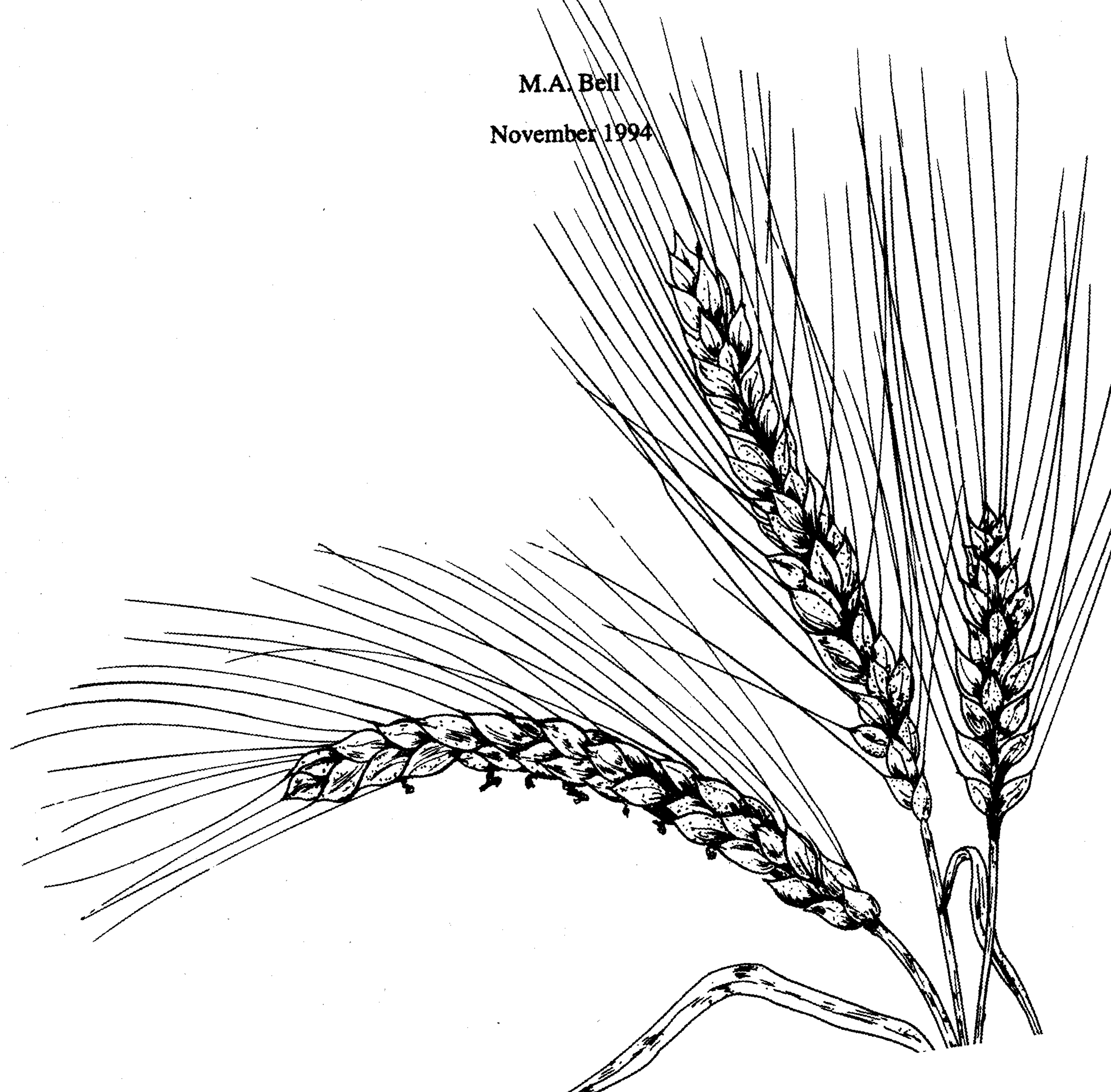
Wheat Special Report No. 34

Four Years of On-Farm Research Results at Chalco, Mexico

M.A. Bell

November 1994



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Contents

Contents (Continued)

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Preface

The purpose of this special report is to record the on-farm research activities conducted around the area of Chalco, in the High Valley of Mexico, from 1986-1990. The research was conducted as part of the CIMMYT Wheat Crop Management Research Training Program. The results are presented as tables for each trial type, plus a small discussion for each year summarizing results and reasons for some of the research strategy and treatments used. Recommendations for farmers have already been generated by the Mexican National program (INIFAP) from the data. It is hoped that the work can be used as a case study to analyze and critique an on-farm research program.

Mark A. Bell

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Zone Description

The "Chalco" study zone covers an area of approximately 25,000 ha largely about the town of Juchiltepec, Mexico (**Figure 1**). During the course of the four-year study, the zone expanded each year to include sites in more marginal areas. The altitude of these sites range from 2200 to 2900 masl. Average rainfall for Juchiltepec (2300 masl) is 782 mm (**Figure 2**). Rainfall is distributed in a normal pattern starting about the end of May and finishing in mid- to late October. Considerable variation in precipitation exists throughout the zone, however, as rainfall is chiefly from convective storms. Average maximum and minimum temperatures vary little during the growing season (May-October) being 25.2 and 6.6^{o}C, respectively, for Juchiltepec (**Figure 3**). Frosts often occur in late November.

Soils range from sandy loams to clay loams. The average soil properties for 50 fields throughout the region were (range in brackets) pH, 5.9 (5.6-6.4); soil organic matter, 2.12% (0.80-5.68); N, 0.114% (0.050-0.240); Ca, 1037 ppm (450-1935); Mg, 151 ppm (54-398); K, 229 ppm (68-638); and P (Bray), 25.7 ppm (4.6-69.2).

1986 Informal Survey

An informal survey was conducted in the zone during 1986. A number of fields were surveyed and any farmers found in their fields were interviewed. The survey identified three factors as probable limitations to crop yield, namely: 1) crop establishment (i.e., plant distribution and stand; moderate problem), 2) weeds (notably *sicius*; moderate to severe problem), and 3) diseases and insects (some aphids; moderate problem). In addition, as tillering was generally low, it was concluded that fertility and/or variety were likely to be problematic. Testing of new varieties would also be expected to reduce the disease problems. The presence of *commelina* sp. throughout the zone indicated the area to be a high-rainfall zone, and therefore presumably one of good yield potential. Visual estimates of yields in well managed fields identified yields up to 5 t/ha.

General Approach Used in Experimentation

The general approach to experimentation was to have researcher-managed trials with high levels of nonexperimental variables (NEV) (i.e., those factors not being studied in the trial were held at a high level of management--e.g., good weed control in variety trials). High

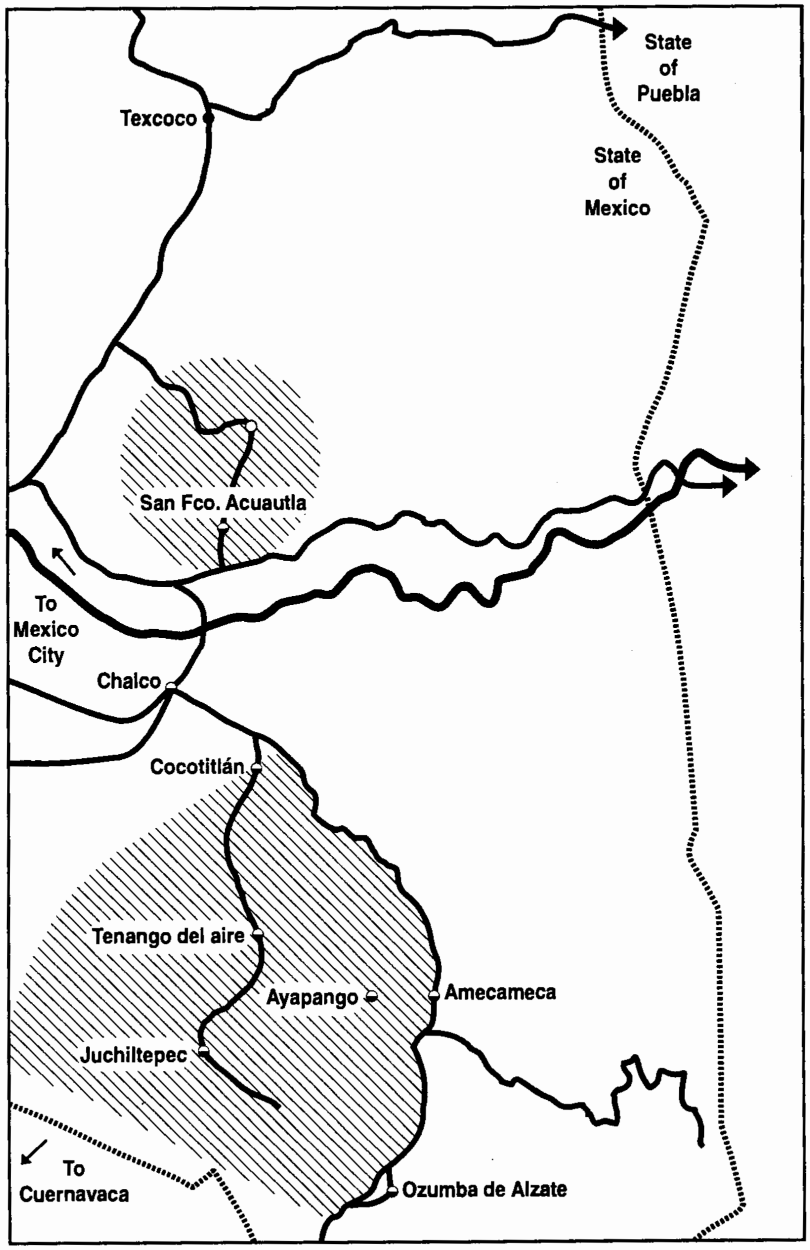

Figure 1. Chalco area study zone. Shaded areas show major concentration of trials. Area involves around 25,000 ha.

