Discussion Paper No. 17

THE EFFECT OF FERTILIZER USE ON THE VARIABILITY OF BARLEY YIELDS IN DRY AREAS

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ABSTRACT

This paper attempts to measure the effect of fertilizer use (N and P) on the variability of barley yields in dry areas. Two sets of data are utilized to measure variability of yields. These data come from multiple site-multiple season (MS-MS) researcher managed trials conducted mostly on farmers' fields. The evidence quite clearly indicates that fertilizer use reduces variability in barley yields under rainfed conditions in dry areas. Furthermore, <u>substantial gains in yields are possible along with reductions in variability</u>.

Research on this important crop of the drier regions of West Asia and North Africa (WANA) indicates that improved cultural practices, with emphasis on fertilizer use, improves the efficiency of use of the most critical limiting factor: water. Fertilizer use improves water use efficiency without increasing water use. Increased root growth and early plant establishment allow increased transpiration and reduce evaporative losses from the soil surface. Furthermore, maturity is advanced and this provides an escape mechanism from the drought stresses that invariably occur at the end of a season. These can be identified as the principal factors that reduce the variability of yields.

These results are expected to influence a review of policies that restrict fertilizer allocation to dry areas as well as a review of the relative neglect of research on barley and rainfed agriculture in general at the national level.

Keywords: yield variability, barley, fertilizer, nitrogen, phosphorus, rainfed agriculture.

I. INTRODUCTION

Barley has a comparative biological advantage in the dry regions of WANA primarily due to its higher drought adaptation. In these dry areas, barley is grown primarily as a feed crop; food use is localized and malting use is disproportionately small. Sheep, barley and the grazing areas of the steppe, fallow lands and other non-arable lands form a triangle that characterizes the basic farming systems of these dry areas.

ICARDA uses several venues in agricultural research for these dry areas:

a. Development of improved cultivars.

b. Development of practices to increase productivity of existing systems.

c. Development of practices to increase productivity through increased cropping intensity (reduction of fallow).

A fairly comprehensive interdisciplinary systems approach characterizes this research effort. Considerable research is carried out on cereals, food and forage legumes and livestock management. Many research activities are conducted in collaboration with national organizations.

One of the initial research activities on barley at ICARDA was conducted by the Farming Systems Program (FSP). This research focused on improving the efficiency of use of the most critical limiting element in rainfed farming systems in the dry areas: water. The results of these research activities have been adequately documented (Cooper, Cooper _et al._, 1980, 1985; Somel and Cooper; Somel, 1984a, b; SD/FSP, 1984, 1985; Gregory _et al._). It was observed that N and P fertilizer use, but particularly P, improves water use efficiency without increasing water use (Cooper). Furthermore, considering long term climatic variability, fertilizer use would be expected to pay off around 80% of the time (Somel, 1984a).

These results were discussed in a workshop (SD/FSP, 1984) which led to a collaborative research project between the Soils Directorate of the Ministry of Agriculture and Agrarian Reform in Syria and ICARDA/FSP. This project is currently in its second season. Multiple site-multiple season researcher managed trials are implemented on farmers' fields throughout N. Syria. Site characterization is emphasized through measurement of soil characteristics, particularly available N and P, as well as weekly rainfall measurements. Site characterization is incorporated into pooled analyses to observe the effects of N and P (SD/FSP, 1985; Cooper _et al._, 1985).

Data from the first season of these collaborative trials and data selected from earlier ICARDA/FSP trials are analysed in this paper with a view to assessing the effects of fertilizer use on the variability of barley yields.

II. MATERIAL AND METHODS

The two sets of data utilized are described as follows:

1. Data from 4x4 factorial experiments conducted at 10 sites on farmers' fields (with the exception of Breda) in N. Syria. (2) These trials used four rates of N (0, 20, 40, 60 kg/ha N) and four rates of P (0, 30, 60, 90 kg/ha P_2O_5). A widely used local variety of barley (var. Arabic Aswad) was drill planted at 100 kg/ha. Chemical weed control and seed dressing were standard treatments. These data will be referred to as SD/FSP trials.

2. Data from the last two years of a three year seed rate-nitrogen-phosphorus (SNP) trial conducted by ICARDA/FSP at 5 sites in NW Syria. Only part of the data set was utilized for two reasons:

   (a) The lack of continuity in the treatments between the years.

   (b) To eliminate (reduce) the effect of the seed rate factor.

As a consequence, only 10 treatments were utilized. These have seed rates of 90 or 120 kg/ha. The N and P rates are 0, 30, 60, 90 and 120 kg/ha N or P_2O_5 but the combinations are incomplete because of the modified central composite design used for the experiments. An improved cultivar of barley (cv Beecher) was drill planted. Chemical weed control and seed dressing were standard treatments. These data will be referred to as SNP-S trials.

Grain yields and total dry matter (TDM), both in kg/ha, are utilized in analyzing variability across environments. Each site/season is viewed as a state of the environment. A substantial range of environmental conditions (rainfall and available soil nutrients) as well as the manifestation of this range in yields can be observed in the trials (Tables 1 and 2).

Of particular interest are the low levels of available phosphorus. Soils in N. Syria are particularly deficient in phosphorus. According to the results of a survey of barley producers in N. Syria in 1981/82, the average P-Olsen (ppm) was 7.1 in NW Syria and 4.9 in NE Syria. Overall, 86% of the fields surveyed had less than 9 ppm of available phosphorus (92% in NE and 79% in NW Syria) (Somel, et al.).

