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Application of Potassium Nitrate Influenced Yield, Nutrient and Water Use Efficiency and Profitability of *Gossypium herbaceum* in Canal Irrigated Region of Western India

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Abstract

The study was carried out during April to October, 2022 in Srigangangar district of Rajasthan, India, at randomly selected farmer's field with two treatments to validate the efficiency of potassum nitrate in cotton crop. Previous studies have highlighted the benefits of potassium nitrate for cotton crops under controlled conditions at research centers. However, these results have yet to be validated in farmers' fields irrigated by the Western Canal. Productivity of cotton at farmers' field is low as compare to its potential because of shortage of irrigation water is common in canal irrigated area. In first treatment foliar application of potassium nitrate @ 2% at flower initiation and ball formation stage with recommended dose of fertilizer however in second treatment there was no use of potassium nitrate with recommended dose of fertilizer. The results revealed that the seed cotton yield and lint percent were improved with two foliar application of potassium nitrate @ 2% at flower initiation and ball formation stage. Two foliar application of potassium nitrate @ 2% at flower initiation and ball formation stage increased partial factor productivity of applied nutrient, water use efficiency and water economic productivity as compared to control. Higher net realization and B:C ratio were obtained with foliar application of potassium nitrate @ 2% at flower initiation and ball formation stages as compare to control. Therefore, it is suggested that foliar application of potassium nitrate can be helpful to increase cotton yield, resource use efficiency and higher returns in farmers' fields of canal irrigated area of western India.

Keywords: Cotton, input use efficiency, potassium nitrate, yield

1. Introduction

Among the most significant cash crops grown worldwide is cotton (Chen et al., 2021; Zaidi et al., 2018). Around two-thirds of the world's total cotton production is produced in more than 80 countries, with China, India, and the United States. It is important to global economic and social concerns. An average of 18.9 million cotton plants is produced annually in more than 100 countries across an area of 33.2 mha (Asewar et al., 2021). Drought, heat, waterlogging, and salinity are some of the abiotic variables that have a major impact on cotton production and cause large losses in the desired productivity. Increased frequency and duration of drought occurrences are anticipated in forthcoming periods, particularly in arid and semi-arid regions globally, ascribed to climatic change (Touma et al., 2015; Schwalm et al., 2017). Consequently, the adoption of water-efficient agricultural technologies becomes imperative to maintain productivity levels and safeguard global food security (Alam et al., 2021).

Fertilization significantly influences the growth, yield, and quality of cotton fibers throughout the growing season (Watts et al., 2017). Farmers have been using more nitrogenous and phosphorus based fertilizers since long time, resulted in an imbalanced supply of nutrients and substantial drop in cotton yield. Balanced amount of nutrients will play significant in maintaining productivity. Potassium not only promote healthy plant growth and development, but also mitigate other abiotic stresses, such as heat, drought etc.

Potassium is necessary for the typical growth and developmental processes of cotton (Oosterhuis et al., 2013; Tung et al., 2019). Potassium is a third most essential nutrient of crop nutrition, contributing significantly to both increased yield and improved quality, which made plant more resilient to water-stressed and rainfed conditions. Potassium is the element that is most readily absorbed after nitrogen (Brennan and Bolland, 2009), and it is crucial for raising crop yields and enhancing product quality (Sharma et al., 2022). Prudent potassium application is pivotal for normal plant growth, development, and yield, as it regulates essential physiological processes such as carbohydrate metabolism (Wang et al., 2012; Hu et al., 2015; Zahoor et al., 2017; Ali et al., 2018), carbon-nitrogen balance (Hu et al., 2017), and nitrogen metabolism (Hu et al., 2016; Zahoor et al., 2017). Potassium deficiencies have been found to decrease cotton biomass production and yields (Yang et al., 2017) in addition to reducing photosynthesis and the quality of cotton fibers (Oosterhuis et al., 2014). Balanced K nutrition is indispensable for uptake of other essential nutrients from the soil, transportation to the areal part, and ultimate use in metabolism (Ali et al., 2019).