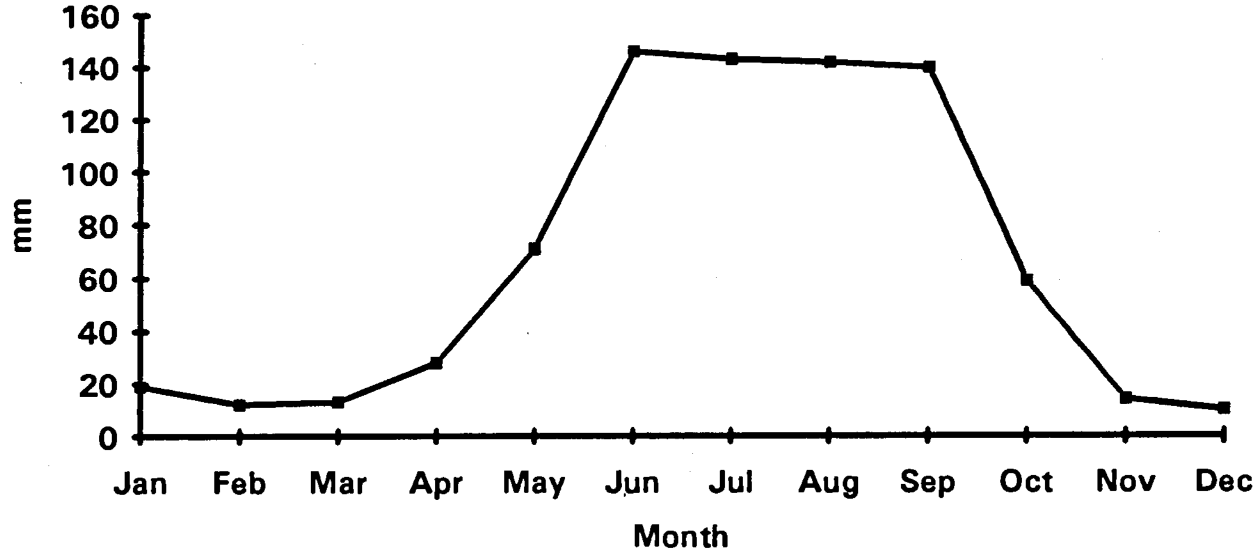

Figure 2. Annual average rainfall for Juchiltepec (average 27 years).

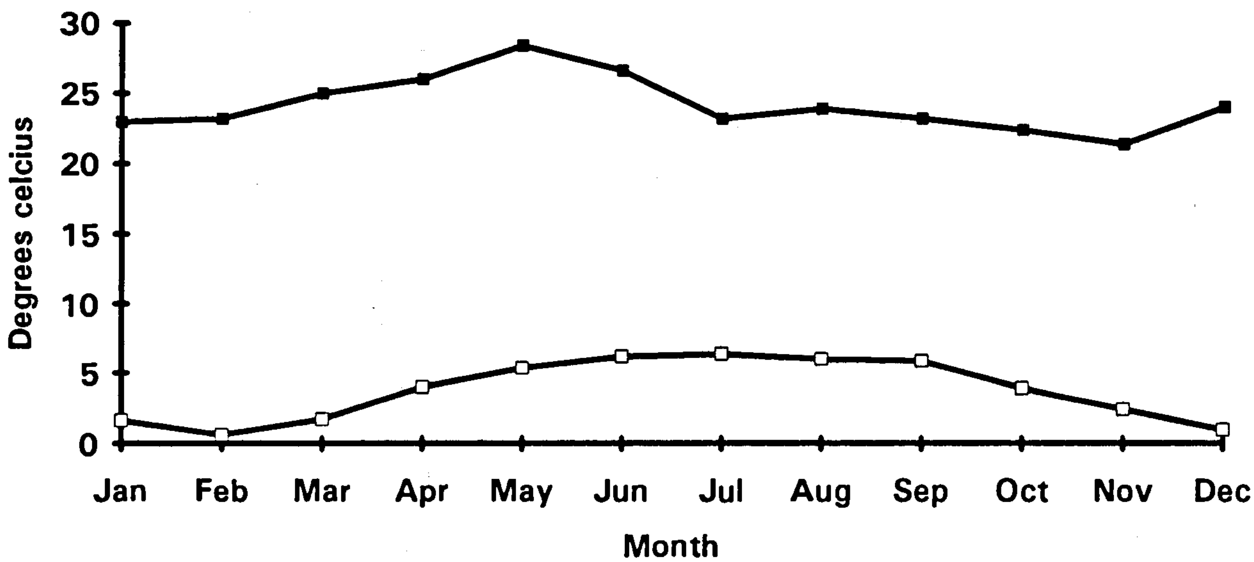

Figure 3. Annual average maximum and minimum temperatures for Juchiltepec (average 27 years).

levels of NEVs were deemed appropriate, particularly for factors such as weed control and insect damage, which generally occur randomly in the field. It is recognized, however, that there is a wide range of opinion over what level of NEVs is appropriate in research. The basis for the approach used here, however, was that we sort to understand the yield potential of the zone, and to understand the contribution of the factors under investigation to that potential--without limitations from other factors. In using this research approach, however, it is recognized that a valid criticism of the "high NEV" approach is that inappropriate recommendations can be developed (i.e., technologies may be recommended that will not succeed given the lower level of management used by farmers for other factors). Thus, when research is conducted at high NEV levels (i.e., understanding the effects of factors), care is required to not overlook possible interactions between farmers practices and the recommendations being generated. Therefore, the researcher must understand when possible interactions between factors may occur. The 2^3 factorial trials used throughout the research program, therefore, formed a vital part of the research process in providing understanding of what interactions may occur in the system and, therefore, how recommendations should be modified.

The approach using high levels of NEVs was originally believed to reduce the error mean square (EMS) (i.e., experimental error), and thus increase precision. However, experimental error actually is essentially independent of yield level (**Figure 4**). Since field experience shows that high levels of NEVs generally allow greater differentiation of treatments, the conclusion is that the effect is to increase the "Treatment mean squares" term rather than reduce the EMS.

Other factors contribute to the approach of using high levels of NEVs. For example, it was felt that all trials in the field (be they exploratory or levels, etc.) are a demonstration to the farmer. Therefore, the better the crop, the greater the impact on the farmers.

In terms of selecting sites, and choosing what trials to put at what sites, the generalized approach was to have more sites for those production factors experiencing greater variability. Therefore, fertility and variety trials which generally show greater variability in responses across a zone require more sites. For herbicide trials, however, where the researcher seeks to understand basically which products control which weeds, site selection was more on the basis of ensuring that sites had weed infestations (This could be ascertained during the growing cycle, or from plant residues at the time of site inspection).

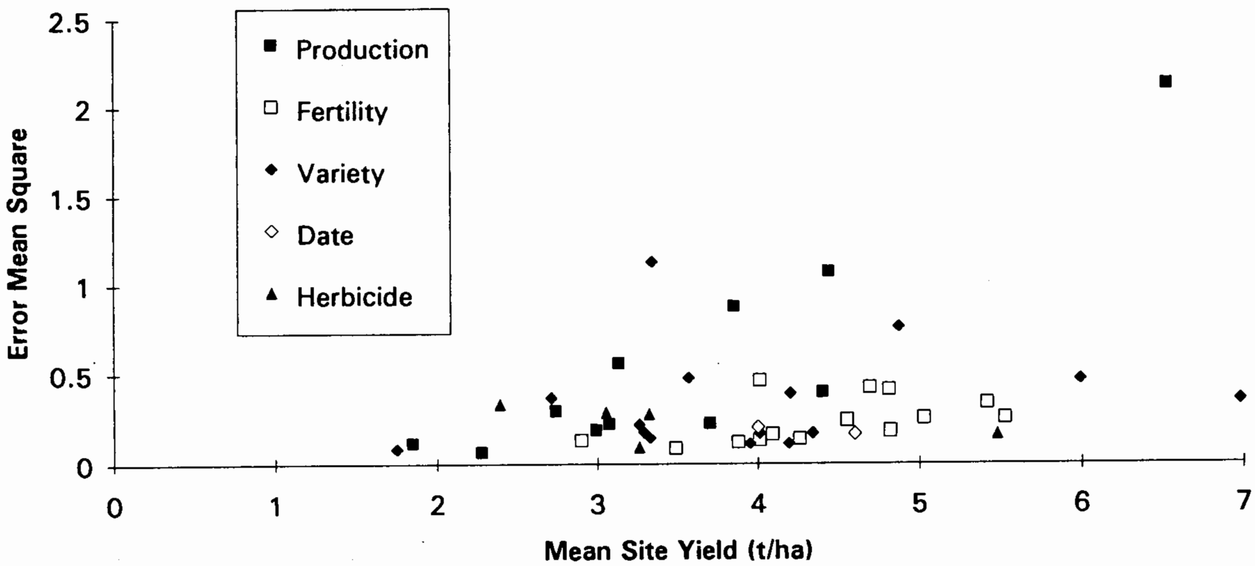

Figure 4. Error mean square versus site yield for a range of trial types conducted in the Chalco area.

1987 On-Farm Research

Introduction

As there were no trials previously conducted in the zone, the results of the 1986 informal survey were used to design a research program aimed at solving problems of soil fertility, weed control, and variety (**Table 1**). The actual trial design is described under each trial type. Trials were sown across 10 sites (**Table 2**). Sites were selected throughout the zone.

Table 1. Summary of trials planted in 1987.

Trial type	# sites	Production factors
Production	5	N, P, Herbicide
Fertility	5	N, P, K
Date of planting	2	3 varieties, 3 planting dates
Variety	5	10 varieties
Herbicide	3	10 herbicide combinations
Total	20	

Table 2. Site characteristics.

