EFFECT OF NITROGEN AND PHOSPHORUS ON YIELD AND YELLOW BERRY DEVELOPMENT IN BREAD AND DURUM WHEAT

by

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ABSTRACT

This study was initiated to evaluate the effect of N and P fertilization on yield and yellow berry development in bread and durum wheat.

Two wheat varieties, Cocorit 71 (durum) and Cajeme 71 (bread wheat), were grown under irrigation at The University of Arizona Experimental Farm, Marana, on Pima clay loam soil during the 1976-77 growing season. Twelve treatments involving four levels of N and three of P were arranged in a randomized block design with six replications. These were 0, 168, 252 and 336 kg N/ha and 0, 44.8 and 89.6 kg P/ha. Prior to harvest, samples were taken and analyzed for number of heads, head weight, straw weight, and grain weight. Grain yield was determined at harvest. Percent yellow berry content, number of grains per head and number of grains per 25 g were determined later. Yellow berry and vitreous grains were analyzed for N content.

Grain yield increased with increased N and P but N in excess of 252 kg/ha decreased yields of both varieties slightly. The maximum grain yields of both varieties were associated with 89.6 kg P/ha. Yield increases were primarily due to production of more heads and grains as well as increase in grain weight per unit area. Percent yellow berry decreased with increased N with no significant effect of P. Percent N in yellow berry grains was generally lower than in vitreous grains.

INTRODUCTION

Wheat (Triticum aestivum) is the major food crop of the world in terms of area sown and size of harvest, with 228 million hectares and 355 million tonnes of production in 1975 (Anonymous, 1975). In the United States, wheat ranks second to corn (Zea mays) in area sown (Chapman and Carter, 1976). Arizona's wheat production has increased with the introduction of high yielding cultivars. The area sown to wheat in Arizona has increased from 10,520 hectares (26,000 acres) in 1966 to 178,060 hectares (440,000 acres) in 1976. The production of durum wheat is also increasing, with 34,398 hectares (85,000 acres) in 1977 and 38,445 hectares (95,000 acres) projected for 1978 (Mayes, Britton and Riggs, 1977). Durum and milling varieties now account for most of the wheat acreage in Arizona.

Nitrogen (N) and phosphorus (P) are required for high yields of wheat and are usually the only elements lacking in Arizona soils for wheat production. The low availability of N and P in the cultivated desert soils of Arizona makes fertilizer additions necessary for the maintenance of adequate soil fertility for maximum wheat production.

Wheat breeders and growers are concerned about grain quality, in particular the protein content and percentage of yellow berry kernels. The protein content of wheat grain is influenced by soil N concentration. Low levels of N usually reduce the protein content. This occurs when

grains are grown under excessive irrigation encouraging leaching losses. High levels occur when moisture is limiting (Dennis et al., 1975). The highest incidence of yellow berry (hard and flinty kernels that become partially or entirely starchy, opaque, soft and light yellow) occurs in durum and milling wheat grown under conditions of low available nitrogen. It is important, however, to mention that some wheat varieties are more susceptible to yellow berry than others. Among the local durum varieties, Cocorit 71 has been the most susceptible. Low incidence of yellow berry is required for wheat varieties accepted for pasta and bread making.

The principal concern of wheat growers in Arizona is how much fertilizer N and P to apply, and when to apply it to optimize yield, improve grain quality and/or maximize profit. To achieve this goal, an improvement of fertilizer use efficiency is needed.

The purpose of this study is to evaluate the effect of fertilizer N and P on yield and yellow berry development in bread and durum wheat.

LITERATURE REVIEW

The yield and quality of wheat varies with variety, nutrient availability and environmental conditions such as temperature and soil moisture conditions. Investigations of the response of wheat to N and P is hereby reviewed.

Effect of N on Plant Growth

The growth of agricultural plants is limited more often by a deficiency of N than any other nutrient (Tisdale and Nelson, 1975). Viets (1965) calculated that plants contain more atoms of N than of any other element except hydrogen derived from the soil. Nitrogen has a number of important functions in plants. All plant cells require N for their formation and functions. The nucleus and chromosomes or mitochondria are N containing structures of living plant cells (Fuller and Ray, 1967). Nitrogen also enter into the structure of chlorophyll, the amino acids, amides, alkaloids, protein and the protoplasm of the plant (Fuller and Ray, 1967; Tisdale and Nelson, 1975). Nitrogen excesses delay maturity and fruiting, by promoting vegetative growth. However, severe N deficiencies can also delay crop maturity and reduce yields (Black, 1968; Janick et al., 1974).

Many workers have studied the effect of N on the yield and protein content of wheat in an attempt to increase yields and improve the quality of old and new cultivars. In a 4-year experiment with

semidwarf wheat varieties, Woodward (1966) in North Dakota found that yield and protein content was increased by the addition of N. In Canada, Alkier, Racz and Soper (1972) found that large increases in yield were obtained when 34 and 67 kg N/ha was broadcast over non-fallow land at time of seeding but protein content decreased or increased only slightly. Protein content increased substantially when 100-202 kg N/ha was applied to non-fallow land, whereas yields were not increased above that obtained with 67 kg N/ha. Wheat protein content was found to be related to N supply.

Hutcheon and Paul (1966) showed that additions of nitrogenous fertilizers did not have a significant influence on wheat protein content under conditions of high soil nitrate-nitrogen content. Other workers (Dubetz, 1961; Russell, Smith and Pittman, 1958) showed that increase in wheat protein content resulted in lower grain yield. Hutcheon and Rennie (1960) found that additions of N in amounts greater than that required to obtain yield increases, increased only the grain protein content.

Macleod and Macleod (1975) and Gardner and Jackson (1976) reported an increase in grain yield and N content with increased N fertilizer additions. Macleod and Macleod also found that increasing the rate of N from 67 to 100 kg N/ha increased grain yield by only 0.14 metric tons, accompanied by 0.21% increase in grain N concentration.

In Canada, Bishop and Maceachern (1971) found from a 3-year fertilizer trial with spring wheat and barley, that, grain yield and crude protein content increased with increased N applications. A

similar trend was reported by Terman et al. (1969) in Nebraska. They found significant grain yield response to N and an increase in protein content. Where little or no yield response occurred, N did increase protein content.

The effect of N on yield and protein content has been used by wheat breeders to identify superior wheat varieties. In Australia, Syme, Craswell and Compton (1975), working on three wheat cultivars that differed in their grain protein content, found that grain yield and protein content increase with increased N additions. Protein contents were inversely related to grain yields. Ranking of cultivars for protein content was independent of nutrient regime.

In an experiment by Dubetz (1977) on irrigated wheat in southern Alberta, Canada, it was found that grain yield responded mainly to N. Yields were maximized with about 100 kg N/ha on soils with low fertility. When soil N was relatively low, it was possible to increase the protein content 51-76% by applying high rates of N.

The effect of N fertilization on the components of yield has also been a subject of several investigations. Schlehuber and Tucker (1967) reported that grain yield variations were the result of the combined effects of number of spikelets per unit area, number of grains per spikelet and average grain weight. These yield components varied with moisture supply, soil fertility level and the growth limiting factors (Rhodes, 1963). In Kansas, Hobbs (1953) reported that yield response to N resulted from an increase in tillering and number of grains per head.

Rhodes (1963) in Oregon and Woodward (1966) in Utah reported on the effect of N fertilizers on tillering and other yield components. They concluded that N fertilization caused an increase in yield and number of tillers but decreased test weight, plant height and weight of straw. Wahhab and Hussain (1957) found that N fertilization at seedling time increased the number of tillers per plant, number of mature heads per plant and number of grains per head. The greatest increase was observed in the number of mature heads per plant.

In North Dakota, Power and Alessi (1978) found that N fertilizer application significantly increased grain yield with additions of 50 to 270 kg N/ha. Most of this response resulted from an increase in the number of heads per hectare arising from reduced tiller mortality. Ishag and Taha (1974) in Sudan, Bhadauria and Verma (1977) in India, and Scott, Dougherty and Larger (1977) in New Zealand reported similar findings.