Leaf feeding refers to the application of foliar fertilizers aimed at augmenting the overall nutrient status in plants and elevating sugar production particularly during periods of stress (Rao and Gopinath, 2016; Asewar et al., 2021). By increasing the efficiency of the photosynthetic process, enzyme activity, and water use efficiency (Ahanger and Agarwal, 2017; Ahanger et al., 2015), adequate potassium levels, can improve plant growth and output (Tittal et al., 2021). The distribution of vegetative growth is influenced by potassium, which affects cotton yields and fiber quality (Tariq et al., 2018). Potassium application mitigated drought susceptibility in maize hybrids by enhancing water productivity, especially under conditions of water stress (Bahrami-Rad and Hajiboland, 2017; Ul-Allah et al., 2020). Numerous researchers (Jyothi and Hebsur, 2018; EL-Shazly et al., 2021) have reported the positive effects of potassium on cotton in experimental fields at research stations. However, at farmers' field, this type of study and scientific literatures are very limited. Considering this, the study's aims were to study the effect of potassium nitrate in cotton yield, lint percentage, input indices.

2. Materials and Methods

The front-line demonstration conducted at farmers' fields with cotton crop during *kharif* (rainy) season (April to October), 2022 in the Padampur block of Srigangangar district, Rajasthan (335041), India. This region is irrigated by the Gang canal. The climate is arid subtropical with large variation of temperature where maximum temperature recorded up to 50°C during summer season (may, June and July) and lowest temperature sometime observed as low as 0°C or even less during winter season (December-January). The average annual rainfall is 261 mm with a coefficient of variation of 50%. The soil was loamy-sand, alkaline in reaction (pH>8.2) having low level of available nitrogen and phosphorus and medium in level available potassium. The treatments were consisted control (RDF @ 100 N:40 P:20 K kg ha^{-1}) and RDF+two foliar sprays of potassium nitrate (2%) at flower initiation and ball formation which were replicated at twenty-five farmers' fields under randomized block design. The size of selected fields for experiment was one acre (4000 m^2) at each farmer's fields. Bt cotton was sown at first fortnight of May month with recommended seed rate *i.e.*16 kg ha^{-1}. Row spacing was maintained at 67.5 cm wide. Recommended dose of fertilizer used in mustard i.e. N:P:K @ 100:40:20 kg ha^{-1}, out of this one third of N and 100% P were applied as basal dose at the time of sowing. Rest N was applied in equal split dose at after first irrigation and during square formation. Six irrigations were applied through flood irrigation system as per crop requirement. Other cultivation processes were kept similar for all the treatments. Yield of cotton was recorded after harvesting and converted on hectare basis.

Effective rainfall was estimated by using U.S. Bureau of Reclamation Method. This method described by Stamm (1967), is recommended for arid and semi-arid regions and uses mean seasonal precipitation of the five driest consecutive years (Kumari et al., 2018)

Applied quantities of N, P and K through different fertilizers were calculated (Kumari et al., 2021). Then, the yield was divided by total applied quantity of each nutrient (N, P and K) to estimate the partial factor productivity (PFP) (Sharma et al., 2023).

The irrigation water was measured by the discharge of irrigation water per irrigation and converted in depth of water applied and calculated total irrigation water use during the growing period. Irrigation use efficiency (IUE) and Water use efficiency (WUE) (in kg ha^{-1} mm^{-1}) were then calculated by dividing the cotton seed yield (kg ha^{-1}) by the total amount of water applied in the field through irrigation and irrigation+ effective rainfall (mm) by using Eq. 1 and 2, respectively (Kumari et al., 2015; 2022).