Site	pH	SOM %	P ppm	Key site characteristics
1	7.9	1.98	10.9	Few weeds, High fertility
2	5.5	1.26	21.1	*Sicius* sp. present
3	5.6	0.84	17.0	High fertility site; residual fertilizer from previous crop
4	5.8	1.52	11.0	*Sicius* sp present
5	6.0	1.15	27.0	Avena fatua present
6	5.6	1.50	28.8	Avena fatua, Tusas
7	5.9	1.03	12.8	Shallow soil (<30 cm) in parts
8	6.1	1.74	8.8	No *Sicius* sp. present
9	5.7	1.40	28.3	Volunteers present
10	5.9	3.62	9.1	Take-all, High altitude zone
11	6.8	1.18	13.8	Trials damaged by animals

Production trial results

The production trials had a 2^3 factorial field design with three replications and were sown at five sites. The factors were:

- N0 = 0, N1 = 150 kg N/ha--Split application; half at seeding, half at 35 days after seeding (DAE).
- P0 = 0, P1 = 75 kg P_2O_5/ha.
- H0 = 2,4-D, H1 = Brominal (1 L/ha) + Glean (15 g/ha). See **Appendix 1** for active ingredients in the pesticides.

The variety was Genaro T 81 (sown broadcast at 120 kg/ha). Where necessary, aphids were controlled using Metasystox (2 L/ha). Plot size varied from (4 x 6) to (10 x 10) m^2. **Table 3** shows the results. As there were no interactions between factors, the main effects in **Table 4** show the dominant effect of N, except where *sicius* sp was present.

Fertility trial results

A 5x5 (N x P) incomplete factorial (**Table 5**) with a K satellite treatment (150:100:75) (total of 14 treatments) with three replications was sown at 5 sites. N applications were split (half at seeding, half at 35 DAE). The variety Genaro T 81 was planted at 120 kg/ha. Weeds were controlled using Brominal (1 L/ha) + 2,4-D (1 L/ha) and Iloxan (4 L/ha). Where necessary, aphids were controlled using Metasystox (2 L/ha). Plot size varied from (4 x 10) to (5 x 10) m^2.

Table 3. Production trial results.

Level of N	Level of P	Level of H	Sites 4	5	7	9	10
			Yield (t/ha)				
0	0	0	2.71	1.77	1.87	4.01	1.06
0	0	1	3.83	1.85	2.38	3.71	1.66
0	1	0	2.17	1.51	1.58	2.66	1.00
0	1	1	4.21	2.11	2.10	3.85	1.69
1	0	0	3.60	3.99	3.60	5.37	1.98
1	0	1	5.20	4.67	4.08	5.22	2.19
1	1	0	2.96	3.95	4.16	5.09	2.39
1	1	1	4.96	4.74	4.17	5.36	2.85
Average			3.70	3.07	2.99	4.40	1.85
LSD 5%			0.83	0.82	0.27	1.10	0.60

Table 4. Yield gap and main effects of the production trial.

Site	Treatment effects N1P1H1-N0P0H0	N effect Σ(N1-N0)	P effect Σ(P1-P0)	H effect Σ(H1-H0)
4	2.25	0.95	-0.36	1.69
5	2.97	2.53	0.01	0.54
7	2.30	2.02	0.02	0.38
9	1.35	1.70	0.34	0.25
10	1.79	1.00	0.26	0.49
Average	2.13	1.64	0.05	0.67

Table 5. Treatment combinations (X) used in fertility trials.

kg N/ha	kg P_2O_5/ha 0	50	100	150	200
0	X		X		X
50		X		X	
100	X		X		
150		X		X	
200	X		X		X

There was no response to either P or the K satellite treatment, but generally large responses to N (**Table 6**).

Table 6. Fertility trial results.

Level of N	Sites 1	3	6	7	10	Average
			Yield (t/ha)			
0	5.36	4.06	3.08	2.23	2.18	3.38
50	5.47	5.08	4.51	3.88	2.86	4.36
100	5.37	5.57	5.27	4.65	2.87	4.75
150	5.45	5.31	5.32	4.85	2.79	4.74
200	5.50	5.20	5.60	4.83	3.07	4.84
Average	5.42	5.03	4.82	4.09	3.88	
LSD 5%	0.31	0.84	0.71	0.98	0.61	0.66

Variety trial results

Ten varieties--including six bread wheats, two triticales (Tcl), and two barleys (B) (**Table 7**) were sown at a density of 120 kg/ha at 5 sites with 2 replications. Trials were fertilized with 150:75 ($N:P_2O_5$---half N at seeding and half at 35 DAE) and weeds were controlled using Brominal (1 L/ha) + 2,4-D (1 L/ha) and Iloxan (4 L/ha). Where necessary aphids were controlled using Metasystox (2 L/ha). Plot size varied from (4 x 10) to (4 x 25) m^2.

Table 7. Variety trial results.

Variety	Sites 4	7	9	10	11	Average
			Yield (t/ha)			
Eronga (Tcl)	5.98	4.03	6.15	4.32	5.14	5.12
Pavon F 76	5.35	3.54	5.54	3.93	2.91	4.25
Opata M 85	5.24	4.07	6.02	2.97	2.86	4.23
Alamos (Tcl)	5.19	2.92	5.49	3.94	3.26	4.16
Genaro T 81	5.46	3.41	4.91	2.54	3.18	3.90
Galvez	4.45	3.35	4.72	2.86	2.79	3.63
Gloria/Comanche (B)	4.33	3.73	3.78	2.66	2.27	3.35
Mexico 82	3.77	2.85	3.74	4.14	1.62	3.22
Salamanca	3.76	2.53	4.45	2.99	1.69	3.08
Centinela (B)	2.94	2.90	3.87	2.53	1.35	2.72
Site Average	4.20	3.33	4.87	3.29	2.71	
LSD 5%	1.41	0.85	1.97	0.96	1.36	0.65

Date of planting trial results

Four varieties representing materials of differing growth cycles were planted at 120 kg/ha across three planting dates, May 20, June 10, and June 30 (**Table 8**), with three replications at two sites. Trials were fertilized with 150:75 ($N:P_2O_5$) (half N at seeding and half at 35 DAE) and weeds were controlled using Brominal (1 L/ha) + 2,4-D (1 L/ha) and Iloxan (4 L/ha). Where necessary aphids were controlled using Metasystox (2 L/ha). Plot size was (4 x 10) m^2.

Table 8. Date of planting trial results.

Variety	Date of sowing	Sites 5	Sites 6	Average
		Yield (t/ha)		
Eronga	May 20	5.70	4.97	5.34
	June 10	5.50	5.74	5.62
	June 30	2.60	3.25	2.93
Genaro T 81	May 20	4.30	4.64	4.47
	June 10	5.30	5.75	5.53
	June 30	4.00	5.21	4.61
Galvez	May 20	4.20	3.00	3.60
	June 10	5.00	5.41	5.21
	June 30	4.50	4.74	4.62
Salamanca	May 20	2.90	2.45	2.68
	June 10	4.00	4.95	4.48
	June 30	-	5.11	5.11
Average		4.00	4.60	
LSD 5%		0.57	0.70	

Herbicide trial results

Ten treatments aimed primarily at broadleaf weed control (**Table 9**) were planted at three sites with three replications at each. The variety Genaro T 81 was planted at 120 kg/ha and fertilizer at a rate of 150:75 ($N:P_2O_5$) was applied (half N at seeding and half at 35 DAE). Where necessary aphids were controlled using Metasystox (2 L/ha). Plot size varied from (4 x 8) to (4 x 10) m^2.

Discussion and conclusions

The first year of researched establish the relative importance of production factors identified in the informal survey as potentially problematic. The 2^3 production trials, in particular,

Table. 9. Herbicide trial results.

Treatment	Sites 1	2	8	Average
	Yield (t/ha)			
Nonweeded	4.87	0.57	1.72	2.39
2,4-D 1 L/ha 35 DAE	5.58	0.80	3.97	3.45
2,4-D 2 L/ha 35 DAE	5.89	1.67	4.26	3.94
Brominal 2 L/ha 15 DAE	5.60	4.27	3.10	4.32
Basagran 2.5 L/ha 15 DAE	4.99	1.82	2.90	3.24
Glean 20 g/ha 15 DAE	5.39	0.77	3.44	3.20
Brominal 1 L/ha + Basagran 2.5 l/ha 15 DAE	5.81	3.87	3.61	4.43
Glean 20 g/ha 15 DAE + Brominal 1 L/ha 25 DAE	5.65	4.36	3.15	4.39
Glean 20 g/ha + Brominal 1 L/ha 15 DAE	5.64	3.51	3.60	4.25
Glean 20 g/ha + Basagran 2.5 L/ha 15 DAE	5.37	2.29	3.42	3.69
Average	5.48	2.39	3.32	
LSD 5%	0.70	1.56	0.90	0.62

DAE = Days after emergence.

were useful for establishing the relative economic importance of N, P, and weed control (Table 4), and for showing that there was no interaction between the three factors studied (ANOVA not shown); the latter point being particularly important for making recommendations. The production trials showed that N was the major factor contributing to production, except where *sicius* sp. was present (**Figure 5**). The herbicide trials complemented these findings nicely as they offered a means of establishing economic alternatives for fields with and without *sicius* sp. Weeds were most economically controlled by 2,4-D except where *Sicius* sp. was present - in which case Brominal was best.

