EFFECT OF N, P, AND S ON YIELD AND COMPOSITION OF SIX SEMI-DWARF WHEATS GROWN UNDER IRRIGATION

By

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SEMI-DWARF WHEAT NUTRITION

CHAUDHRI

AN ABSTRACT OF THE THESIS OF

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Title: Effect of N, P, and S on yield and composition of six semi-dwarf wheats grown under irrigation.

In a field experiment on a calcareous clay soil 46.5 to 478 kg per hectare each of N, P, and S were applied to irrigated semi-dwarf wheats, Jaral-66, Pitic-62, Penjamo-62, TZPP-An 64, Sonora-64, and Rogue-66, before planting on November 14, 1966. The application of N significantly increased grain yield and plant height and decreased protein percentage of grain. The effects of P, S, and the interactions were generally small. Applied P increased protein percentage of grain of two varieties. Pitic, yielding up to 6.89 metric tons of grain per hectare, was the outstanding variety followed by Penjamo.

The application of N increased soluble nitrate-N of Pitic leaves at tillering, but reduced it at the dough stage. Applied P resulted in a probably real decrease in nitrate-N of the leaves at tillering. The application of N significantly reduced the soluble P and S contents of leaves at the boot and dough stages. Applied S increased soluble-S in leaves at all stages. At the boot stage, N application resulted in a slight increase in total N, but the P and S concentrations were greatly reduced. The application of S significantly increased total S and probably increased total P concentration of leaves. The decreasing effects of applied nutrients, especially N, on soluble nutrients of leaves at boot and dough stages were attributed to their translocation from leaves to heads for grain formation. Leaf sheath and stem-base tissues of young wheat plants have been suggested for studying critical levels of nitrate-N. Split application of N, before planting and at boot stage, has been suggested to obtain higher yield of high protein grain. If irrigation facilities and an adequate supply of nitrogenous fertilizers are provided the introduction of Pitic or a similar high yielding short-statured variety for general cultivation holds great promise for wheat production in the area.

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I. INTRODUCTION

Efforts to increase yields of wheat by applying high levels of fertilizers, tend to result in lodging, and reduced yields. High yielding short-statured varieties which are resistant to lodging have been developed. Some of the short-statured wheats have demonstrated broad adaptation and high yields in Pakistan, Turkey and some other countries. Most soils of the area are deficient in N and P, and protein formation of wheat grain requires considerable amounts of both nutrients along with S. There is an evident need, therefore, for information on the effects of the application of N, P, and S on high yielding short-statured wheats grown under irrigation in areas new to these varieties.

The balance sheet of the soil budget with respect to these nutrients may be reflected to varying degrees in the nutrient content of the leaves at various stages of plant growth. Relatively little information is available on the "critical levels" of nutrients in wheat under conditions suitable for high yield levels. More information is needed on the effects of applied N, P, and S on the protein concentration of grain. An experiment on the effect of N, P, and S application on the yield and composition of six semi-dwarf wheats grown under irrigation was carried out in the Beqa'a plain of Lebanon with the following objectives:

1. To determine the semi-dwarf varieties best suited under irrigation in Lebanon.
2. To study the response of these wheat varieties to N, P, and S application in relation to plant height, lodging and yield of grain.
3. To study the effect of these nutrients on the protein concentration of wheat grain.
4. To study the critical levels of nutrients in the leaves at various stages of growth.

II. REVIEW OF LITERATURE

A number of reports on the effects of N, P, and S application to commonly grown tall varieties of wheat are available. However, because of only recent interest in short-statured varieties, information regarding these wheats is limited. Some of the available reports on N, P, and S application to wheat have been reviewed.

Effects of N Application

Effects on Grain Yield

Hamdi *et al.* (1962) reported 15 kg per feddan* of N as ammonium nitrate to be the most economical treatment for wheat on calcareous loam soil (pH 8.5) of Egypt. Aziz and Bajwa (1965) reported that Mexican wheats, Pitic-62 and Penjamo-62, yielded 49 and 51 maunds** per acre respectively with the application of 60 lb N per acre under irrigation in 1964-65 in West Pakistan. Nitrogen at the rate of 120 lb combined with 60 lb P_2O_5 per acre resulted in 57.07 and 53.77 maunds per acre yields of Pitic and Penjamo respectively at Kalabagh. With 60 lb N plus

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* One feddan = 1.038 acre.
** One maund = 82 lb.

60 lb P_2O_5 per acre, Pitic yielded 55 maunds per acre at Maraka.

In fertilizer trials on irrigated Mexican wheats at Lyallpur, West Pakistan*, Pitic-62 and Penjamo-62 yielded 54.62 and 51.26 maunds per acre respectively with 120 lb N application, while the controls yielded 50.84 and 48.74 maunds per acre, respectively. The following year, Penjamo-62 and Mexipak (red) yielded 54.03 and 59.98 maunds per acre respectively with 150 lb N application and the control plots yielded 47.64 and 52.18 maunds per acre, respectively. Porter _et al._ (1964) reported that 15 short-statured wheat selections grown under irrigation in Texas with 60 lb per acre of N before seeding and 45 lb in February, gave an average yield of 4040 lb per acre without lodging as compared to 3160 lb per acre for commercial varieties. Woodward (1966) found that early N application to hard red winter wheats increased yields of semi-dwarf varieties more than those of tall varieties and that yield increases were primarily due to production of more tillers.

Effects on Percentage Protein in Grain, Plant Height and Lodging

In two years experiments in southern Alberta, Russell _et al._ (1958) reported increase in protein content

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* Personal communication from Mr. Manzoor Ilahi Raja, Agricultural Chemist-I, Ayub Agricultural Research Institute, Lyallpur, West Pakistan.

at two of the three fields where N was applied. Eck et al. (1963) and Woodward (1966) also reported increase in protein from N application to wheat. Woodward (1966) further reported that N application increased plant height and lodging.

Effects on Leaf Composition

Reports on this aspect of wheat are limited. Seth et al. (1960) investigated the effect of stage of growth with four varieties and reported that no differences were found in total N content of vegetative parts of high and low protein wheats prior to heading. After heading, there was a general tendency for the high protein varieties to have a lower protein content in vegetative parts than the low protein varieties. Greenwood (1966) grew wheat plants in nutrient solution with different levels of N and showed that total N and free ninhydrin N in the youngest fully expanded leaf increased with increasing concentration of N in nutrient solution. Symptoms of N deficiency occurred on all plants which had a concentration of total N of less than 3.9 percent at 3 weeks or of 2.6 percent at 5 weeks after emergence. The total N concentration of youngest fully developed leaf was reported to be about 1.6 percent at 100 percent N stress and 7 percent for absence of stress at an average age of 4 weeks. It was further stated that at a nitrogen stress of 100 percent there remains a pool of about 600 ppm free ninhydrin N existing in the youngest fully expanded leaf of Gabo wheat, even though growth in terms of dry matter would be prevented by N deficiency. Symptoms of N deficiency appeared in plants with a concentration of 1400 and 800 ppm ninhydrin N in the leaf at 3 and 5 weeks, respectively. A value of 3000 ppm may be taken as indicating the absence of nitrogen stress at 4 weeks. Boatwright and Haas (1961) showed that the concentration of total N in wheat leaves was maximum at early stage and declined with advancing plant growth. Application of 45 lb N as ammonium nitrate per acre increased N, but decreased P content of leaves especially at early stages. Combined N-P application generally decreased N content of leaves, but increased P content. Nitrogen concentration of leaves due to N application was somewhat higher during most of the growing period.

