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Cottonseed, Protein, Oil Yields and Oil Properties as Affected by Nitrogen Fertilization and Foliar Application of Potassium and a Plant Growth Retardant

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Abstract: Field experiments were conducted in two successive seasons, at the Agricultural Research Center, Giza, Egypt. The aim was to investigate the effect of N-fertilization rate (95.2 and 142.8 kg of N/ha, applied as ammonium nitrate containing 33.5% N in two equal doses at 6 and 8 weeks after sowing), together with foliar application of potassium (applied as potassium sulfate containing 48% K_2O at 0.0, 400, 800 or 1200 ppm K_2O, applied twice: 70 and 95 days after sowing) and the plant growth retardant (PGR) Pix (applied twice: 75 days after sowing at 0.0 or 50 ppm and 90 days after sowing at 0.0 and 25 ppm) on seed, protein and oil yields and oil properties of Egyptian cotton cultivar "Giza 86 (*Gossypium barbadense*). The higher N-rate, as well as the application of potassium at different concentrations and plant growth retardant Pix resulted in an increase in cottonseed yield/ha, seed index, seed protein content, oil and protein yield/ha, seed oil refractive index, unsaponifiable matter and total unsaturated fatty acids (oleic and linoleic). Those treatments decreased, though oil acid value, saponification value and total saturated fatty acids. The seed oil content tended to decrease when the high N-rate was applied, but tended to increase with the application of potassium at different concentrations and Pix. There were some differences between potassium concentrations regarding their effects on the studied characters.

Key words: Cottonseed yield % nitrogen % oil fatty acids composition % plant growth retardant % potassium % seed protein content % seed oil content % seed oil properties

INTRODUCTION

Cotton is not only the most important fiber crop in the world, it is also the second best potential source for plant proteins after soybean and the fifth best oil-producing plant after soybean, palm-tree, colza and sunflower [1]. Cotton occupies a prominent position in Egyptian agriculture. It is the main raw material for the largest national industry, the textile industry, as well as the main source of locally produced cottonseed oil. Also, cottonseed meal is classed as a protein supplement in the feed trade. In Egypt, the need to increase the national supply, particularly oil and protein, in quantity and quality is a challenge to agricultural researchers. Oil quality is determined by both nutritional and functional aspects, which are, in turn, primarily determined by the fatty acid profile (i.e., fatty acid composition) of the oil. Economic conditions in modern agriculture demand high crop yields in order to be profitable and consequently match population growth with high demand for food. Crop production can be improved through improving the metabolic activity and nutritional status of crop plants. There are several factors, which can cause such high yields, i.e., development of new high yielding varieties, control of pests and the application of appropriate agronomic practices are potential solutions. Researchers trying some compounds have hormonal effects, while others are nutritions (the proper use of fertilizers, in terms of the quantity and nutrients used and the method of application), which can play and important role in increasing crop production and the quality [2].

In cotton culture, chemical fertilizers, particularly nitrogen (N), are one of the greatest production inputs. Nitrogen is an essential nutrient in creating the plant dry matter, as well as many energy-rich compounds that regulate photosynthesis and plant production [3].

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Synthesis of fat requires both N and carbon skeletons during the course of seed development [4]. The fatty acid composition of seed oil crops is mainly under genetic control, but can affected to some extent by N nutrition [5]. Nitrogen plays the most important role in building the protein structure [6]. Excess N in combination with adequate moisture and high plant populations can increase mutual leaf shading that decreases light intensity in canopy, leading to decrease photosynthate supply and subsequent square shed [7]. Early in development, N deficiency is associated with elevated levels of ethylene, suggesting ethylene production in response to N-deficiency stress [8]. Research in this area has resulted in a decrease in the levels of undesirable long-chain fatty acids. Another beneficial change in fatty acid composition would be an increase in the linoleic and oleic acid contents.

