Effect of Nitrogen and Zinc Fertilization and Plant Growth Retardants on Cottonseed, Protein, Oil Yields, and Oil Properties

Zakaria M. Sawan[a,*], Saeb A. Hafez[b], and Ahmed E. Basyony[b]

[a]Cotton Research Institute and [b]Food Technology Research Institute, Agricultural Research Center, Ministry of Agriculture & Land Reclamation, 12619 Giza, Egypt

ABSTRACT: The increase in the population in Egypt makes it imperative to explore promising approaches to increase food supply, including protein and oil, to meet the needs of the Egyptian people. Cotton is the principal crop of Egyptian agriculture. It is grown mainly for its fiber, but cottonseed products are also of economic importance. Cottonseed is presently the main source of edible oil and meal for livestock in Egypt. Field experiments were conducted in two successive seasons at the Agricultural Research Center (Giza, Egypt) on cotton (*Gossypium barbadense* L. cv. Giza 75) to determine the effect of nitrogen (N) fertilizer rate (107 and 161 kg of N/ha applied as ammonium nitrate containing 33.5% N in two equal doses at 6 and 8 wk after sowing), together with foliar applications of plant growth retardants (mepiquat chloride "Pix," chloromequat chloride "Cycocel," and daminozide "Alar," each applied once at 288 g active ingredient/ha, after 75 d from sowing) and zinc (Zn) (applied in chelated form after 80 and 95 d from sowing at 48 g of Zn/ha) on seed, protein and oil yields and oil properties of cotton. The higher N-rate, as well as the application of all growth retardants and Zn, resulted in an increase in cottonseed yield, seed protein content, oil and protein yields/ha, seed oil refractive index, unsaponifiable matter, and total unsaturated fatty acids (oleic and linoleic). These treatments tended to decrease oil acid value, saponification value, and total saturated fatty acids. The seed oil content tended to decrease as N-rate increased and increased with the application of all growth retardants and Zn. There were some differences between Pix, Cycocel, and Alar regarding their effects on the studied characters. The highest increase in seed, oil, and protein yields/ha was found with Pix, followed by Cycocel. The Cycocel treatment gave the lowest total saturated fatty acids oil content, followed by Alar.

Paper no. J9875 in *JAOCS 78,* 1087–1092 (November 2001).

KEY WORDS: Cottonseed yield, nitrogen, oil fatty acids composition, plant growth retardants, seed oil content, seed oil properties, seed protein content, zinc.

The need to increase both the national and world food supply is perhaps one of the biggest challenges that has ever been seen. Agricultural scientists believe that this challenge can be met by developing high-yielding new varieties, effectively controlling pests, and applying appropriate agronomic practices. They are working hard to find different means of increasing crop production by formulating new compounds to reach this goal.

In cotton (*Gossypium barbadense* L.) culture, chemical fertilizers, particularly nitrogen (N), have the most impact of production inputs. N is an important nutrient, which controls growth and prevents abscission of squares and bolls (1), essential for photosynthetic activity (2), and stimulates the mobilization and accumulation of metabolites in newly developed bolls, thus increasing their number and weight.

Several approaches have been tried to raise cotton productivity. Application of plant growth regulators (PGR), particularly growth retardants, may maintain internal hormonal balance, i.e., efficient sink–source relationship, thus enhancing crop productivity (3). Mepiquat chloride and chloromequat chloride were found by Dippenaar *et al.* (4) and Pípolo *et al.* (5) to restrict vegetative growth, thus enhancing reproductive organs (6). Mepiquat chloride, chloromequat chloride, and daminozide also have been associated with increased photosynthesis (7–9) through increased total chlorophyll concentration in plant leaves. In the latter studies, increased photosynthesis greatly increased flowering, boll retention, and yield.

Zn deficiency appears when cotton grows in high-pH soils of Egypt or when phosphorus (P) is applied at high rates (10). Zn is required in the synthesis of tryptophan, which is a precursor in the synthesis of indole-3-acetic acid (10), a hormone that inhibits abscission of squares and bolls. Also, this nutrient has favorable effects on the photosynthetic activity of leaves and plant metabolism (11), which might account for higher accumulation of metabolites in reproductive organs (bolls).

