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Cottonseed Yield, Seed Viability and Seedling Vigour as Affected by Nitrogen, Potassium, Phosphorus, Zinc and a Plant Growth Retardant

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ABSTRACT

Seed vigour and viability are important components influencing seedling establishment, crop growth, and productivity. Cottonseed quality is affected to a large extent by the indeterminate growth habit of a cotton plant, which allows seed to set and develop over an extended period. Two field experiments were conducted at the Agricultural Research Center, Giza, Egypt, during two consecutive seasons on Egyptian cotton (*Gossypium barbadense*) cv. 'Giza 86'. The aim was to identify production treatments, which may improve seed yield and quality. The first study investigated the effect of soil N-fertilization (at 95.5 and 142.8 kg N/ha) and foliar application of potassium (at 0.0, 400, 800 or 1200 ppm K_2O, applied twice; 70 and 95 days after planting) and the plant growth retardant (PGR) mepiquat chloride (applied twice; 75 days after planting at 0.0 or 50 ppm, and 90 days after planting at 0.0 and 25 ppm). The second studied the effect of soil potassium fertilization (at 0.0 and 57.1 kg K_2O/ha, eight weeks after sowing) and foliar application of chelated zinc (applied twice, at 70 and 85 days after sowing, at 0.0 and 60 ppm) and phosphorus (at 0.0, 600, 1200 and 1800 ppm P_2O_5; applied twice, 80 and 95 days after sowing). The first experiment showed that seed yield/plant and seed yield/plot, seed weight, seed viability, seedling vigour and cool germination test performance, were all found to increase due to the addition of the high N-rate (142.8 kg N/ha). Application of the three potassium concentrations and mepiquat chloride also showed similar effects. Under the conditions of this study, applying N at 142.8 kg/ha combined with spraying cotton plants with K_2O at 1200 ppm and also with mepiquat chloride at 50 and 25 ppm can be recommended to improve seed yield, as well as seed viability, and seedling vigour in the next season. In the second experiment seed yield/plant, seed yield/plot, seed weight, seed viability, seedling vigour, and cool germination test performance increased as a result of the addition of K_2O, and from the application of Zn, and P_2O_5 at different concentrations. Under the conditions of this study, applying K_2O at 57.1 kg/ha and spraying cotton plants with Zn at 60 ppm and also with P_2O_5 at 1800 ppm can be recommended to improve seed yield, as well as seed viability, and seedling vigour in the next season.

Keywords: cool germination test performance, hypocotyl and radicle length, mepiquat chloride, seedling fresh and dry weight, seed weight

INTRODUCTION

Sowing is a critical time in the life cycle of any crop and seeds are frequently exposed to adverse conditions that may compromise the establishment of seedlings in the field (Albuquerque and de Carvalho 2003). Any factor (biotic and/or environmental) that negatively affects seed vigour and viability during seed development will have adverse consequences on crop production, especially when seeds are sown under environmentally stressful conditions (Welch 1995). Both size and number of seeds, produced by maternal plants, are most likely determined by their nutritional status at the time of flowering and bud initiation. Often, the number of sink organs is the yield component that is affected mostly by mineral nutrients (Borowski 2001). Plant nutrition using a balanced fertilization program with both macro- and micronutrients has become very important in the production of high quality seed. Also, some improvement may be achieved through the use of plant growth regulators (PGRs).

Under nitrogen (N) deficiency, a considerably larger proportion of dry matter (photosynthates) is partitioned to roots than shoots, leading to reduced shoot/root dry weight ratios (Engels and Marschner 1995). Additionally, with a dynamic crop like cotton, excess N serves to delay maturity, promote vegetative tendencies, and usually results in lower yields (McConnell *et al.* 1996; Rinehardt *et al.* 2004). Therefore, errors made in N management that can impact the crop can be through either deficiencies or excesses. If an N deficiency is developing in a cotton crop, it is not particularly difficult to diagnose and correct. Excess N fertility levels, which, can be damaging to final crop productivity, are subtler to detect, and are difficult to correct (Silvertooth and Norten 1998). Ansari and Mahey (2003) evaluate the effects of N level (0,40, 80, 120 and 160 kg/ha) on the yield of American cotton (*Gossypium hirsutum*) cv. F846 and desi cotton (*G. arboreum*) cv. LD327 and found that seed yield increased with increasing N level up to 80 kg/ha.

Potassium (K) increases the photosynthetic rates of crop leaves, CO_2 assimilation and facilitating carbon movement (Sangakkara *et al.* 2000). The high concentration of K^+ is thought to be essential for normal protein synthesis. The requirement of cotton for K increases with the beginning of bud formation stage. The physiological role of K during the fruit formation and maturation periods is mainly expressed in carbohydrate metabolism and translocation of metabolites from leaves and other vegetative organs to developing bolls. Pettigrew (1999) stated that the elevated carbohydrate concentrations remaining in source tissue, such as leaves, appear to be part of the overall effect of K defici-

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ency in reducing the amount of photosynthate available for reproductive sinks and thereby producing changes in yield and quality seen in cotton. Studies have shown increased yield and quality of cotton in response to K fertilization. Notable improvements in cotton yield and quality resulting from K input were reported by Ghourab *et al.* (2000), Gormus (2002), Aneela *et al.* (2003), Pervez *et al.* (2004) and Pettigrew *et al.* (2005). These may be reflected in distinct changes in seed weight and quality.

Considerable interest exists for the use of plant growth regulators (PGRs) in cotton production. These compounds represent diverse chemistries and modes of action, and provide numerous possibilities for altering crop growth and development (Cothren 1994). An important objective for using PGRs in cotton is to balance vegetative and reproductive growth as well as to improve yield and its quality (Zhao and Oosterhuis 2000). Techniques have been developed to monitor the growth and development of the crop, with specific emphasis on the fruiting characteristics. In this connection, Wang *et al.* (1995) stated that application of the plant growth retardant mepiquat chloride to the cotton plants at squaring decreased the partitioning of assimilates to the main stem, the branches and their growing points, and increased partitioning to the reproductive organs and roots. Also, they indicated that, from bloom to boll setting, mepiquat chloride application was very effective in restricting the vegetative growth of the cotton canopy and in promoting the partitioning of assimilates into reproductive organs. Kumar *et al.* (2004) evaluated the effects of mepiquat chloride (500, 750 and 1000 ppm) on hybrid cotton (*G. hirsutum* cv. 'DHH-11'). These treatments increased the values for photosynthetic rate, stomatal conductance, transpiration rate, total chlorophyll content, nitrate reductase activity, number of bolls/plant, boll weight and yield.