The particular analysis used essentially substitutes space for time. The SNP-S trials have a time dimension of two years at five locations. The SD/FSP trials will continue but at other locations, incorporating differing rotations, depth of soils, etc. This approach is adopted as a tool in FSP to accelerate research in the face of the urgent agricultural problems faced in WANA.

Two approaches are utilized in the analysis. The first of these looks at the mean and variability (as measured by the standard deviation) of yields across environments. The coefficient of variation can also be used as an indicator of variability in this approach. The trade-offs between increases in yields and variability can subsequently be assessed.

The second approach was developed by Finlay and Wilkinson and is used primarily for assessing genotype x environment interactions. Here it is used to assess fertilizer x environment interactions with certain caveat.

Hill indicates that (p 480)

"Usually, when a number of genotypes are grown in a range of environments, no single physical factor can effectively discriminate between these environments. Each represents an amalgam of several factors (nutrient levels, moisture level, incoming light energy, etc.) each of which can vary continuously and independently of the others.

Faced with this problem, recourse has been made to a biological, as opposed to a physical, assessment of the environment."

This biological measure of the environment is taken as the mean yields of all the varieties at a given site each season, i.e., at each environment. Subsequently, the yields of a given variety are related to the average yields across environments in a linear regression. "In this way the average yield of a large group of varieties is used to describe a complex natural environment, without the complexities of defining or analyzing the interacting edaphic and seasonal factors." (Finlay and Wilkinson, p 745)

There are certain dangers in transferring this method to analyze fertilizer x environment interactions. In assessing genotype x environment interactions it can safely be assumed that the influence of a genotype on the environmental characteristics at a given site is minimal, if not nil. However, fertilizer application influences the soil characteristics of a given environment drastically. Some of these influences, such as residual phosphorus can have long term effects. However, in a given season, different fertilizer treatments imply different effects on the otherwise constant environment. Therefore, the results of the exercise using the Finlay-Wilkinson approach need to be interpreted with extreme caution.

The preference at ICARDA/FSP is to characterize environments (site/season) with at least a minimum set of parameters (rainfall, available N and P) and assess environment x fertilizer interactions by incorporating the environmental characterization into analysis in the manner of Colwell, Colwell and Morton and Ryan and Perrin (Somel, 1984a, SD/FSP, 1985, Cooper et al., 1985). The two approaches used in this paper do not incorporate the available soil nutrient levels, which can influence fertilizer responses and the consequent variability of yields.

The first approach would query if fertilizer use reduces variability of yields particularly as compared to no fertilizer use which is quite common in barley production in N. Syria. Fertilizer is not allocated to the dry zones but can be bought without credit in the medium dry zones. Less than 15% of barley producers use N or P (Somel, et al.).

The second approach relates yields of each treatment to average yields at each environment in a linear regression: (3)

$$y_{ij} = a_i + b_i y_{.j} \qquad \text{for each } i$$

where y = yields (kg/ha)

i = number of treatments $i = 1.....n$

j = number of environments $j = 1....m$

Hence, $y_{.j}$ is the average of all treatments in environment j.

The intercept a would indicate shifts in the relationship. However, the slope b_i is the more important parameter. $b_i > 1$ would imply that the treatment performs better in favourable environments, whereas $b_i<1$ would imply better performance in the unfavourable or in the lower range of the environments. Hence, $b_i<1$ is indicative of lower variability across environments. Looking at genotype x environment interactions, Finlay and Wilkinson associate mean yields of a genotype and the value of b with implications of adaptability across environments (p 748). A parallel exercise can be conducted with the caveat discussed above in mind. In this exercise

a. Lower yields and $b_i<1$ would imply the appropriateness of the fertilizer treatments to unfavourable environments.

b. Lower yields and $b_i>1$ would imply appropriateness to favourable environments and above average variability.

c. Lower yields and $b_i \cong 1$ would imply that the treatment is not appropriate across all environments.

d. Higher yields and $b_i \cong 1$ would imply average variability and appropriateness across all environments.

III. RESULTS

In the SD/FSP trials, fertilizer use generally reduces variability. This is observed in the lower CVs associated with fertilizer treatments as compared to no fertilizer. However, it is also apparent that each fertilizer, by itself causes a higher than average variability. Treatments that are balanced in N and P generally have considerably lower variability (Tables 3 and 4).

What is more significant is that, as compared to the no fertilizer treatment, <u>with fertilizer use it is possible to increase yields without increasing variability or with reduced variability</u>. In Figures 1 and 2, the treatments to the northwest of the (0, 0) treatment offer these possibilities. These are generally either balanced treatments or treatments with P only. Treatments with only N or with high N usually achieve higher yields with increased variability.

The results of the SNP-S trials reinforce those of the SD/FSP trials. Again, fertilizer treatments reduce variability and more importantly, with fertilizer use, it is possible to increase yields and <u>not</u> increase variability (Tables 5 and 6, Figures 3 and 4).

Similar results are observed with the Finlay-Wilkinson approach. Treatments with only P are more stable and are more appropriate for the unfavourable environments. However, balanced treatments have the average variability characteristic of the no fertilizer treatment but achieve considerably higher yields which indicate appropriateness across environments (Tables 3 and 6, Figures 5 and 6).