Most previous research has focused on studying the effect of N fertilization and foliar application of PGR, and Zn on cotton yield and fiber quality (5,12–14). However, few studies have dealt with the effect of applying N, PGR, and Zn on the quantity and quality of oil and protein of cottonseed. Patil *et al.* (15) stated that N applications increased seed protein content of cotton. Kheir *et al.* (16) found that the higher N-rate increased the percentage of unsaturated fatty acids and decreased saturated fatty acids of flax oil. Sawan *et al.* (17) indicated that application of mepiquat chloride to cotton plants increased protein and oil yields and also caused a general decrease in the oil saturated fatty acids, associated with an increase in unsaturated fatty acids. Al-Gharbi and Yousif (18) observed that application of chloromequat chloride increased sunflower oil seed content. Osman and Abu-Lila (19) showed that spraying flax plants with chloromequat chloride increased the levels of unsaturated fatty acids. Osman and Ahmed (20) found that spraying sesame plants with daminozide caused an increase in the oil unsaturated fatty acids. Zafirova *et al.* (21) reported that Alar increased seed and oil yields of sunflower. Sawan *et al.* (22) indicated that the oil unsaponifiable matter tended to increase, while saponification value tended to decrease when applying Zn to cotton plants.

Due to the economic importance of cottonseed as the main source of edible oil for human consumption and meal for livestock in Egypt, this study was designed to determine the

*To whom correspondence should be addressed at Agricultural Research Center, 9 Gamaa St., 12619 Giza, Egypt. E-mail: zmsawan@hotmail.com

extent of improvement in cottonseed, protein and oil yields and oil properties of Egyptian cotton (*G. barbadense* L.) as affected by N fertilization rate and foliar application of PGR [mepiquate chloride, chloromequate chloride (ABM Chemicals, United Kingdom), and daminozide (Uniroyal Chemicals, United Kingdom)] and Zn (in chelated form) during square initiation and boll formation stages of growth.

MATERIALS AND METHODS

Two field experiments were conducted at the Agricultural Research Center, Ministry of Agriculture, Giza (30°N, 31°28′E), Egypt, on cotton (*G. barbadense* L.) cv. Giza 75 for two seasons during 1992 and 1993 on a clay loam soil. Mechanical soil analysis and chemical characteristics appear in Table 1 to provide information about the availability of nutrients in the soil in relation to established regional guidelines. Each experiment included 16 treatments of the following combinations: (i) Two N-rates (107 and 161 kg of N/ha) were applied as ammonium nitrate with lime (33.5% N) in two equal amounts, 6 and 8 wk after sowing; each application (in the form of pinches beside each hill) was followed immediately by irrigation. (ii) Three PGR, 1,1-dimethylpiperidinium chloride (mepiquat chloride, BASF, Germany, or Pix), 2-chloroethyltrimethylammonium chloride [chloromequat chloride, Cycocel or CCC (ABM Chemicals)], and succinic acid 2, 2-dimethylhydrazide [daminozide, SADH, B-Nine, Kylar, or Alar; Uniroyal, Uniroyal Chemicals)] were used. Each was foliar-sprayed once at 288 g active ingredient/ha, 75 d after planting (during square initiation and bolling stage) at solution volume of 960 L/ha. Water was used as the control treatment. (iii) Two chelated Zn (EDTA) rates (0.0 and 48 g of Zn/ha) were foliar-sprayed twice, 80 and 95 d after planting at a solution volume of 960 L/ha. The three PGR and Zn were both applied to the leaves with uniform coverage using a Knapsack sprayer (ICI, United KIngdom). The pressure used with the sprayer utilized in the study was 0.4 kg/cm^2, resulting in a nozzle output of 1.43 L/min. The application was carried out between 09.00 and 11.00 h. A summary of all treatments is shown in Table 2.

