J. of Plant Production, Mansoura Univ., Vol., 12 (8):869-879, 2021

Journal of Plant Production

Journal homepage: www.jpp.mans.edu.eg
Available online at: www.jpp.journals.ekb.eg

Effect of Different Potassium Forms on growth, some Physiological Aspects and Productivity of Egyptian Cotton

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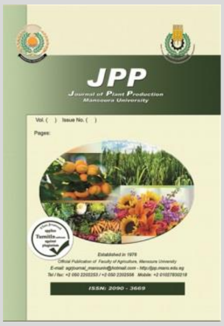

ABSTRACT

Two field experiments were carried out at El-Gemmeiza Agricultural Research Station, El-Gharbia Governorate, Egypt during 2019 and 2020 seasons, to evaluate the effect of foliar feeding with three sources of potassium [1- mineral source (potassium sulphate), 2- organic source (potassium humate) and 3- natural source (potassium ore)] at two levels from each source (0.5 and 1g/L), (2 and 4 g/L) and (4 and 8 g/L) in respective order. The effect of combination between the three sources at the two levels, in addition to the control treatment were also evaluated on growth, some physiological aspects and productivity of Egyptian cotton cultivar Giza 86. The obtained results indicated that foliar feeding with the combination of the three sources examined at the low level or at the high level resulted in significant increase in leaves N, P, K, Mg and photosynthetic pigments contents, growth parameters, earliness measurements (except boll shedding percentage which was decreased) and seed cotton yield feddan^{-1}, boll weight and open bolls number plant^{-1} in 2019 and 2020 seasons as well as seed index, lint%, fiber length, micronaire reading and fiber strength in 2020 season as compared with the control. It was recommended to spraying combination of the three examined K sources (potassium sulphate, potassium humate and potassium ore) at the low level (0.5, 2 and 4 g/L) in respective order three times as alternative to soil K fertilization to reduce cost, overcome K fixation and obtain high cotton productivity under conditions similar to that of El-Gemmeiza region.

Keywords: Cotton; potassium sources; mineral; organic; natural; ore.

INTRODUCTION

Potassium (K^+) is an element taken up by plants in greatest amounts after nitrogen and is important for growth of all plants as a macronutrient. Its uptake pattern by cotton plants shows that foliar feeding with potassium met the cotton requirements and it must be early supply in the growth period in adequate amount, where potassium fertilizer when added to the soil major part of it becomes unavailable to the plant. The fulfil high potassium needs of cotton plants, its application as foliar spraying becomes necessary, where soil potassium availability for plants face some challenges including; low soil K availability, the soil surface dryness, alkalinity of soil, low root activity, as well as water scarcity in arid and semi-arid locations (Comerford, 2005). Also, potassium can be lost through leaching from coarse-textured soils under heavy irrigation. The loss of K through leaching and erosion is a waste of resources. Foliar application of K corrects mid-season deficiency quickly and efficiently. It is one of the high economic efficiency methods (Alshaal and El-Ramady, 2017). In addition, the advantages of using foliar feeding with K were; 1- A quick plant response and deficiency correct, where foliar-applied K moved into the leaf and to the boll within 20 hours and efficiently as reported by Kafkafi (1990), especially late in the season when soil application of K may not be effective. 2- Low cost, where the use of small amounts of fertilizer is appropriate compared to soil fertilization. 3-Compensation for the lack of soil fixation of K and independence of root uptake problems. In foliar application, K is easily absorbed through leaves (Hussain *et al.*, 2015). 4- It highly utilized especially under drought, salinity, and high temperatures (Shareef, 2016). On the other hand, only a limited amount of K can be applied in the case of severe deficiency and the cost of multiple applications can be more than in ordinary soil-applied K fertilizers (Snyder *et al.*, 1991). When using high concentrations of K include the possibility of foliar burn, compatibility problems with certain pesticides, and low solubility of certain K salts, especially in cold water.

In photosynthesis, K^+ has a special role in synthesis of carbohydrate and translocation of photosynthates for plant growth or storage in fruits or roots, as it maintains the balance of electrical charges at the site of ATP production and regulates the balance between assimilation and respiration in a way that increases net assimilation (Imas and John, 2013). K^+ plays a vital role in many physiological and biochemical processes such as water transport in whole plant, division and elongation of cell, carbohydrates and protein compounds metabolism (Marschner, 1995 and Valadabadi and Farahani, 2010).

Main reasons for K deficiency; 1-Many factors affect K^+ fixation in clay minerals and soils, such as the clay minerals type and quantity, the clays charge density and capacity, soil moisture content, K^+ and other competing cations concentrations and pH of the soil solution (Rich, 1968 and Sparks and Huang, 1985). 2- One of the main reasons for K deficiency is biomass removal from the soil in the form of crop products at harvesting (Smil, 1999), and in recent years it is not adequately replaced and K fertilizers use has declined leading to deficient soils (Dobermann, 2007), where K fertilizers are applied only to replenish 35% of the K removed.

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DOI: 10.21608/JPP.2021.198683

Additionally, Manning (2015) reported that K mining from soil far exceeds the counter balancing inputs, typically less than 10% of K removal.

Using appropriate K source and foliar application as proper method can improved the nutrition of K (Etesami *et al*., 2017); Using some potassium sources *i.e.*, KCL, when applied as soil fertilizer, it releases an equal amount of K and Cl^{-1} in soil solution. The K is relatively immobile, whereas Cl ion is mobile and removed easily through leaching or excessive accumulation in leaves causing toxicity (Roemheld and Kirkby, 2010). Modern varieties of cotton reduced the length of the flowering period from 5 to 7 weeks in the older indeterminant cultivars to 3 to 5 weeks, thus they produce a larger crop during a shorter period. If the crop is stressed for moisture and the boll load is heavy, low sub-soil K can result in late season deficiency. The need for K rises dramatically when bolls are set on plants because developing bolls have a high K requirement. It is crucial that potassium be available when the cotton plant is setting fruit on the first position of the first several branches, because 70 to 75 percent of the total yield occurs from first position bolls on the first 7 or 8 fruiting branches. More potassium (K) required by modern cotton cultivars during peak bloom and boll setting period and its deficiency adversely affects the yield of seed-cotton (Muhammad *et al*., 2016). Potassium found in soil into four pools: soil solution K, exchangeable K, non-exchangeable K and structural K (Moody and Bell, 2006) and most of it is not available to plants. Late season K deficiency in cotton typically coincides with a period of high K demand and reduced root establishment as a result of developing bolls. The developing bolls serves as major sink for K, and cotton K uptake can reach about 3-4 lbs K_2O/ac during boll development. The widespread K deficiency that has occurred across the cotton has been related to: the K use of earlier maturing, higher-yielding, fast-fruiting cultivars (Oosterhuis *et al*., 1991), planting of cotton on soils low in available K (Kerby and Adams, 1985), and the relative inefficiency of cotton in absorbing K from the soil compared to other crop species (Cassman *et al*., 1989). The occurrence of K-deficiency under heavy clay and sandy soils increased the demand of K fertilization for the cotton plants (Marchand and Bourrie, 1999).