In a study by Hutcheon and Paul (1966) in Canada, it was found that high N application had a greater influence on the growth of straw than on grain, thus the straw to grain ratio widened with increasing increments of N. In Oregon, Rhodes (1963) reported that the effect of N fertilization on heading data, test weight and straw to grain ratio were variable.

The effect of time of N application on the performance of wheat has been reported by several investigators. Gingrich and Smith (1953) in Kansas found that time of application of N had no influence on yields of wheat or oats. Doll (1962) in Kentucky reported that fall

application of N fertilizer was not as effective as spring top dressing, although a small application might be needed to establish a vigorous stand in the fall. The low effectiveness of fall applied N was attributed to leaching losses.

The most widely used N fertilizers are anhydrous ammonia, ammonium nitrate, ammonium sulfate, ammonium phosphate, urea and magnesium ammonium phosphate (Janick et al., 1974). The relative effectiveness of nitrogen fertilizers depend upon the way in which they are used, the chemistry of the soil and moisture regime related to the soil texture (Pesek, Stanford and Case, 1971). Under conditions of high soil moisture content and significant percolation of water, N fertilizers carrying nitrate will be found inferior due to leaching losses (Tisdale and Nelson, 1975).

Urea is becoming a prominent source of N, but it has some properties which may lead to its reduced effectiveness. Urea is hydrolyzed by urease. Hence, urea applied to the surface of the soil may be readily hydrolyzed to ammonium carbonate with the subsequent loss of N as ammonia, especially if the soil is alkaline (Meyer, Olson and Rhoades, 1961).

Different rates of fertilizer N have been used in wheat fertilization, depending on soil test results. In general, applying 45-90 kg N/ha usually increase yields and heavier rates are common where environmental conditions favor high yields (Chapman and Carter, 1976).

Effect of P on Plant Growth

Phosphorus is invariably classed as one of the macronutrients, but its content in the plant is less than that of N (Black, 1968). Phosphorus is a constituent of nucleic acid, phytin and phospholipids and hence plant metabolism is heavily dependent on it. An adequate supply early in the life of the plant is important in laying down the primordia for its reproductive parts. Phosphorus has been associated with early maturity of cereal crops and a shortage causes marked reduction in growth. It is essential for seed formation (Black, 1968; Tisdale and Nelson, 1975).

The effect of P nutrition on yield and yield components has been studied by several investigators. Rahman and Wilson (1977) in Australia found that 40 kg P/ha increased spikelet number per ear, rate of spikelet initiation, and apex length in the seven wheat cultivars studied. However, no effect of the duration of the vegetative phase, spikelet phase or leaf number was observed. The increase in spikelet number was due to an increase in spikelet initiation. Forster and Vasey (1930) and Dann (1969) observed that P increased grain yields by increasing the number of grains per head and the weight of grains.

Woodward (1966) and Sharma et al. (1977) reported significant increases in number of tillers, number of grains per ear and grain weight with increase in P. Mitchell et al. (1953) found that increasing rates of P increased grain yield. Plant weight steadily increased

while the uptake of soil P decreased. However, Dalal and Hallsworth (1976) reported that yield increases from fertilizer P were in general very small, especially for grain and total dry matter yield. However, dry matter yield and P uptake were significantly correlated.

In Japan, Shimuzu (1960) observed that a P deficiency resulted in a marked delay of the initiation of spikelet primordia in wheat. He suggested that P could have an important physiological role in the process of the transition of the shoot apex from the vegetative to reproductive stage. Doyle (1973) reported that application of superphosphate hastened the onset of ear initiation by 1 to 3 days, but did not affect the time to maturity. Total shoot dry weight was considerably increased but there was little effect on grain yield.

The method and time of fertilizer P application are important to P utilization by wheat. Duley (1930) in Kansas, compared yields of winter wheat produced by 13 kg P/ha banded, with the yield of an equal amount broadcast, yield from the banded P was 43% greater than that of the broadcast fertilizer. Hamid and Sarnar (1977), studying the efficiency of fertilizer P on irrigated wheat as affected by method and time of application, found that P applied at tillering was most productive for grain and straw yield, and its utilization was significantly higher than P applied at planting. Phosphorus broadcast at planting was less effectively utilized.

In a study by Fox and Kang (1978) in Nigeria on the influence of P fertilizer placement and rate on maize nutrition, it was found

that response to P was greatest when the plants were young and decreased with advancing age. Grain yield increased with increased P fertilizer rates.

One of the factors that affect availability of P to plants is available soil moisture content. Drought causes a decrease in P availability (Janick et al., 1974). In eastern Montana, Power, Grunes and Reichman (1961) reported that plant growth, grain yields and nutrient uptake were proportional to available soil moisture. Phosphorus fertilization had no consistent effect on total moisture use at any stage of growth. However, at soft dough and harvest, P fertilization increased the plant material produced per unit of moisture used.

The main types of P fertilizers are superphosphate, triple superphosphate, ammonium phosphate, calcium metaphosphate and finely ground rock phosphate. Superphosphates and ammonium phosphate are the most widely used sources of highly water soluble phosphates (Phillips and Webb, 1971).

Rates of P fertilization have gradually increased in recent years in most regions. The aim of farmers is to apply enough to prevent P levels from limiting crop yields. The major field crops remove from 10 to 50 kg of P/ha but most farmers apply in excess of this amount (Phillips and Webb, 1971). Rates of P required for the maintenance of good yields are determined through soil tests.

Interaction of N and P on Yield and P Uptake

Increased absorption of soil and fertilizer P by plants when N is added to the soil has been recognized as a significant phenomenon in

soil-plant relations. Several mechanisms have been shown to be responsible in part for this effect. The principal ones are, increased root growth in the fertilized volume, increased physiological capacity of the roots to absorb P, probably due to an involvement of N intermediates in the absorption process and alteration of the pH at the soil-root interface (Carson, 1974).

Robertson et al. (1954) in a field experiment in Indiana in 1949 found that absorption of banded fertilizer P by corn was greater when N was included in the band than when it was applied separately. In Saskatchewan, Canada, Rennie and Mitchell (1954) and Olson and Dreier (1956) obtained similar results for wheat. In an experiment by Grunes, Haise and Fine (1958) it was found that additions of N fertilizer generally increased the P absorbed by sugar beets and potatoes. Hobbs (1953) in Kansas found that the magnitude of response to N was greater when P fertilizer was applied. In a growth chamber experiment by Thien and Mcfee (1970) on the effect of N on P absorption by corn, they found that N significantly increased P absorption and translocation rates.

Interaction of N and P has been studied from the standpoint of its effect on yield and yield components. In India, Sharma et al. (1977) reported a significant effect of N and P on the yield of wheat. The highest grain yield was obtained with 120 kg N/ha and 34 kg P/ha. Nitrogen application beyond 120 kg/ha lowered grain yield as well as response to P. Black and Siddoway (1977) reported that applying N and P each at 45 kg/ha significantly increased grain yield 30-60%.

Hobbs (1953) and Gingrich and Smith (1953) found that application of P and N increased wheat grain yield appreciably but Gingrich and Smith found that the inclusion of P with N did not significantly affect the yield of oats. A linear increase in the yield of wheat grains with increase in levels of N and P was reported by Bishop and Maceachern (1971).

Black and Siddoway (1977) in north eastern Montana, found that N and P fertilization increased the number of heads per hectare about 40% but had no significant influence on number of kernels per head. Volke and Inostroza (1967) in a trial with N and P, found that N and P had a positive effect on ear number per meter of row, but a negative effect on number of grains per ear. Phosphorus had a significant effect on grain weight. Yield was positively correlated with tillering and number of grains per ear.

Yellow Berry Development in Wheat

The percentage of yellow berry kernels in durum and bread wheat is an important consideration to wheat breeders and growers. This percentage is a measure of the crop quality and determines in part the domestic and world market price. Yellow berry kernels consist of soft starch with reduced amounts of protein between starch granules (Cudney, 1977; Dennis et al., 1975). When milled, the kernels of low protein content produce flour that is soft and fine. Durum wheat with a high percentage of yellow berry produce flour similar to that

obtained from bread wheat and will reduce its quality for semolina (Dennis et al., 1975).