F-test results indicate that both for TDM and grain yields, the individual regressions have coefficients that are significantly different from each other. The joint hypothesis tested was

$$H_o: \quad a_1 = a_2 = \ldots\ldots = a_n$$
$$b_1 = b_2 = \ldots\ldots = b_n$$

The hypothesis was rejected at the 1% level of significance for all the four sets of regressions. However, the group of the more balanced treatments have similar coefficients. The joint hypothesis for treatments 11, 12, 15 and 16 in the SD/FSP trials could not be rejected at the 1% level for TDM and for treatments 5, 6, 8 and 15 in the SNP-S trials for both TDM and grain yields. Hence, these balanced treatments have similar characteristics in achieving at most average variability but with significantly increased yields as compared to no fertilizer use.

IV. CONCLUSIONS

The significant yield increasing effects of N and P fertilizer use on rainfed barley in the dry regions of WANA have been adequately demonstrated. There are also adequate indications that fertilizer use would lead to increased profitability. The specific issue addressed in this paper was whether fertilizer use also affected yield variability.

The results clearly indicate that it is possible to increase barley yields <u>and</u> reduce or maintain variability through fertilizer use. This was demonstrated with data from multiple site-multiple season researcher managed trials conducted generally on farmers' fields in N. Syria. Results of on-going research are expected to reinforce these conclusions.

Given the high element of uncertainty primarily due to variability in rainfall, fertilizer use on barley appears to be an appropriate medium of promoting stability and security.

Notes

(1) Economist and Acting Program Leader, Farming Systems Program, ICARDA. The views presented in this paper do not necessarily reflect the policies of ICARDA donors or the collaborating organizations. The SD/FSP data used in this paper come from a collaborative research project involving input from Dr. J.A. Karim, Mr. K. El Hajj and provincial staff from the Syrian Ministry of Agriculture and Agrarian Reform and Drs. H. Harris, P. Cooper, D. Keatinge, A. Matar and field staff from ICARDA. Their contribution is gratefully acknowledged. All errors are the responsibility of the author.

(2) The actual number of sites in this experiment was 16. Data from the other sites are excluded because of sampling problems, bird damage or because the farmer harvested the crop. The data are not excluded because of crop failure.

(3) Finlay and Wilkinson actually estimate a non-linear (log-log) relationship. A linear relationship is used here as it appears to perform satisfactorily for the purposes of this paper. However, this does not imply a blanket acceptance of linearity in environmental relations. Actually, previous exercises (Somel, 1984a; SD/FSP, 1985 and Cooper et al., 1985) indicate that non-linearities arise due both to direct environmental effects and to the interaction of the environmental and experimental factors.

Table 1. Environmental Parameters in the SD/FSP trials.

Site	Seasonal Rainfall (mm)	Available Phosphorus (ppm) (1)	Mineral Nitrogen (ppm) (2)	Yields (kg/ha) TDM	Grain
Ibtin	260	3.6	9.1	5320	2292
Mariamine	294	8.3	6.2	3993	1816
Hobar	268	4.2	6.7	6000	2582
Breda	268	2.1	8.4	5017	2312
Jifr Mansour	246	3.4	11.8	3800	1540
Grerifeh	232	1.8	4.9	2226	869
Maar Shahour	323	1.7	8.2	2958	1296
Skiro	208	2.8	20.5	3105	1382
Khashouka	279	3.1	7.5	5379	2413
Jesaah	398	3.5	16.9	7231	3334

Notes:

(1) P-Olsen in top 40 cm of soil, determined at planting.

(2) NH_4 and NO_3 in top 40 cm of soil, determined at planting.

Table 2. Environmental Parameters in the SNP-S trials.

Site		Seasonal Rainfall (mm)	Available Phosphorus (ppm) (1)	Mineral Nitrogen (ppm) (2)	Yields (kg/ha) TDM	Grain
Khanasser	(80/81)	246	3.8	31.1	3689	1651
Khanasser	(81/82)	263	-	-	2299	979
Breda	(80/81)	292	2.9	7.9	6904	2312
Breda	(81/82)	324	-	-	4588	1645
Tel Hadya	(80/81)	373	4.9	25.3	10609	4057
Tel Hadya	(81/82)	338	-	-	10408	3184
Kafr Antoon	(80/81)	467	2.4	17.0	11826	4851
Kafr Antoon	(81/82)	397	-	-	7867	3662
Jinderess	(80/81)	472	2.5	8.5	9269	3694
Jinderess	(81/82)	358	-	-	7033	2905

Notes:

(1) P-Olsen in the top 40 cm of soil, measured at planting in 1980.

(2) NH_4 and NO_3 in the top 40 cm of soil, mean values for the 80/81 season.

Table 3. Variability of Grain Yields (kg/ha) in the SD/FSP trials.

Treatment	N (kg/ha)	P_2O_5 (kg/ha)	Yields Mean	SD	CV (%)	Regression Intercept	Slope	R^2
1	0	0	1621	771	47.6	-367	1.0022	0.87
2	0	30	1717	704	41.0	-6	0.8685	0.78
3	0	60	1795	739	41.2	-70	0.9403	0.83
4	0	90	1783	741	41.6	-23	0.9107	0.77
5	20	0	1609	731	45.4	-216	0.9204	0.81
6	20	30	1916	712	37.2	25	0.9534	0.92
7	20	60	2070	830	40.1	-122	1.1054	0.91
8	20	90	2029	704	34.7	304	0.8694	0.78
9	40	0	1811	798	44.1	-214	1.0207	0.84
10	40	30	2101	819	39.0	-90	1.1046	0.93
11	40	60	2202	771	35.0	165	1.0271	0.91
12	40	90	2377	790	33.2	390	1.0017	0.83
13	60	0	1798	870	48.3	-338	1.0769	0.78
14	60	30	2188	839	38.3	-33	1.1194	0.91
15	60	60	2285	760	33.3	277	1.0122	0.91
16	60	90	2432	815	33.5	316	1.0673	0.88
Overall	-	-	1983	800	40.3	-	-	-

Notes: All the intercept terms are not significantly different from zero at the 5% level. All the slope coefficients are significantly different from zero at the 0.005% level. n=20 for each treatment.