This study aimed to evaluate the effects of three different K forms and their combination on cotton leaf chemical composition, growth, some physiological aspects, yield and fiber quality of cotton plants grown under El-Gemmeiza location.

MATERIALS AND METHODS

The current research was carried out at El-Gemmeiza Agricultural research Station, El-Gharbia Governorate, Egypt in 2019 and 2020 seasons.

Three sources of potassium were examined as a foliar application compared to the control (fertilized with potassium sulphate as soil application at the recommended rate, CRI, ARC, Egypt and spraying with tap water at the application times of foliar feeding with K sources). In both seasons, two levels of each potassium source were used either alone or in combination.

A randomized complete block design with three replicates was used, where nine treatments were applied as follows:

T_1- Control (fertilized with potassium sulphate as soil application at the recommended rate and sprayed with the same amount of tap water at the application times of foliar feeding with K sources).

T_2- Foliar feeding with mineral K source (potassium sulphate, 48% K_2O) at the level of 0.5 g/L.

T_3- Foliar feeding with mineral K source (potassium sulphate, 48% K_2O) at the level of 1 g/L.

T_4- Foliar feeding with organic K source (potassium humate, 12.5% K_2O) at the level of 2 g/L.

T_5- Foliar feeding with organic K source (potassium humate, 12.5% K_2O) at the level of 4 g/L.

T_6- Foliar feeding with natural K source (potassium ore, 6.5% K_2O) at the level of 4 g/L.

T_7- Foliar feeding with natural K source (potassium ore, 6.5% K_2O) at the level of 8 g/L.

T_8-Foliar feeding with mineral K source (potassium sulphate, 48% K_2O) at the level of 0.5 g/L + organic K source (potassium humate, 12.5% K_2O) at the level of 2 g/L + natural K source (potassium ore, 6.5% K_2O) at the level of 4 g/L.

T_9-Foliar feeding with mineral K source (potassium sulphate, 48% K_2O) at the level of 1 g/L + Foliar feeding with organic K source (potassium humate, 12.5% K_2O) at the level of 4 g/L + Foliar feeding with natural K source (potassium ore, 6.5% K_2O) at the level of 8 g/L.

Foliar application was applied three times (at squaring stage, flowering start and peak of flowering stage) by using hand operated sprayer compressed air at the rate of 200 liter water/fed. Tween-20 (0.01%) was used as a wetting agent and spraying was carried out between 07:00 and 9:00 am till dripping

In both seasons, soil samples were taken at random from the experimental field area at a depth of 0-30 cm from soil surface before sowing, mixed, cleaned and analysed according to Chapman and Parker (1981). The data are presented in Table 1.

Table 1. The characteristics of the experimental soil sites prior to sowing in 2019 and 2020 seasons

Properties		*Optimal value	2019 season	2020 season
Mechanical analysis:				
Clay%			44.2	45.1
Silt%			33.0	32.6
Sand%			22.8	22.3
Texture			Clayey	Clayey
Chemical analysis:				
pH (1 soil: 2.5 distilled water)		6.7-7.3	8.1	7.9
EC (1 soil: 2.5 distilled water)	ds/m^2	1.5	0.99	0.64
Organic matter	%	2.6-3.0	1.40	1.25
Total N		30-60	49.00	43.75
Available P		1.2-2.7	1.28	0.96
Available K	(mg/	21-30	31.0	21.0
Available Mg	100g)	30-180	23	20
Available Fe		10-16	12.4	10.7
Available Mn		8-12	3.9	3.1
Available Zn	(ppm)	1.5-3.0	1.12	1.20
Available Cu		0.8-1.2	1.7	0.9

*** Optimal value according to (Ankerman and Large, 1974)**

Seeds of cotton cultivar Giza 86 (*Gossypium barbadence* L.) were attained from Cotton Research Institute, Agricultural Research Center, Egypt and sown on 10/4/2019 and 14/4/2020 in hills 25 cm apart leaving two vigour's seedlings/hill at thinning time to insure 48,000 plants/fed.

The plot size was 14 m^2, (3.5 m x 4 m) including 5 ridges of 70 cm wide and 4 m long.

The preceding crop was Egyptian clover (*Trifolium alexandrinum* L.) "berseem" in both seasons.

In both seasons, all plots were fertilized with phosphorus and nitrogen as recommended (Cotton Research Institute, Agricultural Research Center, Egypt). Phosphorus fertilizer was added during soil preparation in the form of calcium super phosphate (15.5 % P_2O_5) at the rate of 22.5 kg P_2O_5 /fed. Nitrogen fertilizer was applied at the rate of 45 kg N/fed as urea (46 % N) in two equal splits after thinning and 15 days later. The control plots were fertilized with potassium fertilizer in the form of potassium sulphate (48% K_2O) at the rate of 24 kg K_2O side-dressed in one dose after thinning before irrigation. The other cultural practices were carried out as recommended for conventional cotton cultivation in the local production district (CRI, ARC, Egypt).

Traits recorded:

A-Leaves chemical composition: In both seasons, a sample of 20 leaves (blade + petiole) was randomly taken from the youngest fully matured leaves (fourth upper leaf) from plants of each plot after two weeks from the last spraying (115 days old) to determine nitrogen, phosphorus, potassium and magnesium percentages according to Chapman and Parker (1981). Moreover, chlorophyll a, b and a+b (mg/g d.w.) were determined according to the method described by Fadeel (1962). Leaf carotenoids content (mg/g d. w.) was determined using the method described in A.O.A.C. (1995).