Fertility trials established pattern and extent of the response curve to N. The response to N was high being of the order of 20 kg grain/kg N for the first 50 kg N applied. In addition, the fertility and production trials showed that there were no responses to P or K. A problem with fertility trial interpretation was differential responses based primarily on soil organic matter (SOM) levels (e.g., no response in site 1 with high SOM--2%). Since

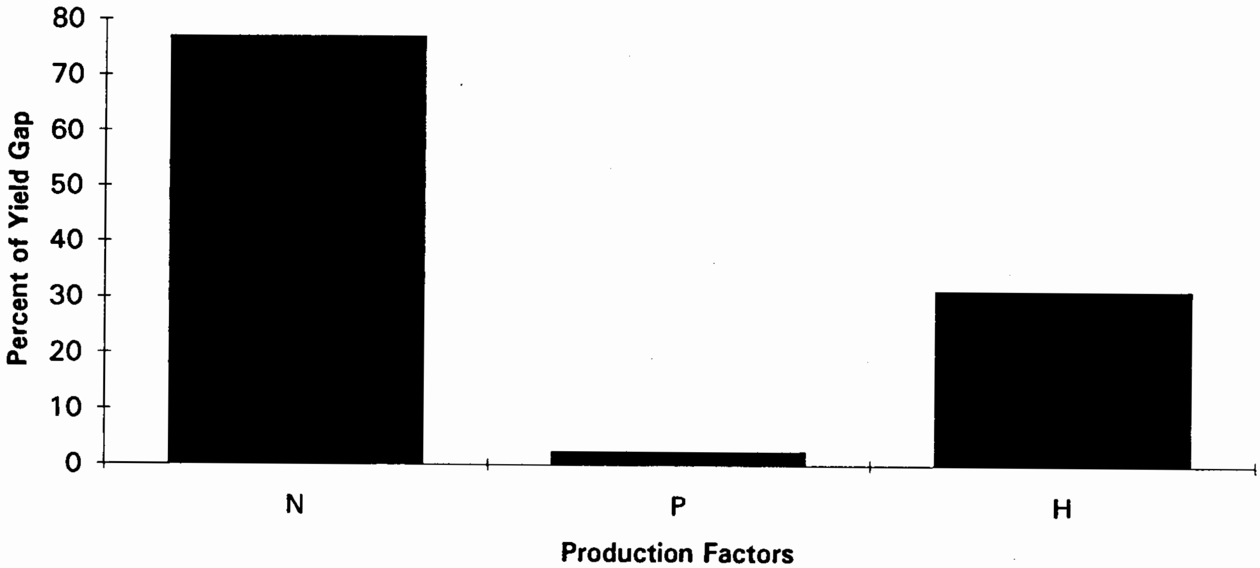

Figure 5. Percent of yield gap explained in 1987 production trials by nitrogen (N), phosphorus (P), or herbicide.

soil analysis is not available to the farmers, generating N recommendations in the light of SOM variability was identified as a problem. Given the trial results (including no P or K responses), it was decided to simplify the trial design for 1988, and have a 5 x 2 (N x P) design.

Only the triticale 'Eronga' was identified as superior to the principal variety grown in the area (Pavon F 76). Based on trial results and yield potential of the area, it was decided to eliminate barleys from the variety trials (due to their lower yield potential) and to also eliminate those varieties that, on the basis of yield, consistently fell in the lower 50% of Table 7 for each site. The exception was Mexico 82, which yielded well at the higher altitude site (Site 10). Genotype by environment (site) interactions (GxE) were apparent (ANOVA not shown) complicating the development of recommendations. For 1988, it was decided to increase the number of replications from two to three for 1988. This change was based on the number of degrees of freedom for error (df) in the ANOVA. The aim was to have between 12 and 20 df for error--this is because the relative changes in the F value below 12 df are quite high (**Figure 6**), and above 20 df means the trial is getting quite

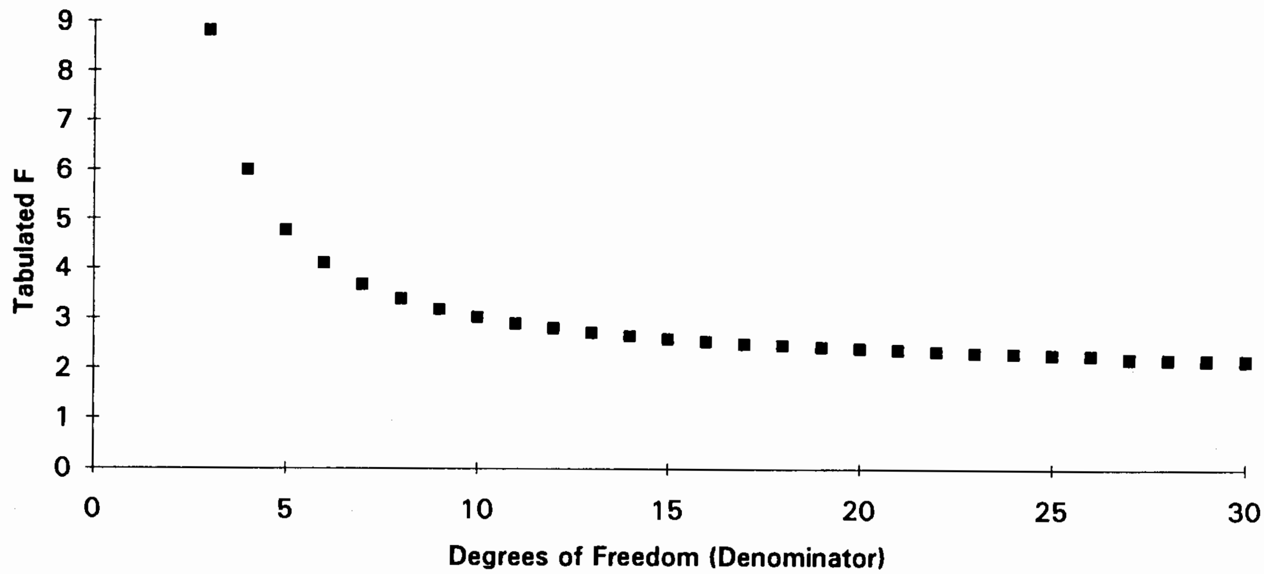

Figure 6. Tabulated F value (at 5%) versus degrees of freedom for error for a denominator with 9 degrees of freedom.

large for research in farmers fields. With 10 entries, and 2 replicates, there are only 9 df, while with three replicates there are 18 df for error.

The date of planting showed that late May to early June was the best time to sow. With these results combined with an analysis of the general rainfall distribution (Figure 2) and temperatures (Figure 3), it was decided that further planting date research was unnecessary.

1988 On-Farm Research

Introduction

Based on the trial results of 1987 and further informal surveys, four trials were designed for 1988 (**Table 10**). (Actual trial design is described under each trial type). Trials were sown across 8 sites within the region (**Table 11**); sites differed from those planted in 1987.

Table 10. Summary of trials planted in Chalco area, 1988.

Trial type	# sites	Production factors
Production	3	N, Seeding density, Herbicide
Fertility	4	N, P, K
Variety	5	10 Varieties
Herbicide	2	10 Herbicide combinations
Total	14	

Table 11. Site characteristics.

Site	pH	SOM %	P ppm	Key site Characteristics
1	7.0	1.10	3.6	Dry site
2	6.8	1.18	43.8	Eragrostis
3	6.3	2.01	18.5	Avena fatua present
4	5.8	1.89	16.4	*Sicius* sp.
5	5.2	1.23	69.0	Nematodes
6	5.8	1.87	26.8	Moist site
7	6.2	1.65	75.8	
8	5.8	5.33	13.6	Take-all, high-altitude zone

Production trial results

The production trials had a 2^3 factorial field design (**Table 12**) with three replications, and were sown at five sites. The factors were:

- N0 = 0:50, N1 = 150:50 ($N:P_2O_5$) (half N at seeding and half at 35 DAE),
- D0 = 120, D1 = 200 kg seed/ha,
- H0 = 2,4-D, H1 = Brominal (2 L/ha).

The variety Pavon F 76 was broadcast planted at 150 kg/ha at sites 2 and 6, while Mexico 82 was planted at the high-altitude site (Site 8). Where necessary, aphids were controlled using Metasystox (2 L/ha). Plot size was (4 x 10) m^2. Site 2 had a high infestation of eragrostis and was very uneven--the effect of manure applications in the previous cycle. Site 6 had very high lodging, especially in those plots receiving N. The results, therefore, were good for training, especially from the aspect of highlighting potential problems that can be encountered in the field, but were less useful for helping with recommendation generation.

Table 12. Production trial results.

Level of N	Level of D	Level of H	Yields (t/ha) Sites 2	6	8
0	0	0	2.74	2.80	3.15
0	1	0	1.93	3.47	2.97
0	0	1	2.79	6.45	3.17
0	1	1	1.56	6.02	3.00
1	0	0	2.27	1.27	5.98
1	1	0	2.77	1.67	5.77
1	0	1	2.36	4.93	5.73
1	1	1	1.81	4.15	5.73
Average			2.28	3.85	4.44
LSD 5%			1.64	1.80	0.39

As there were no interactions between factors the main effects in **Table 13** show the dominant effect of N (site 8), except where *sicius* sp. was present (site 6).

Table 13. Yield gap and main treatment effects.

Site	Treatment effects N1D1H1-N0D0H0	N effect Σ(N1-N0)	D effect Σ(D1-D0)	H effect Σ(H1-H0)
2	-0.93	0.05	-0.52	-0.30
6	1.35	-1.68	-0.04	3.09
8	2.58	2.73	-0.14	-0.06
Average	1.00	0.37	-0.23	0.91

Fertility trial results

A 5x2 (NxP) complete factorial (half N at seeding and half at 35 DAE) with a K satellite treatment (150:75:75) with three replications was sown in five sites. The variety Pavon F 76 was planted broadcast at 150 kg/ha. Weeds were controlled using either Brominal (2 L/ha) or 2,4-D (2 L/ha), and Iloxan (4 L/ha) where required. Where necessary, aphids were controlled using Metasystox (2 L/ha). Plot size was (4 x 10) m^2.