Table 4. Variability of Total Dry Matter (TDM) yields (kg/ha) in the SD/FSP trials.

Treatment	N	P_2O_5	Yields			Regression		
	(kg/ha)	(kg/ha)	Mean	SD	CV (%)	Intercept	Slope	R^2
1	0	0	3397	1591	46.8	-1091 b	0.9965	0.89
2	0	30	3729	1578	42.3	-385	0.9136	0.76
3	0	60	3857	1580	41.0	-352	0.9346	0.80
4	0	90	3863	1586	41.1	-113	0.8832	0.69
5	20	0	3542	1569	44.3	-771	0.9578	0.85
6	20	30	4201	1516	36.1	-90	0.9530	0.90
7	20	60	4717	1827	38.8	-438	1.1449	0.90
8	20	90	4646	1375	29.6	1026 b	0.8040	0.78
9	40	0	4097	1770	43.2	-658	1.0561	0.81
10	40	30	4813	1761	36.6	-271	1.1290	0.94
11	40	60	5183	1547	29.8	749 b	0.9847	0.92
12	40	90	5590	1718	30.7	1014	1.0163	0.80
13	60	0	4052	1975	48.7	-1199	1.1661	0.79
14	60	30	5027	1746	34.7	76	1.0996	0.90
15	60	60	5423	1517	28.0	1104 a	0.9591	0.91
16	60	90	5904	1621	27.5	1392 a	1.0021	0.87
Overall	-	-	4503	1775	39.4	-	-	-

Notes: (a) Significantly different from zero at the 1% level.
(b) Significantly different from zero at the 5% level.
All other intercept terms are not significantly different from zero at the 5% level. All slope coefficients are significantly different from zero at the 0.005% level. n=20 for each treatment.

Table 5. Variability of Grain Yields (kg/ha) in the SNP-S trials.

Treatment	N (kg/ha)	P_2O_5 (kg/ha)	Yields Mean	Yields SD	Yields CV (%)	Regression Intercept	Regression Slope	R^2
5	30	30	2824	1134	40.2	167	0.9182	0.94
6	30	90	2998	1086	36.2	469 b	0.8736	0.93
7	90	30	2996	1297	43.3	-60	1.0557	0.95
8	90	90	3173	1094	34.4	704 a	0.8530	0.87
11	0	60	2453	1141	46.5	-1	0.8481	0.79
12	120	60	3084	1427	46.2	-164	1.1220	0.88
13	60	0	2641	1411	53.4	-673 a	1.1452	0.94
14	60	120	3207	1324	41.3	198	1.0396	0.88
15	60	60	2946	1309	44.4	-63	1.0397	0.90
17	0	0	1926	1164	60.4	-686	1.0553	0.92
Overall	-	-	2872	1260	43.9	-	-	-

Notes: (a) Significantly different from zero at the 1% level.
(b) Significantly different from zero at the 5% level.

All other intercept terms are not significantly different from zero at the 5% level. All slope coefficients are significantly different from zero at the 0.005% level.

n=20 for each treatment except n=10 for treatment 17.

Table 6. Variability of Total Dry Matter (TDM) yields (kg/ha) in the SNP-S trials.

Treatment	N	P_2O_5	Yields			Regression		
	(kg/ha)	(kg/ha)	Mean	SD	CV (%)	Intercept	Slope	R^2
5	30	30	7045	3093	43.9	-120	0.9619	0.92
6	30	90	7645	3050	39.9	526	0.9557	0.94
7	90	30	7423	3264	48.8	-253	1.0304	0.95
8	90	90	8394	3212	38.3	1240	0.9604	0.85
11	0	60	6178	2508	40.6	810	0.7205	0.79
12	120	60	8031	3617	45.0	-260	1.1131	0.90
13	60	0	6327	3498	55.3	-1760 a	1.0856	0.92
14	60	120	8556	3920	45.8	-211	1.1769	0.86
15	60	60	7942	3097	39.0	1010	0.9306	0.86
17	0	0	5444	3116	57.2	-1149	1.0239	0.93
Overall	-	-	7396	3313	44.8	-	-	-

Notes: (a) Significantly different from zero at the 1% level.

All other intercept terms are not significantly different from zero at the 5% level. All slope coefficients are significantly different from zero at the 0.005% level.

n=20 for each treatment except n=10 for treatment 17.

REFERENCES

Colwell, J.D. (1973). The derivation of fertilizer recommendations for crops in a non-uniform environment, Pont. Acad. Sci. Scr. Var., No. 38.

Colwell, J.D. and R. Morton (1984). Development and evaluation of general or transfer models of relationships between wheat yields and fertilizer rates in southern Australia, Aust. J. Soil Res., 22: 191-205.

Cooper, P. (1983). Crop management in rainfed agriculture with special reference to water use efficiency. In Proceedings of 17th Coll. Int. Potash Institute, Bern, 63-79.

Cooper, P., A. Allan, K. Harmsen, D. Nygaard, M. Saxena and R. Islam (1980). Soil water and nutrient research. Project Report 3, FSP/ICARDA.