Zinc is an essential component of a number of dehydrogenases, proteinases, and peptidases; thus Zn influences electron transfer reactions including those of the Krebs cycle, and hence affecting the plant's energy production (Sharma *et al.* 1982). Further, Zn is required in the biosynthesis of tryptophan, a precursor of the auxin indole-3-acetic acid (IAA) (Oosterhuis *et al.* 1991), which is the major hormone, inhibits abscission of squares and bolls. Zinc is also involved in formation of growing sink organs by its effect on fertilization and abortion after fertilization, where the development and viability of pollen grains is adversely affected by Zn deficiency (Sharma *et al.* 1990). Zinc deficiency symptoms include: small leaves, shortened internodes giving the plant a stunted appearance, reduced boll set and small boll size (Oosterhuis *et al.* 1991). Zinc deficiency occurs in cotton on high-pH soils, particularly where topsoil has been removed in preparing fields for irrigation and thereby exposing the Zn-deficient subsoil. Also, Zn deficiencies have occurred where high rates of P are applied. The high P rates in the plant interfere with the utilization of Zn (Oosterhuis *et al.* 1991).

Phosphorus (P) has been found to be the life-limiting element in natural ecosystems because it is often bound in highly insoluble compounds and hence it becomes unavailable for plant uptake or utilization. The high soil pH (>7.6) and the high quantities of $CaCO_3$ result in precipitation of P, which reduces the soluble P supply. Its deficiency tends to limit the growth of cotton plants, especially when plants were deprived from phosphorus at early stages than later stages of growth (Hearn 1981). Under P deficiencies a reduction in the rate of leaf expansion and in photosynthetic rate per unit of leaf area occurred (Rodriguez *et al.* 1998).

Obtaining high-quality cotton seed under Egyptian conditions is difficult. Therefore, the objective of the present study was to evaluate the effects of N-fertilization rate and foliar application of K_2O and the plant growth retardant mepiquat chloride in the first experiment. Furthermore, we also evaluated the addition of K fertilization and foliar application of chelated Zn and P in the second experiment on seed yield, and seed quality as measured by viability, seedling vigour and the cool germination test performance of Egyptian cotton (*Gossypium barbadense* L., cv. 'Giza 86'). The intention was to identify treatments that may improve seed yield and quality, thereby improving emergence and seedling growth, which in turn positively influence cotton yield in the next season.

Table 1 Mechanical and chemical analysis of soil samples.

Season	1999	2000
Mechanical analysis		
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	Clay loam
Chemical analysis		
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
Available zinc (mg/kg soil)	1.30	1.90
Calcium (meq/100g)	0.20	0.20

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 (*Gossypium barbadense* L.) cultivar 'Giza 86' in two seasons: 1999 and 2000. The soil type in both seasons was a clay loam. Average mechanical analysis (Kilmer and Alexander 1940) and chemical characteristics (Chapman and Pratt 1961) for soil in both seasons is illustrated in **Table 1**.

Experiment I: Nitrogen fertilization and foliar application of potassium and a plant growth retardant

Sixteen combined treatments were included: Two nitrogen rates (95.2 (ordinary) 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. 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 boll setting stage) and the solution volume was 960 L/ha. Two rates of the PGR, 1,1-dimethylpiperidinium chloride (mepiquat chloride or "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 (7.8 cm^3/plant). K_2O and PGR were both applied to all cotton leaves with uniform coverage using a knapsack sprayer. The application was carried out between 09.00 and 11.00 h. A summary of all treatments is shown in **Table 2**.

Experiment II: Potassium fertilization and foliar application of zinc and phosphorus

Sixteen combined treatments were included: two potassium rates, two zinc rates and four phosphorus rates. The potassium rates (0.0 and 57.1 kg of K_2O/ha) were applied as potassium sulfate (K_2SO_4, "48% K_2O"), eight weeks after sowing (as a concentrated band close to the seed ridge), and the application was followed immediately by irrigation. The zinc rates were applied (0.0 or 60 ppm of Zn) in chelated form [ethylenediaminetetraacetic acid (EDTA)], and each was foliar sprayed two times (70 and 85 days after sowing, "during square initiation and boll setting stage"). The phosphorus rates (0.0, 600, 1200 and 1800 ppm of P_2O_5) were applied as calcium super phosphate (15% P_2O_5), and each was foliar sprayed twice (80 and 95 days after sowing). Zn and K_2O were

Table 2 A summary of all treatments in Experiment I.

Treatment №	**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
Mepiquat chloride rate (ppm)	0.0	25, 50	0.0	25, 50	0.0	25, 50	0.0	25, 50	0.0	25, 50	0.0	25, 50	0.0	25, 50	0.0	25, 50

Table 3 A summary of all treatments in Experiment II.

Treatment №	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
K_2O rate (kg /ha)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	57.1	57.1	57.1	57.1	57.1	57.1	57.1	57.1
Zn rate (ppm)	0.0	0.0	0.0	0.0	60	60	60	60	0.0	0.0	0.0	0.0	60	60	60	60
P_2O_5 (ppm)	0.0	600	1200	1800	0.0	600	1200	1800	0.0	600	1200	1800	0.0	600	1200	1800

both applied to all cotton leaves with uniform coverage at a volume solution of 960 L/ha (7.8 cm^3/plant), using a knapsack sprayer. The application was carried out between 09.00 and 11.00 h. A summary of all treatments is shown in **Table 3**.

Crop management and measurement of results

Both experiments used the crop management procedures and tests to determine treatment effects. A randomized complete block design with four replications was used. Seeds were planted on the 3rd and 20th of April in 1999 and 2000 seasons, respectively. The plot size was 1.95 m × 4 m, including three ridges (after precaution of border effect was taken into consideration). Hills were spaced 25 cm apart on one side of the ridge, and seedlings were thinned to two plants/hill 6 weeks after planting, providing a 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) 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. In every experiment the other fertilization, insect and weed management were carried out during the growth season, according to local practice performed at the experimental station.