The development of yellow berry character in wheat is influenced by wheat variety and cultural practices. The highest incidence of yellow berry occurs when wheat is grown under conditions of low available N and high moisture, and when high temperatures occur during heading and maturity (Dennis et al., 1975). Espericienta, Ortiz and Amaya (1973), studying the effect of the levels of N fertilizers on yellow berry character in durum wheat, found that the expression of yellow berry was different for the three wheat varieties studied. Environmental conditions did not affect the expression of the character except N levels, especially when N applied was less than 100 kg/ha. A positive correlation was found between carotene content and protein content. In the Imperial Valley of California, Robinson, Cudney and Lehman (1977) reported that yellow berry in Cocorit durum wheat was closely associated with protein percentage in the grain. They found that an increase of 1% in protein content reduced yellow berry by 23.8%. Nitrogen at 202 or 270 kg/ha split in three equal applications at preplant, tillering and boot stage, produced the best yields with less than 25% reduction in yellow berry.

Studies in Italy by Fortiti, Alessandroni and Galterio (1975), on two durum wheat varieties that differed in degrees of resistance to yellow berry, showed that protein synthesis was superior in the resistant variety increased with increased N supply. The effect of yellow berry on protein fractions of the grains was considerable.

MATERIALS AND METHODS

The study was conducted at The University of Arizona Experimental Farm, Marana, during the 1976-77 growing season. Marana is located 40 kilometers northwest of Tucson. The soil type is Pima clay loam, fine-loamy mixed family of typic torrifluvents. Soils of the Marana farm are in Land Capability Class I (Pereira, 1971). Prior to planting, soil samples were taken and analyzed for N and P (Table 1).

Experimental Methods

Two wheat varieties were chosen for the study. The varieties were Cocorit 71 (durum wheat) and Cajeme 71 (bread wheat). These were planted in December 1976, with a seeding rate of 112 kg/ha. A 2.4 m wide 15 cm row seed drill was used for planting. The fertilizers used were urea (45% N) and treble superphosphate (20% P). Border irrigation was used for the experiment.

Fertilizer treatments were four levels of N combined with three levels of P to provide twelve treatment combinations (Table 2). Each of the levels of N which were 0, 168, 252 and 336 kg N/ha was split into three equal parts and applied at preplant, vegetative and preboot stages. The P levels of 0, 44.8 and 89.6 kg P/ha were all applied preplant. The preplant N and P was broadcast and disced into the soil. Subsequent N applications were broadcast and watered into the soil by irrigation.

The first irrigation was on December 27, 1976. Subsequent irrigations were on February 16 and 17, March 24 and 25, April 11 and

Table 1. Initial soil N and P concentrations.

	kg/ha	
	N	P
Maximum	52.1	5.6
Minimum	0.6	0.54
Mean	14.8	1.93

Table 2. Fertilizer rates and treatments.

Treatments

N_1P_0	N_1P_1	N_1P_2
N_2P_0	N_2P_1	N_2P_2
N_3P_0	N_3P_1	N_3P_2
N_4P_0	N_4P_1	N_4P_2

N fertilizer rates (kg N/ha)		P fertilizer rates (kg P/ha)	
N_1	0	P_0	0
N_2	168	P_1	44.8
N_3	252	P_2	89.6
N_4	336		

12 and May 5 and 6, 1977. The depth of irrigation water applied was 170 mm per border per irrigation. The total rainfall at Marana throughout the growing season was 52 mm.

The experimental design was a factorial arrangement in a randomized block with six replications per treatment. Each treatment was in a 3.7 m x 18.3 m plot. Plots were in 7.4 m wide irrigation borders with 24 rows per plot. There were a total of 144 plots, 72 plots per wheat variety.

Sampling Procedure

Prior to harvest in June, 1977, samples were taken from a one meter row length at two locations in each of the plots. The samples were analyzed for straw weight, number of heads and weight of heads. The heads were thrashed with a head thrasher to remove the grains. The grains were cleaned and analyzed for grain weight, number of grains per head, number of grains per 25 g and percent yellow berry content. The straw to grain ratio was calculated. A 1.4 m x 9.1 m strip at the center of each plot was subsequently harvested for grain yield, with a self-propelled combine. The grain harvested was cleaned with a seed cleaner and the clean weight determined.

Chemical Analysis

Total N in yellow berry and vitreous grains was determined by the macro-Kjeldahl method as outlined below.

Samples weighing 1 g were transferred to macro-Kjeldahl digestion flasks. Ten grams of potassium sulfate catalyst

(K_2SO_4 + $CuSO_4$ + Se) were added to each flask, followed by 30 ml of concentrated (95%) H_2SO_4. The flasks were placed on low heat for 30 minutes. The heat was then increased and maintained for about five hours. The flasks were rotated and shaken every half hour to ensure uniform digestion of the sample.

After cooling, about 300 ml of water was added. The solution was made alkaline by addition of 80 ml of 40% sodium hydroxide solution. The N in ammonium form, was collected by steam distillation into a 200 ml beaker containing 50 ml of boric acid indicator solution. The N was determined by titrating the distillate (about 150 ml) with N/14 H_2SO_4 (Bremner, 1965).

Calculation

1 ml of N/14 H_2SO_4 = .0714 meq. H_2SO_4

1 meq. of N = 14 mg

.0714 meq. N = $\frac{14 \times .0714}{1}$ mg

= 1 mg N

$\therefore$ 1 ml of N/14 H_2SO_4 = 1 mg N

mg N = ml N/14 H_2SO_4 used - Ml N/14 H_2SO_4 blank

For 1 g tissue sample,

$$\%N = \frac{\text{ml N/14 } H_2SO_4 \text{ sample} - \text{ml N/14 } H_2SO_4 \text{ blank}}{1000} \times 100$$

Statistical Analysis

The data collected for the two wheat varieties were subjected to an analysis of variance. A comparison of treatment means was determined for the appropriate set of data using Duncan's Least Significant Differences (LSD) procedure at the 0.05 level of significance.

RESULTS AND DISCUSSION

Effects of N and P on yield and various yield components, percent yellow berry and N concentration in yellow berry and vitreous grains were determined. All data reported are averages of six replications.

Treatments and fertilizer rates referred to below are defined in Table 2.

Effect of N and P on Grain Yield

The mean grain yield in kg/ha of Cocorit 71 and Cajeme 71 are presented in Table 3. Effects of N and P were significant at the 0.05 level of probability (Table 4).

The lowest yields were associated with the lowest level of N which was N_1. There was a significant increase from N_1 to N_2 but differences between N_2, N_3 and N_4 were slight. The highest yields were associated with N_3 and N_4. The varieties differed significantly in response to N fertilization with Cocorit 71 giving the higher response.

Phosphorus at the lowest N level had little effect on grain yield. There was a significant increase from P_0 to P_1 at N_2, N_3 and N_4, but little differences between P_1 and P_2. Effect of N on both varieties increased with increasing levels of P. The highest grain yield of both varieties was obtained with 252 kg N/ha and 89.6 kg P/ha i.e., N_3P_2.

Table 3. Mean grain yield of Cocorit 71 and Cajeme 71.

Treatments	Kg/ha	
	Cocorit 71	Cajeme 71
N_1P_0	1897 a	2848 a
N_2P_0	5048 b	4517 bc
N_3P_0	4987 b	5312 cd
N_4P_0	5708 bc	4776 cd
N_1P_1	1205 a	3325 ab
N_2P_1	5451 b	5162 cd
N_3P_1	5945 bc	5379 cd
N_4P_1	6072 bc	5589 cd
N_1P_2	1253 a	2687 a
N_2P_2	5909 bc	4915 cd
N_3P_2	6873 c	6114 d
N_4P_2	5577 bc	5228 cd

LSD = 962

Means in the same column followed by the same letter do not differ significantly (P = 0.05).