B-Growth parameters: In both seasons, six guarded plants were randomly taken from each plot after 15 days from the last spraying. Roots of sample plants were removed at the cotyledonary nodes, then the different plant fractions were washed and dried to a constant weight in a forced air oven at 70 °C then, dry weight was calculated in expression of canopy dry weight (g/plant). Leaf area index (LAI): It is the ratio of leaf area $plant^{-1}$ to the total land area occupied by the plant. The LAI was measured as proposed by Hunt (1978). At harvesting, five guarded hills from each plot were taken at random to determine final plant height (cm). The fruiting branches arising on the main stem were counted separately in the ten tagged plants and the average value was recorded.

C-Earliness measurements: Number of total flowers/plant (Kadapa, 1975), number of total bolls set/plant, boll setting percentage denotes that out of total flowers formed, how many were eventually set into bolls, boll shedding percentage and first picking percentage (Richmond and Radwan, 1962) were determined.

D- Yield and its components: Number of open bolls/plant and boll weight (g) were recorded on the above ten random plants at harvest. Lint percentage and seed index (g) were obtained after ginning seed cotton of each treatment**.** The seed cotton yield was hand-picked two times from each plot, weighted in kilograms and calculated as kentars per feddan (one kentar = 157.5 kg)

E-Fiber quality; Samples of lint cotton were taken from the above ten representative plants from each plot after ginning seed cotton on a laboratory gin stand. 2.5% span length (mm) and length uniformity ratio (%), fiber fineness (micronaire reading) and fiber strength (Pressley units) were determined on digital fibrograph instrument 630, micronaire instrument 675 and Pressley instrument, respectively, according to **A.S.T.M. (2012)** at the laboratories of the Cotton Technology Research Division, Cotton Research Institute, Agricultural Research Center, Giza, Egypt.

Statistical analysis:

The statistical analysis of the obtained data in the two seasons was done and performed according to Steel *et al.* (1997). Whenever, the results were found to be significant, the treatments means were compared using LSD at 0.05 level of probability according to Waller and Duncan (1969).

RESULTS AND DISCUSSION

A-Leaves chemical composition:

A-1. N, P, K and Mg concentrations:

Foliar application of the three sources of potassium at the two levels examined either alone or in combination produced the highest N, P, K and Mg percentages in cotton leaves as compared to the control treatment in both seasons (Table 2). Foliar feeding with the combination of the three sources at the low level or at the high level resulted in significant increase in nitrogen, potassium, phosphorus and magnesium percentages in cotton leaves at 115 days old in both seasons. N, P, K and Mg percentages in cotton leaves due to the combination of the three sources at the high level reached to 4.70, 0.50, 2.90 and 0.54%; 4.90, 0.50, 3.59 and 0.65% for N, P, K and Mg in the first and second seasons, respectively. The low levels were detected in the control plants since they recorded 3.80, 0.33, 2.30 and 0.38%; 3.99, 0.28, 2.87 and 0.42% for N, P, K and Mg in 2019 and 2020 seasons, respectively.

The positive effect of foliar feeding with potassium on leaves N, P, K and Mg percentages may be related to; The enhancing effects of K on improving root growth absorption of nutrients through nutrient movements (El-Fouly and El-Sayed, 1997). It was found that K increases guard cells' turgor pressure in the wet leaf resulted in stomata's opening and increased the cuticle permeability for nutrients which penetrate by the pores present inside the cuticle and through small water channels that are also pathways for absorbing the nutrients (Jones and Jeff Jacobsen, 2001). Potassium was needed for producing the necessary conditions for the metabolites, such as sucrose and amino acids through its role of stimulating the plasmalemma ATPase (Barker and Pilbeam, 2007).

In this respect, El-Masri *et al.* (2005) found that foliar feeding with K at the high level (2% K_2O) twice significantly increased percentages of N and K in cotton leaves in both seasons and P percentage in the first season. It gave insignificant effect on leave Mg content as compared to the control treatment. Abdel-Gayed and Awadalla (2014) found that provided cotton plants with 5 kg potassium sulphate/fed as foliar spraying twice at start of flowering and the peak of flowering stages exerted the highest percentages of NPK in cotton leaves.

A-2. Photosynthetic pigments:

Table 3 shows that, foliar spraying of the three potassium forms at the two levels examined either alone or in combination gave the highest concentrations of photosynthetic pigments in the leaves of cotton plants compared to the control during the two growing seasons.

Table 2. Effect of foliar feeding with three sources of potassium at two levels either alone or in combination on N, P, K and Mg percentages in cotton leaves in 2019 and 2020 seasons.

Treatments	N	P	K	Mg
	%			
	2019 season			
T_1 - Control (without application).	3.80	0.33	2.30	0.38
T_2 - Mineral source (potassium sulphate), 0.5g/L.	3.90	0.35	2.40	0.40
T_3 - Mineral source (potassium sulphate), 1g/L.	4.00	0.37	2.40	0.41
T_4 - Organic source (potassium humate), 2g/L.	4.35	0.45	2.50	0.45
T_5 - Organic source (potassium humate), 4g/L.	4.55	0.45	2.75	0.47
T_6 - Natural source (potassium ore), 4g/L.	4.10	0.39	2.40	0.41
T_7 - Natural source (potassium ore), 8g/L.	4.25	0.42	2.50	0.41
T_8 - (T_2+T_4 +T_6).	4.60	0.45	2.90	0.49
T_9 - (T_3+T_5+T_7).	4.70	0.50	2.90	0.54
LSD at 0.05	0.11	0.04	0.11	0.02
Treatments	2020 season			
T_1 - Control (without application).	3.99	0.28	2.87	0.42
T_2 - Mineral source (potassium sulphate), 0.5g/L.	4.09	0.30	2.99	0.45
T_3 - Mineral source (potassium sulphate), 1g/L.	4.19	0.33	2.99	0.46
T_4 - Organic source (potassium humate), 2g/L.	4.55	0.44	3.11	0.50
T_5 - Organic source (potassium humate), 4g/L.	4.75	0.44	3.41	0.53
T_6 - Natural source (potassium ore), 4g/L.	4.14	0.36	3.07	0.46
T_7 - Natural source (potassium ore), 8g/L.	4.39	0.36	3.03	0.46
T_8 - (T_2+T_4 +T_6).	4.80	0.44	3.59	0.55
T_9 - (T_3+T_5+T_7).	4.90	0.50	3.59	0.65
LSD at 0.05	0.12	0.05	0.17	0.03