At harvest, seed cotton yield of 10 randomly chosen plants from each plot was harvested and laboratory-ginned to determine seed yield in g/plant. Total seed cotton yield of each plot (including the 10-plant sub-sample) was lab-ginned to determine seed yield in kg/plot. A random sample of 100 g of seed from each treatment plot was taken to determine seed weight (weight of 100 seed in g) and to evaluate seed quality in terms of seed viability, cool germination test performance and seedling vigour tests.

Seed viability

Germination was evaluated using the International Rules of Seed Testing (ISTA 1976) in the Seed Research Unit, Central Administration of Seed, Agricultural Research Center, Giza, Egypt. Aluminum dishes 17 cm in diameter and 3 cm deep were used and the sand substratum was sieved/washed/sterilized and kept moistened to 50% of water-holding capacity. Fifty seeds were planted in each dish, in sand depressions made with a standard puncher, and then covered with a top layer of 2 cm of loose moist sand. This was then leveled without touching the seed. To ensure proper gas exchange, top and bottom layers of sand were marked and loosened with a metal sand scraper. Each of the four replicates of each treatment included two dishes. Dishes were then incubated at 30 ± 1°C for 12 days. The following parameters were measured: (a) Germination velocity (first count): percentage of seeds which sprouted after four days of incubation. (b) Second germination count: percentage of seeds sprouted after eight days of incubation. This count is used to calculate germination rate index. (c) Total germination capacity (final count): total percentage of normal seedlings after 12 days of incubation, and (d) Germination rate index (GRI): was calculated according to Bartlett (1937) as follows:

$$\mathrm{GRI} = \frac{a + (a + b) + (a + b + c)}{n\,(a + b + c)}$$

where:

n = Number of counts.

Cool germination test performance

In this test the germinator was maintained at a constant temperature of 18 ± 1°C with sufficient humidity to prevent drying of the paper towel substratum (Byrd and Reyes 1967). Four paper towels represented each of the four replicates of each treatment, and in each towel 50 seeds were planted. Seeds were randomly placed on moist towels, as a standard germination test. Two towels were placed over the seeds before rolling. The towels were moistened, but not so wet, this was indicated by the fact that when pressing them, a film of water formed around the finger. Rolled towel tests were then set upright in wire mesh baskets in the germinator. Additional moisture was not needed during the test period. Two counts were made for germination: the first on the fourth, and the second on the seventh, day under test conditions.

Seedling vigour

Aluminum dishes similar to those described regarding the seed viability test were used to evaluate seedling vigour. Two dishes represented each of the four replicates of each treatment, and in each dish 50 seeds were planted. Ten seedlings were randomly taken from each dish after eight days of incubation at 30 ± 1°C to measure the following seedling vigour characters: (1) Length (in cm) of hypocotyl, radicle and entire seedling, and (2) Fresh and dry weights (g) of 10 seedlings. The 10 seedlings were weighed immediately to record fresh weight, and then oven-dried for 72 hours at 85°C to determine dry weight.

Statistical analysis

Data were analyzed as a factorial experiment (Snedecor and Cochran 1980). The L.S.D. test was used to identify the significance of differences among treatment means.

RESULTS AND DISCUSSION

Experiment I: Nitrogen fertilization and foliar application of potassium and a plant growth retardant

Seed yield

Seed yield/plant and seed yield/plot significantly increased (by as much as 12.82 and 13.30%, in the first season and by 12.78 and 13.32%, in the second season) by raising the N-rate from 95.2 to 142.8 kg of N/ha (**Table 4**). This could be attributed to the fact that N is an important nutrient controlling new growth and abscission of squares and bolls (Addicott and Lyon 1973). Nitrogen is also an essential nutrient in creating plant dry matter, as well as many energy-rich compounds which regulate photosynthesis and plant production (Wu *et al.* 1998), thus influencing boll development, increasing the number of bolls/plant and boll weight. Similar findings were obtained by Ram *et al.* (2001) when N was applied to cotton (*Gossypium hirsutum* L.) plants up to 100 kg/ha, McConnell and Mozaffari (2004) when N fertilizer was applied at 120 kg/ha and Wiatrak *et al.* (2006) when N fertilizer was applied at 67-202 kg/ha. On the other hand Boquet (2005) reported that increasing N from 90 to

157 kg/ha did not result in increased cotton yield in irrigated or rain-fed cotton.

In both years, all the three K concentrations (400, 800 and 1200 ppm of K_2O) significantly increased seed yield/plant (by 9.03-15.81; 11.57-17.07%, respectively) and seed yield/plot (by 8.92-15.78; 11.28-16.89%, respectively), compared to untreated control, with no statistically significant differences between them. The highest numerical increase in seed yield was achieved by applying a high K concentration (1200 ppm of K_2O). These increases could be due to favourable effects of this nutrient on yield components of number of opened bolls/plant and boll weight, leading to higher cotton yield. Zeng (1996) indicated that K fertilizer affects abscission and reduced boll shedding and it certainly affects yield. Cakmak *et al.* (1994) found that potassium nutrition has 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.* (1999) evaluated cotton yield under a long-term surface application of K at 60-180 kg K_2O/ha and found that K application increased yield. Results obtained here confirmed those obtained by Gormus (2002) when applying K_2O at the rates of 80, 160 and 240 kg K_2O/ha, Aneela *et al.* (2003) when applying 200 kg K_2O/ha, Pervez *et al.* (2004) under 62.5, 125, 250 kg K/ha, and Pettigrew *et al.* (2005) under K fertilizer (112 kg/ha).