Effects of P Application

Significant yield increase of spring wheat was reported by Olsen and Gardner (1949) from the application of 40 lb P_2O_5 per acre as superphosphate to a fine sandy loam calcareous soil. From two years experiments on three areas of southern Alberta, Russell et al. (1958) reported that wheat yield was increased in two areas in 1955 and in one area in 1956 by applications of 10-40 lb P_2O_5 per acre along with N. The application of P significantly reduced the protein increasing effect of N in one area in one year, but had no consistent effect in the other experiments. Hamdi _et al_. (1962) reported that on a calcareous loam soil (pH 8.5) there was no significant yield response to the application of 16 kg P_2O_5 per feddan as superphosphate. After seven-year trials, Eck _et al_. (1963) reported yield response to P applications in five seasons only. Grain protein was decreased. Aziz and Bajwa (1965) reported high yields of short-statured Mexican wheats with combined application of N and P under irrigation in West Pakistan. In fertilizer trials on irrigated Mexican wheats at Lyallpur, West Pakistan*, the yield of Pitic-62 and Penjamo-62 increased from 52.52 and 50.83 maunds per acre with 60 lb N application, to 61.67 and 53.78 maunds per acre respectively when 60 lb N was applied in combination with 60 lb P per acre. In another season, the yield of Penjamo-62 and Mexipak (red) increased from 47.93 and 58.00 maunds with 225 lb N application to 53.03 and 65.37 maunds per acre respectively when 150 lb P per acre was also added. However, Woodward (1966) found no significant increase in yield, height, lodging or percent protein of grain from P application to semi-dwarf and tall wheats. Lipsett (1964)

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* Personal communication from Mr. Manzoor Ilahi Raja, Agricultural Chemist-I, Ayub Agricultural Research Institute, Lyallpur, West Pakistan.

observed that in high yielding varieties of wheat, higher yields were not associated with a higher P uptake and their relatively lower P content was associated with success in selection for dry matter yield where the uptake of the nutrient was limited. Regarding leaf composition Magnitski (1961) stated that the application of superphosphate sharply increased P content of wheat leaves and advancing maturity decreased it. Boatwright and Haas (1961) showed that combined application of 45 lb N as ammonium nitrate and 43 lb P as superphosphate per acre, generally decreased N content of leaves but increased P content when compared to the application of N alone. The concentration of P in leaves was maximum at early stage of plant growth and the effect of fertilizer was prominent at early stage only. The application of fertilizer had very little effect on P concentration of all vegetative plant parts as a whole.

Effects of S Application

Reviewing the S requirements of crops Beaton (1966, pp 267) stated that even though cereals are regarded as having low S requirements, some experiments have shown response to direct applications of S. In some studies showing no direct response to S, there was a strong N-S interaction and it appeared that S needs depended upon the levels of other nutrients such as P, K, and particularly, N. Wheat yielding 40 bushels per acre per year absorbed

9-12 lb S per acre per year (Beaton 1966, pp 275). Work of Jordan and Baker (1959) showed that the application of S-material improved the yield of wheat as much as 30 percent.

From the foregoing review it can be concluded that N application generally increased grain yield, plant height, lodging, total N of leaf, and protein content of grain of wheat. Application of P or S increased yields in some areas. P application had little effect on protein percentage of wheat grain. Reports on leaf composition are limited.

III. MATERIALS AND METHODS

A field experiment was carried out in 1966-67 to study the effect of N, P, and S on yield and protein content of wheat grain. The effect on leaf composition with respect to soluble nitrate-N, phosphate-P, sulfate-S, and total N,P, and S was also studied. In this experiment six semi-dwarf wheats were grown under irrigation at the Agricultural Research and Education Center (AREC) in the Beqa'a plain of Lebanon.

Experimental Design

A central composite, rotatable, factorial design as described by Cochran and Cox (1957, pp 350) was used for each of the six varieties. This design allows the study of response due to three variables (five levels each) and their interactions with a total of 15 treatment combinations. One of these treatments is replicated six times in order to make possible the determination of experimental error. The levels of N, P, and S used in this experiment were varied according to a logarithmic scale (to the base 2) and were coded (Table 1) as -1.68, -1, 0, +1, and +1.68, as required by the design. The statistical computations were done by IBM 1620 computer.

Table 1. Levels of applied N, P, and S.

Levels (log_2 scale)	Coded levels	N, P, and S kg/ha
1	-1.68	46.5
2	-1.00	75.0
3	0	150.0
4	+1.00	300.0
5	+1.68	478.0

The varieties of semi-dwarf wheat used were:

1. Jaral-66.
2. Pitic-62.
3. Penjamo-62.
4. TZPP-An 64 (not yet established as a variety).
5. Sonora-64.
6. Rogue-66.

Field Procedures

The experiment was established on a calcareous soil in the Beqa'a plain of Lebanon. The land had been in a non-irrigated fallow-vetch-wheat-barley rotation and had been under wheat the previous year. The field was plowed after the removal of the previous wheat crop and subtilled twice before planting the experiment.

Field layout of the experiment was in six parallel strips, with each randomly allocated to one variety. Each strip was divided into 21 plots, each 3.5 x 3 m, to which the 15 fertilizer treatments were randomly allocated. Treatment combinations applied to each plot, as required by the statistical design, along with an additional one, without fertilizer (not part of the experimental design) have been shown in Table 2.

Fertilizer Application

The sources of N, P, and S were ammonium nitrate, concentrated superphosphate, and calcium sulfate respectively. The total required quantities of the three fertilizers were applied before planting by use of a small, hand-driven fertilizer spreader, which was previously calibrated for the delivery of the three fertilizers.

Planting

Thirteen rows of each variety were planted on November 14, 1967. Planting was done by calibrated Planet Jr. drill with its setting at 25 which gave an average seed-rate of 67.5 kg per hectare. Row to row distance was 20 cm and the depth of planting was 5 cm.

Irrigation

Sprinkler irrigations were given to assist germination and seedling emergence. During winter, rains provided enough moisture for the crop. After the cessation of winter rains, the plot boundaries were ridged to make basins. The first irrigation by gated pipe was given on March 9, 1968, followed by weekly irrigations. At each

Table 2. Treatment combinations of N, P, and S, applied for irrigated wheat.

Treatment	Variables, coded levels		
	N	P	S
1	-1	-1	-1
2	+1	-1	-1
3	-1	+1	-1
4	+1	+1	-1
5	-1	-1	+1
6	+1	-1	+1
7	-1	+1	+1
8	+1	+1	+1
9	+1.68	0	0
10	-1.68	0	0
11	0	+1.68	0
12	0	-1.68	0
13	0	0	+1.68
14	0	0	-1.68
15	0	0	0
16	0	0	0
17	0	0	0
18	0	0	0
19	0	0	0
20	0	0	0
21	No fertilizer (not part of the experimental design).		

irrigation the plots were flooded to about 5 cm depth and kept ponded for about one hour. The last irrigation was given on June 19 except that variety Pitic was still green and was given an extra irrigation on June 26.

Weeding and Leaf Sampling

The crop was hand-weeded twice during the growing season. Leaf samples consisting of 50 leaf blades each were taken at five dates (Table 3). An attempt was made to select fully developed, recently matured leaves, but this was difficult during the earliest growth stage.

Table 3. Leaf sampling dates and treatments sampled.

Sampling No.	Date	Growth stage	Treatments sampled
1	March 2, 1967	Tillering	All
2	April 6, 1967	Jointing	9-15 only
3	April 27, 1967	Boot	All
4	May 18, 1967	Heading	9-15 only
5	June 4, 1967	Dough	All

Measurements of Plant Height

After the plants had ceased growing in height, three plants per plot were measured on June 15 and the average heights were reported.

Harvesting and Threshing

As the varieties matured, the middle 1.5 m length of the five middle rows from each plot was harvested, giving a harvested area of 1.5 m^2 per plot. Jaral, Penjamo, TZPP, and Sonora were harvested on June 26, Rogue on June 29, and Pitic on July 3. The harvested material, with its heads tied in cloth or paper bags, was hung to allow it to dry in the sun until July 13. Threshing was done by electrically operated thresher and the grain obtained was brought to the laboratory for moisture and crude protein determinations.

Laboratory Procedure

The grain from each plot was weighed and its moisture content was determined by model EH Universal Moisture Tester. The grain yield was corrected to and reported at 14 percent moisture. The leaf samples as brought from the field were oven-dried at 70°C. The dried leaves were ground to pass a 40-mesh sieve and stored for chemical analysis.

Analytical Methods

Crude protein of grain was determined on duplicate 2 gm samples by the Kjeldahl method as described by Horwitz (1965, pp 328).

Nitrate-N was determined by the method described by Johnson and Ulrich (1959, pp 45).

Phosphate-P soluble in 2 percent acetic acid was determined by the method of Johnson and Ulrich (1959, pp 49-52).

Sulfate-S soluble in 2 percent acetic acid was determined turbidimetrically according to the method of Jackson (1962, pp 265-266).

For total P and total S, one gram samples were digested by wet oxidation with nitric acid and perchloric acid according to the method reported by Johnson and Ulrich (1959, pp 32-33). Subsequently P and S were determined as reported for 2 percent acetic acid extract.