A P response, but not K, was observed at site 3. There were no responses to either P or the K satellite treatment at other sites. Generally large responses to N were observed (**Table 14**).

Table 14. Fertility trial results.

Level of N	Sites 3	5	7	9	10	Average
			Yield (t/ha)			
0	3.31	3.58	2.23	4.55	2.83	3.30
50	4.34	4.81	2.72	4.50	3.74	4.02
100	4.50	4.24	3.21	5.38	4.80	4.43
150	4.56	3.89	3.28	4.54	5.07	4.27
200	4.72	3.54	3.04	4.48	4.87	4.13
Average	4.29	4.01	2.90	4.69	4.26	
LSD 5%	1.25	1.16	0.61	1.11	0.64	1.18

Variety trial results

Ten varieties, including 7 bread wheats, 2 triticales (Tcl), and 1 durum wheat (D), were sown at five sites with three replications (**Table 15**). Seed rate was 120 kg/ha and fertilizer was applied at a rate of 150:50 ($N:P_2O_5$), half N at seeding and half at 35 DAE. Weeds were controlled using either Brominal (2 L/ha) or 2,4-D (2 L/ha), and Iloxan (4 L/ha) where required. Where necessary, aphids were controlled using Metasystox (2 L/ha). Plot size varied from (3.4 x 16) to (4 x 20) m^2.

Herbicide trial results

Ten treatments aimed primarily at broadleaf weed control were planted at three sites with three replications at each (**Table 16**). The variety Pavon F 76 was broadcast planted at 150 kg/ha and fertilizer was applied at a rate of 150:50 ($N:P_2O_5$) (half N at seeding and half at 35 DAE). Where necessary, aphids were controlled using Metasystox (2 L/ha). Plot size was (4 x 10) m^2.

Formal survey

A formal survey of 50 farmers was undertaken in 1988. **Table 17** shows the results relative to tillage, fertility, planting date, and variety practices. Tillage commences during

Table 15. Variety trial results.

Variety	Sites 1	3	5	6	8	Average
			Yield (t/ha)			
Bacanora T 88	4.62	4.58	3.93	4.03	7.30	4.89
Opata M 85	3.88	4.79	4.25	5.52	5.21	4.73
Alamos (Tcl)	4.10	3.87	3.94	4.59	6.47	4.59
Pavon F 76	4.44	4.67	2.79	4.13	6.61	4.53
Bagula	3.92	3.73	3.30	5.66	5.99	4.52
Genaro T 81	4.44	3.88	3.55	4.25	6.12	4.45
Temporalera	4.48	3.38	3.02	3.93	6.92	4.35
Eronga (Tcl)	3.05	4.66	3.13	4.08	5.09	4.00
Somos (DW)	3.92	2.96	2.39	4.07	4.47	3.56
Mexico 82	3.29	2.94	2.27	3.17	5.75	3.48
Site Average	4.01	3.95	3.26	4.34	5.99	
LSD 5%	0.89	0.57	0.80	0.71	1.17	0.86

Table 16. Herbicide trial results.

Treatment	Sites 4	7	Average
Nonweeded	1.52	1.96	1.74
Prowl	2.19	1.61	1.90
Dicuran	2.66	1.40	2.03
2,4-D, 1 L/ha 35 DAE	2.47	4.15	3.31
2,4-D + Karmex 35 DAE	3.48	4.04	3.76
Brominal 1 L/ha 15 DAE	3.40	4.01	3.71
Brominal 2 L/ha 15 DAE	3.74	4.16	3.95
Brominal 1 L/ha 30 DAE	3.29	3.64	3.47
Brominal 2 L/ha 30 DAE	3.82	3.64	3.73
Brominal 1 L/ha 15 DAE + 30 DAE	3.96	3.96	3.96
Average	3.05	3.26	
LSD 5%	0.91	0.53	0.72

DAE = Days after emergence.

the dry season, with a further pass of the disk plow or harrow at the onset of the rains, a final disking is done to prepare the seedbed and control the initial flush of weeds. Only some 10% of sown seed is certified, the rest is either seed kept by the farmers or seed

Table 17. Synopsis of some of the agronomic practices found within the Chalco study region for 1988.

Agronomic Practice	Average	Minimum	Maximum
Disk plow (# passes)	0.44	0	1
Disk harrow (# passes)	1.8	0	3
Seed rate (kg/ha)	256	175	440
Nitrogen (kg N/ha)	112	55	215
Phosphorus (kg P_2O_5/ha)	53	23	92

Variety:	(frequency %)	**Planting date:**	(frequency %)
Pavon F 76	56	May 11-20	6
Zacatecus	22	May 20-31	6
Salamanca	12	June 1-10	20
Mexico 82	4	June 11-20	38
Triticale	4	June 21-30	14
Toluca	2	July 1-10	8
		July 11-20	6
		July 21-31	2

purchased from neighboring farms. All noncertified seed is untreated; but the germination is generally high (i.e., > 90%). In the cooler higher areas, seed is sown from May 15 to June 15, while in the lower areas, the planting dates range from June 1 to July 15. Weeds are controlled by 2,4-D, and manual control for *sicius* sp.. Both aphids and diseases (e.g., *Fusarium, Septoria and Gaeumannomyces*) are present, but no form of chemical control is used.

The survey was undertaken primarily to test the hypothesis that yield could be related to practices through regression , and thus certain aspects of research may be avoided. Thus, observations and practices were noted on fields in which yield cuts were taken. However, due to the large variation throughout the zone of rainfall and differences in temperature (factors that could not be measured on a field by field basis), correlations between yield and production factors were poor. Based on visual field scores (0 to 3; 0 = no problem, 3 = serious problems), however, the problems of weeds, plant stand and crop nutrition were confirmed.

Discussion and conclusions

The results of 1988 confirmed observations and results of 1987, namely: that the major limitations to yield in Chalco were nitrogen, and *sicius* sp., when present (**Figure 7**).

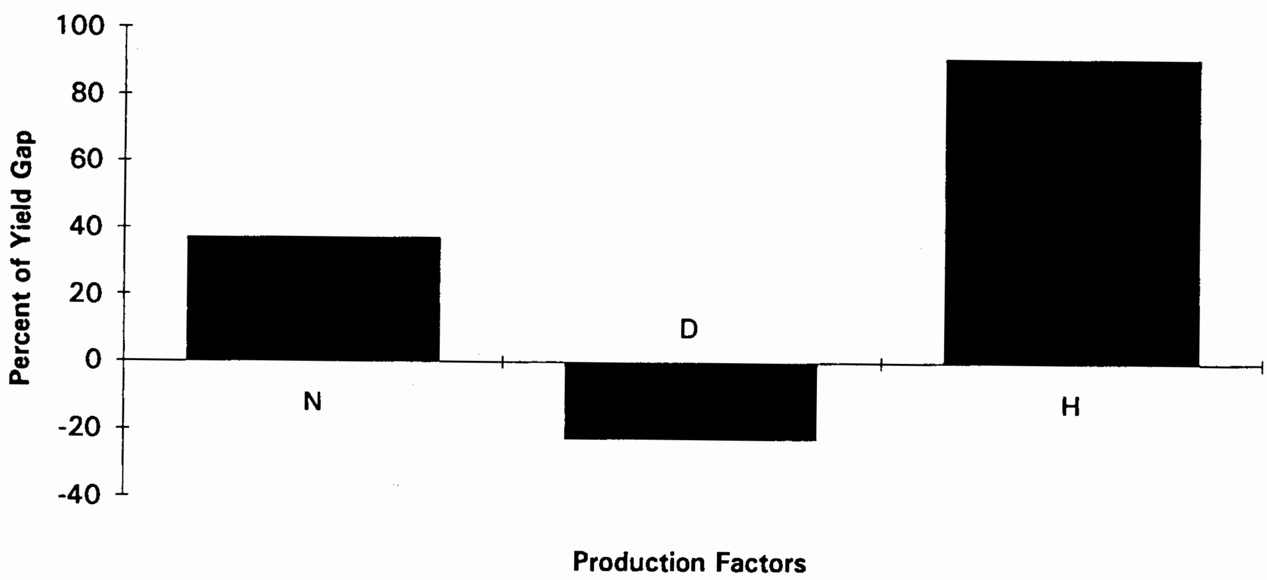

Figure 7. Percent of yield gap explained in 1988 production trials by nitrogen (N), seeding density (D), or Herbicide (H).

Seeding density actually had a negative effect, which we felt confirmed that the farmers were using high seed rates because of the method of incorporation and not due to climatic stress causing poor tillering or some other factor. The production trial at site 2 highlighted the importance of historical information for sites. The site had a high infestation of eragrostis and large N variability across the field. Both appeared to arise from previous season manure applications. Site 6 highlighted the problem of balancing SOM level with N requirements. In this field, which had a relatively high level of SOM (1.87%) and good moisture throughout the cycle, plots with *sicius* sp. controlled but no N gave much higher yields than plots receiving N. This difference arose due to a very high percentage of lodging in the plots with N applied.

Again, no responses to K were observed, and only one field had a P response. Based on these results, it was recommended that in future only a basal dose of P (30 kg P_2O_5/ha) be used in trials (the base level was determined by estimating the P requirements of the plant for a reasonable yield). As seen in 1987, large responses to N were observed (14 kg grain/kg N), as well as the problem of variability across sites in the response to N.

The decision to eliminate some varieties and introduce new varieties was successful in the sense that some of the new varieties (noticeably Bacanora T 88) were superior to the checks

(Pavon F 76 and Mexico 82). Lodging of materials in the trials, in general, was more of a problem in 1988 than in 1987. This problem was likely to be the combination of high N rates, wet weather, and the use of Pavon F 76 as the principal trial variety (vs. Genaro T 81 in 1987). Again, as in 1987, genotype by environment (site) interactions (GxE) were apparently complicating the development of recommendations (ANOVA not shown). As in 1987, those varieties that consistently performed poorly were eliminated for the following cycle (to allow inclusion of new potentially higher yielding entries).

