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Original Article

The application of ammonium sulphate and amino acid on cotton: effects on can improve growth, yield, quality and nitrogen absorption

Aplicação de sulfato de amônio e aminoácido no algodão: efeitos sobre o crescimento, o rendimento, a qualidade e a absorção de nitrogênio

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Abstract

A field study was carried out to determine the influence of foliage applied plant growth promoter and retardant in improving soil applied sulphur fertilizer use efficiency in cotton during two consecutive summers 2014 and 2015. Experimental trial comprised of three different sources of sulphur (ammonium sulphate, potassium sulphate and elemental sulphur) and foliar spray of plant growth promoter and growth retardant including tap water was taken as control. Among treatments soil applied ammonium sulphate with foliage applied amino acid produced maximum plant height, sympodial branches, pods per plant, seed cotton yield, fiber yield, biological yield, protein contents, oil contents and leaf nitrogen uptake as compared to the other treatments. Whereas, soil applied potassium sulphate with foliar spray of mepiquat chloride on cotton significantly improved the boll weight and leaf potassium uptake. We conclude that soil applied ammonium sulphate and foliage spray of amino acid was more effective in improving the productivity and quality attributes of cotton.

Keywords: mepiquat chloride, seed protein, nutrients uptake, potassium sulphate, sulphur.

Resumo

Foi realizado um estudo de campo para determinar a influência do promotor de crescimento das plantas e retardador da folhagem em algodão, para melhora da eficiência do uso de fertilizantes à base de enxofre aplicados no solo durante dois verões consecutivos (2014 e 2015). O ensaio experimental foi composto de três fontes diferentes de enxofre (sulfato de amônio, sulfato de potássio e enxofre elementar) e pulverização foliar do promotor de crescimento de plantas e retardador de crescimento, incluindo água da torneira que foi tomada como controle. Entre os tratamentos, o sulfato de amônio aplicado no solo com aminoácido aplicado na folhagem produziu o máximo na altura da planta, ramos simodiais, capulhos por planta, rendimento de algodão em caroço, rendimento de fibra, rendimento biológico, conteúdo de proteínas, conteúdo de óleo e absorção de nitrogênio nas folhas quando comparado a outros tratamentos. Enquanto o solo fertilizado com sulfato de potássio e aplicação foliar de cloreto de mepiquat no algodão melhorou, significativamente, o peso do capulho e a absorção de potássio nas folhas. Sulfato de amônio aplicado no solo e a aplicação foliar de aminoácidos foram mais eficazes na melhora dos atributos de produtividade e qualidade do algodão.

Palavras-chave: cloreto de mepiquat, proteína em sementes, absorção de nutrientes, sulfato de potássio, enxofre.

1. Introduction

Cotton (*Gossypium hirsutum* L.), the king of fibers, is a major cash crop, which is commercially grown for agricultural and industrial purposes (Iqbal et al., 2017). Cotton fiber in earlier times and its by-products nowadays has dominated the economy of developing and developed countries of the world as well. Cotton is an important agricultural commodity and occupies a distinctive position in the agriculture-based economy. It is the key source of employment for millions involved in production; processing, ginning, fabric and oil industry and trade related activities (Noreen et al., 2013).

Improvement in crop productivity with the adoption of high-yielding genotypes and multiple cropping systems, use of fertilizers has become more and more imperative to enhance the crops produce and quality. Sulphur is the fourth element essential for plant growth after nitrogen, phosphorus and potassium. It is indispensable for the synthesis of amino acids, proteins, oils, and stimulates enzyme system in the plants (Najafian and

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Zahedifar, 2015). It is also an essential component of vitamin A, biotin and thiamine (B_1) required for the plant to carry out its biochemical processes and an iron-sulphur protein occurring in the chloroplasts called ferredoxins (Scherer et al., 2008). Sulphur application reduced the soil pH, which considerably improved the chlorophyll concentration, nutrient uptake and dry matter accumulation (Motior et al., 2011). The function of sulphur is to assist plants in the synthesis of proteins and chlorophyll and improves root growth. It also plays an active role in development and quality of cottonseed.