Application of the plant growth retardant mepiquat chloride significantly increased seed yield/plant in the two seasons (by 10.47and 8.86%, respectively), and seed yield/plot (by 10.39 and 9.03%, respectively), as compared with untreated plants. Application of PGRs, particularly growth retardants may maintain internal hormonal balance, efficient sink source relationship and thus enhance crop productivity (Singh *et al.* 1987). Mepiquat chloride has been found by Pípolo *et al.* (1993) to restrict vegetative growth and thus enhance reproductive organs by allowing plants to direct more energy towards the reproductive structure (Fletcher *et al.* 1994; Kumar *et al.* 2004). This means that bolls on treated cotton would have a larger photosynthetically supplied sink of carbohydrates and other metabolites than did those on untreated cotton (Wang *et al.* 1995). Results here agree with those of Ram *et al.* (2001) who applied mepiquat chloride at 50 ppm and Kumar *et al.* (2004).

Seed weight

Seed weight significantly increased by adding the high N-rate in both years (**Table 4**). This may be due to increased photosynthetic activity, which increases accumulation of metabolites, with direct impact on seed weight. Reddy *et al.* (1996), 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. Ali and El-Sayed (2001) reported similar finding, when N was applied at 95-190 kg/ha.

Seed weight significantly increased with K application at all three concentrations, compared with the control in both years. Spraying plants with a high K concentration (1200 ppm of K_2O) produced the highest numerical seed weight. This may be due to its favourable effects on photosynthetic activity, improving mobilization of photosynthates (Pettigrew 1999) and directly influencing boll weight that generally coincide with seed weight. Results obtained here are confirmed by those of Sabino *et al.* (1999) in which an increase in seed weight was due to K application.

Application of the plant growth retardant mepiquat chloride significantly increased seed weight as compared to untreated control in both years. This indicates that treated cotton bolls had larger photosynthetically supplied sinks for carbohydrates and other metabolites than untreated bolls (Zhao and Oosterhuis 1999; Kumar *et al.* 2004), and in turn increases formation of fully mature seed and thus increases seed weight. These results agree with those of Lamas (2001) where an increase in seed weight was due to mepiquat chloride application.

Table 4 Effect of N-rate and foliar application of potassium and the plant growth retardant mepiquat chloride (MC) on seed yield/plant and seed yield/plot, and seed weight.

Treatments	Cotton seed yield (g/plant)		Cotton seed yield (kg/plot)		Seed weight (g/100 seed)	
	1999	2000	1999	2000	1999	2000
N-rate (kg/ha)						
95.2	19.65	18.57	1.494	1.411	10.20	9.97
142.8	22.17**	21.04**	1.685**	1.599**	10.43**	10.21**
L.S.D.						
0.05	1.211	1.270	0.0892	0.0985	0.124	0.105
0.01	1.618	1.696	0.1192	0.1315	0.166	0.140
K_2O-rate (ppm)						
0, control	19.16	17.81	1.458	1.356	10.12	9.93
400	20.89*	19.87*	1.588*	1.509*	10.30*	10.08*
800	21.40*	20.70**	1.624*	1.570**	10.38**	10.15**
1200	22.19**	20.85**	1.688**	1.585**	10.45**	10.19**
L.S.D.						
0.05	1.713	1.796	0.1262	0.1393	0.176	0.148
0.01	2.289	2.399	0.1686	0.1860	0.235	0.198
MC-rate (ppm)						
0, control	19.87	18.97	1.511	1.440	10.23	10.03
50 and 25	21.95**	20.65*	1.668**	1.570*	10.40*	10.15*
L.S.D.						
0.05	1.211	1.270	0.0892	0.0985	0.124	0.105
0.01	1.618	n.s.	0.1192	n.s.	n.s.	n.s.

n.s.: Not significant; * Significant at $P<0.05$; and ** Significant at $P<0.01$.

Seed viability, seedling vigour and cool germination test

Seed viability (as measured by germination velocity, second germination count, and total germination capacity), seedling vigour (as revealed by length of hypocotyls, radicle and entire seedling; as well as seedling fresh and dry weights) and cool germination test performance (four- and seven-day counts) significantly increased by adding high levels of N. Also, the same pattern was true with the application of the three K concentrations and the plant growth retardant mepiquat chloride in both years (**Tables 5** and **6**). However, the exceptions of this trend were in the case of the cool germination test performance (four and seven-day counts), and hypocotyl length, which did not significantly increase when K was applied at a low concentration (400 ppm of K_2O) in the 2000 season. The differences between the effects of the three concerned K_2O rates were statistically insignificant, with the exception of 1200 ppm in the first season, which produce a significant increase in seed viability relative to 400 ppm. Germination rate index was not significantly affected in either year by the N rate, three K concentrations or the plant growth retardant mepiquat chloride. Beneficial residual effects of a high N-rate, application of potassium at different concentrations and mepiquat chloride on seed viability, seedling vigour and cool germination test performance which are important in stand establishment, may be attributed to their favourable effects on increased seed weight associated with changes in its internal composition (Sharma *et al.* 1990; Taiz and Zeiger 1991; Welch 1995; Wiatrak *et al.* 2005). These effects are manifested in metabolites formed in plant tissues, and have direct impact through utilization in growth and development processes, which may be reflected in distinct changes in seed quality and weight. Speed *et al.* (1996) stated that seed density was positively associated with germination capability at 15°C. Gadallah (2000) indicated that viability, germination and seedling emergence were directly related to seed density for the *G. barbadense* cultivars. He pointed out that high seed density of all cultivars usually exhibited faster and more uniform rates of radicle emergence than low seed density. Seedlings from heavier seeds had greater accumulation of fresh and dry weight, and quality and vigour indices were

Table 5 Effect of N-rate and foliar application of potassium and the plant growth retardant mepiquat chloride MC) on seed viability and cool germination test performance.