Potassium (K) is one of the most important elements in plant nutrition. All living organisms required in large amounts for normal plant growth and development. This attributed to the role of K in biochemical pathways in plants. Potassium increases the photosynthetic rates of crop leaves, CO_2 assimilation and facilitates carbon movement [9]. Potassium has favorable effects on metabolism of nucleic acids, proteins, vitamins and growth substances [10, 11]. These are manifested in metabolites formed in plant tissues and directly influence the growth and development processes. Furthermore, K has an important role in the translocation of photosynthates from sources to sinks [12]. Notable improvements in cotton yield and quality resulting from K input were reported by Mullins *et al*., [13] and Cassman *et al*., [14]. These may be reflected in distinct changes in seed weight and quality. Pettigrew [15], stated that the elevated carbohydrate concentrations remaining in source tissue, such as leaves, appear to be part of the overall effect of K deficiency in reducing the amount of photosynthate available for reproductive sinks and thereby producing changes in yield and quality seen in cotton.

Several approaches have been tried rise to cotton conductivity. Application of plant growth regulators, particularly growth retardants (PGR) may maintain internal hormonal balance, efficient sink source relationship and thus enhance crop productivity [16]. Mepiquat chloride (Pix) has been found to restrict the vegetative growth and thus enhance reproductive organs [2]. Fan *et al*., [17] indicated that higher photosynthetic efficiency, good population type and canopy structure with dwarf plants, short sympodia, smaller leaves and bigger bolls could be obtained by chemical regulation (Pix).

Table 1: Mechanical and chemical analysis of soil samples

Season	I	II
Mechanical analysis[a]		
Clay (%)	43.00	46.46
Silt (%)	28.40	26.38
Fine sand (%)	19.33	20.69
Coarse sand (%)	4.31	1.69
Texture	Clay loam	Clayloam
Chemical analysis[b]		
Organic matter (%)	1.83	1.92
Calcium carbonate (%)	3.00	2.73
Total soluble salts (%)	0.13	0.13
pH (1:2.5)	8.10	8.08
Total nitrogen (%)	0.12	0.12
Available nitrogen (mg/kg soil)	50.00	57.50
Available phosphorus (mg/kg soil)	15.66	14.19
Available potassium (mg/kg soil)	370.00	385.00
Calcium (meq/100 g)	0.20	0.20

[a]According to Kilmer and Alexander [18],
[b]According to Chapman and Pratt [19],
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

In the present study, an attempt was made to investigate the effects of nitrogen fertilization rate and foliar application of potassium and Pix, during square initiation and boll setting stage on cottonseed, protein and oil yields and on oil properties and fatty acid profiles of oil in the seed of Egyptian cotton (*Gossypium barbadense* L., cv. Giza 86), because a suitable management practice for application of N, K and Pix to optimize these traits has not yet been developed.

MATERIALS AND METHODS

Two field experiments were conducted at the Agricultural Research Center, Ministry of Agriculture in Giza (30°N, 31° :28'E and 19 m altitude), Egypt using the cotton cultivar "Giza 86" (*Gossypium barbadense* L.) in two successive seasons. The soil type in both seasons was a clay loam. Average mechanical analysis [18] and chemical characteristics [19], for soil in both seasons is illustrated in Table 1. Each experiment included 16 treatment combinationsof the following: (i) Two nitrogen rates (95.2 and 142.8 kg of N/ha) were applied as ammonium nitrate with lime (NH_4NO_3 + $CaCO_3$, 33.5% N) at two equal doses, 6 and 8 weeks after sowing. Each application (in the form of pinches beside each hill) was followed immediately by irrigation. (ii) Four K rates (0.0, 400, 800 and 1200 ppm of K_2O) were applied as potassium sulfate (K_2SO_4, "48% K_2O"). Each was foliar sprayed twice, 70 and 95 days after planting (during square initiation and bolling stage) and the solution volume was 960 L/ha. (iii) Two rates from the PGR, 1,1-dimethylpiperidinium chloride (mepiquat chloride or