Besides plant essential nutrients, certain growth promoters have also improved the productivity and quality attributes of cotton (Arif et al., 2019). Among different growth promoters, amino acids are gaining a lot of consideration nowadays, which has encouraging influence on the plant growth and productivity (Kowalczyk and Zielony, 2008). Amino acids are organic molecules, comprised of nitrogen, hydrogen, oxygen and carbon, which have an organic side-chain in their structure that differentiates the distinctive amino acids (Buchanan et al., 2000). The principal amino acids produced by plants are the glutamine, aspartate and glutamate, and from these other amino acids may be synthesized. Glutamate is the major amino acid in which the nitrogen absorbed by the plants is incorporated and from it, a series of amino acids can be achieved with the aminotransferases activity (Taiz and Zeiger, 2013). They have encouraging influences on the physiological activities of growth and development in different plants and improved the productivity (Koukounaras et al., 2013; Sadak et al., 2015).

In addition to growth promoters, some plant growth retardants also play an important role in internal control mechanism of cotton plant growth by interacting with crucial metabolic activities like protein synthesis and nucleic acid. The most commonly used growth inhibitor in cotton is mepiquat chloride, which is inhibits the formation of gibberellic acid. It controls the undesired vegetative development, enhances the leaf thickness, decreases leaf area, shortens internodes and reduces the plant height, and hence consequences in a compact plant structure (Yasmeen et al., 2016). Adjustment in cotton plant architecture influences the light penetration into the canopy and improves the light interception in the middle part of the canopy and increases the light use efficiency that resulting in improved retention of bolls at lower sympodial branches and higher seed cotton yield along with reduced square and flowers abortion can stimulate early maturity (Nuti et al., 2006; Gonias et al., 2012).

Though numerous studies indicated the constructive roles of sulphur, amino acid and mepiquat chloride on cotton productivity but to best of our information no study has been carried out to explore the interactive effects of sulphur, amino acid and mepiquat chloride on growth, yield and quality attributes of cotton. Therefore, this study was planned to determine the influence of foliage applied plant growth promoter and growth retardant in improving the soil applied sulphur fertilizer use efficiency in cotton.

2. Material and Methods

A field study was carried to explore the influence of foliar application of plant growth promoter and retardant in improving the soil applied sulphur fertilizer use efficiency in cotton during two successive years 2014 and 2015. Experimental soil was silt clay loam having ECe 2.01 and 2.10 dS m^{-1}, pH 7.95 and 8.08, organic matter 0.58 and 0.53%, total nitrogen 0.0052 and 0.0057%, available phosphorus 6.2 and 6.7 ppm and available potassium 270 and 245 ppm. Experimental trial comprised of three different sources of sulphur (ammonium sulphate, potassium sulphate and elemental sulphur) and foliar spray of plant growth promoter (glutamina amino acid 10 ppm) and growth retardant (mepiquat chloride 12 g ha^{-1} a.i.) including control (tap water). Foliar spray of different treatments was applied 100 and 130 days after sowing. The field study was designed in a completely randomized block with factorial arrangement having three repeats.

2.1. Crop husbandry

Before land preparation for research activities, pre-soaking irrigation (Rauni) was applied. As the soil reached to a workable moisture level, a fine seedbed was prepared by cultivating the experimental plot thrice and then bed shaper was used for proper beds formation. Delinted seeds of FH-142 were manually sown during first week of April 2014 and 2015 by keeping 20 cm plant-to-plant distance. To ensure optimum plant population, each experimental unit was again irrigated two days after dibbling. Succeeding irrigations were applied according to crop requirements. Nitrogen fertilizer (150 kg ha^{-1}) was applied, in the form of Urea, at three unique growth periods i.e. at the time of sowing, start of bloom and peak flowering stage. However, complete dose of phosphorus (60 kg ha^{-1}) and potassium fertilizer (65 kg ha^{-1}) was applied in the form of SSP and SOP at the time of sowing, respectively. Pre-emergence herbicide was sprayed to control weeds along with three-hand weeding at the 12^{th}, 21^{st} and 30^{th} days after sowing. Various plant protection measures were used to retain the cotton pests under the threshold level. All the agronomic practices excluding experimental treatments were kept identical for each experimental unit.

