Cottonseed, Protein and Oil Yields and Oil Properties as Affected by Nitrogen and Phosphorus Fertilization and Growth Regulators

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Two experiments were carried out at our research center during the 1981 and 1982 seasons on cotton cultivar Giza 75 (*Gossypium barbadense L.*) to investigate the influence of nitrogen fertilization rates (72, 144 or 216 kg/ha.), phosphorus levels (36 or 72 kg P_2O_5/ha.) and three growth regulators (IAA, IBA or NAA) applied to cotton plants at 10 ppm and sprayed three times (70, 85 and 100 days after sowing) on protein and oil yields, and oil properties. A randomized complete block design with four replications treatment combinations was used.

The combined analysis of the results of the two seasons revealed that yields of cottonseed, oil and protein increased by raising nitrogen and phosphorus levels and under the application of growth regulators. Seed index increased by raising the added nitrogen and the applied growth regulants. No detectable effect of phosphorus levels was observed. The seed oil percentage decreased, although the protein percentage increased, when the nitrogen application rate was raised. Application of growth regulators and a high phosphorus level increased the seed oil percentage, but the seed protein percentage was not affected. The seed oil properties, i.e., acidity, saponification and iodine values, tended to decrease slightly by increasing the nitrogen application rate and the application of growth substances, but the trend reversed when the phosphorus level was raised. The mean values of oil specific gravity and refractive index did not show any definite responses.

Cotton's internal metabolism can be controlled by the optimum use of essential macronutrients, especially nitrogen and phosphorus, and by the application of growth regulators, which modify the crop by changing the rate or pattern or both of its responses to internal and external factors (such as changes in crop nutrition) that govern crop development. This might have a direct effect on cottonseed, protein and oil yields, as well as on oil quality.

In this respect, Bairamova (1) found that raising the phosphorus level resulted in increased seed oil percentages. Sam et al. (2) concluded that cottonseed yield could be increased by raising the phosphorus application rate. Chakravorty and Singh (3) mentioned that seed weight and seed protein content increased, but the seed oil content decreased, when the nitrogen rate was raised. Sawan et al. (4) applied IBA to cotton plants and found that cottonseed yield, seed index and seed oil content increased, but seed protein was unchanged. Sakr et al. (5) applied IAA, and El-Halawany (6) used NAA and observed that cottonseed yield and seed index increased.

The current investigation was conducted to investigate the effect of added nitrogen and phosphorus levels and the application of some growth regulators (IAA, IBA or NAA) sprayed during square initiation and boll development on improving seed, protein and oil yields, and other oil quality characteristics of Egyptian cotton.

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MATERIALS AND METHODS

Two field experiments were carried out during the 1981 and 1982 seasons using the Egyptian cotton cultivar Giza 75 (*Gossypium barbadense L.*). Soil for both experiments was clay loam with available nitrogen of 46 and 26 ppm and available phosphorus of 12 and 12 ppm in the 1981 and 1982 seasons, respectively. Each experiment included 24 treatments. These were the combination of three nitrogen application rates (72, 144 or 216 kg/ha., added to the soil in the form of ammonium nitrate with lime NH_4NO_3, containing 33.5% nitrogen), applied in two equal doses (one after thinning and the other before the second irrigation); two phosphorus application rates (36 or 72 kg P_2O_5/ha., in the form of triple-phosphate 46% P_2O_5), applied after thinning, and three growth regulators (indole-3-acetic acid [IAA], indole-3-butyric acid [IBA] and naphthalene acetic acid [NAA]) plus a control treatment sprayed with water only. Growth regulators were applied as foliar spray to cotton plants at the rate of 10 ppm, at 70, 85 and 100 days after sowing.

The experimental design was randomized complete blocks with four replications. Seeds were sown during the last week of March in both seasons. The plot area was 1.8 × 4 m, including three ridges. Culture was according to the usual practices at the farm.

At harvest, cotton of each plot was picked and ginned to determine the cottonseed yield in kg/ha. A random sample of 200 g seed representing each plot was taken for the determination of seed index (weight of 100 seed, in g), seed oil and percent protein content (determined according to the methods recommended by AOAC [7]), and other oil quality traits, i.e., specific gravity, refractive index, acidity, saponification and iodine values (measured according to the methods described by AOCS [8]). Data obtained were statistically analyzed factorially according to Snedecor and Cochran (9) for each characteristic in each season. Thereafter, the combined analysis of data for both seasons was performed to eliminate seasonal environmental effects. The least significant difference (LSD) for the combined data of both seasons was used to verify the significance of differences between treatment means.