Table 2: Treatments number and summary

Treatment No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
N rate (kg/ha)	95.2	95.2	95.2	95.2	95.2	95.2	95.2	95.2	142.8	142.8	142.8	142.8	142.8	142.8	142.8	142.8
K_2O rate (ppm)	0.0	0.0	400	400	800	800	1200	1200	0.0	0.0	400	400	800	800	1200	1200
Pix rate (ppm)	0.0	50 & 25	0.0	50 & 25	0.0	50 & 25	0.0	50 & 25	0.0	50 & 25	0.0	50 & 25	0.0	50 & 25	0.0	50 & 25

"Pix") were foliar sprayed twice, (75 days after planting at 0.0 or 50 ppm and 90 days after planting at 0.0 and 25 ppm), where the solution volume was also 960 L/ha. The K_2O and PGR were both applied to the leaves with uniform coverage using a knapsack sprayer. 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.

A randomized complete block design with four replications was used. Seeds were planted in plots 1.95 m x 4.0 m. (after the precaution of border effect was taken into consideration) on April 3rd and 8th in the first and second seasons, respectively. The size consisted of three ridges. Hills were spaced at 25 cm apart on one side of the ridge and seedlings were thinned to two plants/hill 6 weeks after planting, providing plant density of 123,000 plants/ha. Total irrigation amount during the growing season (surface irrigation) was about 6,000 m^3/ha. The first irrigation (after sowing irrigation) was applied 3 weeks after sowing and the second one was 3 weeks later. Thereafter, the plots were irrigated every 2 weeks until the end of the season, thus providing a total of nine irrigations. On the basis of soil test results, phosphorus fertilizer was applied at the rate of 54 kg P_2O_5 ha^{-1} as calcium superphosphate during land preparation and potassium fertilizer was applied at the rate of 57 kg K_2O ha^{-1} as potassium sulphate before the first irrigation (the recommended level for semi-fertile soil). Pest and weed management were carried out during the growth season, according to local practice performed at the experimental station.

Total cotton yield/plot was determined by first hand-picking on September 20 and 27 with final picking on October 5 and 12 in the first and second seasons, respectively. At harvest, total cotton yield/plot was determined. Following ginning, the cottonseed yields were determined in kg/ha, along with seed index weight in g/100 seeds. 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 [20]; (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 [21]; (iii) oil quality traits, i.e., refractive index, acid value, saponification value, unsaponifiable matter and iodine value were determined according to methods described by AOCS [22] 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 after acidification of the saponifiable materials. The free fatty acids were methylated with diazomethane [23]. The fatty acid methyl esters were analyzed by a Hewlett Packard model 5890 gas chromatograph (Palo Alto, CA) equipped with dual flame-ionization detectors. The separation procedures were similar to those reported by Ashoub *et al*., [24] as follows: The chromatograph was fitted with an FFAP (crosslinked) 30 m (length) x 0.32 mm (column i.d.) x 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.

Statistical analysis: Data obtained for the cottonseed yield and seed index were statistically analyzed factorially according to procedures outlined by Snedecor and Cochran [25] and the least significant difference (LSD) 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: Seed yield per hectare significantly ($p<0.05$) increased (as much as 13.03%) due to raising the

Table 3: Effect of N rate and foliar application of K and a plant growth retardant "Pix" on cottonseed yield, seed index, seed oil, seed protein, oil and protein yields

Treatments	Cottonseed yield (kg/ha)[a]	Seed index (g)[a]	Seed oil (%)[b]	Oil yield (kg/ha)[b]	Seed protein (%)[b]	Protein yield (kg/ha)[b]
N-rate (kg/ha)						
95.2	1862.4	10.09	19.73	367.5	22.24	414.2
142.8	2105.0[d]	10.32[d]	19.60	413.0[d]	22.44[d]	472.2[d]
LSD 0.05[c]	78.78	0.075	-	-	-	-
SD[c]	-	-	0.167	33.65	0.113	35.5
K_2O-rate (ppm)						
0, control	1804.4	10.03	19.49	351.6	22.32	402.9
400	1985.2[d]	10.19[d]	19.61	389.3[d]	22.32	443.1
800	2047.7[d]	10.27[d]	19.73[d]	404.2[d]	22.34	457.7[d]
1200	2097.6[d]	10.32[d]	19.83[d]	415.8[d]	22.37	469.3[d]
LSD 0.05[c]	111.41	0.106	-	-	-	-
SD[c]	-	-	0.129	35.06	0.165	41.87
Pix-rate (ppm)						
0, control	1891.8	10.13	19.61	371.1	22.31	422.1
50 & 25	2075.6[d]	10.27[d]	19.72	409.4[d]	22.37	464.4[d]
LSD 0.05[c]	78.78	0.075	-	-	-	-
SD[c]	-	-	0.170	36.11	0.151	41.35