The herbicide trials focused on control options for *sicius* sp. In terms of other weed problems, informal observation noted an increase in the number of fields showing some degree of infestation with *avena fatua.* This increase in infestation appeared to be related to a greater number of fields being planted to continuous wheat.

During the cycle, some serious problems of erosion were identified in fields in the higher altitude regions.

1989 On-Farm Research

Introduction

Based on the informal survey of 1988, and trial results of 1987 and 1988, four trials were designed for 1989 (**Table 18**). The actual trial design is described under each trial type. Trials were sown across eight sites (**Table 19**). All sites except Site 2 differed from those sown in 1988. In an effort to reduce the costs and time involved in OFR, the herbicide trials were superimposed (i.e., parts of the field that were already sown, simply had treatments applied to them). Due to the observed increase in *avena fatua* in many fields, grass control was introduced as a factor in the production trials. Also, because erosion was more noticeable throughout the zone in 1988, a reduced-till demonstration plot was planted. The latter was primarily for the researchers to learn and observe if any particular problems would arise with the technology.

Production trial results

The production trials had a 2^3 factorial field design (**Table 20**) with three replications and were sown in 3 sites. The factors were:

- N0 = 0:30, N1 = 120:30 (N:P_2O_5),
- B0 = 2,4-D, B1 = Brominal (2 L/ha),

Table 18. Summary of trials planted in 1989.

Trial type	# sites	Production factors
Production	4	N, Broadleaf control, Grass control
Fertility	5	N, P, K
Variety	5	10 varieties
Herbicide trial	2	7 Herbicide treatments (superimposed)
Herbicide demonstration	3	6 Herbicide treatments (superimposed)
Tillage demonstration	1	After primary tillage, crop was direct drilled.
Total	20	

Table 19. Site characteristics.

Site	pH	SOM%	P	Key site Characteristics
1	5.8	3.22	18.2	Take-all present, High Zone.
2	5.8	5.33	13.6	Take-all present, High Zone.
3	5.8	1.89	16.4	*Sicius* sp present
4	5.2	1.23	69.0	Nematodes present
5	7.0	1.10	10.2	Dry zone
6	5.8	1.64	24.0	
7	6.4	1.36	14.7	
8	5.8	1.52	41.3	Fertile site.

Table 20. Production trial results.

Level of N	Level of B	Level of I	Sites 2	4	8
			Yields (t/ha)		
0	0	0	2.90	2.88	4.96
0	0	1	2.48	2.51	4.56
0	1	0	2.21	2.84	5.60
0	1	1	2.79	2.84	6.49
1	0	0	3.89	3.17	9.18
1	0	1	3.66	1.84	6.36
1	1	0	3.72	2.89	7.29
1	1	1	3.35	2.92	7.76
Average			3.13	2.74	6.53
LSD 5%			1.31	0.95	2.55

• I0 = No Iloxan, I1 = Iloxan (4 L/ha).

The variety was Pavon F 76 (sown broadcast at 150 kg/ha). Where necessary aphids were controlled using Metasystox (2 l/ha). Plot size was (4 x 10) m^2. A further factorial trial was sown at site 3 to evaluate nematode control (results not shown). The yields at site 8 are somewhat high--this is believed to be due to yields having been estimated from crop cuts. The relative ranking of treatments, however, is not believed to have been affected.

As there were no interactions between factors, the main effects in **Table 21** show the dominant effect of N, except where *sicius* sp. was present.

Table 21. Yield gap and main effects.

Site	Treatment effects N1B1I1-N0B0I0	N effect Σ(N1-N0)	B effect Σ(B1-B0)	I effect Σ(I1-I0)
2	0.45	1.06	-0.22	-0.11
4	0.04	-0.06	0.27	-0.42
8	2.80	2.25	0.52	-0.47
Average	1.10	1.08	0.19	-0.33

Fertility trial results

The fertility trial consisted of nine treatments aimed at determining optimum N levels and management plus a micronutrient (120:30:0 + Micronutrients applied foliarly) and no P (120:0) satellite treatment (**Table 22**). Most N treatments were split, half at planting and half at 35 DAE. However, other treatments were All (at planting), 1/3 (1/3 at planting, and 2/3 at 35 DAE), and late (1/2 at planting and 1/2 at 60 DAE). The variety was Pavon F 76 sown broadcast at 150 kg/ha. Weeds were controlled using Brominal (2 L/ha) (and Iloxan (4 L/ha) where required). Where necessary aphids were controlled using Metasystox (2 L/ha). Plot size was (94 x 100) m^2.

Table 22. Fertility trial results.

Treatment	1	2	Sites 5	6	7	Average
				Yield (t/ha)		
0:30	5.06	2.69	3.32	3.22	2.42	3.34
40:30	5.39	3.62	3.49	3.96	3.96	4.08
80:30	5.45	4.18	3.86	5.21	4.55	4.65
120:30	6.11	4.40	3.34	4.74	4.85	4.69
160:30	5.92	4.72	3.36	5.61	5.00	4.92
120:0	4.98	4.09	3.33	4.81	4.88	4.42
120:30 + micro.	5.20	3.82	3.48	4.99	5.03	4.50
120:30 All	5.36	4.27	3.60	5.67	5.25	4.83
120:30 (1/3)	6.16	4.16	3.60	5.18	4.88	4.80
120:30 (Late)	5.69	4.18	3.54	4.73	4.63	4.55
Average	5.53	4.01	3.49	4.81	4.55	
LSD 5%	0.86	0.62	0.50	1.10	0.84	0.34

Variety trial results

Ten varieties, including 7 bread wheats, 2 triticales (Tcl), and 1 durum wheat (D), were sown at five sites with three replications (**Table 23**). Fertilizer was applied at a rate of 120:30 ($N:P_2O_5$), half N at seeding and half at 35 DAE. Weeds were controlled using Brominal (2 L/ha), and Iloxan (4 L/ha) where required. Where necessary, aphids were controlled using Metasystox (2 L/ha). Plot size was (4 x 15) m^2. The yields at site 8 are somewhat high--this is believed to be due to yields having been estimated from crop cuts. The relative ranking of treatments, however, is not believed to have been affected.

Herbicide trial results

Seven treatments aimed primarily at broadleaf weed control (**Table 24**) were superimposed on farmers fields at two sites with two replications at each. The trial was not well designed, as no check was included to compare with farmers practice. In 3 other sites, a different series of treatments without replication were superimposed on farmers' fields (**Table 25**).

Table 23. Variety trial results.

Variety	2	3	Sites 4	5	8	Average
			Yield (t/ha)			
Eronga (Tcl)	4.03	2.01	-	3.96	8.16	4.54
Bacanora T 88	3.48	1.63	3.98	5.27	7.91	4.45
Temporalera	4.74	1.88	3.09	4.64	7.51	4.37
Opata M 85	3.96	1.65	3.91	4.04	6.53	4.02
Alamos (Tcl)	3.11	2.15	-	3.27	7.53	4.02
UHU 'S'	3.75	2.04	3.62	4.16	6.28	3.97
Pavon F 76	3.86	1.65	2.90	4.15	7.21	3.95
Genaro T 81	2.70	1.56	3.91	4.29	6.17	3.73
Altar 84 (DW)	2.26	1.19	2.91	4.23	6.91	3.50
Mexico 82	3.77	1.78	2.43	3.84	5.60	3.48
Site Average	3.57	1.75	3.34	4.19	6.98	
LSD 5%	1.18	0.49	1.94	0.57	1.02	1.06

Table 24. Herbicide trial results (2 replications).

Treatment	Sites 4	8
Logran (10 g/ha)	4.21	5.14
Logran (10 g/ha) + Agroplus (0.5% v/v)	3.87	5.41
Dicuran Forte (1 kg/ha)	4.44	6.47
Dicuran Forte (2 kg/ha)		6.54
Amber (0.25 g/ha) + Brominal (2 L/ha)	3.59	5.50
Glean (25 g/ha)		5.59
Glean (25 g/ha) + Agroplus (0.5% v/v)		5.93

Table 25. Herbicide demonstration results.

Treatment	1	Sites 3	4
Check (no control)	3.98	0.93	2.22
Harmony (25 g/ha)	5.01	1.26	3.31
Harmony (25 g/ha) + Grasp (2.5 l/ha)	4.32	1.05	3.10
Harmony (25 g/ha) + Puma (2.5 l/ha)	4.44	0.95	3.20
2,4-D (2 l/ha)	4.28	1.40	2.90
2,4-D (2 l/ha) + Grasp	5.44	2.22	4.10

Tillage demonstration

A demonstration of reduced tillage was conducted in the High altitude zone (site 2). A plot that had been disk plowed in the dry season only was direct-drilled with the variety Pavon F 76 (120 kg/ha). Paraquat (2 L/ha) was applied at seeding and fertilizer applied at 120:30 ($N:P_2O_5$). The plot (50 x 20 m^2) had a high infestation of *bromus* sp., while the land to each side, which had the usual secondary tillage, had virtually no *bromus* sp. present. The presence of *Bromus* sp. seems to be only in the cooler higher altitude zones. Yield was not estimated.

Conclusions

The importance of N as a production factor was again demonstrated (**Figure 8**). The response to brominal (vs. 2,4-D) was not as great in other years, as the sites in 1989 did not have severe infestations of *sicius* sp. found in other years. The effect of grass control was negative, assumed to be due to low infestations of *avena fatua* at the sites, and some phytotoxicity of the product.