Treatments	**Germination velocity (%)**		**Second germination count (%)**		**Total germination capacity (%)**		**Germination rate index (GRI unit)**		**Cool germination test performance (%)**			
									4-day count		**7-day count**	
	1999	**2000**	**1999**	**2000**	**1999**	**2000**	**1999**	**2000**	**1999**	**2000**	**1999**	**2000**
N-rate (kg/ha)												
95.2	75.06	74.06	81.94	80.56	83.56	82.25	0.655	0.655	33.13	32.00	71.13	68.94
142.8	79.69**	76.56*	85.88**	83.81**	87.06**	84.94**	0.657	0.655	35.31**	34.69**	73.56**	71.44**
L.S.D.												
0.05	2.007	1.938	1.851	1.965	1.775	1.688	n.s.	n.s.	1.419	1.666	1.626	1.706
0.01	2.681	n.s.	2.472	2.625	2.371	2.255	n.s.	n.s.	1.896	2.225	2.172	2.278
K_2O rate (ppm)												
0, control	73.63	72.13	80.63	79.00	82.38	80.88	0.654	0.654	32.25	31.38	69.75	68.00
400	76.88*	74.88*	83.50*	81.88*	85.00*	83.63*	0.656	0.654	34.38*	33.25	72.25*	70.25
800	78.75**	76.75**	85.13**	83.38**	86.13**	84.50**	0.657	0.656	34.75*	34.00*	73.50**	70.88*
1200	80.25**	77.50**	86.38**	84.50**	87.75**	85.38**	0.657	0.656	35.50*	34.75*	73.88**	71.63*
L.S.D.												
0.05	2.839	2.741	2.618	2.779	2.511	2.388	n.s.	n.s.	2.007	2.356	2.300	2.412
0.01	3.792	3.662	3.496	3.712	3.354	3.190	n.s.	n.s.	n.s.	n.s.	3.073	n.s.
MC-rate (ppm)												
0, control	75.44	74.25	82.19	80.94	83.75	82.63	0.655	0.655	33.38	32.44	71.31	69.25
50 and 25	79.31**	76.38*	85.63**	83.44*	86.88**	84.56*	0.657	0.655	35.06*	34.25*	73.38*	71.13*
L.S.D.												
0.05	2.007	1.938	1.851	1.965	1.775	1.688	n.s.	n.s.	1.419	1.666	1.626	1.706
0.01	2.681	n.s.	2.472	n.s.	2.371	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Table 6 Effect of N-rate and foliar application of potassium and the plant growth retardant mepiquat chloride (MC) on seedling vigour.

Treatments	**Hypocotyl length (cm)**		**Radicle length (cm)**		**Seedling length (cm)**		**Seedling fresh weight (g/10 seedling)**		**Seedling dry weight (g/10 seedling)**	
	1999	**2000**	**1999**	**2000**	**1999**	**2000**	**1999**	**2000**	**1999**	**2000**
N-rate (kg/ha)										
95.2	7.42	7.20	16.42	16.07	23.84	23.27	6.89	6.73	0.644	0.629
142.8	7.73**	7.51**	16.90**	16.49*	24.64**	23.99*	7.12**	6.97**	0.663**	0.647**
L.S.D.										
0.05	0.202	0.255	0.352	0.335	0.535	0.547	0.142	0.148	0.0126	0.0116
0.01	0.270	0.301	0.470	n.s.	0.714	n.s.	0.190	0.198	0.0168	0.0155
K_2O rate (ppm)										
0, control	7.29	7.07	16.09	15.74	23.38	22.81	6.79	6.64	0.635	0.618
400	7.58*	7.32	16.66*	16.30*	24.24*	23.62*	7.01*	6.86*	0.653*	0.640*
800	7.65*	7.46*	16.89**	16.49**	24.53**	23.95**	7.07**	6.91*	0.661**	0.646**
1200	7.80**	7.58*	17.01**	16.57**	24.80**	24.15**	7.15**	7.00**	0.666**	0.649**
L.S.D.										
0.05	0.286	0.319	0.498	0.474	0.756	0.773	0.201	0.210	0.0178	0.0165
0.01	0.382	n.s.	0.665	0.633	1.010	1.033	0.269	0.280	0.0238	0.0221
MC-rate (ppm)										
0, control	7.45	7.22	16.46	16.09	23.91	23.31	6.92	6.75	0.645	0.631
50 and 25	7.71*	7.49*	16.86*	16.46*	24.57*	23.95*	7.09*	6.95**	0.662**	0.645*
L.S.D.										
0.05	0.202	0.225	0.352	0.335	0.535	0.547	0.142	0.148	0.0126	0.0116
0.01	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.198	0.0168	n.s.

also higher than those from light seeds.

Field and Moony (1986) claimed that photosynthesis-nitrogen relationships are intrinsically complex due to the fact that photosynthesis represents an integrated operation of a series of biochemical and photobiological processes, requiring nitrogenous compounds. Further nitrogen is essential for plant protein synthesis. The most important plant protein is chlorophyll, which is indispensable for photosynthesis. Other important plant proteins include enzymes which act as catalysts in biochemical reactions, and seed reserve proteins (Bisson *et al.* 1994). Maiya *et al.* (2001) indicated that the large- and medium-sized seeds (>4.75 mm) recorded higher field emergence (>65%) and produced vigorous seedlings compared to smaller seeds (<4.75 mm). The shoot and root length of seedlings increased with an increase in seed size. Thus, heavier cottonseed has a higher growth potential than lighter seed.

Potassium application has favourable effects as an activator of several enzymes involved in carbohydrate metabolism and on the metabolism of nucleic acids, proteins, vitamins and growth substances (Bisson *et al.* 1994; Bednarz and Oosterhuis 1999). This may be reflected in distinct changes in seed weight and quality. However, metabolites formed in plant tissues directly influence growth and development processes. Rajeev *et al.* (2001) reported that K deficiency (<4 mM) decreased chlorophyll, nucleic acid and sugar fractions, and also decreased the activity of catalase. Vasudevan *et al.* (1997) studied the response of sunflower to K, P, and Zn along with recommended doses of N, P and K, and found that those nutrients increased the seed-quality parameters such as higher germination after accelerated ageing, higher speed of germination, higher shoot and root lengths, higher vigour index and seedling-growth rate compared with the control. No information on residual effects of K on cool germination test performance was found in the available literature on cotton plants.

Beneficial residual effects of mepiquat chloride on seed viability, seedling vigour and cool germination test performance may be due to their favourable effects on seed weight (Kumar *et al.* (2004). Wang *et al.* (1995) stated that the application of mepiquat chloride (at 50 or 100 mg kg^{-1}) to the cotton plants at squaring decreased the partitioning of assimilates to the main stem, the branches and their growing points, and increased partitioning to the reproductive organs and roots. Also, they indicated that, from bloom to boll setting, mepiquat chloride application was very effective in promoting the partitioning of assimilates into reproductive organs (seeds). It is proposed that application of mepiquat chloride would be useful in producing strong seedlings that grow steadily, and produce high yields. Lamas and Athayde (1999) indicated that seedling emergence and seedling dry matter increased with increasing mepiquat chloride rate, when applied at 50, 75, 100 or 125 g/ha.