Total N of leaves was determined by the Kjeldahl method as described by Horwitz (1965, pp 16).

IV. RESULTS AND DISCUSSION

A field experiment was conducted on a calcareous clay soil at AREC in the Beqa'a plain of Lebanon to study the effect of applied N, P, and S on plant height, grain yield, protein content of grain, and leaf composition of six semi-dwarf wheats grown under irrigation.

The predicted values were calculated from a regression equation (Cochran and Cox, 1957, pp 350) which was modified as follows to include the three-way interaction:

$$Y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_{11}x_1^2 + b_{22}x_2^2 + b_{33}x_3^2 + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{23}x_2x_3 + b_{123}x_1x_2x_3$$

Where Y = predicted values

b_0= mean with all variables applied at coded "0" levels

b_1, b_2, etc = regression coefficients

x_1, x_2, x_3 = coded levels of N, P, and S, respectively.

A positive first order regression coefficient indicated that the slope of the response curve was upwards at the "0" coded levels of all variables. As the level increased there was a corresponding increase in the property measured. A negative first order coefficient indicated the reverse. A positive squared effect indicated a positive or less negative change of the slope of the response curve in the direction of increasing application rate of the element concerned, while a negative squared sign indicated the reverse. A positive two-way interaction indicated that at a high level of one variable, as compared to a low level, the response to the other variable was more positive or less negative. The three-way interaction effect depended on the combination of levels of all variables. The net effect of any one variable depended on the combination of levels for all variables and the magnitude of the various regression coefficients involved.

Effects of N, P, and S on Grain Yield

Increasing the yields of grains is a major factor in increasing food production. In persuance of this objective, the effects of N, P, and S application at five levels each, on the grain yield of six irrigated semi-dwarf wheats was studied. The first order regression coefficients for the effect of application of N were significantly positive for all varieties of wheat studied (Table 4, Figure 1). The effects of P, S, and the interactions were small in general indicating little effect on grain yield. The effect of P was significant on Sonora variety only and was negative. The N-P interaction was significantly positive for the Sonora and negative for TZPP, but was not very important for the other varieties. The N-S interaction was significantly negative for the

Table 4. Regression coefficients for grain yield (14% of moisture) of six varieties of wheat as affected by N, P, and S treatments.

Terms	Jaral	Pitic	Penjamo	TZPP	Sonora	Rogue	Average
				Metric tons/ha			
b_0	2.1725	4.3397	2.9986	1.9596	2.3536	2.3093	2.6884
N	+0.2773**	+0.6346*	+0.5614**	+0.4492**	+0.3466**	+0.3546**	+0.4375**
P	+0.1043[e]	-0.0133	-0.0138	-0.0518[e]	-0.1066*	-0.1388[e]	-0.0353
S	-0.0409	+0.0411	+0.0437	+0.0519[e]	+0.0301	+0.0646	+0.0327
s_b	±0.0653	±0.1904	±0.0759	±0.0296	±0.0432	±0.0872	±0.0413
N^2	-0.1107[e]	+0.2321[e]	+0.1045[e]	+0.1814**	+0.0536[e]	-0.0396	+0.0711[e]
P^2	-0.1655*	-0.2787[e]	+0.0055	+0.0541[e]	+0.0324	+0.0064	-0.0579[e]
S^2	+0.0272	-0.3618[e]	-0.0775[e]	+0.0806*	+0.0059	-0.1050[e]	-0.0703[e]
s_b	±0.0633	±0.1848	±0.0736	±0.0287	±0.0420	±0.0847	±0.0400
NP	+0.0100	-0.1550	+0.0988	-0.1125*	+0.2750**	+0.1812[e]	+0.0488
NS	-0.0100	-0.0125	+0.0262	-0.0625[e]	-0.0050	-0.3188*	-0.0638[e]
PS	+0.0625	+0.0175	+0.0512	+0.2300**	-0.1175[e]	-0.1088	+0.0212
NPS	+0.0325	-0.1225	-0.3012*	+0.0925[e]	-0.0775	-0.1112	-0.0812[e]
s_b	±0.0852	±0.2487	±0.0991	±0.0386	±0.0565	±0.1140	±0.0539
R[1]	0.827	0.822	0.879	0.980	0.960	0.875	0.958

e Probably real because greater than standard error (s_b).
* Significant at 5% level.
** Significant at 1% level.
1 Multiple correlation coefficient.

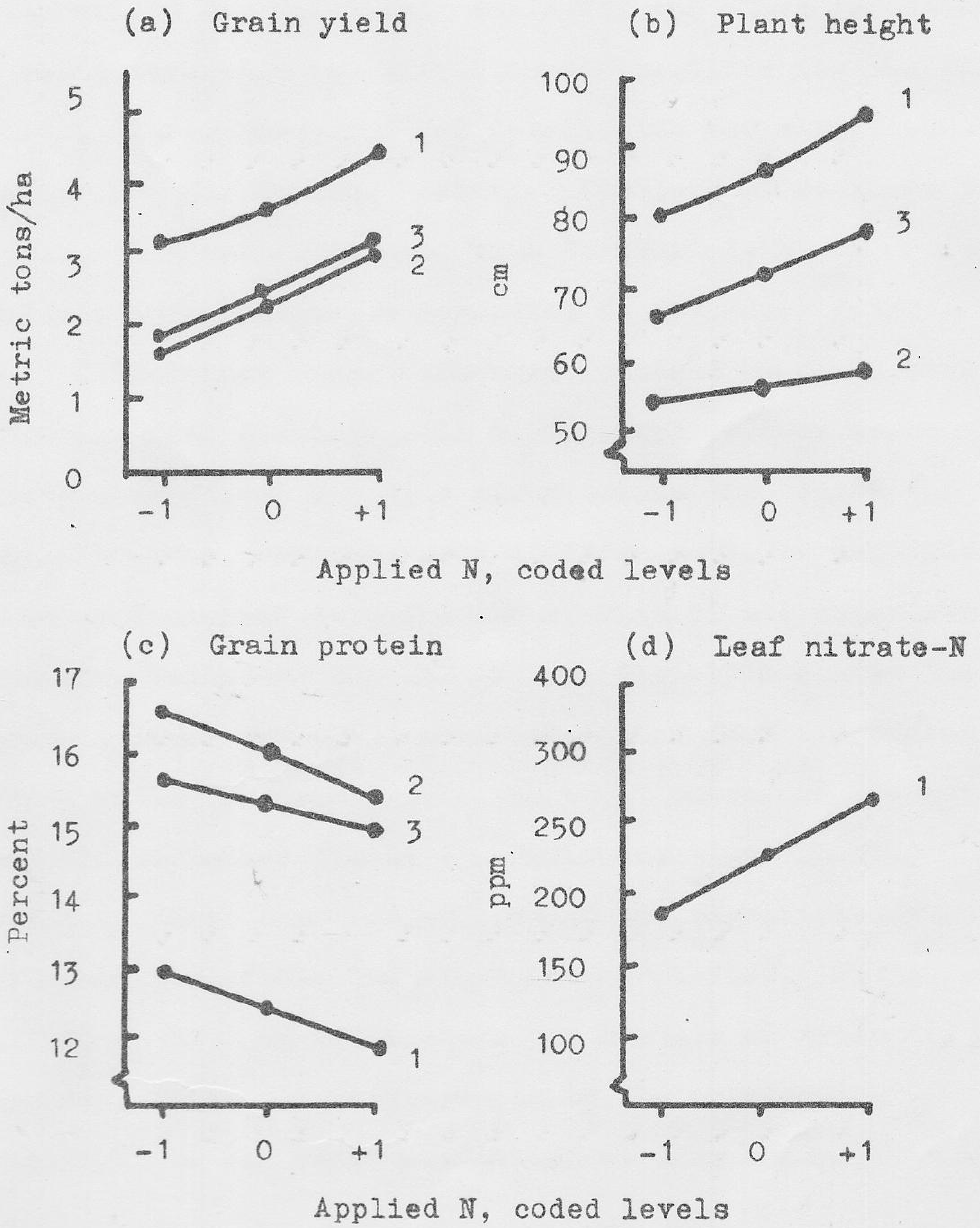

Figure 1. Predicted grain yields, plant heights, grain protein contents, and leaf nitrate-N contents for Pitic (1), Sonora (2), and the average for 6 varieties (3) at tillering stage, as affected by increasing N application with P and S held constant at +1 and -1 coded levels, respectively.

