 350 FS (200ml/100kg seed) and subsequent monthly application of metasystox (0.5 l/ha) for 2 months. Although insecticide treatments would be used to control other insects as well, RWA was by far the predominant insect pest species present. The crop was not caged.

Parameters measured

The following parameters were measured during the growth period of the crop:

Plant height was taken at tillering, jointing and maturity to determine the number of plants stunted due to RWA damage.

Damage rating scores were taken at tillering and jointing from 5 randomly selected plants in each plot to determine the degree of RWA damage. A visual 1-6 scale (1=resistant to 6=very susceptible) using a nondestructive method was used.

Number of infested plants per m^2 per plot was recorded on naturally infested plots at harvest.

Type of natural enemies and observed predators on 5 random plants was observed at tillering and jointing to determine the number of predators reducing aphid numbers.

Number of parasitized (mummies) and diseased (cadavers) per five random plants sampled at Zadok's 12 (8 DAE), tillering 26 (29 DAE), to harvest was measured.

Number of spikes per plant at harvest, with average taken from 3 plants in 3 replicates. Total grain weight was determined in 3 replicates by harvesting the entire plot.

Thousand Kernel weight (TKW) at harvest was determined by taking the weight of 1000 seeds.

Reductions in grain yield, spike number, tiller number and 1000-kernel weight were calculated using the formula $XR=(1-X^i/X^u)\ 100$ where X is the component of yield in question, X^i is the value of X in infested plots and X^u is the value in un-infested plots (Calhoun *et al*., 1991).

Field temperatures, humidity, and rainfall were collected over the test period.

Data collection and analysis

Data was collected on using a quadrant (0.5m X 0.5m) taken from the two middle rows at three stages (tillering, booting and harvesting) for RWA damage, plant height, tiller number, and spike length. However, all rows constituted the harvest plot from which both thousand kernel weight and grain yield were derived. Data was analyzed using SAS package and means separated using Duncan mean range test. Correlations were also carried out to determine significant associations.

Results and Discussion

Across location and year analysis

The analysis of insecticide treatment and genotypic variation within and across locations and years is shown in Table 2. Highly significant differences were found on all traits between years except on tiller number. Significant differences were reported on locations and location x year interaction on all traits. Significant Insecticide treatment x year, Insecticide treatment x location interaction and Insecticide x year x location was recorded on RWA damage, thousand kernel weight and grain yield.

Environment means for RWA damage, plant height, tiller number thousand kernel weight and grain yield over locations over two years are presented in Tables 3 and 4. There were highly significant ($P<0.05$) differences among insecticide treatment and genotypes at all locations in both years for all traits except tiller number. Thousand kernel weights and yields were reported in insecticide treated plots with significantly ($P<0.05$) lower damage. When the means over two years were considered, RWA damage reduced yields by 41% in untreated plots than in control plots. Thousand kernel weights recorded 11% reduction.

Table 2: Combined mean squares for Russian wheat aphid damage, agronomic traits and yield for seven bread wheat commercial varieties at five locations, 2002 and 2003.

Source of variation	df	RWA damage (score 1-6)	Plant height	Tiller number	Thousand kernel weight	Yield
Years (Y)	1	2.6**	20847.8***	0.003ns	1260.1***	12.3***
Locations (L)	4	18.9***	14031.6***	35.7***	2186.2***	59.1***
LxY	4	6.5***	3655.7***	107.3***	820.6***	22.6***
Rep(LxY)	20	0.8ns	115.2ns	3.3ns	15.3ns	0.2ns
Factor A	1	226.2***	2033.2**	7.0ns	1529.6***	39.3***
YxA	1	9.7***	205.9ns	0.4ns	269.6***	4.6***
LxA	4	5.4***	216.6ns	1.9ns	34.1*	2.5***
YxLxA	4	3.1***	132.5ns	4.5ns	84.4***	1.5***
Error	8	6.1	195.3	2.6	11.0	0.2

Factor B	6	4.3***	6037.8***	3.2ns	467.2***	3.4***
YxB	6	0.9*	65.4ns	5.3ns	13.1*	0.2ns
LxB	24	0.9***	130.4***	2.9ns	86.0***	0.9***
YxLxB	24	0.4ns	121.6***	1.5ns	30.0***	0.6***
AxB	6	1.0**	12.8ns	1.6ns	4.8ns	0.1ns
YxAxB	6	0.7ns	27.2ns	0.9ns	1.8ns	0.2ns
LxAxB	24	1.0***	49.6ns	2.0ns	5.2ns	0.1ns
YxLxAxB	24	0.5ns	73.9ns	1.3ns	8.1ns	0..2ns
Error	240	0.3	48.5	1.8	5.2	0.2
Total	419	586.7	158960.5	1393.5	23403.7	508.7

Genotypic means over locations and years showed that one variety, K. Fahari significantly (P<0.05) out-yielded all others, and significantly (P<0.05) recorded the highest thousand kernel weight, tallest plant height. However, significantly lower RWA damage (2.3) was found on K. Fahari. RWA damage on Duma and Chozi (2.5) did not differ from that on K. Fahari. Both Duma and Chozi are varieties bred for dry areas. Significantly low RWA damage indicates low resistance to RWA. K. Kwale was significantly (P<0.05) the most susceptible to RWA and had the most the shortest plant heights, thousand kernel weights and yields.

Table 3. Mean response and percentage loss for agronomic traits on seven wheat cultivars infested with Russian wheat aphid, at five locations, 2002 and 2003.

	Damage	Plant Height	% Red.	Tiller no	% Red.	TKW	% Red.	Yield	% Red.
Chozi	3.2d	92.8b	5	6.5	10	36.0b	12	1.7b	35
Duma	2.9e	84.9cd	4	5.8	2	34.5c	9	1.8b	39
Fahari	2.9e	103.2a	4	6.2	5	37.6a	10	2.1a	29
Heroe	3.5bc	87.2c	5	6.1	0	31.2e	13	1.6bc	31
Kwale	3.9a	77.0e	7	6.5	9	32.8d	14	1.4c	43
Mbuni	3.3cd	82.7d	4	5.9	5	32.9d	11	1.6bc	37
Pasa	3.6b	72.8f	4	5.5	-2	30.0f	13	1.4c	43
Se (0.05)	0.1	1.2		ns		0.4		0.1	
CV	21.9	8.3		22.9		7.2		28.2	
Combined over sites	***	***		***		***		***	
Combined over years	**	***		ns		***		***	

Table 4. Means of Russian wheat aphid damage, yield and yield parameters at each of the 5 locations in Kenya, 2002 and 2003.

	RWA damage	Plant height	Tiller no	Thousand Kernel weight	Yield
Eldoret	2.7c	86.1b	5.3ab	31.0c	1.0c
Njoro	1.9e	86.5b	6.9c	27.8d	0.7d
Timau	3.0b	92.5a	6.2ab	37.6a	2.3a
Naivasha	2.5d	91.9a	5.5b	36.3b	2.1b
Katumani	3.1a	61.1c	5.7a	26.0e	0.5e
Mean	2.6	83.6	5.9	31.7	1.3
Se (0.05)	0.1	1.5	0.2	0.4	0.1
CV%	21.9	8.3	22.9	7.2	28.3

Significant at P≤0.05

Table 5. Pearson's correlation coefficient matrix

	Damage	% Dam. Red.	Plant ht.	% Plant ht. Red.	Tiller no.	% Tiller Red.	TKW	% TKW Red.	Yield	% Yield Red.
Damage	1.00	0.50	-0.73	0.71	0.13	0.02	-0.72	0.90*	-0.89*	0.57
% dam Red.		1.00	-0.57	0.37	-0.10	-0.26	-0.66	0.27	-0.61	0.28
Plant ht.			1.00	-0.26	0.43	0.32	0.85	-0.479	0.94-	-0.89*
% Plant Ht Red.				1.00	0.71	0.55	-0.13	0.70	-0.46.	0.31
Tiller no.					1.00	0.87*	0.52	0.33	0.21	-0.29
% Tiller no. Red.						1.00	0.60	0.15	0.20	-0.04
TKW							1.00	-0.54	0.89*	-0.54
% TKW Red.								1.00	-0.73	0.33
Yield									1.00	-0.76
% Yield Red.										1.00

* Significant at 5%

Correlation between parameters

Pearson's correlation coefficients across two seasons for RWA damage, plant height, tiller number, thousand kernel weight and yield are presented in Table 5. There were highly significantly strong and positive associations were recorded over the two years between damage and percent TKW reduction (r=0.90) ; and, damage and yield (r=-0.89). In addition significantly strong and positive associations were also recorded between plant height and kernel weight (pooled r=0.85, P<0.001); plant height and yield (pooled r= (0.94, P<0.001) and plant height and percentage yield reduction. Thus, taller plants had heavier kernels and higher yields. Subsequently a significant strong and positive association was recorded between percentage TKW reduction and yield (pooled r=0.89, P<0.001). However there was no significant association recorded between percentage plant height reduction and damage.

Conclusion

In this study, K. Fahari and Duma suffered the lowest RWA damages. In addition, K. Fahari a tall wheat variety sustained better yields when infested with RWA. Perhaps the ability to recover through rapid and extended stem growth period enables the plants of this variety to compensate for the attack borne on its growing shoot.

Environment has a bearing on degree of RWA damage and final yields received in the field. This is seen from high yield losses due to RWA found in drier areas Katumani and Naivasha where particularly high RWA damage was recorded. This is important considering the fact that the future of wheat expansion in Kenya lies within the marginal lands. The higher yield losses in marginal areas were somewhat expected. Higher temperatures lead to shorter lifecycles for RWA and under extremely high temperatures paedogenesis (nymphs giving birth to young) occurs (Wanjama, 1986). The implications are that taking wheat to dry land regions must be accompanied by a package and development of resistant and adapted varieties must be a cornerstone.

Acknowledgments-This work is part of PhD study at Egerton University. The funds used were from The World Bank through Kenya Agricultural Research Institute (KARI).

References

Du Toit, F. 1989. Inheritance of resistance in two *Triticum aestivum* lines to Russian wheat aphid (Homoptera; Aphididae). J. Econ. Entomol. 82: 1251-1253

Du Toit. 1988. Another source of Russian wheat aphid (Diuraphis noxia) resistance in *Triticum aestivum*. Cereal Res. Commun. 16:105-106.

Ehdaie B and C. A. Baker. 1999. Inheritance and allelism for resistance to Russian wheat aphid in an Iranian spring wheat. *Euphytica* 107: 71-78.

Elsidaig A. and P.K. Zwer. 1993. Genes for resistance to Russian wheat aphid in PI 294994 wheat. *Crop Sc.* 33: 998-1001.

Gomez K.A. and A.A. Gomez. 1984. *Statistical procedure for Agricultural research.* John Wiley and Sons. Inc.

Jaetzold R and Schmidt 1983. *Farm Management handbook of Kenya*. Ministry of Agriculture. Kenya. Central Kenya (Rift Valley and Central Province). Vol II /B

Liu X.M., Smith C. M., Gill B. S. and Tolmay V. 2001. Micro satellite markers linked to six Russian wheat aphid resistance genes in wheat. *Theor. Appl. Genet.* 102: 504-510

Malinga J. N., M. Kinyua, L. Karanja L and E. Alomba. 2001. Multi-locational evaluation of wheat lines for resistance to cereal aphids with particular reference to Russian wheat aphid. *In Proceedings of the first Annual Conference of National Plant Breeding Research Centre, Njoro. 26th-30th November 2001:* 44-47

Marais G.F. and F. Du Toit. 1993. A monosomic analysis of Russian wheat aphid resistance in the common wheat PI 294994. *Plant Breed*. 111:246-248.

Marasas C.; Anandajayasekeram, P.; Tolmay V.: Martella, D; Purchase J.; Prinsloo, G: 1997. *Socioeconomic impact of the Russian wheat aphid control Research Program.* SACCAR. Gaberone, Botswana.147 p.

Miller, C. A., A. ALtinkut and N.L.V.Lapitan. 2001. A micro satellite marker for Tagging *Dn,* a wheat gene conferring resistance to the Russian wheat aphid*. Crop Sci*. 41:1584-1589.

Meyer W. L., K.K Nkongolo., F. B Peairs. and J. S. Quick 1989. Mechanism of resistance in the wheat line PI 37129 to the Russian wheat aphid. In: D. Baker (ed) *Proceedings of the 3rd Russian wheat aphid conference. Albuquerque, New Mexico. 25-27 Oct. 1989*. : 23-24

Nkongolo K.K., J.S. Quick and F.B. Peairs and W. L. Meyer. 1991. Inheritance of P1 372129 wheat to Russian wheat aphid. *Crop Sc*i. 31: 689-692.

Robinson J. 1994. Identification and characterization of Resistance to the Russian wheat aphid in small grain cereals: Investigations at CIMMYT, 1990-1992. *CIMMYT Research Report No 3* Mexico D. F. CIMMYT. 44p

Tolmay V., van Deventer C. S. and van der Westhuizen M. C. 1999. Inheritance to resistance to Russian wheat aphid (Diuraphis noxia (Homoptera: aphididae) in two wheat lines, In: *Proceedings of the tenth regional wheat workshop for Eastern, Central and Southern Africa. Pretoria University, South Africa* 13-17, January 1997: 408-417.

Walters, M.C.1984. Progress in Russian wheat aphid (*Diuraphis noxia* Mord.) research in the Republic of South Africa. Proceedings of a meeting of the Russian Aphid Task Team held at the University of the Orange free State. Bloemfontein 5-6 May 1982. (ed) M.C. Walters. Technical Communication No 191. department of agriculture, republic of South Africa.

Zadok J.C. , Chang T.T. and Konzak C. F. 1974. A decimal code for growth stages of cereals *Weed Sci*. 14: 415-421

On-Farm Evaluation and Comparison of New and Old Wheat Varieties

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Abstract—Progress in new wheat variety development is measured by how much the new wheat varieties excel old varieties in terms of disease resistance, yield, consumer preference and other desirable agronomic traits. In 2002 eight old wheat varieties were evaluated and compared with 22 new advanced wheat lines on farmers' fields in different agro-ecological zones in Morogoro, Iringa, Arusha and Kilimanjaro wheat growing regions of Tanzania. Data on reaction to diseases, grain yield and farmers' variety preference was obtained from various sites. Most of the old wheat varieties were susceptible to stem, leaf and yellow rust, while many new wheat varieties were resistant to most prevailing wheat diseases. Combined analysis across locations indicated that mean grain yields ranged from 1.0 t/ha to 1.87 t/ha with five new wheat varieties having the highest mean grain yields. During field days at various sites, farmers selected seven new wheat varieties and only one of the old wheat varieties. The most preferred new wheat varieties will be further evaluated on farm to confirm on their superiority over old wheat varieties.

Introduction

Wheat varieties currently used by farmers in Tanzania were released more than fifteen years ago and are now susceptible to nearly all three rusts (stem, leaf and yellow rust) and their yield potential has been greatly reduced (Ndondi *et al.*2001). Therefore old wheat varieties need to be replaced with new improved disease resistant and high yielding wheat varieties. Such cultivars are available, however, these varieties have not been tested extensively in different agro-ecological zones of Morogoro, Iringa, Arusha and Kilimanjaro regions, mainly due to lack of funds. These varieties have consequqntly not been exposed to small scale farmers and farmer preferences have not been determined. Variety evaluation in different environments is vital to determine the performance of varieties across locations (Sariah *et al.*1990, Chirot *et al.*1990, Eberhart *et al.*1966).

In order to identify new, well adapted wheat varieties for small scale farmers in these regions, on-farm trials were conducted in the different agro-ecological zones with full participation of small scale farmers and village extension officers. The purpose of these trials is to ensure availability of new improved well adapted wheat varieties for small scale farmers in Tanzania.

Materials and Methods

During February and March 2002, thirteen villages representing different agro-ecological charactaristics of the wheat growing regions were identified and selected in collaboration with District Agriculture and Livestock Development Officers (DALDOs), Village Extension Officers (VEOs), Village leaders and farmers in respective districts and trial sites in Iringa, Morogoro, Arusha and Kilimanjaro regions. These sites represented medium to high altitude with marginal, medium to high rainfall agro-ecological zones. Four villages namely Itungi, Dabaga, Kinenulo and Ulembwe were selected in Iringa, two villages (Lumbiji and Vidunda) in Morogoro, four villages (Musa, Kilimatembo, Kainam and Tloma) in Arusha and three villages (Ngare,Olmolog and Moshas). Sites in Arusha and Kilimanjaro regions were selected in February while site selection in Iringa and Morogoro was done in March.

Eight old and twenty two new improved wheat cultivars were seeded on-farm at 13 villages in a randomized complete block design with two replications. Plots were 2.5m long with 10 rows each and 0.25m between rows. Seeding was done by hand. Weeds were controlled by applying post emergence herbicide 2 4 D Amine or Buctril Mc at five leaf stage at a rate of 1.25 l ha^{-1}, also hand weeding was done to remove late emerging broad leaf weeds and grass weeds respectively.

Data was collected on reaction to diseases, grain yield and farmers' variety preference. The wheat cultivars and their pedigree are presented in Table1. Entries1-8 are old cultivars; entries 9-30 are new cultivars.

Table1. Name and cross of wheat cultivars evaluated on-farm

No.	Entry	Pedigree or Cross
1	Selian 87	BN-YR 70/T.aestivum x KAL-BB
2	Mbayuwayu	KVZ-K4500 LA4
3	Kware	BB-GALLO xCj71/T.aestivum x KAL-BB
4	Juhudi	HAHN "S" Cm33682
5	Njombe 7	CMH 78.409-37Y-7B-1Y-1 PTZ-OY
6	Azimio	PAVON 76 (CM x CNO 67-7C / KAL-BB)
7	Tausi	VEERY "S"-8
8	Mbuni	TROPHY x K6106-1
9	Chiriku	TSI / VEE " S "
10	W9811	TIA.2/4/CS/TH.CU//GLEN/3/ALD/PVN
11	W9905	BJY/COC//PRL/BOW
12	W9920	GIM/LIRA//TURACO/CHIL/3/IRENA
13	W9921	TJB368.251/BUC//TURACO
14	RV10	SW99-5124*2 /FASAN
15	RV212	NING MAI 96019
16	RV227	BATAN F96
17	RV292	BR23/PF869107
18	RV427	R37/GHL121//KAL/BB/3/JUP/MUS/4/2*YM1#6/5/CBRD
19	RV428	R37/GHL121//KAL/BB/3/JUP/MUS/4/2*YM1#6/5/CBRD
20	RV635	HXL 8088 / DUCULA
21	RV768	SITELLA
22	RV992	PSN /BOW //KAUZ
23	RV1163	LD*6KVZ//LD*6/AGE/3/LD*6/KVZ//LD*6/WTP/4/IAS63/ALDAN/5/RIVADENEIRA7
24	RV1165	LD*6KVZ//LD*6/AGE/3/LD*6/KVZ//LD*6/WTP/4/IAS63/ALDAN/5/RIVADENEIRA7
25	RV1166	LD*6KVZ//LD*6/AGE/3/LD*6/KVZ//LD*6/WTP/4/IAS63/ALDAN/5/RIVADENEIRA7
26	RV1183	TNMU / PF85487 // DUCULA
27	RV1267	CBRD/POS//ESDA/LIRA
28	RV1270	GALVEZ S 87
29	RV1421	ALUBUC / BUC // PRL / VEE # 6
30	RV1434	LAJ3302 /2*BORL95

Results

Nearly all trial sites received medium to high rainfall at the beginning of the season. In Arusha region rains started in February, continued into March and tailed off in mid April. In Kilimanjaro region, rains started in March ending in mid April. Rains in Iringa and Morogoro regions continued in March and stopped in the third week of April. Data obtained from six sites in Arusha and Kilimanjaro sites will be presented and discussed in this paper

Arusha and Kilimanjaro region sites

1.0 Grain Yield

Grain yields from trial sites in Arusha and Kilimanjaro regions are presented in Table 2. Grain yields at Kilimatembo site varied from 0.53t/ha to 2.60t/ha. W9912 gave the highest yields (2.60t/ha) followed by RV227 (2.58t/ha), RV212 (2.47tha^{-1}), W9905 (2.40t/ha), RV1166 (2.33t/ha), Chiriku (2.32t/ha), RV1165 (2.28t/ha) and RV1434 with 2.27t/ha. At this site 13 of the new improved wheat varieties had mean grain yields of over 2 t/ha, while the eight old wheat varieties had mean grain yields of less than 2 t/ha. The low mean grain yields of the old wheat varieties may be due to diseases mainly leaf and stem rust (Table 3).

During the field day held on 14.6.02 at Kilimatembo site, farmers selected the following entries: W9905, RV212, RV227, RV1165, RV1166, RV10 and RV1434 (Appendix2), which are all new improved wheat cultivars. Mean grain yields at Kainam site ranged from 0.75t/ha to 2.17t/ha. W9811 yielded 2.17 t/ha, followed by W9912 (2.07t/ha), RV227 (2.03t/ha), RV635 (2.0t/ha), W9905 (1.92t/ha) and RV1434 with a mean grain yield of 1.91t/ha.

During the field day at Kainam, on 20.6.02 farmers selected following entries: W9905, W9912, W9811, RV10, RV212, RV427, RV1166 and Selian 87. Four of the entries selected by Kilimatembo farmers (W9905, RV10, RV212, RV1166) were also selected by Kainam farmers.

At Tloma site yields ranged from 1.55t/ha to 2.70t/ha. Cultivar RV428 had the highest mean grain yield of 2.70 t/ha followed by RV1183 (2.60 t/ha), RV593 (2.58t/ha), Chiriku (2.57 t/ha), Juhudi (2.50 t/ha), RV427 (2.45 t/ha) and RV1234 with 2.43 t/ha.

At Musa site, grain yields ranged from 0.53t//ha to 2.97t/ha. Grain yields at Musa village were lower than those at Kilimatembo and Kainam sites. This may be due to drought and severe stem and leaf rust infection at this site. Musa site was the best screening site for resistance to wheat diseases in the 2002 crop season.

Grain yields at Ngare site were generally low, mainly due to drought. Yields ranged from 0.33t/ha to 1.93t/ha. Cultivar W9905 gave the highest yields (1.93t/ha).

The trial at Olmolog received only one rain, which allowed seeds to germinate. No further rain was received, providing an excellent opportunity to identify drought tolerant wheat cultivars. Grain yields ranged from 0.38t/ha to 1.10t/ha. Juhudi gave the highest grain yield of 1.10t/ha followed by W9921 (0.87t/ha), RV1166 (0.87t/ha), Chiriku (0.85t/ha), RV10 (0.83t/ha), RV1434(0.82t/ha) and RV292 with 0.73t/ha. These seven wheat cultivars are either early maturing or drought tolerant.

In the combined analysis across six locations, mean grain yields ranged from 1.01t/ha to 1.87 t/ha. Cultivars Cultivar Chiriku had the highest mean grain yield (1.87) followed by RV1166 (1.72 t/ha), W9921 (1.70 t/ha), W9905 (1.70 t/ha), and W9912 with 1.67 t/ha (Table 2).

Table2. Mean grain yield of wheat varieties in Arusha and Kilimanjaro regions in 2002 crop season.

No.	Variety	Location and Mean grain yield (t/ha)						
		KIL'MBO	KAINAM	NGARE	TLOMA	MUSA	OLMOL	Combined
1	Selian 87	1.83 b-f*	1.16 g-i	0.83 de	1.67 de	1.80 ab	0.40 f	1.11 fg
2	Mbayuwayu	1.58 e-g	1.48 b-g	1.23 a-e	2.10 a-e	2.97 a	0.43 ef	1.60 a-d
3	Kware	1.90 a-g	1.73 a-g	1.23 a-d	2.12 a-e	2.15 ab	0.58 b-f	1.60 a-d
4	Juhudi	1.90 a-f	1.38 d-h	0.72 de	2.50 a-c	2.03 ab	1.10 a	1.66 a-c
5	Njombe 7	1.98 a-f	1.33 d-i	0.68 de	1.73 c-e	1.57bc	0.47 ef	1.39 b-f
6	Azimio	1.93 a-f	1.63 a-g	0.86 c-e	2.00 a-e	1.80ab	0.65 b-f	1.51 a-e
7	Tausi	1.07 gh	0.87 hi	0.63 de	1.87 b-e	1.57 bc	0.55 b-f	1.01 g
8	Mbuni	1.50 fg	1.40 c-h	0.88 c-f	1.82 b-e	1.52 bc	0.50 d-f	1.28 d-g
9	Chiriku	2.32 a-d	1.88 a-e	1.33 a-d	2.57 ab	1.83ab	0.85 ab	1.87 a
10	W9811	2.00 a-f	2.17 a	1.08 b-f	2.07 a-e	1.65 bc	0.45 ef	1.62 a-d
11	W9905	2.40 a-c	1.92 a-d	1.93 a	2.00 a-e	1.55bc	0.68 b-f	1.70 ab
12	W9912	2.60 a	2.07 ab	1.37 a-d	2.13 a-e	1.42bc	0.58 b-f	1.67 a-c
13	W9921	1.92 a-f	1.33 d-i	1.68 ab	2.27 a-e	2.03 ab	0.87 ab	1.70 a-c
14	RV10	2.05 a-f	1.69 a-g	1.50 a-c	2.23 a-e	1.77-c	0.83 a-c	1.62 a-d
15	RV212	2.47 ab	1.23 f-i	1.23 a-d	1.55 e	1.45 bc	0.52 c-f	1.41 b-f
16	RV227	2.58 a	2.03 ab	0.77 c-f	2.03a-e	1.52 c	0.43 ef	1.57 a-e
17	RV292	2.07 a-f	1.37 d-h	0.82 c-e	2.58 ab	1.70bc	0.73 be	1.47 b-f
18	RV427	1.88 a-f	1.68 a-g	0.75 c-e	2.45 a-d	1.70bc	0.40 f	1.40 b-f
19	RV428	1.90 a-f	1.28 e-i	0.90 c-e	2.70 a	1.62bc	0.37 f	1.36 b-g
20	RV635	1.67 d-g	2.00 a-c	0.33 e	1.83 b-e	1.77 a-c	0.37 b-f	1.36 b-g
21	RV768	2.13 a-f	1.77 a-f	0.38 e	2.32 a-e	1.70 bc	0.57 b-f	1.51 a-e
22	RV992	2.03 a-f	1.70 a-g	0.77 c-e	2.13 a-e	1.45 bc	057 c-f	1.53 a-e
23	RV1163	1.65 d-g	1.30 e-i	0.93 b-e	2.32 a-e	1.35 bc	0.52 b-f	1.34 b-g
24	RV1165	2.28 a-e	1.63 a-g	1.07 b-e	2.08 a-e	1.97 ab	0.62 b-f	1.62 a-d
25	RV1166	2.33 a-d	1.62 a-g	1.22 a-d	2.20 a-e	123 bc	0.87 ab	1.72 ab
26	RV1183	1.87 a-f	0.75 i	0.83 c-e	2.60 ab	1.47bc	0.58 b-f	1.32 c-g
27	RV1267	2.18 a-f	1.35 d-h	0.83 c-e	2.28 a-e	1.07 bc	0.60 b-f	1.43 b-f
28	RV1270	0.53 h	1.41 c-h	0.43 e	2.38 a-d	1.10*bc	0.38 f	1.09 fg
29	RV1421	1.68 c-g	1.15 g-i	0.43 e	2.43 a-d	1.03 bc	0.50 d-f	1.20 e-g
30	RV1434	2.27 a-e	1.91 a-d	0.72 de	2.25 a-e	0.53 c	0.82 a-d	1.52 a-e
	MEAN	1.95	1.54	0.95	2.17	1.61	0.59	1.47
	LSD.05	0.73	0.59	0.76	0.80	0.12	0.32	0.38
	CV%	18.2	18.9	39.3	17.8	37.7	26.9	22.64

* Means within a column followed by the same letter(s) are not significantly different according to DMRT.

Disease Reaction

Wheat diseases were recorded at Musa, Tloma and Kilimatembo sites. .These sites allowed good screening for stem, leaf and yellow rust. Powdery mildew occurred at Ngare and Olmolog sites. The disease reaction of the old and new wheat varieties is presented in Table 3. Almost all of the old wheat cultivars are susceptible to stem and leaf rust, while several of the new wheat cultivars have either trace to low levels of infection to stem and leaf rust.

Table 3. Disease reaction of old and new wheat varieties in 2002 crop season.

No.	Variety	Plant height (cm)	Diseases		
			Stem rust (SR)	Leaf rust (LR)	Yellow rut (YR)
1	Selian 87	84	80S	TR	D
2	Mbayuwayu	90	R	50S	E
3	Kware	91	10MR	10MR	L
4	Juhudi	73	70S	80S	E
5	Njombe 7	96	30MR	40MS	T
6	Azimio	101	40MR	20MR	E
7	Tausi	86	70S	30S	
8	Mbuni	87	50MS	40MS	
9	Chiriku	72	40MR	40MR	T
10	W9811	95	80S	80MS	H
11	W9905	86	80S	50MR	I
12	W9912	86	60MR	30MR	S
13	W9921	70	10R	5R	
14	RV10	69	10MR	30MR	C
15	RV212	84	70S	60MS	O
16	RV227	97	40MR	30MR	L
17	RV292	119	40MR	20MR	U
18	RV427	84	80MS	30MS	M
19	RV428	92	TR	10MR	N
20	RV635	97	R	30MR	
21	RV768	92	30MR	10MR	
22	RV992	100	R	TR	
23	RV1163	90	R	5MR	
24	RV1165	86	R	5MR	
25	RV1166	89	R	5MR	
26	RV1183	79	R	R	
27	RV1267	110	20MR	TR	
28	RV1270	89	5R	5MR	
29	RV1421	102	TR	R	
30	RV1434	85	5R	R	

Key: R = Resistant MR = Moderately Resistant Tr = Trace MS = Moderately Susceptible S = Susceptible

3.0 Field Days and Farmers' Assessment of Wheat Varieties

3.1 Field days

As part of new wheat variety promotion and farmers' wheat variety assessment, field days were planned at all sites so that participating farmers and farmers from surrounding villages could contribute in identifying well adapted wheat varieties in their zone. Due to severe drought and low temperatures at some trial sites the wheat varieties in these sites could not depict the intended messages easily.

Field days were held at Kainam, Kilimatembo, and Musa., and were attended by 60 to 150 farmers. Farmers using their own criteria selected wheat varieties presented in Table 4. Several cultivars were selected at more than one location. The differences in variety choice at some sites may be due to differences in agro –ecological zones.