2.2. Data collect

After 35 days of sowing, fifteen plants were selected randomly in each experimental unit and tagged to record the data on various agronomic parameters through adopting standard procedures. Data regarding plant height from tagged plants of each plot were noted from the base to the tip of the main stem and averaged. Sympodial (fruit bearing) branches and number of bolls per plant from tagged plants of each experimental unit were counted and averaged. Mean boll weight was recorded from twenty bolls of tagged plants covering base to top in each picking and averaged. Similarly, seed cotton yield was picked three times from net plot of each experimental unit and weighed and then converted into kilograms per hectare. Moreover, fiber yield attained from selected area bolls of the each plot and weighed and then converted into kilograms per hectare. Biological yield was recorded from net plot of each plot was collected and weighed and then converted into kilograms per hectare.

To record oil contents, 3g of the processed samples were weighed into a known weight of thimble. A clean dry extraction flask (250ml capacity) was weighed and sufficient quantity of 400C – 600 c acetone was poured into it. The thimble with the sample was placed into the flask and oil was extracted as already described above. At the end of extraction, the resulting mixture containing oil was heated to recover the solvent and the weight of the round bottom flask with oil was noted after cooling (Okonkwo and Okafor, 2016).

The crude protein was determined by Kjeldahl method. 2g of processed sample were taken and placed into 100ml Kjeldahl digestion flasks. Few grams of Kjeldahl catalyst mixture (Na_2SO_4 + $CuSO_4$) and 15ml of conc. H_2SO_4 were added. The mixtures were mixed thoroughly and heated in a fume cupboard for about 2 hours until complete digestion was reached. This was identified when a clear solution was obtained. The cool digest was diluted to 100ml and only 10ml of the digest was mixed with equal volume of 10mol/dm^3 NaOH. The mixture was placed in micro-Kjeldahl distillation apparatus which was distilled by steam and the distillate was collected into a conical flask containing 10ml of 4%Boric acid. Few drops of mixed indicator (5g bromocrysol green and 1g methyl red in 100ml of ethanol) were added into 50ml of the distillate and titrated against 0.1M H_2SO_4 solution. A blank was conducted simultaneously under similar experimental condition (Okonkwo and Okafor, 2016).

Total nitrogen in organic material was estimated by Kjeldahl distillation method described by Jackson (1962). While, phosphorus was determined by spectrophotometer (Milton Roy Company) using the Barton reagent described by Ashraf et al. (1992). Potassium content in the filtrate was determined by Jenway PFP-7 flame photometer described by Richards (1954).

2.3. Statistical analysis

All the collected data was statistically analyzed by using the computed based software M STAT C. DMR test was used to compare variations among different treatment means at 5% probability level (Steel et al., 1997).

3. Results

Application of plant growth promoters and retardant significantly affected the growth, yield and quality attributes of cotton. Results showed that interaction among different sources of sulphur and foliar spray of plant growth regulators significantly affected plant height during 2014 and 2015 (Table 1). Soil applied ammonium sulphate and foliar spray of amino acid produced significantly taller plants against the minimum height was recorded with the application of elemental sulphur with foliar spray of mepiquat chloride (Table 1). Likewise, sympodial branches also significantly improved by interactive influences of sulphur sources and foliar spray of plant growth regulators. Application of ammonium sulphate with foliar spray of amino acid produced maximum sympodial branches per plant. While the minimum sympodial branches were observed with the application of elemental sulphur with foliar spray of mepiquat chloride during both growing seasons (Table 1).

Bolls per plant of cotton crop is identified as a fundamental and foremost yield-determining constituent and contributes considerably to the final productivity. Results showed that interaction among sulphur sources and foliar spray of plant growth regulators significantly affected the bolls per plant during both growing season (Table 1). Application of ammonium sulphate with foliar spray of amino acid produced maximum bolls per plant. While soil applied elemental sulpur produced minimum number of bolls per plant from control plots (Table 1).

Interaction among sulphur sources and foliar application of plant growth regulators significantly affected the boll weight during 2014 and 2015 (Table 1). Application of potassium sulphate with foliar spray of mepiquat chloride produced significantly higher boll weight. While the minimum boll weight was recorded with the soil application of elemental sulphur from control plots (Table 1).

A numerous internal and external aspects control seed cotton yield and any discrepancy in them is responsible to bring modifications in yield. Application of sulphur fertilizer and foliar application of plant growth regulators significantly affected the seed cotton and fiber yield during both growing seasons (Table 2). However, application of ammonium sulphate with foliar spray of amino acid produced significantly higher seed cotton yield. While the minimum seed cotton and fiber yield was observed from control plots (Table 2).