Although fertility trials again demonstrated the importance of N nutrition, the need for such trials perhaps can be questioned as the recommended level (100-120 kg N/ha) is what the farmers are already applying (112 kg N/ha). Average response levels were similar to other years being 19 kg grain/kg N for the first 40 kg N applied. As seen in other years, the extent of response was somewhat variable and appeared to be related, at least in part, to soil organic matter levels. Thus despite the question as to the need for research given the present levels of application, if soil analyses become available, the data forms a basis for generating recommendations. The problem of risk associated with a recommendation in Chalco has been discussed by Barredos and Bell (Fertilizer Research, in press).

The herbicide trials and demonstration mainly tested new products. Interestingly, the results had greater variability, and the results were not as clear as in previous years. It was concluded that, although for demonstration of a recommendation superimposed trials may be suitable for gaining understanding of products, more control is desirable (i.e., increased replication and control).

Again, GxE interaction complicated the generation of variety recommendations. Eronga was again the top yielder (as in 1987). This raised the question as to what happened in 1988 (where Eronga ranked eighth). After checking, it was concluded that the major

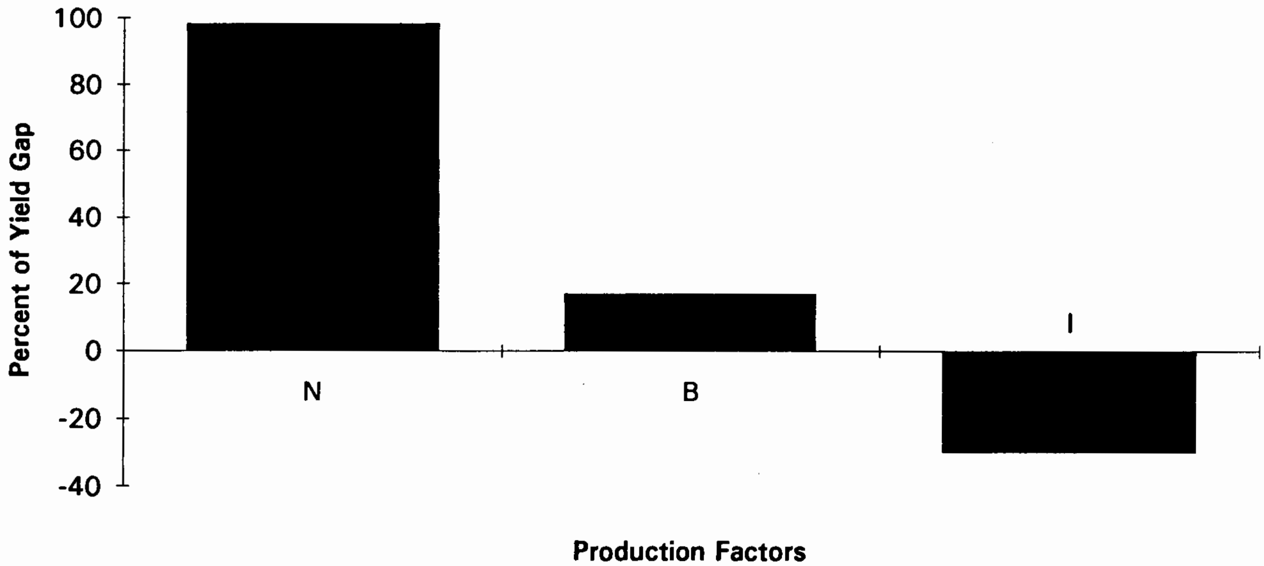

Figure 8. Percent of yield gap explained in 1989 Production trials by nitrogen (N), broadleaf control (B), or grass control (I).

problem in 1988 had been the use of old seed. Apparently, triticales can be somewhat susceptible to a loss of plant vigor as storage time increases. Thus, although, the germination was adequate (> 95%), the plant vigor was reduced, which was confirmed by the fact that tillering of Eronga was reduced in 1988 versus other years.

The reduced tillage demonstration highlighted a particular problem of Brome grass. Interestingly, this weed, which is particularly difficult to control, was prevalent only in those parts of the field where wheat was planted under reduced tillage. As the ground had been plowed during the dry season, there was no problem of straw management, however, the seeder used (Aitcheson) relies on a flat surface for uniform planting depth--something not observed in the field. Therefore, there were some problems of variable planting depth across the field.

Again, serious erosion was noted in some parts of the region--particularly in the higher regions where slopes are generally greater, highlighting the need for more conservation tillage.

1990 On-Farm Research

Introduction

The focus of research changed in 1990 to study longer term issues involving tillage, straw management, N requirements, and weed control (**Table 26**) across contrasting environments (**Table 27**). The change in research focus was initiated as it was felt that recommendations had been generated for the major production restraints, and in 1988 and 1989, increasing levels of erosion had been noted throughout the zone.

Table 26. Factors and levels in production trial.

Factor	Levels
Tillage	Conventional, zero
Straw	Plus, burnt
N	40, 120 kg N/ha (N applications split)
Weeds	Brominal, Brominal + Iloxan

Table 27. Site characteristics.

Site	pH	SOM %	Straw	Key site characteristics
1	5.8	3.22	6 t/ha	Take-all present, high zone, High rainfall
2	6.8	1.6	4 t/ha	Low zone, high rainfall
3	6.2	1.2	2 t/ha	Low zone, low rainfall

The variety Pavon F 76 was planted at a rate of 120 kg/ha using the Aitcheson seedmatic reduced tillage seeder. Weed control was split across the plots being Brominal (2 L/ha) (B) or Brominal (2 L/ha) + Iloxan (4 L/ha) (B+I). Thirty kg P_2O_5/ha were applied at each site. Plot sizes ranged from (4 x 18) to (10 x 25) m^2.

Tillage trial results

Results were dependent on the level of weed control used (**Tables 28-30**). Yields were generally higher when Iloxan was included. There was no straw effect (despite the wide range of straw levels--Table 27). This was somewhat of a surprise as there was a clear N deficiency in plots with straw at all sites during the initial part of the cycle. **Figure 9** shows the summarized main effects.

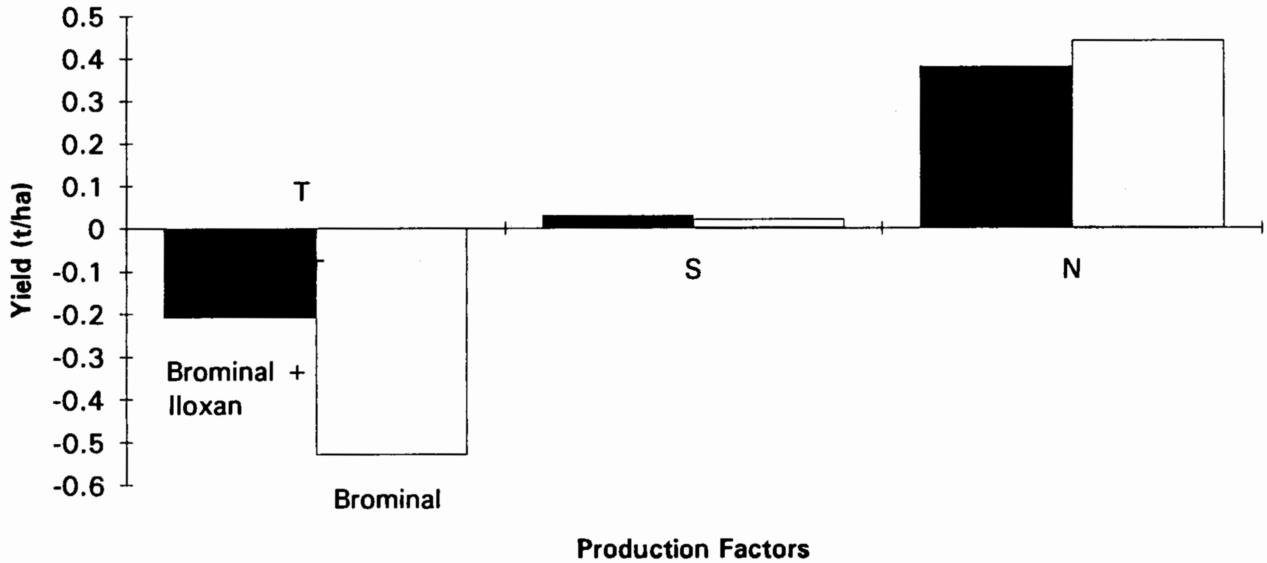

Figure 9. Main factor effects of tillage (T), straw management (S), and nitrogen (N) in 1990 production trial for two levels of weed control.

Table 28. Tillage trial results (where Brominal + Iloxan used).

Treatment Brominal + Iloxan			Yield (t/ha) Sites			
T	S	N	1	2	3	Average
0	0	0	3.66	2.04	2.14	2.61
0	0	1	4.32	1.64	2.62	2.86
0	1	0	2.92	2.16	2.25	2.44
0	1	1	4.02	1.78	2.27	2.69
1	0	0	2.44	2.06	1.40	1.97
1	0	1	3.72	2.06	2.27	2.68
1	1	0	3.39	2.35	1.55	2.43
1	1	1	3.41	2.50	2.21	2.71
Average			3.49	2.07	2.09	
LSD 5%			1.30	0.78	0.37	

Table 29. Tillage trial results (where Brominal only used).

Treatment Brominal T	S	N	Yield (t/ha) Sites 1	2	3	Average
0	0	0	3.03	1.66	2.11	2.27
0	0	1	4.22	1.51	2.76	2.83
0	1	0	3.44	1.73	2.36	2.51
0	1	1	3.68	1.00	2.57	2.42
1	0	0	2.05	1.82	1.11	1.66
1	0	1	3.25	1.74	1.90	2.30
1	1	0	1.80	1.87	1.21	1.63
1	1	1	3.27	1.78	1.84	2.30
Average			3.09	1.64	1.98	
LSD 5%			1.26	0.76	0.40	

Formal survey

To complement the information gathered in 1988 and further test the methodology relating practices to yield, 33 fields and farmers were surveyed in 1990. The results showed a strong correlation between yield and altitude--which in this year (vs. 1988) appeared to be related to rainfall distribution. In other respects the information was similar to that collected in 1988.