Table 4. List of varieties selected by farmers and their pedigree/parentage

No.	Variety	Pedigree or Cross
1	RV10	SW99-5124*2 /FASAN
2	W9905	BJY/COC//PRL/BOW
3	RV212	NING MAI 96019
4	RV227	BATAN F96
5	RV427	R37/GHL121//KAL/BB/3/JUP/MUS/4/2*YM1#6/5/CBRD
6	RV1165	LD*6KVZ//LD*6/AGE/3/LD*6/KVZ//LD*6/WTP/4/IAS63/ALDAN/5/RIVADENEIRA7
7	RV1166	LD*6KVZ//LD*6/AGE/3/LD*6/KVZ//LD*6/WTP/4/IAS63/ALDAN/5/RIVADENEIRA7
8	W9920	GIM/LIRA//TURACO/CHIL/3/IRENA
9	W9811	TIA.2/4/CS/TH.CU//GLEN/3/ALD/PVN
10	RV1434	LAJ3302 /2*BORL95
11	RV992	PSN /BOW //KAUZ
12	RV1263	MILAN/DUCULA//ATTILA
13	W9921	TJB368.251/BUC//TURACO
14	RV1395	CHIL/ESDA/3/HEI/3*CNO79//2*SERI
15	Chiriku	TSI / VEE “ S ”
16	Selian	BN-YR 70/T.aestivum x KAL-BB

3.2 Farmers’ assessment

On June 14th, 2002, 107 farmers at Kilimatembo site assessed the wheat cultivars. Staff from Socio-economics department and extension staff from Karatu facilitated this evaluation. Fifteen farmers (5 females and 10 males) were chosen to assess the wheat varieties. The 15 farmers had either participated in on-farm wheat trials or had been observing the performance of the wheat varieties in the trials.

Farmers were first asked to examine all the wheat varieties in the trial. After thorough examination of the varieties they were asked to rank them in order of preference (Table 5)

Table 5. Absolute ranking of selected wheat varieties at Kilimatembo village in 2002 crop season.

Wheat varieties	**Rank**
RV 212	2
RV 227	4
W 9905	6
RV 1165	3
RV 1166	1
RV 1434	7
RV 10	5
Selian 87	8

RV 1166 was the most preferred cultivar, followed by RV212 , RV 1165 and RV227. Criteria applied by farmers to select cultivars were good to excellent resistance to diseases, many spikes, early maturity, strong stem and plumb big grains. Selian 87, an old wheat variety was the least preferred because of its susceptibility to diseases as indicated in Appendix 1.

Farmers were asked to mention and rank criteria used to select good wheat cultivars as indicated in Table 6.

Table 6. Farmers' criteria for selecting good wheat varieties at Kilimatembo in 2002 crop season.

Criteria	Rank
Resistance to diseases	1
Many spikes	3
Strong stem	4
Carried over seed	2
Drought tolerance	5
Grain Size	7
Baking quality	6
Early maturity	8

A matrix ranking (Table7) was done using all the eight (8) important criteria and the eight selected wheat varieties as shown in Table 8. The eight selected wheat varieties were ranked excellent to average in most criteria. Varieties RV1166, RV 1165, RV212 and RV227 ranked good to excellent in disease resistance. Varieties RV 10, RV1166 and RV1165 were ranked excellent in earliness.

Table 7. Matrix ranking of wheat varieties at Kilimatembo site in 2002 crop season.

Criteria	Varieties									
	RV 10	RV1434	RV1166	RV1165	RV212	RV227	W9905	Selian	Total	Rank
Disease resistance	2	3	4	4	5	5	4	2	24	8
Spike number	2	3	3	4	5	5	5	5	32	4
Baking Quality	3	3	4	4	3	4	4	3	28	7
Grain Size	5	4	4	4	5	5	4	4	35	1
Drought tolerance	5	4	5	5	5	4	3	2	33	3
Carried over seeds	5	3	5	3	5	4	4	3	32	4
Strong stems	5	5	5	5	4	3	4	3	34	2
Early maturity	5	3	5	5	3	3	3	2	29	6
Total	32	28	35	34	35	33	31	23		
Rank	5	7	1	3	2	4	6	8		

Key: 5 = Excellent, 4 = Good, 3 = Average, 2 = Satisfactory, and 1 = Poor

Pair wise ranking of the selected eight wheat cultivars was done (Table 8). During pair wise comparison the variety RV212, RV227 and Selian were the most preferred.

Table 8. Pair wise ranking of farmer selected wheat varieties

	RV10	RV1434	RV1166	RV1165	RV212	RV227	W9905	Selian	Total	Rank
RV10		RV1434	RV1166	RV1165	RV212	RV227	RV1434	Selian	0	8
RV1434			RV1434	RV1434	RV212	RV227	W9905	Selian	4	4
RV1166				RV1166	RV212	RV227	W9905	Selian	2	6
RV1165					RV212	RV227	RV212	Selian	1	7
RV212						RV212	RV212	RV212	7	1
RV227							RV227	RV227	6	2
W9905								Selian	3	5
Selian									5	3

4.0 Discussion

The performance of old and new wheat cultivars in 6 on-farm trials in different agro-ecological zones in Arusha and Kilimanjaro region (Table 2) 2 show significant differences in grain yield.. Severe drought at some sites caused low grain yields, but enabled selection for drought tolerance. Cultivars with highest yield under severe drought conditions were Chiriku, Juhudi, W9921, RV10, RV292, RV1166 and RV1434. These cultivars were also the earliest.

At sites without drought, mean grain yields were high for most cultivars and differences in grain yield among cultivars were significant. At locations with high disease pressure (Tloma and Musa), grain yield of susceptible varieties were reduced. Most old wheat varieties are susceptible to stem and leaf rust. Sowing the trials at different but well selected agro-ecological zones allowed identifying cultivars with disease resistance, tolerance to drought and high yield potential. Farmers and extension staff in these regions participated in the evaluation and selection of well adapted disease resistant wheat cultivars. At sites where field days were held, farmers selected the new improved wheat cultivars, while the old cultivars were mostly discarded due to their susceptibility to diseases.

The new improved wheat cultivars have high levels of disease resistance to stem and leaf rust and have high yield potential. These cultivars will further evaluated in on-farm trials in Iringa, Morogoro, Arusha and Kilimanjaro regions to verify their agronomic superiority and disease resistance over the old cultivars, before finally being released for small scale farmers.

Acknowledgement -The financial and material support from ASPS-Seed Unit is highly acknowledged, without which these activities would have been impossible.

References

Allard, R.W., and A.D. Bradshaw. 1964. Implications of genotype-environment interaction. Crop Sci. 4: 503-507

Chirot, Y. and Hailu, B. 1990. On farm evaluation of three bread wheat varieties in the Wolmera red soil zone. . In Tanner, D.G., M. van Ginkel, and W.Mwangi, eds. 1990. Sixth Regional Wheat Workshop for Eastern, Central and Southern Africa. Nakuru ,Kenya: CIMMYT

Sariah, M. A., R.V.Ndondi, and M. J. Mollel. 1990. Grain yield potential and adaptation of ten bread wheat varieties in Tanzania. . In Tanner, D.G., M. van Ginkel, and W.Mwangi, eds. 1990. Sixth Regional Wheat Workshop for Eastern, Central and Southern Africa. Nakuru , Kenya: CIMMYT

Ndondi, R.V., H. Mansoor, C.A. Kuwite, M. Mugendi and R. Shekibula. 2001. On farm evaluation of five pre-released wheat varieties at Karatu. In Wheat Research Programme Annual Progress Report 2000/ 01.

Appendix 1. Farmers observations in the field on the characteristics of the selected wheat varieties were:

1. RV 1166 Good disease resistance
   Many spikes
   Early maturity
   Drought resistance
   Heavy seeds
   Strong stems
   Good baking quality

2. RV 212 Good disease resistance
   Many spikes
   Medium maturity
   Drought resistance
   Heavy seeds
   Strong stems
   Good baking quality

3. RV 1165 Good disease resistance
   Many spikes
   Medium maturity
   Drought resistance
   Heavy seeds
   Strong stems
   Good baking quality

4. RV 227 Moderate disease resistance
   Many spikes
   Medium maturity
   Drought resistance
   Heavy seeds
   Strong stems
   Good baking quality

5. RV 10 Moderate disease resistance
   Many spikes
   Early maturity
   Drought resistant
   Heavy seeds
   Strong stems
   Good baking quality

6. W 9905 Moderate disease resistance
   Many spikes
   Early maturity
   Drought tolerant
   Heavy seeds
   Strong stems
   Good baking quality

7. RV 1434 Moderate disease resistance
   Many spikes
   Early maturity
   Drought resistance
   Heavy seeds
   Strong stems

8. Selian 87 Moderate disease resistance
   Many long spikes
   Late maturity
   Poor drought tolerance
   Heavy seeds
   Strong stems.

Evaluation of Improved Wheat Varieties Under Different Management Practices in Eastern Wallagga Highlands

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Abstract—A trial was conducted during the 1997-1999 cropping seasons at two locations. Four improved wheat (*Triticum aestivum*) varieties and one local variety were planted in a factorial design with two (research and farmers') management practices. Yield of the wheat varieties was significantly different across the two locations. Improved varieties performed better under research management practices. Higher grain yield was observed in the improved management practices compared to farmer practice. Improved management practices gave a higher marginal rate of return (57.51%) whereas the local variety gave higher mean grain yield under farmer management practices. Improved management practices resulted in a yield advantage of 7.25%. The use of improved varieties with improved management practices is essential if wheat grain yield is to be maximized. Maximum grain yield and higher net return were realized from improved agronomic packages for wheat production. The variety HAR-1685 gave better yield with research management practices and is recommended for production. More importantly, the use of improved management techniques targeted at increasing yield allowed wheat producers to greatly increase economic returns. Thus, extension agents should consider this recommendation for wheat production in Eastern Wallagga highlands.

Introduction

The introduction of new crop varieties on soils with improved management packages has increased food production in some smallholder farms. The trend, however, has been the opposite in most smallholder farms due to poor soil fertility and crop management (Woomer and Ingram, 1990). The rising cost of commercial fertilizers has limited smallholder use. According to Buresh and Giller, (1998), in the smallholder farming systems of Africa nutrient outputs exceed nutrient inputs. Management options to increase yield and ameliorate productivity of crops are urgently needed for wheat production.

Wheat (*Triticum aestivum*) grain yield potential has significantly increased due to the release of improved high yielding varieties (Amsal *et al*., 1995). Generally high yielding crop varieties require more intensive agronomic management practices to express their potential yield. Amsal *et al.* (1999) and Tanner *et al.*, (1993) indicated that recently released cultivars of wheat are highly responsive to improved management practices and require high rates of nutrient application. They further stated that the productivity of improved varieties of wheat is more sensitive to management practices compared to local varieties . The adoption of high yielding improved varieties without improved management practices may not boost the productivity of wheat. To date, however, wheat production with improved management practices is limited due to the cost and inaccessibility of fertilizers and the overlapping farming activities to smallholder farmers. In addition, the low current market price of wheat makes wheat production unprofitable. Furthermore, improved varieties have failed to adequately meet the needs and requirement of marginal environments(Hardon ,1996). Plant breeding programs mainly direct their efforts at increasing yield in more favorable environments. Looking for broad adaptability to different environments with alternative management practices for sustainable production of wheat is urgently needed. Giving value to wheat varieties because of their adaptation to alternative management practices will encourage sustainable production. Therefore, the objectives of this study were to estimate the extent of cultivars x management level interaction, identify cultivars that suit alternate management practices and identify stable cultivars that can better perform under both farmer and improved management practices

Materials and Methods

The experiment was conducted during the 1997, 1998 and 1999 cropping seasons on farmers fields in the eastern Wallagga highlands (Shambo and Arjo). Shambo lies between $9^{o}34'$N latitude and $37^{o}06'$E longitude at an altitude of 2400 meter above sea level with a mean annual rainfall of 1,695 mm (NMSA, 2003). It has a cool humid climate with mean minimum, mean maximum, and average air temperatures of 8.15^{o}C, 15.72^{o}C, and 11.94^{o}C, respectively. Arjo lies between $8^{o}45'$N latitude and $36^{o}40'$E longitude at an altitude of 2400 meter above sea level. Mean annual rainfall is 1,330 mm (NMSA, 2003). It has a cool humid climate and the mean minimum, mean maximum, and average air temperatures are 9.33^{o}C, 17.85^{o}C, and 13.59^{o}C, respectively. The experiment was laid out as split plot in a randomized complete block design with variety as main plots and management practices as sub-plots. The improved varieties tested were HAR-710, HAR-1685, HAR-1709, ET-13 and a local variety was also chosen. Management practices were farmers' management and research management.

The improved cultural practice was the research recommendation for production of wheat. The local cultural practices were local farmers' cultural practices for wheat production in that area. The seed rate used was 160 kg ha^{-1} for local and 150 kg ha^{-1} for improved cultural practices. Sowing dates followed farmers' practices, which are between mid June to early July. The plot size used was 4 m x 4 m. The recommended fertilizer rates of 100 kg ha^{-1} DAP and 100 kg ha^{-1} Urea was applied at planting. For the improved cultural practices, two times hand weeding was practiced as per recommendation for wheat production. For the farmer's cultural practices, hand weeding was done once 25 days after planting. The data were analyzed using Mstatc Computer Software. Mean separation was done using least significance difference (LSD) at 5 % probability level.

For economic evaluation, partial budget, values to cost ratio (VCR) and marginal analyses were used. To estimate economic parameters, wheat grain yield was valued at an average open market price of EB 143.00 100 kg^{-1} for the last five years. The yield was adjusted down by 10 % to reflect actual production environments (CIMMYT, 1988). The seed cost of wheat was EB 3.75 kg^{-1} for the improved varieties and EB 1.43 kg^{-1} for the local variety. Urea and DAP were valued at the official prices of EB 269.65 and 303.35 100 kg^{-1}, respectively. The cost of labour for weeding was EB 3.50 day^{-1}.

Results and Discussion

Cropping season significantly ($P < 0.05$) affected mean plant height and grain yield (Table 1). This might be likely due to the distribution pattern of rainfall. Environmental factors had a positive impact on the productivity of wheat. In addition to management practices, environmental factors also greatly influence the sustainability of wheat production. Locations and year x location interaction had significant ($P<0.05$) effects on mean plant height and grain yield (Table 1). This indicates that the varieties performed differently at the two locations and across cropping seasons.

Varieties were significantly ($P<0.05$) different for mean plant height and grain yield (Tables 1,2 and 3). Year x variety, location x variety and year x location x variety interaction were significant for plant height and grain yield (Table 1), indicating that different wheat varieties performed differently within and among locations. Clearly, different varieties have different yield potential at each location. Yield of wheat can therefore be improved by providing different varieties to wheat producers in a given area.

Management practices significantly ($P<0.05$) affected mean plant height and grain yield (Tables 1, 2 and 3). This indicated that management practice influenced the yield potential of different wheat varieties. Higher mean plant height and grain yield of wheat was obtained from improved management practices. Clearly, higher grain yield of wheat with improved agronomic practices is possible for the area. All varieties showed a significant response to management practices at both locations. Improved wheat varieties showed greater response to improved management levels across the two fields. This result agrees with Amsal *et al.* (1999) who reported that improved cultivars are highly responsive to improved crop management systems.

Improved agronomic practices gave yields 7.25% higher than the farmers' local practices (Table 3). Farmers using improved agronomic packages can maximize the grain yield of wheat and their profit.

Interaction effects of varieties and management practices were significant ($P<0.05$) for mean grain yield but non-significant for plant height (Tables 1, 2 and 3). Different varieties had different responses to management practices. Greater grain yield of wheat was achieved from improved management practices for all varieties. These findings are similar to those of Katyal (1999) who found that improved practices, improved cultivars, and NPK application gave the highest yield, returns, and profitability. Similarly, Bhagat and Singh (1998) reported that improved agronomic practices gave a 47 % increase in rice-equivalent yield compared with local farmers practices (local cultivars and 30 kg N ha^{-1}).

The improved wheat variety HAR-1685 gave higher mean grain yield compared to all other varieties. This variety (HAR- 1685) had wide adaptability compared to other varieties. Our results show that improved agronomic practices will significantly improve wheat production and the sustainability of production in this region. The technologies for sustainable crop management practices relevant to small wheat farmers outlined by Sayre (1999) can become a reality. Providing improved wheat varieties with improved management packages to farmers is essential practices for maximum production and profit.

Economic analysis for management practices indicated that the highest net benefit of EB 2391 ha^{-1} with a marginal rate of return of 66.22 % and a value to cost ratio of EB 3.02 profit per unit of investment for wheat was obtained from improved management practices (Table 4). The net benefit for farmers' cultural practices was EB 2305 ha^{-1} with a value to cost ratio of EB 3.49 profit per unit investment for wheat production. The value to cost ratio with both management practices includes the price of production and provides an estimate of profit for wheat producers in the area. Using the average current price of inputs, both management technologies were economically viable.

Table 1. Mean square of straw and grain yield of wheat due to variety and management levels across years and location at Shambo and Arjo.

Source of variation	DF	Mean square	
		Plant height (cm)	Grain yield (kg/ha)
Year	2	2590.557**	23111592.129**
Location	1	1988.929**	48860448.004**
Year x Location	2	1724.407**	10284810.779**
Variety	4	14691.787**	7477252.869**
Year x variety	8	150.72**	2442707.478**
Location x variety	4	565.227**	560040.515**
Year x Location x variety	8	201.859**	787328.493**
Error	72	39.931	150684.932
Management levels	1	651.092**	1664167.604**
Year x Management levels	2	219.934**	298755.204
Location x Management levels	1	102.573	124556.337**
Year x Location x Management levels	2	583.403**	348527.587
Variety x management levels	4	53.162	473592.135**
Year x Variety x Management levels	8	115.474**	67066.532
Location x variety x Management levels	4	14.534	181936.223
Year x Location x Variety x Management levels	8	55.2	194826.426
Error	90	41.923	117243.876

** Significant at 1% and 5% level of probability respectively

Table 2. Combined mean effects of varieties and management practices on plant height (cm) of wheat at Shambo and Arjo

Treatments	Varieties					Mean
Management practices	HAR-710	HAR-1685	HAR-1709	ET-13	Local	
Farmers management	89	81	103	102	127	100
Improved management	91	84	106	109	129	104
Mean	90	82	104	105	128	

	Varieties	Management practices	Varieties vs. Management practices
LSD (5%)	2.57	1.66	Ns
CV %	6.20	6.35	

Table 3. Combined mean effects of variety and management practices on grain yield (kg/ha) of wheat at Shambo and Arjo

Treatments	Varieties					Mean
Management practices	HAR-710	HAR-1685	HAR-1709	ET-13	Local	
Farmers management	2134	3043	2117	1976	2256	2305
Improved management	2293	3145	2262	2462	2197	2472
Mean	2213	3094	2190	2219	2226	

	Varieties	Management practices	Varieties vs. Management practices
LSD (5%)	58	87.79	196.4
CV %	16.25	14.34	

Table 4. Partial budget and marginal rate of return (MRR) analysis for the effects of management practices on the mean grain yield of wheat combined over locations

Items	Management practices	
	Farmers management	Research management
Average yield (kg/ha) Wheat	2305	2472
Adjusted yield (kg/ha) Wheat	2074.5	2224.8
Gross field benefit of Wheat	2966.54	3181.46
Seed cost (EB/ha) Weeding cost (EB/ha)	414.40 246.95	388.5 402.15
Total costs that vary (EB/ha)	661.35	790.65
Net benefit	2305.19	2390.81
Values to cost ratio	3.49	3.02
Marginal rate of return (MRR)		66.23%

Note: D= dominated treatment, Grain price= EB 1.43 /kg, Seed price = EB 3.75/kg for improved variety, Seed price = EB 1.43/kg for local variety, Yield was down adjusted with 10% coefficient

Conculsion

Improved management practices significantly boost the yield of wheat. Therefore, use of improved management practices is agronomically and economically feasible. These recommendations should be extended to wheat producers in the Shambo and Arjo highlands to ensure sustainability of production and to increase profits.

Acknowledgment—The authors thank Oromiya Agricultural Research Institute for funding the project. We are also grateful to Mr. Tesfaye G/Gorges and Yosef kenea for their assistance in carrying out the experiment and efficiently collecting the data. Bako Research Center Management is also thanked for facilitating the execution of the field trial.

References

Amsal Tarekegne, Tanner, D.G. and Getinet Gebeyehu. 1995. Improvement in yield of bread wheat cultivars released in Ethiopia from 1949 to 1987. *African crop Science Journal* 3: 41 - 49.

Amsal Tarekegne, Tanner, D.G., Taye Tessema and Chanyalew Mandefro. 1999. A study of variety by management interaction in bread wheat varieties released in Ethiopia. In The Tenth Regional Wheat Workshop for Eastern, Central and Southern Africa. pp 196 - 212. Addis Ababa Ethiopia: CIMMYT

Bhagat, R. K. and Singh, R. S. 1998. Crop management in rice-wheat cropping system. Research Journal of Birsa Agricultural University.10 (1): 30-33.

Buresh, R.J. and Giller, K.E. 1998. Strategies to replenish soil fertility in African smallholder agriculture. In Soil fertility Research for Maize-based Farming Systems in Malawi and Zimbabwe. Proceedings of the Soil Fert Net Result and Planning Workshop. Waddington, S.R., Murwira, H.K., Kumwenda J.D.T., Hikwa, D. and Tagwira, F. (eds.). pp 13-19. Africa University, Mutare, Zimbabwe. Soil Fert Net and CIMMYT-Zimbabwe, Harare, Zimbabwe.

CIMMYT. 1998. From Agronomic Data to Farmer Recommendations. An Economics Training Manual. Completely Revised Edition. CIMMYT, Mexico, D.F., Mexico. 79 pp

Hardon, J. 1996. The Global Context: Breeding and Crop genetic Diversity. pp 1 - 3. *In*: Eyzaguirre, P and Iwanaga, M. (eds.). Participatory Plant Breeding. Proceedings of a Workshop on Participatory Plant Breeding, 26 - 29 July 1995, Wageningen, The Netherlands. IPGRI, Rome, Italy.

Katyal, V.; Gangwar, K. S. and Gangwar, B. 1999. Influence of input use and management practices on sustainability and economics of rice cultivation. *Journal of the Andaman Science Association.* 15: 56-59.

NMSA (National Meteorological Service Agency). 2003. Meteorological data of Shambo area for 1969-2003. NMSA, Addis Ababa, Ethiopia.

Sayre, K. D. 1999. Ensuring the use of sustainable crop management strategies by small-scale wheat farmers in the 21st century. In The Tenth Regional Wheat Workshop for Eastern, Central and Southern Africa. pp. 119 - 141. Addis Ababa Ethiopia: CIMMYT

Tanner, D. G., Amanuel Gorfu and Asefa Taa. 1993. Fertilizer effects on sustainability in the wheat-base smallholder farming systems of southeastern Ethiopia. *Field Crops Research* 33: 235 - 248.

Woomer, P and Ingram, J.S.I. 1990. The biology and fertility of tropical soils. TSBF Report. 1992. MARVEL EPZ, Nairobi, Kenya. 44 pp.

Cell Membrane Stability (CMS) as Screening Technique for Drought Tolerance in Bread and Durum Wheat Genotypes

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Abstract— Genetic improvement of drought resistance in crop plants requires identification of relevant drought resistance mechanisms and the development of a suitable methodology for their measurement in large breeding populations. Bread and durum wheat genotypes/cultivars were used in study to determine their level of injury using cell membrane stability as a measure of drought tolerance. The drought tolerance test is based on the measurement of the electro-conductivity of aqueous media containing leaf discs that were previously water stressed in vitro by exposure to a solution of polyethylene glycol 6,000 (PEG). Genotypes differences were highly significant for percent injury level. Wheat leaves of bread and durum genotypes exposed under conditions of moisture stress varied significantly in their membrane injury level. Injury levels among bread wheat genotypes were lower (6.8 to 21.5%) than among the durums (11.5 to 24.55%) when the genotypes were screened artificially using a 20% PEG solution as a dehydration medium. Although minimum injury levels among genotypes of both types of wheat were recorded, the test would be used for initial screening for drought tolerance along with the other artificial screening methods.

Introduction

Drought is a multidimensional problem and covers large areas throughout the world (William, 1989). Gupta (1997) estimated that about 26% (17,255,700 square miles) of the world's total cultivable land is arid or semi-arid, where water is the limiting factor to crop production. An estimated 32% of the 99 million hectares of wheat grown in developing countries experiences varying levels drought stress (Rajaram *et al.*, 1996)

Consequently, the development of drought tolerant varieties became a major objective in plant breeding programs for crops grown in tropical regions without irrigation. Evaluating drought tolerance based on yield compared to standard cultivars over several years and location where drought is likely to occur is a common procedure in countries, including Ethiopia. This process is dependent on year-to-year changes in weather and extremely time consuming. Plant breeders have long desired simple and rapid measurement techniques for use on early generation material to identify potential drought resistance (Matin, M.A. *et al.* 1989).

The role of cell membrane stability under conditions of moisture stress could be considered a major measurement of electrolyte leakage from the cells. The rate of injury to cell membranes is commonly used as a measure of tolerance to additional plant stresses, such as freezing and heat (Chen *et al.*, 1982). It would therefore be important to determine the drought tolerance of genotypes using simple laboratory techniques like cell membrane stability (CMS) test to supplement the data obtained through field screening so that breeders would have additional information for selecting genotypes for to drought tolerance.

This study attempted to differentiate varietal differences of durum and bread wheat genotypes of Ethiopian and South African origin in response to moisture stress using the cell membrane stability (CMS) test.

Materials and Methods

Ten bread wheat and 10 durum wheat genotypes were used for this study. The bread wheat genotypes/cultivars used in this study are of Ethiopia and South Africa origin, where as the durum wheat cultivars were of Ethiopian origin (Table1).

Table 1.Designation and origin of two species of wheat genotypes used for the study.

Bread wheat	Origin	Year of release		Durum wheat	Origin	Year of release
BD1-10	SA			Cocorit-71	Et	1976
Bdl-41	SA			Gerardo	Et	1976
BD1-48	SA			LD-357	Et	1979
Bdl-24	SA			Boohai	Et	1982
BDl-20	SA			Foka	Et	1993
HAR-1685	Et			Kilinto	Et	1994
HAR-604	Et			Tob-66	Et	1996
Dereselign	Et			Quamy	Et	1996
Et-13	Et			Tob-2	Et	2002
				Cadu-57		

Growing conditions
The materials used in this study were planted in pots containing 3kg of soil in a glasshouse with three replications.

Sampling
Leaf samples of about 10mm in diameter were taken from fully expanded young leaves. Five samples were taken from two or three leaves per genotype. Samples were kept in an airtight test tube, wetted a drop of water, and transferred to the laboratory within an hour.

Drought tolerance test
The method of Sullivan (1972) was followed to test the drought tolerance. Samples were washed with three changes of distilled water to remove surface-adhered electrolytes. Five leaves samples for the stress treatment were placed in test tubes with a 10cc solution of a 20% concentration of Polyethylene Glycol (600 PGC). Five samples for the control treatment were placed in 10cc of distilled water. All the samples were incubated at 10°C for 24 hours and then equilibrated in a water bath at 25°C. Conductivity of the incubation medium was read using a conductivity meter. After reading, the samples were autoclaved for 15min to kill the leaf tissues and a second conductivity reading was made after the samples reached room temperature of 25°^{o}c. Calculation of percentage injury due to desiccation was made as follows:

$$\% \text{ injury}=1-[1-(T_1/T_2)/1-C_1/C_2)]*100$$

Where T and C refer to mean of the treatment and control reading, respectively, and the subscripts1 and 2 refer to initial and final conductivities, respectively.

Statistical analysis
The data were subjected to a variance analysis (ANOVA) using SAS computer software (SAS Institute 1996).

Results and Discussion

Analyses of variance for percent injury of the wheat genotypes are presented in Table 2. Genotypes differences were highly significant (P<0.01) for percent injury. A significant difference (P<0.05) between groups of bread and durum wheat genotypes was also found. Analysis of variance data between groups of wheat genotypes of different origins indicated significant difference (P<0.05) in percent injury level.

Mean values of percent injury for the 20 wheat genotypes are given in Table 3. The highest injury level was obtained from the durum wheat genotype Cocorit-71, while the lowest was from Israel (6.8%), significantly different from all the other genotypes. Although the contrast comparisons between bread and durum wheat were significant, there were inconsistencies between genotypes of the two species. The durum wheat cultivars had relatively high levels of injury compared to the bread wheat genotypes/cultivars. For instance, the three highest percent injury levels, as well as and the second, fourth, and fifth low percent injury level were obtained from the durum wheat cultivars (Table 3).

Similarly, based on the LSD values, significant differences were observed between South African and Ethiopian bread wheat genotypes. The percent injury levels of bread wheat genotypes of Ethiopian origin ranged from 19.8 to 6.8, with a mean of 14.5. The South African bread wheat genotypes varied from 21.48 to 13.28, with a mean value of 16.8 (Table 4). It is highly suspected that this difference could be due to environmental variation between the countries of origin.

Table 2. Analysis of variance and contrast comparison between two species groups and three origin groups of wheat genotypes/cultivars.

Source of Variation	df	Mean squares	F-value
Genotypes	19	86.591868	4.67**
Error	58		
Species	1	131.07200	6.86**
Origin	2	91.642125	4.94*

** Significant at the 0.01 level
* Significant at the 0.05 level

Table 3.Percent injury by dehydration for all bread and durum wheat genotypes/cultivarsGenotypes that exhibited a low percent of injury could be considered as drought tolerant (Blum and Ebercon, 1981: Mark et al, 1991)

Bread Wheat Genotypes/cultivars	Percent injury	Durum Wheat Genotypes/cultivars	Percent injury
BD1-10	21.48	Foka	23.98
Bdl-20	16.83	Kilinto	20.55
BD1-24	13.28	Tob-66	11.50
Bdl-48	18.48	LD-357	17.65
BDl-41	14.10	Cadu-17	18.05
Israel	6.83	Cocorit-71	24.55
Dereselign	19.78	Gerardo	22.18
HAR-1685	16.20	Quamy	19.58
HAR-604	17.93	Fetan	12.38
Et-13	12.0	Boohai	12.08
Mean	15.69	Mean	18.25
LSD(0.05)	6.096		

Table 4.Ranges and mean values of percent injury for groups of genotypes

Groups		
Species	Ranges	Mean
Bread Wheat	21.48- 6.83	15.69
Durum Wheat	24.55-11.5	18.25
Origin		
SABW	21.48-13.28	16.8
ETBW	19.78-6.83	14.5
ETDW	24.55-11.5	

According to this study, genotypes with a minimum percent injury by dehydration are considered more tolerant. Hence, among bread wheat genotypes, Israel, Et-13, Bdl-24, and Bdl-41 were tolerant, whereas Bdl-10, Dereselign, and Bdl-48 all had highest level of injury and could be classified as non-tolerant genotypes.

On the other hand, among the durum wheat cultivars Tob-66, Boohai, and Fetan showed low level of injury after dehydration and could be considered tolerant. Foka and Cocorit-71 had high levels of injury; therefore they are non-tolerant genotypes. In contrary to this theory, the performance of Cocorit-71 (early maturing type) was promising, thus making it a drought tolerant cultivar, which has also been seen under field experiments carried out in Ethiopia when yield and its components were used as a selection criteria for drought tolerance. This could due to major drought tolerance mechanisms, probably drought avoidance.

In a similar study, Blum and Ebercon (1981) explained this adaptation as osmotic adjustment when the cell membrane adjusts to drought stress. The degree of injury to cell membrane stability by controlled dehydration was found to decrease in plants that were subjected to a period of drought stress.

The percentage cell membrane injury level obtained in this study was very low less than 30% compared to 70% injury level reported by Blum and Ebercon (1981). The reason is probably that the PGE concentration used in this study was low, 20 % to induce osmotic stress, as opposed to the 40% PGE concentration used in their studies.

In general, based on this study, the performance of durum wheat genotypes in terms of drought tolerance seemed to be progressive and showed some level of improvement over time. For instance, the old cultivars, Cocorit 71 and Gerardo showed relatively higher level of injury than the recently released cultivars Tob-66 and Fetan, despite a few inconsistancies. These could be due to the environmental conditions under which they were evaluated and developed, which changed over time.