TABLE 1
Mechanical and Chemical Analysis of Soil Samples

Season	1992	1993
Mechanical analysis[a]		
Clay (%)	45.27	39.00
Silt (%)	27.21	27.49
Fine sand (%)	18.49	26.60
Coarse sand (%)	4.12	2.32
Texture	Clay loam	Clay loam
Chemical analysis[b]		
Organic matter (%)	1.81	1.58
Calcium carbonate (%)	2.97	2.90
Total soluble salts (%)	0.13	0.11
pH (1:2.5)	8.04	8.10
Total nitrogen (%)	0.12	0.08
Available nitrogen (mg/kg soil)	34.00	57.00
Available phosphorus (mg/kg soil)	14.00	19.00
Available potassium (mg/kg soil)	300.00	310.00
Available zinc (mg/kg soil)	1.36	1.30
Calcium (meq/100 g)	0.20	0.20

[a]According to Kilmer and Alexander (23).
[b]According to Chapman and Pratt (24). Note: The field was divided into uniform soil areas; eight soil samples to plow depth 30 cm were collected at random over the field and mixed to give a composite sample.

A randomized complete block design with four replications was used. Seeds were planted in plots 1.8 × 4.0 m on March 19 and 23 in 1992 and 1993, respectively. The plot consisted of three ridges. Hills were spaced 20 cm apart on one side of the ridge, and seedlings were thinned to two plants/hill 6 wk after planting, providing plant density of 166,000 plants/ha. Total water irrigation amount during the growing season (surface irrigation) was about 6,000 m^3/ha. The first irrigation was applied 3 wk after sowing, and the second was 3 wk later. Thereafter, the plots were irrigated every 2 wk until the end of the season, providing a total of nine irrigations. On the basis of soil test results, P fertilizer was applied before sowing (during land preparation) at a rate of 54 kg P_2O_5/ha as calcium phosphate. The K fertilizer was applied (as a concentrated band close to the seed ridge) before the first irrigation (3 wk after sowing) at a rate of 57 kg K_2O/ha as potassium sulfate. Pest management was carried out on an as-needed basis, according to local practice performed at the experimental station.

Total cotton yield/plot was determined by first hand-picking on September 25 and 29 with final picking on October 11 and 15 in the two seasons of 1992 and 1993, respectively. Following ginning, lint yields were determined in kg/ha. Seed samples of the four replicates/treatment were combined for chemical analyses. The following chemical analyses were conducted: (i) seed crude protein content according to AOAC standards (25); (ii) seed oil content in which oil was extracted three times with chloroform/methanol (2:1, vol/vol) mixture according to the method outlined by Kates (26); (iii) oil-quality traits, i.e., refractive index, acid value, saponification value, and unsaponifiable matter were determined according to methods described by AOCS (27); and (iv) identification and determination of oil fatty acids by gas–liquid chromatography. The lipid materials were saponified, unsaponifiable matter was removed, and the fatty acids were separated. The free fatty acids were methylated with diazomethane (28). The fatty acid methyl esters were analyzed by a Hewlett-Packard (5890) chromatograph (Palo Alto, CA) equipped with dual flame-ionization detectors. The separation procedures were similar to those reported by Ashoub *et al.* (29) as follows: The chromatograph was fitted with an FFAP (crosslinked) 30 M (length) × 0.32 mm (column i.d.) × 0.25 µm (film thickness) capillary column coated with polyethylene glycol. The column oven temperature was programmed at 7°C/min from 50 to 240°C and kept finally to 30 min. Injector and detector temperatures were 250 and 260°C, respectively. Gas flow rates were 33, 30, and 330 mL/min for N_2, H_2, and air, respectively, with N_2 flow rate inside column of 2 mL/min. Under these conditions, all peaks from C8 to 20 homologous series were well defined. Peak identification was performed by comparison of the relative retention time (RRT) for each peak with those of standard chromatograms. The RRT of oleic acid was given a value of 1.0. Results were expressed as an area percentage of chromatograms. Data obtained for the cottonseed

TABLE 2
Treatment Number

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
N-rate (kg/ha)	107	107	107	107	107	107	107	107	161	161	161	161	161	161	161	161
PGR[a]	0	0	Px	Px	Cyc	Cyc	A	A	0	0	Px	Px	Cyc	Cyc	A	A
Zn-rate (g/ha)	0	48	0	48	0	48	0	48	0	48	0	48	0	48	0	48

[a]Each plant growth regulator (PGR) was foliar sprayed at a rate of 288 g active ingredient/ha. Px, Pix (BASF Corp., Germany); CYC, Cycocel (ABM Chemicals, United Kingdom); A, Alar (Uniroyal Chemicals, United Kingdom); 0, control.

yield were statistically analyzed factorially according to procedures outlined by Snedecor and Cochran (30) and the least significant difference (L.S.D.) was used to determine the significance of differences between treatment means at 0.05 level. As for the chemical properties considered in the study, the *t*-test computed in accordance with standard deviation was utilized to verify the significance between every two treatment means at the 0.05 level of significance.