Cooper, P., K. Somel, A. Matar, H. Harris, D. Keatinge, J.A. Karim, K. El Hajj (1985). The effect of fertilizer on barley yield, water use and water use efficiency in the barley-livestock farming systems of Syria. Paper presented at the 25th Science Week, 2-7 November 1985, Damascus, Syria.

Finlay, K.W. and G.N. Wilkinson (1963). The analysis of adaptation in a plant breeding programme. Aust. J. of Agric. Res., 14: 742-754.

Gregory, P.J., K.D. Shepherd and P.J. Cooper (1984). Effects of fertilizer on root growth and water use of barley in northern Syria. J. Agric. Sci., Camb., 103: 429-438.

Hill, J. (1975). Genotype-environment interactions -- a challenge for plant breeding. J. Agric. Sci., Camb., 85: 477-493.

Ryan, J.G. and R.K. Perrin (1973). The estimation and use of a generalized response function for potatoes in the Sierra of Peru, North Carolina Agr. Exp. Sta. Tech. Bull 214.

SD/FSP (1984). Proceedings of the Soils Directorate/ICARDA Workshop on fertilizer use in the dry areas. ICARDA, Aleppo, 26-29 March 1984. Syrian Arab Republic, Ministry of Agriculture and Agrarian Reform, Soils Directorate, and, ICARDA, Farming Systems Program.

SD/FSP (1985). Fertilizer use on barley, northern Syria, 1984/85. Collaborative Research Project Report, Soils Directorate and Farming Systems Program.

Somel, K. (1984a). Environmental variability and multiple site-multiple season trials. Discussion Paper No. 14, FSP/ICARDA.

Somel, K. (1984b). Three years of seed rate-nitrogen-phosphorus trials, regression results. Research Report 11, FSP/ICARDA.

Somel, K. and P. Cooper (1985). Farming Systems Research at ICARDA, FSP Discussion Paper No. 16, FSP/ICARDA.

Somel, K., A. Mazid and M. Hallajian (1984). Survey of barley producers in N. Syria, 1981/1982. Research Report 12-III, FSP/ICARDA.