[a]Combined statistical analysis from the two seasons, [b]Mean data from a four replicate composites for the two seasons,
[c]LSD = Least significant differences, SD = 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

N-rate from 95.2 to 142.8 kg of N/ha (Table 3). This could be attributed to the fact that N is an essential nutrient in creating the plant dry matter, as well as many energy-rich compounds which regulate photosynthesis and plant production [3]. There is an optimal relationship between the nitrogen content in the plant and CO_2 assimilation [26], where decreases in CO_2 fixation are well documented for N-deficient plants. Nitrogen deficiency is associated with elevated levels of ethylene (which increase boll shedding), suggesting ethylene production in response to N-deficiency stress [8]. These results agreed with those obtained by Brar *et al*., [27], when N was applied up to 150 kg/ha and Ram *et al*., [28], when N was applied up to 100 kg/ha.

Potassium application significantly increased cottonseed yield per hectare, where the three concentrations applied (400, 800 and 1200 ppm of K_2O) proved to excel the control (by 10.02-16.25%). Nevertheless, the differences between the effects of the three concerned K_2O rates were statistically insignificant; with the exception of the 1200 ppm concentration which proved to produce significantly higher cottonseed yield per hectare (5.66%) than the 400 ppm concentration. In general, it could be stated that the highest K_2O concentration (1200 ppm) was numerically better than the other two concentrations (400 or 800 ppm). These increases could be due to favorable effects of this nutrient on yield components such as number of opened bolls/plant, boll weight, or both, leading to higher cotton yield. Zeng [29] indicated that, K fertilizer reduced boll shedding. Pettigrew [15] stated that, the elevated carbohydrate concentrations remaining in source tissue, such as leaves, appear to be part of the overall effect of K deficiency in reducing the amount of photosynthate available for reproductive sinks and thereby producing changes in boll weight. Cakmak *et al*., [12] found that, potassium nutrition had pronounced effects on carbohydrate partitioning by affecting either phloem export of photosynthates (sucrose) or growth rate of sink and/or source organs. Mullins *et al*., [30] evaluated cotton (*Gossypium hirsutum*) yield under a long-term surface application of K at 60-180 lb K_2O/acre and found that K application increased yield. The obtained results confirmed those of Howard *et al*., [31] and Gormus [32].

Application of the plant growth retardant Pix significantly increased seed yield per hectare (by 9.72%), as compared with untreated plants. Such increases could be due to that, application of Pix may maintain internal hormonal balance, efficient sink source relationship and thus enhance crop productivity [16]. Pix have been found to restrict the vegetative growth and thus enhance reproductive organs by allowing plants to direct more energy towards the reproductive structure [2]. Also, such increases may be due to increase photosynthetic activity of leaves when this substance is applied [33]. This means that bolls on treated cotton plants would have a larger photosynthetically-supplied sink of carbohydrates and other metabolites than did those on untreated cotton plants. Results agreed with those obtained by Mekki [34], when Pix was applied at 100 ppm and Ram *et al*., [28], when Pix was applied at 50 ppm.

Seed index: Seed index significantly increased by adding the high N-rate (Table 3). This may be due to increased photosynthetic activity which increases accumulation of metabolites, with direct impact on seed weight. Reddy *et al*., [35], in a pot experiment under natural environmental conditions, where 20-day old cotton plants received 0, 0.5, 1.5 or 6 mM NO_3, found that, net photosynthetic rates, stomatal conductance and transpiration were positively correlated with leaf N concentration. Similar findings were reported by Palomo *et al*., [36], when N was applied at 40-200 kg/ha and Ali and El-Sayed [37], when N was applied at 95-190 kg/ha.