Foliar feeding with the combination of the three sources at the low level or at the high level significantly increased leaves photosynthetic pigments (chlorophyll a, chlorophyll b, total chlorophyll and carotenoids) additively in the two seasons. The observed increment in the percentage of K in the leaves due to increasing of K application rate can be explained on the basis of increasing the availability of nutrients in the soil (Marschner, 1995). Wallingford (1980) mentioned that potassium is involved in the activation of more than 60 enzymes, which are necessary for essential plant processes such as energy utilization, starch synthesis, N metabolism and respiration this can explain the previous findings. In this respect, it was found that K deficiency resulted into significant decrease in the P uptake indicating that a specific P ion adsorption site existing is activated by application of potassium (Adams and Shin, 2014). N and P use efficiency improved by K fertilization (Epstein and Bloom, 2005). Temiz *et al*. (2009) found that application of foliar potassium increased potassium percentage in cotton leaves compared to the control. There is a significant reduction in leaves nitrogen, phosphorus, potassium and magnesium percentages by cotton under control compared to foliar potassium treatments, where Bennett *et al.* (1965) showed that cotton plants continue to accumulate K at rates above that needed to produce maximum yields, with the highest K content occurring in older leaves and petioles. However, there is evidence that luxury consumption of K is actually beneficial and a relatively cheap insurance policy against environmental stress (Kafkafi, 1990).

Table 3. Effect of foliar feeding with three sources of potassium at two levels either alone or in combination on cotton leaves photosynthetic pigments content in 2019 and 2020 seasons.

Treatments	Chlorophyll a	Chlorophyll b	Total Chlorophyll a+b	Carotenoids
	(mg /g dry weight) 2019 season			
T_1 - Control (without application).	3.57	1.30	4.87	1.82
T_2 - Mineral source (potassium sulphate), 0.5g/L.	3.61	1.32	4.93	1.87
T_3 - Mineral source (potassium sulphate), 1g/L.	3.72	1.37	5.09	1.91
T_4 - Organic source (potassium humate), 2g/L.	3.97	1.46	5.42	2.04
T_5 - Organic source (potassium humate), 4g/L.	4.20	1.56	5.76	2.14
T_6 - Natural source (potassium ore), 4g/L.	3.76	1.39	5.14	1.93
T_7 - Natural source (potassium ore), 8g/L.	3.85	1.43	5.28	1.98
T_8 - (T_2+T_4 +T_6).	4.57	1.70	6.27	2.34
T_9 - (T_3+T_5+T_7).	4.76	1.76	6.52	2.44
LSD at 0.05	0.01	0.05	0.08	0.05
Treatments			2020 season	
T_1 - Control (without application).	3.29	1.22	4.51	1.57
T_2 - Mineral source (potassium sulphate), 0.5g/L.	3.43	1.25	4.68	1.58
T_3 - Mineral source (potassium sulphate), 1g/L.	3.72	1.36	5.08	1.71
T_4 - Organic source (potassium humate), 2g/L.	4.70	1.70	6.40	1.82
T_5 - Organic source (potassium humate), 4g/L.	4.88	1.80	6.68	1.89
T_6 - Natural source (potassium ore), 4g/L.	4.05	1.48	5.53	1.81
T_7 - Natural source (potassium ore), 8g/L.	4.17	1.53	5.69	1.82
T_8 - (T_2+T_4 +T_6).	5.02	1.84	6.86	1.90
T_9 - (T_3+T_5+T_7).	5.22	1.91	7.12	2.08
LSD at 0.05	0.08	0.09	0.14	0.05

Potassium deficiency resulting in reduced stomatal conductance increased the mesophyll resistance and lowered the ribulose-1,5-bisphosphate carboxylase/oxygenase (RuBisCO) activity in plants, which eventually decreased the total photosynthesis rate (Zhao *et al*., 2001). Developing fruits are stronger sinks for photo assimilates than roots and vegetative tissues. This competition for photo assimilates reduces root growth energy supply for nutrient uptake including K (Marschner, 1995). 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 deficiency in reducing the amount of photosynthesis products available for reproductive sinks and thereby producing changes in yield and quality seen in cotton. Abdel-Gayed and Awadalla (2014) found that provided cotton plant with 5 kg potassium sulphate/fed as foliar spraying twice at start of flowering and the peak of flowering stages exerted the highest concentrations of chlorophyl (a), chlorophyll (b) and carotenoids in cotton leaves.

B- Growth parameters:

Data presented in Table 4 revealed that, canopy dry weight (g/plant) and LAI after 115 days from sowing were significantly increased by foliar application of different sources of potassium at the two levels examined as compared with the control. The highest values of these parameters (138.67 g and 3.02;148.00 g and 3.10) were observed where the combination of the three sources at the high level was applied, followed by the combination of the three sources at the low level (129.33 g and 2.92; 144.00 g and 3.01). The lowest values (88.00 g and 2.38; 99.33 g and 2.63) were recorded, for the control during the first and second seasons, respectively.

Foliar application with the three sources at the two levels either alone or in combination resulted in proportionate increase in the plant height and its number of fruiting branches at harvesting. The taller plants with the highest

number of fruiting branches (166.90 cm and 17.30;165.83 cm and 17.10) were recorded on cotton plants treated with the combination of the three sources at the high level, followed by the combination of the three sources at the low level (164.33 cm and 17.10; 164.30 cm and 16.93). The lowest values (153.80 cm and 14.27; 151.47 cm and 14.13) were recorded in the control during the first and second seasons, respectively. This increment in vegetative growth noticed in cotton plants sprayed with potassium sources may be due to; The role of potassium on plant nutrition (significant increase in leaves N, P, K and Mg percentages and significant increase in leaves photosynthetic pigments content as shown in Tables 2 and 3) as compared to the control treatment. The results confirm that although, soil K content is at optimal value as indicated in Table (1) according to Ankerman and Large (1974), soil potassium content is not enough to the needs of cotton plants. Both the leaf number and size are increased when K is enough and later the rate of photosynthetic per unit leaf area increased and thus account for an overall increment in the available amount of photosynthetic assimilates for growth (Pettigrew, 2008). Potassium is involved in a large number of plant functions, including; enzyme activation, osmoregulation via-stomatal control, cell extension, phloem transport of sugars and starch, protein synthesis, photosynthesis, respiration, ion absorption and transport (cation-anion balance) and disease resistance (Barker and Pilbeam, 2015).