Rogue variety but relatively small for the other varieties. The P-S interaction was significantly positive for the TZPP variety. The three-way N-P-S interaction was significantly negative for the Penjamo variety. The lack of response to P application was attributed to a "medium" level of available soil phosphorus according to the Olsen method.

Differences among varieties in yield of grain were confounded with possible soil differences because each variety constituted a single strip across the slight slope. However, assuming soil differences to be negligible, and using the error term for the average of all experiments (Appendix, Table 18) the LSD between variety means at the 5 percent level was 0.613 when calculated from the probable range/s ratio (Snedecor, 1946, pp 98). Comparing the b_0 terms for varieties (Table 4), Pitic was significantly greater in yield than Penjamo, which was significantly greater in yield than the other four varieties. Pitic, yielding up to 6.89 metric tons per hectare of grain (Appendix, Table 11), appeared to be the outstanding variety of the six under conditions of this study.

Effects of N, P, and S on Plant Height

The yield of wheat grain is limited if excessive plant height induces lodging. In an effort to increase grain yield by the application of fertilizers, especially nitrogenous ones, the effects on plant height must be considered. The regression coefficients (Table 5) for all the six varieties indicate that N application increased plant height highly significantly (Figure 1b). Similar results were reported by Woodward (1966) on semi-dwarf wheats. The N-P interaction tended to be negative for the three tallest varieties, Pitic, Penjamo, and TZPP, and positive for the three shorter varieties. This indicates a possible role of P application in keeping the varieties reasonably short in the face of the need for high levels of applied N to increase the yield. The P-S interaction tended to be positive for the four tallest varieties and negative for the shortest varieties indicating that a low level of S would enhance the shortening effect of applied P. Thus, a combination of high levels of applied N and P combined with a low level of applied S would result in a high yield and still keep the plants reasonably short. Pitic, the tallest variety, reached a height of 109 cm at the highest level of applied N (Appendix, Table 12) and was on the verge of lodging at the time of harvest. Thus, further efforts to increase grain yield of this variety must be with a view of avoiding any further increase in height.

Table 5. Regression coefficients for plant heights of six varieties of wheat as affected by N, P, and S treatments.

Terms	Jaral	Pitic	Penjamo	TZPP	Sonora	Rogue	Average
				cm			
b_0	70.68	89.01	83.134	83.10	60.24	60.38	74.443
N	+5.17**	+7.62**	+8.864**	+9.42**	+4.85**	+4.53**	+6.758**
P	$+1.05^e$	+1.03	-0.326	-0.76	-1.95^e	$+1.47^e$	+0.084
S	-2.10^e	$+1.15^e$	+0.473	$+1.92^e$	+1.28	-0.07	$+0.443^e$
s_b	±1.02	±1.05	±0.514	±1.08	±1.36	±1.21	±0.208
N^2	+0.47	$+2.16^e$	+0.436	+0.08	-0.88	-1.46^e	+0.131
P^2	-0.23	-0.14	-0.801^e	+0.61	-0.88	+0.83	-0.116
S^2	+0.30	-1.38^e	-1.154^e	$+1.50^e$	+0.89	-1.11	-0.169
s_b	±0.99	±1.02	±0.499	±1.04	±1.32	±1.17	±0.201
NP	$+1.88^e$	-1.62^e	-1.625^e	-0.75	+0.25	+0.38	-0.238
NS	-3.88*	-1.62^e	$+1.875^e$	-1.25	$+3.00^e$	+0.12	-0.262
PS	$+1.38^e$	+1.12	+2.125*	+1.25	-0.25	-1.62^e	$+0.662^e$
NPS	$+1.88^e$	-0.12	-1.625^e	$+2.75^e$	+0.25	+0.12	$+0.538^e$
s_b	±1.34	±1.37	±0.672	±1.41	±1.77	±1.57	±0.271
R^1	0.87	0.92	0.94	0.93	0.83	0.83	0.97

e Probably real because greater than standard error (s_b).
* Significant at 5% level.
** Significant at 1% level.
1 Multiple correlation coefficient.

Effects of N, P, and S on Crude Protein Content of Wheat Grain

The proteins in food grains are desirable from the point of view of human and animal nutrition. Nitrogen is an essential constituent of all, and P and S of some, proteins. The application of N, P, and S may have an effect on the crude protein content of grains. The varieties Pitic and Penjamo, which had the greatest yield, were least in the level of protein (b_0 values, Table 6). Application of N resulted in considerable decrease in percent protein in all varieties except Jaral (first order regression coefficients, Table 6, Figure 1c). The decrease in protein content parallelled the increase in yield from N application (Table 4) with Jaral having the least yield response to N. As N is a major constituent of protein, deficiency of N would be expected to decrease the concentration of N in the grain. In this case, where all the N was applied before planting, the effect was to greatly increase the total yield of grain resulting in dilution of the protein. Therefore, attempts to increase protein percentage by application of N would probably involve ensuring an adequate supply of soil N at the time of grain formation by applying additional N at or just prior to that stage. However, with the taller varieties, excessive height due to high N application might be a problem.

Table 6. Regression coefficients for crude protein in wheat grain of six varieties as affected by N, P, and S treatments.

Terms	Jaral	Pitic	Penjamo	TZPP	Sonora	Rogue	Average
			Percent, dry basis				
b_0	17.213	12.718	12.885	16.8336	16.257	15.7211	15.2677
N	+0.046	-0.803**	-0.608**	-0.7186**	-0.140^e	-0.1548^e	-0.3821*
P	+0.059	-0.047	-0.041	+0.4317**	-0.005	+0.2749*	+0.1155^e
S	-0.099	+0.259^e	-0.302^e	-0.0842^e	+0.039	+0.4770**	+0.0532
s_b	±0.130	±0.230	±0.183	±0.0533	±0.134	±0.0881	±0.0980
N^2	-0.025	+0.011	+0.469*	-0.2290**	-0.174^e	-0.1454^e	-0.0173
P^2	+0.064	-0.219	+0.168	-0.1583*	+0.198^e	-0.0216	+0.0004
S^2	-0.148^e	-0.025	+0.204^e	-0.0876^e	-0.050	-0.0040	-0.0173
s_b	±0.126	±0.223	±0.178	±0.0517	±0.131	±0.0855	±0.0951
NP	+0.125	+0.262	+0.112	+0.0625	-0.375^e	-0.1750^e	0.0000
NS	+0.175^e	-0.038	+0.238	-0.0375	+0.050	+0.0250	+0.0750
PS	-0.075	-0.162	-0.162	-0.1125^e	+0.250^e	+0.1250^e	-0.0250
NPS	+0.050	+0.012	-0.088	-0.4875**	+0.075	-0.3250*	-0.1250
s_b	±0.170	±0.301	±0.239	±0.0696	±0.176	±0.1151	±0.1280
R[1]	0.557	0.799	0.857	0.902	0.781	0.908	0.836

e Probably real because greater than standard error (s_b).
* Significant at 5% level.
** Significant at 1% level.
1 Multiple correlation coefficient.

Woodward (1966) found that the protein percentage of semi-dwarf wheats was increased by N and not by P application. In the present experiment on the other hand, the crude protein percentage of three of the six varieties was significantly decreased by N application, while that of two was significantly increased by P application. The explanation for the decrease in protein content may be found in the observations of Wood and Fox (1965). It was reported that total protein seemed to be a function of total grain yield rather than of percent protein. With no application of N, application of water increased protein percentage in grain, but where N was applied at sowing time (as was the case in the present experiment), water application lowered percent protein. The nitrogen-water interaction was therefore, very important in this respect. Sosulski et al. (1963) have also reported that the protein content of wheat grain, grown with 40-200 lb N per acre under different moisture stresses, varied between 10.2 and 23.0 percent and that moisture regime was the chief controlling factor. Under high moisture regime applying 200 lb N per acre did not raise the protein level above 12.7 percent. It appears, therefore, that future work in maximizing grain and protein yields of irrigated wheat should involve the effects of moisture stress and irrigation frequency.

The application of P resulted in a positive effect on the Rogue and TZPP varieties both of which have relatively high protein levels (Table 6). The application of S had variable effects resulting in a positive first order effect, which was significant for Rogue and probably real for Pitic. There was a probably real negative first order effect for the Penjamo and TZPP varieties. The N-P interaction effect on protein content of grain was negative and probably real for the two shortest varieties, Sonora and Rogue. The P-S interaction was probably real and positive for Sonora and Rogue and negative for TZPP.