Seed index significantly increased with K application at all the three concentrations, over the control. The highest rate of K_2O (1200 ppm) showed the highest numerical value of seed index although it differ significantly from the value of the lower rate (400 ppm). Possible explanation for increasing seed index due to the application of K may be due in part to its favorable effects on photosynthetic activity rate of crop leaves [11] and CO_2 assimilation, which improves mobilization of photosynthates and directly influences boll weight that directly effect seed weight. This finding corroborated the results obtained by Sabino *et al*., [38] and Ghourab *et al*., [39]. Application of Pix, significantly increased seed index over the untreated control. Increased seed weight as a result of Pix applications may be due to increase in photosynthetic activity which stimulates photosynthetic activity and dry matter accumulation [33] and in turn increases formation of fully-mature seed and thus increases seed weight. This finding was in good accordance with those obtained by Mekki [34].

Seed oil content and yield: Seed oil content was slightly decreased when additional N was applied, but oil yield per hectare (total production) significantly increased (by 45.5 kg oil/ha), which is attributed to the significant increase in cottonseed yield (Table 3). Nitrogen is an essential nutrient in creating the plant dry matter, as well as many energy-rich compounds which regulate photosynthesis and plant production [3], thus influencing boll development, increasing the number of bolls/plant and boll weight. Synthesis of fat requires both N and carbon skeletons during the course of seed development [4]. Similar results were obtained by Froment *et al*., [40], in linseed and Zubillaga *et al*., [41], in sunflower.

Application of K at all the three concentrations tended to increase numerically the seed oil content and oil yield per hectare over the control (by 37.7-64.2 kg oil/ha), but was statistically significant only for 800 and 1200 ppm K_2O concentrations on the seed oil content and with K application at all the three concentrations on the oil yield per hectare. The highest rate of K (1200 ppm K_2O) showed the highest numerical values of seed oil content and oil yield per hectare compared with the other two concentrations (400 and 800 ppm K_2O). This could be attributed to the role of K in biochemical pathways in plants. Pettigrew [15] stated that, the elevated carbohydrate concentrations remaining in source tissue, such as leaves, appear to be part of the overall effect of K deficiency in reducing the amount of photosynthate available for reproductive sinks and thereby producing changes in yield and quality seen in cotton. Madraimov [42] indicated that, increasing the rates of applied K_2O from 0 to 150 kg/ha produced linear increases in cottonseed oil contents. Previously, favorable effects of K on seed oil content and oil yield were mentioned by Fan *et al*., [17] and Abou El-Nour *et al*., [43]. They reported that increasing K supply to maternal cotton plants increased crude fat content of seed.

Application of Pix resulted in an insignificant increase in seed oil content over that of the control. Also significantly increased the seed oil yield per hectare compared with the untreated control (by 38.3 kg oil/ha). 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 Pix [17]. This result agreed with those obtained by Mekki and El-Kholy [44], in rape.

Seed protein content and yield: High N-rate increased significantly the seed protein content and yield per hectare (by 58.0 kg protein/ha) (Table 3). Stitt [45] indicated that nitrate (NO_3^-) induces genes involved in different aspects of carbon metabolism, including the synthesis of organic acids used for amino acid synthesis. These results suggest that the high N rate increases the amino acids synthesis in the leaves and this stimulate the accumulation of protein in the seed. The present results confirmed the findings of Patil *et al*., [46].