Table 4. Analysis of variance for grain yield of Cocorit 71 and Cajeme 71.

Source of Variation	Degree of freedom	Mean square	F value
Variety	1	1248.44	.00
Error A	10	8806296.09	
Nitrogen	3	98589020.09	139.33**
Phosphorus	2	2667988.55	3.77*
Nitrogen x Phosphorus interaction	6	1947750.47	2.75*
Nitrogen x Variety interaction	3	9232926.46	13.05**
Phosphorus x Variety interaction	2	409847.30	.58
Nitrogen x Phosphorus x Variety interaction	6	764136.37	1.08
Error B	110	707584.95	
Total	143		

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

Nitrogen in excess of 252 kg/ha reduced grain yields at the P_2 level. The trend is similar to that produced with grain weight where N_3P_2 was the best treatment.

These results are similar to those of Sharma et al. (1977) who reported that 120 kg N/ha and 34 kg P/ha produced the highest yield of wheat grains. Applications of N in excess of 120 kg N/ha with 34 kg P/ha lowered grain yield as well as response to phosphate.

Effect of N and P on Straw Weight

Mean straw weight of Cocorit 71 and Cajeme 71 for the twelve treatments are presented in Table 5. An analysis of variance (Table 6) showed that there were significant effects of N and P on straw weight.

Straw weight generally increased with increased levels of N. The lowest straw weight was associated with N_1. There was a significant increase from N_1 to N_2 but no significant difference between N_3 and N_4. The highest straw weight was reached with N_3 and N_4. The two varieties differed significantly in response to N.

An increase in P from P_0 to P_1 caused a significant increase in straw weight for any level of N, but no significant difference between P_1 and P_2. The maximum straw weight of 461 g for Cocorit 71 was reached with N_4P_1, while the maximum of 384 g for Cajeme 71 was reached with N_4P_2. There were generally no differences between N_3 and N_4 or P_1 and P_2.

These results are similar to those of Black and Siddoway (1977) who reported that fertilization with N or N and P increased straw weight

Table 5. Mean straw weight per 2 m row length for Cocorit 71 and Cajeme 71.

Treatments	Straw weight (g)	
	Cocorit 71	Cajeme 71
N_1P_0	116 a	154 a
N_2P_0	345 c	253 bc
N_3P_0	275 b	307 cde
N_4P_0	369 ed	294 cd
N_1P_1	89 a	215 ab
N_2P_1	369 cd	342 def
N_3P_1	418 de	371 ef
N_4P_1	461 e	365 ef
N_1P_2	114 a	185 ab
N_2P_2	375 cd	352 def
N_3P_2	425 de	380 f
N_4P_2	435 de	384 f

LSD = 69

Means in the same column followed by the same letter do not differ significantly (P = 0.05).

Table 6. Analysis of variance for straw weight of Cocorit 71 and Cajeme 71.

Source of variation	Degree of freedom	Mean square	F value
Variety	1	8960.20	.34
Error A	10	26629.56	
Nitrogen	3	435595.71	120.16**
Phosphorus	2	69295.60	19.11**
Nitrogen x Phosphorus interaction	6	6040.88	1.67
Nitrogen x Variety interaction	3	40003.69	11.03**
Phosphorus x Variety interaction	2	618.87	.17
Nitrogen x Phosphorus x Variety interaction	6	5796.72	1.60
Error B	110	3625.28	
Total	143		

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

and Sharma et al. (1977) who found that straw yield was significantly increased by P fertilization.

Effect of N and P on Number of Heads

The number of heads per unit area is one of the simplest yield components to observe in the field. In a uniform stand of wheat, the number of heads produced per unit area is a reflection of tillering although it is an absolute function of initial stand and tillering.

The mean number of heads per 2 m row length for Cocorit 71 and Cajeme 71 are given in Table 7. An analysis of variance for the effects of N and P and various interactions is presented in Table 8.

The number of heads produced by both varieties increased with increased N. The lowest number of heads was associated with N_1. There was a significant increase from N_1 to N_2 but differences between N_2, N_3 and N_4 were not significantly different. The two varieties differed significantly in response to N fertilization.

The effect of P at N_1 was small but there was a significant increase from P_0 to P_1 at N_2, N_3 and N_4. The difference between P_1 and P_2 at all levels of N was not significant. The two varieties differed in the number of heads produced. More heads were produced by Cajeme 71 at all treatments. A N-P interaction was very significant i.e., the effect of an increase in N caused significant differences with different levels of P. The maximum head number for Cajeme 71 was reached with N_4P_2 while the maximum for Cocorit 71 was reached with N_4P_1. This was similar to straw weight i.e., N_4P_2 and N_4P_1 produced

Table 7. Mean number of heads per 2 m row length for Cocorit 71 and Cajeme 71.

Treatments	Number of heads/2 m row	
	Cocorit 71	Cajeme 71
N_1P_0	158 a	185 a
N_2P_0	259 cd	265 bc
N_3P_0	214 bc	293 c
N_4P_0	260 d	284 c
N_1P_1	147 a	224 ab
N_2P_1	287 de	346 d
N_3P_1	326 ef	369 d
N_4P_1	352 f	365 d
N_1P_2	169 ab	225 ab
N_2P_2	293 de	340 d
N_3P_2	328 ef	385 de
N_4P_2	344 f	414 e

LSD = 45

Means in the same column followed by the same letter do not differ significantly (P = 0.05).

Table 8. Analysis of variance for number of heads per 2 m row length of Cocorit 71 and Cajeme 71.

Source of variation	Degree of freedom	Mean square	F value
Variety	1	77330.34	21.80**
Error A	10	3547.30	
Nitrogen	3	168102.08	107.47**
Phosphorus	2	73590.65	47.05**
Nitrogen x Phosphorus interaction	6	5859.94	3.75*
Nitrogen x Variety interaction	3	1267.08	.81
Phosphorus x Variety interaction	2	1654.34	1.06
Nitrogen x Phosphorus x Variety interaction	6	2068.91	1.32
Error B	110	1564.15	
Total	143		

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

the maximum number of heads for Cajeme 71 and Cocorit 71, respectively. An increase in number of head was directly related to increased grain yield.

These results are similar to those of Rhodes (1963), Volke and Inostroza (1967) and Black and Siddoway (1977), who reported an increase in the number of heads per unit area with increased N and/or P.

Effect of N and P on Weight of Heads

Data for the mean weight of heads of Cocorit 71 and Cajeme 71 for the twelve treatments are given in Table 9. Increased weight of heads due to N fertilization was the only significant nutritional effect noted (Table 10).

The lowest head weight was associated with N_1. A significant increase in head weight resulted from an increase from N_1 to N_2 but differences between N_2, N_3 and N_4 again, were slight. Nitrogen in excess of N_3 (252 kg/ha) caused a slight reduction in the weight of heads produced by Cajeme 71. The varieties differed significantly in response to N fertilization.

Phosphorus was not significant at any level. The head weight of Cocorit 71 was higher than that of Cajeme 71. Maximum weight of heads of Cocorit 71 was associated with N_4P_1 and that of Cajeme 71 was associated with N_3P_2. There were generally no significant differences between N_2, N_3 and N_4 or between P_0, P_1 and P_2. Increase in head weight was directly related with increase in grain yield.

Table 9. Mean weight of heads per 2 m row length of Cocorit 71 and Cajeme 71.

Treatments	Weight of heads/2 m row (g)	
	Cocorit 71	Cajeme 71
N_1P_0	211 a	267 a
N_2P_0	573 bcd	450 b
N_3P_0	475 b	509 b
N_4P_0	603 cd	513 bc
N_1P_1	176 a	325 a
N_2P_1	571 bcd	523 bc
N_3P_1	585 cd	530 bc
N_4P_1	648 d	517 bc
N_1P_2	205 a	284 a
N_2P_2	534 bc	521 bc
N_3P_2	635 cd	561 c
N_4P_2	547 bcd	505 bc

LSD = 104

Means in the same column followed by the same letter do not differ significantly (P = 0.05).

