

Implication of rate and time of nitrogen application on wheat (*Triticum aestivum. l.*) yield and quality in Kenya

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1 SUMMARY

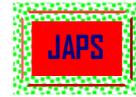
In Kenya, Nitrogen is the first limiting macro-element on many farms where bread wheat (*Triticum aestivum*) has been grown continuously for more than a decade. On-farm trials were conducted in Kenya by superimposing the treatments on farmers' fields in Nakuru (5 sites), Uasin Gishu (3 sites), and Timau (2 sites) districts during the main growing seasons of 1997-99. This was to study the effect of rate and time of application of fertilizer nitrogen (N) on bread wheat (*Triticum aestivum*) grain yield, yield components, and grain quality. Wheat grain samples from the ten (N) nitrogen rates and timing treatments combined across replications were analysed at the Small Grain Institute, Bethlehem, Republic of South Africa for milling and baking quality in accordance with standard analytical procedures (Pylar, 1973; Kent, 1983; Hosney, 1986). Results revealed that flour protein content (FPC) and grain nitrogen (GN) increased significantly in response to N rate. Nitrogen application increased timing of sedimentation (SDSS) rate and loaf volume, but decreased the kernel weight, falling number (FLN) and flour yield (FLY) percentage. N application had $P \leq 0.05$ effects only on mixing development time (MDT), FLN and (SDSS). Split application of N resulted in superior quality attributes than when the entire N was applied at once. The sensitivity of rate and time of N application was found to be greater in the wheat quality attributes than the grain yield and yield components. These results can therefore be used in situations where good wheat prices are determined on the basis of grain quality.

2 INTRODUCTION

Nitrogen is a key factor in achieving optimum grain yield. Plant use efficiency of nitrogen depends on several factors including application time, rate of nitrogen applied, cultivar and climatic conditions (Moll *et al.*, 1982). According to Gooding and Davis, (1997) variability in grain protein can be attributed to environments that differ across locations and years with respect to seasonal temperatures, moisture, and soil type. Variability on grain protein can also be attributed to differences to cultivar genetic potential and to management decisions (Smith and Gooding, 1996; Lopez-

Bellido, *et al.*, 1998). Among the most important management practices influencing grain protein content is N fertilizer application rate and timing. Increasing N fertilizer rates can result in higher grain protein content (Vaughan *et al.*, 1990; Kelley, 1995).

Soil nitrogen (N) is frequently deficient in continuous cereal cropping systems, and this is commonly encountered in soils on which crops are cultivated more than once annually (Hanson *et al.*, 1982). In Kenya, N is the first limiting macro-element on farms where bread wheat (*Triticum aestivum*) has been grown continuously



for more than a decade (Mwangi, 1995). In spite of this, most wheat farmers in Kenya apply basal fertiliser in the form of MAP (Mono-ammonium phosphate) or DAP (Di-ammonium phosphate) at an average rate of 130 kg DAP or MAP/ha (Hassan *et al.*, 1992). Thus, the amount of N applied by such applications is insufficient (i.e., only 16 to 23 kg N ha⁻¹) for optimal crop production.

In Kenya, wheat grain was previously purchased from farmers on a weight, rather than quality, basis. Grain merchants currently tend to pay higher prices for grain of “hard” wheat cultivars, and farmers thus are sensitive to the quality of grain. In general, the grain quality of Kenyan wheat cultivars grown at high altitudes (i.e., 2000-2300 m.) is lower than that of the same cultivars grown below 2000 m due to cooler temperatures, higher rainfall, and a longer growing season at the higher elevations.

3 MATERIALS AND METHODS

Field trials were carried out during 1997 and 1999 at ten site-season combinations. The N fertiliser trials were superimposed on farmers fields in Nakuru (5 sites), Uasin Gishu (3 sites), and Timau districts (2 sites) during the main growing seasons. Urea (46% N) was the source of fertiliser N. Host farmers applied DAP (Di-Ammonium Phosphate) basally as the source of phosphorous in wheat fields on which trials were carried out. These farmers planted the wheat using their own preferred seed rates; basal DAP application rate, and sowing date. All trials were superimposed on farmers’ fields sown with the recently recommended Kenyan semi-dwarf bread wheat cultivars. Subsequent to sowing by each host farmer, research staff marked out plots on farmers’ fields and laid out treatments using three N rates: 20, 40 and 80 kg N/ha. Three N application timings were used in factorial combination with the three N rates as follows;