Figure 1 SD/FSP TRIALS

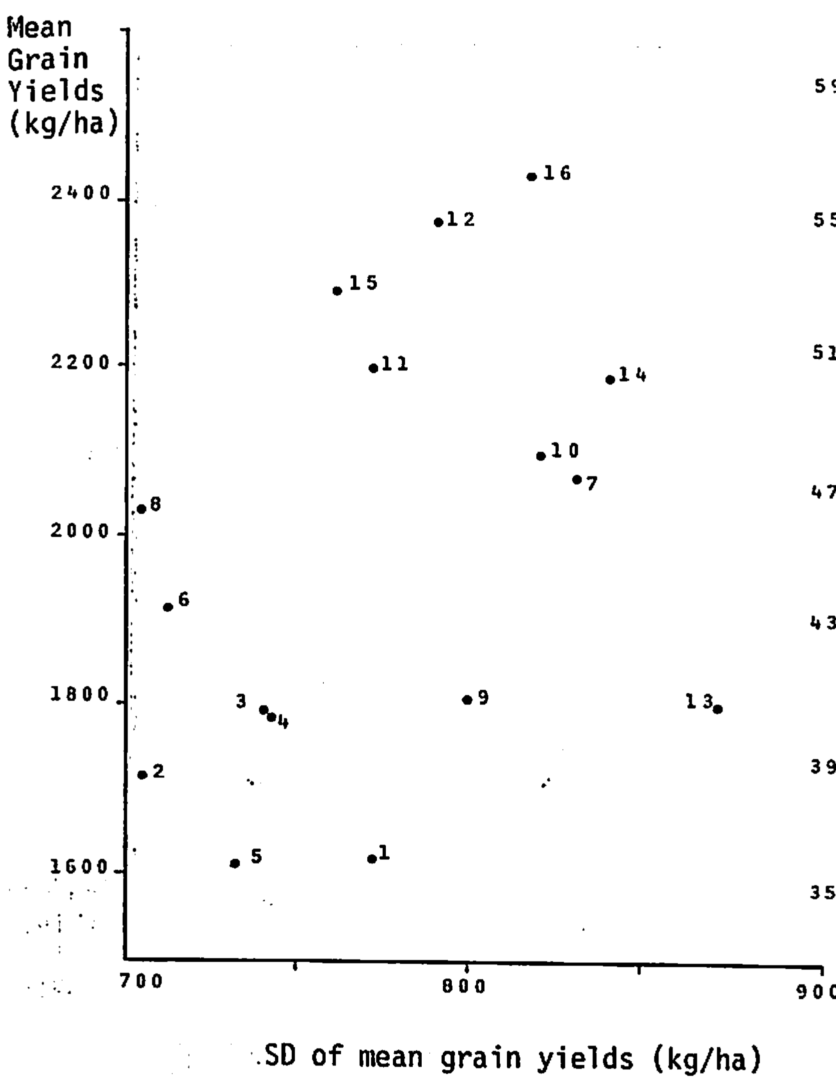


Figure 2 SD/FSP TRIALS

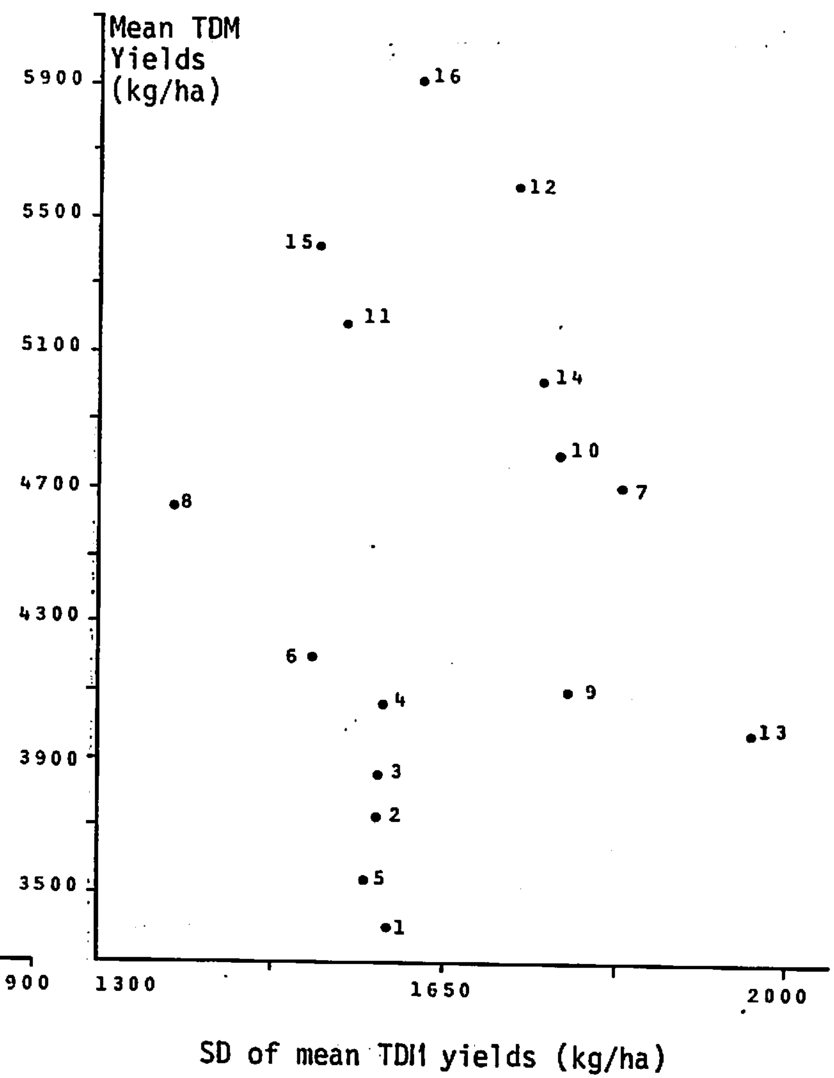


Figure 3 SNP-S TRIALS