IUE=Yield/Irrigation water applied 1

WUE=Yield/(Irrigation water applied+Effective rainfall) 2

The irrigation economic productivity (IEP) and Water economic productivity (WEP) of the cotton was estimated by dividing the economic value obtained [Indian Rupees per hectare (₹ ha^{-1})] by the amount of applied irrigation water (mm) and total water usage i.e. irrigation+rainfall (mm) by using Eq. 3 and 4, respectively (Kahramanoglu et al., 2020; Kumari et al., 2018).

IEP (₹ ha^{-1} mm^{-1})=Economic value of yield/Irrigation water applied 3

WEP (₹ ha^{-1} mm^{-1}) =Economic value of yield/(Irrigation water applied+Effective rainfall) 4

A simple economic analysis took into the cost of inputs and return from selling of yield, which was computed using the procurement price i.e. ₹ 60.80 kg^{-1} seed cotton (Anonymous, 2023). The net income (₹ ha^{-1}) and benefit-cost ratio were calculated by using the following formula given in eq. 5 and

6, respectively.

Net returns=Gross returns (₹ ha^{-1})-cost of cultivation (₹ ha^{-1})...5

B:C ratio=Gross returns (₹ ha^{-1})/Cost of cultivation (₹ ha^{-1}) ...6

The observed data of the investigation were statistically analyzed by SPSS 20.0 version (SPSS Inc., Chicago, IL). Statistical analysis and interpretation of observed data were evaluated by using ANOVA technique of RBD and critical difference (CD) at 5% level of significance.

3. Results and Discussion

The meteorological data during the study time was collected from the meteorological observatory, Agricultural Research Station, Sri Ganagnagar, Rajasthan, India. Out of total rainfall, 89.30% occurred during July and August months, whereas for more than four months the period of occurrence of rainfall was very low. The maximum rainfall happened in very short duration so, the losses of rain water was high. That's why, the effective rainfall was estimated and it was 26.91% of total rainfall (Figure 1). The average variation between maximum and minimum temperature was observed 12.79ºC during the crop growing period. The average highest and lowest relative humidity was observed 72.40 and 48.20% respectively in the months of October and June.

The seed cotton yield, lint yield and lint percentage were significantly affected through the foliar application of potassium nitrate (Table 1). The seed cotton yield was improved 2.96 q ha^{-1} under T_1 as compared to T_2. This might be due to reduce the abiotic stress mainly water scarcity at latter stage of crop through the foliar application of potassium nitrate in cotton crop. Similarly, lint yield was improved 1.79 q ha^{-1} under T_1 as compared to T_2. The variation in lint percentage was recorded 43.12 and 50.35% under T_1 and T_2. Whereas, enhancement of lint percentage recorded 15.91% under T_1 as compared to T_2. Higher seed cotton and lint yield were observed this could be obtained due to foliar application of potassium nitrate. yield were observed with the foliar application of potassium nitrate. Foliar application of potassium nitrate enhanced the stomata resistance coupled with reduced transpiration rate and increased relative water content, thus, may improve water storage capacity of the cells and providing favorable conditions for better yields (Ewais et al., 2020). Sharma et al. (2022) observed that the foliar application of potassium nitrate improved the yield attributes and yield of tomato.

Table 1: Yield and lint percentage of cotton influenced through foliar application of potassium nitrate

Parameters	T_1			T_2			CD
	Maximum	Minimum	Mean	Maximum	Minimum	Mean	(p=0.05)
Seed cotton yield (kg ha^{-1})	2650.00	1750.00	2048.44	2300.00	1300.00	1751.60	136.92
Lint yield (kg ha^{-1})	1015.61	444.15	672.13	676.20	334.03	493.21	64.77
Lint %	40.24	22.89	32.71	34.32	17.04	28.22	2.51