- (i) All N applied at planning (i.e., top dressed on the soil immediately after the host farmer’s sowing);
- (ii) All N applied at tillering stage
- (iii) One-third of N applied at planting and two-thirds applied at tillering stage

Thus, with the addition of one control plot (i.e., nil N), there were 10 treatments. The N treatments

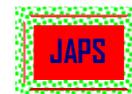
Pinto and Hurd (1970) indicated that the effect of altitude seems to confound the correlation between protein content and baking quality in some cultivars with little evidence to indicate that breeding for higher protein content would improve bread-making quality proportionately. With the advent of market liberalisation, Kenya, like other countries of the world, has had to re-assess its agricultural research strategy. Presently, market-oriented interventions, such as industrial quality, have been given a relatively high priority. Farmers must now be provided with the appropriate wheat cultivars and associated crop management practices to meet the demand for standards of high bread-making quality. Agronomic practices pertaining to the appropriate rates and timing of N fertiliser application and the resultant effects on the quality and yield of bread wheat grain in Kenya are discussed in this paper.

were applied to gross plots of 5 m x 5 m with three replications laid out in a Randomised Complete Block Design (RCBD).

Weed control was done by use of herbicide. At crop maturity, net plots of 3m x 3 m were harvested by hand-sickling, and the grain threshed with a Vogel thresher. The wheat grain was sun-dried and weighed and then the grain yield data were converted to 12.5% standard moisture content using the formula as shown below:

$$\text{Grain yield at standard moisture content} = \frac{[100\text{-standard moisture}] \times [\text{plot grain weight}]}{[100\text{-actual moisture}]}$$

Data on selected yield components were also collected during the growing season. Grain samples from the ten treatments and ten site season combinations were bulked across replications within sites and sent to the Small Grain institute, Bethlehem, Republic of South Africa for grain quality analysis, in accordance with standard analytical procedures (Pyler, 1973; Kent, 1983; Hosoney, 1986). All data were subjected to analysis of variance (ANOVA) using MSTATC software, and single degree of freedom orthogonal contrasts were applied to treatment means to assess individual components of the aggregate treatment effects.



4 RESULTS AND DISCUSSION

4.1 The effect on N rate and timing on wheat industrial quality: The effect of nitrogenous (N) fertiliser rate and timing on selected wheat grain quality parameters are summarised in Table 1.

Table 1: The effect of fertilizer N application rate and timing on selected quality attributes of wheat grain in Kenya

N rate (Kg/ha)	TKW (g)	FLN (s)	SDSS (ml)	FLY (%)	FPC ^a (%)	MDT (min)	LFV (cc)
0	36.1	453	59.9	52.9	9.92	3.00	8.46
20	34.3	426	63.2	49.8	10.1	3.08	847
40	35.3	435	61.1	52.7	10.4	2.87	917
80	34.1	443	63.4	52.5	11.0	2.92	916
Mean	34.7	436	62.3	51.8	10.4	2.96	889
C.V. (%)	5.0	6.3	4.7	3.9	7.9	8.9	5.5
Beta DN (check)	38.0	398	90.0	60.7	12.2	2.70	956
Orthogonal contrasts							
0 vs N	**	*	**	P<0.1	*		**
N _{linear}		*	**	***	***	P<0.1	***
N _{quadratic}	**	**	***			***	
Pl & Spl vs. Till ^b						**	
Pl vs. Spl ^c		**	*				

^aFlour protein content at 12% moisture

^bContrast effect of (all N at planting or split applied) vs. (all N at crop tillering stage)

^cContrast of effect of (all N at planting) vs. (N split applied)

^d*, **, ***: Significant at the 5, 1 and 0.1% level, respectively.

TKW=Kernel weight; FLN=Falling number; SDSS=Sedimentation; FLY=Flour yield; MDT: Mixing development time.

Application of N (i.e., the mean effect of the three N rates) decreased thousand kernel weight (TKW), falling number (FLN), and flour yield (FLY), but increased sedimentation (SDSS), flour protein content (FPC), and loaf volume (LV). However, it had no effect on mixing development time (MDT) (Table 2).