RESULTS AND DISCUSSION

Cottonseed yield. Data in Table 1 show that cottonseed yield/ha. increased significantly by application of nitrogen at 144 kg/ha., followed by 216 kg/ha., compared with 72 kg/ha. treatment. Cottonseed yield increases due to nitrogen fertilization may be attributed primarily to the production of more flower buds, re-

TABLE 1

Effect of Nitrogen and Phosphorus Rates and Growth Regulators on Cottonseed Yield, Seed Index, Seed Oil and Protein Content and Yield[a]

Characters / Treatments	Cottonseed yield (kg/ha.)	Seed index (g)	Seed oil (%)	Oil (kg/ha.)	Seed protein (%)	Protein (kg/ha.)
			Nitrogen rates (kg/ha.)			
72	1893.7	9.99	19.90[b]	376.9	20.92	396.2
144	2092.7[b]	10.21[b]	19.02[b]	397.3[c]	21.59[b]	451.5[b]
216	2086.1[b]	10.28[b]	18.87	393.2	21.97[b]	457.4[b]
LSD 0.05	87.4	0.08	0.14	17.1	0.15	18.8
0.01	115.4	0.11	0.19	n.s.	0.20	24.9
			Phosphorus rates (kg P_2O_5/ha.)			
36	1966.4	10.15	19.18	376.1	21.42	421.4
72	2081.9[b]	10.17	19.35[c]	402.2[b]	21.56	448.6[b]
LSD 0.05	71.4	n.s.	0.12	13.9	n.s.	15.4
0.01	94.2	n.s.	n.s.	18.4	n.s.	20.3
			Growth regulators			
O	1893.0	9.96	19.02	359.1	21.34	404.2
IAA	2016.8[c]	10.21[b]	19.29[c]	388.2[b]	21.50	433.4[b]
IBA	2123.0[b]	10.21[b]	19.34[c]	409.7[b]	21.57	457.9[b]
NAA	2063.8[b]	10.26[b]	19.40[c]	399.6[b]	21.56	444.6[b]
LSD 0.05	100.9	0.10	0.17	19.7	n.s.	21.7
0.01	133.2	0.13	n.s.	26.0	n.s.	28.7

[a]Combined data for 1981 and 1982 seasons.

[b]Significant at 1% level.

[c]Significant at 5% level.

n.s., not significant.

flecting the enhancement of meristematic tissues and, consequently, a larger number of bolls/plant that came to maturity by the end of the season. A secondary effect is to increase the photosynthetic activity of leaves (10), which accounts for much of the high accumulation of metabolites having a direct impact upon boll weight. The increase in cottonseed yield observed herein confirmed the results obtained by Ogunlela et al. (11) and Shafshak et al. (12).

Cottonseed yield/ha. was increased significantly by raising the added phosphorus; these results could be attributed to the direct impact of phosphorus on an unlimited number of enzymatic reactions that depend on phosphorylation. Phosphorus is a constituent of the cell nucleus and is essential for cell division and for development of meristematic tissue stimulating the number of buds and bolls/plant (13). These results showed great similarity to those obtained by Usmanov (14) and Sam et al. (2).

Seed yield under all growth regulants significantly surpassed that of the control treatment. The highest yield was achieved under IBA application, followed by NAA and IAA. Such results could be due to the effect of these substances on the fruit retention/abscission ratio (15), caused by an increase in plant content of growth-promoting substances which obviously decrease the rate of bud and boll abscission. Treatment with auxin prevented the increase in the specific cellulase that apparently causes abscission (16). Also, auxin has been reported to maintain membrane integrity and selective permeability (17), and therefore tends to prevent secretion of pectinase and cellulase through the plasma membrane. In addition, application of auxin to young bolls increased boll weight (18). Several investigators obtained similar results: Lall and Shastri (19) with IAA; Sawan et al. (4) with IBA, and Jadhav and Kalbhor (20) and El-Halawany (6), with NAA.

Seed index. Results in Table 1 indicate that increases in the added nitrogen level resulted in significant increases of seed index, which can be due to the enhancement in photosynthetic activity in leaves, where nitrogen is essential for photosynthesis as a component of chlorophyll, enzymes and cell membranes (21). Chakravorty and Singh (3) and Gomaa et al. (22) came to the same conclusion. Phosphorus application rates failed to exert any significant effect upon seed index. This result was in harmony with those obtained by Varshney (23).

Application of growth regulators significantly increased seed index, with no particular difference in response between them. This may be attributed to the fact that application of these substances at the right concentration and proper time during development can increase the photosynthesis capability of chloroplasts by the stimulation of photophosphorylation and CO_2 fixation (24). Also, their transportation to the bolls (25) can stimulate growth and this, in turn, is reflected in high seed index. These results were in harmony with those obtained by Sakr et al. (5), using IAA, and Sawan et al. (4), using IBA.

Seed oil percentage and yield. Data in Table 1 show that seed oil percent was decreased significantly by raising the nitrogen level. Chakravorty and Singh (3) and Sawan et al. (4) came to similar conclusions. Oil yield/ha. increased with increased nitrogen application and was significant by the application of 144 kg/ha. due to seed yield increment. In this case, the depression in seed oil percent was not enough to offset the favorable effects of nitrogen fertilizer on seed yield.

Raising the phosphorus level caused increases in seed oil percentage that reached a significant level. These results agreed with those obtained by Bairamova (1). Oil yield/ha. was increased by raising the phosphorus application rate resulting from an improvement in both cottonseed yield and seed oil percentage.