Bread wheat genotype Bd-l0 demonstrated a high level of injury has also been categorized as a non-tolerant line in a screening trial carried out to differentiate genotypes based on yield and yield component for drought tolerance (Alemayehu, 2001) Bdl-24 showed a low level of injury and was considereda tolerant line. This indicates that osmotic adjustment could be correlated with drought tolerance.

In conclusion, although the injury levels among genotypes was minimum, it was possible to differentiate the genotype's reaction to drought tolerance using this test. Along with other artifical screening methods, this test could be useful for initial screening for drought tolerance.

Using many simple screening techniques to generate various types of data is very important when classifying drought tolerant and susceptible genotypes. In addition, these tests should be correlated with the field results.

References

Alemayehu Zemede, 2001. The Characterization of Ethiopian and South African bread and durum wheat genotypes for Drought Tolerance. M.SC. Thesis, Department of Plant breeding, Faculty of Natural Sciences and Agriculture , University of Free State , Bloemfontein, South Africa.

Beweley, J.D., 1979 Physiological aspects of desiccation tolerant, Annu. Rev.Plant Physiology 30:195-238

Blum, A and A.Ebercon, 1981. Cell Membrane Stability as a measure of drought and hear tolerance. Crop Science 21:43-47

Chen.H.H., Zheng-Yan Shen, and P.H.Li., 1982 Adaptability of crop plants to high temperature stress. Crop science 22:719-725.

Gupta, U.S. 1997. Crop improvement : Stress tolerance , volume 2 , Science Publishers, Inc., New York, London.

Mark,R.,A.A. Kenneth and H.D. Stanley, 1991. Leakage of Intracellular substances as an indicator of freezing injury in Alfalfa. Crop Science 31:430-435

Matin, M.A., H.B., Jarvis and F.Hayden, 1989. Leaf water potential, Relative Water content, and Diffusive Resistant as a screening Techniques for drought Tolerance in Barley. Agronomy Journal 81:100-105.

SAS Institute , 1996: SAS for analysis of variance. SAS Institute, Cary.

Sullivan, C.Y. 1972. Mechanisms of heat and drought resistance in sorghum and methods measurement. In N.G.P Rao and L.R House (ed.), Sorghum in the seventies. Oxford and IBH Publishing CO., New Delhi, India, pp. 65-69.

Rajaram, S.H.J, Braun, and M. Van Ginkel, 1996. CIMMYT's approach to breeding for drought tolerance. Euphytica 92:142-153.

William J.R. 1989. The dimensions of drought : Drought Resistance in cereals. In Baker, F.W.C. (ed.) CAB International pp.1-13.

Physiological Races and Virulence Diversity of *Puccinia graminis* f. sp. *tritici* on Wheat in Ethiopia

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Abstract—Physiologic races of *Puccinia graminis f. sp. tritici* (Pgt) isolates collected in Ethiopia were determined on seedlings of wheat stem rust differential cultivars following the international system of nomenclature for *Puccinia graminis*. 39 different races were identified from 49 isolates studied. The 16 rust isolates collected in 2001 belonged to 16 different race groups, whereas the 33 isolates collected in 2002 belonged to 23 different race groups. Most of the single pustule isolates selected from a single population showed variability, whereas some of them belonged to the same race group. The composition of physiologic races differed greatly between 2001 and 2002. Only races TTR and JGH were identified in both cropping seasons. Races such as TTT, TTR, TPT and RTT have wider spectra of virulence. Races such as TTR, TRR, TPR and DBL have wider spatial distribution whereas the rest are confined to certain localities. Generally, Pgt populations in Ethiopia appear to be highly variable, and this would be an important consideration for the breeding programme in the country.

Introduction

Wheat (*Triticum aestivum* L.) is the fourth largest food crop in Ethiopia, covering more than one million hectares of land and making up about 13% of the total crop production with an average yield of 1.4 ton per hectare (CSA, 2002). Demand of wheat has steadily increased in the last decades in Ethiopia. Though over 30 fungal diseases of wheat have been identified in Ethiopia, stem rust (caused by *Puccinia graminis* f. sp. *tritici*) is a major production constraint in most wheat growing areas of the country, causing yield losses of up to 100% in epidemic outbreaks. One such outbreak was reported in 1993/94 in the Southwestern part of Ethiopia in the Arsi and Bale regions, which are major wheat producing areas of the country. The previously resistant bread wheat cv. 'Enkoy' became highly susceptible during the epidemic (Ayele, 2002). Outbreaks of stem rust were also reported in 2003 in the same part of the country, the cause of which is as yet unknown.

Cultivation of resistant high yielding varieties is the most economical method of controlling rusts; however, due to sudden change in the rust race-pattern, commercial varieties often become vulnerable to rust attack. Breeding for vertical resistance, i.e. resistance to certain races of a pathogen has been main part of cereal breeding since earlier times (Hoerner, 1919; Stakman and Levine, 1922). Breeding varieties with a specific resistance has demanded systematic studies of race composition of pathogens. Thus, to study the prevailing and virulent races and the dynamics of race composition of the stem rust pathogen has a significant role in attaining sustainable disease control. This study was conducted to study the variations in the pathogen and to determine the prevalence and distribution of physiologic races of *P. graminis* f. sp. *tritici* in the major wheat growing regions of Ethiopia.

Materials and Methods

Field surveys were conducted in North Shewa, Arsi and Bale regions of Ethiopia in 2001and 2002 cropping seasons to collect samples of wheat stem rust. In both years the surveys were done during mid October when wheat plants were at flag leaf stage. The surveys followed main and feeder roads on preselected routes where wheat is important and stem rust is known to be present. Samples were randomly collected from commercial fields every 10 km or at the first field thereafter. In addition, biased sampling was done from strategically located Ethiopian Wheat Rust Trap Nursery sites throughout the regions. Infected leaf or stem samples were collected from breeding materials or commercial cultivars grown in the vicinity of those locations exhibiting infections. Three samples were collected per field including geographic information, and kept in paper bags.

A total of 49 stem rust isolates (16 in 2001 and 33 in 2002) were collected from Shewa, Arsi and Bale regions of Ethiopia. Seven day old seedlings of Morocco (highly susceptible genotype to stem rust) were inoculated with bulked spore populations collected from each field. Two to three single pustules were isolated from each sample, and were increased on morocco in separate pots in a greenhouse adjusted at 25 ± 2^{o}C to produce enough inoculum for the race study. Spores from each single pustule isolate was collected in separate test tubes and stored at 4^{o}C until they were inoculated on the standard differential sets of *P. graminis* f. sp. *tritici*.

A suspension of the spores (prepared by mixing urediospores with lightweight mineral oil) was inoculated onto seven day old seedlings of the standard differential cultivars. Immediately after inoculation, the seedlings were placed in a humid chamber in the dark for 24 hrs at 19-21^{o}C. After 24 hours, they were transferred to a greenhouse where the temperatures varied between 20 to 26^{o}C. In addition to the 12 standard differential hosts (that carried genes *Sr5, Sr6, Sr7b, Sr8a, Sr9b*, *Sr9e*, *Sr9g, Sr11*, *Sr17*, *Sr21*, *Sr30* and *Sr36*) used in determining *Puccinia graminis* f. sp. *tritici* races, several other known stem rust resistance genes were also included in the experiment.

Infection types displayed by the differential lines were scored 14 days after inoculation using the 0 – 4 scale of Mains and Jackson (1926). Races of *Puccinia graminis* f. sp *tritici* were assigned using the International code of Roelfs & Martens (1988).

Results and Discussion

Using the International system of nomenclature for *Puccinia graminis* f. sp. *tritici* (Roelfs and Martens 1988), 39 different races were identified from the 49 isolates. The 16 rust isolates collected in 2001 were identified as 16 different races and the 33 isolates collected in 2002 belonged to 23 different race groups. Most of the single pustules selected from a single population showed variability, whereas some of them belonged to the same race. The avirulence/virulence formulae for the 37 races are given in Table 2. Plants with genes *Sr9b* and *Sr17* displayed consistently high infection types to all races identified in 2001 except to isolates GDB, and RRG and GDB respectively. On the other hand, plants with genes *Sr30* displayed low infection types with the exception of races RTK and TTT. In 2002 plants with *Sr9b* and *Sr9e* genes were susceptible to most of the isolates identified in that year. Similar to the 2001 reaction of plants with the *Sr30* gene was found to be resistant to most of the collections made in 2002.

Most of the races identified in Ethiopia during the two seasons are virulent to most wheat differentials. For instance, a race like TTT identified in 2001 was virulent to all 12 standard differentials, which is a threat to Ethiopian wheat production. Similarly, race TTR which has got a wide spectrum of distribution (in the three regions) was virulent to all differentials except gene *Sr30*. It is also important to note that gene *Sr31*, which is known to confer resistance to races recorded up to now, has maintained its resistance to the races identified during 2001 and 2002 in Ethiopia.

The composition of physiologic races differed greatly between 2001 and 2002. Only races TTR and JGH were identified in both cropping seasons. Races such as TTT, TTR, TPT and RTT have wider spectra of virulence. Races such as TTR, TRR, TPR and DBL have wider spatial distribution whereas the rest are confined to certain localities. In all, 19 races from Bale, 15 from Arsi, and 7 from Shewa regions were recorded during the two years. This finding is indicative of high variability in occurrence of races across regions and over time.

Some of the races, e.g. RTR, TTR and KTR, differed in virulence or avirulence for only one gene. In case of such minor variations the more virulent race could have arose by simple mutation as has been stated by Singh (1991).

In general, absence of virulence in all rust pathotypes towards *Sr30* gene is a good indication that this genotype could serve as a source of resistance to the prevailing races in Ethiopia. Contrary to this, the breeding programmes in Ethiopia should avoid using materials with genes *Sr9b, Sr9e* and *Sr17* to develop wheat varieties for production purpose as they are susceptible to most of the races prevailing in the country. In addition, high virulence diversity observed in this study across regions and over time is assumed to be the cause for resistant materials to lose their resistance in a very short time. Therefore, the breeding programmes in the country should focus towards maintaining high genetic diversity in the cultivars and deploy cultivars with different resistance genes int different regions.

Table 1. *P. graminis tritici* races in Arsi, Bale and Shewa regions of Ethiopia during 2001 and 2002

Year	Region	Races
2001	Arsi	DRR, DTR, HGR, HRR, LPR, RTK, TTT
	Bale	JGH, KKR, KTR
	Shewa	CPR, GDB, KJR, RRG, RTR, TTR
2002	Arsi	DGG, DPR, JGH, JGQ, KGH, SGH, TRK, TTR
	Bale	DBG, FGG, FGR, FGQ, JGR, KGQ, KGR, KKQ, KQQ, RRT, RTT, TPR, TPT, TRR, TRT, TTR
	Shewa	KTR

Table 2. Avirulence/virulence formulae on *Sr* genes based on seedling reactions, for 37 races of *Puccinia graminis* f. sp. *tritici* identified in Ethiopia during 2001 and 2002

Number	Race	Avirulence/virulence formulae
1	CPR	5, 6, 9e, 21, 30 / 7b, 8a, 9b, 9g, 11, 17, 36
2	DBG	5, 6, 7b, 8a, 9g, 11, 17, 21, 30, 36 / 9b, 9e
3	DGG	5, 6, 7b, 9b, 11, 21, 36 / 8a, 9e, 9g, 17, 30
4	DPR	5, 6, 7b, 21, 30 / 8a, 9b, 9e, 9g, 11, 17, 36
5	DRR	5, 7b, 8a, 21, 30 / 6, 9b, 9e, 9g, 11, 17, 36
6	DTR	5, 7b, 21, 30 / 6, 8a, 9b, 9e, 9g, 11, 17, 36
7	FGG	5, 8a, 9g, 11, 17, 21, 30, 36 / 6, 7b, 9b, 9e
8	FGR	5, 8a, 9g, 11, 21, 30 / 6, 7b, 9b, 9e, 17, 36
9	FGQ	5, 8a, 9g, 11, 17, 21, 30 / 6, 7b, 9b, 9e, 36
10	GDB	5, 6, 7b, 9b, 9e, 9g, 11, 17, 30, 36 / 8a, 21
11	HGR	5, 8a, 9e, 9g, 11, 30 / 6, 7b, 9b, 17, 21, 36
12	HRR	5, 8a, 9e, 30 / 6, 7b, 9b, 9g, 11, 17, 21, 36
13	JGH	5, 7b, 8a, 9g, 11, 30, 36 / 6, 9b, 9e, 17, 21
14	JGQ	5, 7b, 8a, 9g, 11, 17, 30 / 6, 9b, 9e, 21, 36
15	JGR	5, 7b, 8a, 9g, 11, 30 / 6, 9b, 9e, 17, 21, 36
16	KGH	5, 8a, 9g, 11, 30, 36 / 6, 7b, 9b, 9e, 17, 21
17	KGQ	5, 8a, 9g, 11, 17 30 / 6, 7b, 9b, 9e, 21, 36
18	KGR	5, 8a, 9g, 11, 30 / 6, 7b, 9b, 9e, 17, 21, 36
19	KJR	5, 9g, 11, 30 / 6, 7b, 8a, 9b, 9e, 17, 21, 36
20	KKQ	5, 11, 17, 30 / 6, 7b, 8a, 9b, 9e, 9g, 21, 36
21	KKR	5, 11, 30 / 6, 7b, 8a, 9b, 9e, 9g, 17, 21, 36
22	KQQ	5, 8a, 9g, 17, 30 / 6, 7b, 9b, 9e, 11, 21, 36
23	KTR	5, 30 / 6, 7b, 8a, 9b, 9e, 9g, 11, 17, 21, 36
24	LPR	6, 7b, 9e, 21, 30 / 5, 8a, 9b, 9g, 11, 17, 36
25	RRG	8a, 9e, 17, 30, 36 / 5, 6, 7b, 9b, 9g, 11, 21
26	RRT	8a, 9e / 5, 6, 7b, 9b, 9g, 11, 17, 21, 30, 36
27	RTK	9e, 36 / 5, 6, 7b, 8a, 9b, 9g, 11, 17, 21, 30
28	RTR	9e, 30 / 5, 6, 7b, 8a, 9b, 9g, 11, 17, 21, 36
29	RTT	9e / 5, 6, 7b, 8a, 9b, 9g, 11, 17, 21, 30, 36
30	SGH	7b, 8a, 9g, 11, 30, 36 / 5, 6, 9b, 9e, 17, 21
31	TPR	6, 30 / 5, 7b, 8a, 9b, 9e, 9g, 11, 17, 21, 36
32	TPT	6 / 5, 7b, 8a, 9b, 9e, 9g, 11, 17, 21, 30, 36
33	TRK	8a, 36 / 5, 6, 7b, 9b, 9e, 9g, 11, 17, 21, 30
34	TRR	8a, 30 / 5, 6, 7b, 9b, 9e, 9g, 11, 17, 21, 36
35	TRT	8a / 5, 6, 7b, 9b, 9e, 9g, 11, 17, 21, 30, 36
36	TTR	30 / 5, 6, 7b, 8a, 9b, 9e, 9g, 11, 17, 21, 36
37	TTT	5, 6, 7b, 8a, 9b, 9e, 9g, 11, 17, 21, 30, 36

Table 3. Distribution of *Puccinia graminis* f. sp. *tritici* races in Arsi, Bale and Shewa regions of Ethiopia in 2001 - 2002.

Pathotype	Bale								Arsi							Shewa		Total	Percentage
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17		
CPR																1		1	2.7
DBG			2															2	5.4
DGG											1							1	2.7
DPR													1					1	2.7
DRR												1						1	2.7
DTR												1						1	2.7
FGG				1														1	2.7
FGR	1																	1	2.7
FGQ					1													1	2.7
GDB															1			1	2.7
HGR									1									1	2.7
HRR												1						1	2.7
JGH		1									1							2	5.4
JGQ													1					1	2.7
JGR						1												1	2.7
KGH														1				1	2.7
KGQ							1											1	2.7
KGR					1													1	2.7
KJR	1																	1	2.7
KKQ						1												1	2.7
KKR	1																	1	2.7
KQQ					1													1	2.7
KTR																	1	1	2.7
LPR											1							1	2.7
RRG															1			1	2.7
RRT	1																	1	2.7
RTK										1								1	2.7
RTR																1		1	2.7
RTT								1										1	2.7
SGH													1					1	2.7
TPR							1	2										3	8.1
TPT					1													1	2.7
TRK													1					1	2.7
TRR								1										1	2.7
TRT			1															1	2.7
TTR				1		1	3				1			1		1		8	21.6
TTT												1						1	2.7

1 = Adaba, 2 = Asasa, 3 = Robe, 4 = Sagure, 5 = Adali, 6 = Lemo, 7 = Sinana, 8 = Agarfa
9 = Kofele, 10 = Wabe, 11 = Bekoji, 12 = Kulumsa, 13 = Iteya, 14 = Era, 15 = Debre Zeit
16 = Negelle, 17 = Ankober

References

Badebo, A. 2002. Breeding bread wheat with multiple disease resistance and high yield for the Ethiopian highlands: Broadening the genetic basis of yellow rust and tan spot resistance. Cuvillier Verlag. Goettingen. Germany. Ph.D. Thesis.

CSA. 2002. Report on the preliminary results of area, production and yield of temporary crops. Addis Ababa. Ethiopia.

Hoerner, G. R. 1919. Biologic forms of *Puccinia recondita* on oats. Phytopathology 9: 309-314.

Mains, E. B. and Jackson, H. S. 1926. Physiologic specialization in the leaf rust of wheat, *Puccinia triticina* Erikss. Phytopathology 16: 89-92.

Roelfs, A. P. and Martens, J. W. 1988. An international system of nomenclature for *Puccinia graminis* f. sp. *tritici*. Phytopathology 78: 526-533.

Singh, R. P. 1991. Pathogenicity variation of *Puccinia recondita* f. sp. *tritici* and *P. graminis* f. sp. *tritici* in wheat-growing areas of Mexico during 1988 and 1989. Plant Disease 75: 790-794.

Stakman, E. C. and Levine M. N. 1922. The determination of physiologic forms of *P. graminis* on *Triticum spp*. Tech. Bull. 10. Univ. Minn. Agric. Exp. Stn. 1-10.

Participatory Evaluation of Bread Wheat Varieties in the Central Highlands of Ethiopia

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Abstract—Six bread wheat varieties were evaluated on a total of 26 non-water logging environments in four districts and on 20 water logging farms at the Ginchi watershed site in the central highlands of Ethiopia in 1999 and 2000. Combined analysis of variance over environments showed that Galema and Ketar significantly (P = 0.05) outyielded the rest of the varieties in non-water logging environments. At Ginchi, four varieties, namely Wetera, Shina, Galema and Ketar gave significantly (P = 0.05) higher yield than Tura and ET-13. Among the superior varieties, Wetera had the highest mean grain yield. In the participatory evaluations, farmers used their own criteria to select varieties. Weighted acceptance rank analysis showed that Galema scored first in their preference followed by Ketar, Wetera, Shina, ET-13 and Tura in descending order. The significance of such participatory evaluation of varieties on the seed systems in the region is discussed in the paper.

Introduction

In Ethiopia, bread (60%) and durum (40%) wheat occupy about 1.02 million ha of the total cultivated land, with a total annual production of 1.14 million tones (NSIA, 1998). The average national yield is low, and ranges from 1.1 t/ha for peasant farmers to about 2 t/ha on state farms (Hailu *et al.*, 1991). Other sources and personal communication with farmers in the central highlands, particularly Northern Shewa farmers, have revealed that they produce less than the national average yield. The use of unimproved varieties by subsistence farmers, for reasons that include lack of awareness, or the improved varieties themselves, (Hailu, 1988), is one of the major reasons for low productivity. Therefore, increasing the productivity of bread wheat is an important approach towards improving the living standards of low imput farmers, and could resolve, in part, the increased food demand of Ethiopia's rapidly growing population.

The national wheat improvement program, now split into the national bread and durum wheat improvement projects, has been conducting research in the central highlands of Ethiopia. This research indicates that there is a possibility of increasing wheat production by using improved technologies such as high yielding varieties, optimum fertilizer rate, integrated pest management, improved drainage on waterlogged areas and other crop management practices. Although selection, hybridisation and evaluation of bread wheat varieties under diversified soil conditions have taken place at various stages (Bekele *et al.*, 1994), evaluation of these elite bread wheat varieties for wider adaptation and sustainability under on-farm conditions, though the participation of farmers received little attention. In addition to these, the seed multiplication scale of the Ethiopian Seed Enterprise (ESE) does not meet current demand.

The short life span of improved varieties in production is also another constraint and it was estimated that the mean number of years a new variety stays in production is low, and ranges from 2.5 to 4 years (Reggassa *et al.*, 1998), beyond which the yield potential or disease resistance starts to decline. If a variety takes long to multiply and disseminate, it may not be as useful at the time it reaches the farmers. In this regard, more researchers are suggesting other avenues for seed production and multiplication that can supplement the ESE's production. These include the use of irrigation, informal secondary seed production, and the participation of the private sector.

Informal seed production on farmers' fields could contribute to meeting the farmers' seed demand, as well as facilitate the dissemination of technologies to the farmers (Gemechu *et al.*, 2004). As a result, research on adaptability and acceptance of new varieties in different localities with participation of farmers is desirable. With this in mind, the bread wheat breeding project at Holetta Agricultural Research Centre conducted a participatory bread wheat evaluation trial in the central highlands of Ethiopia.

The objectives of the experiments were to evaluate the adaptation and acceptability to farmers, of different bread wheat varieties under non-waterlogged and waterlogged sites, and to inform participating farmers about the benefits of secondary seed multiplication, both for seed, and income generation.

Materials and Methods

On-farm evaluation studies on six bread wheat varieties were conducted on non-waterlogged and waterlogged environments in the central highlands of Ethiopia for two cropping seasons (1999 and 2000). Thirteen (13) sites were selected from four districts: Guder, Jeldu, Meta-Robi and Selale in Northwest and West Shewa to represent non-waterlogged environments, and 10 farms from Ginchi to represent waterlogged environments. In the case of Ginchi each farm was considered as a block, whereas in other locations, each site had a complete experiment in RCB design with 4 replications. The varieties were sown on 10 x 10 m, and 4 x 5 m plots in the waterlogged and non-waterlogged sites respectively. DAP and urea fertilizers were applied at rate of 60:69 kg N: P_2O_5/ ha for non-waterlogged site, and 69:60 kg N: P_2O_5/ ha at Ginchi waterlogged farms. A seed rate of 175 kg/ha was used for all sites. Except for data collection, the farmers themselves handled all management practices.

In a field day organized by Wheat Research and Vertisol Project in 2000, farmers and researchers came together and evaluated the six varieties based on qualitative parameters, i.e. by seed color, seed size, baking quality, bread taste, nifro (boiled grain) and kolo (roasted grain) quality, with the full participation of farmers. The panelist farmers were asked to prioritize/ rank their selection criteria according to their importance. Average values of ranks were then used to give weights during ranking of the varieties against each selection criterion. Each panelist farmers (35 in number) were then given a chance to evaluate the varieties independently on a 1-10 scale (where 1 refers to the best and 10 refers to the least preferred) across each qualitative criterion. Finally, the acceptance of the varieties by the farmers was determined by analyses of weighted acceptance rank matrix i.e. by the sum of the product of the weight given to the criterion and ranks assigned to the varieties against each selection parameter.

For the combined ANOVA for grain yield in non-waterlogged environments, environments were assumed to be the combinations of locations, years and sites and only five of the varieties common for both years were analyzed using the SAS statistical software (SAS, 1998). For waterlogged sites combined ANOVAs by years were analyzed using MSTAT-C statistical software.

Results and Discussion

Grain yield

The results of combined ANOVA over environments in the non-waterlogged environments for grain yield revealed that there was significant (P = 0.05) yield difference among the tested varieties, environments and the interaction of variety x environment, suggesting a relatively inconsistent yield ranking of the varieties across a range of the test environments (Table 8).

With mean grain yields of 26.82 and 26.54 q/ha respectively, varieties Galema and Ketar yielded significantly better (*P* = 0.05) than the other varieties. Shina and the "local variety" (ET-13 A2) had statistically equivalent yield and gave significantly higher grain yield than Tura (Table 1). The analyses of variance for the varieties' grain yield performance across the years have also showed that there were highly significant (*P* = 0.05) variations among genotypes, environments and their interaction, except for year 1999, where the interaction was insignificant (Table 2). In most of the environments, except five cases, Galema and Ketar out yielded the "local check"(Table 3 and 4). The third best varieties for some environments was Shina, whereas Tura had lower yield than ET-13-A2 in most of the tested environments. The analyses of variance for grain yield across the environments showed that environment15 is the most suitable environment for wheat production with higher yield of 39.46 q/ha than the rest of testing environments and followed by environment 21,7 and 1 as the second, third and forth consecutively (Table 3 and 4).

Table 1. Mean grain and biomass+ yield (q/ha) of bread wheat varieties grown in non-waterlogged and waterlogged environments after combined analysis over years and environments*

	Non-waterlogged sites	Waterlogged farms	
Varieties	Grain yield	Grain yield	Biomass yield
Galema (HAR 604)	26.82	26.50 a	106.9 a
Tura (HAR 1775)	20.89	20.98 b	87.03 c
Shina (HAR 1868)	23.09	26.82 a	90.09 c
Ketar (HAR 1899)	26.54	26.27 a	98.16 b
Wetera (HAR 1920)		27.43 a	92.00 bc
"Local check" (EA-13-A2)	22.93	20.99 b	98.36 b
Mean	24.1	24.8	95.4
CV (%)	21.3	13.4	13.5
LSD (5%)		2.0	8.0
Root MSE	5.11		

*Combined analysis over locations refers only to non-waterlogged sites
+Biomass yield was taken only for waterlogged environments
Note: For non-waterlogged environments combined analysis was made only for five of the varieties, which were common for both years.

Table 2. Analysis of Variance of mean grain yield of bread wheat varieties grown in 13non-waterlogged environments for year 1999 and 2000

Year1999			Year 2000		
Source	DF	Mean Square	Source	DF	Mean Square
Env	12	1109.44**	Env	12	1613.83**
Gen	4	325.42**	Gen	5	441.61**
Env*gen	48	29.07NS	Env*gen	60	34.85*
Error	195	27.42	Error	234	24.94
Mean		23.90	Mean		23.59
Root MSE		5.24	Root MSE		4.99
C.V (%)		21.92	C.V (%)		21.17

NS, *, **= non significant, significant (p<0.05), and highly significant (p<0.01) respectively

Abbreviations: gen= genotype, Env= Environment

Table 3. Mean grain yield performance of bread wheat varieties grown in 13 non-water logged environments for year 1999

Varieties	Env1	Env2	Env3	Env4	Env5	Env6	Env7	Env8	Env9	Env10	Env11	Env12	Env13
ET_13	34.00	30.14	28.06	26.19	16.04	27.93	32.03	16.41	11.28	20.63	17.10	15.55	18.10
HAR1775	36.99	22.95	29.70	28.54	15.19	22.76	30.85	9.45	11.30	25.00	14.32	13.39	16.11
HAR1868	30.28	26.89	29.24	23.71	13.73	24.94	35.79	18.80	16.24	20.00	14.47	15.42	24.57
HAR1899	38.61	28.13	32.49	32.35	16.36	31.90	43.38	17.70	12.87	26.25	25.94	21.63	27.01
HAR604	38.88	29.35	31.18	30.43	15.85	23.80	36.70	19.11	17.06	24.75	19.17	21.41	26.70
Grand Mean	35.43	27.39	29.96	28.12	15.66	26.00	35.43	16.50	14.03	23.34	18.35	17.65	22.54
C.V (%)	4.57	5.92	5.41	5.76	10.35	6.18	4.57	9.82	11.55	6.94	8.83	9.19	7.19

Table 4. Mean grain yield performance of bread wheat varieties grown in 13 non-water logged environments for year 2000

Varieties	Env14	Env15	Env16	Env17	Env18	Env19	Env20	Env21	Env22	Env23	Env24	Env25	Env26
ET_13	25.65	36.98	21.94	16.22	18.94	24.36	12.05	41.77	25.06	18.41	22.24	19.06	20.03
HAR1775	20.03	38.09	22.66	14.70	16.37	21.01	9.81	28.58	19.73	18.36	19.38	17.63	20.27
HAR1868	22.16	40.89	27.99	15.77	15.64	23.06	10.88	43.27	19.30	18.87	26.23	16.64	24.06
HAR1899	22.66	42.38	25.98	16.82	18.48	23.01	14.74	47.64	21.59	22.85	28.05	21.91	29.52
HAR1920	14.83	37.12	19.96	14.03	15.88	20.70	10.84	33.17	18.42	16.17	17.44	21.73	26.42
HAR604	24.70	45.80	33.32	17.76	19.25	25.06	17.25	46.12	22.67	20.83	23.87	33.09	33.24
Grand Mean	21.76	39.46	25.32	16.23	17.71	22.90	13.09	39.35	21.24	19.44	22.90	21.76	25.50
C.V (%)	9.42	5.20	8.14	12.63	11.58	8.95	15.65	5.21	9.65	10.55	8.95	9.42	8.00

At Ginchi, in waterlogged farms, results of the combined analysis of variance over year revealed that there was significant difference in grain yield among the varieties (Table 9). However, year and year-by-variety interactions were non-significant. Among the tested varieties, Wetera gave the highest mean grain yield, 35.76 q/ha. Three varieties, namely Galema, Ketar, and Shina had statistically equivalent grain yield with Wetera, and showned significant yield advantage over Tura (27.62 q/ha) and ET-13A2 (27.32 q/ha) (Table 1). It seems that Shina could be a variety of choice under both conditions than the local check.

Results of the combined analysis of variance over years for biomass yield in waterlogged farms showed that there was insignificant differences among the varieties at the 5% level of significance. Unlike grain yield, variety-by-year interaction was also significant (Table 9). The highest mean biomass yield was obtained from Galema, which gave significantly higher biomass yields of 106.9 q/ha than the rest of the varieties followed by ET-13-A2, Ketar and Wetera in descending orders. Like the grain yield, the least biomass yield was registered in Tura (Table 1).