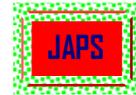
Table 2: Effect of fertilizer N application on selected quality attributes of wheat grain in Kenya

	TKW (g)	FLN (s)	SDSS (ml)	FLY (%)	FPC ^a (%)	MDT (min)	LFV (cc)
0 N	36.1	453	59.9	52.9	9.9	3.00	846
+ N ^b	34.5	435	62.6	51.7	10.5	2.96	983
C.V. (%)	5.0	6.3	4.7	3.9	7.9	8.9	5.5
Beta DN (check)	38.0	398	90.0	60.7	12.2	2.70	956
Probability	**	*	**	P<0.1	*	NS	**

^aFlour protein content at 12% moisture, ^bMean of 20, 40 and 80 kg N topdressed/ha

^c*, **: Significant at the 5 and 1% level, respectively., TKW=Kernel weight; FLN=Falling number; SDSS=Sedimentation; FLY=Flour yield; MDT: Mixing development time.

In general, the measured traits associated with baking of leavened bread were enhanced by N application, while flour milling traits were diminished. Such negative correlations were not common, nor were the absence of an association between FPC and MDT (Kent, 1983). The contrasts between application of whole N rate at planting or split application versus the delayed application of all



N at crop tillering stage, exhibited a significant effect on MDT, although the significance of this effect is questionable (Table 3).

Table 3: Effect of applying all N at planting or split application of N versus all N applied at the crop tillering stage on selected quality attributes of wheat grain in Kenya

Time of N application	TKW (g)	FLN (s)	SDSS (ml)	FLY (%)	FPC ^a (%)	MDT (min)	LFV (cc)
N at planting or split	34.4	434	62.7	51.9	10.4	2.94	891
N at tillering	34.8	436	62.2	51.3	10.6	2.99	898
Probability	NS	NS	NS	NS	NS	**	NS

^aFlour protein content at 12% moisture, ^{b**}: Significant at the 1% level.

TKW=Kernel weight; FLN=Falling number; SDSS=Sedimentation; FLY=Flour yield; MDT: Mixing development time.

Contracts between all N at planting versus, splitting revealed significant differences for FLN and SDSS, but not for TKW, FLY, FPC, MDT or LFV (Table 4).

Table 4: Effect of applying all N at planting vs. split application on selected quality attributes of wheat grain in Kenya

Time	TKW (g)	FLN (s)	SDSS (ml)	FLY (%)	FPC ^a (%)	MDT (min)	LFV (cc)
N at planting	34.5	425	62.0	52.2	10.4	2.96	897
N split	34.3	443	63.5	51.6	10.4	2.91	886
Probability	NS	**	*	NS	NS	NS	NS

^aFlour protein content at 12% moisture, ^{b**}: Significant at the 1% level.

TKW=Kernel weight; FLN=Falling number; SDSS=Sedimentation; FLY=Flour yield; MDT: Mixing development time.

MDT was highest with all N applied at tillering versus either all at planting or splitting. FLN and SDSS values were higher with split N application than with all N applied at planting.

Increasing rates of top-dressed N clearly enhanced FPC and LFV (Table 1), the important nutritional and baking industry traits. The response of FLN, FPC and MDT to N rate exhibited significant linear and non-significant quadratic components, indicating that peak N response was not attained with the highest rate of N applied in the current study. The suggestion that higher rates of N could be optimal for these traits would only be of practical significance if N response was also positive for grain yield (GY).

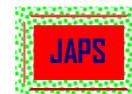
4.2 The effect of N rate and time of application on yield components of wheat:

Spike density m² (SPM) and biomass yield were not significantly affected by the main effect of N application rate (Table 5); their corresponding linear and quadratic orthogonal components were also non-significant. Plant height (PH) only exhibited a significant difference (P<0.1) between the N treatment (i.e., 90.5cm and the mean of the nine treatments receiving N (i.e., 92.4 cm)

GY exhibited non-significance of the main effect of N rate (Table 5); however, the orthogonal contrast for N_{Quadratic} exhibited response (P<0.1), whereas the N_{Linear} contrast was non significant.

Table 5: Effect of fertilizer N rate on selected yield components of wheat in Kenya

N rate (kg/ha)	SPM (m ²)	Biomass (t/ha)	PH (cm)	GNU (Kg/ha)	GY ^a (Kg/ha)
20	391	11.2	91.7	44.1	2748



40	398	11.9	92.9	49.2	2979
80	393	11.9	92.6	50.3	2880
C.V.(%) 13.9	13.4	3.43	18.4	17.5	
Probability	NS	NS	NS	*	NS

^aGrain yield at 12.5% moisture level

^b*, **: Significance at the 5 and 1% level, respectively.