Table 10. Analysis of variance for weight of heads per 2 m row of Cocorit 71 and Cajeme 71.

Source of variation	Degree of freedom	Mean square	F value
Variety	1	16595.88	.26
Error A	10	64729.42	
Nitrogen	3	812965.47	98.58**
Phosphorus	2	14821.60	1.80
Nitrogen x Phosphorus interaction	6	11148.60	1.35
Nitrogen x Variety interaction	3	58641.63	7.11**
Phosphorus x Variety interaction	2	998.79	.12
Nitrogen x Phosphorus x Variety interaction	6	10582.46	1.28
Error B	110	8246.80	
Total	143		

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

Effect of N and P on Weight of Grains

Mean weight of grain from a 2 m row length of Cocorit 71 and Cajeme 71 are presented in Table 11. Increased weight of heads of both varieties resulting from N fertilization was the only significant effect (Table 12).

The lowest grain weight was associated with N_1. There was a significant increase from N_1 to N_2 but only slight differences between N_2, N_3 and N_4. Nitrogen in excess of 252 kg/ha caused a slight reduction in grain weight of both varieties. The two varieties differed in response to N, Cocorit 71 producing a higher grain weight at N_2, N_3 and N_4.

There were no significant differences at any level of P for all levels of N. The maximum grain weight for both varieties was reached with N_3P_2. Increased grain weight with increased levels of N, was directly related to grain yield. Treatment N_3P_2 was associated with the highest yield and grain weight.

Effect of N and P on Number of Grains per Head

Mean number of grains per head of Cocorit 71 and Cajeme 71 for the twelve treatments are given in Table 13. Analysis of variance (Table 14) show that effects of N and P were significant at the 0.05 and 0.01 levels of probability.

The lowest number of grains per head was associated with N_1. There was a significant increase from N_1 to N_2 but little differences between N_2, N_3 and N_4. The varieties differed significantly in response

Table 11. Mean weight of grain per 2 m row length of Cocorit 71 and Cajeme 71.

Treatments	Grain weight (g)	
	Cocorit 71	Cajeme 71
N_1P_0	157 a	188 a
N_2P_0	424 cd	322 b
N_3P_0	346 b	362 b
N_4P_0	439 cd	368 b
N_1P_1	132 a	229 a
N_2P_1	430 cd	370 b
N_3P_1	425 cd	371 b
N_4P_1	473 d	359 b
N_1P_2	152 a	200 a
N_2P_2	404 bcd	374 b
N_3P_2	480 d	392 b
N_4P_2	370 bc	337 b

LSD = 76

Means in the same column followed by the same letter do not differ significantly (P = 0.05).

Table 12. Analysis of variance for grain weight per 2 m row length of Cocorit 71 and Cajeme 71.

Source of variation	Degree of freedom	Mean square	F value
Variety	1	33339.72	.85
Error A	10	39233.01	
Nitrogen	3	416705.21	94.06**
Phosphorus	2	6084.03	1.37
Nitrogen x Phosphorus interaction	6	9538.65	2.15
Nitrogen x Variety interaction	3	33307.29	7.52*
Phosphorus x Variety interaction	2	213.53	.05
Nitrogen x Phosphorus x Variety interaction	6	7081.22	1.60
Error B	110	4430.34	
Total	143		

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

Table 13. Mean number of grains per head of Cocorit 71 and Cajeme 71.

Treatment	Number of grains/head	
	Cocorit 71	Cajeme 71
N_1P_0	20 a	22 b
N_2P_0	32 c	28 de
N_3P_0	32 c	29 de
N_4P_0	36 d	30 e
N_1P_1	19 a	22 b
N_2P_1	31 c	27 cd
N_3P_1	30 bc	28 cde
N_4P_1	32 c	29 de
N_1P_2	19 a	19 a
N_2P_2	29 bc	25 bc
N_3P_2	31 c	28 de
N_4P_2	27 b	26 cd

LSD = 3

Means in the same column followed by the same letter do not differ significantly (P = 0.05).

Table 14. Analysis of variance for number of grains per head of Cocorit 71 and Cajeme 71.

Source of variation	Degree of freedom	Mean square	F value
Variety	1	156.25	2.24
Error A	10	69.73	
Nitrogen	3	772.67	103.99**
Phosphorus	2	125.22	16.85**
Nitrogen x Phosphorus interaction	6	19.30	2.60*
Nitrogen x Variety interaction	3	55.21	7.43*
Phosphorus x Variety interaction	2	3.06	.41
Nitrogen x Phosphorus x Variety interaction	6	5.50	.74
Error B	110	7.43	
Total	143		

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

to N. Cocorit 71 produced more grains per head with an increase in levels of N.

Increased P at N_2, N_3 and N_4 caused a significant reduction in number of grains per head. There was a significant N and P interaction i.e., the potential increase in number of grains per head with increase in N was significantly reduced by an increase in the level of P.

These results are similar to those of Volke and Inostroza (1967) who reported that an increase in N and P had a negative effect on number of grains per head but a positive effect on grain weight.

Number of grains per head is inversely related to grain yield since number of grain per head decreased with increase in N and P and grain yield increased with increase in N and P.

Effect of N and P on Number of Grains per 25 g

The number of grains per 25 g was determined to reflect the size and shape of grains as well as their density as affected by the various treatments. The mean number of grains per 25 g of Cocorit 71 and Cajeme 71 are given in Table 15. An analysis of variance (Table 16) shows that effects of N and P were significant at the 0.05 and 0.01 levels of probability. A N-P interaction was also significant.

An increase in N at the P_0 level had no significant effect on the number of grains per 25 g for both varieties but there was a significant increase at N_2, N_3 and N_4 levels when combined with P_1 or P_2. The varieties differed in response to N, with Cajeme 71 having a higher response to N at all levels.

Table 15. Mean number of grains per 25 g of Cocorit 71 and Cajeme 71.

Treatments	Number of grains/25 g	
	Cocorit 71	Cajeme 71
N_1P_0	519 ab	565 a
N_2P_0	488 a	599 a
N_3P_0	483 a	583 a
N_4P_0	529 abc	593 a
N_1P_1	530 abc	564 a
N_2P_1	590 ab	640 ab
N_3P_1	606 cd	730 c
N_4P_1	587 bcd	756 c
N_1P_2	533 abc	589 a
N_2P_2	528 abc	571 a
N_3P_2	542 abc	715 bc
N_4P_2	637 d	849 d

LSD = 80

Means in the same column followed by the same letter do not differ significantly (P = 0.05).

Table 16. Analysis of variance for number of grains per 25 g of Cocorit 71 and Cajeme 71.

Source of variation	Degree of freedom	Mean square	F value
Variety	1	390833.36	8.91*
Error A	10	43858.58	
Nitrogen	3	94077.97	19.22**
Phosphorus	2	82053.36	16.77**
Nitrogen x Phosphorus interaction	6	25425.17	5.20*
Nitrogen x Variety interaction	3	18339.27	3.75*
Phosphorus x Variety interaction	2	6567.53	1.34
Nitrogen x Phosphorus x Variety interaction	6	7609.41	1.55
Error B	110	4893.90	
Total	143		

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

Phosphorus had little effect at the N_1 level but there was a significant increase from P_0 to P_1 at levels of N_2, N_3 and N_4. The difference between P_1 and P_2 was not significant. The number of grains per 25 g was significantly increased when P was applied with levels of N. The maximum number for both varieties was associated with N_4P_2. There were more grains per 25 g of Cajeme 71 at all treatments.

The increase in number of grains with increase in levels of N and P was due to a decrease in size and weight of individual grains. However an overall increase in grain yield at these levels resulted from an increase in the number of grains per head and number of heads per plant.

Effect of N and P on Straw to Grain Ratio

Mean straw to grain ratios for Cocorit 71 and Cajeme 71 are given in Table 17. Calculation of straw to grain ratios permits a study of the effect of N and P on a single expression of these two plant characteristics. A wide straw to grain ratio indicates increased straw weight relative to the grain weight. An analysis of variance presented in Table 18 shows that the effects of N and P were significant at the 0.05 and 0.01 levels of probability.