Table 5. Importance of wheat quality variables as ranked by farmers at Ginchi

Variables	Farmers						Total	Rank
	1	2	3	4	5	6		
Seed colour (SC)	4	5	3	3	4	4	23	4
Seed size (SS)	2	2	5	2	3	2	16	2
Backing quality (BQ)	7	3	4	5	7	5	31	5
Bread taste (BT)	3	7	2	4	2	3	21	3
Nifro quality (NQ)	8	8	7	7	8	7	45	8
Kolo quality (KQ)	6	4	6	6	6	6	34	6
Grain yield (GY)	1	1	1	1	1	1	6	1
Biomass yield (BY)	5	6	8	8	5	8	40	7

Table 6. Sum of scores given to the varieties against each selection criterion by 35 farmers and ranks (in parenthesis) determined accordingly

Variables	Varieties					
	Galema	Tura	Shina	Ketar	Wetera	Et-13
Seed colour	90(3)	188(6	66(1)	68(2)	143(4)	179(5)
Seed size	109(4)	176(5	73(1)	73(1)	88(3)	209(6)
Backing quality	61(1)	207(6	114(4)	114(4)	91(2)	103(3)
Bread taste	92(1)	191(6	106(3)	106(3)	98(2)	116(4)
Nifro quality	116(3)	161(6	84(1)	84(1)	126(4)	156(5)
Kolo quality	82(1)	162(5	107(4)	107(4)	96(3)	200(6)
Field performance*	92(3)	113(4	63(1)	122(5)	75(2)	157(6)
Grain yield**	(3)	(5)	(2)	(4)	(1)	(6)
Biomass yield**	(1)	(5)	(6)	(2)	(4)	(3)

* It was taken from 30 panellists; ** Ranks are determined from mean yield values

Table 7. Weighted acceptance values obtained by multiplying of weights given to each selection criterion and the ranks of the varieties against each parameters used to determine final acceptability rank

	Variables with their weights									
Variety	GY (1)	SS (2)	BT (3)	SC (4)	BQ (5)	KQ (6)	BY (7)	NQ (8)	Total	Final rank
Galema	3	8	3	12	5	6	7	24	68	1
Tura	5	10	18	24	30	30	35	48	200	6
Shina	2	4	15	4	25	12	42	16	120	4
Ketar	4	2	9	8	20	24	14	8	89	2
Wetera	1	6	6	16	10	18	28	32	117	3
Et-13	6	12	12	20	15	36	21	40	162	5

Table 8. Combined analysis of variance over environments for grain yield of five bread wheat varieties grown in 26 non-waterlogged environments in year 1999 and 2000

	Grain yield	
Source of variations	DF	Mean square
Env	25	1210.108**
Gen	4	675.991**
Env x Gen	100	33.555*
Error	390	26.12
Mean		24.05
Root MSE		5.11
C.V (%)		21.25

NS, *, **= non significant, significant (p<0.05), and highly significant (p<0.01) respectively
Abbreviations: gen= genotype, Env= Environment

Table 9. Combined analysis of variance over years for grain and biomass yield (q/ha) for six bread wheat varieties tested at Ginchi watershed farmlands

	Grain yield		Biomass yield
Source of variations	DF	Mean square	Mean Square
Year			
Farmlands within year	1	105.1 NS	113.1*
Variety	18	83.73 NS	989.1NS
Year x variety	5	180.6**	1031.1*
Error	5	10.8NS	525.6*
r	90	9.2	164.8
Mean		24.8	95.4
C.V (5%)		13.4	13.5
LSD		2.0	8.0

NS, *, **= non significant, significant (p<0.05), and highly significant (p<0.01) respectively
Abbreviations: gen= genotype, Env= Environment

Farmer participatory evaluation of the six wheat varieties considered both qualitative and quantitative parameters. Qualitative parameters determining farmers' varietal preferences, as identified by farmers themselves, were seed color, seed size, baking quality, bread test, nifro (boiled grain) and kolo (roasted grain) quality. Grain and biomass yield were also considered. Farmers also evaluated field performances of the varieties before harvesting. The participant farmers made the prioritization of these pre- and post-harvest parameters in field days organized by the vertisols project and the bread wheat research project at Holetta Agricultural Research Center.

Grain yield was unanimously considered to be of paramount importance by all farmers reflecting that it has been a prime selection criterion for the subsistence farmers in particular. Quality of boilded grain ranked lowest as a criterion for evaluating the varieties (Table 4). Results of variety-acceptance evaluation from more than 30 participant farmers/ panelists for all qualitative and quantitative criteria indicated that Galema was preferred over the local check. Ketar and Wetera were also ranked higher than the local check for all qualitative and quantitative parameters, except baking quality and biomass yield respectively (Table 5).

The final weighted direct matrix for acceptance rank showed that, all the varieties except Tura ranked higher than the local check, and that Galema was the overall favorite variety, followed by Ketar, Wetera and Shina (Table 6).

During field days, farmers recognized the importance of secondary seed multiplication as a path to obtaining improved seeds. These farmers had sown their preferred varieties (Wetera, Galema and Ketar) from their first year harvest on larger plots to use as seeds for subsequent years, and to sell or barter with fellow farmers.

Access to improved technology has been constrained by many factors contingent with poorly developed seed industry. Among theses factors is smallholder farmers' inability to pay for the improved seed and fertilizer. Through participatory variety evaluation, however, the farmers were spent less money on seed purchase, and obtained the newly released variety, which otherwise would take many more years to reach them, ahead of time. Kassa *et al.* (2000) have indicated the positive impact of such an intervention based on the success observed in Gudar, one of the study areas of this work. In that study, it was possible to disseminate variety Galema around Gudar and other areas, in less than 4 years, with the distribution to remoter areas being mediated by NGOs. Although we did not take actual figures as to the extent of dissemination, we did witness the fascination of the workshop participants with their fellow farmers who had taken the lead to work with the researchers in seed production. The participating farmers were very eager to obtain the improved wheat varieties.

Although the ESE has been showing comprehensive and rapid progress in seed production through contractual seed production agreements with private enterprises, Ethiopian Agricultural Research Organization (EARO), Regional Agricultural Research Centers (RARC), farmers and state farmers, it has not been meeting the escalating demand for improved seed in the country (Demesie, 2004 and Girma *et al.*, 2004). According to CTA (1999), only about 7% of the total seed requirement for wheat has been supplied by ESE. The majority of the national seed demand still depends on the informal community based seed system (Abdissa *et al.,* 2001). Hailu (1992) has shown that the informal farmer-to-farmer exchange system contributes 85% of the total seed requirement.

In addition to the aforementioned problems, lack of information about improved seeds has been crucial in addition to the complex socioeconomic problems of the stakeholders. Farmer participatory evaluation and demonstration of improved crop varieties, therefore, has a vital role to play in effective diffusion of technology among farmers rather than any others technology transformation methods (Tesfaye *et al.*, 2004). Some earlier reports have also emphasized that informal seed systems, where by farmers themselves produce seeds with some technical assistance from seed specialist, extension workers or breeders should be strengthened to overcome seed availability constraints (Frew and David's, 1999).

Conclusions and recommendations

In non-waterlogged areas, Galema and Ketar yielded well, and could be promoted on a large scale in the central highlands of Ethiopia and in other areas with similar agro-ecologies.

In waterlogged areas, Wetera, Shina, Galema and Ketar performed almost equally, and could be promoted there. Shina yielded better, and was less sensitive to the environment than the local check in waterlogged areas. However, in non-waterlogged sites Shina yielded lower that the local check.

The performance of Tura, in both waterlogged and non-waterlogged environments was poorer than the local check, and hence it would not be a good choice for production in the study areas.

Based on our experience in the study areas, if strengthened, informal farmer-to-farmer seed exchange system could be of great importance in disseminating improved seed, of wheat and other crops.

Acknowledgement—The authors acknowledge the staff of Ethiopian Rural Self Help Association (ERSHA) at Gudar and Food for Hunger International (FHI) at Metarobe for their help in organizing farmers for participatory work. We are also grateful to Vertisols project team for the support in financing the field days. The contribution of technical assistants of bread wheat improvement project, namely Assefa Yilma, Chanyalew Mandefro, Adane Meresa, Emebet Admasu, Kassech Birhanu, Assefa Gabisa and Hirut Yirga is sincerely appreciated.

References

Abdisa Gemeda, Girma Aborha, H. Verkuijl and W. Mwongi. 2001. Farmers' Maize Seed Systems in Western Oromia, Ethiopia. Mexico, D.F, International Maize and Wheat Improvement Center (CIMMYT) and Ethiopian Agricultural Research Organization (EARO). p. 18 – 20.

Bekele Geleta, Ammanuael Gorfu and Getnet Gebeyehu. 1994. Wheat Production Research in Ethiopia: Constraints and Sustainability. In: Tanner, D.G (eds.). Developing Sustainable Wheat Production Systems: The Eighth Regional Wheat Workshop for Eastern, Central and Southern Africa. Addis Ababa, Ethiopia: CIMMYT. p. 12 – 18

CTA. 1999. The Role of Smallholder Farmers in Seed Production Systems. Report and Recommendation of Study Visit to Zimbabwe. 15 – 16 February 1999. Syee Publishing, London, United Kingdom.

Demesie Chanyalew. 2004. Improved Crop Varieties, Food Deficit, Seed and Land Use in Ethiopia: Trend and Gap Analysis. In: Asefaw Zelleke, Getachew Belay, Belay Simane, Bulcha Weyessa and Nigussie Alemayehu (eds.). Crop Science Society of Ethiopia (CSSE). Sebil.Vol.10. Proceedings of the tenth conference, 19 – 21 June 2001, Addis Ababa, Ethiopia. p. 279 – 292

Frew Mekibib and S. David. 1999. Informal Bean (*P. Vulgaris* .L) Seed System in Eastern Ethiopia: Implication for Establishment of Sustainable Seed System in Ethiopia. Alemaya University, Research Report. Series No. 1, Alemaya, Ethiopia.

Gemechu Keneni and Adugna Wakjira. 2004. Genetic Uniformity of Crop Cultivars: Challenges and Opportunities. In: Asefaw Zelleke, Getachew Belay, Belay Simane, Bulcha Weyessa and Nigussie Alemayehu (eds.). Crop Science Society of Ethiopia (CSSE). Sebil.Vol.10. Proceeding of the tenth conference, 19 – 21 June 2001, Addis Ababa, Ethiopia. P. 1 – 9.

Girma Abera, Mathewos Belissa, Shimellis Dejene, Hailu Gudeta and Gebremedhin W/Giorgis. 2004. Enhancing Food Security Through Farmers Based Seed System, The Case of Improved Potato Production Technology Transfer in Western Ethiopia. Research Report. Oromiya Agricultural Research Institution, Bako ARC, Oromiya, Ethiopia.

Hailu Gebre.1988. Crop Agronomy Research on Vertisol in the Central Highlands of Ethiopia: In: S.C. Jutzi, L. Haque, J. Mc Intire and J.E. Stares (eds.). Management of Vertisols in Sub-Saharan Africa. Proceeding of a Conference, 31 Aug- 4 Sept. 1987. ILCA, Addis Ababa. p. 263-283.

Hailu Beyene, Wilfred Mwangi and Workneh Negatu. 1991. Research Conducted on Wheat Production Constraints in Ethiopia. In: Hailu Gebremariam, Tanner, D.G. and Mengistu Hulluka (eds.). 1991. Wheat Research in Ethiopia: A Historical Perspective, Addis Ababa, IAR/CIMMYT. p. 17 – 32

Hailu Gebremariam. 1992. Availability and Use of Seed in Ethiopia. Addis Ababa, Ethiopia. Program Support Unit, Canadian International Development Agency.

Kassa Getu, Kassahun Zewdi, Amsal Tarekegne and Girma Taye. 2000. Farmer Participatory Evaluation of Bread Wheat Varieties and Its Impacts on Adoption of Technology in West Shewa Zones of Ethiopia. In: The Eleventh Regional Wheat Workshop for Eastern, Centeral and Southern Africa. Addis Ababa, Ethiopia: CIMMYT. p. 427-431.

NSIA (National Seed Industry Agency). 1998. Crop Variety Registration. Issue Number 1. Addis Ababa, Ethiopia. p. 12.

Reggassa Ensermu, Wilfred Mwangi, Hugo Verkujil, Mohammed Hassena and Zewdie Alemayehu. 1998. Farmers' Wheat Seed Source and Seed Management in Chilalo Awraja, Ethiopia. Mexico, D.F: IAR and CIMMYT.

SAS. 1998. The SAS System for Windows^{TM}. SAS Institute Inc.

Tesfaye Zegeye, Girma Taye, Douglas Tanner, Hugo Verkuiji, Aklilu Agidie and Wilfred Mulangi. 2004. Adoption of Improved Bread Wheat Varieties and Inorganic Fertilizer by Small Scale Farmers in Yelmane Bensa and Forta Districts of North West Ethiopia. In: Asefaw Zelleke, Getachew Belay, Belay Simane, Bulcha Weyessa and Nigussie Alemayehu (eds.). Crop Science Society of Ethiopia (CSSE). Sebil.Vol.10. Proceeding of the Tenth Conference, 19 – 21 June 2001, Addis Ababa, Ethiopia. p. 246 - 258

Part 3. PROTECTION

Survey of Natural Enemies of the Russian Wheat Aphid, *Diuraphis Noxia* (Kurdijimov) in Kenya

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Abstract—The Russian wheat aphid, *Diuraphis noxia* (Kurdijimov), was first noticed in Kenyan farmers' wheat (*Triticum aestivu*m L.) fields in 1995. Currently, Russian wheat aphid control relies mainly on use of insecticides to kill aphids already established on the crop. In an effort to enhance the integration of natural enemies in an integrated pest management control strategy, surveys were initiated to document and determine the effectiveness of natural enemies that attack the Russian wheat aphid. A number of predators and parasitoids were observed to attack cereal aphids, but none of these bio-control agents exerted adequate controls. The observed predators were Coleoptera: *Adonia variegata* and *Cheilomenes* spp.; Diptera: Syrphidae (hover flies); Arachnoidea (spiders) and Neuroptera (lacewings). Parasitoids observed were Hymenoptera: *Aphidius* spp. and *Aphelinus* spp. Field observations and results of research carried out indicated that peak population densities occurred after peak percentage infestation by the wheat aphid. It was observed that the increased numbers of natural enemies did not have any noticeable impact on RWA as they arrived late in the season when the pest had already caused damage to the wheat crop. Russian wheat aphid was observed to be attacked by several predators and parasitoids commonly associated with other cereal aphids. Efforts should therefore be made to conserve these bio-control agents. They are of great importance in controlling other cereal aphids, and may as well reduce Russian wheat aphid populations.

Introduction

In Kenya, the six important cereal aphids species that attack wheat are *Diuraphis noxia*, *Schizaphis graminum*, *Sitobion avenae, Rhopalosiphum padi, R. maidis*, and *Metopolophium dirhodum* (Wanjama, 1990; Macharia et al, 1993; Macharia et al, 1997). Of these six species of cereal aphids, D. noxia, the Russian wheat aphid (RWA), is the most destructive followed by *S. graminum*. The other species are less important. Besides their direct damage to wheat crops through sucking of plants sap, the aphids transmit barley yellow dwarf virus (Wangai and Torres, 1990).

Currently in Kenya, RWA control relies mainly on use of insecticides to kill cereal aphids already established on the crop and so prevent or reduce the risk of further spread. However, chemical control of RWA has proven difficult because of its habit of colonising the inner surfaces of tightly curled leaves of damaged plants.

Worldwide, the use of biological control agents is seen as a desirable alternative to insecticides because of its low cost, sustainability and environmental friendiness. In Kenya, most of the growers are subsistence farmers, and neither the crop, nor the resources of the farmers can warrant the use of repeated insecticidal applications against the cereal aphid pests. Expense and possible environmental pollution from insecticide use are of major concern to the farmers. Farmers may prefer to reduce losses through the use of resistant cultivars and/or in combination with effective natural enemies.

Majority of wheat growers in Kenya are not aware of cereal aphid biological control measures. However, majority of farmers will be willing to stop spraying pesticides should the biological control strategy be effective. Due to the wide range of aphid species that attack wheat and barley (Hordeum vulgare L.) in Kenya, causing substantial yield losses of 10-100% (Macharia et al, 1997), biological control strategies must be developed that will enhance the integration of these control agents in an Integrated Pest Management (IPM) control strategy. Therefore surveys were initiated to document and determine the effectiveness of natural enemies that attack RWA. In addition, studies were also initiated to evaluate the effectiveness of these natural enemies.

Materials and Methods

Surveys in the farmers' fields around Njoro, Kenya were carried out in 2001-2002 cropping season. The surveys were carried out at late tillering stage (G.S. 25; Lancashire *et al*., 1991) of the wheat crop. The aphids were sampled by examining 20 plants randomly along diagonals within the fields at approximately 50m intervals. The aphid species were collected, identified for confirmation and recorded (Blackman *et al,* 1985). Predators, parasitized aphids and parasitoids were also collected for species identification.

Field studies to determine the effectiveness if the natural enemies were initiated in 2002. In June 2002, a 20 x 20m strip was seeded with the bread wheat cultivar Kwale at 75 kg/ha. This late planting was timed to coincide with peak aphid infestations at Njoro. Plots were fertilized at the rate 18kg nitrogen and 46kg P_2O_5 /ha. Plots were kept weed free by application of Buctril MC (Bromoxynil +MCPA) at the rate of 1.25 l/ha. Leaf diseases were controlled by applying Folicur 250 EW (Tebuconazole) at the rate of 0.75 l/ha.

Assessment of the RWA and endemic natural enemies' [predators and parasitoids] occurrence was done by taking a random sample of 20 plants from the wheat field, once per week. Sampling commenced 2 weeks after germination and continued for 8 weeks. The data taken included: number of RWA/plant; number of *Adonia variegata* and coccinellid larvae; incidence of parasitism; and percentage of plants damaged by RWA. The infested wheat plants were examined in the field for the presence of natural enemies. The aphid species were identified (Blackman and Eastop, 1985) and the particular predator/parasitoid identified and recorded.

Results and Discussion

The survey revealed that wheat is attacked by several species of cereal aphids.
The aphid species collected during the survey, in decreasing order of importance were, *D. noxia, M. dirhodum, R. maidis, R. padi, S. avenae and S. graminnum*. Similar observations have been reported by Macharia *et al*. (1997).
Several types of predators and parasitoids (Table 1) attacked most of these cereal aphids.

Predators
(a) Coccinellid beetles, *Adonia variegata* (Goeze) and *Cheilomenes* species were the most important. Their populations were rather low and tended to occur late in the season, at heading stage of the wheat crop. Population density of the coccinellid beetles was observed to be about 1.8 beetles per plant. Haile and Megenasa (1987) have reported similar observations.
(b) Hoverflies (Syrphidae) were also important predators with their population peaks coinciding with peak aphid infestation at heading stage of wheat. They were second in importance to coccinellid beetles. Population density of the hoverfly was observed to be about 0.6 larvae per plant

(c) Lacewings (Neuroptera) and spiders (Arachnoid) were also observed in very low population levels and tended to occur from late tillering to heading stage of the crop. Population density of the Lacewings was observed to be about 0.3 and 0.1 spiders per plant.

Parasitoids

The most important parasitoids were *Aphidius spp* and *Aphelinus spp* both of which attack *D. noxia.* Their population densities tended to be low and appeared late in the season after RWA population peak and showed only about 5% parasitism. All these natural enemies somehow occur at different times during the cropping season and they may be collectively contributing to season long control of RWA and other cereal aphids in the wheat crop. The survey revealed that many of the natural enemies (predators and parasitoids) of other cereal aphids also attack RWA although none of them exerted adequate control (Table 1). Peairs (1998) and Gary *et al.* (1998) have reported similar results. The absence of successful aphid predators and parasitoids may explain the rapid spread of RWA. Field observations also revealed that the natural enemies of RWA were only present late in the crop season when damage to wheat and barley crops had already taken place.

Data presented in (Table 2) indicates that peak percentage infestation by RWA occurred at the end of mid-July to mid-August which coincided with start of stem elongation to full flag leaf emergence (GS 37; Lancashire *et al*., 1991).
This was the period of exponential increase in percentage infestation.

Population density of RWA peaked in mid- August [135.3 aphids per plant] (Table 2). Field observations revealed that initial field infestations of wheat by RWA started from the edges of the field followed by high natural enemy activity. The number of coccinelids *A. variegata* and *Aphidius* spp rose from end of July onwards, reaching population peak at the end of August. This is probably in response to the increase in aphid numbers (Table 2). This indicates that the natural enemies had their greatest impact at the end of the season when RWA population was on the decline. It was observed that the increased numbers of natural enemies did not have any noticeable impact on RWA as they arrived late in the season when the pest had already caused damage to the crop.

Table 1. Predators and parasitoids of aphids recorded in wheat fields around Njoro, Kenya, 2001-2002.

Predators and parasitoids	Cereal aphid species					
	D. noxia	*M. dirhodum*	*R. maidis*	*R. padi*	*S. avenae*	*S. graminum*
Predators						
Coleoptera [Beetles]						
Adonia variegata	x	x	x	-	x	x
Cheilomenes spp.	x	x	x	-	x	x
Diptera						
Syrphidae [Hover flies]	x	x	-	x	x	x
Arachnoidea [Spiders]	x	x	x	x	x	x
Neuroptera [Lacewings]	x	x	x	x	x	x
Parasitoids						
Hymenoptera						
Aphidius spp.	x	x	-	x	x	x
2. Aphelinus spp.	x	x	-	x	x	x

Table 2. Mean counts of percentage Russian wheat aphid (RWA) infestation, No. of RWA per plant [apterae and alates], *Adonia variegata* and coccinellid larvae, and No. of mummies [*Aphidius* spp] at Njoro, 2002.

	Sampling dates					
	30 June	5 July	30 July	15 Aug.	30 Aug.	15 Sept.
Growth stage	21	25	29	37	51	59
% RWA infestation	4.2	23.9	82.5	100.0	100.0	100.0
No. of RWA/plant	5.2	32.5	100.2	135.3	10.3	1.1
No. of *Adonia variegata* & larvae/plant	0.0	0.0	5.6	22.5	30.3	20.1
No. of mummies [*Aphidius* spp.]/plant	0.0	0.0	2.1	10.5	12.2	9.2

Conclusion

Several natural agents, including predators such as coccinelids beetles, hoverflies, lacewings, spiders and parasitoids including *Aphidius* spp and *Aphelinus* spp were recorded during the survey as important natural enemies of cereal aphid populations. Due to their low numbers, they were not effective controls and were unable to keep RWA populations below damaging levels. Efforts should be made to conserve these natural enemies as they of great importance in controlling the cereal aphids and may as well reduce RWA populations.

It was also observed that at earlier seedling stages, the population of natural enemies was too low to exert effective cereal aphid control. The populations of these natural enemies increased only with the rise of cereal aphids. The increased numbers of natural enemies were observed not to have any effective impact on the population control of RWA.

Biological control strategies must be developed that enhance the integrated operation of these natural enemies of cereal aphids. RWA management will become increasingly reliant on adoption of wheat crop production systems that enhance and improve in the effectiveness of biological control agents.

References

Blackman, R.L., and V. F. Eastop. 1985. Aphids on the world's crops, An Identification Guide. Wiley, Chichester. U.K.

Gary, L.H., F. P. Baxendale, J. B. Campbell, A. F. Hagen, and J. A. Kalisch. 1989. Russian Wheat Aphid. Neb Guide G89-936-A. Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln.

Haile A. and T. Megenasa. 1987. Survey of aphids of barley in parts of Shewa, Welo and Tigrai, Ethiopia. Ethiop. J. Agric. Sci. Vol 9 No. 1: 39-53.

Lancashire, P.PD., Bleiholde, H., v.d. Boom, T.,Langeludedeke, P.,Staus, R., Weber, E. and Witzenberger,A. 19991. A uniform decimal code for growth stages of crops and weeds. Ann appl. Biol.119,561-601

Macharia, M., P.M. Muthangya and J.K. Wanjama. 1997. Management of Russian wheat aphid, *Diuraphis noxia*, on wheat in Kenya by use of seed dressing insecticides. African Crop Science Conference Proceedings, Vol. 3. Pp. 1191-1198.

Macharia, M., P.M. Muthangya, A.W. Wangai and J.K. Wanjama. 1993. Barley Yellow Dwarf Virus Report 1990-1993. Kenya Agricultural Research Institute, National Plant Breeding Research Centre, Njoro, Kenya.

Peairs, F.B. 1998. Russian Wheat Aphid Management. In: The Inaugural National Wheat Industry Research Forum Proceedings .San Diego, California. January 14 and15, 1998

Wanjama, J.K. 1990. Ecology of cereal aphids transmitting Barley yellow dwarf virus in Kenya. Pages 240-243. In: P.A. Burnnet (ed.), World perspectives in Barley Yellow Dwarf. CIMMYT, MEXICO, D.F.

Wangai, A.W. and E. Torres. 1990. Barley yellow dwarf virus situation report for Eastern Africa with special emphasis in Kenya. Page 71 In: P.A. Burnnet (ed.), World perspectives in Barley Yellow Dwarf. CIMMYT, MEXICO, D.F.

Evaluation of the Herbicide Monitor, Alone and in Tank-Mixes for Weed Control in Wheat (*Triticum aestivum* L.)

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Abstract—Experiments were conducted at Wangu Embori Farm (Timau) and Purko Farm (Mau Narok), Kenya to evaluate the effect of the herbicide Monitor [1-(2-ethylsulfonylimidazo [1,2-a] pyridin-3-ylsulfonyl)-3-(4,6-dimethoxypyrimidin-2-yl) urea] alone and in tank-mixes with Derby (a.i. Flurasulam + Flumetsulam) and Buctril MC (a.i. Bromoxynil + MPCA), for management of brome grass (*Bromus* spp.) and broadleaf weeds in wheat (*Triticum aestivum* L.). Monitor, was screened at 20, 25, 30, 35, 40, and 40g ha^{-1} (two applications of 20g ha^{-1} each with an interval of three weeks) and 80g ha^{-1}, all with Agral 90 as a surfactant at 0.25% v/v. At 40g ha^{-1} Monitor was tank mixed with Derby and Buctril MC at the rates of 50 and 375ml ha^{-1} respectively, but in the second and third seasons the rate of Buctril MC was increased to 700ml ha^{-1}. Monitor was also tank mixed with Derby at 80g ha^{-1} and 100ml ha^{-1} respectively. Cossack (a.i. Mesosulfuron + iodosulfuron) was used as the standard herbicide at the rate of 300g ha^{-1} + 150ml ha^{-1} of Agral 90. Monitor at 30, 40 and 80g ha^{-1} gave excellent control of *Bromus sterilis*, G*alium spurum*, *Emex australis* and *Chenopodium album.* The activity of Cossack on the target weeds at the site was comparable to that of Monitor at 80g ha^{-1} and its tank mix partners. Some significant differences were observed among treatments with regard to efficacy and phytotoxicity (crop height). Crop emergence (m^{-2}), TKW (g), spike density m^{-2} and wheat grain yield (t ha^{-1}) in certain seasons did not have any significant differences between the herbicide treatments. Herbicide phytotoxicity was influenced by the rate of application of Agral 90.

Introduction

Wheat is the second-most-important cereal crop in Kenya, but local production does not satisfy demand, and the deficit must be imported. It is therefore vital to place emphasis on production strategies that will inrease wheat grain yield. Improved weed management is one such strategy.

Under farm conditions in Kenya, the weed flora is in a state of continuous change. Human activities influence and alter the balance of the weed species in specific localities. Cultural practices such as liming, increased fertilizer usage and changing cropping patterns all favour some weeds, and reduces others. The more widespread use of herbicides that selectively kill broadleaf weeds has favoured profuse multiplication of some annual grasses, previously not important agronomic weeds. *Bromus* spp. and other annual grasses are now very important weeds, and require proper management.

As is always the case weeds are competitive, persistent and pernicious. Because of these attributes, efficient and successful weed control should integrate different methods. Farmers' efforts to reduce the growth and proliferation of weeds in their wheat fields by means of rotations, and other cultural practices do much to reduce the number of weeds able to set seed and so improve the quality of grain harvested. But these activities are not enough to ensure a wheat crop that is not adversely affected by weeds.

Economic weed control in cereals requires strategies based on intelligent or judicious use of herbicides, coupled with appropriate cultural practices. Weed populations at which an economic yield response can be expected from the use of herbicides are difficult to define and vary according to the time of weed germination and the growth of weeds in comparison to the crop.

This evaluation trial focused mainly on the effect of Monitor at different application rates, alone and in tank-mixes with Derby and Buctril MC, on brome grass (*Bromus* spp.) and broad-leaf weeds. The pernicious effects of the herbicide treatments on the wheat crop were also assessed.

Monitor (sulfosulfuron) has the chemical name: [1-(2-ethylsulfonylimidazo [1,2-a] pyridin-3-ylsulfonyl)-3-(4,6-dimethoxypyrimidin-2-yl) urea]. It is a post-emergence herbicide that enters the plant through both foliar uptake (60%) and root uptake (40%). Monitor kills the target plants by inhibiting the formation of amino acids essential for cell division.

Materials and Methods

The experiment was conducted in three seasons. The first season trial was done at Purko Farm, Mau Narok. It was planted on 28-8-02, using the wheat cultivar Mbuni at a seed rate of 90kg ha^{-1}. Basal fertilizer (DAP = 18:46:0 N:P_2O_5:K_2O) was applied at the time of planting at the rate of 100kg ha^{-1}.

The second season experiment was superimposed on a commercial wheat crop (cv. K. Kwale) planted on 3-4-2003 at Wangu Embori Farm in Timau. The seed rate was 110kg ha^{-1}. Monoammonium phosphate (MAP 11:52:0 N:P_2O_5:K_20) was applied at seeding at the rate of 147kg ha^{-1}. The site was previously under commercial wheat.

The third season trial was also conducted at Wangu Embori Farm. Wheat cultivar, Kenya Mbuni was seeded on 16-10-2003 using a crop seeder at a seed rate of 100kg ha^{-1}. MAP was drilled with the seed at 150kg ha^{-1}. The trial site was previously under commercial wheat where weeds were controlled using Attribut 75 WG (a.i. Propoxycarbozone).

The herbicide treatments applied in the three seasons are shown in Tables 1 and 2. Herbicide treatments were applied at 48 days, 55 days and 28 days after planting in the first, second and third seasons respectively.

Table 1. Herbicide treatments included in the first (Purko Farm, Mau Narok) and second (Wangu Embori Farm, Timau) seasons.

Herbicide treatment	Rate ha^{-1}
Monitor + Agral 2%*	20g + 3L
Monitor + Agral 2%	25g + 3L
Monitor + Agral 2%	30g + 3L
Monitor + Agral 2%	35g + 3L
Monitor + Agral 2%	40g + 3L
Monitor + Agral 2% Two applications 3 weeks apart	20g + 3L and 20g + 3L
Monitor + Buctril MC + Agral 2%	40g + 375ml + 3L
Monitor + Derby + Agral 2%	40g + 50ml + 3L
Cossack + Agral 1%	250g + 1.5L
Cossack + Agral 1%	300g + 1.5L
Monitor + Hussar OF + Agral 2%	30g + 150g + 3L
Untreated control	-

* Vol/vol.

Table 2. Herbicide treatments in the third season. Wangu Embori Farm, Timau.

Herbicide treatment	Product Rate ha^{-1}
Monitor + Agral 0.25% v/v	30g + 375ml
Monitor + Agral 0.25% v/v	40g + 375ml
Monitor + Agral 0.25% v/v	20g + 375ml (Repeated 3 wks later)
Monitor + Derby + Agral 0.25%	40g + 50ml + 375ml
Monitor + Agral 0.25% v/v	80g + 375ml
Monitor + Derby + Agral 0.25% v/v	80g + 100ml + 375ml
Monitor + Buctril MC + Agral 0.25% v/v	40g + 700ml + 370ml
Cossack + Agral 0.1% v/v	300g + 150ml
Untreated check	-
Hand weed check	-

In all trials, the herbicide treatments were arranged in a randomized complete block replicated four times. The trial plots measured 3m X 6m. The herbicide treatments were applied using a hand operated knapsack sprayer with a 2m spray swath and 150L ha^{-1} nozzle delivery volume. Measurements of relative humidity, ambient temperatures and wind speed were not made due to lack of instruments. The soil was moist at the time of herbicide application in all the trials and the crop and weeds were growing vigorously: a prerequisite for effective performance of soil acting herbicides.