Table 4. Effect of foliar feeding with three sources of potassium at two levels either alone or in combination on cotton growth parameters in 2019 and 2020 seasons.

Treatments	Canopy dry weight (g plant^{-1})	Leaf area Index	Final plant height (cm)	Number of fruiting branches Plant^{-1}
	2019 season			
T_1 - Control (without application).	88.00	2.38	153.80	14.27
T_2 - Mineral source (potassium sulphate), 0.5g/L.	107.67	2.40	157.40	15.77
T_3 - Mineral source (potassium sulphate), 1g/L.	114.00	2.51	158.40	16.00
T_4 - Organic source (potassium humate), 2g/L.	119.33	2.71	159.10	16.67
T_5 - Organic source (potassium humate), 4g/L.	114.00	2.78	161.00	16.80
T_6 - Natural source (potassium ore), 4g/L.	118.00	2.55	156.50	15.50
T_7 - Natural source (potassium ore), 8g/L.	120.00	2.65	155.40	15.00
T_8 - (T_2+T_4 +T_6).	129.33	2.92	164.33	17.10
T_9 - (T_3+T_5+T_7).	138.67	3.02	166.90	17.30
LSD at 0.05	3.12	0.05	1.22	0.48
Treatments	2020 season			
T_1 - Control (without application).	99.33	2.63	151.47	14.13
T_2 - Mineral source (potassium sulphate), 0.5g/L.	104.67	2.67	156.43	15.27
T_3 - Mineral source (potassium sulphate), 1g/L.	112.67	2.73	156.93	15.97
T_4 - Organic source (potassium humate), 2g/L.	127.33	2.82	157.17	16.10
T_5 - Organic source (potassium humate), 4g/L.	133.33	2.87	159.07	16.40
T_6 - Natural source (potassium ore), 4g/L.	126.00	2.67	155.07	15.03
T_7 - Natural source (potassium ore), 8g/L.	130.00	2.75	153.00	14.83
T_8 - (T_2+T_4 +T_6).	144.00	3.01	164.30	16.93
T_9 - (T_3+T_5+T_7).	148.00	3.10	165.83	17.10
LSD at 0.05	3.64	0.04	1.15	0.46

In this regard, El-Masri *et al.* (2005) found that foliar feeding with K at the high level (2% K_2O) and at the low level (1% K_2O) twice significantly increased number of fruiting branches/plant in one season only and plant height in both seasons as compared to the control treatment. Waraich *et al.* (2011) found that foliar application of KNO_3 at 2% markedly increased number of leaves, number of sympodia/plant and plant height (cm). Cheema *et al.* (2012) found that K increases the utilization of carbohydrates, regulates the biosynthesis, conversion, and allocation of metabolites, increases the leaf area index and the dry matter accumulation. Marschner (2012) reported that during stomatal movement K plays a vital role in regulate turgor within the guard cells. K is essential for the translocation of photo assimilates. In higher plants, K regulates the metabolite pattern and changes metabolite concentrations. K is essential for multiple functions of plant enzyme. Under K-deficit condition, NO_3^-, amino acids, and amides accumulate in the cell, where protein formation is hampered even when there is an abundant N supply (Fageria, 2016). Abdel-Gayed and Awadalla (2014) found that provided cotton plant with 5 kg potassium sulphate/fed as foliar spraying twice at start of flowering and the peak of flowering stages exerted the highest values of plant height and number of fruiting branches/plant. Bakker (2018) reported that potassium is primarily present as ionic K^+, with a very small percentage incorporated into organic tissue, and is the most abundant cation in plant cytosol.

C. Earliness measurements:

Significant differences were exhibited on boll shedding percentage as affected by foliar application with the three sources of potassium at the two levels examined (Table 5), where boll shedding percentage significantly increased from 20.31 and 21.46%; 26.93 and 24.93% in foliar feeding with the combination of the three sources at the low level and at the high level to 38.79 and 38.96% in the control treatment in 2019 and 2020 seasons, respectively. The opposite trend was obtained with regard to boll setting% in both seasons. Also, these two combinations produced the highest earliness% (71.70 and 73.10%; 72.70 and 71.86%) as compared to the control which produced the lowest percentage (58.29 and 50.90%) in 2019 and 2020 seasons, respectively. The greater number of total bolls/plant (24.37 and 18.97) was recorded, from the combination treatment of the three sources at the high level in 2019 season and at the low level in 2020 season. Also, the greater number of total flowers/plant (31.92 and 25.98) was recorded, where foliar spraying with potassium humate treatment at the low level in the first season and the combination treatment of the three sources at the low level in the second season. The lowest number of total flowers/plant (25.39 and 23.71) was recorded, where foliar spraying with potassium ore at the high level in the first season and foliar spraying with potassium sulphate at the low level in the second season.

Table 5. Effect of foliar feeding with three sources of potassium at two levels either alone or in combination on cotton earliness measurements in 2019 and 2020 seasons.

Treatments	No. of total bolls $plant^{-1}$	No. of total flowers $plant^{-1}$	Boll setting %	Boll shedding %	Earliness %
			2019 season		
T_1 - Control (without application).	16.97	27.73	61.21	38.79	58.29
T_2 - Mineral source (potassium sulphate), 0.5g/L.	19.53	29.70	65.80	34.20	62.67
T_3 - Mineral source (potassium sulphate), 1g/L.	21.43	31.34	68.39	31.61	64.30
T_4 - Organic source (potassium humate), 2g/L.	22.30	31.92	69.90	30.10	66.90
T_5 - Organic source (potassium humate), 4g/L.	21.93	30.11	72.82	27.18	65.80
T_6 - Natural source (potassium ore), 4g/L.	19.23	28.73	66.95	33.05	58.70
T_7 - Natural source (potassium ore), 8g/L.	18.33	25.39	72.38	27.62	59.00
T_8 - (T_2+T_4 +T_6).	23.90	29.99	79.69	20.31	71.70
T_9 - (T_3+T_5+T_7).	24.37	31.04	78.54	21.46	73.10
LSD at 0.05	0.96	1.83	3.06	3.06	2.37
Treatments			2020 season		
T_1 - Control (without application).	14.57	23.88	61.04	38.96	50.90
T_2 - Mineral source (potassium sulphate), 0.5g/L.	15.67	23.71	66.06	33.94	58.60
T_3 - Mineral source (potassium sulphate), 1g/L.	16.28	24.14	67.47	32.53	65.13
T_4 - Organic source (potassium humate), 2g/L.	16.64	24.38	68.27	31.73	66.57
T_5 - Organic source (potassium humate), 4g/L.	17.34	24.55	70.61	29.39	68.64
T_6 - Natural source (potassium ore), 4g/L.	15.94	23.75	67.12	32.88	63.76
T_7 - Natural source (potassium ore), 8g/L/	17.23	25.84	66.67	33.33	68.27
T_8 - (T_2+T_4 +T_6).	18.97	25.98	73.07	26.93	72.70
T_9 - (T_3+T_5+T_7).	18.70	24.91	75.07	24.93	71.86
LSD at 0.05	0.73	0.99	1.66	1.66	2.39