Potassium tended to increase insignificantly the seed protein content compared with untreated control, when applied at 800 and 1200 ppm K_2O. Applied K at all rates also, increased numerically the protein yield per hectare (by 40.2-66.4 kg protein/ha), resulting from an improvement in both cottonseed yield and seed protein content. The increase in protein yield per hectare was statistically significant when applied the 800 and 1200 ppm K_2O concentrations. Best protein yield was obtained at the high K concentration (1200 ppm K_2O)

Table 4: Effect of N rate and foliar application of K and a plant growth retardant "Pix" on seed oil properties[a]

Treatments	Refractive index	Acid value	Saponification value	Unsaponifiable matter (%)	Iodine value
N-rate (kg/ha)					
95.2	1.4684	0.1339	190.84	0.3762	128.89
142.8	1.4695	0.1313[c]	189.74	0.3913	131.14
SD[b]	0.00118	0.00259	1.453	0.01786	3.349
K_2O-rate (ppm)					
0, control	1.4682	0.1352	190.78	0.3675	125.79
400	1.4689	0.1337	190.06	0.3825	130.30[c]
800	1.4692	0.1315[c]	190.25	0.3875[c]	131.59[c]
1200	1.4694	0.1300[c]	190.07	0.3975[c]	132.39[c]
SD[b]	0.00129	0.00217	1.526	0.01707	2.468
Pix-rate (ppm)					
0, control	1.4683	0.1331	190.62	0.3750	128.28
50 & 25	1.4696[c]	0.1321	189.96	0.3925[c]	131.75[c]
SD[b]	0.00110	0.00289	1.658	0.01721	3.036

[a]Mean data from a four replicate composites for the two seasons, [b]SD = Standard deviation, [c]Significant at 0.05 level

compared with the other two concentrations (400 and 800 ppm K_2O). This could be attributed to the role of K in biochemical pathways in plants. Potassium has favorable effects on metabolism of nucleic acids and proteins[10, 11]. These are manifested in metabolites formed in plant tissues and directly influence the growth and development processes and thereby producing changes in yield and quality seen in cotton. These results were in good agreement with those obtained Abou El-Nour *et al*., [43] and Ghourab *et al*., [39].

Seed protein content was increased insignificantly, while seed protein yield per hectare was significantly increased (by 42.3 kg protein/ha) in plants treated with Pix compared with the untreated control. 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 [47]. Also, for the favorable and significant effect of Pix on cottonseed yield. These results were confirmed by Abdel-Al *et al*., [48].

There was no clear relationship between protein and oil, in this which may be due to low application doses not sufficiently great enough to allow expression of the expected inverse relationship between oil and protein.

Seed oil properties: The seed oil refractive index, unsaponifiable matter and iodine value tended to increase, while the oil saponification value and acid value tended to decrease insignificantly by raising N-rate (Table 4). The increase in unsaponifiable matter is beneficial as it increases the oil stability. Narang *et al*., [49] indicated that, N application increased the oil-quality index (iodine number) in rape.

Application of K at different concentrations tended to increase the seed oil refractive index, unsaponifiable matter and iodine value and to decrease the oil saponification value and acid value, numerically, compared with the untreated control, especially when applied K at the high concentration (1200 ppm K_2O). The effect was significant for the two concentrations 800 and 1200 ppm K_2O on acid value and unsaponifiable matter and for all different concentrations on iodine value. The effect of K_2O-concentrations on oil refractive index were very limited. Potassium is an essential nutrient and an integral component of several important compounds in plant cells. This attributed to the role of K in biochemical pathways in plants, where K acts as an activator for several enzymes involved in carbohydrates metabolism [50]. These may be reflected in distinct changes in seed oil quality. Mekki *et al*., [51] stated that, foliar application with K (0 or 3.5% K_2O) on sunflower at the seed-filling stage, decreased oil acid value. Froment *et al*., [40] in linseed found that, the iodine value, which indicates the degree of unsaturation of the final oil, was highest in treatment receiving extra K.

Application of Pix tended to increase significantly the oil refractive index, unsaponifiable matter and iodine value, while tended to decrease insignificantly the oil acid value and saponification value, compared with the untreated control. Application of plant growth regulators, particularly growth retardants may maintain internal hormonal balance and efficient sink source relationship [16]. This may be reflected in distinct changes in seed oil quality.