RESULTS AND DISCUSSION

Cottonseed yield. Cottonseed yield per ha was significantly ($P \leq 0.05$) increased (8.96%) by raising N rate (Table 3). Abdel-Malak *et al.* (31) stated that cotton yield was higher when N was applied at a rate of 190 kg/ha than at the rate of 143 kg/ha. Gil and González (12) applied N at a rate ranging from 40 to 200 kg/ha to cotton plants and found that the highest yield was associated with high rates of applied N.

All tested growth retardants (Pix, Cycocel and Alar) significantly increased cottonseed yield per ha (7.79–12.08%), compared with the untreated control. The most effective was Pix (12.08%), followed by Cycocel (10.57%). These results may be attributed to the promoting effect of these substances on numerous physiological processes, leading to improvement of all yield components.

Pix applications increased CO_2 uptake [Gausman *et al.* (32)] and fixation in cotton plant leaves. In cotton stems, the xylem was expanded with Pix treatment, perhaps increasing the transport ability and accounting for heavier bolls (33). Abdel-Al (13) indicated that cotton yield significantly increased with Pix treatment at a rate of 1190 mL (formulation)/ha at the beginning of flowering. Pípolo *et al.* (5) found that spraying cotton plants at an age of 70 d after emergence with Cycocel at rates ranging from 25 to 100 g/ha resulted in yield increases. Sawan *et al.* (34) stated that application of Cycocel and Alar at rates ranging from 250 to 700 ppm (105 d after planting) increased cottonseed yield per ha.

Application of Zn significantly increased cottonseed yield per ha (8.44%), as compared with untreated plants. Zeng (14) stated that application of Zn to cotton plants on calcareous soil increased yield by 7.8–25.7%.

Seed oil content and yield. Seed oil content was unchanged with increased N-rate. Oil yield per ha significantly increased (32.9 kg oil/ha), which is attributed to the increase in cottonseed yield (Table 3). Pandrangi *et al.* (35) applied N at a rate of 25 or 50 kg/ha to cotton plants and found that the percentage of seed oil content decreased but oil yield increased with increasing N rate.

Application of all growth retardants resulted in an insignificant increase in seed oil content above the control and also significantly increased the oil yield per ha over the control (29.3–45.2 kg oil/ha), with the clearest effect from Pix (45.2 kg/ha), followed by Cycocel (39.8 kg/ha). Sawan *et al.* (17) indicated that a slight increase in cottonseed oil content was detected with Pix application at rates ranging 10–100 ppm. Pix was sprayed once (90 d) or twice (90 and 110 d from sowing). Oil yield also increased due to Pix application compared with the control. Sawan *et al.* (34) observed that application of Cycocel and Alar (250–750 ppm, 105 d after planting) increased oil yield per ha.

Applications of Zn resulted in an insignificant increase in seed oil content over that of the control. The seed oil yield was also significantly increased (34.7 kg oil/ha) compared with the untreated control. These results could be attributed to the increase of total photoassimilates (e.g., lipids) and the translocated assimilates to the sink as a result of applying Zn nutrient (36). Sawan *et al.* (22) found that oil yield increased by the application of Zn to cotton plants at a rate of 12 g Zn/ha. Zn was sprayed three times, i.e., 70, 85, and 100 d after

TABLE 3
Effect of N Rate and Foliar Application of Plant Growth Retardants and Zn on Cottonseed Yield, Seed Oil, Seed Protein, Oil and Protein Yields