Table 30 Yield gap and main effects.

Herbicide	Site	Treatment effects T1S1N1-T0S0N0	T effect Σ(T1-T0)	S effect Σ(S1-S0)	N effect Σ(N1-N0)
B+I	1	-0.25	-0.52	-0.10	0.81
B	1	0.24	-0.98	0.11	1.01
B+I	2	0.46	0.34	0.24	-0.16
B	2	0.12	0.32	-0.09	-0.26
B+I	3	0.07	-0.46	-0.04	0.50
B	3	-0.27	-0.93	0.03	0.57

Discussion and conclusions

The tillage trial highlighted problems more with equipment than with reduced technology *per se*. The seeder had planting shoes that rely on a flat surface to have uniform planting depth--these conditions were not present in the fields, which led to variation of planting depth. In addition, the machine only handled straw well in site 3, the site with the lowest amount of residue (Table 27). Site 1 had serious problems of brome grass infestations in the reduced tillage plots. Site 2 had serious problems of late weeds (especially rape)--this was attributed primarily to problems at seeding which led to an inadequate plant stand, which allowed a lot of light penetration. In addition, the problems of weeds at site 2 were exacerbated at the higher level of N application.

In general, reduced tillage seems viable, with the primary problems being brome grass control in high sites, straw management at planting, and uniform seeding depth. As a note of caution, the possibilities of problems due to disease build-up arising over time with reduced tillage are unknown. A system of alternating the tillage system (e.g., one year direct drilling, next year chisel) to handle disease and/or weed problems may be best. One of the problems limiting the usefulness of reduced tillage in terms of moisture conservation is that most often the residue is grazed by wandering mobs of sheep during the dry season; thus limiting the amount of straw that can be kept on the soil surface.

The survey highlighted the field problems of plant stand, nutrition, and weeds. Given the level of inputs, these problems arise primarily from poor application of N, inappropriate weed control (i.e., 2,4-D rather than Brominal for *Sicius* sp.), and an inappropriate method of seed incorporation rather than a lack of inputs *per se*.

General Discussion and Conclusions

The area of Chalco is a region of high yield potential--yields of up to 7 t/ha were observed in large plots in farmers fields. A number of production factors, however, presently limit yields. The most important are:

- Weeds,
- Plant stand and distribution,
- Variety, and
- Nitrogen nutrition.

Weed control options were developed and were especially important if *sicius* sp. was present. When present, the farmers practice of 2,4-D had to be supplemented by expensive hand weeding or else large yield losses occurred. Research generated a number of options including the use of Brominal, 2,4-D + Karmex or Harmony.

The problems of plant stand arise primarily from the principal method of planting (i.e., being a combination of uneven hand distribution of seed combined with incorporation using a large disk harrow ($\pm$ 35 cm)).

A number of varieties superior to the local checks were identified (**Figure 10**). Diseases were a major problem for some varieties (especially Salamanca), and the newer varieties, in part, were superior due to increased disease resistance.

The problem of N nutrition is surprising given the high level of application in the zone, an average of 112 kg N/ha--close to the level recommended from fertility trial results (**Figure 11**). The problem appears to arise, therefore, primarily from poor fertilizer distribution in the field although a large range in N application rates is apparent.

Another issue in the zone is crop rotation which affects disease, and weed population dynamics. Although better rotation with Maize (*Zea mays*) would certainly benefit wheat (e.g., fields regularly sown to wheat had increasing problems of *avena fatua* --whereas the populations decreased when rotated with maize), crop rotation is primarily driven by market prices. Presently, maize and wheat are the dominant crops of the region, with minor amounts of horticultural crops (e.g., carrots, flowers) sown.

Erosion was an increasing problem in the higher altitude areas. Although reduced tillage appears to be an option, free range grazing, primarily by sheep, in the dry season presents problems in attaining target residues. In addition, Brome grass, which traditionally has been extremely difficult to control, was prevalent in the reduced tillage work in higher altitude fields.

Crop harvest had problems. The main problem was use of poorly adjusted combines. The combines, which are rented, harvest the majority of the wheat in the zone, are paid by the ha and therefore are interested in the number of ha harvested rather than yield.

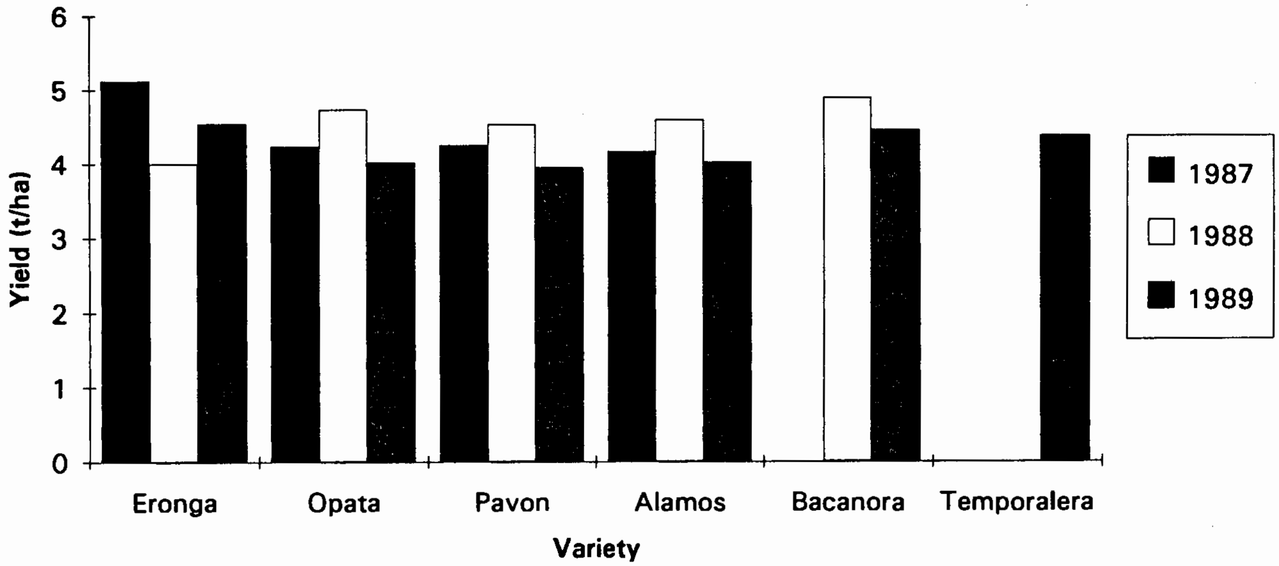

Figure 10. Summary of variety trial results from 1987-1989 showing varieties superior to the local check Pavon .

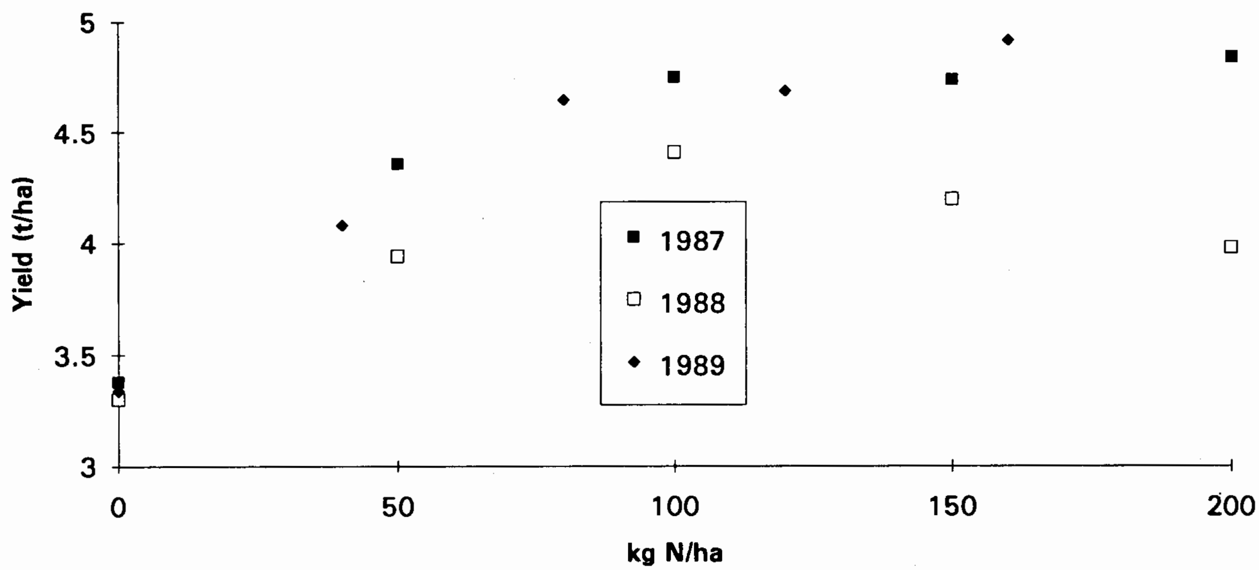

Figure 11. Summary of fertility trials for 1987-1989.

Appendix 1. Summary of products and active ingredients used.

Commercial name	Active ingredient
Herbicides	
Amber	Triasulfuron
Basagran	Bentazon
Brominal	Bromoxynil
Dicuran	Chlortoluron
Dicuran forte	Chlortoluran + triasulfuron
Glean	Chlorsulfuron
Grasp	Tralkoxydim
Harmony	Harmony
Iloxan	Diclofop-methyl
Karmex	Diuron
Logran	Triasulfuron
Puma	Fenoxaprop-P-ethyl
Prowl	Pendamethalin
Insecticides	
Metasystox	Oxydemeton-methyl

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