The positive effect of using the combination of the three sources at the two levels examined on earliness measurements is mainly due to that externally applied potassium helps to increase flowering, pollen germination rate and tube growth as well as boll development (Fan *et al*., 2001). Choudhury *et al*. (2013) found that KNO_3 plays a major role in pollen germination and development. The reproductive growth particularly flowering and boll setting are highly sensitive to low soil water potentials, where enough supply with K can play a vital role in this respect. K application has impact on boll setting. Shahzad *et al.* (2019) reported that cotton requires potassium (K) in copious amounts as compared to other crops. As cotton is grown in arid and semiarid areas, therefore often prone to water deficiency. The problem of boll shedding is the possible reason of decrease in number of bolls per plant. Shedding of flower buds followed the damage in the leaves by K deficiency (Loka *et al*., 2019). In cotton, the problem of boll shedding arises from nutrient deficiency and drought stress. In drought conditions, potassium maintains plant turgor and makes plant withstand drought conditions. So, in adverse environment condition of hot climate, plants deficient in potassium could not retain their bolls.

In this regard, El-Masri *et al.* (2005) found that foliar feeding with K at the high level (2% K_2O) and at the low level (1% K_2O) twice significantly increased number of total flowers/plant and number of total bolls set/plant in one season only and earliness% in both seasons as compared to the control treatment.

D- Seed cotton yield and its components:

The three sources of potassium examined at the two levels either alone or in combination resulted in positive effect on seed index and lint% in the second season. Maximum seed index (10.65 and 10.38 g) and lint% (42.37 and 42.39%) were recorded, where foliar spray three times with the combination of the three sources at the low level or at the high level, respectively. Also, the three sources of potassium examined at the two levels either alone or in combination resulted in positive effect on number of open bolls/plant and boll weight in both seasons (Table 6). Maximum number of open bolls/plant (23.90 and 24.37; 18.97 and 18.70) and boll weight (3.28 and 3.25 g; 3.44 and 3.29 g) were recorded, where foliar spray three times with the combination of the three sources at the low level or at the high level, respectively. The minimum seed index (9.09 g) and lint% (40.43%) in the second season, number of open bolls/plant (16.97 and 14.57) and boll weight (2.93 and 2.43 g) in the first and second seasons resulted, where recommended rate of K was soil applied only (control treatment). The increase in boll weight of foliar spray three times with the combination of the three sources may be contributed to additional potassium nutrition along with higher percentages of leaves nitrogen, phosphorus, potassium and magnesium(Table 2), so the top bolls of cotton plant developed completely and was higher in weight and number. Results pertaining to seed

cotton yield/feddan as affected by foliar feeding with the three sources of potassium at the two levels examined either alone or in combination as mentioned in Table 6 show significant effect on the seed cotton yield/feddan in both seasons, where combination of the three sources at the low level significantly increased seed cotton yield/fed by 25.22,14.68, 12.04, 9.40, 8.87, 21.81, 12.49 and 10.92% over the control treatment, foliar spraying with potassium sulphate at the low level, foliar spraying with potassium sulphate at the high level, foliar spraying with potassium humate at the low level, foliar spraying with potassium humate at the high level, foliar spraying with potassium ore at the low level, foliar spraying with potassium ore at the high level and foliar spraying with the combination of the three sources at the high level in the first season and by 24.11, 18.70, 15.87, 15.87, 11.36, 13.86, 13.98 and 8.24% in the second season, in respective order. Potassium regulates the metabolites biosynthesis, conversion, and allocation that ultimately increases the yield. Cheema *et al.* (2012) found that K helps to increase the carbohydrates utilization and the leaf area index, which help to increase the accumulation of dry matter and ultimately increase the yields. The cotton plant moves more quickly (earlier) from the vegetative phase to the reproductive phase when K levels in soil are insufficient (Pettigrew, 1999), resulting in yield reduction (Pettigrew, 2008). Potassium application was found to have significant effect and improved the yield of cotton. The increasing levels of potassium caused significant increase in cotton yield. The necessity of inclusion of application of potassium in the fertilization of cotton grown on clayey soil for increasing productivity as well as increasing nutrient uptake by cotton. The favourable influences of foliar spraying with potassium sources on increasing yield and its components might be attributed to its positive effects on enhancing leaf mineral composition and photosynthesis pigments (Tables 2 and 3), vegetative growth (Table 4) and earliness attributes (Table 5).

Table 6. Effect of foliar feeding with three sources of potassium at two levels either alone or in combination on seed cotton yield and its components of cotton Giza 86 cultivar in 2019 and 2020 seasons.