Treatments	Cottonseed yield (kg/ha)[a]	Seed oil (%)[b]	Oil yield (kg/ha)[b]	Seed protein (%)[b]	Protein yield (kg/ha)[b]
N-rate (kg/ha)					
107	1907.7	19.92	380.1	21.96	418.8
161	2078.7[d]	19.87	413.0[d]	22.51[d]	468.4[d]
L.S.D. 0.05[c]	67.88	—	—	—	—
S.D.[c]	—	0.339	27.67	0.429	34.60
Plant growth retardants (g active ingredient/ha)					
Control 0	1852.2	19.86	368.0	22.08	409.1
Pix 288	2076.0[d]	19.88	413.2[d]	22.35	465.0
Cycocel 288	2048.0[d]	19.94	407.8	22.24	455.8
Alar 288	1996.5[d]	19.90	397.3	22.26	444.5
L.S.D. 0.05[c]	96.00	—	—	—	—
S.D.[c]	—	0.366	29.15	0.552	40.20
Zn-rate (g/ha)					
Control 0	1912.4	19.82	379.2	22.10	422.8
48	2073.9[d]	19.97	413.9[d]	22.37	464.4[d]
L.S.D. 0.05[c]	67.88	—	—	—	—
S.D.[c]	—	0.332	27.03	0.500	37.49

[a]Combined statistical analysis from the two seasons.
[b]Mean data from a four replicate composites for the two seasons.
[c]L.S.D. = least significant differences, S.D. = standard deviation was used to conduct *t*-test to verify the significance between every two treatment means at 0.05 level.
[d]Significant at 0.05 level.

sowing. Prabhuraj *et al.* (37) found that applying Zn at 5 ppm rate increased seed and oil yields of sunflower.

Seed protein content and yield. High N rate significantly increased the seed protein content and protein yield per ha (49.6 kg protein/ha) (Table 3). According to Sugiyama *et al.* (38), soluble proteins are increased with better N supply and favorable growth condition. Greef (39) reported that high values of the reduced N fraction (protein fraction) were found in photosynthetic active leaf tissue. This is true especially under conditions of favorable nitrate supply. These results suggest that the high N-rate increases the amino acids synthesis in the leaves, and this stimulates the accumulation of protein in the seed rather than oil content. Patil *et al.* (15) found that N application (50 kg N/ha) increased the seed protein content.

Seed protein content and protein yield per ha were increased insignificantly in plants treated with the three growth retardants (35.4–55.9 kg protein/ha) compared with the untreated control. Highest protein content was produced by Pix application, followed by Alar, while the highest seed protein yield was obtained with Pix (55.9 kg/ha), followed by Cycocel (46.7 kg/ha). Hedin *et al.* (40) found that Cycocel increased protein content by 17–50% in leaves and squares harvested 4 wk after the first application. Kar *et al.* (41) in safflower showed that Cycocel and Alar maintained the level of chlorophyll, protein, and RNA contents. Also, the increase in seed protein content may be caused by the role of Pix in protein synthesis, encouraging the conversion of amino acids into protein (42). Sawan *et al.* (17) stated that cottonseed protein content and yield per ha increased due to the application of Pix. Kler *et al.* (43) found that when cotton was sprayed using Cycocel rates of 40, 60, or 80 ppm at the age of 63 d after sowing, seed protein content increased. Sawan *et al.* (34) stated that applications of Cycocel or Alar increased seed protein content and protein yield per ha.

Application of Zn increased insignificantly the seed protein content and significantly increased protein yield per ha (41.6 kg protein/ha) over the untreated control. In this circumstance Sawan *et al.* (22) found that application of Zn to cotton plants increased seed protein content and protein yield per ha.

Seed oil properties. The seed oil refractive index and unsaponifiable matter tended to increase insignificantly, while the oil acid value and saponification value tended to decrease by raising N-rate (Table 4). The increase in unsaponifiable matter is beneficial as it increases the oil stability. Sawan *et al.* (22) applied N to cotton plants at rates of 108 and 216 kg/ha and found that oil unsaponifiable matter tended to increase, while saponification value tended to decrease by raising N-rate.