Interaction among sulphur sources and foliar application of plant growth regulators significantly affected the biological yield during 2014 only (Table 2). Application of ammonium sulphate with foliar spray of amino acid produced significantly higher biological yield against the minimum was observed with the soil application of elemental sulphur and foliar spray of mepiquat chloride. Similarly, soil applied sulphur fertilizer and foliage applied growth regulators significantly affected the protein and oil contents during both growing seasons (Table 2 and 3). Application of ammonium sulphate with foliar spray of amino acid produced significantly higher protein and oil contents. While the minimum protein and oil contents was observed with the application of elemental sulphur from control plots (Table 2 and 3).

Interaction among sulphur sources and foliar application of plant growth regulators significantly affected the nitrogen contents during both growing seasons (Table 3). Application of ammonium sulphate with foliar spray of amino acid uptake maximum nitrogen contents. While the minimum leaf nitrogen contents was observed with the application of elemental sulphur from control plots (Table 3). However, application of sulphur fertilizer and growth regulators had insignificant effect on leaf phosphorus uptake during both growing seasons (Table 3).

Results showed that interaction between different sources of sulphur fertilizers and foliar application of plant growth regulators significantly affected the leaf potassium uptake during both growing seasons (Table 3). Application

Table 1. Effect of sulphur sources and foliar spray of growth regulators on plant height (cm), sympodial branches, pods per plant and mean boll weight (g).

	Foliar spray	2014				2015			
		Sources of sulphur				Sources of sulphur			
		Ammonium Sulphate	Potassium Sulphate	Elemental Sulphur	Mean	Ammonium Sulphate	Potassium Sulphate	Elemental Sulphur	Mean
Plant height (cm)	Control	146.28ab	141.01b	135.40bc	140.90B	143.95ab	144.35ab	141.40bc	143.23B
	Amino Acid	155.85a	149.21ab	143.32ab	149.46A	157.19a	151.54ab	147.32ab	152.02A
	Mepiquat Chloride	126.06c	124.86c	122.98c	124.63C	128.39cd	123.19d	120.31d	123.97C
	Mean	142.73A	138.36AB	133.90B		143.18ns	139.69	136.34	
	LSD 0.05*p*=	Sulphur sources 8.3026, Foliar spray 8.3026, Interaction 14.381				Sulphur sources ns, Foliar spray 7.8017, Interaction 13.513			
Sympodial branches per plant	Control	14.04ab	12.91bd	11.72cd	12.89A	13.37bc	13.0bd	12.09ce	12.83B
	Amino Acid	15.41a	13.95ac	11.97bd	13.77A	15.08a	14.45ab	12.80bd	14.11A
	Mepiquat Chloride	12.02bd	11.30d	11.04d	11.46B	12.49ce	11.63de	11.04e	11.72C
	Mean	13.82A	12.72AB	11.58B		13.65A	13.04A	11.98B	
	LSD 0.05*p*=	Sulphur sources 1.2918, Foliar spray 1.2918, Interaction 2.2375				Sulphur sources 0.9778, Foliar spray 0.9778, Interaction 1.6936			
No. of bolls per plant	Control	24.54ab	23.88ab	21.02b	23.15B	22.77bc	22.88bc	21.72c	22.46B
	Amino Acid	27.18a	26.33a	24.87ab	26.13A	28.35a	24.49ab	24.90ac	25.58A
	Mepiquat Chloride	24.60ab	24.83ab	21.97b	23.80AB	24.80ac	25.20ac	23.97bc	24.66AB
	Mean	25.44A	25.01A	22.62B		25.31ns	24.86	23.53	
	LSD 0.05*p*=	Sulphur sources 2.3322, Foliar spray 2.3322, Interaction 4.0395				Sulphur sources ns, Foliar spray 2.4772, Interaction 4.2906			
Mean boll weight (g)	Control	3.36ab	3.43a	3.29b	3.36B	3.26c	3.36ab	3.26c	3.29B
	Amino Acid	3.38ab	3.47a	3.37ab	3.41AB	3.33bc	3.40ab	3.32bc	3.35A
	Mepiquat Chloride	3.43a	3.47a	3.41a	3.44A	3.36ab	3.43a	3.35ac	3.38A
	Mean	3.39B	3.46A	3.36B		3.31B	3.40A	3.31B	
	LSD 0.05*p*=	Sulphur sources 0.0663, Foliar spray 0.0663, Interaction 0.1148				Sulphur sources 0.0527, Foliar spray 0.0527, Interaction 0.0914			

Means followed by same letter(s) are not significantly different at P<0.05. LSD= Least significant difference.

of potassium sulphate with foliar spray of mepiquat chloride produced significantly higher potassium contents against the minimum was observed with the soil application of elemental sulphur from control plots.