Experiment II: Potassium fertilization and foliar application of zinc and phosphorus

Seed yield

Seed yield/plant, as well as seed yield/plot, significantly increased when K was applied (by as much as 14.72, 13.13; 14.69, 13.26%, respectively) in both seasons (**Table 7**). Potassium would have a favourable impact on yield components, including number of opened bolls/plant and boll weight, leading to a higher cotton yield. Guinn (1985) suggested that growth, flowering, and boll retention decrease when the demand for photosynthate increases and exceeds the supply. This means that an increase in photosynthesis should permit more bolls to be set before cutout. Sangakkara *et al.* (2000) indicated that, potassium increases the photosynthetic rates of crop leaves, CO_2 assimilation and facilitates carbon movement. Also, the role of K suggests that it affects abscission and reduced boll shedding and it certainly affects yield (Zeng 1996). Mullins *et al.* (1999) evaluated cotton yield to long-term surface application of K at 60-180 kg K_2O/ha and found that K application increased yield. Results obtained here were confirmed by those of Gormus (2002), Aneela *et al.* (2003), Pervez *et al.* (2004) and Pettigrew *et al.* (2005).

Application of Zn significantly increased seed yield/plant, and seed yield/plot, as compared with the untreated control (by 10.22, 8.81; 10.07, 8.70%, respectively) in the two seasons. Zinc could have a favourable effect on photosynthetic activity of leaves (Sharma *et al.* 1982), which improves mobilization of photosynthates and directly influences boll weight. Further, Zn is required in the synthesis of tryptophan, a precursor of indole-3-acetic acid synthesis (Oosterhuis *et al.* 1991), which is the major hormone that inhibits abscission of squares and bolls. Thus the number of retained bolls/plant and consequently seed yield/plant and yield/plot, would be increased. Similar results were obtained by Rathinavel *et al.* (2000), by soil application of $ZnSO_4$ at 50 kg/ha.

Applying P also significantly increased seed yield/plant, and seed yield/plot in both seasons, as compared to the untreated plants, when treatment rate was increased up to 1800 ppm (by 11.21-17.95, 8.31-16.39; 10.83-17.98, 8.03-16.20%, respectively). There was only one exception in the second season, where the low P_2O_5 concentration (600 ppm) increased seed yield/plant, and seed yield/plot numerically. Generally seed yield/plant, and seed yield/plot were the greatest when the highest P_2O_5-concentration (1800 ppm) was applied. Such results reflect the pronounced improvement in yield components due to the application of P_2O_5, which is possibly ascribed to its involvement in photosynthesis, and translocation of carbohydrates to young bolls. Phosphorus as a constituent of cell nucleus is also essential for cell division and development of meristematic tissue, and hence it would have a stimulating effect on increasing the number of flowers and bolls per plant (Russell 1973). Further, P has a well known impact on photosynthesis as well as synthesis of nucleic acids, proteins, lipids and other essential compounds (Taiz and Zeiger 1991; Guidi *et al.* 1994), which are major constituents affecting boll weight and consequently cottonseed. They added that, P deficiency affected leaf chlorophyll fluorescence parameters negatively. Results here (increase of seed yield/plant, and seed yield/plot due to P application) agreed with those reported by Sasthri *et al.* (2001), and Katkar *et al.* (2002).

Table 7 Effect of K-rate and foliar application of Zn and P on seed yield/plant and seed yield/plot, and seed weight.

Treatments	Cotton seed yield (g/plant)		Cotton seed yield (kg/plot)		Seed weight (g/100 seed)	
	1999	2000	1999	2000	1999	2000
K_2O-rate (kg/ha)						
0, control	19.16	18.35	1.457	1.395	10.12	9.89
57.1	21.98**	20.76**	1.671**	1.580**	10.29**	10.04**
L.S.D.						
0.05	1.145	1.277	0.0946	0.0977	0.088	0.079
0.01	1.530	1.706	0.1264	0.1305	0.118	0.105
Zn-rate (ppm)						
0, control	19.57	18.73	1.489	1.425	10.15	9.92
60	21.57**	20.38*	1.639**	1.549*	10.26*	10.00*
L.S.D.						
0.05	1.145	1.277	0.0946	0.0977	0.088	0.079
0.01	1.530	n.s.	0.1264	n.s.	n.s.	n.s.
P_2O_5-rate (ppm)						
0, control	18.55	17.82	1.413	1.358	10.08	9.86
600	20.63*	19.30	1.566*	1.467	10.21*	9.95
1200	21.21**	20.35*	1.611**	1.546*	10.26**	10.00*
1800	21.88**	20.74*	1.667**	1.578*	10.29**	10.04*
L.S.D.						
0.05	1.620	1.806	0.1338	0.1382	0.125	0.111
0.01	2.164	n.s.	0.1787	n.s.	0.167	n.s.

Seed weight

Seed weight significantly increased when K was applied in both years (**Table 7**). This may be due to its favourable effects on photosynthetic activity, improving mobilization of photosynthates (Pettigrew 1999) and directly influences boll weight that coincides with increased seed weight. Result was similar to those obtained by Sabino *et al.* (1999), i.e. an increase in seed weight due to K application.

Application of Zn significantly increased seed weight compared to the untreated control in both seasons. A possible explanation for the increased seed weight might be due to increased photosynthesis activity resulting from the application of Zn, which improves mobilization of photosynthates and the amount of photosynthate available for reproductive sinks and thereby producing changes in seed weight (Sharma *et al.* 1982). A similar result (increase in seed weight due to Zn application) was obtained by Rathinavel *et al.* (2000).