An increase in the level of N generally caused a slight increase in the straw to grain ratio at the P_2 level. N_4 was associated with the highest ratio.

There was a significant increase from P_0 to P_1 at N_2, N_3 and N_4 levels but differences between P_1 and P_2 were very small. A N-P

Table 17. Mean straw to grain ratio for Cocorit 71 and Cajeme 71.

Treatments	Cocorit 71	Cajeme 71
N_1P_0	0.73 abc	0.80 ab
N_2P_0	0.81 abcd	0.78 a
N_3P_0	0.80 abcd	0.83 abc
N_4P_0	0.83 bcde	0.79 ab
N_1P_1	0.67 a	0.92 abcde
N_2P_1	0.87 cde	0.94 bcde
N_3P_1	1.04 fg	1.05 e
N_4P_1	0.93 ef	1.05 e
N_1P_2	0.71 ab	0.89 abcd
N_2P_2	0.95 def	0.75 cde
N_3P_2	0.91 def	1.00 de
N_4P_2	1.18 g	1.23 f

LSD = 0.15

Means in the same column followed by the same letter do not differ significantly (P = 0.05).

Table 18. Analysis of variance for straw to grain ratio of Cocorit 71 and Cajeme 71.

Source of variation	Degree of freedom	Mean square	F value
Variety	1	.1450	2.36
Error A	10	.0615	
Nitrogen	3	.3176	17.94**
Phosphorus	2	.4356	24.61**
Nitrogen x Phosphorus interaction	6	.0885	5.0*
Nitrogen x Variety interaction	3	.0456	2.58
Phosphorus x Variety interaction	2	.0279	1.58
Nitrogen x Phosphorus x Variety interaction	6	.0006	.03
Error B	110	.0177	
Total	143		

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

interaction was significant especially at the P_2 level. The highest straw to grain ratio for both varieties was obtained with N_4P_2. Cajeme 71 had a higher straw to grain ratio. The straw to grain ratio reflects the high straw yield at the highest levels of N and P. This means that at the N_4P_2 treatment, more straw was produced than grain.

These results are similar to those reported by Halliday (1948) and Hutcheon and Paul (1966) who reported that the straw to grain ratio increased with an increase in N supply.

Effect of N and P on Percent Yellow Berry Content

The percent yellow berry means of Cocorit 71 and Cajeme 71 for the twelve treatments are presented in Fig. 1 and Table A.1. An analysis of variance (Table 19) shows that the two varieties differed significantly in yellow berry content.

The effect of N on percent yellow berry was the most significant effect noted. Percent yellow berry decreased with an increase in the level of N (Fig. 1). The highest percentage was associated with the N_1 level. There was a significant decrease from N_1 to N_2. Differences between N_2, N_3 and N_4 levels were significant with Cocorit 71 but not with Cajeme 71. The N_4 level was associated with the lowest percentages for both varieties. The effect of N was more significant on Cajeme 71.

Phosphorus showed no significant effect at any level of N. The lowest percentages for both varieties was associated with N_4P_1

P_0, P_1, P_2 - Levels of phosphorus.
N_1, N_2, N_3, N_4 - Levels of nitrogen.

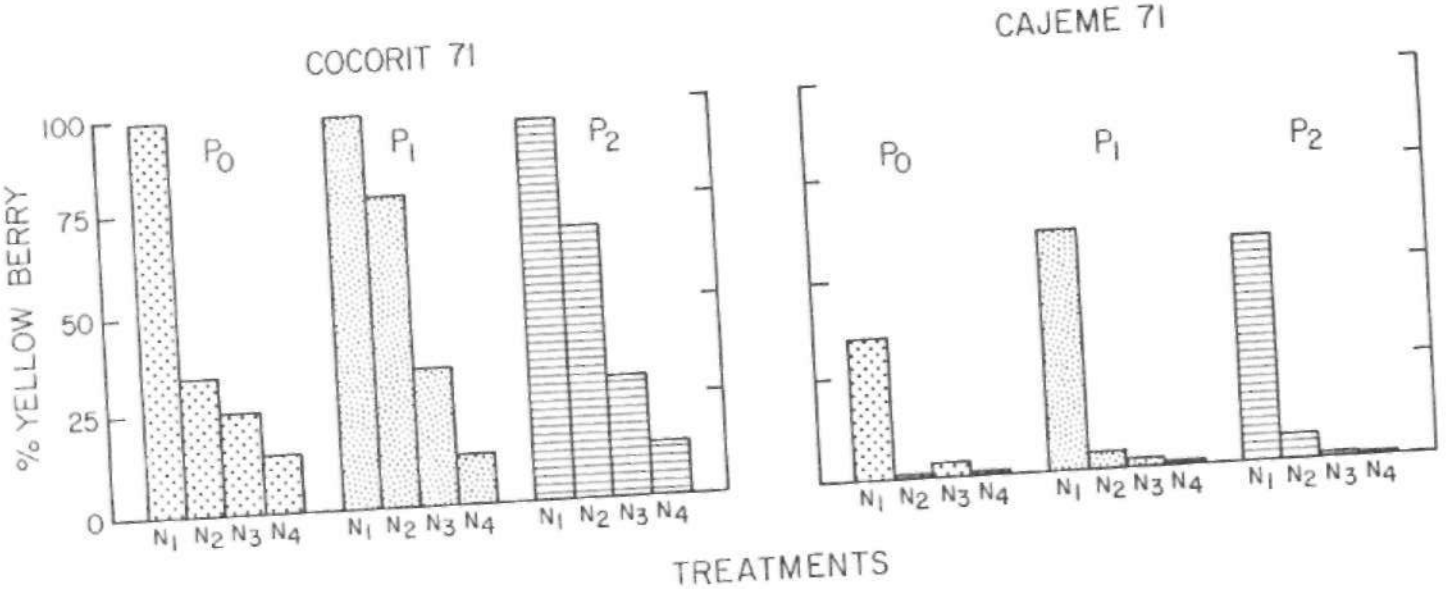


Figure 1. Percent yellow berry content of Cocorit 71 and Cajeme 71.

Table 19. Analysis of variance for percent yellow berry content of Cocorit 71 and Cajeme 71.

Source of variation	Degree of freedom	Mean square	F value
Variety	1	46027.05	67.76**
Error A	10	679.05	
Nitrogen	3	32125.31	148.30**
Phosphorus	2	1261.00	5.82*
Nitrogen x Phosphorus interaction	6	414.66	1.91
Nitrogen x Variety interaction	3	3201.44	14.78*
Phosphorus x Variety interaction	2	92.19	.43
Nitrogen x Phosphorus x Variety interaction	6	628.34	2.90*
Error B	110	216.63	
Total	143		

*Significant at the 0.05 level of probability.

**Significant at the 0.01 level of probability.

treatment. Cajeme 71 had a lower yellow berry content at all treatments.

These results are similar to those of Robinson et al. (1977) who reported that percent yellow berry decreased with an increase in the level of N. Dennis et al. (1975) recently reported that Cocorit 71 is highly susceptible to yellow berry.

Effect of N and P on Percent N in Yellow Berry Grains

The mean percent N in yellow berry grains of Cocorit 71 and Cajeme 71 are given in Table A.2. An analysis of variance is shown in Table 20.

An increase in the level of N generally caused a slight increase in the percent N of grains for both varieties (Figs. 2 and 3). Percent N in yellow berry grains of both varieties was generally low. The highest N in grains was associated with N_4. There were no significant differences between both varieties in the percent N in yellow berry grains.

These results are similar to those of Fortiti et al. (1975) who reported that yellow berry reduces the protein fraction in durum wheat grains and with those of Robinson et al. (1977) who reported that yellow berry grains are low in protein content.

Effect of N and P on Percent N in Vitreous Grains

Mean percent N in vitreous grains of Cocorit 71 and Cajeme 71 are presented in Table A.3. The effect of N was the only significant effect noted (Table 21).