Treatments	Lint %	Seed index (g)	Number of open bolls Plant^{-1}	Boll weight (g)	Seed cotton yield fed^{-1} (kentar)
			2019 season		
T_1 - Control (without application).	40.16	10.20	16.97	2.93	8.92
T_2 - Mineral source (potassium sulphate), 0.5g/L.	41.04	10.36	19.53	3.09	9.74
T_3 - Mineral source (potassium sulphate), 1g/L.	41.12	10.25	21.43	3.05	9.97
T_4 - Organic source (potassium humate), 2g/L.	40.26	10.30	22.30	3.13	10.21
T_5 - Organic source (potassium humate), 4g/L.	41.65	10.08	21.93	3.16	10.26
T_6 - Natural source (potassium ore), 4g/L.	40.61	10.39	19.23	3.01	9.17
T_7 - Natural source (potassium ore), 8g/L.	40.49	10.55	18.33	3.14	9.93
T_8 - (T_2+T_4 +T_6).	40.64	10.67	23.90	3.28	11.17
T_9 - (T_3+T_5+T_7).	40.15	10.35	24.37	3.25	10.07
LSD at 0.05	NS	NS	0.96	0.05	0.62
Treatments			2020 season		
T_1 - Control (without application).	40.43	9.09	14.57	2.43	9.00
T_2 - Mineral source (potassium sulphate), 0.5g/L.	40.44	9.27	15.67	2.85	9.41
T_3 - Mineral source (potassium sulphate), 1g/L.	40.50	10.09	16.28	2.86	9.64
T_4 - Organic source (potassium humate), 2g/L.	41.33	9.29	16.64	2.85	9.64
T_5 - Organic source (potassium humate), 4g/L.	41.37	10.34	17.34	3.20	10.03
T_6 - Natural source (potassium ore), 4g/L.	40.50	10.10	15.94	3.06	9.81
T_7 - Natural source (potassium ore), 8g/L.	40.76	10.07	17.23	2.99	9.80
T_8 - (T_2+T_4 +T_6).	42.37	10.65	18.97	3.44	11.17
T_9 - (T_3+T_5+T_7).	42.39	10.38	18.70	3.29	10.32
LSD at 0.05	0.57	0.13	0.73	0.08	0.54

In this regard, El-Masri *et al.* (2005) found that foliar feeding with K at the high level (2% K_2O) and at the low level (1% K_2O) twice significantly increased seed cotton yield over the control treatment by 15.56 and 5.81%; 7.72 and 5.67% in the first and second seasons, respectively. Foliar feeding with K at the high level (2% K_2O) significantly increased number of open bolls/plant and seed index in one season only and boll weight in both seasons as compared to the control treatment. Lint% did not affected. Sawan *et al*. (2008) found that seed-cotton yield significantly increased by K application due to positive effects of this nutrient on yield components (open bolls number/plant and boll weight). Temiz *et al*. (2009) found that applying potassium as foliar spraying insignificantly affected lint% and yield of seed-cotton. Waraich *et al.* (2011) reported that increasing concentrations of foliar potassium significantly affected bolls number. They added that, foliar application of KNO_3 at 2% significantly increased number of bolls and ginning out turn (GOT%). Abdel-Gayed and Awadalla (2014) found that provided cotton plant with 5 kg potassium sulphate/fed as foliar spraying twice at start of flowering and the peak of flowering stages exerted the highest values of number of open bolls/plant, boll weight and seed cotton yield. Lint% did not affected. Muhammad *et al*. (2016) reported that more potassium (K) required by modern cotton cultivars during peak bloom and boll setting period and its deficiency adversely affects the yield of seed-cotton. Kadam *et al.* (2017) found that the increasing levels of potassium caused significant increase in yield of cotton. Hussain *et al.* (2020) found that foliar application of K_2SO_4 improved seed cotton yield under the arid climate.

E-Fiber quality traits:

Concerning the effect of foliar feeding with K in the form of three sources coupled with two levels on 2.5% span length (mm), uniformity ratio (%), fiber strength (Pressley units) and fiber fineness (micronaire reading), the results in Table 7, show significant differences in 2.5% span length (mm), fiber strength (Pressley units) and fiber fineness (micronaire reading) in the second season only, in favor of foliar feeding with the combination between the three sources at the high level (1, 2 and 8 g)/L followed by the low level (0.5, 2 and 4 g)/L. These two levels produced the longest fibre length (35.20 and 35.10 mm), and the highest fiber strength (11.59 and 11.75 Pressley units), respectively. The control recorded the lowest values of these traits in consideration (10.57 Pressley units and 33.10 mm). Micronaire reading was significantly increased from applying potassium as foliar spraying with the combination between the three sources at the two levels used. They recorded (4.47 and 4.47 micronaire units). However, applying potassium as foliar spraying in the form of mineral source (potassium sulphate) at the two levels used recorded the lowest values (4.07 and 4.17 micronaire units).

Improvement in quality due to K application as foliar feeding with the combination between the three sources at the two levels examined might be attributed to; K improves water use efficiency and maintains surplus water pressure within the boll, which eventually improve fiber quality and increase carbohydrate available amount to mature bolls (Pettigrew, 2001), where K increases rate of photosynthetic through its role in CO_2 fixation, cell turgor control (Marschner, 1995) and carbohydrate metabolism and translocation, which eventually improve the fiber quality (Lu *et al*., 2016). The role of K in transport sugar into the developing boll leads to higher cellulose deposition in the secondary fiber cell wall was detected (Hu *et al*., 2015). This is reflected in the increase of the micronaire value. Fiber occurs as a thin cell wall of carbohydrate polymers which deposited allowing the fiber to elongate lengthening (DeLanghe, 1986), where potassium serving as an osmoticum, producing turgor pressure inside the developing fibre in conjunction with carbohydrate polymers deposition for fibre elongation (Dhindas *et al*., 1975). During the process of fiber thickening, sucrose synthetase (SS) and sucrose phosphatase synthase (SPS) serve as the main enzymes for cellulose synthesis, and their activities are highly dependent upon the K application rate (Zahoor *et al.*, 2017 and Ali *et al.*, 2018).

Table 7. Effect of foliar feeding with three sources of potassium at two levels either alone or in combination on some fiber traits of cotton Giza 86 cultivar in 2019 and 2020 seasons.

Treatments	**Fiber fineness (micronairereading)**	**Fiber strength (Pressley units)**	**2.5% span length (mm)**	**Length uniformity ratio (%)**
		2019 season		
T_1 - Control (without application).	4.6	10.7	34.1	86.6
T_2 - Mineral source (potassium sulphate), 0.5g/L.	4.6	10.6	34.3	86.4
T_3 - Mineral source (potassium sulphate), 1g/L.	4.6	10.9	34.4	86.4
T_4 - Organic source (potassium humate), 2g/L.	4.4	10.7	34.5	87.0
T_5 - Organic source (potassium humate), 4g/L.	4.7	10.8	34.8	86.6
T_6 - Natural source (potassium ore), 4g/L.	4.6	10.9	34.5	86.2
T_7 - Natural source (potassium ore), 8g/L.	4.6	10.6	34.0	86.8
T_8 - (T_2+T_4 +T_6).	4.6	11.1	34.7	86.9
T_9 - (T_3+T_5+T_7).	4.5	11.0	35.2	86.6
LSD at 0.05	NS	NS	NS	NS
Treatments		2020 season		
T_1 - Control (without application).	4.20	10.57	33.10	84.50
T_2 - Mineral source (potassium sulphate), 0.5g/L.	4.07	11.27	33.47	85.77
T_3 - Mineral source (potassium sulphate), 1g/L.	4.17	11.50	33.67	85.80
T_4 - Organic source (potassium humate), 2g/L.	4.30	11.40	34.40	85.87
T_5 - Organic source (potassium humate), 4g/L.	4.37	11.57	34.60	86.30
T_6 - Natural source (potassium ore), 4g/L.	4.20	11.27	33.17	85.27
T_7 - Natural source (potassium ore), 8g/L.	4.30	11.40	33.57	85.40
T_8 - (T_2+T_4 +T_6).	4.47	11.59	35.10	86.77
T_9 - (T_3+T_5+T_7).	4.47	11.75	35.20	86.47
LSD at 0.05	0.20	0.28	0.91	NS