Oil fatty acids composition: The oil saturated fatty acids, lauric, myristic, palmitic and the total ones decreased, while capric and stearic increased by raising N-rate (Table 5). The effect was significant only on palmitic acid, which was the dominant saturated fatty acid. Low content of saturated fatty acids is desirable for edible uses. The total unsaturated fatty acids (oleic and linoleic) and the ratio between total unsaturated fatty acids and total

Table 5: Effect of N rate and foliar application of K and a plant growth retardant "Pix" on the relative percentage of saturated fatty acids[a]

Treatments	Capric	Lauric	Myristic	Palmitic	Stearic	Total
	Relative % of saturated fatty acids					
N-rate (kg/ha)						
95.2	0.0684	0.0680	0.6912	21.77	2.157	24.7526
142.8	0.0691	0.0666	0.6450	20.18[c]	2.969	22.9345
SD[b]	0.00929	0.00649	0.45113	1.446	0.4705	2.28338
K_2O-rate (ppm)						
0, control	0.0775	0.0745	1.3075	22.40	2.602	26.4670
400	0.0722	0.0698[c]	0.6750[c]	21.02	1.955[c]	23.7920[c]
800	0.0648[c]	0.0632[c]	0.3500[c]	20.52[c]	1.905[c]	22.9030[c]
1200	0.0605[c]	0.0618[c]	0.3400[c]	19.96[c]	1.790[c]	22.2122[c]
SD[b]	0.00659	0.00384	0.17971	1.477	0.3690	1.92554
Pix-rate (ppm)						
0, control	0.0739	0.0655	0.7750	21.97	2.336	25.2206
50 & 25	0.0636[c]	0.0691	0.5612	19.98[c]	1.790[c]	22.4665[c]
SD[b]	0.00752	0.00623	0.43717	1.296	0.3826	1.99777

[a]Mean data from a four replicate composite for the two seasons, [b]SD = Standard deviation, [c]Significant at 0.05 level

Table 6: Effect of N rate and foliar application of K and a plant growth retardant "Pix" on the relative percentage of unsaturated fatty acids[a]

Treatments	Oleic	Linoleic	Total	TU/TS[b] ratio
	Relative % of unsaturated fatty acids			
N-rate (kg/ha)				
95.2	21.59	53.65	75.24	3.069
142.8	22.99[d]	54.08	77.06	3.397
SD[c]	1.353	1.144	2.284	0.4030
K_2O-rate (ppm)				
0, control	21.26	52.26	73.53	2.790
400	22.11	54.10[d]	76.20[d]	3.228[d]
800	22.60	54.50[d]	77.09[d]	3.390[d]
1200	23.18	54.60[d]	77.78[d]	3.523[d]
SD[c]	1.370	0.634	1.925	0.3519
Pix-rate (ppm)				
0, control	21.27	53.51	74.77	2.984
50 & 25	23.31[d]	54.22	77.53[d]	3.482[d]
SD[c]	1.095	1.102	1.998	0.3496

[a]Mean data from a four replicate composite for the two seasons,
[b]TU/TS ratio = (total unsaturated fatty acids) / (total saturated fatty acids)
[c]SD = Standard deviation, [d]Significant at 0.05 level

saturated fatty acids (TU/TS) were increased (by 2.42 and 10.69%, respectively) by raising N-rate (Table 6). The effect was significant only on oleic acid. Linoleic acid was the most abundant unsaturated fatty acid. Holmes and Bennett [5] commented that, the fatty acid composition of rape oil is mainly under genetic control, but can be modified to some extent by N nutrition. Seo *et al*., [52] found that, when sesame was given 0-160 kg N, oleic acid content was highest at the highest N rates and linoleic acid content was highest at the intermediate rates. Khan *et al*., [53] indicated that, oleic acid increased by increasing levels of N added to rapeseed-mustard. Kheir *et al*., [54], in flax, found that the higher N-rate increased the percentage of unsaturated fatty acids and decreased saturated fatty acids in the seed oil.