Table 20. Analysis of variance for percent nitrogen in yellow berry grains of Cocorit 71 and Cajeme 71.

Source of variation	Degree of freedom	Mean square	F value
Variety	1	.0130	.03
Error A	10	.3967	
Nitrogen	3	.5249	2.25
Phosphorus	2	.6267	2.68
Nitrogen x Phosphorus interaction	6	.9250	3.96*
Nitrogen x Variety interaction	3	.3725	1.60
Phosphorus x Variety interaction	2	.1984	.85
Nitrogen x Phosphorus x Variety interaction	6	.7355	3.15*
Error B	110	.2335	
Total	143		

*Significant at the 0.05 level of probability.

P_0, P_1, P_2 - Levels of phosphorus.
N_1, N_2, N_3, N_4 - Levels of nitrogen.

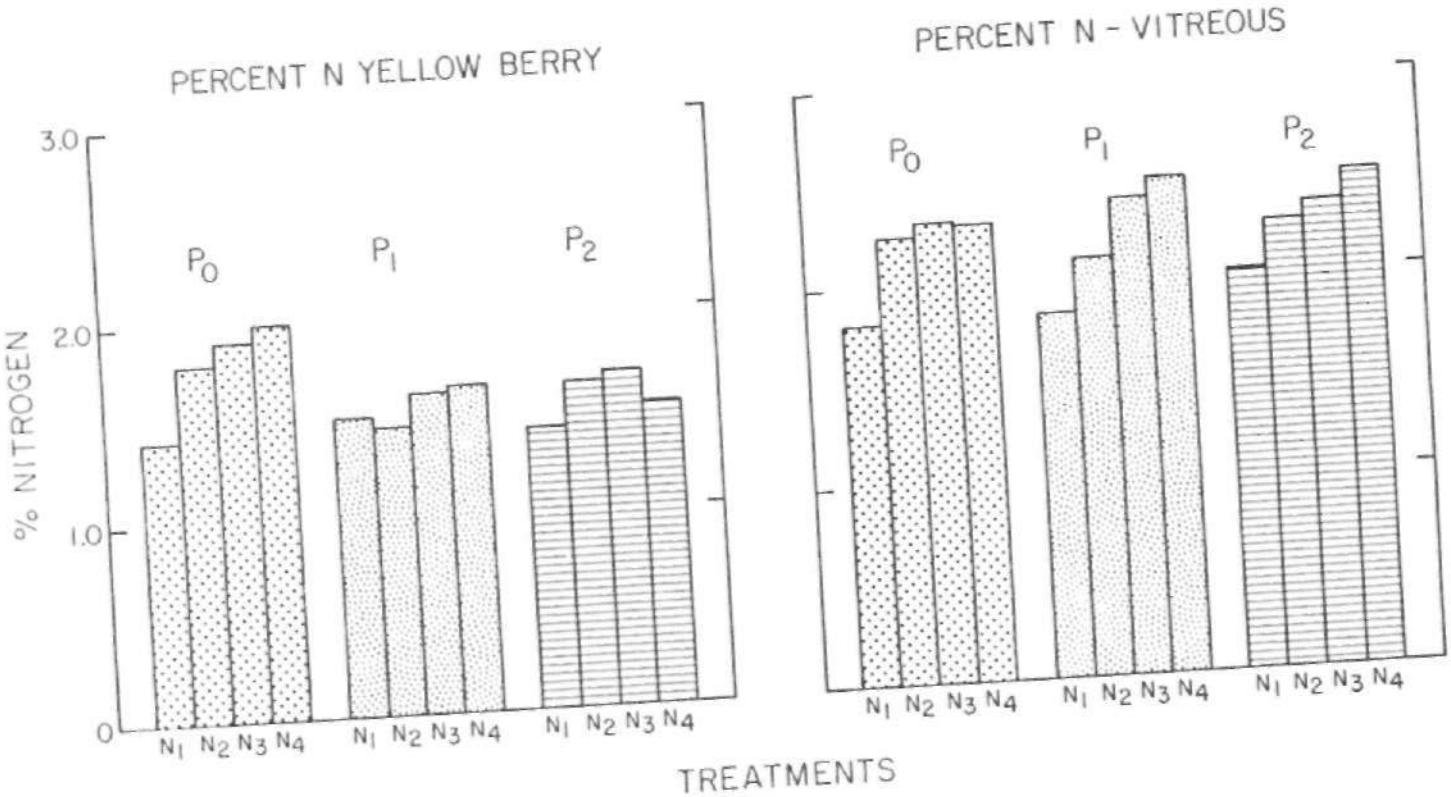


Figure 2. Percent N in yellow berry and vitreous grains of Cocorit 71.

P_0, P_1, P_2 - Levels of phosphorus.
N_1, N_2, N_3, N_4 - Levels of nitrogen.

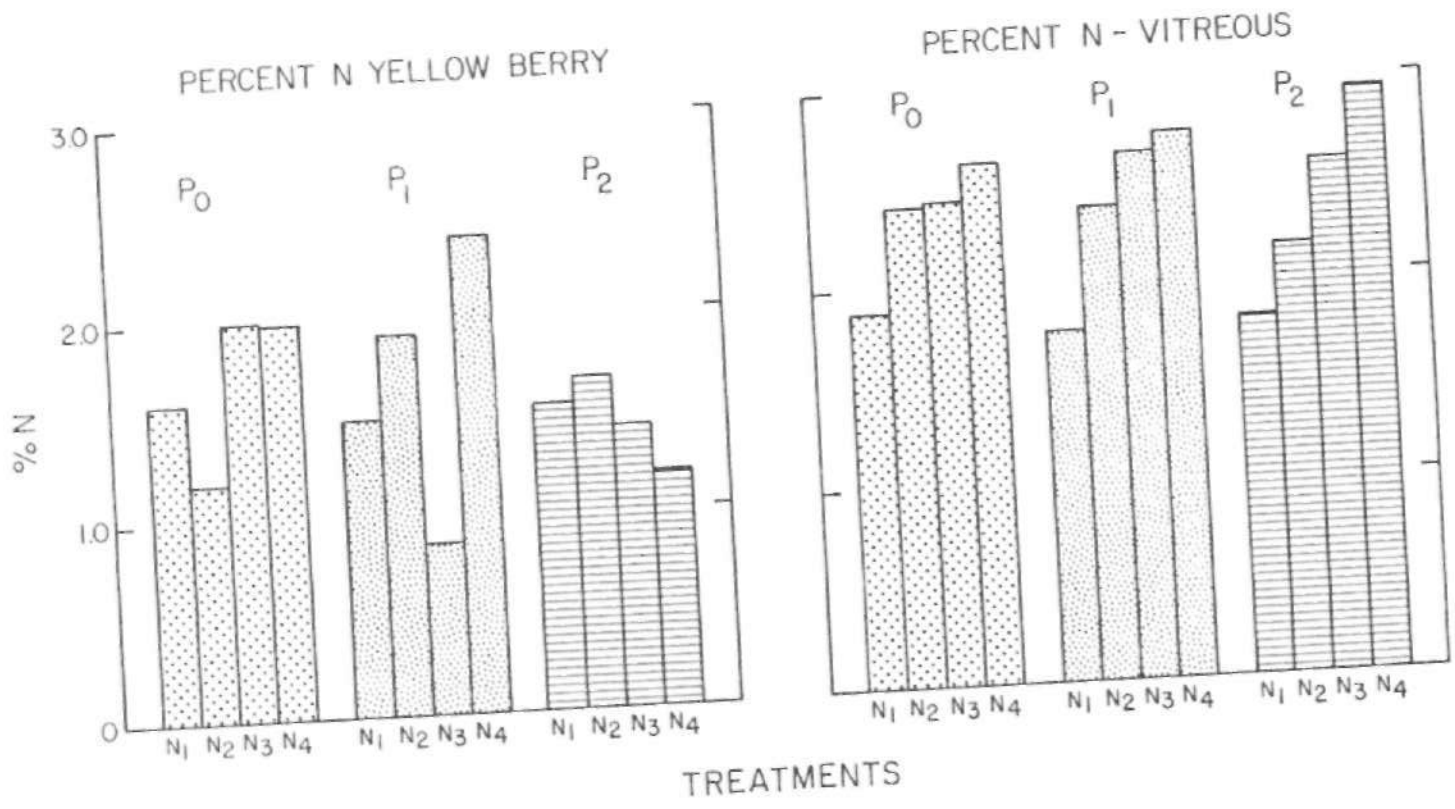


Figure 3. Percent N in yellow berry and vitreous grains of Cajeme 71.