Application of all PGR significantly increased the oil refractive index. However, unsaponifiable matter was insignificantly increased, whereas acid value and saponification value tended to decrease insignificantly as compared with the untreated control. Applied Cycocel gave the highest refractive index and the lowest acid value, while Pix gave the highest unsaponifiable matter. Also, applied Alar gave the lowest saponification value. Sawan *et al.* (34) stated that application of Cycocel and Alar to cotton plants increased oil refractive index and unsaponifiable matter and decreased oil acid value and saponification value. Osman and Abu-Lila (19) found a negligible variation in refractive index of flax oil when the plants were treated with Cycocel at the application rates of 25–100 ppm twice; the first one 20 d after sowing and the second spray 2 mon later.

TABLE 4
Effect of N Rate and Foliar Application of Plant Growth Retardants and Zn on Seed Oil Properties[a]

Treatments	Refractive index	Acid value	Saponification value	Unsaponifiable matter (%)
N-rate (kg/ha)				
107	1.4733	0.1336	193.7	0.3700
161	1.4734	0.1310	191.6	0.3738
S.D.[b]	0.00042	0.00479	2.43	0.03315
Plant growth retardant (g active ingredient/ha)				
Control 0	1.4729	0.1338	193.4	0.3675
Pix 288	1.4734[c]	0.1327	192.9	0.3750
Cycocel 288	1.4738[c]	0.1312	193.1	0.3725
Alar 288	1.4735[c]	0.1317	191.2	0.3725
S.D.[b]	0.00029	0.00527	2.69	0.03281
Zn-rate (g/ha)				
Control 0	1.4732	0.1325	193.8	0.3688
48	1.4735	0.1322	191.6	0.3750
S.D.[b]	0.00040	0.00499	2.38	0.03304

[a]Mean data from a four replicate composites for the two seasons.
[b]S.D. = standard deviation.
[c]Significant at 0.05 level.

The oil refractive index and unsaponifiable matter tended to increase insignificantly, while acid value and saponification value decreased insignificantly by applied Zn compared with control. Sawan *et al.* (22) found that application of Zn to cotton plants exhibited negligible effect upon oil-quality characters, i.e., refractive index, oil acid value, unsaponifiable matter, and saponification value.

Oil fatty acids composition. Low content of saturated fatty acids is desirable for edible uses. The oil saturated fatty acids (capric, myristic, palmitic, stearic) decreased insignificantly, while lauric acid increased insignificantly in response to raising the N-rate (Table 5). Palmitic acid was the dominant saturated fatty acid.

Application of the three PGR resulted in a decrease in the total saturated fatty acids compared with the untreated control. The decrease was significant with the Cycocel and Alar treatments. Cycocel gave the lowest total saturated fatty acids in oil contents, followed by Alar and also tended to increase insignificantly the saturated fatty acid capric acid compared with the untreated control. Applied Pix gave the highest capric and the lowest stearic acid content, while applied Cycocel gave the lowest lauric acid content. Alar application tended to give the lowest myristic and palmitic acids contents compared with control.

Application of Zn resulted in a significant decrease in the total saturated fatty acids (capric, palmitic, and stearic) while it resulted in an increase in the lauric and myristic saturated fatty acids, compared with untreated plants.

The total unsaturated fatty acids (oleic and linoleic) and the ratio between total unsaturated fatty acids and total saturated fatty acids (TU/TS) increased insignificantly (3.53 and 15.93%, respectively) by raising N-rate (Table 6). Linoleic acid was the most abundant of the unsaturated fatty acids. Kheir *et al.* (16) found that the higher N-rate increased the

TABLE 5
Effect of N Rate and Foliar Application of Plant Growth Retardants and Zn on the Relative Percentage of Saturated Fatty Acids[a]