Spraying plants with growth substances resulted in significant increases in seed oil compared with an untreated control. The highest seed oil was achieved by NAA application, followed by IBA and IAA. This indicates that application growth regulators favors the accumulation of more oil in the seed. Oil yield/ha. was increased significantly by application of growth regulators. Application of IBA gave the highest yield, followed by NAA and IAA. This contributed to the increase in the cottonseed yield/ha. and seed oil percentages. The present results confirmed those obtained by Sawan and co-workers (4,26) with IBA.

Seed protein percentage and yield. Data in Table 1 indicate that seed protein percentage was increased significantly by added nitrogen. These results suggest that the high nitrogen application rates might enhance protein synthesis in the cotton leaves (27) and stimulate the accumulation of protein in the seed (28) more than oil. These results parallel those obtained by Chakravorty and Singh (3) and Sawan et al. (4). Seed protein yield/ha. was increased significantly by raising the nitrogen levels.

Phosphorus application rates caused no significant difference in seed protein percentages. However, there was a tendency to a slight increase with the highest phosphorus levels. Seed protein yield/ha. was increased significantly by raising the phosphorus level, which may be due to the increases in cottonseed yield/ha.

Application of growth regulators had insignificant effects on seed protein percentages. Very slight increases in seed protein percentages were noticed in plots sprayed with growth regulators. The results obtained by Sawan and co-workers (4,26) confirmed the present ones as due to IBA application. Seed protein yield/ha. was increased significantly by application of growth substances as compared to control; IBA gave the best result, followed by NAA and IAA. The stimulating effects of application of the three growth regulators on cottonseed yields could be attributed to auxin involvement in regulation of plant growth (29) and its effect on DNA, RNA and protein synthesis, as well as its effect on the direction and end product of diverse metabolic processes (30). It is likely that these substances also affect the mechanism of ion uptake (31) and/or their translocation (32). These effects are manifested in the metabolites formed in plant tissues, have direct impact on growth and developmental processes and cause distinct changes in yield and quality.

Seed oil properties. Results in Table 2 show that variations in all seed oil properties with changes in nitrogen or phosphorus levels as well as application growth regulators were usually nil or very scarce. The

TABLE 2

Effect of Nitrogen and Phosphorus Rates and Growth Regulators on Seed Oil Properties[a]

Characters / Treatments	Specific gravity	Refractive index	Acid value	Saponification value	Iodine value
			Nitrogen rates (kg/ha.)		
72	0.9300	1.4774	0.1302	190.06	106.00
144	0.9300	1.4774	0.1299	189.86	105.96
216	0.9300	1.4774	0.1298	189.76	105.91
LSD 0.05	n.s.	n.s.	n.s.	n.s.	n.s.
			Phosphorus rates (kg P_2O_5/ha.)		
36	0.9300	1.4774	0.1299	189.86	105.93
72	0.9300	1.4774	0.1300	189.92	105.99
LSD 0.05	n.s.	n.s.	n.s.	n.s.	n.s.
			Growth regulators		
O	0.9300	1.4774	0.1303	189.97	106.01
IAA	0.9300	1.4774	0.1301	189.95	105.99
IBA	0.9300	1.4774	0.1299	189.84	105.89
NAA	0.9300	1.4774	0.1296	189.81	105.95
LSD 0.05	n.s.	n.s.	n.s.	n.s.	n.s.

[a]Combined data for 1981 and 1982 seasons.
n.s., not significant.

averages of oil specific gravity and refractive index did not show a definite trend due to nitrogen application rates. These results were in agreement with those obtained by Sawan et al. (4). El-Halawany (33) observed that oil refractive index tended to decrease with nitrogen level increment. The oil acidity, saponification and iodine values obtained a very slight reduction as a result of increased nitrogen application rate. This trend agreed with that obtained by El-Halawany (33) and Sawan et al. (4) for oil iodine and saponification values and by Sawan et al. (4) for oil acid value. However, Krishnakumari and Narasimham (34) showed that acid value for sunflower oil appeared to be slightly affected by nitrogen fertilization.

Data for oil specific gravity and refractive index did not show any patterns due to phosphorus levels. The oil acidity, saponification and iodine values tended to be increased slightly by high phosphorus use. Osman and Lila (35) noticed that refractive index for sunflower oil was generally lower with added phosphorus.

The averages of oil specific gravity and refractive index did not show any definite trend due to the application of growth substances. The oil acidity, saponification and iodine value tended to decrease very slightly with the application of growth regulators. Similar results were obtained by Sawan et al. (4) using IBA.

The combined analysis of data showed that the crop years had significant effect on the characteristics of cottonseed, oil and protein yield/ha., seed index, seed oil and protein percentage and oil specific gravity, which is a rather logical phenomenon. The first order interaction (years × nitrogen fertilization) exhibited a significant effect on seed oil and protein percent. Interactions did not reach a level of significance in all the other characteristics studied.

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