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Direct and residual effects of nitrogen fertilization, foliar application of potassium and plant growth retardant on Egyptian cotton growth, seed yield, seed viability and seedling vigor

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ABSTRACT

In order to obtain high productivity for a cotton crop, one of the major requirements is to establish an adequate plant population. The use of good-quality seed may ultimately be the best approach to attain this goal problem. The objective of this research was to study the effect of N-fertilization (at rates of 95.2 and 142.8 kg of N ha^{-1}), foliar application of K (at rates of 0, 0.38, 0.77, 1.15 kg of K_2O ha^{-1}, applied twice during square initiation and boll development stages) and the plant growth retardant (PGR), mepiquat chloride (applied twice, 75 days after planting at 0.0 [control] and 0.048 kg a.i. ha^{-1}, and 90 days after planting at 0.0 [control] and 0.024 kg a.i. ha^{-1}), on seed yield, viability, and seedling vigor of Egyptian cotton (*Gossypium barbadense* cv. Giza 86). A field experiment was conducted at the Agricultural Research Center, Giza, Egypt in two growing seasons. Growth, mineral uptake, seed yield per plant and per ha, seed weight, seed viability, seedling vigor and cool germination test performance were all found to increase significantly due to the addition of the high N-rate, the foliar application of three potassium concentrations, and the PGR mepiquat chloride. The N and K rates as well as application of mepiquat chloride had no significant effect on the germination rate index in both seasons. Under the conditions of this study, applying N at a rate of 142.8 kg ha^{-1} combined with spraying cotton plants with K_2O at 1.15 kg ha^{-1} and with mepiquat chloride at 0.048 + 0.024 kg ha^{-1} were found to improve seed yield as well as seed viability and seedling vigor in the next season.

Seed vigor is an important component affecting seedling establishment and crop growth and productivity. Any factor, biotic or abiotic, that negatively affects seed vigor and viability during seed development will have adverse consequences on crop production, especially when seeds are sown under environmentally stressful conditions (poor seedbed preparation, low temperature, excess or insufficient moisture, soil micro-organisms and pests and chemical injury [1]).

In Egypt, cotton (*Gossypium barbadense* L.) requires approximately seven months from planting to harvest. During this growing season, fertilization has a major direct impact on cotton growth, and influences both yield and quality characters. Conditions prevailing during seed formation affect the quality of seed produced, and, in such a way, crop establishment in the next growing season [2]. Soil fertilization is the primary limiting factor affecting growth and production under intensive land use for two or more crops per year. Furthermore, recently released varieties have high yielding ability, which largely depends on providing the plant's essential nutritional requirements (e.g., nitrogen and potassium). Considerable interest also exists in using plant growth regulators (PGRs) for cotton production because of their potential altering of crop growth and seed development [3].

Mineral nutritional status of plants has a considerable impact on partitioning carbohydrates and dry matter between plant shoots and roots. Under nitrogen (N) deficiency, a considerably larger proportion of dry matter (photosynthates) is partitioned to roots rather than shoots, leading to reduced shoot/root dry weight ratios [4]. Additionally, with a dynamic crop like cotton, excess N serves to delay maturity, promote vegetative tendencies, and usually results in lower yields [5,6]. Therefore, errors made in N management that can impact the crop can be through either deficiencies or excesses of applications. If an N deficiency is developing in a cotton crop, it is not particularly difficult to diagnose and correct. Excess N levels, which can be damaging to final crop productivity, are subtle to detect, and are difficult to correct [7]. Ansari and Mahey [8] evaluate the effects of N level (0, 40, 80, 120 and 160 kg ha^{-1}) on the yield of American cotton (*Gossypium hirsutum*)

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cv. F846 and Desi cotton (*G. arboreum*) cv. LD327 and found that seed yield increased with increasing N level up to 80 kg ha^{-1}.

Potassium (K) increases the photosynthetic rates of crop leaves, CO_2 assimilation rate and facilitating carbon movement [9]. The high concentration of K^+ is thought to be essential for normal protein synthesis. The need 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 [10] 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. 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 Gormus [11], Aneela et al. [12], Pervez et al. [13] and Pettigrew et al. [14]. 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 [3]. An important objective for using PGRs in cotton is to balance vegetative and reproductive growth as well as to improve yield and its quality [15]. 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. [16] 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. [17] evaluated the effects of 5% mepiquat chloride (500, 750 and 1000 ppm) on a hybrid cotton (*G. hirsutum* cv. 'DHH-11'). These treatments increased the values of photosynthetic rate, stomatal conductance, transpiration rate, total chlorophyll content, nitrate reductase activity, number of bolls plant^{-1}, boll weight and yield.