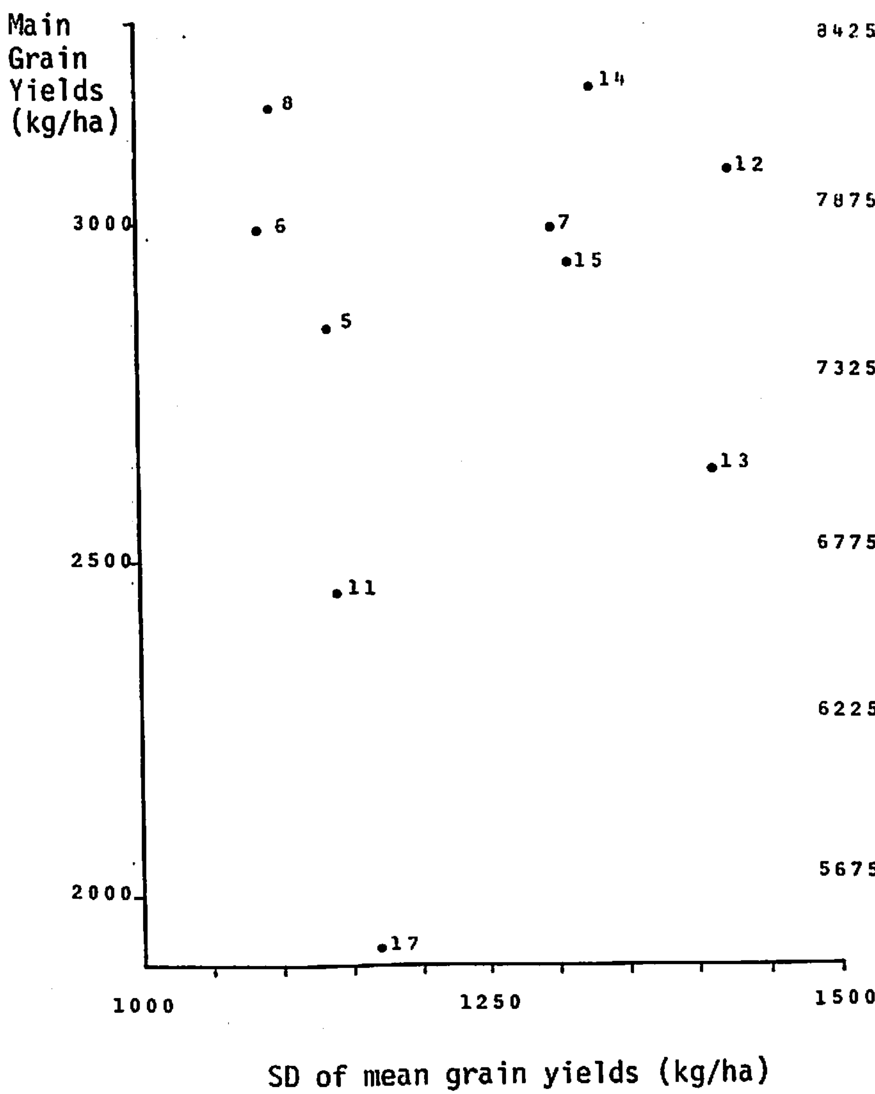


Figure 4 SNP-S TRIALS

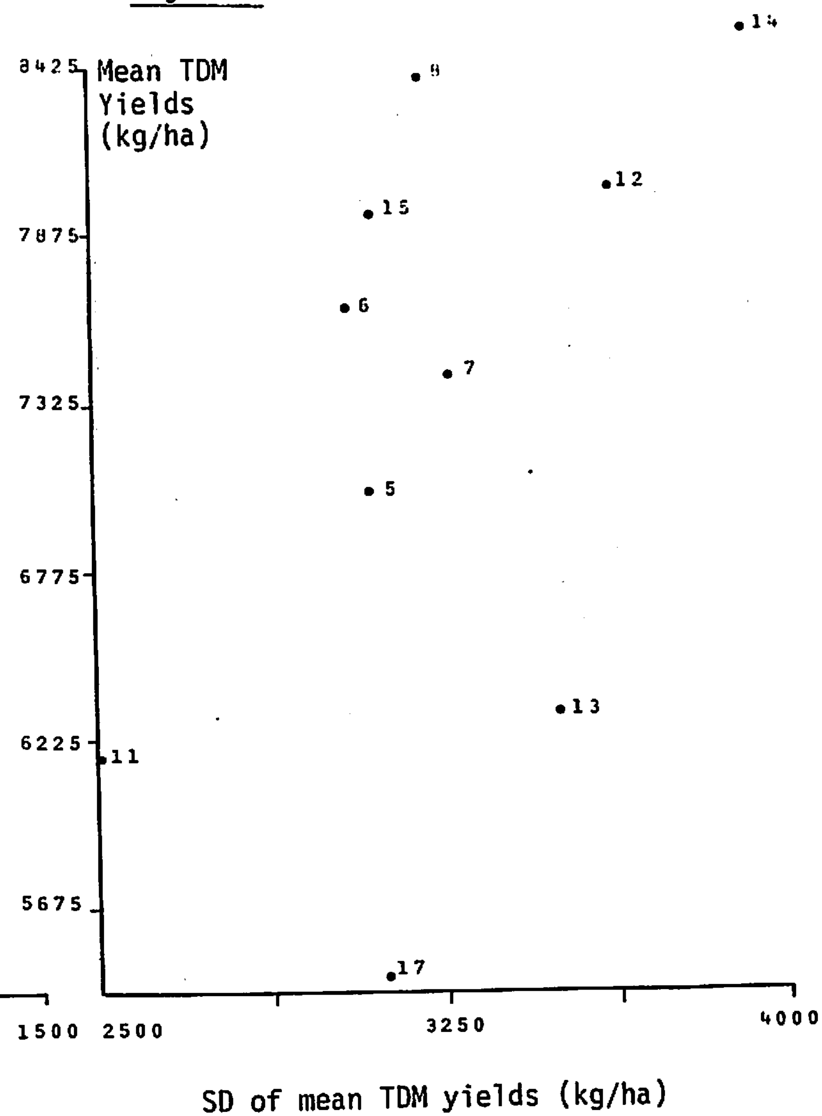


Figure 5 SD/FSP TRIALS