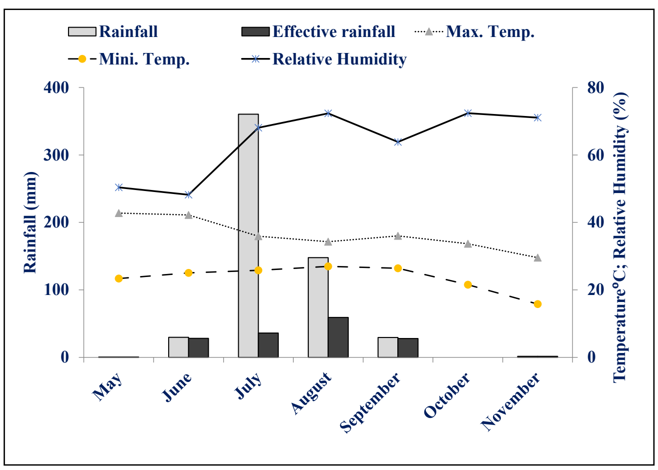

Figure 1: Monthly meteorological data during the study period

The nutrient use efficiency of applied nutrients was significantly improved through the foliar application of potassium nitrate and depicted in Table 2. The partial factor productivity of nitrogen was improved 1.94 kg kg^{-1} under T_1 as compared to T_2. Mean partial factor productivity of phosphorus was improved 16.95% under T_1 over T_2. Whereas, mean partial factor productivity of potassium was significantly inferior and obtained 14.49% under T_2 as compared to T_1. The foliar applications of potassium nitrate enhanced growth and yield of crop under water stress condition and indirectly use efficiency of applied nutrient through fertilizer. Katkar et al.

Table 2: Changes in partial factor productivity of applied nutrient under foliar application of potassium nitrate in cotton crop

Parameters	T_1			T_2			CD
	Maximum	Minimum	Mean	Maximum	Minimum	Mean	(p=0.05)
PFP N (kg kg^{-1})	17.28	11.41	13.36	15.00	8.48	11.42	0.89
PFP P (kg kg^{-1})	66.25	43.75	51.21	57.50	32.50	43.79	3.42
PFP K (kg kg^{-1})	104.33	68.90	80.65	90.55	51.18	68.96	5.39

(2021) supported these finding and stated that the two foliar spray of potassium nitrate (2%) in cotton fields improved the nutrient uptake and nutrients use efficiency as compared to control plot and RDF treated experimental fields.

The irrigation use efficiency, water use efficiency, irrigation economic productivity and water economic productivity were significantly improved through the foliar application of potassium nitrate and are displayed in Table 3. The variation of irrigation use efficiency was recorded 5.83 to 8.83 kg ha^{-1} mm^{-1} and 4.33 to 7.67 kg ha^{-1} mm^{-1} under T_1 and T_2, respectively. T_1 treatment improved irrigation use efficiency 17.24% as compared to T_2. The water use efficiency of cotton crop was enhanced 0.66 kg ha^{-1} mm^{-1} under T_1 as compared to T_2. Irrigation economic productivity was observed ₹ 251.64 ha^{-1} mm^{-1} under T_1, it was 23.69% higher than T_2. Water economic productivity estimated ₹ 167.13 ha^{-1} mm^{-1} under T_1, It was significantly superior 31.06% than T_2. This study shown that the application of potassium nitrate enhanced economical productivity of applied irrigation water. Ul-Allah et al. (2020) confirmed this study and reported that application of potassium alleviates drought susceptibility of maize hybrids and improves yield traits and water productivity particularly under water stress conditions.

Table 3: Irrigation use efficiency (IUE), water use efficiency (WUE), irrigation economic productivity (IEP) and water economic productivity (WEP) of cotton affected under foliar application of potassium nitrate

Parameters	T_1			T_2			CD (p=0.05)
	Maximum	Minimum	Mean	Maximum	Minimum	Mean	
IUE (kg ha^{-1} mm^{-1})	8.83	5.83	6.83	7.67	4.33	5.84	0.46
WUE (kg ha^{-1} mm^{-1})	5.87	3.87	4.53	5.09	2.88	3.88	0.30
IEP (₹ ha^{-1} mm^{-1})	373.90	185.83	251.64	300.13	97.47	191.98	27.75
WEP (₹ ha^{-1} mm^{-1})	248.33	123.42	167.13	199.34	64.73	127.50	18.43