The results of this study indicate a considerable decrease in percent protein of grain from application of N at the same time that grain yield is substantially increased. Future work should emphasize application of N such that yield and protein content of grain are both maximized.

Effect of N, P, and S Application on Leaf Composition

The plant food nutrients absorbed by the plant from the soil are metabolised in the leaves. The nutrient contents of the leaves at a particular stage of development of the plant may indicate the nutritional status of the plant and the need for fertilizer application. Pitic being the most promising variety, work on leaf composition was concentrated mainly on this variety.

Effect on Nitrate-N

The nitrate-N concentration of leaves was found to be less than 800 ppm (b_0, Table 7; Table 14) at all stages of plant growth. The application of N resulted in a probably real increase in nitrate-N at an early stage of development of the plant (March 2, Table 7; Figure 1d). The effect of N application on the leaf nitrate-N of the Pitic variety at later stages was negative. The reason was probably related to the considerable grain yield response to N, which resulted in N being translocated to the heads rather than to the leaves. The June 4 sampling of Penjamo (Table 7), the second high yielding variety, indicated the same trend. However, the June 4 sampling of Sonora (Table 7), which was a low yielding variety, indicated a positive effect of N on nitrate-N of leaves. This indicates that the content of nitrate-N in leaves at the time of grain formation depends on the amount that is moving to the grain and being utilized. Varieties with a large yield potential have most of the available N moving past the leaves, while a smaller grain yield results in more leaf accumulation. It would appear that nitrate-N content of leaves would be an indication of N nutrition status only before heads start to form. Moreover, the early indication would be important in that additional N could still be applied. Since the yield of grain was still increasing at the highest level of N application, a definite

Table 7. Regression coefficients for water soluble nitrate-N of Pitic, Penjamo, and Sonora leaves at different stages of plant growth.

Terms	Pitic March 2	Pitic April 27	Pitic June 4	Pitic Average	Penjamo June 4	Sonora June 4
	ppm, dry basis					
b_0	318.7	406.2	519.7	416.8	630.8	391.4
N	+69.8[e]	+11.4	−21.5[e]	+13.0	−15.9	+36.5[e]
P	−40.3[e]	+4.7	+9.1	−9.0	−18.9	+11.1
S	+1.6	−9.1	−10.5	−6.6	+46.3[e]	+2.8
s_b	±33.9	±15.2	±19.8	±13.3	±29.9	±14.6
N^2	+1.5	−1.0	−49.2*	−8.9	−6.4	+54.4*
P^2	−40.9[e]	−20.4[e]	−50.9*	−40.7*	−41.7[e]	+6.7
S^2	+42.1[e]	−13.3	−47.4*	−8.9	+9.5	+4.9
s_b	±32.9	±14.7	±19.2	±12.9	±29.0	±14.2
NP	−8.8	−23.8[e]	−3.8	−12.5	+15.0	+31.2[e]
NS	−8.8	−8.8	+26.3[e]	+2.5	+25.0	−3.8
PS	+48.8[e]	+48.8[e]	+56.3[e]	+52.5*	−17.5	+1.2
NPS	+28.8	+16.3	−23.8	+7.5	+20.0	−6.2
s_b	±44.3	±19.8	±25.9	±17.4	±39.0	±19.1
R[1]	0.740	0.718	0.856	0.830	0.639	0.827

e Probably real because greater than standard error (s_b).
* Significant at 5% level.
1 Multiple correlation coefficient.

critical level could not be determined. However, a probable critical level of greater than 500 ppm at the early stage is indicated although further data is needed. Phosphorus application resulted in a probably real decrease in nitrate-N of Pitic leaves at the early stage (Table 7). Application of S had little effect on nitrate-N concentration of leaves.

Murphy and Smith (1967) reported that wheat plants accumulated little nitrate-N and that N and P application had little effect on nitrate-N content of wheat plant. The results of the present experiment indicate some effect of N application on nitrate-N concentration of wheat leaf, and it brings to the forefront the need to search for a tissue of wheat plant that is more sensitive to concentration of nitrate-N. It was found from some later work that the leaf sheaths and the stem-base of wheat plants had high concentration of nitrate-N, which was sensitive to fertilizer application.

Effect on Soluble Phosphate-P

The soluble phosphate-P of Pitic leaves tended to decline with advancing plant growth (b_0, Table 8). The effect of application of N was insignificant at the initial stage, but at the later stages (April 27 and June 4, Table 8) it decreased the soluble phosphate-P of leaf significantly, probably because of the large positive N effect on grain yield and more of the P moving from soil to the grain rather

Table 8. Regression coefficients for soluble P in Pitic leaves at different stages of plant growth.

Terms	March 2	April 27	June 4	Average
		ppm, dry basis		
b_0	2398.3	2304.6	1634.6	2112.9
N	+76.8	-222.4*	-178.4*	-107.0[e]
P	+47.9	-71.6	-39.1	-20.0
S	+71.5	+53.7	+25.8	+50.2
s_b	±90.1	±96.9	±63.9	±67.1
N^2	-60.4	-15.6	+39.6	-11.7
P^2	+45.7	-42.2	-18.7	-6.4
S^2	+45.7	+48.0	+69.7[e]	+55.4
s_b	±87.5	±94.0	±62.0	±65.2
NP	-91.3	-22.5	+51.3	-20.0
NS	-133.7[e]	+35.0	+1.3	-30.0
PS	-31.3	-110.0	-31.3	-57.5
NPS	+38.8	+297.5*	+46.3	+127.5[e]
s_b	±117.7	±126.5	±83.4	±87.7
R[1]	0.592	0.770	0.742	0.656

[e] Probably real because greater than standard error (s_b)
* Significant at 5% level.
** Significant at 1% level.
[1] Multiple correlation coefficient.

than leaves. The effect of P and S application was non-significant but indicated a decreasing trend with advancing plant development. The small effect of P application on the P concentration of leaves indicated that P in soil was probably not very deficient. The Olsen test for available P in the soil was "medium" and a further indication of probable P sufficiency. A soluble concentration of 2500 ppm at early stage appeared to be adequate for high grain yield but no definite critical level could be determined due to lack of yield response from P application.

Effect on Soluble Sulfate-S

Pitic leaf accumulated high quantities of soluble sulfate-S especially at the dough stage (June 4, Table 9). Considering the average of three samplings (Table 9), N application significantly decreased soluble sulfate-S, while S application increased it significantly. Application of P resulted in little effect. The N-P-S interaction effect was positive and significant. The P-S interaction was also positive and probably real. Considering soluble sulfate-S in leaves at the three sampling dates individually, the depressing effect of N became more significant with successive samplings. This effect of N can be attributed to increased grain yield taking more of S to heads than to the leaves. Application of S increased soluble sulfate-S concentration of leaves. A relatively high concentration in

Table 9. Regression coefficients for soluble sulfate-S in Pitic leaves at different stages of plant growth.

Terms	March 2	April 27	June 4	Average of 3 complete samplings
		ppm, dry basis		
b_0	1589.7	1037.3	4617.5	2415.4
N	-122.9^e	-183.1**	-1429.6**	-577.2**
P	$+64.8^e$	+12.4	+45.2	+40.8
S	$+121.7^e$	+218.1**	$+251.8^e$	+196.3*
s_b	±50.0	±33.7	±202.8	±54.2
N^2	-102.6^e	+98.1*	+5.3	-0.1
P^2	-35.4	+119.3*	-53.0	+10.5
S^2	+166.1*	+283.6**	$+293.4^e$	+247.4**
s_b	±48.5	±32.7	±196.8	±52.6
NP	-48.8	$+46.2^e$	-198.8	-66.2
NS	+43.8	$+46.2^e$	-131.2	-13.7
PS	+51.2	$+46.2^e$	$+283.8^e$	$+128.8^e$
NPS	+43.8	$+71.2^e$	$+566.2^e$	+226.2*
s_b	±65.3	±44.0	±264.8	±70.9
R^1	0.763	0.845	0.933	0.917

e Probably real because greater than standard error (s_b)
* Significant at 5% level.
** Significant at 1% level.
1 Multiple correlation coefficient.

the June 4 sampling was possibly due to continued build up of S from irrigation water. A soluble sulfate-S concentration of 1300 ppm of leaf at early stage appears to be sufficient for a high grain yield.