Before treatment application the most prevalent weed species at the sites were identified and counted in $1m^2$ quadrats in each plot. These sampling areas were marked and changes in weed density monitored three times at intervals of fourteen days. Crop reaction to herbicide treatments was first assessed visually three days after application and subsequently on each day weed counts were taken.

Weed species that were biologically alive 28 days after herbicide application were deemed to have escaped herbicidal effect. Treatment effects on weeds were expressed in terms of percentage mortality, a quantitative response that reflects the degree of weed control (efficacy) achieved. The formula below was used to derive mortality.

$$\text{Percentage mortality (efficacy)} = \frac{(X - Y)}{X} \times 100$$

where,

X is the mean number of weeds per plot in untreated plots and

Y is the mean number of weeds per plot receiving specific treatment.

Crop emergence (plants m^{-2}) and crop height (5 plants/plot) in all the experimental units were taken 14 days after planting and at physiologic maturity respectively. A $9m^2$ central area of the treated plot was harvested, threshed and grain yield and moisture content determined. Yields are expressed as grain yield at 12.5% moisture.

The percentage efficacy, wheat grain yield, thousand kernel weight (TKW), spike density m^{-2} and crop height were subjected to analysis of variance. Treatment means were separated using Duncan Multiple Range Test (DMRT).

Results and Discussion

The trial sites had a narrow spectrum of weeds as shown in Table 3 below. The weed growth stages at the time of application are defined in terms of the number of leaves. It should be noted that the weed growth stages in certain instances were beyond those recommended for effective performance of Monitor.

The efficacy of the individual herbicide treatments in controlling the principal weeds present is shown in Tables 4, 5 and 6 for the three seasons. At Purko Farm in the first season, brome grass, the main target weed, did not germinate at the right time. In Timau (2nd Season) Monitor alone (20g ha^{-1}, 25g ha^{-1}, 30g ha^{-1}, 35g ha^{-1} and 40g ha^{-1}) did not satisfactorily control *Bromus sterilis* (Table 6). The 40g ha^{-1} rate gave significantly better control of the grass than the lower rates, but it was still not adequate. This treatment however provided somewhat satisfactory control of *Galinsoga parviflora* (75.5%), and gave some control of *Emex australis*, *Chenopodium album* and *Cortula abysinica*. A tank mix of 40g ha^{-1} Monitor with Derby or Buctril MC did not control brome grass any better than Monitor alone at 40g ha^{-1}. However, the

Table 3. Weed species and growth stages at time of herbicide application in the three seasons.

	No. of leaves		
Weed species	1st Season (Purko Farm)	2nd Season (Timau)	3rd Season (Timau)
Bromus sterilis		2-mid tillering	3-4
Cyperus diformis		6-12	
Emex australis		4-9	2-4
Chenopodium album	7-8	4-8	2-4
Cortula abysinica		4-10	
Galinsoga parviflora	4-8	4-8	
Raphanus raphanistrum	6-8		
Polygonum convolvulus	5-9		
Lolium temulentum	3-early tillering		
Galium spurium			2-4

Table 4. Control of individual weed species by the various herbicide treatments on. Purko Farm, 2002,

	Weed control (Percentage Efficacy)						
Herbicide treatment	Galinsoga parviflora	Chenopodium album	Raphanus raphanistrum	Polygonum convolvulus	Lolium temulentum	Cortula abysinica	Mean %-efficacy
Monitor 20g ha^{-1} + Agral 2%	60.5	47.8	78.2	20.0	23.3	64.6	49.1 E
Monitor 25g ha^{-1} + Agral 2%	64.8	75.1	100.0	65.0	37.9	67.7	68.4 D
Monitor 30g ha^{-1} + Agral 2%	86.9	95.2	100.0	71.4	52.2	89.5	82.5 C
Monitor 35g ha^{-1} + Agral 2%	88.6	94.4	100.0	44.3	48.9	93.3	78.3 C
Monitor 40g ha^{-1} + Agral 2%	86.7	87.5	100.0	40.0	57.7	80.0	75.3 C
Monitor 20g ha^{-1} + Agral 2% (2 applications 3 wks apart)	55.6	68.3	91.7	44.3	36.9	90.4	64.5 D
Monitor 40g ha^{-1} + Buctril MC 375ml ha^{-1} + Agral 2%	88.5	100.0	100.0	79.2	42.0	92.7	83.7 BC
Monitor 40g ha^{-1} + Derby 50ml ha^{-1} + Agral 2%	100.0	100.0	97.0	100.0	47.7	100.0	90.7 AB
Cossack 250g ha^{-1} + Agral 1%	98.2	94.4	100.0	93.3	72.4	100.0	93.1 A
Cossack 300g ha^{-1} + Agral 1%	99.5	100.0	100.0	89.7	78.1	100.0	94.6 A
Monitor 30g ha^{-1} + Hussar 150g ha^{-1} + Agral 2%	0.0	0.0	0.0	0.0	0.0	6.7	1012 F
Untreated control	0.1	0.0	0.0	0.0	0.0	0.0	0.0 F
C.V							8.71%
LSD at alpha=0.05							9.6
S.E							3.26

tank mixes did give fair control of the other broadleaf weeds. None of the treatment combinations gave any control of *Cyperus diformis*.

Percentage efficacy results in the second season (Table 5) show that Cossack treatments were superior to all other treatments in overall weed control and suppression. At the rates of 300g ha^{-1} + Agral 1% and 250g ha^{-1} + Agral 1% the levels of weed kill were 79.3% and 77.9% respectively. These percentages represent average performance on all the weed species at the site.

Table 5. Control of individual weed species by the various herbicide treatments on Wango Emburi Farm, Timau. 2002 (2nd season)

Herbicide treatment	Weed Control (Percentage Efficacy)						
	Bromus sterilis	Cyperus diformis	Emex australis	Chenopodium album	Cortula abysinica	Galium spurium	Mean
Monitor 20g ha^{-1} + Agral 2%	30.9 F	0.1	38.1	54.1	56.4	66.8	41.08 F
Monitor 25g ha^{-1} + Agral 2%	31.8 F	0.03	38.0	54.2	58.2	66.9	41.53 F
Monitor 30g ha^{-1} + Agral 2%	35.4 E	1.1	39.0	55.4	61.8	67.6	43.39 EF
Monitor 35g ha^{-1} + Agral 2%	37.8 D	1.2	39.5	60.9	62.8	68.8	45.16 E
Monitor 40g ha^{-1} + Agral 2%	43.6 C	1.7	41.1	66.5	73.4	75.5	50.29 D
Monitor 20g ha^{-1} + Agral 2% (2 applications 3 wks apart)	39.1 D	0.35	42.0	56.9	58.6	72.0	44.82 E
Monitor 40g ha^{-1} + Buctril MC 375ml ha^{-1} + Agral 2%	43.2 C	1.5	71.0	72.9	76.8	78.5	57.31 C
Monitor 40g ha^{-1} + Derby 50ml ha^{-1} + Agral 2%	43.4 C	0.8	81.8	93.1	94.9	98.4	68.73 B
Cossack 250g ha^{-1} + Agral 1%	87.5 B	1.7	85.9	96.3	96.7	99.3	77.90 A
Cossack 300g ha^{-1} + Agral 1%	91.8 A	1.9	87.6	96.4	97.9	99.9	79.30 A
Untreated check	0.15 G	0.1	0.0	0.1	0.13	0.25	0.12 G
C.V	3.53						2.90%
S.E.	0.77						0.7207
LSD at alpha =0.05	2.25						2.081

Treatments followed by the same letter(s) are not significantly different.

At the time of treatment application in the second season in Timau most of the brome grass seedlings were at mid-tillering stage. Monitor is reported to be most effective on brome grass when the weed has between 2 and 4 leaves, and therefore the application was too late and poor control was obtained with all rates of Monitor and with the tank mixes with Derby and Buctril MC. The split application (20g ha^{-1} twice at an interval of three weeks) of Monitor gave significantly lower brome grass control than a single application of 40g ha^{-1}, and therefore was not economic. Broadleaf weed control was also poor at all rates of Monitor, but the tank mixes with Derby and Buctril MC enhanced its performance on the broadleaf weeds at the site (Table6).

Table 6. Mean grain yield, crop height and mean levels of weed control (% efficacy) in the trial in the second season Wango Emburi Farm, Timau

Herbicide treatment	Crop height (cm)	Grain yield (ton ha^{-1})	Efficacy %
Monitor 20g ha^{-1} + Agral 2%	95.75 B	1.305 G	41.08 F
Monitor 25g ha^{-1} + Agral 2%	92.50 BC	1.330 G	41.53 F
Monitor 30g ha^{-1} + Agral 2%	92.75 BC	1.523 F	43.39 EF
Monitor 35g ha^{-1} + Agral 2%	92.25 C	1.560 F	45.16 E
Monitor 40g ha^{-1} + Agral 2%	93.25 BC	1.832 E	50.29 D
Monitor 20g ha^{-1} + Agral 2% (2 applications 3 wks apart)	92.25 C	1.563 F	44.82 E
Monitor 40g ha^{-1} + Buctril 37ml ha^{-1} + Agral 2%	95.50 BC	2.575 D	57.31 C
Monitor 40g ha^{-1} + Derby 50ml ha^{-1} + Agral 2%	93.00 BC	2.820 C	68.73 B
Cossack 250g ha^{-1} + Agral 1%	94.75 BC	3.463 B	77.90 A
Cossack 300g ha^{-1} + Agral 1%	93.00 BC	3.560 A	79.30 A
Untreated check	107.00 A	1.100 B	0.12 G
C.V	2.45	2.57	2.90%
S.E.	1.1624	0.0266	0.7207
LSD at alpha =0.05	3.357	0.07910	2.081

Treatments followed by same letter(s) are not significantly different.

The improvement in the control of broadleaf weeds when Monitor was tank mixed with Buctril MC and Derby was statistically significant. The Monitor/Derby tank mix was the most effective, and therefore it would be worthwhile to tank mix Buctril MC and Derby with Monitor in situations where the spectrum of broadleaf weeds is wide. Increasing the rate of Buctril MC from 375ml ha^{-1} to about 700ml ha^{-1} could significantly improve the degree of control of broadleaf weeds.

Cossack did not control *Cyperus diformis*, but this is a weed whose growth habit and morphological characteristics do not favour aggressive competition for growth resources. All the broadleaf weeds at the site were vulnerable to Cossack. It is also instructive to note that despite the delayed application Cossack still gave impressive control of *Bromis sterilis*. Statistical analysis (p=0.05) showed that there was no significant difference between the Cossack rates of 250g ha^{-1} and 300g ha^{-1} in terms of their activity on weeds. This suggests that the lower rate should be used for early applications.

In this second season trial visual assessment of crop tolerance to the herbicide treatments showed remarkable crop reaction symptoms in virtually all the treatments. General chlorosis was observed three days after treatment application. The wheat crop (cv. K. Kwale) became even more chlorotic seven days after application and at this time general crop stunting was discernable. Crop recovery was evident fourteen days after application, and by 28 days after application the yellowing of wheat foliage had drastically decreased. Forty two days after treatment the crop had fully recovered but height differences between the treated areas and the adjacent untreated buffer strips could be seen. The intensity of chlorosis appeared uniform in all the treatments. This observation suggests that Agral 90 (2% and 1% v/v) was perhaps responsible for the crop reaction.

To further investigate herbicide phytotoxicity, wheat crop height was measured in all the plots: treatment means are shown in Table 6. The untreated plots on average had the tallest plants (107cm). This was probably due to competition for light with the weeds, mainly brome grass. Plots treated with Monitor at the rates of 35g ha^{-1} and 20g ha^{-1} (same treatment repeated after three weeks) had the shortest plants (92.25cm). There was no evidence that tank mixing Monitor with Derby or Buctril MC gave a greater degree of phytotoxicity.

Results in Table 6 indicate that grain yield was to a large extent dependent on the level of weed suppression attained by individual herbicide treatments, whereas a negative effect of phytotoxicity (crop height) is not evident. Late application of treatments probably reduced the activity of Monitor on brome grass, stressing the importance of timely application of this particular product.

Table 7: Control of individual weed species by the various herbicide treatments on Wango Emburi Farm, Timau. 2002 (3rd season)

	Weed Control (Percentage Efficacy)				
Herbicide treatments	Emex australis	Galium spurium	Bromus sterilis	Chepnoodium album	Mean efficacy %
Monitor 30g ha^{-1} + Agral 0.25%	72.2	82.6	84.2	46.7	71.4 E
Monitor 40g ha^{-1} + Agral 0.25%	74.4	93.7	95.2	66.7	82.5 C
Monitor 20g ha^{-1} + Agral 0.25%	80.4	73.1	79.5	68.8	75.5 D
Monitor 40g ha^{-1} + Derby 50ml ha^{-1} + Agral 0.25%	95.5	96.0	96.4	100	97.0 AB
Monitor 80g ha^{-1} + Agral 0.25%	87.3	94.3	100	100	95.4 B
Monitor 80g ha^{-1} + Derby 100ml ha^{-1}+ Agral 0.25%	100	100	100	100	100 A
Monitor 40g ha^{-1} + Buctril MC 700ml ha^{-1} + Agral 0.25%	100	100	95.6	100	98.9 A
Cossack 300g ha^{-1} + Agral 0.1%	97.3	100	100	100	99.3 A
Untreated check	3.4	0	3.1	4.6	2.8 G
Hand weeded check	57.0	56.5	52.2	12.5	44.6 F
C.V					2.78%
S.E					1.07
LSD at alpha =0.05					3.1

All values followed by the same letter within columns are not significantly different at 5%.

In the third season's experiment (Timau) the timing of treatment application was correct. The rates of the wetting agent, Agral 90, were also altered (Table 2).

Results indicate that Monitor at 30g ha^{-1}, 40g ha^{-1} and 80g ha^{-1} with Agral 90 (0.25% v/v) gave significant control of *Bromus sterilis* (Table 7). At 80g ha^{-1} Monitor gave complete kill of brome grass (%-efficacy =100). Lower rates of 30g ha^{-1} and 40g ha^{-1} had %-efficacy of 84.2 and 95.2 respectively. These levels of control fall within the acceptability limit. When the 40g ha^{-1} rate was applied in two split applications of 20g ha^{-1} at an interval of three weeks, the level of performance was not as good as a single application. This suggests that the second application was not effective due to the advanced stage of weed growth. Analysis of variance (p=0.05) showed significant differences among the Monitor rates in terms of their activities on brome.

Emex australis, Galium spurium and *Chenopodium album* were satisfactorily controlled by Monitor at 80g ha^{-1}. *Galium spurium* was the most vulnerable broadleaf weed to all the test rates of Monitor (Table 7)

The inclusion of Derby and Buctril MC as tank mixes with Monitor enhanced the level of control of the broadleaf weeds at the site. Monitor + Derby + Agral 90 at 40g ha^{-1} + 50ml ha^{-1} + 375ml ha^{-1} respectively attained a mean efficacy of 97.2% on broadleaf weeds. At double rates of the products (80g ha^{-1} and 100ml ha^{-1}) the level of performance rose to 100%. The Monitor and Buctril MC combination at 40g ha^{-1-1} and 700ml ha^{-1-1} respectively gave complete control of all the broadleaf weeds present.

Some weeds in the untreated control plots probably died from natural causes, hence the 2.8% mean %-efficacy. Hand weeded plots had late germinating weeds which accounted for the low average %-efficacy.

Crop tolerance to herbicide treatments was first assessed three days after application. No discernable crop reaction to the treatments was noted at this time or subsequently. The wheat cultivar Mbuni, used in the trial, appears to have good tolerance to Monitor treatments. In a separate trial designed to determine the sensitivity of popular wheat cultivars to Monitor, Mbuni was one of the cultivars which tolerated Monitor at 80g ha^{-1}.

Mean crop height, plant populations, grain yield and yield components, together with the efficacy of weed control of the treatments are shown in Table 8.

There were some significant differences in crop height in plots receiving specific herbicide treatments. However, it is difficult to attribute these differences to treatment effects. For instance, the wheat crop in plots treated with Monitor at 30g ha^{-1} was shorter than those in plots that received 40g ha^{-1} of Monitor. If the crop height depression was dependant on product rate then the converse should have been true. Plots treated with Monitor at 80g ha^{-1} and its tank mix with Derby at 100mls ha^{-1} had significantly shorter plants than those from plots treated with lower Monitor rates. The untreated control plots had the tallest wheat plants.

Table 8. Crop height, plant populations, grain yield, spike numbers, kernel weights and efficacy of weed control in the third season Wangu Embori Farm, Timau.

Herbicide treatments	Crop height (cm)	Plants/m^2	Grain yield (t ha^{-1})	Spikes/m^2	TKW (g)	%-efficacy
Monitor 30g ha^{-1} + Agral 0.25%	91.00 C	180.8 A	3.720 A	379.5 AB	40.95 A	71.40 E
Monitor 40g ha^{-1} + Agral 0.25%	91.25 C	148.3 A	3.478 A	379.3 AB	41.10 A	82.50 C
Monitor 20g ha^{-1} + Agral 0.25%	91.50 BC	186.0 A	3.592 A	429.0 A	40.70 A	75.50 D
Monitor 40g ha^{-1} + Derby 50ml ha^{-1} + Agral 0.25%	92.50 B	152.0 A	3.695 A	389.3 AB	40.35 A	97.00 AB
Monitor 80g ha^{-1} + Agral 0.25%	88.25 D	181.0 A	3.553 A	403.3 A	38.70 A	95.40 B
Monitor 80g ha^{-1} + Derby 100ml ha^{-1}+ Agral 0.25%	88.50 D	159.0 A	3.767 A	425.5 A	38.80 A	100.00 A
Monitor 40g ha^{-1} + Buctril MC 700ml ha^{-1} + Agral 0.25%	91.25 C	174.5 A	3.717 A	362.8 AB	39.15 A	98.90 A
Cossack 300g ha^{-1} + Agral 0.1%	92.50 B	171.0 A	3.680 A	360.3 AB	39.70 A	99.30 A
Untreated check	94.00 A	166.5 A	2.456 B	321.0 B	40.42 A	2.800 G
Hand weed check	92.00 BC	169.3 A	3.459 A	355.5 AB	40.50 A	44.42 F
C.V.	0.89%	18.22%	18.37%	13.63%	4.42%	2.78%
S.E	0.04084	15.3909	0.3225	25.9232	0.8858	1.0659
LSD at p=0.05	1.184	44.66	0.9358	75.22	2.570	3.098

Crop emergence counts taken 14 days after planting were not significantly different (p=0.05). There were only slight differences in spike density, with untreated plots having the lowest number of spikes (321 m^{-2}), and no significant treatment effects on TKW (p=0.05). Similarly, there were few treatment effects on grain yield was only significantly lower in the unweeded check.

Monitor (80g ha^{-1}) + Derby (100ml ha^{-1}) gave the highest grain yield (3.78 t ha^{-1}). It was noted that TKW as well as spike density m^{-2} did not directly influence wheat grain yield (t ha^{-1}).

Results of the experiment in the three seasons indicate that the activity of Monitor alone on brome grass was dependent on the stage of growth of the weeds and the soil hydrological status.

In conclusion, Monitor at 30g ha^{-1}, 40g ha^{-1} and 80g ha^{-1} will significantly suppress brome grass if applied before the grass exceeds the four-leaf stage. But this is only achievable if the target brome is vigorously growing and the soil has sufficient moisture. Derby and Buctril MC have been shown to be compatible with Monitor and tank mixes with these products broaden the spectrum of weeds controlled. Care should be taken in the use of Agral 90 as a wetting agent: applications at rates above the recommended rate are antagonistic as was evidenced in the second season (Timau), when 2% (v/v) of Agral 90 suppressed the crop and caused general chlorosis. At 0.25% (v/v) the crop reaction attributable to Agral 90 in combination with Monitor was not detectable.

Control of the Russian Wheat Aphid, *Diuraphis Noxia* (Kurdijumov) in Wheat Using Systemic Insecticides in Kenya

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Abstract—Wheat crops in Kenya are subject to widespread and heavy infestations of the Russian wheat aphid (RWA). Control by applications of contact insecticide sprays is difficult because the aphid feeds inside tightly rolled leaves. Initial RWA infestations are usually caused by migrant winged aphids settling on wheat crop. Subsequent spread results from the movement of the original colonizing aphids and their offspring. Effective Russian wheat aphid management strategies require control at the initial stage of infestation. In the current work, four systemic insecticides were screened to determine their effectiveness in controlling RWA. Evaluation tests carried out in Mau Narok (2835 masl) demonstrated that using systemic insecticides could substantially avoid RWA damage. In Mau Narok average yield gain was 26.2, 21.9, 19.9 and 13.0 % for Gaucho 350FS, Cruiser 350FS, Metasystox 250EC and Furadan 350ST treatments, respectively, compared with the untreated control. Systemic insecticides are effective in the control of RWA and such treatment can prevent heavy production losses. Seed dressing treatments with Furadan 350ST was not effective against RWA because of incomplete protection of the crop. The cost benefit analysis indicated that foliar application of Metasystox 250EC was more beneficial than those of Gaucho, 350FS and Cruiser 350FS.

Introduction

About 135,000 ha are sown to wheat annually in Kenya (FAO, 2003) with average yields being about 2.3 t /ha. Among the main constraints that limit wheat production in Kenya are the cereal aphids (Wanjama, 1990). Important cereal aphids that attack wheat include greenbug, S*chizaphis graminum* (Rondani); rose grain aphid, *Metopolophium dirhodum* (Walker); bird cherry aphid, *Rhopalosiphum padi* (Linneus); cereal leaf aphid, *Rhopalosiphum maidis* (Fetch); and English grain aphid, *Sitobion avenae* (Walker) (Wanjama, 1990; Macharia *et al.*, 1993; Muthangya *et al.*, 1994).

Apart from the damage they cause by directly feeding on crops, cereal aphids transmit barley yellow dwarf virus (BYDV) disease as they feed (Wangai and Torres, 1990b). Yield losses of 47% and 27% have been recorded in wheat and barley, respectively (Wangai, 1990a).

The Russian wheat aphid (RWA) *Diuraphis noxia* is a recent introduction in Kenya. Having invaded the country in mid-1995, it has become one of the most important pests of cereal crops, potentially threatening all of the country's wheat production (Macharia *et al.*, 1997a). Although an important pest, however, *D. noxia*, is poor in transmitting BYDV (Dickey, 1998).

All commercial wheat varieties currently being grown by farmers are susceptible to RWA (Macharia *et al.*, 1997a). Current control strategies rely mainly on the use of contact aphicides to kill RWA already established on crops. However RWA feeds inside rolled leaves, making control by contact insecticides difficult (Valiulus, 1986; Dickey, 1998 and Peairs, 1998).

Russian wheat aphid is causing considerable losses to wheat in Kenya and crop losses range from 10-100% depending on the stage of infestation (Macharia *et al.*, 1997a). Toxins injected by RWA into the host plant as it feeds cause damage (Summers *et a*l., 2004). Damage is also often associated with reduction in photosynthetic area caused by rolling of leaves when attacked (Valiulus, 1986, and Peairs, 1998). In addition, crops attacked by RWA tend to retain other cereal aphids longer, since they are able to hide inside the rolled leaves of the attacked crops.

In an effort to minimize damage, studies were conducted to evaluate the effectiveness of systemic insecticides on RWA. Early sown wheat crops, in Kenya, can also be severely damaged by BYDV introduced and spread by migrant winged aphid vectors early in the season. The systemic insecticides will also be evaluated for control of the migrant winged cereal aphids as a preventive measure against BYDV infection.

Materials and Methods

In 2001/2002, a series of field trials were set out to investigate the effectiveness of systemic aphicides on cereal aphids and BYDV control. The trials were conducted in Mau Narok (2835 m asl), a site that is particularly favoured by severe BYDV infections and a composition of different cereal aphid species. Four systemic aphicides were evaluated, namely Gaucho 350FS [imidacloprid], Cruiser 350FS [thiomethoxam], Furadan 350ST [carbofuran] and Metasystox 250EC [oxydemeton-s-methyl] and untreated control. All the aphicides were assessed for signs of phytotoxicity from crop emergence to 4 weeks and crop vigour was assessed at heading stage. Details of seed-dressing insecticides admixed with the seed at planting and foliar aphicide evaluated and the rates of application are indicated in Table 1. Mbuni variety planted at 100 kg/ha was used as the test crop, and was fertilized using DAP at 130 kg/ha.

The trial was designed, as a randomized block design with four replicates and the plot size was 1.5 x 6.0m [9m^2]. The trials were seeded using “Oyjord’’ seed drill. The systemic insecticides Gaucho 350FS, Cruiser 350FS and Furadan 350ST were admixed with the seed before planting. The systemic foliar systemic Metasystox 250EC was applied immediately after early symptoms of RWA infestation were noticed on the wheat crop after scouting. The foliar spray treatment was applied using a knapsack CP3 sprayer system set to emit 200 l/ha^{-1} spray volume.

Aphid severity was determined by counting the number of cereal aphids on five randomly selected plants at 2 weekly intervals for 8 weeks. The incidence of BYDV was assessed at crop heading based on visual symptoms using a 1-9 scale, where 1= no infection and 9= very severe infection (Macharia *et al*., 1997b) . In addition, crop vigour was also assessed using 1-9 scale [where 1 = not vigorous and 9 = very vigorous]. Harvesting was done using a small plot Hege combine and yields from each plot were recorded and adjusted to a standard moisture content of 12.5%. Plot yields were later converted to kg/ha.

Analysis of variance [ANOVA] was used to analyse all the data and means separated using Duncan’s multiple range test ($P<0.05$). Statistical analysis was done on aphid population means transformed using square root ($\sqrt{x+1}$) and the means were transformed back to original values. Comparative efficacy of insecticides on cereal aphid populations was calculated as percentage aphid population reduction compared to the control. The effect of insecticides on grain yields was also assessed as the percentage grain yield increase over the control. In addition, the cost: benefit analysis was calculated for the systemic aphicides using 2003/2004 pricing structure.

Results and Discussion

In Mau Narok, the most abundant cereal aphid species was the Russian wheat aphid, *D. noxia* followed by *M. dirhodum*, *R. maidis* and *R. padi.* However infestation by last three aphid species was comparatively lower.

All the treatments resulted into improved RWA control compared to the untreated control. The best RWA control was achieved by Gaucho 350FS followed by Cruiser 350FS and Metasystox 250EC foliar spray. (Table 1). As reported previously (Macharia *et al.*, 1997a; Macharia *et al.*, 1997b; Macharia *et al.*, 2001) systemic insecticides Gaucho 350FS and Cruiser 350FS were more effective than Furadan 350ST against RWA. Field observations also revealed that applications of Gaucho 350FS, Cruiser 350FS and Metasystox 250EC are not phytotoxic and gave better control of RWA than Furadan 350ST, the standard treatment. No effect on crop growth or marked phytotoxicity by any of the treatment was observed.

Previous conclusions (Macharia, 2002) were confirmed that with the exception of Furadan 350ST, applications of Gaucho 350FS and Cruiser 350FS were effective as control measures against RWA. The Metasystox 250EC treatments performed well when applied before the establishment of RWA on the new crop on detection of early symptoms of infestation. These results suggest that applications of Gaucho 350FS, Cruiser 350FS, Furadan 350ST and Metasystox 250EC controlled the initial RWA population, thereby preventing further spread of the aphid and improved on the BYDV control. Similar results have been reported on the control of cereal aphids in Kenya [Muthangya *et al.*, 1994; Macharia *et al.*, 1997b].

The crop vigor was improved by the use of systemic insecticides [Table 2]. The incidence of BYDV ranged from low to moderate during the trial period. All the treatments resulted into adequate BYDV control except for the untreated control (Table 2). Field observations revealed that Furadan 350ST was not effective against RWA but was effective against *M. dirhodum, R. maidis* and *R. padi* which are good vectors of BYDV. Gaucho 350FS and Cruiser 350FS were effective on all species of cereal aphids, therefore resulting in good control of BYDV.

The various control options resulted into improved wheat yields. Significantly higher yields were recorded for Gaucho 350FS, Cruiser 350FS and Metasystox 250EC foliar spray (Table 3).

The cost benefit analysis (Table 4) indicated that Metasystox 250EC foliar spray application was more beneficial, with cost benefit ratio of 1:17.7 than the other systemic insecticides. Gaucho 350FS and Cruiser 350FS were not significantly different, with cost benefit ratios of 1:11.2 and 1:11.3 respectively. Furadan 350ST had the lowest cost benefit ratio of 1:4.6.

Table 1. Effect of systemic insecticides on the control of Russian wheat aphid in Mau Narok

Product	Rate/ 100 kg seed	Rate/ ha	Mean no. of RWA/ 5 plants	Percentage reduction over untreated control
Gaucho 350FS	200 ml	-	0.2 a*	97.6
Cruiser 350FS	150 ml	-	0.4 a	95.3
Furadan 350ST	714 ml	-	3.6 b	57.6
Metasystox	-	0.5 l	0.9 a	89.4
Untreated control	-	-	8.5 c	-
LSD [5%]			1.5	
CV(%)			20.61	

*Means in the same column followed by the same letter do not differ significantly at the 5% level.

Table 2. Effect of systemic insecticides on crop vigour and control of Barley yellow dwarf [BYDV] in Mau Narok.

Product	Rate/ 100 kg seed	Rate/ ha	Crop vigour [1 - 9 scale}	Barley yellow dwarf score [0-9 scale]
Gaucho 350FS	200 ml	-	7.1c*	1.2a*
Cruiser 350FS	150 ml	-	7.4c	1.6a
Furadan 350ST	714 ml	-	6.9c	2.0a
Metasystox	-	0.5 l	6.0b	2.6a
Untreated control	-	-	4.0a	4.2b
LSD			0.8	
CV (%)			10.0	

*Means in the same column followed by the same letter do not differ significantly at the 5% level.

Table 3. Effect of systemic insecticides on wheat grain yields in Mau Narok

.Product	Rate/ 100 kg seed	Rate/ ha	Mean grain yields [kg/ha]	Percentage yield increase over untreated control
Gaucho 350FS	200 ml	-	4430.0 a*	26.2
Cruiser 350FS	150 ml	-	4379.0a	21.9
Furadan 350ST	714 ml	-	3967.0c	13.0
Metasystox	-	0.5 l	4288.0a	19.9
Untreated control	-	-	3508.0d	-
LSD [5%]			138.0	
CV (%)			25.60	

*Means in the same column followed by the same letter do not differ significantly at the 5% level.

Table 4. Cost benefit analysis for systemic insecticides on the control of Russian wheat aphid

Product	Rate/ 100 kg seed	Rate/ ha	Cost/ ha [K.shs]	Yield increase [bags/ha]	Value* [K.shs]	Cost: Benefit ratio
Gaucho 350FS	200 ml	-	1,400.00	9.2	15,640.00	1: 11.2
Cruiser 350FS	150 ml	-	1,320.00	8.8	14,960.00	1: 11.3
Furadan 350ST	714 ml	-	1,713.00	4.6	7,820.00	1: 4.6
Metasystox	-	0.5 l	750.00	7.8	13,260.00	1: 17.7

*Price of wheat at K.shs 1,700.00 per 100kg bag.
The price of systemic insecticides for 2003/2004 cropping season was:
Gaucho 350FS @ K.shs 7,000.00 per litre.
Cruiser 350FS @ K.shs 8,800.00 per litre.
Furadan 350ST @ K.shs 2,400.00 per litre.
Metasystox @ K.shs 1,500.00 per litre.