4. Discussion

Plant growth promoters and retardants play dynamic roles in controlling the cotton plants growth, development and improved the final productivity (Yasmeen et al., 2016). In present study, soil application of ammonium sulphate with foliar spray of amino acid on cotton plants produced significantly taller plants. Whereas, minimum plant height was observed with the soil application of elemental sulphur and foliar spray of mepiquat chloride. Significantly higher plant height with ammonium sulphate and foliar spray of amino acid might be due to the fact that it contributes to the production of growth hormones that improved the cell division and cell enlargement (Sadak et al., 2015). These findings was also confirmed by Hammad and Ali (2014) they also reported that foliar spray of amino acid on crop plants can in enhance the chlorophyll contents, hence increased the photosynthetic rate that improves plant metabolism and protein assimilation which are necessary for cell formation and as a result improved the plant height. Likewise it was also reported that taller plants with the application of amino acid might be due to the biosynthesis of gibberellins (Shekari and Javanmardi, 2017). On the other

Table 2. Effect of sulphur sources and foliar spray of growth regulators on seed cotton yield (Kg ha^{-1}), fiber yield (Kg ha^{-1}), biological yield (Kg ha^{-1}) and protein contents (%).

	Foliar spray	2014				2015			
		Sources of sulphur				Sources of sulphur			
		Ammonium Sulphate	Potassium Sulphate	Elemental Sulphur	Mean	Ammonium Sulphate	Potassium Sulphate	Elemental Sulphur	Mean
Seed cotton yield (kg ha^{-1})	Control	3291.5ab	3273.5ac	2769.9c	3111.6B	2969.7cd	3079.1bd	2833.0d	2960.6B
	Amino Acid	3677.6a	3650.2a	3352.1ab	3559.9A	3772.4a	3604.9ab	3311.9ad	3563.1A
	Mepiquat Chloride	3373.7ab	3451.2ab	2998.5bc	3274.4AB	3330.5ad	3459.2ac	3207.2ad	3332.3A
	Mean	3447.6A	3458.3A	3040.1B		3357.6ns	3381.1	3117.3	
	LSD 0.05*p*=	Sulphur sources 297.83, Foliar spray 297.83, Interaction 515.87				Sulphur sources ns, Foliar spray 332.95, Interaction 576.69			
Fiber yield (kg ha^{-1})	Control	1346.0ab	1308.1ab	1071.2c	1241.8B	1239.3ab	1321.4ab	1107.9b	1222.9ns
	Amino Acid	1480.7a	1455.6a	1362.1ab	1432.8A	1487.4a	1483.2a	1275.4ab	1415.3
	Mepiquat Chloride	1358.6ab	1390.4ab	1213.8bc	1320.9B	1325.3ab	1363.7ab	1193.8ab	1294.3
	Mean	1395.1A	1384.7A	1215.7B		1350.7ns	1389.5	1192.4	
	LSD 0.05*p*=	Sulphur sources 102.17, Foliar spray 102.17, Interaction 176.96				Sulphur sources ns, Foliar spray ns, Interaction 369.73			
Biological yield (kg ha^{-1})	Control	13353ac	13644ab	11664bc	12887B	12686ns	13094	11964	12581ns
	Amino Acid	14411a	14022a	13800a	14078A	14078	13722	12800	13533
	Mepiquat Chloride	12454ac	12776ac	11483c	12238B	13554	13310	12316	13060
	Mean	13406AB	13481A	12315B		13439ns	13375	12360	
	LSD 0.05*p*=	Sulphur sources 1158.8, Foliar spray 1158.8, Interaction 2007.1				Sulphur sources ns, Foliar spray ns, Interaction ns			
Protein contents (%)	Control	20.07ab	19.97b	19.41c	19.81B	19.97ab	19.90bc	19.60c	19.82B
	Amino Acid	20.44a	20.24ab	20.01b	20.23A	20.28a	20.16ab	19.95ac	20.13A
	Mepiquat Chloride	20.11ab	20.14ab	19.97b	20.08A	20.01ab	20.08ab	19.91bc	20.00AB
	Mean	20.21A	20.12A	19.80B		20.09A	20.04A	19.82B	
	LSD 0.05*p*=	Sulphur sources 0.2432, Foliar spray 0.2432, Interaction 0.4213				Sulphur sources 0.2126, Foliar spray 0.2126, Interaction 0.3682			