	Relative % of saturated fatty acids					
Treatments	Capric	Lauric	Myristic	Palmitic	Stearic	Total
N-rate (kg/ha)						
107	0.5887	0.4375	0.7700	20.72	2.767	25.2832
161	0.3212	0.8212	0.6812	18.67	2.152	22.6456
S.D.[b]	0.40798	0.69859	0.74187	4.122	1.1510	4.95780
Plant growth retardants (g active ingredient/ha)						
Control 0	0.3350	1.2325	1.4050	23.06	2.427	28.4595
Pix 288	0.7500	0.7125	0.9225	20.88	1.982	25.2470
Cycocel 288	0.3600	0.2600	0.3200[c]	17.59	2.327	20.8570[c]
Alar 288	0.3750	0.3125	0.2550[c]	17.25[c]	3.102	21.2945[c]
S.D.[b]	0.42320	0.64494	0.59100	3.674	1.2050	4.25466
Zn-rate (g/ha)						
Control 0	0.6325	0.5825	0.5825	22.41	2.472	26.6795
48	0.2775	0.6762	0.8687	16.98[c]	2.447	21.2494[c]
S.D.[b]	0.38844	0.72635	0.72747	3.121	1.1970	4.25630

[a]Mean data from a four replicate composites for the two seasons.
[b]S.D. = standard deviation.
[c]Significant at 0.05 level.

percentage of unsaturated fatty acids and decreased the saturated fatty acids of flax oil.

All tested growth retardants increased the total unsaturated fatty acids and TU/TS ratio, compared with the control. The increase was significant by the application of Cycocel and Alar. Applied Cycocel gave the highest linoleic acid content, total unsaturated fatty acids (10.64%), and TU/TS ratio (51.0%), followed by Alar (10.02 and 47.01%, respectively). The increase in TU/TS as a result of the application of the three PGR may be attributed to their encouraging effects on enzymes that catalyzed the biosynthesis of the unsaturated fatty acids. Spraying plants with Zn significantly increased the total unsaturated fatty acids (7.4%) and TU/TS ratio (35.04%), compared with untreated control. Sawan *et al.* (17) reported that applying Pix to cotton plants caused a general decrease in oil saturated fatty acids, associated with an increase in oil unsaturated fatty acids. Sawan *et al.* (34) stated that application of Cycocel and Alar to cotton increased oil unsaturated fatty acids. Osman and Abu-Lila (19) when applied Cycocel at rates of 25–100 ppm to flax plants found that generally the higher concentrations (50 and 100 ppm) caused a decrease in the total oil saturated fatty acids, while they increased the unsaturated fatty acids.

From the findings of the present study, it seems rational to recommended application of N at a rate of 161 kg/ha, spraying of cotton plants with PGR, and application of Zn. In comparison with the ordinary cultural practices adopted by Egyptian cotton producers, it is quite apparent that applications of such PGR, Zn, and increased N fertilization rates could bring about better impact on cottonseed yield, seed protein content, oil and protein yields, oil refractive index, unsaponifiable matter, and unsaturated fatty acids. On the other hand, there was a decrease in acid oil value and saponification value. The increase in seed yield and subsequent increase in oil and meal due to the application of PGR, Zn, and increased N fertilization were sufficient to cover the cost of using those chemicals and further attain an economical profit.

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TABLE 6
Effect of N-Rate and Foliar Application of Plant Growth Retardants and Zn on the Relative Percentage of Unsaturated Fatty Acids[a]

	Relative % of unsaturated fatty acids			TU/TS[b]
Treatments	Oleic	Linoleic	Total	ratio
N-rate (kg/ha)				
107	21.67	53.04	74.71	2.95
161	22.57	54.78	77.35	3.42
S.D.[c]	1.885	3.837	4.957	0.867
Plant growth retardants (g active ingredient/ha)				
Control 0	20.67	50.86	71.53	2.51
Pix 288	21.20	53.55	74.75	2.96
Cycocel 288	23.07[d]	56.07	79.14[d]	3.79[d]
Alar 288	23.54[d]	55.16	78.70[d]	3.69[d]
S.D.[c]	1.568	3.601	4.254	0.742
Zn-rate (g/ha)				
Control 0	21.46	51.86	73.32	2.74
48	22.79	55.96[d]	78.75[d]	3.70[d]
S.D.[c]	1.810	3.282	4.256	0.730

[a]Mean data from a four replicate composites for the two seasons.
[b]TU/TS ratio = (total unsaturated fatty acids)/(total saturated fatty acids).
[c]S.D. = standard deviation.
[d]Significant at 0.05 level.

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[Received January 22, 2001; accepted August 14, 2001]