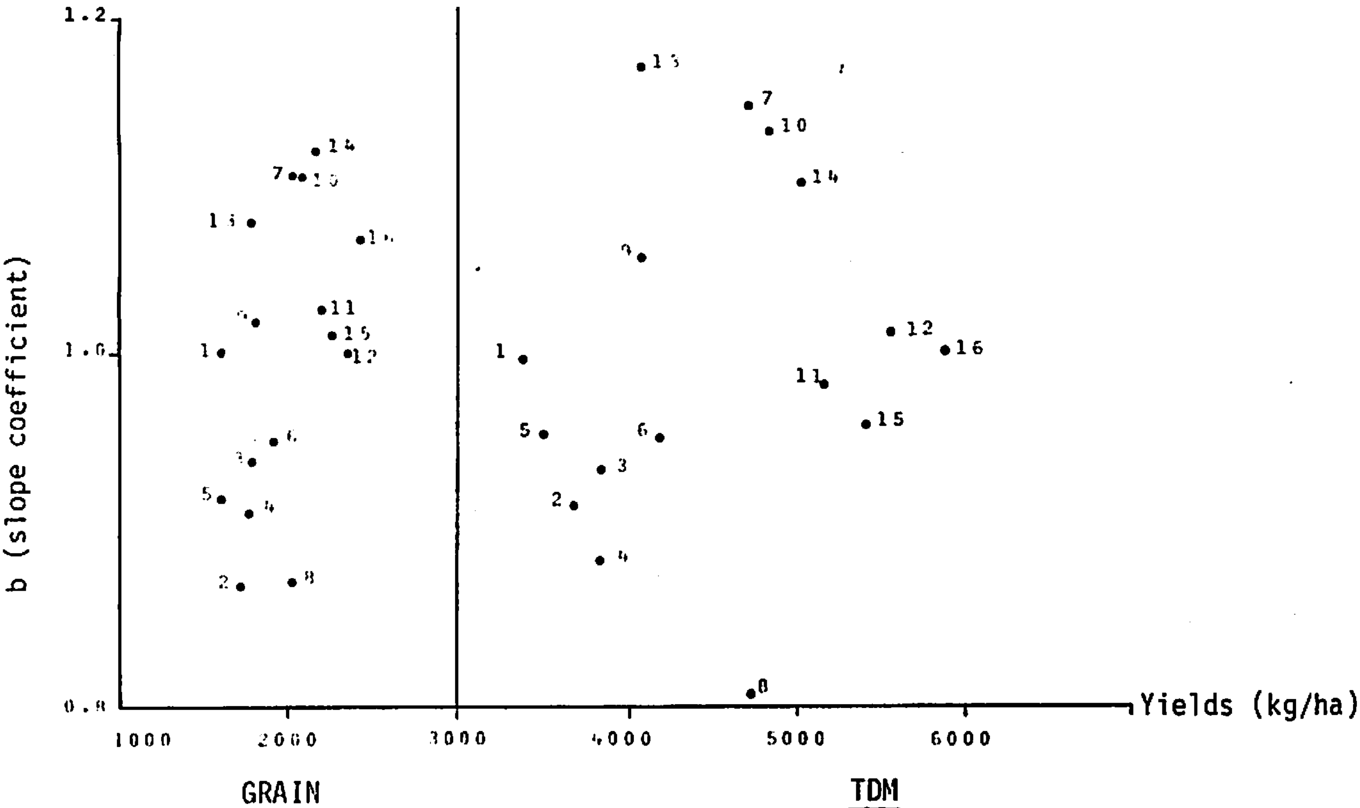
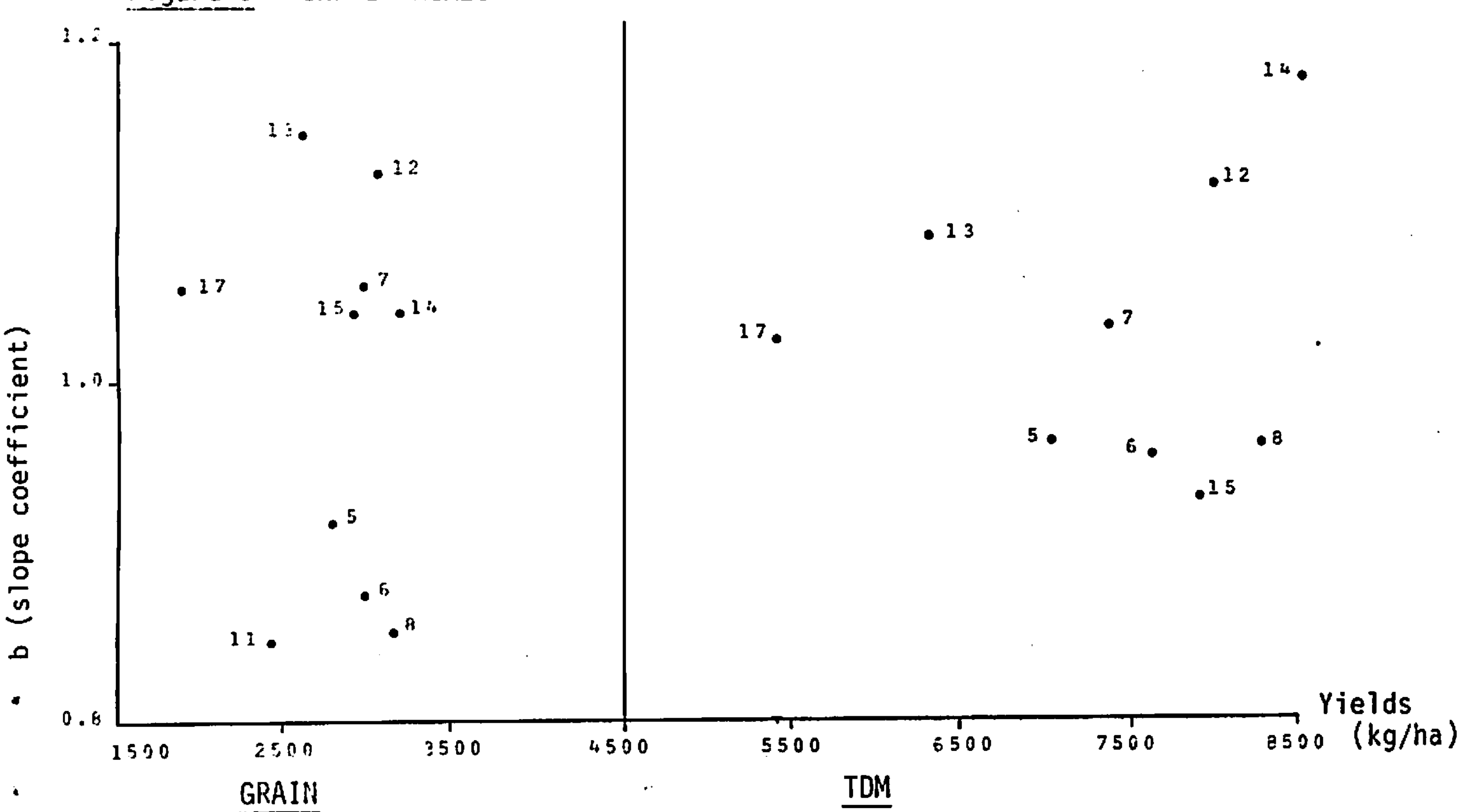


Figure 6 SNP-S TRIALS



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