Means followed by same letter(s) are not significantly different at P<0.05. LSD= Least significant difference.

hand, foliar spray of mepiquat chloride reduced the plant growth parameters. This decline in growth attributes is might be due to reduction of gibberellic acid concentration in plant cells, which causes hardening of the cell wall and reduced flexibility, which inhibited the extension and reproduction ability of the cells (Wang et al., 2014).

Higher number of reproductive / sympodial branches with the use of ammonium sulphate and amino acid might be credited to the higher photosynthetic rate and the absorption of mineral nutrients and they play a key role in secondary metabolism in cotton plants (Hildebrandt et al., 2015; Sadak et al., 2015). While, application of mepiquat chloride significantly reduced the sympodial branches might be due to the reduction of gibberellic acid that decreases the overall vegetative growth and therefore improves the reproductive structures by letting plants to translocate additional energy towards the reproductive structure (Yasmeen et al., 2016).

Application of potassium sulphate with foliar spray of mepiquat chloride produced significantly higher boll weight, which might be due to the fact that it modifies the source-sink relationship while restricting the vegetative growth and improved reproductive growth by allowing the cotton plants to translocate more photosynthates towards the reproductive organs and demonstrating the bolls on treated plants as larger sink for photosynthates (Yasmeen et al., 2016; Xiao et al., 2016). Whereas, it was also observed that application of ammonium sulphate with foliar spray of amino acid produced significantly higher number of bolls per plant, which ultimately

Table 3. Effect of sulphur sources and foliar spray of growth regulators on oil contents (%), nitrogen uptake (%), phosphorus uptake (%) and potassium uptake (%).

	Foliar spray	2014 Sources of sulphur				2015 Sources of sulphur			
		Ammonium Sulphate	**Potassium Sulphate**	**Elemental Sulphur**	**Mean**	**Ammonium Sulphate**	**Potassium Sulphate**	**Elemental Sulphur**	**Mean**
Oil contents (%)	**Control**	19.73b	19.82ab	19.36c	19.64B	19.95ac	19.85bc	19.52d	19.78B
	Amino Acid	20.12a	20.07a	19.84ab	20.01A	20.19a	20.16a	19.80bd	20.05A
	Mepiquat Chloride	19.91ab	19.94ab	19.80ab	19.88A	20.05ab	20.03ac	19.74cd	19.94AB
	Mean	19.92A	19.94A	19.67B		20.06A	20.01A	19.69B	
	LSD 0.05*p*=	Sulphur sources 0.1878, Foliar spray 0.1878, Interaction 0.3252				Sulphur sources 0.1768, Foliar spray 0.1768, Interaction 0.3062			
Nitrogen uptake (%)	**Control**	0.247bc	0.210ce	0.180e	0.212B	0.257b	0.223bc	0.203c	0.228B
	Amino Acid	0.313a	0.263b	0.213ce	0.263A	0.307a	0.247bc	0.230bc	0.261A
	Mepiquat Chloride	0.253bc	0.233bd	0.190de	0.226B	0.260b	0.237bc	0.207c	0.234B
	Mean	0.271A	0.236B	0.194C		0.274A	0.236B	0.213B	
	LSD 0.05*p*=	Sulphur sources 0.0288, Foliar spray 0.0288, Interaction 0.0499				Sulphur sources 0.0260, Foliar spray 0.0260, Interaction 0.0451			
Phosphorus uptake (%)	**Control**	0.230ns	0.233	0.234	0.232ns	0.237ns	0.227	0.237	0.233ns
	Amino Acid	0.233	0.247	0.230	0.237	0.247	0.240	0.247	0.244
	Mepiquat Chloride	0.227	0.237	0.237	0.233	0.240	0.233	0.240	0.238
	Mean	0.230ns	0.239	0.234		0.233ns	0.241	0.241	
	LSD 0.05*p*=	Sulphur sources ns, Foliar spray ns, Interaction ns				Sulphur sources ns, Foliar spray ns, Interaction ns			
Potassium uptake (%)	**Control**	1.82b	2.09a	1.78b	1.90ns	1.85b	2.11a	1.82b	1.93ns
	Amino Acid	1.84b	2.08a	1.83b	1.92	1.91b	2.23a	1.88b	2.00
	Mepiquat Chloride	1.89b	2.10a	1.87b	1.95	1.92b	2.12a	1.85b	1.97
	Mean	1.85B	2.09A	1.83B		1.89B	2.15A	1.85B	
	LSD 0.05*p*=	Sulphur sources 0.0910, Foliar spray ns, Interaction 0.1575				Sulphur sources 0.0836, Foliar spray ns, Interaction 0.1448			