Effect on Total N, P, and S Concentration

The results for total N, P, and S concentration were available for only the middle sampling of Pitic leaf. At this stage the effect of N application on total N concentration was relatively small (Table 10) except at the highest rate of N application (treatment 9, Appendix Table 17). At this stage, protein of the leaves had started to be translocated to the heads and total N of the leaves was generally not directly related to the supply in the soil. Since much of the total P and S was in soluble form at this stage, the large negative effect of N and slightly negative effect of P application on total P and S concentration (Table 10) can be attributed to their movement to the heads for protein formation. The application of S resulted in a slight increase of total P and a highly significant increase of total S concentration of leaves. The various interactions were similar for both total P and total S concentration. The N-P and P-S interactions were negative while N-S and N-P-S interactions were positive. The data on total N, P, and S concentration of leaf, at the boot stage only,are insufficient to be a base for

Table 10. Regression coefficients for total N, P, and S, in Pitic leaves on April 27, 1967.

Terms	Total N %	Total P ppm	Total S ppm
b_0	2.0469	3079.3	2737.3
N	+0.0254[e]	-317.1**	-375.2**
P	-0.0049	-78.9[e]	-37.5
S	+0.0099	+77.1[e]	+174.6**
s_b	±0.0180	±44.2	±40.7
N^2	+0.1568**	+175.6**	+223.4**
P^2	+0.0613*	-69.0[e]	+66.1[e]
S^2	-0.0094	+58.2[e]	+89.1[e]
s_b	±0.0175	±42.9	±39.5
NP	-0.0350[e]	-68.8[e]	-103.8[e]
NS	-0.0225	+93.8[e]	+56.2[e]
PS	-0.0100	-203.8*	-183.8*
NPS	+0.0175	+158.8*	+111.2[e]
s_b	±0.0235	±57.7	±53.1
R[1]	0.875	0.926	0.848

[e] Probably real because greater than standard error (s_b)
* Significant at 5% level.
** Significant at 1% level.
[1] Multiple correlation coefficient.

critical levels of these nutrients because their translocation from leaves to the heads for grain formation had already set in. However, these results lend support to the data on soluble nutrient concentration of Pitic leaf.

V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A field experiment on the effects of N, P, and S application on yield and composition of six irrigated semi-dwarf wheats was conducted in 1966-67 on a calcareous clay soil at AREC in the Beqa'a plain of Lebanon. From 46.5 to 478 kg per hectare each of N, P, and S were applied in a central composite, rotatable, factorial design before planting Jaral, Pitic, Penjamo, TZPP, Sonora, and Rogue varieties on November 14, 1966. The application of N significantly increased plant height and grain yield, and decreased crude protein percent of grain. The effects of P, S, and the interactions were generally small. Application of P tended to decrease plant height and increased protein percentage of some varieties. Pitic, yielding up to 6.89 metric tons of grain per hectare, appeared to be the outstanding variety among those tested, followed by Penjamo.

Leaf composition of Pitic at tillering, boot, and dough stages indicated that N application increased nitrate-N at the initial stage and decreased it at the later stages due to translocation to the heads. The application of P resulted in some decrease of nitrate-N and increase of soluble S at the initial stage. The application of N significantly reduced soluble P and S at the later stages. A probable critical level of about 500 ppm nitrate-N is indicated at the early stage but the need for further work with more sensitive tissue is implied.

The application of S increased soluble S concentration of leaves at all stages. The P-S and N-P-S interactions were positive and probably real at later stages. At the boot stage, applied N only slightly increased the total N and greatly reduced the total P and S concentration of Pitic leaves. Total P concentration was somewhat decreased by P application, and slightly increased by S application. Application of S significantly increased the S concentration. The decreasing effects of applied nutrients, especially N, on soluble nutrients of leaves at boot and dough stages, were attributed to their translocation from leaves to heads during grain formation. It was not possible in this experiment to establish general critical levels for N, P, and S in the leaves because of lack of yield response to P and S and because the maximum response to N was not attained. It appeared that 2500 ppm of soluble P and 1300 ppm of soluble S were adequate under the conditions of this experiment.

It was concluded that the exploratory experiment conducted established the possibility of obtaining sufficiently high levels of grain yields to make irrigated wheat an economically competitive crop.

It is recommended that further study be done on the rate and time of application of N. This is important from the standpoint of maximizing grain yield and minimizing the salt effect at the time of germination. Split application of N may result in maximum yield levels without drastically reducing the protein content of the grain as found in this study. It is further recommended that additional work be done on correlating the nitrate-N level of specific plant tissues at various stages of growth with the time and amount of additional N application.

A SELECTED BIBLIOGRAPHY

Aziz, M.A., and M.A. Bajwa. 1965. Performance and future of Mexican wheat varieties in West Pakistan. West Pak. J. Agri. Res. Vol. 3, No. 2 & 3, pp 200-203.

Beaton, J.D. 1966. Sulfur requirements of cereals, tree fruits, vegetables, and other crops. Soil Sci. 101: 267-282.

Boatwright, G.O., and H.J. Haas. 1961. Development and composition of spring wheat as influenced by nitrogen and phosphorus fertilization. Agron. J. 53: 33-36.

Cochran, W.G., and G.M. Cox. 1957. Experimental Designs. John Wiley and Sons, Inc., New York, 2nd ed.

Eck, H.V., B.B. Tucker, and A.M. Schleuhuber. 1963. Influence of fertilizer treatments on yield, grain protein, and heading dates of five wheat varieties. Agron. J. 55: 556-558.

Greenwood, E.A.N. 1966. Nitrogen stress in wheat - its measurement and relation to leaf nitrogen. Plant and Soil. 24: 279-288.

Hamdi, H., A.H. El-Damaty, T.A. El-Baradi, et al. 1962. Yields of wheat and barley as influenced by fertilizer applications at Bahtim Experimental Station. J. Soil Sci. U.A.R. 2: 117-129. Abstracted in Soils and Fertilizers (3761). Vol. 27, No. 6, 1964.

Horwitz, W. (Editor). 1965. Official Methods of Analysis. Association of Official Agricultural Chemists, Incorporated, Washington, D.C., 10th ed.

Jackson, M.L. 1958. Soil Chemical Analysis. Prentice-Hall, Inc., Englewood Cliffs, N.J.

Johnson, M.C., and A. Ulrich. 1959. Analytical methods for use in plant analysis. Calif. Agri. Exp. Sta. Bul. 766.

Jordan, J.V., and G.O. Baker. 1959. Sulphur studies in North Idaho soils using radiosulphur. Soil Sci. 88: 1-6.

Lipsett, J. 1964. The phosphorus content and yield of grain of different wheat varieties in relation to phosphorus deficiency. Aust. J. Agri. Res. 15: 1-8.

Magnitski, K.P. 1961. The diagnosis of mineral nutrition of plants according to chemical composition of leaves. Plant Analysis and Fertilizer Problems. Reuther, W. (Editor). Publication No. 8. Amer. Inst. Biological Sciences, Washington 6, D.C.

Murphy, L.S., and G.E. Smith. 1967. Nitrate accumulations in forage crops. Agron. J. 59: 171-174.

Olsen, S.R., and R. Gardner. 1949. Utilization of phosphorus materials from various fertilizer materials. IV. Sugar beets, wheat and barley in Colorado. Soil Sci. 68: 163-169.

Porter, K.B., I.M. Atkins, E.C. Gilmore, K.A. Lahr, and Scottino Paschal. 1964. Evaluation of short stature winter wheat (Triticum aestivum L.) for production under Texas conditions. Agron. J. 56: 393-396.

Russell, G.C., A.D. Smith, and V.J. Pittman. 1958. The effect of nitrogen and phosphorus fertilizers on the yield and protein content of spring wheat grown on stubble fields in southern Alberta. Can. J. Plant Sci. 38: 139-144.

Seth, J., T.T. Hebert, and G.K. Middleton. 1960. Nitrogen utilization in high and low protein wheat varieties. Agron. J. 52: 207-209.

Snedecor, G.W. 1946. Statistical Methods. The Iowa State University Press, Ames, Iowa, U.S.A., 4th ed.

Sosulski, F.W., E.A. Paul, and W.L. Hutcheon. 1963. The influence of soil moisture, nitrogen fertilization, and temperature on quality and amino acid composition of Thatcher wheat. Can. J. Soil Sci. 43: 219-228.