Conclusion

Adequate RWA control was achieved by the use of systemic insecticides, Gaucho 350FS, Cruiser 350FS and Metasystox 250EC. Seed treatment with Gaucho 350FS and Cruiser was effective in the management of RWA and improved grain yields. Foliar spray with Metasystox 250EC increased grain yields, but its satisfactory control depends on early detection of infestation through periodic scouting. Furadan was effective against other cereal aphids (S. *graminum, M dirhodum, R. padi, R. maidis* and *S. avenae*) but not RWA. This approach will therefore offer a cheaper strategy for cereal aphid and BYDV control.

Acknowledgement-We acknowledge Kenya Agricultural Research Institute for financial support in carrying out this work.

References

Dickey, E.C. (1998). Russian Wheat Aphid: Neb Guide In: Insects and Pests. C-31, Field Crops. Institute of Agriculture and Natural Resources. University of Nebraska.

FAO (2003). Wheat production in Kenya. FAO Crop Protection Compendium. CAB International 2003, Wallingford, Oxon 0X10 8DE, UK.

Macharia, M., P.M. Muthangya, A.W. Wangai and J.K. Wanjama. 1993. Barley Yellow Dwarf Virus Report 1990-1993. Kenya Agricultural Research Institute, National Plant Breeding Research Centre, Njoro, Kenya.

Macharia, M., Muthangya P.M. and Wanjama J.K. (1997a). Management of Russian wheat aphid, *Diuraphis noxia,* on wheat in Kenya by use of seed dressing insecticides. African Crop Science Conference Proceedings, Vol. 3. pp. 1191-1198.

Macharia, M., Muthangya P.M. and Wanjama J.K. (1997b). Barley Yellow Dwarf Virus Report 1994-1997. Kenya Agricultural Research Institute, National Plant Breeding Research Centre, Njoro, Kenya.

Macharia, M. P. Muthangya and J.K. Wanjama. (2001) Effectiveness of Foliar applied aphicides in the control of cereal aphids and barley yellow dwarf. Egerton University, Faculty of Agriculture/KARI-NPBRC Symposium, 14-15 November 2001, ARC, Egerton University.

Macharia, M., J.N. Malinga and M.G. Kinyua [2002] Occurrence of Russian Wheat Aphid in Kenya: The problem and control strategies. Egerton University/ KARI -NPBRC Symposium, 25- 26 November 2002, NPBRC-Njoro.

Muthangya, P.M., Migui, S.M., Macharia, M. & Wanjama, J.K. (1992). Survey of cereal aphid predominance and barley dwarf virus disease incidence in wheat and barley growing areas of Kenya. Seventh Regional Wheat workshop for Eastern, Central and Southern Africa. Nakuru, Kenya. CIMMYT.

Muthangya, P.M., Migui, S.M., Macharia, M. & Wanjama, J.K. (1994). Effectiveness of Gaucho [imidacloprid] seed dressing and foliar aphicide to control cereal aphids and barley yellow dwarf virus disease on barley in Kenya. Ninth Regional Wheat Workshop for Eastern, Central and Southern Africa. October 1995. Addis Ababa, Ethiopia.

Peairs, F.B. (1998). Russian Wheat Aphid Management. In: The Inaugural National Wheat Industry Research Forum Proceedings .San Diego, California. January 14 and 15, 1998.

Summers, C.G., Godfrey, L.D. and Gonzales, F. (2004). Russian Wheat Aphid. UC IPM. Pest Management Guidelines: Small Grains, UC ANR Publication 3466. Statewide IPM Program, Agriculture and Natural Resources, University of California.

Valiulus, D. (1986). Russian Wheat Aphid: A new pest that may be here to stay. Agrochemical age 30,10-11.

Wangai, A.W. (1990 a). Effects of barley yellow dwarf virus on cereals in Kenya. Pages 391-393. In P.A. Burnet (Ed.), World perspectives on Barley yellow dwarf virus. Mexico CIMMYT, D.F.

Wangai, A.W. and E. Torres. (1990 b). Barley yellow dwarf virus situation report for Eastern Africa with special emphasis in Kenya. Page 71 In: P.A. Burnnet (ed.), World perspectives in Barley Yellow Dwarf. CIMMYT, MEXICO, D.F.

Wanjama, J.K. (1990). Ecology of cereal aphids transmitting Barley yellow dwarf virus in Kenya. Pages 240-243. In: P.A. Burnnet (ed.), World perspectives in Barley Yellow Dwarf. CIMMYT, MEXICO, D.F.

Part 4. ECONOMICS

Analysis of Marketing and Pricing Policies on Technology, Input Use and Production of Wheat in the Sudan

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Abstract—This paper discusses the situation of wheat production with respect to its financial and economic profitability and international competitiveness in The Sudan. It analyses government reform policies and their role in wheat production, consumption and input use in the 1990s. Policy Analysis Matrix (PAM) was used to measure the domestic resource cost ratio to international value added, nominal and effective protection coefficients. Results indicated that wheat production utilized the country's resources inefficiently, thus enjoyed no competitive position during the last decade. The implementation of economic liberalization policy and removal of subsidy in 1990s has negatively affected the adoption of improved technology and led to low crop productivity. The government policy has also resulted in escalated prices of tradable inputs, and consequently, the cost of production. During the last decade wheat prices did not increase proportionately with production costs, leading to lower returns and an accumulation of debt for the majority of wheat producers in Sudan.

Introduction

Since the mid-seventies, most sub-Saharan African countries have been experiencing decline in economic performance. The economic decline in Africa has largely been attributed to poor domestic policies which resulted in economic distortions rather than to external factors (Ogbu, 1991). As in most African countries, Sudan embarked on Structural Adjustment Program aimed at eliminating the economic distortions, adapting the economy to market forces, and improving the efficiency of resource allocation and utilization. The adjustment process involved the realignment of the exchange rates, changes in relative prices, improving incentive structures and institutional reforms.

The agricultural sector is perhaps one sector that has been extensively affected by the adjustment process. Agricultural marketing has also been deregulated and liberalized with the abolition of marketing boards. Agricultural inputs including fertilizers are witnessing the de-subsidization since 1992 country-wide. Fertilizer procurement, distribution and pricing policy reform is intended to increase the consumption of the commodity and thereby raise the productivity of the farmers and aggregate agricultural outputs. However, even with the removal of subsidy, the total consumption of fertilizers in Sudan is relatively low compared to its large endowment of 85 million hectares of arable land (Table 1). It is worth noting that the agricultural sector supports over 75 percent of the population, contributes to over 90 percent of the foreign exchange earnings before oil extraction and 30 – 45% of the GDP (Appendix1).

Wheat is the main staple cereal in Sudan especially in urban areas and second to sorghum in many irrigated rural areas. It is traditionally produced and consumed in northern Sudan. However, since the early 1960's, its production has expanded into the large public projects of central Sudan, which contribute 90% to domestic production since mid nineties. Most of production decisions in the public projects are determined by the government, but wheat has received greater attention in the food sector. The government intervenes at all stages of production, processing and distribution This is largely because wheat constitutes the staple food for the urban population which has strong political power to influence bread prices.

Table 1. Quantities and values of imported fertilizers in Sudan, 1994 –1998.

Year	Fertilizers quantity (tone)	Value (000 US$)
1994	58,586	12,726
1995	47,397	15,745
1996	261,447	74,711
1997	183,838	47,349
1998	70,882	10,624

Source: Bank of Sudan annual reports.

Sudan's domestic wheat production has always run short of satisfying the rising domestic demand. The average per capita consumption increased from 10.5 kg in 1960 to 20.4 kg in 1971 and from 31.7 kg in 1986, to about 40 kg in 1999 (Fig. 1). Wheat consumption has been increasing sharply and the gap between consumption and domestic production levels has widened (Fig. 2 and Appendix 2). The contribution of the domestic production to wheat demand has been fluctuating, ranging from 97% in 1992 to about 12.5% in 1999 and 17% in 2001 (Elamin, 2002). This has been mainly due to faster growth in demand and drastic reduction in domestic production, as a result of reduction in wheat acreage in central Sudan especially in the Gezira project, which used to be the main producer, coupled with a reduction in the productivity of the crop (Table 2).

A national wheat program was developed in the late 1990's to make the country self-sufficient in wheat. This program involved horizontal expansion of wheat production in the middle and high terrace soil of northern Sudan and vertical expansion through promotion of improved wheat technologies, mainly improved seeds and nitrogenous-phosphorus. The liberalization policies implemented by the government affected the adoption of these technologies in different ways.

Table 2. Wheat cultivated area, productivity and production in the Gezira project, 1992 – 2002.

Season	Area grown (acres)	% to total area	Production (tons)	Yield (ton/acre)
1991/92	532,813	58.7	499.779	0.94
1992/93	514,033	64.4	629,868	0.53
1993/94	522,783	85.6	273,938	0.52
1994/95	392,690	55.9	230,116	0.59
1995/96	390,490	56.5	256,552	0.66
1996/97	389,801	50.1	250,642	0.64
1997/98	301,925	50.2	211,348	0.70
1998/99	123,016	37.9	37,766	0.31
1999/2000	58,627	28.3	29,314	0.50
2000/2001	70,409	26.6	56,327	0.80
2001/2002	80,818	26.5	68,695	0.80

Source: SGB, Department of Statistics, MANRAW and Socio-Economic Research.

Objectives and Methodology

The objectives of this study were to (i) examine the situation of wheat production with respect to its financial and economic profitability and international competitiveness when using domestic resources; and (ii) analyze the government economic policies and their role in the adoption of wheat technology, production and consumption in the Sudan.

Firstly, the study hypothesized that the reforms have not significantly made fertilizers and seeds available and accessible to farmers at affordable prices. Secondly, that there is no significant impact on the productivity of the farms at the micro- level. That is, farmers do not readily have access to fertilizers and seeds, and where available, they cannot afford the prices offered and do not actually use fertilizers and or seeds, and where they do, the quantities used are not adequate as to make noticeable impact on production.

Financial and economic evaluations were conducted using the theory of comparative advantage and policy analysis matrix. Domestic Resource Cost (DRC) analysis was employed as a procedure for tracing the competitiveness of wheat production over alternative productive uses of Sudan’s resources. DRC ratio indicates whether it is cheaper for a region or a country to produce wheat locally or import it. The method can also be used to rank production alternatives showing comparative advantage over trade options. The crop activity with the biggest comparative advantage is the one which has the most efficient use of the region's or country's resources. The results from these analyses are used to propose appropriate intervention and strategy for the expansion of wheat production in northern Sudan. Both primary and secondary data were collected to achieve the stated objectives.

Results and Discussion

Production policy

Wheat is entirely grown under irrigation in the public projects, mainly in central Sudan, or in private pump projects in northern Sudan. The irrigated public projects, where the cultivators are tenants of the government, are characterized by fairly extensive use of modern inputs such as machinery, fertilizers, pesticides and seeds. These inputs in addition to irrigation water are provided on credit basis. The tenants are responsible for all manual work and obliged to follow the prescribed cropping pattern determined by the project administration. On the other hand, private irrigated farms are owned and managed by small semi-commercial families.

According to Elamin (2001), Sudan’s local wheat production has always run short of domestic demand. Wheat consumption has risen sharply, increasing the gap between consumption and local production (Appendix 2). Excessive consumption pattern requires rationalization and regulation that positively contributes to narrowing the wheat consumption gap. Most of the wheat consumed in Sudan is imported but increased wheat imports are likely to erode the country's balance of payments. For instance, in 1998 wheat imports reached 984,000 tons with total value of US $ 132 million or 22 percent of the country’s total foreign exchange earnings and 77% of the total value of agricultural exports (Tables 3 and 4).

Table 3. Wheat and wheat flour import in the Sudan, 1990- 2001.

Year	Amount (000 ton)	Value (million US $)
1990	132.573	21.762
1991	361.134	74.809
1992	213.334	31.195
1993	212.449	45.795
1994	488.127	112.928
1995	307.810	89.847
1996	354.345	97.859
1997	576.623	138.401
1998	984.108	**131.945**
1999	549.483	123.333
2000	1013.400	207.942
2001	650.232	138.096

Source: Ministry of External Trade and Bank of Sudan.

Table 4. Value of wheat import and agricultural export, 1997-2000.

Year	Wheat and wheat flour imports (US $)	Agricultural exports value (US $)	%
1997	138.402	133.372	103.7
1998	131.945	171.370	76.9
1999	123.333	142.566	86.5
2000	207.942	91.187	228.0

Source: Bank of Sudan, Annual Reports.

The increased wheat consumption may have encouraged the policy makers to increase public resources devoted to wheat production. However, successful implementation of this policy shift could only occur if domestic resources are being used efficiently and farmers find it profitable to grow more wheat. This is possible if and only if wheat is using domestic resources efficiently both financially and economically at the farm and national levels, respectively.

The pricing policies have played a negative role in promoting domestic wheat production. Wheat farmers used to receive an indirect subsidy on the price of imported inputs (fertilizer and fuel) but at the same time they had to deliver their produce at substantially lower prices than local market clearing prices. This policy taxes wheat producers. The economic liberalization policy and removal of subsidy in the 1990s has resulted in increasing the price of tradable inputs and consequently the costs of production. The increase in wheat price did not offset the effect of rising costs of production (Table 5). Consequently, some wheat producers have fetched low returns and the majority of them accumulated debts during the last decade (Table 6).

When the national economy adopted the free market system, the government withdrew from direct financing of the agricultural sector. A consortium of commercial banks was formed to serve as a financial resource fund lending production and marketing of agricultural commodities. They mostly cater for crops grown in the irrigated sub-sector but the costs of lending have been found to be high.

The farmers' union with the assistance from the government has acquired the Commercial Bank of Sudan and renamed it the Farmers' Bank. The farmers' union also acquired the Cotton Company, formerly government cotton marketing owned company. These two institutions have considerably increased farmers' access to credit and other financial resources. However, the huge financial services required by farmers are beyond the capacity of the Farmers' Bank and the Cotton Company. Moreover, farmers' financial base is poor and insufficient to finance their agricultural operations.

Most of the agricultural operations in the public projects in central Sudan (e.g. the Gezira and Rahad) are provided by the project administration with costs paid after harvest or deducted from the farmer's individual account (from his crop receipts). In this production relationship, farmers often get credit to be paid in form of produce at an agreed upon price significantly below the expected market price. Labor and incidental costs are usually met from the farmer own resources. When the harvest is poor, the farmer may go bankrupt. For the private projects, the credit situation is even worse where failure of repayment is prominent. Farmers in these private projects express their dissatisfaction with the amount, timing and conditions of credit which is not conducive for adopting technology and sustaining production.

Again, after liberalization of the market for grains, imported wheat out-competed domestic wheat, with a relative imported price of 0.77 of the local wheat price in 1999. Therefore, high production costs, low productivity and less competition with imported wheat have made wheat an unattractive crop. Eventually, wheat yields in the Gezira project decreased from 0.94 ton/acre (2.2 ton/ha) in 1992 to 0.31 ton/acre (0.7 ton/ha) in 1999. In Rahad project, they have declined by 575 percent over the same period. This situation has led to low or even negative wheat profits and hence increased indebtedness of the farmers during the last decade. As a result, wheat production has been discontinued in the Rahad project and the area under wheat drastically reduced in the Gezira project to only 11 percent of the area in 1992. Wheat became an optional crop enterprise starting from 2000 season (Elamin, 2001). Countrywide, the total wheat cultivation has declined to about 123,000 hectares (294,000 acre) and production to 266,000 tones, representing only 17 percent of total wheat consumption (Appendix2). This widening gap between supply and demand can not be significantly reduced in the very short run.

To bridge the consumption gap, the government has two options: to rationalize wheat consumption by reducing wheat import or to rely again on a crash program for promoting wheat production in its traditional areas. Since the latter option should reduce pressure on the limited foreign exchange available to Sudan, the government launched a national wheat production program in late 1990s with the objectives of restoring areas of wheat cultivation needed for self-sufficiency through horizontal expansion in the middle and high terrace soil of northern Sudan. This comes through the rehabilitation of the existing projects, establishing new projects and amalgamating small ownership into large scale farms that economize irrigation water. The target areas are 184,000 and 113,000 hectares in the Nile River and Northern States, respectively. This program extends for five years with a total budget of US$ 440 million to be secured by the Agricultural Bank of Sudan (ABS).

Some serious questions against the successful completion of this wheat relocation program may arise. Private profitability, soil reclamation, and provision of water to distant areas from the Nile are critical at the farm level. At the national level, comparative advantage in terms of domestic resource costs is a pertinent issue. To utilize the country’s resources efficiently, local wheat must generate foreign exchange earnings (savings) that exceed the value of traded inputs used in its production.

Efficiency indicators

In the central Sudan (Gezira project) where wheat used to contribute more than 60% of the Sudan wheat production during early 1990s and 10% in early 2000, wheat is grown in rotations with cotton, sorghum, groundnuts and to some extent vegetables and fodder with more or less similar inputs levels. Despite these similarities, wide crop yields variations exist due to variability in irrigation-water, climate, soil types, weeds intensity, and the levels of farm management.

As a result of recent economic changes following the adoption of liberal economic policies and changes in different agricultural policies, production returns, comparative advantages and competitiveness of different crops were affected at varying degrees (Elamin, 2002). This resulted in an increase in prices of tradable inputs and consequently an increase in the cost of production. Product prices have also increased but by lower percentage than the increase in cost resulting in a decrease in returns to the producers.

Fertilizer price index in the Gezira Scheme has increased from 100 in 1990 to 48,249 in 1999 that is 482 times during the period 1990-1999. By contrast, increases in wheat price indices are only 16,000 during the same period. In other words, between 1989 and 1999, the price index of fertilizer has moved by as high as 3 times that of wheat. This means that nominal fertilizer price index has increased much more compared to that of wheat (Table 5).

Table. 5. Index of wheat price, cost, return and fertilizer price in the Gezira project, 1990-1999.

Season	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Producer Price (Ls/t)	3000	6000	8750	19000	70000	75125	220000	380000	380849	480000
Nominal Net Return	903	862	3164	-1872	5580	10433	82628	65721	27772	-97591
Wheat Cost (Ls/fed)	960	2110	5015	8710	18598	34567	86552	191479	238228	227191
Fertilizer Price (Ls/t)	1340	3340	8040	26160	50720	105707	249700	581720	646540	646540
Wheat Price Index	**100**	200	292	633	2333	2504	7333	12667	12695	**16000**
Net Return Index	100	95	350	-207	618	1155	9150	7278	3076	-10807
Wheat Cost Index	100	220	522	907	1937	3601	9016	19946	24815	23666
Fertilizer Price Index	**100**	249	600	1952	3785	7889	18634	43412	48249	**48249**

Source: Calculated by the author.

Table 6. Wheat productivity, average cost, net return per feddan in the Gezira project, 1993 – 1999.

	1993	1994	1995	1996	1997	1998	1999
Productivity (ton/acre)	0.525	0.524	0.586	0.657	0.643	0.7	0.31
Break-even point	0.667	0.403	0.450	0.336	0.479	0.627	-
Average cost/acre.	8710	18598	34567	86552	191479	241225	244951
Total revenue/acre	6838	24178	45000	169180	257200	266594	147360
Net revenue/acre	-1872	5580	10433	82628	65721	27772	-97591
Rate of net revenue (%)	**-21%**	**30%**	**30%**	**95%**	**34%**	**12%**	**-39%**

Source: Sudan Gezira Board

The product/input price ratios for wheat in the Gezira project during the last decade is calculated based on productivity per unit area keeping inputs used other than fertilizers constant. The wheat/nitrogen price ratio used to be high at the export market indicating its high comparative advantage, in terms of domestic resource costs, and in utilizing the imported fertilizer using foreign exchange capital. Nevertheless, the crop product/input price ratio is deteriorating over time from early 1990s on wards. This serious deterioration of this crucial measurable economic and pricing indicator is behind the observed fluctuating cultivation of this crop in the Gezira project in the late 1990s (Table 7).

The effect of government policies on comparative advantage for wheat were assessed using PAM which identifies the divergences between existing market (private) values and social (real) optimal values. Results in Table 8 showed that nominal procurement prices offered by the government reflected taxation (negative transfers) to producers, who were at the same time enjoying subsidies on tradable and domestic factors. This is reflected by the Effective Rate of Protection (ERP), which indicates the net level of transfers. It shows high net positive protection (implicit subsidy) with a coefficient of more than one (1.3) during 1996 season. This means that, at this price level, the effect of agricultural policy is to increase producer benefit. While for the period 1997 – 2000, this coefficient has a value of less than one which means that the effect of the government policy is to reduce producer benefit.

The nominal protection coefficient (NPC), which shows the divergences between social and private values, indicates that private prices were lower than social ones, which implies taxed output (its value is less than one during 1996 – 2000). The domestic resource cost (DRC) ratio assesses social returns to domestic factors and serves as a measure of relative efficiency of domestic resource use. The yardstick of comparative advantage is a DRC ratio of unity, which is a break-even point. DRC values of less than unity imply comparative advantage, and greater than unity values indicate no comparative advantage at the given levels of yield and prices. This, therefore, indicates that it is more efficient to import wheat and use domestic resources in more competitive crops. It is obvious that even with the escalated cost of production; wheat had a comparative advantage during 2000 – 2002 growing seasopns, due to the improvement in wheat productivity. Improvement in wheat productivity is due to the fact that wheat cultivation is confined to areas where the soil is more productive and farmers are financially capable as wheat became an optional crop in central Sudan. It is worthy noting that low productivity before 2000 season coupled with escalated cost of production resulted in high value of the domestic resource cost and thus the crop enjoyed no comparative advantage.

These results indicate that the agricultural reform program designed by the government to promote greater self-sufficiency in wheat could be achieved if more protection is provided for farmers. This comes through reducing constraints that hinder the production process, maintaining low cost of production and ensuring marketing of produce at competitive prices. In addition, provision of improved seeds, fertilizers, irrigation water after the establishment of the proposed dams in the Northern States and full mechanization of the crop may act to lower the costs of production. This when coupled with the program of soil reclamation should improve wheat competitiveness, at both the farm and national levels, and pave the road for the dream of self-sufficiency in wheat.

Table 7. Wheat product and fertilizer input price ratio, Gezira project, 1990-1999.

Season	Yield (ton/acre)	Wheat price (Us $ /tone)	Wheat price (SD/tone)	Wheat value (SD/acre)	Fertilizer cost (SD/acre)	Product-input price ratio
1991/92	0.94	291	875	823	95	8.66
1992/93	0.53	139	1,900	1,007	230	4.38
1993/94	0.52	210	7,000	3,640	609	5.98
1994/95	0.59	179	7,500	4,425	1,080	4.10
1995/96	0.66	271	22,000	14,520	2,578	5.63
1996/97	0.64	150	2,000	14,080	6,672	2.11
1997/98	0.70	234	40,000	28,000	6,579	4.26
1998/99	0.31	188	45,000	13,950	7,221	1.93
1999/2000	0.50	233	60,000	30,000	5,847	5.13
2000/2001	0.80	213	55,000	44,000	6,936	6.34
2001/2002	0.80	171	45,000	36,000	7,066	5.09

Table 8. Results of wheat comparative advantage, 1996 - 2002

Season	NPC	ERP	DRC
1995/96	0.56	1.3	1.12
1997/98	0.81	0.68	0.91
1998/99	0.6	0.5	2.4
1999/00	0.81	0.7	0.97
2000/01	0.7	0.55	0.4
2001/02	0.81	0.79	0.8

Procurement of seeds and fertilizers

For improved seeds, the breeder seeds are produced by the Agricultural Research Corporation whereas the foundation and registered seeds are produced by the Seeds Propagation Administration (SPA) of the Ministry of Agricultural but their production was discontinued because of poor budgets and unavailability of breeder seeds (Elamin, 2002). Production of improved seeds has faced by many difficulties that resulted in unavailability of these seeds, and when available their prices are high relative to local seeds.

Sudan consumes about 200 thousand metric tons of fertilizers, mainly in the forms of nitrogen and phosphorus; it is used in both private and public agricultural sectors, annually. This amount of fertilizers costs the economy’s balance of trade a sum of US $60 million per year.

Generally, the use of chemical fertilizers is mostly confined to national irrigated projects such as Gezira, Halfa, Rahad and Suki and a number of privately owned irrigated commercial farms in northern parts of Sudan. Urea fertilizer is usually used by public irrigated projects in more than 90 percent of the area at varying levels but the recommended rate is 190 kg per hectare for wheat. However, in the Northern States of Sudan, where wheat is traditionally irrigated, the rate of urea and supper phosphate application is still low. However, the use of these fertilizers is dependent on the availability and accessibility to credit financing.

Before 1992 and during the seventies, urea fertilizer was acquired through bilateral cooperation between Sudan and Kuwait and government of Japan and the Netherlands. In 1980 the European Foundation for Development and the international Development Agency (IDA) were also engaged in financing agricultural inputs. After international financial aid declined, Sudan resorted to financing importation of agricultural inputs on its own. The system of Consortium Banks was introduced to finance irrigated public projects. These banks were responsible for providing local currency to agricultural projects whereas the Bank of Sudan provided the foreign currency. Nevertheless, and because of the inexperience of Banks in the newly introduced forms of finance and the high costs of finance through the

Consortium of Banks, the agricultural projects resorted to a system of deferred payment through forward sale of cotton to finance agricultural inputs. The new system resulted in several problems which hampered the efficient distribution of inputs. In the private wheat sector, financing of wheat is based on farmer's individual collateral, which includes personal guarantees, the tenancy itself, and farmers' unions' guarantees. This method of finance works as a disincentive for technology transfer, reduced costs, increased productivity and production.

Impact of technology adoption

Technologies, if adopted are expected to have impacts on producers, consumers and the society as a whole. Technology impact could be measured by several indicators at the farm and national levels. The need for improved and modern farm technologies to increase agricultural production in Sudan has been recognized and highlighted in many studies since the early 1980s. Implementation of the liberalization policies has negatively affected the adoption of recommended technologies. Removal of credit facilities had an adverse effect on farmer' financial capabilities. This is coupled with the removal of subsidies has resulted in high cost of essential inputs and consequently low adoption rates of technology. These factors have played a major role in lowering the productivity of wheat crop. Low productivity of the cultivated crops coupled with high cost of production inevitably entailed low and unstable farm incomes and deteriorating standard of living for the rural households.

At the farm level, the real impact attributed to the adoption of technology could be observed in wheat yield improvement after the adoption of technology. The recommended technology proved to be superior to farmers' traditional practices. Among the most influential components of the package were sowing date, improved seeds and fertilizer application. These components are totally dependent upon their availability and their prices.

According to research recommendation, November is the recommended date for sowing. However, due to engagement of farmers with the cultivation of other crops during November and their tendency to delay sowing with the objective of reducing risk of birds' attack if they grow wheat early, the sowing date extended from November to January and thus resulted in a wide range of variability in wheat productivity in the Northern States. About 12% of the farmers cultivated wheat during November while 35% and 53% cultivated wheat during December and January, respectively. It is obvious from Table 9 that farmers who cultivate wheat during November obtain higher yield (4,760 kg/ha) than those who cultivate wheat during December (4,046 kg/ha) and January (2,858 kg/ha), respectively. This means that delaying the sowing date from November to December and January has resulted in a 15% and 40% reduction in yields, respectively. On the other hand, delaying the sowing date from December to January has resulted in a 29% reduction in yields. Regarding the improved seeds, 60% of the farmers used improved seeds while 40% use local seeds. In the northern Sudan, the adoption rate of the improved varieties in the Northern States is higher than that of the Nile State due to the availability of improved seeds coupled with the vital role of the extension service in technology dissemination.

In central Sudan, only about 12 percent of the farmers used the recommended fertilizer rate while about 88 percent did not. Fertilizer application varied from 60 to 400 kg/ha. Financial inability was the main problem facing farmers in using recommended rate of fertilizer. About 11% of the sampled farmers in the Northern States applied the recommended doses of fertilizers while 22% and 55% applied less or more than the recommended dose, respectively (Table 10). Non-adopters of the recommended dose (11%) claimed that fertilizer is not available and is expensive.

Economic evaluation was conducted to assess the profitability of the package against that of farmers' practices. This is necessary because the economic ranking is often different from the agronomic ranking due to differences in factor costs. Whole farm budget was employed using yield and cost data from both groups to appraise the effect of technology adoption on the net benefits between adopters and non-adopters of the package. Only costs that vary between the two groups were considered in the analysis. The field price (SD 70 /kg of wheat) was used to derive total benefit which equals price times yield. Then net benefit was calculated as the difference between total benefit and the cost of production.

The adopters incurred 45% additional costs than non-adopters but obtained 50% yield advantage and 57% increase in net benefits over non-adopters. (Table 11). This means that the additional cost of the package was more than compensated for by its high yield and hence higher returns. To relate the benefits accrued to costs incurred, a marginal rate of return (MRR) was calculated and found to be 181%. This means that with adoption of the package, a farmer is expected to retain every Sudanese Dinar (SD) invested in the package plus additional SD 1.8. Total yield advantage in the Northern Sudan was estimated at about 228,245 tones of wheat as a result of technology adoption. In terms of monetary value, the total incremental benefit as a result of technology adoption in wheat crop will be about 3 billion Sudanese Dinar (Elamin, 2004).

Table 9. Adoption of wheat sowing date and their respective yield and area in the Northern State, 2004.

Sowing date	Cultivated area (ha)	Percentage	Average yield (kg/ha)	% reduction in yield
During November	6,237	12%	4,760	
During December	19,049	35%	4,046	10 %
During January	28,948	53%	2,858	40%
Total area	54,234	100%	3,887	

Table 10. Adoption of fertilizer application in the Northern State, 2004.

Sowing date	Percentage
Apply the recommended dose	11%
More that the recommended dose	55%
Less than the recommended dose	22%
Do not apply fertilizers	11%

Table 11. Cost of package and none package winter crops, 2004

Crops	Package	Farmer's practices	Differences	% difference
Cost of production	147,860	101,788	46,072	45 %
Yield (kg/fed)	3,572	2,381	1,191	50 %
Total return	250,005	166,670	83,335	50%
Net return	102,145	64,882	37,263	
Marginal rate of return				181
Total yield advantage in Northern Sudan (tone)				228,245
Total net return for wheat area in Northern Sudan (Billion SD)				3

Source: Elamin, 2004

Conclusion

Agricultural crop pricing policies followed by the Government of Sudan, during the last decade, have had detrimental effects in promoting crop production and meeting the stated food security goal. The unfair pricing policy coupled with an inefficient fertilizer procurement and distribution policy have led to deteriorating output/input ratios for wheat crop and declining production at the aggregate levels. This situation has resulted in deterioration of the comparative advantage of wheat in central Sudan. Hence wheat acreage has been reduced and production shifted to northern Sudan.

After liberalization of the market for grains in 1999, imported wheat price out-competed domestic wheat price by a large margin of 23 % mainly due to taxation of output and the removal of subsidies. Consequently, high costs of production, low productivity and less competition with imported wheat have made wheat an unattractive crop in Sudan. A serious program for relocation of wheat from its original areas of production in the River Nile and Northern States is currently underway. However, for this agricultural reform program to be successful it needs more protection in terms of reduced constraints to accessing fertilizer, seed and water inputs, reduced costs of production and marketing at competitive prices.