The same pattern was found with regard to application of the three P_2O_5 concentrations, which also brought about a significant increment in seed weight over the control. Applying the three P_2O_5 concentrations increased the seed weight as compared with the control in both seasons. This increase was significant for all P_2O_5 concentrations in the first season and for P_2O_5 at 1200 and 1800 ppm in the second season. Spraying plants with P_2O_5 at 1800 ppm produced the highest seed weight. Plesnicar *et al.* (1994) stated that, photosynthetic CO_2 fixation decreased in plants suffering from P deficiency. Phosphorus plays a decisive role in carbon assimilate transport and metabolic regulation (starch, sucrose biosynthesis) at the whole-plant level (Bisson *et al.* 1994). This indicates that treated cotton bolls had larger photosynthetically supplied sinks for carbohydrates and other metabolites than untreated bolls. Similar results (increase in seed weight due to P_2O_5 application) were obtained by Sabino *et al.* (1991).

Table 8 Effect of K-rate and foliar application of Zn and P on seed viability and cool germination test performance.

Treatments	Germination velocity (%)		Second germination count (%)		Total germination capacity (%)		Germination rate index (GRI unit)		Cool germination test performance (%)			
									4-day count		7-day count	
	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
K_2O-rate (kg/ha)												
0, control	75.19	74.19	82.19	81.13	83.63	82.44	0.655	0.655	32.88	32.38	70.56	68.69
57.1	79.13**	77.00**	87.81**	84.63**	89.13**	86.00**	0.654	0.655	36.06**	35.44**	72.88**	71.25*
L.S.D.												
0.05	1.846	1.969	2.108	1.712	2.067	1.814	n.s.	n.s.	1.492	1.741	1.643	1.940
0.01	2.466	2.630	2.816	2.287	2.760	2.423	n.s.	n.s.	1.993	2.325	2.194	n.s.
Zn-rate (ppm)												
0, control	75.81	74.44	83.38	81.81	84.63	83.19	0.655	0.654	33.13	32.75	70.81	68.88
60	78.50**	76.75*	86.83**	83.94*	88.13**	85.25*	0.654	0.655	35.81**	35.06*	72.63*	71.06*
L.S.D.												
0.05	1.846	1.969	2.108	1.712	2.067	1.814	n.s.	n.s.	1.492	1.741	1.643	1.940
0.01	2.466	n.s.	2.816	n.s.	2.760	n.s.	n.s.	n.s.	1.993	n.s.	n.s.	n.s.
P_2O_5-rate (ppm)												
0, control	74.25	73.38	81.63	80.13	82.88	81.38	0.654	0.655	32.25	32.13	69.50	68.00
600	76.88*	75.13	84.75*	82.63*	86.25*	84.00*	0.654	0.654	34.50*	33.38	71.88*	69.25
1200	78.13**	76.63*	86.25**	83.25*	87.75**	84.88**	0.654	0.655	35.00*	34.63*	72.38*	70.75*
1800	79.38**	77.25*	87.38**	85.50**	88.63**	86.63**	0.655	0.655	36.13**	35.50*	73.13*	71.88*
L.S.D.												
0.05	2.611	2.784	2.982	2.421	2.923	2.565	n.s.	n.s.	2.110	2.462	2.323	2.744
0.01	3.488	n.s.	3.983	3.234	3.904	3.427	n.s.	n.s.	2.818	n.s.	n.s.	n.s.

Table 9 Effect of K-rate and foliar application of Zn and Pon seedling vigour.

Treatments	Hypocotyl length (cm)		Radicle length (cm)		Seedling length (cm)		Seedling fresh weight (g/10 seedling)		Seedling dry weight (g/10 seedling)	
	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
K_2O-rate (kg/ha)										
0, control	7.28	7.12	16.26	15.82	23.54	22.94	6.86	6.66	0.640	0.621
57.1	7.71**	7.41**	16.73*	16.34**	24.44**	23.75**	7.10**	6.88**	0.658**	0.641**
L.S.D.										
0.05	0.224	0.195	0.354	0.358	0.562	0.535	0.140	0.148	0.0113	0.0122
0.01	0.299	0.261	n.s.	0.478	0.751	0.714	0.187	0.198	0.0151	0.0163
Zn-rate (ppm)										
0, control	7.34	7.16	16.30	15.90	23.63	23.05	6.88	6.69	0.642	0.623
60	7.66**	7.37*	16.70*	16.27*	24.36*	23.63*	7.08**	6.85*	0.657*	0.638*
L.S.D.										
0.05	0.224	0.195	0.354	0.358	0.562	0.535	0.140	0.148	0.0113	0.0122
0.01	0.299	n.s.	n.s.	n.s.	n.s.	n.s.	0.187	n.s.	n.s.	n.s.
P_2O_5-rate (ppm)										
0, control	7.12	6.98	15.91	15.58	23.02	22.56	6.77	6.55	0.632	0.614
600	7.51*	7.25	16.50*	16.10*	24.01*	23.35*	7.00*	6.78*	0.649*	0.630
1200	7.65**	7.33*	16.74**	16.26*	24.39**	23.59**	7.04**	6.84**	0.653*	0.637*
1800	7.72**	7.48**	16.84**	16.40*	24.56**	23.87**	7.11**	6.91**	0.662**	0.643**
L.S.D.										
0.05	0.317	0.276	0.501	0.506	0.795	0.756	0.199	0.209	0.0160	0.0172
0.01	0.423	0.369	0.669	n.s.	1.062	1.010	0.265	0.280	0.0214	0.0231