There is limited information about the suitable management practice for application of N, K, and mepiquat chloride to optimize cotton seed yield, seed viability, seedling vigor, and germination under cold stress. The aim of this study was to investigate the effects of soil application of N as well as foliar application of K and mepiquat chloride on growth, seed yield and quality of an Egyptian cotton cultivar (*G. barbadense* L., cv. Giza 86). The study was designed to identify the best combination of these production treatments to improve seed yield and quality. We tested the hypothesis that soil application of N as well as foliar application of K and mepiquat chloride will stimulate growth and improve seed yield and quality (seed viability, seedling vigor, and germination under cold stress).

1. Material and methods

A field experiment was conducted at the Agricultural Research Center, Ministry of Agriculture in Giza, Egypt (30 °N, 31°: 28'E and 19 m altitude) using the cotton cultivar Giza 86 (*G. barbadense* L.) in the two seasons I and II. The experiment was arranged as a randomized complete blocks design with three factors and four replicates. The factors studied were N fertilization, foliar application of potassium, and the plant growth retardant mepiquat chloride. The soil in both seasons was clay loamy. In each season, the experimental 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 to determine its physical and chemical properties. Average particle size analysis and chemical characteristics [18] for soil in both seasons are given in Table 1.

Two N rates, 95.2 and 142.8 kg N ha^{-1}, were applied as ammonium nitrate (NH_4NO_3, 33.5% of N) at two equal doses, six and eight weeks after sowing. Each application in the form of side dressing applications (about 2.31 and 3.46 g hill^{-1} actual ammonium nitrate for the two N rates, respectively) beside each hill was followed immediately by irrigation. Four K rates (0, 0.38, 0.77, and 1.15 kg of K_2O ha^{-1}) were applied in a volume 960 L ha^{-1} as potassium sulfate (K_2SO_4, '48% K_2O') twice during the reproductive stage. The first application occurred 70 days after planting during square initiation and the second at 95 days after planting during boll development. The foliar plant growth regulator mepiquat chloride [1,1-dimethylpiperidinium chloride] was applied twice during the reproductive stage, both at a volume of 960 L H_2O ha^{-1}. The first application (0.048 kg a.i. ha^{-1}) occurred 75 days after planting and the second (0.024 kg a.i. ha^{-1}) 90 days after planting. Control plots received no mepiquat chloride. The K_2O and mepiquat chloride were both applied to the leaves with uniform coverage using a knapsack sprayer. The pressure used was 0.4 kg cm^{-2}, resulting in a nozzle output of 1.43 L min^{-1}. The application was carried out between 9 and 11 a.m. Range and mean values of the weather data during the growing seasons are presented in Table 2. All weather variables were measured according to the methodological directions adapted by the World Meteorology Organization (WMO). These data were obtained from the Agricultural Meteorological Station of the Agricultural Research Center, Giza, Egypt. No rainfall occurred during the two growing seasons.

1.1. Crop management and measurement of results

Seeds were planted on the 3rd and 20th of April in I and II seasons, respectively. Plot size was 1.95 × 4 m, including three ridges (precaution of border effect was taken into account). Hills were

Table 1
Physical and chemical properties of the soil used in I and II seasons.

Season	I	II
Physical analysis (soil fraction)		
Clay (%)	43.0	46.5
Silt (%)	28.4	26.4
Fine sand (%)	19.3	20.7
Coarse sand (%)	4.3	1.7
Soil texture	Clay	Loam
Chemical analysis		
Organic matter (%)	1.8	1.9
Calcium carbonate (%)	3.0	2.7
Total soluble salts (%)	0.13	0.13
pH (1:2.5)	8.1	8.1
Total nitrogen (%)[a]	0.12	0.12
Available nitrogen (mg kg^{-1} soil)[b] (1% K_2SO_4, extract)	50.0	57.5
Available phosphorus (mg kg^{-1} soil) ($NaHCO_3$ 0.5 N, extract)	15.7	14.2
Available potassium (mg kg^{-1} soil) (NH_4OAC 1N, extract)	370.0	385.0
Total Sulfur (mg kg^{-1} soil)	21.3	21.2
Calcium (meq/100g) (with Virsen, extract)	0.2	0.2

The physical analysis (soil fraction) added to the organic matter, calcium carbonate and total soluble salts to a sum of about 100%.
[a] Total nitrogen, i.e. organic N + inorganic N.
[b] Available nitrogen, i.e. NH_4^+ and NO_3^-.