The results of the economic analysis showed that substantial benefits were realized through the adoption of the recommended package. At the farm level, adoption of improved technology resulted in 50% yield advantage and 57% increase in net benefit over the traditional practices. At the state level, it resulted in about 228 thousand tones yield advantage and about 3 billion SD as an incremental benefit.

The government withdrawal from direct financing of the agricultural sector after the orientation of the national economy towards free market economy coupled with poor financial capability of farmers to finance the agricultural operations has affected farmer's behavior towards input use (especially improved seeds and fertilizer) and his performance in conducting different agricultural operations. This calls for the government to revisit its input and credit subsidy policy and support to extension services if the dream of self-sufficiency in wheat is to be realized.

Appendix 1. Contribution of agricultural sector in the annual gross domestic production current producer prices in million LS.

Year	GDP total	Agricultural Sector contribution	%
1980	4792.7	1650.5	34.4
1981	6217.9	2314.7	37.2
1982	6330.8	2915.8	35.0
1983	10403.1	3641.1	35.0
1984	11777.0	3650.9	31.0
1985	16425.3	5748.9	35.0
1986	20763.8	7059.7	34.0
1987	36471.0	12764.9	35.0
1988	46791.0	15909.0	34.0
1989	82562.0	27245.4	33.0
1990	100863.0	30545.6	30.2
1991	190827.1	54701.2	28.7
1992	401840.0	136087.0	33.9
1993	857477.0	326834.0	38.1
1994	2386330.0	973571.0	41.1
1995	4233912.0	1776417.0	43.0
1996	10215174.0	4594675.0	45.0
1997	15929308.0	759828.0	47.6
1998	19916123.0	9699153.0	48.7
1999	24488851.0	12195447.0	49.8
2000	2969452.4	624.4	46.4
2001	3380555.0	653.7	45.6

Source: MOF and Bank of Sudan, Annual Reports.

Appendix 2. Cultivated area, production, consumption, food gap and self-sufficiency ratio.
Source: Ministry of Agriculture and Forests. Ministry of External Trade.

Year	Area (000 acres)	Production (000 tons)	Consumption (000 tons)	Gap (000 tons)	Rates of production to consumption (%)
1980/81	437	218	550	332	39.6
1981/82	329	142	580	438	24.4
1982/83	225	176	610	434	28.8
1983/84	335	157	640	283	24.5
1984/85	111	79	670	591	11.7
1985/86	36	199	700	501	28.4
1986/87	282	157	730	573	21.5
1987/88	34.3	181	740	559	24.4
1988/89	393	247	780	533	31.6
1989/90	614	409	850	441	48.1
1990/91	1104	686	870	184	78.8
1991/92	930	895	920	25	97.2
1992/93	805	445	976	525	45.8
1993/94	881	492	1020	528	48.2
1994/95	741	498	1070	572	46.5
1995/96	774	575	1130	555	50.8
1996/97	782	640	1200	560	53.3
1997/98	646	535	1200	675	44.5
1998/99	405	172	1370	1198	12.5
1999/2000	244	250	1460	1210	17.1
2000/2001	294	266	1500	1234	17.7

Fig. 1 Per capita annual wheat consumption in The Sudan selected years

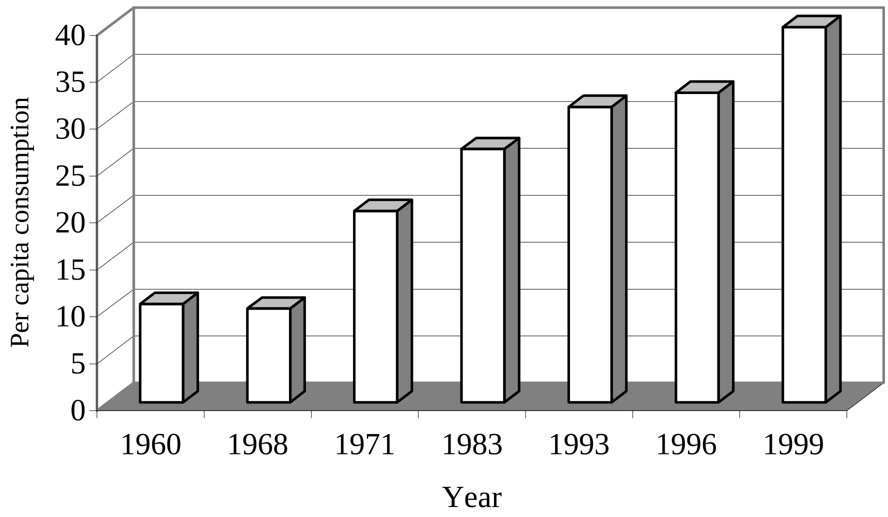
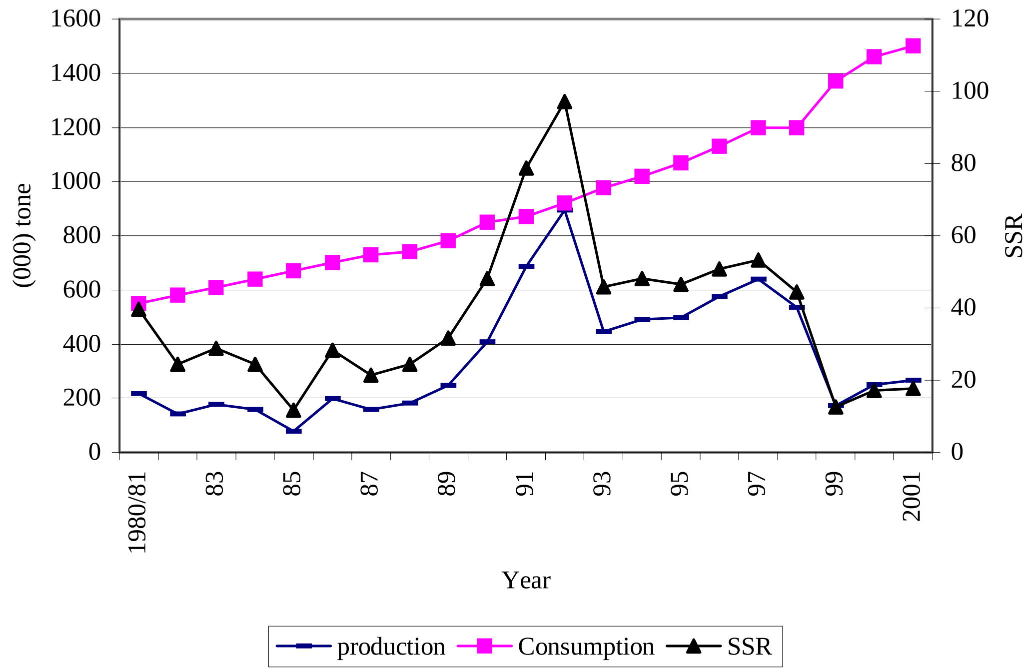


Fig. 2. Wheat production, consumption and self-sufficient ratio (SSR) 1981-2001



References

Elamin, Abbas Elsir Mohamed (2001). Constraints of Wheat Production in Central and Northern Sudan. NVRSRP Newsletter, the International Centre for Agricultural Resources in the Dry Areas (ICARDA), Cairo, Egypt (i*n press*).

Elamin, Abbas Elsir Mohamed (2001). Evolution of Wheat Production Policy in the Sudan. NVRSRP Newsletter, the International Centre for Agricultural Resources in the Dry Areas (ICARDA), Cairo, Egypt (i*n press*).

Elamin, Abbas Elsir Mohamed (2001). Economic Situation of Wheat Production in Central and Northern Sudan, the National Coordination Meeting of the NVRP, Wad Medani, Sudan, August 2001, Annual Report of the ARC, 2001.

Elamin, Abbas Elsir Mohamed (2002). Constraints of Wheat in the Gezira and Northern States, the National Coordination Meeting of the NVRP, Sudan, Khartoum, Aug. 2002, Annual Report of the ARC, 2002.

Elamin, Abbas Elsir Mohamed (2002). Evaluation of Farmer's Attitude and Input Use on Wheat Productivity in the Northern State, the National Coordination Meeting of the NVRP, Sudan, Khartoum, Aug. 2002, Annual Report of the ARC, 2002.

Elamin, Abbas Elsir Mohamed (2004). Economics of Wheat Production in Sudan. A paper to be presented in the National Coordination Meeting of the Nile Valley and Red Sea Regional Program - ICARDA, Wad Medani, Sudan, , Aug. 2004.

Elamin, Abbas Elsir Mohamed (2004). Monitoring and Evaluating Improved Wheat Production Technologies in Northern Sudan. A paper to be presented in the National Coordination Meeting of the Nile Valley and Red Sea Regional Program - ICARDA, Wad Medani, Sudan, , Aug. 2004.

Ogbu, O (1991). "Structural Adjustment and Agricultural Supply Response in Sub-Saharan Africa: Synthesis and Limits of Current Analysis.Research for Development" Vol. 6 No. 2 pp 1-2.

Opening Speech

12th Regional Wheat Workshop for East, Central and Southern Africa

Merica Hotel, Nakuru

22-26 November 2004

by

Hon. John Koech, Minister for East African and Regional Cooperation, Kenya

Participants, distinguished guests, ladies and gentlemen:

It gives me much pleasure to preside over the opening of the 12th Regional Wheat Workshop for East, Central and Southern Africa here in Nakuru. I acknowledge the presence of our international visitors whom we wish a pleasant stay and a fulfilling experience in the short period they will be in the country. On behalf of the Government and the people of Kenya and on my own behalf, I wish to welcome you to this country and in particular to this workshop. We would however, wish that you take some time after the workshop to savour and experience some of the attractions this country offers that makes it one of the premier destinations for tourists from all over the world.

The task that you have before you in the coming days of the workshop is to share your research findings with one another for the benefit of the people in the region and beyond. As you deliberate on the many scientific issues impacting on agriculture in the region, I would wish to remind you that the adoption of the technologies that you develop is what will impact positively on farm productivity and not the generation of the technologies *per se*. It is therefore important that concerted efforts be made to disseminate this information and generated technologies to as many farmers as possible. In this context, I would wish that the future workshops should involve other stakeholders and service providers especially those involved in agricultural extension and if possible farmers. In line with the workshop theme, “Development and dissemination of sustainable wheat production technologies for improved livelihoods in sub-Saharan Africa”, it is important that technologies developed in the region be shared throughout the region to enhance food security and alleviate hunger. I note with satisfaction that scientists in the region apart from generating technologies for increased productivity also ensure that these technologies do not impact negatively on the environment and therefore lead to sustainable exploitation of our natural resources.

Although maize is still the most important cereal in the region, wheat has become increasingly important due to urbanization and changed dietary habits. Regrettably, none of the sub-Saharan countries is self sufficient in this commodity. In Kenya demand has been growing at 5% per annum and this has not been matched by production. I believe that the situation in other countries represented here is not any different. We as a region face similar constraints as we try to improve food production to sustain our people. It is imperative then that we look at opportunities for improving agricultural productivity together. There is need for us to pool together and strategize collectively on ways of increasing wheat productivity. This forum gives us an excellent opportunity to exchange ideas, experiences and knowledge and ensures that duplication of effort is avoided. This will conserve the meagre resources available.
May I briefly talk about the challenges that face wheat production in Kenya and by extension the region. Apart from environmental factors such as drought, the major

constraint impacting negatively on food production in the region is use of inappropriate production technologies by farmers. Despite development over the years of high yielding widely adapted and disease resistant wheat varieties, adoption of these varieties by farmers has been done. There is therefore need to catalyze the adoption of these varieties by farmers to give impact to wheat production and reduce importation bill for wheat.

The potential of high yielding varieties developed by the national programs in the region cannot be exploited unless improved management technologies are also adopted by farmers. We must not only develop agronomic packages for wheat production but must vigorously promote their adoption by as many farmers as possible. Critical areas for agronomic research which need your attention are:

- Land preparation
- Soil fertility management
- Seeding technologies
- Weed control
- Post harvesting
- Quality assessment and value adding.

Another major concern but which Governments in the region are addressing is provision of suitable marketing structures. To ensure farmers derive maximum benefit from their endeavors, the Government of Kenya has taken measures to protect Kenyan farmers from unfair trade practices and ensuring that wheat farming is profitable. In this context there is renewed interest in wheat farming in the last two years. The Government will encourage this trend by making marketing structures in place and improving them. Ladies and gentlemen, I note with satisfaction the role that CIMMYT has played in improving livelihood of so many of our people. Maize and wheat research has immensely benefited from CIMMYT with many different high yielding varieties being developed through CIMMYT support. CIMMYT has also promoted and still does on production aspects such as land preparation, disease and pest control and socio-economics. It is only recently that CIMMYT inaugurated the “Food security and sustainable livelihood for African households” project which will enhance food supplies, food security for the rural and urban poor in sub-Saharan Africa. We in Kenya and indeed all in the region welcome this bold initiative and will work with CIMMYT to ensure the success of this project in improving the welfare of our people. We salute CIMMYT for sponsoring this workshop which goes a long way in ensuring that research in the region remains focused on common constraints and synergies and relative strength of national programs are fully exploited.

Lastly, I wish to thank local sponsors – Bayer East Africa, Brazafric, Osho Chemical industries and Monsanto – who have contributed to the success of this workshop. I also thank the local organizers and CIMMYT staff who have made arrangements to make the workshop a success.

It is now my pleasure and privilege to declare the 12th Regional Wheat Workshop officially open.
Thank you.

Closing Speech

12th Regional Wheat Workshop for East, Central and Southern Africa
Merica Hotel, Nakuru
22-26 November 2004
by
Hon. Moses Akaranga, Assistant Minister for Agriculture

Distinguished Participants, Guests, Ladies and Gentlemen:

It gives me great pleasure to be with you today at the closing of the 12th Regional Wheat workshop here in Nakuru. It is my belief that you have had fruitful deliberations on the way forward for wheat production in the region. I am informed that 6 countries within Eastern Africa (Ethiopia, Kenya, Rwanda, Sudan, Tanzania and Uganda) are represented in this workshop. Other participants from Mexico and India are also in attendance.

This workshop therefore has provided an excellent opportunity to share expertise and experience on issues affecting development and dissemination of sustainable wheat production technologies for improved livelihoods in Sub-Saharan Africa.

Ladies and Gentlemen,
In order for the regional countries to collectively ensure food security there is urgent need to foster closer collaboration and partnerships among research institutes in technology development and dissemination. This has been demonstrated during this workshop. I am informed that the scientific data presented showed that factors which afflict effective production are not restricted within political boundaries.
In our country Kenya, food production has not matched population increment partly due to unpredictable weather patterns, high cost of inputs, marketing constraints and other factors. I believe the situation is not any different in countries represented here.
In order to feed growing populations, our countries will increasingly rely on research to generate and transfer technologies in collaboration with stakeholders.

Ladies and Gentlemen,
In the last six days, you have been deliberating on strategies to increase wheat production in the region. I am informed that you have discussed, identified, ranked priority constraints and suggested possible intervention measures. Some of the identified constraints include drought, diseases (in particular stem rust), pests (especially the Russian wheat aphid), unsatisfactory wheat quality and dissemination channels.

You have also proposed intervention strategies that include development of collaborative regional research projects to address these constraints. This is indeed a commendable achievement.

The challenge ahead is to implement these strategies and to ensure research technologies and products reach the intended end user namely the farmer to improve productivity.

It is my wish that this initiative will be fully supported by the respective governments and development partners. On our part, my Ministry will do everything in its mandate to support this noble undertaking.

It is only in this way that we can slowly but surely move towards self sufficiency in food production and create wealth.

I would urge you all to pass over the deliberations and recommendations to your respective relevant government system for implementation, so that we can all pull together in addressing the constraints in wheat production within the region.
Finally, I would like to thank the sponsors of this workshop namely CIMMYT, Bayer Crop Science, Brazafric, Osho Chemicals and Monsanto for their invaluable contribution. I would also like to appreciate the role played by the Ministry of Agriculture, KARI and the local organizing committee for successfully organizing this workshop. I congratulate the participants for the job well done. Let me take this opportunity to wish our visitors a good and safe trip to their respective destinations.

With these remarks, it is now my great pleasure and duty to declare the 12th Regional Wheat Workshop officially closed.

Thank you.

Question and Answer Sessions

12th Regional Wheat Workshop for East, Central and Southern Africa
Merica Hotel, Nakuru
22-26 November 2004

SESSION NO. 1

Experiences in wheat research in Eastern, Central and Southern Africa- Miriam Kinyua

Comment: C.A. Kuwite (Tanzania)
Production has dropped due to privatization policy whereby large scale parastatal farms which used to produce 60% of wheat that was produced in the country have stopped producing. Once private farmers set in, wheat production is expected to increase. Research is now more focused on small scale production.

Staff:	Co-ordinator (Breeder)	-	R.V. Ndondi
	Breeder	-	Elizabeth Maeda (In studies)
	Weed scientist	-	Tuael Mmboga
	Agronomist	-	Mbayi Mugendi (In studies)

Comment: William Wamala Wagoire (Uganda)
The wheat programme in Uganda has since time back been based in varietal development through selections which has had very limited staff. Priority wise wheat is not highly considered therefore, resources from the government have been put to wheat. There are regions which still demand wheat seeds i.e. South West and Eastern Uganda. Therefore, forum is now on maintenance of varieties and seed germination.

Comment: Nyirigira Ruzindana Antoine

Wheat in Rwanda in not a priority crop. The research consists of screening wheat materials on soil acidity tolerance, bread maker qualities, high yielding characteristics.

The only researcher that was appointed in National wheat programme left the programme two weeks ago. Another researcher named Innocent has been appointed in the programme, but since he is a young scientist, he needs training to let him lead wheat research activities.

Programmes (crop research programmes) in Rwanda have only one researcher and that is due to the 1994 genocide. The country (Rwanda) still suffering from the deep gap of the skilled people as one among may 1994 genocide consequences. This is why “Capacity Building” is an important element for my country.

I think wheat can also be called cash crop since when produced in an acceptable quantity, it should let the government save money that was put in wheat flour importation, and to contribute on people welfare.

Comment: Abbas Elsir (Sudan)
Wheat research in Sudan is carried out by the agricultural corporation which is centered in Central Sudan. We have a national co-ordinator for wheat programme in which different disciplines are contributed to the generation of wheat production technology.

Comment: P. Njau (Kenya)
The wheat research programme is divided into sub programmes. Breeding protection, Agronomy Quality and Socio-economics. The main challenge today is stem rust, Russian wheat aphids, drought tolerance and acid soil problems.

Question: Pfeiffer Wolfgang
Participation of South African countries (Zimbabwe, Zambia, and South Africa) Why not present?

Answer: They did not send their papers for review.

Comment: E.M. Njoka – Njoro (Kenya)
We need to come out and give what we have to farmers as we proceed with research. Let the farmers get involved especially the small scale farmers.

Question: Solomon Gelalcha
Why did you not mention the importance of collaboration of ECAMAW with ICARDA, just like that of CIMMYT?

Answer: The importance of collaboration with ICARDA is not overlooked. We had invited Dr. Osman Abdalla to attend the workshop but due to unknown reason he could not appear, but still the collaboration is expected to be relevant.

Question: A.M. Kibe
Why has the National Agricultural Institution of Learning (universities, colleges, etc) been left out of research programmes? Can funding be channeled to and through universities?

Answer: It is a challenge for us to consider to how we ought to integrate the educational institutions in our research programmes. For some reasons we have somehow forgotten them. Let us select a representative to seat in our forums of discussions, when we chart out the way forward.

Comment: Owuoche
Being one of the beneficiary of CIMMYT training, I would urge CIMMYT not to forget or scale down the training component since it has benefited the third world countries.

Question: Ravi Singh
Changes in programme structure and people in each countries of the region.

Answer: Research management structure and changes in people at CIMMYT was discussed. Two flyers were distributed, which describe the current programme structure and activities related to what research.

Comment: Desalegn Debelo
The status of ECAMAW, the thematic teams formed under ECAMAW according to the current priority not mentioned. Thematic area leaders and countries need to be included.

Application of GIS in Wheat Improvement and Management- Dave Hodson

Question: T.C. Riungu
Where can scientists get the training in GIS?

Answer:
CIMMYT's GIS group has conducted extensive training in the region, especially in user-friendly simple software tools e.g. Maize Atlas and Country Alumna training in advanced tools has not been undertaken as CIMMYT may not have the competitive advantage to do so. In most regions, there should be active GIS workers e.g. at universities, NGO's etc and private companies. These local suppliers may be best options for training. If not then CIMMYT would be willing and happy to work with local partners to increase capacity if feasible.

Question: M. Kinyua
Could it be necessary risking the introduction of wheat in the densely populated areas?

Answer:
A needs assessment would need to be undertaken to identify if suitable technologies for these areas existed, combined with assessment of comparative advantage of wheat vs. other options (wheat may not be the most suitable crop for all areas) and different technologies/materials would be required for different farming types.

Question: Owuoche
How do you determine poverty levels in different countries?

Answer:
Poverty maps are created using advance econ-metric analysis and GIS typically a technique called "small-area estimation". These usually predict income or expenditure which is then compound to national poverty lines. These vary in monetary terms between countries, but are often determined by the cost of buying a basic food budget that meets minimal nutrition requirements.

Question:
If wheat productions increased in marginal areas, mainly rural poor benefit. If increased in intensive, high productive areas mainly urban and land less rural poor benefit from increased surplus production.

Answer:
Yes – both are important.

Question:
Is it possible to estimate risk of production when wheat area is expanded by using GIS combined with crop modeling.

Answer:
In principle yes (although lost capacity in CIMMYT). Access to data inputs for models may be limiting factor.

Question:
How can GIS be used to identify actual wheat production areas where wheat should not be produced or is not competitive with other crops.

Answer:
GIS can identify areas of potential interests that could serve as a framework for detailed econ surveys on the ground to determine competitive advantage of wheat. GIS alone can not do this, bar introducing limiting biophysical factors e.g. acid soils.

Question:
During mapping the poverty map, will you integrate the levels of potential (yield level) of wheat at different places with poverty reduction? e.g. using crop tests?

Answer:
There is a need to do it in the future. Yes, interesting idea to investigate in the future. Investigated at present.

Comment: Solomon Gelalcha
The distribution of the potential wheat producing areas does not exactly match distribution of the needy people in the country (Ethiopia).

Question: T.C. Riungu
GIS is a very useful tool for scientists and other users. How can one get the training.

Answer
There is no organized training but there is an attempt to involve all those dealing with GIS, possibly contact software producers and through universities and other institutions to develop some training.

Question: Desalegn Debelo
Is that possible to see other profitable options in wheat growing areas? What is your comment on the correlation of wheat growing areas and the distribution of research centres? What is your recommendation to the region concerning the price of satellite usage data?

SESSION NO. 2

Social financial evaluation of gender in the adoption and impact of wheat production in Kenya- Z. Nyakwara

Comment: Prof. E.M. Njoka
It is important to have information on the contribution of straw to the soil physical and chemical composition factored into the cost/benefit-ratio.

Answer:
We will look into that.

Question:
Is value of straw factored in cost/benefit ratio?

Answer:
No: Because this is a new technology that has been operated in the area due to persisted drought but there is no factored cost/benefit ratio.

Question: P. Njau
The wheat straw is mainly used to feed livestock directly in the fields. What is the effect of land hiring to both the farmer and the landlord?

Answer:
It is a mutual agreement during hiring that when you harvest your crop the straw is for the cattle. Those who hire land find no negative effect (impact) by not harvesting straw.

Comment: M.G. Kinyua
During drought straw of the wheat has become hardy for the communities living in Narok.

Analysis of marketing and pricing policies on technology input use and production of wheat in the Sudan- Abbas Elsir

Question: A. Kibe
Why is the yield of wheat at the Gezira irrigation scheme so low and with irrigation you should get more than double the yield.

Answer:
The environment at Gezira is very harsh and the yields, however low, give better economic value than the imported commodity.

Comment: Pfeiffer Wolfgang
Smallholder wheat production needs to be subsidized until it is competitive. In countries which have large and small producers, not all farmers need subsidies at the same level e.g. not all through subsidized prices.

Comment:
Subsidies in countries such as India are given to the industries (e.g. chemical, fertilizer, mechanical, etc) by giving tax rebates on the raw materials used for producing the commodity.

Comment:
In this way, the government is able to protect it's farmers because the product is processed at a lower cost. In Africa we should probably try to develop our Agro-industries from this perspective.

Question: C.A. Kuwite
As a result of liberalization policies there are wheat imports that are cheaper than local wheat. What plans are there to ensure that local wheat out competes imported wheat so that production increases in Sudan and in the region at large?

Answer:
The solution is to develop a profitable and cheaper technology that cut or reduce the cost of production starting from high yielding cultivar that are adaptable to low or zero tillage. Another thing is to develop a local industry to reduce the cost of imported fertilizer.

Question: Solomon Gelalcha
In developing countries the government defend, justifies the removal of subsidy by investment on basic infrastructures (road, schools, etc), so what policy options is there to support the poor farmer?

Answer:
The government has to think for long-term effect before completely removing subsidies.

The scientists have to think of technological options for reducing production cost (Ex. Minimum tillage etc).

Question: Prof. E.M. Njoka
What do you think about subsidies in the alleviation of poverty in African country?

Answer:
Subsidies are very essential especially for small scale farmers who are financially incapable. It is the only way of keeping them surviving otherwise they will migrate to the border of the cities and create so many problems.

Comment: Ravi Singh
Personal view on subsidy: Removing subsidy without providing options for poor farmers is likely to have severe effects on the livelihood of people.

Social economic factors influencing the use of recycled wheat and maize by small scale farmers in Nakuru - A.C. Ndiema

Question: Desalegn Debelo
What is the status and contribution of decentralized seed system to overcome the problem of recycled seed? Seed multiplied by small scale farmers for their own use and for the farmers in their village?

Answer:
The practice was workable before liberalization of the industry. They are more seed breeders, multipliers and stockiest than before. The issue in question now is trusting the source of the seed.

Question: Patrick Ooro
What is the projected implication on the quality of seed with particular reference to recycled maize seed?

Recycled seed maize has reduction in yields to the tune of 20% loss. In subsequent recycling this loss is said to go upto 50% because maize is a cross pollinated crop.

Question: J.K. Macharia
Liberalization in seed industry is suppose to make seeds cheaper. How come the seed has become much more expensive?

Answer:
Seed liberalization has only caused confusion among the faring community giving the seed merchants room to exploit ignorant farmers.

Comment: Prof. Njoka
We need quality seed if the accompanying technology has to have the benefit required to the farmers.

SESSION NO. 3

Survey of National Enemies of Rust Wheat Aphids (RWA) in Kenya- Macharia

Question: C.A. Kuwite
Since the parasites and parasitoids come in late during the season what is their population like in late planted wheat?

Answer:
The population trends are just the same, i.e. the population of predators and parasites tends to lag behind RWA population, thus they are unable to offer adequate control as they peak when RWA has already caused damage to the crop.

Question: J.K. Macharia
What % age of predators/plant do you consider sufficient to manage RWA biologically?

Answer:
At the moment, only preliminary studies have been conducted to document the predators that attack RWA. The next phase will be used to determine the bio-efficacy of identified biological agents (natural enemies).

Comment:
In contrast to other aphids, one RWA per plant can cause symptoms, hence biological control may be complicated.

Answer:
RWA management requires IPM control strategies (biological control being one) and the future lies on development of host plant resistance strategies. No single control strategy is effective.

Question:
How do you expect the effect of natural enemies on the host plant when the number of RWA population is decreased?

Answer:
The natural enemies are host specific and will only attack aphids but not the host plants supporting RWA, hence no effect in the increase or decrease of RWA populations.

Comment: M. Kinyua
Study the aphid instead of crop physiology i.e. how the crop behave. However, we decide to study the aphid as well.

Current challenges in the management of wheat diseases - Ravi Singh

Question:
How do you select the parents. Is the molecular marker technique for the ***

Question: Pathak
Clarify the relationship between horizontal/vertical resistance and slow rusting/major genes?

Answer:
They are synonymous terms. Horizontal resistance is synonymous to slow rusting, whereas vertical resistance is synonymous to major genes.

Question: Pathak
New stem rust races have appeared after 15 years in East Africa region. Is it due to change in the environment or evolution of new virulent race?

Answer:
New races have been evolving from time to time in the region. The evolution and migration of the Sv31 resistant race is a very significant case as several cultivars have become susceptible to this race.

Question:
Could we screen wild relatives of wheat also to tap the resistant genes?

Answer:
Yes, it can be done but care must be taken that wild species do not become weed in the field.

Comment: Owuoche
We should incorporate Sr genes into Lr and Yr germplasm that have shown resistance.

Answer:
That is a good suggestion and that is one of the things we plan to carry out in the future.

Question:
After the 1998 stem rust episode in Uganda ***

Answer:
The resistant lines were used in crossing programme. Advanced generation populations need to come back to the region to identify which lines inherited resistance to the Sr31 virulent race.

Comment: Wolfgang Pfeiffer
Fastest way to get Sr resistant varieties to farmers will be using major genes combined with double haploid methods. Then minor genes in phase II varieties.

Answer:
Cost of making double haploid is still a limiting factor for its wide use. Also if two crop seasons are grown per year, then traditional breeding scheme is fast enough.

Evidence of New Russian Wheat Biotypes in Kenya- J. Maling'a

Question:
What capacity is there to deploy predators to control aphid epidemics in *** of the large ** of land that are under wheat growing?

Answer:
We look forward to identifying effective natural enemies, which can then be reared and released on time as RWA attacks the wheat crop usually at the vulnerable growth stages (seedling stage).

Evidence of RWA Biotypes in Kenya- Maling'a J.

Comment: M Kinyua
Study the aphid instead of crop physiology. I.e. how the crop behave. However we decided to study the aphid as well.

Evidence of new Russian Wheat Aphid Biotypes in Kenya- M. Kinyua

Question:
Differences in the AFLPs may not necessarily indicate differences in the effects of the pest. Do you have preliminary observation on the correlation between the diversity of the pest and the effect on wheat?

Answer:
Yes, we had previously evaluated the wheat lines in the greenhouse against 3 chores collected from 3 regions (Eldoret, Timau and Njoro) and observed that there are differences in virulence of Timau against Njoro and Eldoret shores. This promoted the story. The future is to chores from the two regions and screen them against specific lines while evaluating their DNA. The data will be used genotyping of the aphid using one of the current (programmes e.g. power maker).

Physiological Races and Virulence

Comment: Temesgen Kebede
Some of the large scale state farms use fungicides to control stem rust. Few large scale private farmers also utilize fungicides to control stem rust.

Question: John Muchile
What is the short term solution to stem rust pandemic since breeding programs for resistance/tolerance take long?

Answer:
We do have strategies to screen the resistant varieties so as to that identify susceptible genotypes were taken to the shuffling in the long run.

Comment:
The report on Sr31 as resistance is based on the samples collected in 2001 and 2002. The scenario has been changed since 2003.

Wheat rust in India. M. Prashar

Question: Pathak
Why not to test the segregating material rather that advance prevaliased variety of wheat for resistance of wheat rusts?

Answer:
Yes, The rust laboratory is already testing the segregating lines/advance lines from all over the country.

Question: Solomon Gelalcha
Would you please share with us your view/experience of programme in the rust control strategy of Indian wheat research programme.