Seed viability, seedling vigour and cool germination test

Seed viability (as measured by germination velocity, second germination count, and total germination capacity), seedling vigour (measured by length of hypocotyl, radicle and entire seedling; and seedling fresh and dry weight) and cool germination test performance (four- and seven-day counts) all generally significantly increased by the addition of K and by the application of Zn at 60 ppm and P_2O_5 at different concentrations in both years (**Tables 8** and **9**). The differences between the effects of the three P_2O_5 rates were statistically insignificant, with the exception of 1800 ppm in the second season, which significantly increased the second germination count, and total germination count relatively more than 600 ppm. Adding potassium or application of Zn or P_2O_5 at different concentrations had no significant effect in either year on germination rate index. Beneficial residual effects of K_2O addition, and application of Zn, and P_2O_5 at different concentrations on stimulating the seed viability, seedling vigour and cool germination test performance may be attributed to their favourable effects on increased seed weight associated with changes in the metabolism of nucleic acids, proteins, vitamins and growth substances (Sharma *et al.* 1990; Taiz and Zeiger 1991; Welch 1995). These effects are manifested in metabolites formed in plant tissues, and have direct impact through their utilization in growth and development processes, which may be reflected in distinct changes in seed quality and weight. Generally, the effects of mineral deficiency stress on seed development are indirect, resulting from their direct effects on maternal plant development and subsequent seed quality (Sharma *et al.* 1990; Taiz and Zeiger 1991; Welch 1995). Wang *et al.* (2003) studied the influence of physical characteristics of cottonseed on germination and emergence rates of 3 cultivars (‘CCRI 35’, ‘Shiyuan 321’ and ‘Xinmian 33B’) and found that germination rate and seed weight had an extreme positive correlation. Also found that seed weight had an extreme correlation with emergence rate.

Potassium has favourable effects on metabolism of nucleic acids, proteins, vitamins and growth substances (Bisson *et al.* 1994; Bednarz and Oosterhuis 1999). These are mani-

Table 10 Effect of interactions between N-rate and foliar application of K and the plant growth retardant mepiquat chloride (MC) on seed yield/plant and seed yield/plot, and seed weight.

Treatments			**Cotton seed yield (g/plant)**		**Cotton seed yield (kg/plot)**		**Seed weight (g/100 seed)**	
N-rate (kg/ha)	**K_2O-rate (ppm)**	**MC-rate (ppm)**	**1999**	**2000**	**1999**	**2000**	**1999**	**2000**
95.2	0.0	0.0	16.59	16.34	1.262	1.243	9.94	9.78
		50 and 25	18.39	17.56	1.399	1.336	10.15	9.93
	400	0.0	18.54	18.59	1.409	1.409	10.23	10.00
		50 and 25	20.87	18.35	1.587	1.392	10.34	9.99
	800	0.0	19.59	17.27	1.495	1.314	10.14	9.88
		50 and 25	21.10	19.79	1.604	1.499	10.21	10.04
	1200	0.0	20.82	20.09	1.578	1.527	10.28	10.08
		50 and 25	21.33	20.59	1.622	1.566	10.35	10.08
142.8	0.0	0.0	19.47	17.89	1.481	1.361	10.13	9.98
		50 and 25	20.64	20.13	1.571	1.527	10.34	10.11
	400	0.0	22.19	20.90	1.682	1.584	10.41	10.20
		50 and 25	22.31	21.99	1.696	1.672	10.36	10.27
	800	0.0	20.97	19.75	1.596	1.507	10.30	10.10
		50 and 25	23.45	22.01	1.778	1.674	10.52	10.25
	1200	0.0	24.04	23.23	1.828	1.761	10.61	10.33
		50 and 25	24.27	22.46	1.846	1.708	10.76	10.42
L.S.D. 0.05			n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

n.s.: not significant at 5% level.

fested in metabolites formed in plant tissues, and directly influence growth and development processes. In addition to its role as an activator in protein metabolism, potassium also acts as an activator for several enzymes involved in carbohydrates metabolism. Potassium deficiencies can limit the accumulation of crop biomass (Colomb *et al.* 1995). These may be reflected in distinct changes in seed weight and quality. Favourable residual effects of K on seed viability and seedling vigour were mentioned by Vasudevan *et al.* (1997).

The stimulatory effect of Zn application on the studied characters may be attributed to its essential effect on the maternal plant development and subsequent seed quality and weight. Rathinavel *et al.* (2000), who applied $ZnSO_4$ to the soil at 50 kg/ha, found that the quality of the resultant seeds in terms of 100 seed weight, germination, speed of germination, seedling growth, dry matter production, and vigour index were higher than the seeds from plants receiving no $ZnSO_4$.

Phosphorus is an essential nutrient and an integral component of several important compounds in plant cells. These include the sugar-phosphates involved in respiration, photosynthesis and the phospholipids of plant membranes, the nucleotides used in plant energy metabolism and in molecules of DNA and RNA (Taiz and Zeiger 1991). Rodriguez *et al.* (1998) observed that under P deficiency there was a reduction in the rate of leaf expansion and in photosynthetic rate per unit of leaf area. Sasthri *et al.* (2001) found that application of 2% diammonium phosphate increased seed germination, root length, vigour index and dry matter production.

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 mepiquat chloride) or (K-rate and application of Zn or P_2O_5)] on quantitative and qualitative characters under investigation. Regarding insignificant interaction effects, the F ratios exceed unity, but at $P \leq 0.05$, they were not significantly different (characters in **Table 10**, as an example). The interactions indicated numerically that favourable effects accompany the application of N, spraying of cotton plants with K and also mepiquat chloride were more obvious by applying N at 142.8 kg/ha combined with spraying cotton plants with potassium at 1200 ppm of K_2O and also with mepiquat chloride at 50 and 25 ppm. Boman and Westerman (1994) found that no significant effect for N × mepiquat chloride rate interactions on growth and yield of cotton cv. 'Paymaster 404' were noted when treated with N at 0, 56, 112 or 224 kg/ha and sprayed at early flowering with mepiquat chloride at 0, 10, or 20 g/ha.

CONCLUSION

From the findings of experiment I, it seems rational to recommend the 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 mepiquat chloride, also twice (at 50 and 25 ppm, respectively). These treatments would beneficially affect not only the quantity but also the quality of cottonseed, as indicated by better seed viability (as measured by germination velocity, second germination count, and total germination capacity), seedling vigour (as revealed by length of hypocotyls, radicle and entire seedling; as well as seedling fresh and dry weights) and cool germination test performance (four and seven-day counts). It is quite apparent that applications of such treatments could bring about better impact on cottonseed yield, and to improve seed viability, and seedling vigour. Also, from the findings of experiment II, it seems rational to recommend the addition of K at 57.1 kg K_2O/ha, and spraying cotton plants with Zn twice (at 60 ppm) and application of P_2O_5, also twice (especially P_2O_5 at 1800 ppm). These appear to be the most beneficial treatments, affecting not only the quantity but also the quality of cottonseed.

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