Wood, H.L., and W.E. Fox. 1965. The interaction of nitrogen and water on yield, protein and mottling in wheat grown on black earth in Queensland. Exp. Agri. 1: 107-112. In: Bibliography on soil factors affecting wheat quality (1965-1954), No. 928. Commonwealth Bureau of Soils, Harpenden, England.

Woodward, R.W. 1966. Responses of some semi-dwarf spring wheats to nitrogen and phosphorus fertilizer. Agron. J. 58: 65-66.

A P P E N D I X

Table 11. Effect of N, P, and S on grain yield (14% moisture) of six varieties of wheat in 1966-67.

Treatment	Variety						Average
	Jaral	Pitic	Penjamo	TZPP	Sonora	Rogue	
			Metric tons/ha				
1	1.80	3.12	2.77	1.92	2.35	1.56	2.25
2	2.24	4.09	3.09	3.24	2.38	2.55	2.93
3	2.03	3.05	2.06	1.71	1.68	0.79	1.89
4	2.38	3.89	3.98	2.21	3.12	2.95	3.09
5	1.41	3.14	1.80	1.80	2.61	2.43	2.20
6	1.68	4.55	3.43	2.50	2.93	2.59	2.95
7	1.76	3.63	2.50	2.14	1.78	1.67	2.25
8	2.20	3.93	3.32	2.76	2.89	2.11	2.87
9	2.52	6.89	4.41	3.35	3.02	2.65	3.81
10	1.16	3.83	2.64	1.57	1.93	2.00	2.19
11	1.74	3.98	2.96	2.08	2.22	2.37	2.56
12	1.63	3.85	3.53	2.12	2.61	2.54	2.71
13	2.48	3.52	3.44	2.35	2.26	2.12	2.70
14	1.98	3.84	2.58	2.00	2.42	2.16	2.50
15	2.39	4.84	2.47	1.81	2.60	2.34	2.74
16	2.41	4.87	3.11	1.97	2.49	2.40	2.88
17	2.29	3.77	3.25	1.95	2.26	2.16	2.61
18	1.81	3.30	2.96	1.90	2.22	2.76	2.49
19	2.17	4.10	2.94	1.99	2.41	1.78	2.56
20	1.97	5.03	3.18	2.14	2.15	2.37	2.81
21	1.49	2.55	2.18	1.65	1.38	2.07	1.89

Table 12. Effect of N, P, and S on plant height of six varieties of wheat.

Treatment	Variety						Average
	Jaral	Pitic	Penjamo	TZPP	Sonora	Rogue	
			cm				
1	64	75	74	75	60	52	66.7
2	81	98	90	99	63	60	81.8
3	64	78	72	79	53	56	67.0
4	81	95	88	89	56	65	79.0
5	66	78	61	82	56	55	66.3
6	60	95	91	90	70	63	78.2
7	64	86	74	80	47	52	67.1
8	73	96	91	96	63	62	80.2
9	85	109	99	103	68	65	88.2
10	65	87	74	61	50	49	64.3
11	74	93	79	81	60	68	75.8
12	72	90	87	86	58	59	75.3
13	74	90	86	92	68	58	78.0
14	75	86	78	80	60	58	72.8
15	74	95	80	76	61	55	73.5
16	74	85	85	83	62	56	74.2
17	72	86	83	86	61	65	75.6
18	70	86	83	82	54	67	73.7
19	69	90	82	85	68	55	74.8
20	64	91	85	87	55	64	74.3
21	62	63	62	69	44	51	58.5

Table 13. Effect of N, P, and S on crude protein in grain of six varieties of wheat.

Treatment	Variety						Average
	Jaral	Pitic	Penjamo	TZPP	Sonora	Rogue	
	Percent, dry basis						
1	17.4	13.0	14.9	17.4	16.1	15.9	15.6
2	17.1	10.8	13.0	14.3	16.8	14.6	14.4
3	17.1	13.0	14.6	17.2	16.4	14.9	15.5
4	17.1	11.8	13.5	16.3	15.3	15.0	14.8
5	17.3	14.1	14.3	16.9	15.7	15.4	15.6
6	17.5	11.7	13.7	15.6	16.3	16.3	15.2
7	16.5	13.4	13.7	18.2	16.7	17.0	15.9
8	17.4	12.1	13.2	15.2	16.1	15.9	15.0
9	17.0	11.6	12.7	15.7	15.4	14.9	14.6
10	17.1	13.9	15.2	16.6	16.3	15.8	15.8
11	17.9	11.7	13.2	17.3	17.0	16.4	15.6
12	16.7	12.5	13.0	15.4	16.8	15.0	14.9
13	16.3	12.9	12.3	16.0	16.3	16.2	15.0
14	17.1	12.4	14.1	17.1	16.1	15.3	15.4
15	17.4	12.3	13.3	17.0	16.7	16.3	15.5
16	18.0	11.9	12.5	16.7	15.6	15.6	15.0
17	17.3	12.3	13.0	16.7	16.6	15.7	15.3
18	16.9	14.8	13.6	16.9	16.2	15.7	15.7
19	17.1	12.9	13.2	16.6	16.9	15.7	15.4
20	16.6	12.1	11.6	17.1	15.5	15.3	14.7
21	17.6	14.6	14.8	17.9	16.2	15.3	16.1

Table 14. Water soluble nitrate-N of Pitic, Penjamo, and Sonora leaves at different stages of growth.

Treatment	Pitic						Penjamo	Sonora
	March 2	April 2	April 27	May 18	June 4	Average of 3 complete samplings	June 4	June 4
			ppm, dry basis					
1	390	-	410	-	520	440	520	450
2	620	-	500	-	350	490	430	440
3	230	-	400	-	390	340	530	440
4	310	-	330	-	300	310	420	580
5	310	-	340	-	280	310	720	410
6	390	-	330	-	310	340	650	410
7	230	-	460	-	470	390	580	430
8	390	-	420	-	390	400	650	530
9	390	390	420	770	380	400	650	620
10	150	310	310	470	370	330	660	460
11	150	210	320	470	380	280	520	370
12	150	230	300	550	360	270	590	440
13	460	230	320	620	370	380	680	450
14	310	230	340	620	390	350	720	350
15	460	230	420	460	370	420	770	450
16	230	-	380	-	590	400	650	390
17	150	-	400	-	460	340	600	310
18	310	-	480	-	540	440	440	360
19	310	-	320	-	620	420	690	390
20	470	-	450	-	540	490	620	450
21	470	-	470	-	530	490	670	440

Table 15. Soluble phosphate-P of Pitic leaves at different stages of plant growth.

Treatment	March 2	April 6	April 27	May 18	June 4	Average of 3 complete samplings
			ppm, dry basis			
1	1860	-	2140	-	1870	1960
2	2570	-	2140	-	1530	2080
3	2140	-	2890	-	1890	2310
4	2330	-	1610	-	1570	1840
5	2440	-	2980	-	2060	2490
6	2460	-	1930	-	1540	1980
7	2440	-	2100	-	1770	2100
8	2550	-	2150	-	1640	2020
9	2490	1670	2110	1800	1400	2000
10	2300	2280	2560	2540	2070	2310
11	2940	1850	2100	1900	1450	2160
12	2450	3040	2420	1890	1690	2180
13	2780	2060	2620	2010	1880	2430
14	2610	2310	2410	1740	1760	2260
15	2670	2090	2300	1990	1430	2130
16	2020	-	1530	-	1300	1620
17	1900	-	2590	-	1620	2040
18	2750	-	2870	-	2190	2600
19	2460	-	2290	-	1540	2100
20	2530	-	2220	-	1730	2160
21	3140	-	4280	-	2380	3270

Table 16. Soluble sulfate-S of Pitic leaves at different stages of plant growth.

Treatment	March 2	April 6	April 27	May 18	June 4	Average
			ppm, dry basis			
1	1750	-	1750	-	5400	2970
2	1470	-	1200	-	4250	2310
3	2020	-	1750	-	6500	3420
4	1370	-	1100	-	2290	1590
5	1550	-	1750	-	6280	3190
6	1270	-	1100	-	2340	1570
7	1850	-	1650	-	6250	3250
8	1550	-	1470	-	3780	2270
9	1270	1470	1270	1340	2650	1730
10	1370	2120	1550	4910	7260	3390
11	1550	1690	1470	4710	4810	2610
12	1470	1950	1470	3040	4770	2570
13	2690	1740	2770	4530	6730	4060
14	1470	1740	1100	1280	4810	2460
15	1650	1550	1000	1470	4460	2370
16	1370	-	1000	-	5960	2780
17	1650	-	1000	-	4600	2420
18	1370	-	1020	-	4810	2400
19	1650	-	1270	-	3840	2250
20	1840	-	900	-	3920	2220
21	2690	-	7180	-	5180	5020

Table 17. Total N, P, and S of Pitic leaves on April 27, 1967.