Means followed by same letter(s) are not significantly different at $P<0.05$. LSD= Least significant difference.

increased the seed cotton yield, fiber yield and biological yield. Soil application of ammonium sulphate and foliar spray of amino acids supply the cotton plant cells with an instantly accessible nitrogen source that usually can be taken by the cells more quickly than inorganic nitrogen. Availability of soluble sulphur liberates more sulphate ions into the soil solution ensuing in higher absorption of sulphur nutrients. This would have improved the metabolic activities and sustained the photosynthesis activities in the cotton plants and encouraged the meristematic process instigating improved dry matter synthesis due to appropriate partitioning of photosynthates from sources to sink (Braun et al., 2014). The influence of amino acids on crop physiology intensively studied and the principal attitude is that amino acids play the role of stimulates internal hormones production and facilitates the uptake of mineral nutrients (Gomes, 2019). Its foliar spray improved the photosynthetic pigments and as a result the effectiveness of the photosynthetic apparatus was boosted, which in turn substantially improved the sympodial branches, number of harvestable bolls per plant, seed cotton yield, fiber yield and ultimately biological yield per unit area (Sadak et al., 2015). It has direct influence on cotton plants involved modulation of nitrogen uptake and assimilation by the regulation of enzymes included in nitrogen assimilation and of their structural genes and by working on the signaling pathway of nitrogen absorption in roots. Modification in plant physiological and biochemical processes led to a higher yield and yield contributing attributes (Aksona and Unay, 2019).

Application of ammonium sulphate with foliar spray of amino acid produced significantly higher oil and protein contents. In this respect, the improvement in oil and protein contents with different applied treatments are measured as a direct influence of higher minerals uptake that enhanced the photosynthesis rate and translocate photo-assimilates from leaves to cotton seed. Likewise, Hammad and Ali (2014) and El-Ghareib et al. (2014) observed that exogenous application of amino acid produced significantly higher protein content and attributed to its role in protein synthesis through enhanced conversion of amino acids in to protein. While, the improvement in oil content with the application of amino acid might be credited to enhanced assimilation and translocation of photosynthates (Zheljazkov et al., 2009; Mohammadi and Rokhzadi, 2012).

Application of one nutrient can affect mobility of other nutrient in soils, its uptake by plant roots and its metabolism in plant tissues. In present study, soil application of ammonium sulphate with foliar spray of amino acid uptake significantly higher nitrogen content. While soil application of potassium sulphate with foliar spray of mepiquat chloride uptake maximum potassium content. Improvement in nutrients uptake might be due to improved root growth, carbon dioxide assimilation and photosynthetic rate, and assimilate partitioning (Gwathmey and Clement, 2010). These results were confirmed in earlier studies by Liu et al. (2008) they concluded that improvement in mineral content showed the encouraging influence of the foliar spray by offering the plant cells adequate amount of nutrients and improving their uptake by roots and their accumulation and translocation in leaves. Similar results were reported by Sawan (2013) he observed that nitrogen and potassium contents improved in cotton plants with the application of mepiquat chloride.

5. Conclusion

We conclude that soil applied ammonium sulphate with foliage applied amino acid was more effective to improve the yield, quality and fertilizer use efficiency in cotton as compared to the other treatments.

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