Table 6: Effect of fertilizer N application on selected yield components of wheat in Kenya

Time of N Application	SPM (m ²)	Biomass (t/ha)	PH (cm)	GNU (Kg/ha)	GY ^a (Kg/ha)
Planting	398	11.9	93.4	47.8	2888
Split	396	11.7	91.4	48.0	2889
Tillering	388	11.3	92.3	47.8	2830
Probability	NS	NS	NS	NS	NS

^aGrain yield at 12.5% moisture level.

GNU= Grain nitrogen uptake

Grain nitrogen uptake (GNU) was significantly increased by the main effect of N rate (Table 5); furthermore, the N_{Linear} component was significant (P<0.1), while the N_{Quadratic} component was not. Thus the highest rate of N application was associated with the highest GNU. The GNU increase is consistent with findings by researchers in other countries (Johnson *et al.*, 1973; Fowler *et al.*, 1989; Smith and Gooding, 1996; Lopez-Bellido *et al.*, 1998). Despite the non-significance of the GNU quadratic component, it was obvious that this trait exhibited diminishing response to successively higher rates of N. For the first interval of N application, GNU increased by 5.1 kg ha⁻¹ in response to an increase of 20 kg N applied ha⁻¹ (i.e., 25.5% recovery in the grain); for the second

interval, GNU increased by 1.1 kg ha⁻¹ in response to an increase of 40 kg N applied ha⁻¹ (i.e., 2.8% recovery in grain).

None of the wheat yield components were significantly affected by the main effect of N application timing (Table 6). However, the application of all N at planting increased PH relative to the split application of N (P<0.05). Noting that the applied rates did not significantly influence the grain yield and yield components it may necessary to carry out a study involving higher rates of N. This may explain just in case the soils are too deficient of N that may require higher rates than those applied in this paper.

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6 REFERENCES

- Fowler, D.B., Brydon, J., and Baker, R.J.:1989. Nitrogen fertilization of no-till winter and rye: II. Influence on grain protein. *Agron. J.* 81:72-77.
- Gooding, M.J., and Davis, W.P.:1997. Wheat production and utilization: Systems quality and the environment. CAB In: Wallingford, Oxon. UK.
- Hanson, H., Borlaug, N.E. and Anderson, R.C.: 1982. Wheat in the Third World. Westview Press Inc., Boulder, Colorado, USA. 174pp.



- Hassan, R.M., Mwangi, W. and Karanja, D.D: 1992. Wheat Supply in Kenya: Production Technologies, Sources of Inefficiency and Potential for Productivity Growth.
- Hoseney, R.C: 1986. Principles of Cereal Science and Technology: A General Reference On Cereal Foods. AACC, Minneapolis, Minnesota, USA.
- Johnson, V.A., Dreier, A.F. and Grabouski, P.H.: 1973. Yield and protein responses to Nitrogen fertilizer of two winter wheat varieties differing in inherent protein of their grain. *Agron. J.* 65:259-263.
- KARI/CIMMYT Wheat Project Report: 2002. NPBRC, Njoro, Kenya.
- Kelley, K.W.:1995. Rate and timing of nitrogen applications for wheat following different crops. *J. Prod. Agric.* 8:339-345.
- Kent, N.L: 1983. Technology on Cereals. Pergamon Press, Oxford, UK. 221pp.
- Lopez-Bellido, L., Fuentes, M., Castillo, J.E., and Lopez-Garrido, F.J.:1998. Effects of tillage, crop rotation and nitrogen fertilization on wheat grain quality grown under rain fed Mediterranean conditions. *Field Crop Res.* 57:262 – 276.
- Moll, R.H., Kamprath, J. And Jakson, W.A.:1982. Analysis and interpretation of factors which contribute to efficiency of nitro-utilization. *Agron J.* 74:562-564.
- Mwangi, H.G: 1995. Effects of banded-P, soluble and residual-P on maize crop yields for a mollic Andosols. Pages 25 – 27. In: Jewell, D.C., Waddington, S., Ransom, J.K. and Pinto, F.F. and Hurd, E.A: 1970. Seventy years with wheat in Kenya. *East African Agriculture and Forestry Journal* pp.1 -24.
- Pyler, E.J:1973. Baking Science and Technology. Siebel Co., Chicago, Illinois, USA.
- Smith, G.P. and Gooding, M.J.: 1996. Relationship of wheat quality with climate and nitrogen application in regions of England (1974-1993). *Ann. Appl. Biol.* 129:97-108.
- Vaughan, B., Westfall, D.G. and Barbarick, K.A.: 1990. Nitrogen rate and timing effects on winter wheat grain yield, grain protein and economics. *J. Prod. Agric.* 3:324-328.