Table 21. Analysis of variance for percent nitrogen in vitreous grains of Cocorit 71 and Cajeme 71.

Source of variation	Degree of freedom	Mean square	F value
Variety	1	.9950	2.63
Error A	10	.3789	
Nitrogen	3	3.6890	35.13**
Phosphorus	2	.0854	.81
Nitrogen x Phosphorus interaction	6	.0732	.70
Nitrogen x Variety interaction	3	.2886	2.75*
Phosphorus x Variety interaction	2	.0023	.02
Nitrogen x Phosphorus x Variety interaction	6	.046	.45
Error B	110	.1050	
Total	143		

*Significant at the 0.05 level of probability.

** Significant at the 0.01 level of probability.

Percent N in vitreous grains increased with increase in levels of N (Figs. 2 and 3). The lowest percentages were associated with N_1. An increase from N_1 to N_2 caused a significant increase, but N_2, N_3 and N_4 were not significantly different. The highest percentage was associated with N_4. The varieties differed significantly in the effect of N on percent N in vitreous grains. Cajeme 71 had a greater response to N.

Phosphorus had no significant effect on percent N in vitreous grains. There were no differences between levels of P at any level of N. The highest percentage for Cocorit 71 was reached with N_4P_1 while that of Cajeme 71 was reached with N_4P_2. Percent N in vitreous grains of Cajeme 71 was higher than in vitreous grains of Cocorit 71 at all levels of N.

SUMMARY AND CONCLUSIONS

This experiment determined the effects of N and P fertilizer on yield and yellow berry development in bread and durum wheat. The wheat varieties used were Cocorit 71 and Cajeme 71. The fertilizers used were urea (45% N) and treble superphosphate (20% P). Twelve treatments involving four levels of N and three levels of P (Table 2) were arranged in a randomized block design with six replications per treatment.

Prior to harvest, samples were taken from a 2 m row length and analyzed for straw weight, head number, head weight, grain weight, number of grains per head and percent yellow berry content of the grains. A strip at the center of each plot was harvested for yield. Percent N in yellow berry and vitreous grains were analyzed by the macro-Kjeldahl procedure (Bremner, 1965).

Nitrogen treatments were 0, 168, 252 and 336 kg N/ha. The N_2 level was significantly different from the N_1 level in its effect on all responses observed but in most cases, differences between N_2, N_3 and N_4 were not significant. Nitrogen was associated with significant increases in yield, straw weight, number of heads, head weight, number of grains per head, number of grains per 25 g, straw to grain ratio, percent N in yellow berry and vitreous grains and a decrease in percent yellow berry content.

Phosphorus rates were 0, 44.8, and 89.6 kg/ha. Phosphorus application did not significantly affect head weight, grain weight, percent yellow berry content or percent N in yellow berry and vitreous grains at any level. The P_1 level was significantly different from P_0 in all plant responses observed, but differences between P_1 and P_2 was only significant on yield. Increased P was associated with increases in yield, straw weight, number of head, number of grains per 25 g and straw to grain ratio. Increased P caused a reduction in number of grains per head.

For Cocorit 71, N_3P_2 gave the maximum grain weight and yield and N_4P_0 gave the maximum number of grains per head. N_4P_2 gave the maximum number of grains per 25 g and maximum straw to grain ratio. Treatment N_4P_1 was associated with the maximum straw weight, number of heads, head weight, percent N in yellow berry or vitreous grains, and the minimum percentage of yellow berry grains.

For Cajeme 71, N_3P_2 gave the maximum grain weight, yield and head weight. N_4P_0 gave the maximum number of grains per head and percent N in yellow berry grains and N_4P_1 gave the minimum yellow berry percentage. Treatment N_4P_2 was associated with the maximum straw weight, number of heads, number of grains per 25 g, and straw to grain ratio.

Nitrogen-phosphorus interactions were significant on the number of heads, number of grains per head or 25 g, yield, straw to grain ratio and percent N in yellow berry grains. Nitrogen-variety interactions were significant on straw weight, weight of heads, grain

weight, number of grains per head or 25 g yield, percent yellow berry content and percent N in vitreous grains.

An increase in grain yield for both varieties with increased N and P resulted from an increase in number of heads, number of grains and grain weight per unit area. The maximum grain weight was associated with N_3P_2 which was the most economical treatment for grain production for both varieties in terms of N fertilization.

Percentage of yellow berry grains for both varieties decreased with increased N but Cocorit 71 had higher percentages at all levels. N_4 was needed to reduce percent yellow berry of Cocorit 71 to an acceptable quality but N in excess of N_2 was uneconomical for Cajeme 71 since the N_2 level was adequate to reduce the yellow berry content to an acceptable level. Overall, Cocorit 71 was more susceptible to yellow berry than Cajeme 71 and percent N in yellow berry grains was lower than in vitreous grains.

APPENDIX A

PERCENT YELLOW BERRY AND N CONTENT OF COCORIT 71 and CAJEME 71

Table A.1. Mean percent yellow berry content of Cocorit 71 and Cajeme 71.

Treatments	Percent yellow berry	
	Cocorit 71	Cajeme 71
N_1P_0	97.87 d	35.95 b
N_2P_0	34.07 b	0.51 a
N_3P_0	25.42 ab	3.39 a
N_4P_0	14.40 a	0.33 a
N_1P_1	97.53 d	61.66 c
N_2P_1	77.91 c	3.85 a
N_3P_1	33.95 b	2.18 a
N_4P_1	12.11 a	0.17 a
N_1P_2	96.07 d	57.16 c
N_2P_2	67.20 c	7.07 a
N_3P_2	31.95 b	0.54 a
N_4P_2	13.73 a	0.27 a

LSD = 16.83

Means in same column followed by the same letter do not differ significantly (P = 0.05).

Table A.2. Mean percent nitrogen in yellow berry grains of Cocorit 71 and Cajeme 71.

Treatments	Percent nitrogen content	
	Cocorit 71	Cajeme 71
N_1P_0	1.42 a	1.60 bcd
N_2P_0	1.79 a	1.19 ab
N_3P_0	1.90 a	2.00 de
N_4P_0	1.98 a	1.99 de
N_1P_1	1.50 a	1.51 bcd
N_2P_1	1.44 a	1.91 cde
N_3P_1	1.60 a	1.20 a
N_4P_1	1.63 a	2.40 e
N_1P_2	1.41 a	1.54 bcd
N_2P_2	1.63 a	1.67 bcd
N_3P_2	1.68 a	1.41 bc
N_4P_2	1.52 a	1.18 ab

LSD = 0.55

Means in same column followed by the same letter do not differ significantly (P = 0.05).

Table A.3. Mean percent nitrogen in vitreous grains of Cocorit 71 and Cajeme 71.

Treatments	Percent nitrogen content	
	Cocorit 71	Cajeme 71
N_1P_0	1.82 a	1.87 a
N_2P_0	2.25 bcd	2.41 bc
N_3P_0	2.32 bcd	2.43 bc
N_4P_0	2.30 bcd	2.62 bcd
N_1P_1	1.83 a	1.77 a
N_2P_1	2.12 abc	2.38 b
N_3P_1	2.38 bcd	2.65 bcd
N_4P_1	2.49 d	2.75 cd
N_1P_2	2.03 ab	1.80 a
N_2P_2	2.25 bcd	2.35 b
N_3P_2	2.28 bc	2.58 bcd
N_4P_2	2.48 cd	2.93 d

LSD = 0.37

Means in same column followed by the same letter do not differ significantly (P = 0.05).

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