Correlation matrix revealed that seed cotton yield was highly correlated with nutrient use efficiency and irrigation and water use efficiency (r=1.00, p<0.05), irrigation and water economic productivity (r=0.984, p<0.05) and lint yield (Figure 2). But, seed cotton yield was not significantly correlated with lint % (r=0.102, p<0.05). Lint % was not significantly correlated with Lint yield, nutrient use efficiency, irrigation and water use efficiency and Irrigation and water economic productivity values explained 0.101 to 0.147%. Rest all the parameters were significantly highly correlated with each other.

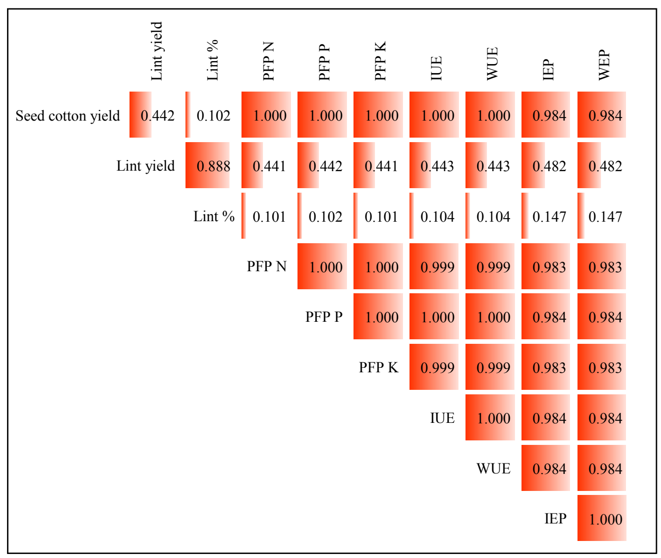

Figure 2: Correlation matrix depicting relationships between different variables and seed cotton yield (r>0.441; significant at p<0.05, others non-significant).

The economics of this study was mentioned in Table 4. This finding is the deciding factor for any research it is adoptable for the farmers or not. Economics of the study revealed that the cost of cultivation was increased through application of potassium nitrate. Higher gross (₹ 124545 ha^{-1}) and net (₹ 75491 ha^{-1}) return were recorded under application of potassium nitrate which were significantly superior to T_2. The B:C ratio also showing similar trend since, the B:C ratio was recorded 2.54 (varies 2.10 to 3.29) under T_1 which was significantly superior than T_2 (2.18). The yield of crop is directly proportion to the B:C ratio, Crop yield enhanced with application of potassium nitrate therefore return and B:C ratio was also improved. Asewar et al. (2021) reported that the

Table 4: Economic of cotton crop under foliar application of potassium nitrate

Parameters	T_1			T_2			CD (p=0.05)
	Maximum	Minimum	Mean	Maximum	Minimum	Mean	
Cost of cultiva-tion (₹ ha^{-1})	50650	47450	49054	50500	47300	48904	-
Gross income (₹ ha^{-1})	161120	106400	124545	139840	79040	106497	8325
Net income (₹ ha^{-1})	112170	55750	75491	90040	29240	57593	8325
B:C Ratio	3.29	2.10	2.54	2.81	1.59	2.18	0.17

foliar application of potassium nitrate was found significantly superior than control (no spray of nutrient) with respect to net returns and B: C ratio in Bt-cotton.

4. Conclusion

Foliar application of 2% potassium nitrate at flowering initiation and ball formation, along with the recommended fertilizer dose, improved seed cotton yield compared to using only the recommended fertilizer dose. It also improved the water and nutrient use efficiency. The foliar application of potassium nitrate @ 2% at flowering initiation and ball formation with recommended dose of fertilizer enhanced the net return (31.08%) and Benefit: Cost ratio (16.51%) as compared to farmer's practices.

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