Answer:
The gene development strategy is not as such successful because of the migratory nature of the rust pathogen. Mover over, the agronomic and quality aspect should be considered in the control strategy.

Question: Desalegn Debelo
Can you share with us the information of puccinia pathways identified in India?

Answer:
Puccinia pathway indicates that brown and black rusts spread from South to Central India and from Northern hills of the country, yellow and brown rusts are disseminated down to the plains of North India.

SESSION NO. 4

Grain yield, water use and water use efficiency as affected by moisture under rain-out shelter- P.A. Ooro

Comment: Prof. E.M. Njoka
Your result should include the environmental effect of rainshelter. Otherwise you would have to give your result in relative terms.

Answer:
The environmental effect of rainshelter in terms of RH and PAR have been addressed hence will be included.

Comment: P.K. Kimurto
The rainshelter effects on the performance of the genotype has been established to be negligible or non-significant from previous studies done on the site.

Question: Solomon Gelalcha
What is your criteria of categorifying your environmental as marginal; is moisture the only criteria?

What is the day to maturity of the varieties used in the experiment.

Answer:
Moisture, temperature, soil type etc. can be used as a criteria but we used moisture as main criteria. The varieties used are early maturing ones.

Question: A.M. Kibe
The crop canopy environment must have been affected under the rain shelter thus reducing the ET. How did you account for it in your calculation. Your formula for TWU was not really what was used because there was no precipitation.

Answer:
The out-rain shelter's tarpolein was lifted and faded in such a way as to allow air movements within the rain shelter. In the TWU formula, R is supposed to be replaced by 1 (irrigation water applied) R(run-off) and D (drainage) was considered to be negligible and therefore was not part of the computations.

Evaluation of Monitor and its tank-mix partners for weed control in wheat - D.O.K. Amadi

Question: Prof. E.M. Njoka
You are dealing with different populations and the yield dealing equations are affected by population. How do you account on this?

Answer:
The different populations are with regard to the different wheat cultivars used in the trials. Our main focus was to target weeds whose response to herbicide treatments may at time be neutral to plant density.

Genotype, nutrient and utilization interaction in wheat grown in the marginal and acid soils environment in Kenya- J. Kamwaga

Comment: Prof. E.M. Njoka
You cannot attribute your effects of N if the interaction of ** are not indicated. Hence your conclusions were not complete.

Answer:
The idea here is to test the cultivars adaptability to low fertility and also at high fertility situation and find out if there is any cultivar and fertilizer interaction. A cultivar that is efficient at** N ** low fertility and respond well to append N would be preferable.

Question:
Do you consider the N in grain (protein content) while studying the rates in relation to N use efficiency?

Answer:
N increases in the grain if you increase the N use efficiency to a certain level.

Evaluation of impaired wheat varieties under different management levels in Eastern Wallaga Highlands - Tolera Abera

Question: Owuoche
Did you cost land preparation?

Answer:
Yes indeed.

Impact of irrigation frequency and farm yard manure on salt affected soil and wheat production in Dongola area- Elmoiez Fadul

Question: Solomon Gelalcha
Is the 7 days interval economical? (It seems so frequent).

Answer:
We applied the same amount of water by the end of season for each treatment so economically we used 7 days as recommendation where the output of 7 is high.

Comment: Prof. E.M. Njoka
In your irrigation interval, care should be taken to put into account the effects of added organic matter (FYM) because of this sponge.

Answer:
We calculate the ET per day by Jensen and Haize equation and estimate the crop factor then due to loss of water by irrigation, multiply by 70% in this formula.
Qimm = Ke ETP x 100 then introduce the plot through partial flame regard less of
Ei treated with FYM or no.

SESSION NO. 5

Agronomic and economic evaluation of break crops and management practices on the grain yield of wheat at Shambo, Western Oramiya-Tolera Abera

Question: Kassa Getu
I wonder why you compared barley with field pea as break crops?

Answer:
The intention was to stimulate the farmers practice and demonstrate the difference to the farmers for sustainable wheat production in the area.

Question: Ravi P.Singh
Whether you are able to communicate to policy makers that improved cultivars and better management practices increase production and is profitable?

Answer:
The communication has no problem but farmers tend to use their own varieties and management practices. This is due to other socio-economics constraints such as cash shortage and credit unavailability to purchase the inputs.

Question: M. Kinyua
What efforts have been made apart from research to make farmers realize this efforts.

Answer:
The research results are well communicated to farmers through on-farms demonstrations and field days organization. So that the farmers see the research results and compare the traditional and improved practices.

Question:
Millions of demonstration plots have been planted in Ethiopia with modern management by Global 2000. What are the limitations of adoption given the rates of adoption are low?

Answer:
The main limiting factors for technology adoption are financial and social constraints. Timely availability of technologies and the purchasing power of the farmers limited to the adoption. But now better than ever.

Effect of Nitrogen fertilizer levels and varieties on Gluten content- Bemnet

Question:
Nitrogen levels did not have an effect on quality of dur ***

Comment: Tadesse Dessalegn
In Ethiopia, processing industries are willing to work with the researchers and wheat producers and buy all the produce if it meets their quality standards.

Question: C.M. Ndirangu
Since farmers are paid on the basis of quantity (rather than quality), what is the impact of the study at farm level?

Answer:
There is a promise from local pasta industries to pay premium price for quality product produced by farmers.

Question:
All varieties in your study are tall and less responsive to N particularly in terms of yield. When will semi-dwarf varieties be available.

Answer:
Since 2002, high yielding quality meeting semi-dwarf varieties have been released at Debre Zeit, Sinana and Adet Research Centre.

SESSION NO. 6

Monitoring of bread wheat cultivars and advanced lines for their resistance to yellow rust-Temesgen Kebede

Question: Ravi Singh
How has the resistance to stem rust seen until 2003 behaved during 2004?

Answer:
We have yet summarized the data for 2004 in the mean time we will include this data.

Question: M. Kinyua
How has it managed the crop improvement programme as far as disease management is concerned in Ethiopia.

Answer:
There has been loose collaboration among breeders and pathologists and the data generated from rust (wheat) monitoring materials were less utilized. However, this will be improved in the future in planning the crossing programme.

Evolution of Kenyan wheat lines for bread making quality - E. Kimani

Question: Nyirigira
Need of more clarification because you said in the talk that in wheat grain, the protein quality is due to genotype while the protein quantity is due to weather.

Answer:
Protein quality is a genotypic trait while the protein quantity varies with environment due to climatic conditions and soil fertility.

Question: C.A. Kuwite
Are you able to look for varieties that take shorter time for maximum water absorption dough development so that cooks will not take longtime cooking/baking?

Answer:
Varieties with shorter DDT are available and are preferred in baking. Bakers prefer varieties with higher water absorption as it relates to amount of loaf baked.

Question:
You told us that these is positive correlation between DDT and loaf volume. What would happen if you shorten DT by using commercialized fermenters (yeast)?

Answer:
Yeast is already used for the bread leavening a constant amount for all the samples DDT is an effect/a result of protein amount in the flour.

Question: Tadesse Dessalegn
Do you consider national quality standards in your breeding process?

Answer:
There are standards in the country used by the researchers as well as the factories millers and bakers.

Question: Kibe
Why was Heroe used as the control?

Answer:
K. Heroe was used as the check in the field trials. It is also a released variety as compared to the others that were yet to be released. It's poorer performance however was probably due to the higher altitude though it's recommended in lower altitude.

Question: P. Njau
What is the practical applicability of heterosis in wheat breeding? Can you comment on the rate of depression of the varietal characters measured? Do you think there might be a correlation between combining ability and choice of parent for top and back crossing.

Answer:
High hybrid vigor expected from crossing than simple selection. The rate of breeding depression is very minimum. Yes, there is correlation between the combining ability of the parents and their performance which leads to utilization of the parental lines in breeding programme (crossing).

Question: Ravi Singh
Is the hybrid vigour seen in your experiment is due to data taken on plant basis or due to the heat stressed environment of the experimental site?

Answer:
May be because the data is taken on plant basis or some other thing. Anyway, the heat stress on the parental lines may encourage the hybrids to perform better than the parental lines did.

Question: Wolfgang
The high parent heterosis you have shown is much higher compared to reports in the literature for wheat. This can not be explained by heterosis for yield components - other factors?

Answer:
There may be other factor but I cannot explain relating to this specific experiment.

Question: P.Njau
Is it possible to fix the hybrid vigour in wheat ** may be use of DH technique?

Answer:
I don't think it is necessary to go to fixation of heterosis in wheat because wheat is self-pollinated crops and the extent of inbreeding depression observed was very minimum (insignificant).

Performance of wheat genotypes in Western Kenya- A.W. Kore

Question:
The grain yield per ha you reported is too low to be research managed plots. Why so?

Answer:
The low yields are possibly due to the high temperatures which hastened maturity and hence did not give enough time for assimilation, we hope to try other genotypes that can tolerate heat and also give other agronomic packages.

Comment: W. W. Wagoire
The trial is commendable. The climate is rather hostile and with time foliar diseases will be a problem. Please keep up and lets get more information. These comments are in view of similar work due in Uganda under similar conditions.

Question:
It looks like termites will become a major constraint in wheat production, what measures have you put in place to ensure sustainable production which is termite free?

Answer:
We would need to do further work with entomologist on this.

Comment: M. Kinyua
It is a little bit hard to take control of small scale farmers, however it tends to provide (wheat) a better option to farmers who are ** to maize and rice in the Western regions.

Comment: Owuoche
Wheat is grown by farmers in Kisii and we need to be aggressive to help them improve the crop.
Question:
Was 2 tonnes the highest from test material?

Answer:
We believe that it is possible to get higher yields than this if adaptable cultivers are used and also proper agronomic practices are brought in place.

Question: D.O.K. Amadi
How was the behaviour of weaver birds and quelea with the wheat crop in your trials?

Answer:
During the trial period, these birds were not a problem probably because wheat is new to the area.

Question:
Due to recipient poverty in Western Kenya, can we say that wheat can be used as an alternative crop for poverty alleviation to improve livelihoods?

Answer:
For now, we can recommend that wheat can be used to supplement what is currently being grown rather than being used as an alternative crop.

Question: Owuoche
Probably you could try to plant wheat in higher areas of Western part of Kenya?

Answer:
Some effort has been made in the higher altitudes as well and the results are commendable.

Question: Nyirigira
Did you, in your observations see crop pest and diseases reactions?

Answer:
The main pest observed were the termites while some insignificant leaf rust was also noticed during the trial period.

Quantification of the value of improved wheat production options in South Western Uganda-William Wagoire

Question: D.O.K. Amadi
Hand weeding currently seems to be the only option available for weed control in wheat in Uganda. Comment on the possible use of herbicides for weed control on your what farm.

Answer:
The cost of herbicide and their application would not be appealing to small-scale farmers. The hand weeding uses family labour which in most cases they never consider.

Question:
Since production of wheat from your presentation at small scale level percentage farm size of upto 0.25ha percentage land, should it be promoted or there are other alternative crops. Is it economical to grow wheat in Uganda.

Answer:
In South Western Uganda wheat is one of the few alternative cash crops while in Eastern Uganda, wheat price is more stable than maize which is the alternative crop. Otherwise at national level, wheat is not a high priority.

Question: M. Kinyua
Whether recommendations have filtered through to the farms, what has been the impact?

Answer:
Yes, the elite lines UW400 and UW309 have been adopted and are being demanded for by the farmers (before they are released).

Paper Title: Allelism of resistance genes- C.A. Kuwite

Question: Owuoche
Why did you not include cross of RxS?

Answer:
Our aim was to study whether the resistance genes were allelic in these cultivars. Including such a cross would not have served our purpose.

Stability analysis and participatory evaluation of bread wheat varieties- Kassa Getu

Question:
How were the small holder groups organized? How did you gain their support. Did you have to offer them incentives before or after the tests?

Answer:
The farmers were organized by NGO's. Had it not been organized that way, it would have been difficult for us to deal with farmers in different districts. For the first year, we give farmers incentives. Once they were sensitized they started to produce variety of their choice at their own cost and were benefited from their produce.

Question: M. Kinyua
Did you find any contradictions in the way they ranked the varieties and factors on the way you know them as a researcher.

Answer:
Yes, farmers do have some times a different interest from what researchers think. However, these variations are area specific, and so is the variety release.

Question: J.K. Macharia
Why was the farmers used for variety evaluation not gender sensitive?

Answer:
Although the number of females were very few, female farmers have attended the variety evaluation during the mini-workshop. Due to different social reasons, females usually do not come to meetings.

Consumption use of water, water and nitrogen use efficiency by wheat in relation to irrigation and nitrogen - A. Kibe

Comment:
Pivot can be used in combination with drip irrigation tubes to increase water productivity.

Answer:
Yes it’s possible.

Question: Kinyua
What are the recommendations for the local farmers.

Answer:
Local wheat farmers should consider irrigating their wheat crop. The large scale farmers are able to harness the water (rain) and pump it to a higher elevation and then supply it through gravity. Yields can be increased to over 6 tons/ha. Small scale farmers can also grow wheat in small plots (1/4 acre) under intensive management (water and N inputs) together with other pulse (chick pea) and oil (mustard linseeds) crops for subsistence use. Harvesting can be managed manually (sickles). Water can be used judiciously so as to supply just sufficient amounts to achieve maximum potential (genetic) of the crop. On farm trials need to be done in order to evaluate water nutrient management options and economic evaluation.

Comment: John Muchile
Centre pivot irrigation starting in Kenya are likely to expand, are the farmers likely to suffer salinization as in India.

Answer:
Salinization harzards normally occur when water is applied in excess quantities under conditions of high evaporative demand. Sprinkler irrigation tends to be a conservative method (though expensive in the initial stage). It tends to avoid salinity problems, especially when just sufficient amounts of water are applied.

Comment: M.C. Mahagayu
There has to be some home made solutions to tackle the issue of irrigation for the case of small scale resource from farmers.

Given yield stability of bread wheat genotypes in favourable and stressed environment in Ethiopia-Debelo

Comment: Solomon Gelalcha
The varieties we have in Ethiopia basically should have come either from CIMMYT/Mexico or somewhere else. But we are trying to improve the long existing obsolete varieties through crossing.

Question: Ravi Singh
How many lines survived with two stem rust race?

Answer:
From international nursery materials only four survived. Most of the commercial varieties were also out by the stem rust. But there are varieties which maintained their resistance, though not preferred by the farmers for their low yield potential.

Question: M. Kinyua
Introductions were doing better than the Ethiopian materials – why? What could you think is the reason.

Answer:
Ethiopian crosses are single crosses. They are good in disease resistant than in yield potential.

Seedling and adult plant resistance of wheat varieties to local stem rust isolates in Ethiopia- Emebet Fekadu

Question:
Where did you carry out the tests on adult plant resistance, was it in the field or greenhouse?

Answer:
It was in the greenhouse at five leaf state assessment that it represents adult plants of the crop.
Question: R.P. Singh
Have you tested the wheat lines with the new race of stem rust?

Answer:
We did not test those materials with the new varieties.

Integrating of other small cereals in wheat production systems in improving livelihoods-Wolfgang P.

Question: M. Kinyua
How do you identify high yielding varieties in your environment. How do you compare environments taking interactions in mind.

Answer:
Testing under both stress and non stress to identify input responsive and/or efficient genotypes. Wide testing with use of a common set of standards to allow for comparing different experiment.

Question: C.M. Ndirangu
Are there any non-phonological anatomical or physiological characteristics that are associated with drought tolerance in wheat?

Answer:
List of traits was presented. Currently CTD and NOVI in the near future offer the largest potential routine use in applied breeding characterization of progenitors for e.g. carbon isotope discrimination is recommended.

Question: Ruth Wanyera
Among the biotic stresses, you mentioned nematodes, Fusarium ep, take all and Septaria sp, what happens to stem rust in this type of environment?

Answer:
Rust diseases are in general the major disease problems under dryland production. Disease epidemics are less frequent under drought. However we need resistance to all prevalent diseases in varieties to combat epidemics in water years.

Question: Owuoche
Data from drought tolerant experiments are often characterized by high CV. How do you handle such data?

Answer:
Uniform area within field for experiment. Larger plot size, more replications, eliminate masking factors, spatial. Experimental design.

Question:
Is insect resistance not a ** in developing drought tolerant germplasm. This dryland evnironment is where the insects ** best.

Answer:
Absolutely insect resistance is very important under drought and often the major biotic constraint.

Question: Tadesse Dessalegn
What will be the success of using large vs few crosses? Regional programmes could not handle large number of segregating population if they go for large number of crosses.

Answer:
Initially the number of crosses can be larger since F2 can be planted in solid seeded plots under drought conditions with best performing populations planted in the following cycle for individual pant selection. Ideally under higher moisture conditions. Parallel planting of F2 under drought observation and higher moisture scenarios is an option if resources are available. Number of crosses are so far your programme.

Question: Patrick Ooro
Materials from Australia especially for drought stress have been around with tiller inhibiting gene. Is it the same trend with CIMMYT? If No, what is your comment.

Answer:
For most of our scient countries we need high tilling to ensure stand under drought and input responsiveness in better years. Often stands are poor due to poor seed or poor land preparation and planting conditions. Further yield from secondary tillers if damage from stress occurs (e.g. Frost) can enhance risk efficiency – similarly, unsynchronized tillering can expand period of water extraction.

SESSION NO. 7

Control of Russian Wheat Aphids (RWA) in wheat using systematic insecticides in Kenya- M. Macharia

Comment: Singh
Use of Gaucho is now banned in France.

Answer:
There are alternative such as cruiser which are effective against RWA. Besides, Kenya farmers can apply foliar systemic herbicides on condition the herbicides is applied on detecting of the initial symptoms of RWA infestation (i.e. rolled leaves resembling spring onions).

Question: D.O.K. Amadi
Yield loss attributable to BYDV in wheat in Kenya is about 47%. Would this percentage loss be true irrespective of the time of infestation.

Answer:
Yield losses will vary depending on the stage of crop at infestation time, prevailing weather conditions.

Comment: Abbas Elsir
There is no serious effect of RWA on wheat production in Sudan, however it has serious effect on legumes especially *** if its sowing is delayed.

Position of Russian Wheat Aphids in Rwanda- M. Macharia.

Comment: Nyirigira
Since RWA is not a problem to wheat production in Rwanda they should be no reason to make input in RWA research.

Question:
What does each country think about Russian Wheat Aphid incorporating it in their wheat programmes?

Answer:
Varied opinion in the E. Africa region.
Uganda: ** are different although they perceive it to be a problem.
Ethiopia: RWA is a sporadic pest and becomes *** during shortage of rainfall.
Kenya feelings: With the current development of virulent biotypes as in Kenya, it is necessary to input I some strategic research, as it is just a question of time before we are in RWA crisis.

Comment:
Research budgets in most of the ECA countries are limiting to address what would be considered "strategic research" and proposition of research issues is varied. Otherwise the RWA, from the presentations made, is a real threat.

Reducing the threat of RWA on wheat and barley- Macharia & Migui

Question: Ravi Singh
Movement of yellow rust from East Africa to South Africa did not occur. Yellow rust in South Africa entered from Southern France through human error. Do you think RWA entered in Kenya from South Africa?

Answer:
Its possible the RWA may have come from the South, as there were very strong winds blowing into Kenya from the South.

Improvement of yield in the drought tolerant wheat varieties of Kenya- P. Njau

Question: Ravi Singh
Can you compare the cost of producing DH verses single seed descend technique?

Answer:
In Kenya most of breeding work is manual and only single season per year. This makes it 8 years to develop homozygous lines at a cost of 5 dollars per day for three months per year. In case of DH technique the initial cost is expensive but it is very cost effective and that we only need the

media and maintenance of the greenhouse. Most of the work is done in the field and so cost reduced. We expect the cost of DH production to be ½ the inbreeding (segregating) population.

Question:
Why did you use F2 instead of e.g. F3 seed after screening for disease resistance?

Answer:
Here we were dealing with very specific character (drought) and both parents were commercially adapted so, we expected to get a recommencement in F2 plants.

Question: Kassa Getu
Is any one of DN gene families sequenced?

Answer:
Yes, some of them have been sequenced particularly DW2 and DW4 but others have not yet been sequenced. It is important to note them as a range of DW genes 1-9 already tagged but not all have been sequenced.

Production of bread making quality of Ethiopian wheat cultivars using direct and indirect quality traits- Tadesse Dessalegn

Comment: Ravi Singh
Often it is mentioned that grain yield and quality have negative relationship. However, my comment is that genes that contribute to quality infact do not have negative effect on quality. The reason why yield and quality often do not go together is due to the probability of combining yield and quality genes together. Yield progress usually is followed by quality in subsequent breeding cycles. So progress in quality follows progress in yield.

Question: E. Kimani
Explain the negative correlation between protein content and mixograph development time (NB in some literature they are positively correlated)

Answer:
The negative correlation might be due to the low protein percentage of the materials as protein has a confounding effect on many parameters, therefore, materials should have optimum protein for optimum results or optimum mixing time.

Comment: Wolfgang
In 50% of your lines you found HMW – GLU – B1 7 + 9 which would indicate the presence of the 1B. 1R translocation. To breed for higher quality do you plan to reduce the proportion of 1B and 1R?

SESSION NO. 8

Integrating of other small cereals in wheat production systems in improving livelihoods–Wolfgang Pfieffer

Comment: M. Kinyua
We have selections of triticals at KARI-Njoro in small samples. We have two releases which are recognized by ministry. They are also in some cases very good in threshing than wheat.

Question: Kibe
Considering it's threshing problems how would our farmers overcome it? How can we get tritical varieties?

There are small machines (hand driven) available. It would however be important to look at the end utilization value of triticale in comparison to other cereals e.g. it doesn't shatter, it's nutritional value is higher, it's drought resistant. There are certain varieties that are easier to thresh than wheat. We have a few lines in KARI-Njoro. Two are released varieties and we can multiply seed if required. CIMMYT can provide the seed through NPBRC KARI-Njoro too.

Question: Kibe
Considering it's taste. How would our farmers in E. Africa adapt it?

Answer:
Triticale is rich in lysine and tryplophan. It would be good if we were to consider it for blending purposes in order to improve nutrition. It can be made into biscuits too. It has been used to make flour mixtures for making bread (chapatti).

Question: P. Ooro
Zero/reduced tillage has worked extremely with regard to large scale farmers in Kenya. For their small scale counterparts, the major limitation is getting the right planters for zero/reduced tillage systems.

Answer:
Agree, machine for smallholders has been developed. Examples from Asia indicate options through machine sharing, renting of machines from government agencies etc. Given that large farms in Kenya have resources to acquire planters. They may serve as pilot projects with an adoption of technologies in a sub sequent phase by smallholders and local machine development or evaluation of existing planters for small scale farming.

Question: H.G. Mwangi
What is the potential of minimum/conservation tillage in this ECASDA region with similar environments like Mexico e.g. 500mm and soils as a way of conserving environment and resources.

Answer:
It will be a pre-requisit for sustainable wheat production in the region due to numerous benefits (soil organic matter, pH water holding, nutrient supply). A direct transfer of the technology developed in Mexico may not be possible. Adaptive research needed with available inputs such as herbicides, machinery and varieties needed.

Question: Ruth Wanyera
Please explain what you mean by 'soil health' in the cropping systems?

Answer
The different small grains have different susceptibility to soil born pathogens e.g. take all. Their inclusion in a crop rotation will decrease the inoculum load in the soil and hence increase soil health for the following cereal crop (example oats).

Question:
Durum wheat in Ethiopia is grown in high potential areas unlike other countries which produce in marginal. With the current quality demand and in the country and high grain protein content in moisture areas there is a need to push DK in low lands. What is your strategy of including drought tolerant cultivars in the international nurseries?

Answer:
The situation for Ethiopia is different from other countries and had plans to make separate tables. Drought tolerant durums are included in international nurseries but all are semi-dwarfs, mainly directed to terminal drought environments. For the more specific conditions of Ethiopia we have developed germplasm with height – short intermediate and tall from crosses between (Ethiopian landraces and Ethiopian varieties) and CIMMYT high yielding dwarfs. This germplasm is targeted to a range of agro-ecologies in Ethiopia.

The current status of stem rust in wheat production in Kenya- Ruth Wanyera

Question: W. Wagoire
You report reoccurrence of stem rust in Kenya in 1996. Is there a possibility with the reported occurrence in Uganda in 1998?

Answer:
We may not know, since there was no follow up until year 2002, but chances are that it could be the Ugandan race.

Question: W. Wagoire
Do you have data on yearly basis that you study in for 2002 –2004? And if not we need to follow up the occurrences every season so as to establish the magnitude of the problem.

Answer:
Yes, there is data for each year, but it was not shown in the presentation. It is true that Sr was observed in 1996, there was no follow up to collect the spares and carry on the identification.

Comment: R. Singh
Kenyan collections from Kenya were sent to USA where preliminary results are indicting that the Ugandan and Kenyan stem rust are likely to be the same.

Responses of physiological traits to drought tolerance in bread wheat under tropical conditions- P.K. Kimurto

Comment: Kibe
The physiological traits are evident in all growing crops. They however vary by genotype. We should aim at determining the farmer friendly traits that are evident on the plant.

Comment:
This can be done by relating the physiological response at different stages of crop growth and relate them to DM, growth, yield attributes and grain yield. This way, we will be able to see the sensitivity of genotype to environmental stress, and therefore, determine the most dependable physiological parameter.

Comment: P. Njau
It is possible to develop varieties with the traits (physiological) but this will depend on the correlation of the traits and their adaptive effect on yield and kennel weight.

Question: Patrick Ooro
Noting that the traits studied appeared to have been associated with genotypes differently. Is it possible to combine these traits on a single ideotype. May be breeders can also comment.

Answer:
Yes, its possible to get ideotype. But care should be taken not to combine traits that will be antagonistic to each other and finally reduce yield. The breeders should take this challenge and us it in their breeding programmes.

Cell membrane stability as a measure of drought tolerance in Ethiopian bread and durum wheat genotypes- A. Zemede

Question: Wolfgang
The region significantly differ in soil fertility, however average yields were similar. Data on 1000 grain weight was 26g for the better soil and 4g for the poor soil location. There must have been severe stress during grain fill can you please elaborate?

Answer:
Between the two locations the big difference is the distribution of rainfall pattern, so at ** district during the grain filling stage of the crop occurred the moisture stress.

Question:
Enlighten us on why both sites P was not applied i.e. 92.0 and 41.0 with much higher MRR (than those recommended) was not recommended?

Answer:
Because the interaction of the two nutrients treatments gave the highest net benefit and highest agronomic grain yield.

The response of bread wheat to nitrogen and phosphorous fertilizer at different agro-ecologies of North-Western Ethiopia- A. Zemede

Question: Abbas Elsir
I noticed that the MRR at 92N level and zero phosphorus is higher as 138N and 46P taking into consideration it is cost effective and labour saving. In the sense that if you take the cost labour into consideration the MRR of the high fertilizer level will be reduced.

Answer:
138N and 46P fertilizer rate gave highest net benefit and within the range of acceptable MRR, (100%). About labour cost, we used broadcasting fertilizer application, so it is not as such higher than the control treatment, however, the comment is well accepted.

Comment: Z. Nyakwara
There is no labour which is free and land should be quantified. Whether owned or hired, hence to arrive at the MRR all variables making up to (total variable costs) should be checked. (Quantified).

Comment:
The comment is well accepted.

Evaluation of wheat (*T.aestivium*) double haploid for resistance in the greenhouse- J. Maling'a

Comment: Wolfgang
It is critical in this kind of yield loss studies to eliminate all confounding factors. Example if we want to determine the effect of stem rust and the stem rust resistant genotype is susceptible to yellow rust with high disease incidence of both Sr and Yr. The effect Jr of the Sr resistant genotype could not be determined and be masked Bx and Yr.

Comment: Kibe
In order for use to have better conclusive results, it might be better to pool a parameter across all sites, and regress the dependable against the independent variables. Carry out regression (and multiple regression) analyses. This would give us better conclusive results.

Comment: M. Macharia
I feel that the field studies needs to be supported by greenhouse studies through inoculation by using fixed number of aphids/plant.

Comment:
The inconsistent in the data over the season and locations pints to an "*****

Answer:
Yes RWA resistance is very limited in bread wheat particularly in spring wheat. So the partial identification of *** is useful.

SESSION NO 2: GENERAL DISCUSSION

Current challenges in the management of wheat diseases- Ravi Singh

Question: Macharia
With the high turnover of scientists, there is need to have the RWW more frequently 2-3 years.

Answer: Ravi
The recommendation was taken to account. Noted that previously it was span 2 years.

Michire:
Gaucho (seed dresser) ban in France. Producted use has been suspended in a specific sector in France, this was seen to have effect in sunflower sector (lowered production). Trials are underway to see effect of Gaucho. But is being used in other sectors.

Kinyua (ECAMAW Chairperson):
There is need to discuss recommendations of the region to complete the workshop.
Meet every 2-3 yrs because of high turnover of scientists.

Comment:
Funding of wheat from ECAMAW ended in 2001. Success has been due to personal initiatives.

Hope for funding in Africa livelihood programme.
There is no ASARECA funding. 1/3 ECAMAW funding.

Macharia:
It is a way of dissemination. As stakeholders we should try to meet more frequently.

Comment:
Strategy of getting the funds.

C. Kuwite:
With the production and import data, we can use this to get the government to give more money.

Comment:
Impact government because the imports show the demand. They should give the money for more production. Pandey gave ideas to approach the government as a region to influence them to act.

Why does the national co-ordinator find it hard to influence the Minister.

Wagoire:
In Uganda, it's difficult to get a meeting with the Minister on such an issue because of protocol. Thus using the regional office is easier to get report from ministers.

Debelo:
RWW is important for exchanging of ideas. Approach the government through the ECAMAW, ASARECA etc.

Abbas:
In Sudan, financial difficulty. Politicians don't recognize wheat research. They would react more from CGs.

Nyirigira:
Talks between scientists and government hasn't bore any fruit. CGs could make more impact; airing out imports and the possibility of more production in wheat and the problems of production.

C.Kuwite:
Access to Minister is not probable. The Minister of Regional Co-operation (who opened the meeting) could be a good channel to air the wheat production constraint in the region.

Prashar:
In India field days invite politicians to enhance awareness. Invite them oftenly to make them aware. This makes them sensitive to the issue.

Can CG centres talk to the government?
CIMMYT. This should be possible thus the formation of Regional programme. Ravi.

Wofgang:
Should be done jointly with regional and CG centres.

Owuoche:
Liberalization has caused harm. Levies of wheat research were erased.

Suggestion:
Impose levy on import wheat – for research.

Michire:
Parliamentary select committee have meetings with scientists so they can influence the parliament.

Wagoire:
Have regional document of the findings and what is to be done, constraints?

Wasike Lusike
If wheat scientists have a quantifiable document e.g. in the next 15 years. SR will reduce wheat production and increase imports past this on media, it would get in.

Solomon:
In Ethiopia, there are questions on impact of research on poverty alleviation. The approach is important. Thus show the support from the government and why there has been a drawback.

Kibe:
Effectiveness can be achieved through educational system – university. Try to channel funds for textbooks for use by the lecturers for teaching students to obtain right information for our region e.g. agronomic strategies, variety development, etc. Source of dissemination.

12th Regional Wheat Workshop For Eastern, Central and Southern Africa

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