Treatment	Total N %	Total P ppm	Total S ppm
		Dry basis	
1	2.25	3110	3480
2	2.31	2770	2630
3	2.35	3720	4040
4	2.20	2470	2330
5	2.35	3650	4070
6	2.25	3050	3000
7	2.34	2810	3450
8	2.17	2570	2410
9	2.67	2660	3150
10	2.25	3790	3420
11	2.20	2960	2970
12	2.18	3000	2710
13	2.03	3650	3480
14	1.95	3030	2330
15	2.01	3100	2670
16	2.15	2890	2710
17	2.06	3190	2860
18	2.05	3070	2740
19	2.07	3300	2950
20	1.95	2890	2520
21	2.65	4900	5090

Table 18. Analysis of variance for grain yield of six varieties of wheat grown under N, P, and S treatments.

	Jaral	Pitic	Penjamo	TZPP	Sonora	Rogue	Average
d.f.							
Total	19	19	19	19	19	19	19
First order	3	3	3	3	3	3	3
Higher order	7	7	7	7	7	7	7
Lack of fit	4	4	4	4	–	4	4
Error	5	5	5	5	9	5	5
S.S.							
Total	2.672	14.543	7.037	4.163	2.848	4.547	3.226
First order	1.222	5.526	4.333	2.828	1.808	2.038	2.646
Higher order	0.602	4.280	1.093	1.165	0.811	1.442	0.311
Lack of fit	0.558	2.268	1.219	0.110	–	0.549	0.153
Error	0.290	2.468	0.392	0.060	0.229	0.518	0.116
M.S.							
First order	0.407*	1.842	1.444**	0.943**	0.603**	0.679*	0.882**
Higher order	0.086	0.611	0.156	0.166**	0.116*	0.206	0.044
Lack of fit	0.140	0.567	0.305	0.028	–	0.137	0.038
Error	0.058	0.494	0.078	0.012	0.025	0.104	0.023
Coefficient of variation %	11.1	16.2	9.3	5.6	6.8	13.9	5.7

* Significant at 5% level.

** Significant at 1% level.

Table 19. Analysis of variance for plant height of six varieties of wheat grown under N, P, and S treatments.

	Jaral	Pitic	Penjamo	TZPP	Sonora	Rogue	Average
d.f.							
Total	19	19	19	19	19	19	19
First order	3	3	3	3	3	3	3
Higher order	7	7	7	7	7	7	7
Lack of fit	4	4	4	4	-	-	4
Error	5	5	5	5	9	9	5
S.S.							
Total	836.95	1150.95	1373.80	1614.80	728.55	569.20	670.57
First order	440.73	824.61	1077.46	1269.94	395.90	310.44	626.59
Higher order	192.82	150.54	132.52	119.65	106.99	80.72	3.21
Lack of fit	131.89	100.97	145.81	146.37	-	-	37.84
Error	71.50	74.83	18.00	78.83	225.66	178.04	2.94
M.S.							
First order	146.91*	274.87**	359.15**	423.31**	131.97*	103.48*	208.86**
Higher order	27.55	21.50	18.93	17.09	15.28	11.53	0.46
Lack of fit	32.97	25.24	36.45*	36.59	-	-	9.46**
Error	14.30	14.97	3.60	15.77	25.07	19.78	0.59
Coefficient of variation %	5.4	4.3	2.3	4.8	8.3	7.4	1.0

* Significant at 5% level.
** Significant at 1% level.

Table 20. Analysis of variance for crude protein of grain of six varieties of wheat grown under N, P, and S treatments.

	Jaral	Pitic	Penjamo	TZPP	Sonora	Rogue	Average
d.f.							
Total	19	19	19	19	19	19	19
First order	3	3	3	3	3	3	3
Higher order	7	7	7	7	7	7	7
Lack of fit	4	-	-	4	-	4	4
Error	5	9	9	5	9	5	5
S.S.							
Total	3.388	17.608	14.802	15.698	5.128	7.270	3.430
First order	0.211	9.758	6.321	9.694	0.290	4.466	2.215
Higher order	0.605	1.353	4.373	2.884	2.619	1.327	0.008
Lack of fit	1.424	-	-	2.926	-	0.948	0.569
Error	1.148	6.497	4.108	0.193	2.219	0.528	0.653
M.S.							
First order	0.070	3.253*	2.107*	3.231**	0.096	1.489**	0.738*
Higher order	0.086	0.193	0.625	0.412**	0.374	0.190	0.001
Lack of fit	0.356	-	-	0.731**	-	0.237	0.142
Error	0.230	0.722	0.456	0.039	0.246	0.106	0.131
Coefficient of variation %	2.8	6.7	5.2	1.2	3.0	2.1	2.4

* Significant at 5% level.
** Significant at 1% level.

Table 21. Analysis of variance for soluble nitrate-N of Pitic, Penjamo, and Sonora leaves at different stages of plant growth.

	Pitic				Penjamo	Sonora
	March 2	April 27	June 4	Average	June 4	June 4
d.f.						
Total	19	19	19	19	9	9
First order	3	3	3	3	3	3
Higher order	7	7	7	7	7	7
Lack of fit	-	4	-	4	4	4
Error	9	5	9	5	5	5
S.S.						
Total	311695	72375	179780	75820	190895	103855
First order	88784	3176	8924	4011	37621	20046
Higher order	82010	34055	122648	48138	40150	50768
Lack of fit	-	19461	-	11588	52441	18558
Error	140900	15683	48208	12083	60683	14483
M.S.						
First order	29594.8	1058	2975	1337	12540	6682
Higher order	11715.7	4865	17521	6877	5736	7253
Lack of fit	-	4865	-	2897	13110	4639
Error	15655.6	3137	5356	2417	12137	2897
Coefficient of variation %	39.3	13.8	14.1	11.8	17.5	13.7

Table 22. Analysis of variance for soluble phosphate-P of Pitic leaves at different stages of plant growth.

	March 2	April 27	June 4	Average
d.f.				
Total	19	19	19	19
First order	3	3	3	3
Higher order	7	7	7	7
Error	9	9	9	9
S.S.				
Total	152570	281812	110565	96205
First order	18174	78476	46477	19632
Higher order	34855	88343	14109	55239
Error	99541	114993	49979	55239
M.S.				
First order	6058	26159	15492	6544
Higher order	4979	12620	2015	3048
Error	11060	12777	5553	6138
Coefficient of variation %	13.9	15.5	14.4	11.7

Table 23. Analysis of variance for soluble sulfate-S of Pitic leaves at different stages of plant growth.

	March 2	April 27	June 4	Average
d.f.				
Total	19	19	19	19
First order	3	3	3	3
Higher order	7	7	7	7
Lack of fit	4	4	-	4
Error	5	5	9	5
S.S.				
Total	200058	355389	3883070	781026
First order	46579	110991	2880618	509838
Higher order	69724	142651	498709	146596
Lack of fit	66746	94019	-	104558
Error	17008	7728	503742	20033
M.S.				
First order	15526	36997**	960206**	169946**
Higher order	9961	20379**	71244	20942*
Lack of fit	16687	23505**	-	26139*
Error	3402	1546	55971	4007
Coefficient of variation %	11.6	12.0	16.2	8.3

* Significant at 5% level.
** Significant at 1% level.

Table 24. Analysis of variance for total N, P, and S of Pitic leaves on April 27, 1967.

	Total N	Total P	Total S
d.f.			
Total	19	19	19
First order	3	3	3
Higher order	7	7	7
Lack of fit	4	4	4
Error	5	5	5
S.S.			
Total	0.5557	269908	506928
First order	0.0104	153943	234814
Higher order	0.4102	76939	127906
Lack of fit	0.1130	25732	131939
Error	0.0221	13293	11268
M.S.			
First order	0.0035	51314**	78605**
Higher order	0.0586**	10991	18272*
Lack of fit	0.0282*	6433	32985**
Error	0.0044	2659	2254
Coefficient of variation %	3.2	5.3	5.5

* Significant at 5% level.
** Significant at 1% level.