Potassium applied at all concentrations resulted in a decrease in the total saturated fatty acids (capric, lauric, myristic, palmitic and stearic) compared with untreated control. Spraying plants with the high K concentration 1200 ppm K_2O gave the lowest total saturated fatty acids oil, compared with the other two concentrations (400 and 800 ppm). The effect was significant for the two concentrations 800 and 1200 ppm K_2O on capric and palmitic and for all different concentrations on lauric, myristic, stearic and the total saturated fatty acids. Potassium applied at all rates increased the total unsaturated fatty acid (oleic and linoleic) and TU/TS ratio (by 1.84-4.48 and 15.70-26.27%, respectively), compared with untreated control. Applied K at 1200 ppm K_2O gave the highest increment, followed by 800 ppm concentration. The effect was significant for all different concentrations on linoleic, the total unsaturated fatty acid and TU/TS ratio. Linoleic acid was the most abundant unsaturated fatty acid. The beneficial effect of applied K on TU and TU/TS ratio suggests that might be due to the regulated effect of K which acts as an activator on many enzymic processes, where some of these enzymes may affect the seed oil content from these organic matters. Seo *et al*., [52] found that, when sesame was given 0-180 kg K_2O, oleic acid content was the highest at the highest K rates and linoleic acid content was the highest at the intermediate rates. Salama [55] indicated that, K fertilizer applied to sunflower cv. IH-173, favoured fatty acid composition (high oleic acid content). Mekki *et al*., [51] stated that, foliar application with K on sunflower increased the oleic acid fatty acid. Froment *et al*., [40] in linseed oil found that, linoleic acid content was greatest in treatment receiving extra K.

Application of Pix resulted in a decrease in the total saturated fatty acids, the abundant saturated fatty acid palmitic, capric, myristic and stearic while resulted in an increase in lauric saturated fatty acid, compared to untreated control. The effect was significant only on capric, palmitic, stearic and the total ones. Application of Pix resulted in an increase in total unsaturated fatty acids (oleic and linoleic) and TU/TS ratio (by 3.69 and 16.69%, respectively), over the control. The effect was significant only on the total unsaturated fatty acid, oleic and the ratio between total unsaturated fatty acids and total saturated fatty acids (TU/TS). The stimulatory residual effects of application Pix on TU and TU/TS ratio was probably due to its favourable effects on fundamental metabolic reactions in plant tissues and would have direct impact through utilization in growth processes which are reflected in distinct changes in seed oil quality. Some of these changes may affect the seed oil fatty acids composition, which may attribute to their encouraging effects on enzymes that catalyzed the biosynthesis of the unsaturated fatty acids. Mekki and El-Kholy [44] investigate the response of oil seed rape to 0, 200 or 400 ppm Pix and found that; palmitic acid was only decreased by using 400 ppm Pix as compared with 200 ppm treatmrnt or control plants.

Low content of saturated fatty acids is desirable for edible uses. Also, regarding oil quality, higher levels of linoleic acid and oleic acid are considered good for oil quality [56].

During the two growing seasons no significant interactions were found between the variables in the present study (N-rate and foliar application of K and the plant growth retardant Pix) on quantitative and qualitative characters under investigation. Regarding insignificant interaction effects, the F ratios worthy exceed unity, but within the level of probability take p#0.05, they did not show significance.

CONCLUSIONS

From the findings of the present study, it seems rational to recommend application of N at a rate of 142.8 kg/ha, combined with spraying cotton plants with K twice (especially K_2O-concentration of 1200 ppm) and application of Pix, also twice (at a rate of 50 and 25 ppm, respictively). These treatments, would beneficially affect not only the quantity (to obtain higher oil and protein yields) but also the quality of oil (as indicated by better fatty acid profile in the oil of cotton) of cottonseed. In comparison with the ordinary cultural practices adopted by Egyptian cotton producers, it is quite apparent that applications such treatments could bring about better impact on cottonseed yield, seed protein content, oil and protein yields, oil refractive index, unsaponifiable matter, iodine value and unsaturated fatty acids. On the other hand, there was a decrease in acid oil value and saponification value.

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