Similarly, Hu *et al.* (2018) have reported that increased regulation of SPS and SS activities in response to higher K availability during the fiber thickening period leads to increased cellulose concentration and better cotton fiber strength. If K is limited during active fiber growth, there is a reduction in the fiber turgor pressure resulting in less cell elongation and shorter fibers at maturity. Potassium plays a pivotal role in the fiber formation and development (Yang *et* *al.,* 2016). It was found that cotton fiber shifts towards a thickening of the secondary cell wall after 16 days of anthesis, in which cellulose synthesis is the prominent metabolism (Haigler *et al*., 2001).

In this respect, Minton and Ebelhar (1991) reported that varying potassium concentrations increased micronaire. Pettigrew *et al*. (1996) found that in eight genotypes of differing relative earliness and regional adaptation, K deficiency reduced 50% span length, micronaire and fiber elongation. Insufficient potassium supply decreases the fiber turgor pressure and the primary fiber cell wall cannot be elongated resulting in shorter fibers (Pettigrew, 2003). In cotton the use of K fertilizers decreased the amount of damaged fibers and improved fiber staple length, tensile strength and fiber micronaire (Li *et al*., 2005). Sawan *et al.* (2008) found that K application significantly increased 2.5% span length and fiber strength. Waraich *et al.* (2011) reported that foliar application of KNO_3 at 2% markedly increased fiber micronaire, fiber uniformity (%), fiber length (mm) and fiber strength. Hussain *et al*. (2020) added that foliar application of K_2SO_4 improved fiber quality of cotton under arid climate. On the other hand, Temiz *et al.* (2009) reported that application of foliar potassium insignificantly affected fiber quality parameters. Abdel-Gayed and Awadalla (2014) found that micronaire reading and Pressley index did not affected by potassium application. Emara (2016) found that the potassium treatments gave insignificant effect on fiber quality traits. Shahzad *et al.* (2019) reported that parameters of fiber quality were insignificantly affected by K application. Micronaire is a composite measure of fiber fineness and maturity since fiber cells with the same wall width can have different micronaire values. Fiber maturity determines by the degree of secondary wall deposition (Davidonis *et al*., 2004). When there is ample supply of carbohydrate to mature bolls set on the plant, micronaire tends to increase (Pettigrew, 2001).

CONCLUSION

It could be concluded that, foliar feeding with the combination of the three K sources examined [mineral source (potassium sulphate), organic source (potassium humate) and natural source (potassium ore)] at the low level of each source (0.5, 2 and 4 g)/L in respective order three times as alternative to soil K fertilization to reduce cost, overcome K fixation and harvest higher productivity along with better fiber quality under conditions similar to El-Gemmeiza region.

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تأثير صور مختلفة للبوتاسيوم على النمو وبعض الصفات الفسيولوجية وإنتاجية القطن المصرى

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أجريت تجربتان حقليتان بمحطة البحوث الزراعية بالجميزة - محافظة الغربية - مصر خلال موسمى 2020,2019م بهدف تقييم تأثير التغذية الورقية بثلاثة مصادر من البوتاسيوم [مصدرمعدني (كبريتات البوتاسيوم) ، مصدر عضوي (هيومات البوتاسيوم) ، مصدر طبيعي (خام البوتاسيوم)] بمستويين لكل مصدر (0.5 ، 1 جم / لتر) ، (2 ، 4 جم / لتر) ، (4 ، 8 جم / لتر) على التوالي كما تم الجمع بين المصادر الثلاثة عند المستوى المنخفض والمستوى العالي ، بالإضافة إلى معاملة الكنترول (إضافة أرضية للبوتاسيوم بالمعدل الموصى به مع الرش بماء الصنبورعند رش المعاملات) وتاثير ذلك على النمو وبعض الصفات الفسيولوجية وإنتاجية صنف القطن المصري جيزة 86 ومحتواه الكيماوى الداخلى وتم استخدام تصميم القطاعات الكاملة العشوائية بثلاث مكررات وتم تطبيق هذه المعاملات ثلاث مرات. وأشارت النتائج المتحصل عليها إلى أن التغذية الورقية بالمصادر الثلاثة عند المستوى المنخفض أو المستوى العالي ادت الى زيادة معنوية فى تركيز النيتروجين، الفوسفور، البوتاسيوم، الماغنسيوم ، صبغات التمثيل الضوئى في أوراق القطن ومؤشرات النمو وقياسات التبكير(باستثناء نسبة تساقط اللوز والتي انخفضت) ومحصول القطن الزهر للفدان ، وزن اللوزة ،عدد اللوز المتفتح على النبات فى الموسمين وكذلك معامل البذرة ، النسبة المئوية للتيلة ، طول التيلة والمتانة وقراءة الميكرونير فى الموسم الثانى مقارنة مع معاملة الكنترول.وتوصى الدراسة بإستخدام هذه المصادر الثلاث مجتمعة بالتركيز المنخفض (0.5جم كبريتات البوتاسيوم. ، 2 جم هيومات البوتاسيوم ،4جم خام البوتاسيوم) /اللتر رشا ولثلاث مرات (في مرحلة الوسواس، بداية التزهير وقمة التزهير) كبديل للتسميد الارضى من البوتاسيوم وخفض التكاليف والتغلب على تثبيت البوتاسيوم وللحصول على أعلى إنتاجية تحت أى ظروف مماثلة لمنطقة الجميزة.