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Effect of precise application of nutrients on yield and uptake of bt. cotton in vertisols

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Abstract
The present investigation was conducted during 2018-19 with a view to study the effect of precise application of nutrients on yield and nutrient uptake of Bt cotton in Vertisols at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The experiment comprised of eight different treatments and their combination with foliar spray of 1 per cent $MgSO_4$ at two different growth stages *viz.* flowering and boll development in randomized block design with three replications. The results indicated that the treatment receiving N at basal, 30 DAS, 60 DAS and 90 DAS, P at basal, K at basal + 60 DAS + foliar spray of 1% $MgSO_4$ at 60 and 90 DAS recorded significantly higher seed cotton yield and stalk yield of Bt cotton which was found at par with N applied at basal, 30 DAS, 60 DAS and 90 DAS, P and K at basal. The concentration and uptake of N, P, K, S, Ca^{++} and Mg^{++} in cotton seed and cotton stalk was increased with increasing splits of N and K fertilizer which was slightly increased with application of magnesium. The concentration of N, P, K, S, Ca and Mg in cotton plant was initially higher at boll development stage which was decreased later at harvest. Foliar application of Magnesium Sulphate @ 1 per cent at two growth stages *viz.* flowering and boll development was also found useful for reducing reddening of leaf in Bt cotton. The optimum dose of NPK with appropriate split application of N and K with magnesium supply at proper growth stage appears to be useful for increasing yield and nutrient uptake by Bt cotton in Vertisols. The correlation among dry matter accumulation at boll development stage and seed cotton and stalk yield was found significant.

Keywords: Bt. cotton, reddening, yield, nutrient uptake, seed cotton and stalk

Introduction
Cotton commonly called as “White Gold” is one of the most important fibre crop and plays vital role in rural, national and international economy. It generates employment opportunities to millions not only at production stage but also in processing, marketing and trade. Apart from fibre, cotton seed is next in importance due to its oil and protein content. The cotton seed obtained after ginning. If scientifically processed, yields four important by-products viz. linters (short fibres) clinging to the seed, hull (protective kernel coating), oil and meal (residue after extraction of oil). Balance nutrition with a optimum level of nutrients is essential for proper growth and development of the crop. The imbalanced nutrition leads to antagonistic effects and ultimately the crop suffers either because of excess or deficiency of essential elements. Besides macro nutrients, it is very essential to assess the uptake of secondary nutrients. Uptake of N, P, and K was reported to be increase progressively with the increase in fertilizer dose. Slightly higher uptake at the first boll opening stage was observed when the dose splitted for five times than three times whereas lower uptake was observed under crobar and conventional methods (Venugopalan *et al.*, 2009) [13].

Among the major plant nutrients, nitrogen is one of the most important and expensive one in cotton production. Low efficiency of nitrogen applied to soil is major problem to farmers especially in content of increasing fertilizer prices. Nitrogen was subject to leaching, denitrification and volatilization losses, which made is unavailable to crop. Therefore, it is essential to introduce such fertilizer practices as would ensure maximum efficiency of applied nitrogen and these relate to placement, split application, appropriate rates and use of nitrification inhibitor for Bt-cotton. Phosphorus (P) plays vital role in conserving and transferring energy in cell metabolism. P deficiency causes a reduction in seedling vigour, plant establishment and root development. Deficient plants are usually stunted, dark green in appearance and exhibit delayed flowering, boll set and maturity. Potassium (K) is mobile element in plant and can readily move between plant organs. It has an important role in a number of enzymes including those involved with energy transfer. It is vital for transferring carbohydrates throughout the plant as well as the osmotic regulation.

Potassium also involved in nitrogen metabolism, protein synthesis and in photosynthesis, closing and opening of stomata.

Magnesium is an essential constituent of chlorophyll and Mg deficiency reduces photosynthesis. It is also important for cell respiration, nitrogen metabolism and oil synthesis. Plants with oil seeds, such as cotton, have a high requirement of Mg. Sulphur (S) plays important role in photosynthesis and is required for protein synthesis, activation of enzymes, production of vitamins and synthesis of oil.

Precision nutrient management system offers improved land stewardship, optimizes resource usage, since every part of a field receives precise amount of fertilizer required to maximize crop yields. Various strategies of precision nutrient management system are being developed among which management zone technique and site-specific nutrient management are gaining importance.

Materials and Methods

The experiment was carried out at Research Farm, Dept. of Soil Science and Agricultural Chemistry, Dr. P.D.K.V., Akola (MS), India with a view to study the effect of effect of precise application of nutrients on yield and nutrient uptake of Bt cotton in Vertisols. The comprised of Absolute control (T1), Nitrogen at basal and 30 DAS, Phosphorus and Potassium at basal application (T2), Nitrogen at basal and 30 DAS, Phosphorus at basal application, Potassium at basal and 60 DAS (50% flowering) (T3), Nitrogen at basal, 30 DAS (square formation), 60 DAS (50% flowering), Phosphorus and Potassium at basal application (T4), Nitrogen at basal, 30 DAS (square formation), 60 DAS (50% Flowering), Phosphorus at basal application, Potassium at basal and 60 DAS (50% flowering) (T5), Nitrogen at basal, 30 DAS (square formation), 60 DAS (50% flowering) and 90 DAS (Boll development), Phosphorus and Potassium at basal application (T6), Nitrogen at basal, 30 DAS (square formation),60 DAS (50% flowering) and 90 DAS (boll development), Phosphorus at basal, Potassium at basal + 60 DAS (50% flowering) (T7), Nitrogen at basal, 30 DAS (square formation), 60 DAS (50% flowering) and 90 DAS (boll development), Phosphorus at basal application, Potassium at basal and 60 DAS (50% Flowering) + foliar spray of 1% $MgSO_4$ at 60 DAS (50% Flowering) and 90 DAS (Boll development) (T8).

The recommended dose (60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1}) was applied to cotton. Full quantity of the recommended dose of phosphorus was applied as a basal dose through single super phosphate. Nitrogen through urea in four-spilt application, at basal, 30, 60 and 90 DAS to cotton. Potassium through MOP in two-spilt application, half at the sowing and half at 60 DAS to cotton. Foliar spray of $MgSO_4$ was applied at 60 and 90 DAS.

The treatment wise plant samples were selected randomly from each net plot. The plant samples were first dried in the shade after that in oven at 65°C. The plant samples were ground in a willey mill and stored in labeled brown papers bags for further analysis.

Total N content was determined by digesting the plant sample in microprocessor based digestion system (KES-12L) using conc. H_2SO_4 and salt mixture (Micro Kjeldahl's method) and distillation with automatic distillation system (Piper,1966). For determination of P and K, finely ground and well mixed plant samples of different stages were weighted accurately (0.2 g) transferred into micro digestion tube and 10 ml di-acid mixture was added and digested on microprocessor based (KES-12L) digester. After completion of digestion (clear) the extract was diluted and filtered through Whatman No. 42. These extracts were used for determination of phosphorus, potassium, sulphur, calcium and magnesium. Briefly, the P content was estimated from di-acid extract by Vanadomolybdate phosphoric acid yellow colour method (Jackson, 1973) [4] using UV based double beam spectrophotometer. The K content was estimated from di-acid extract by using flame photometer (Jackson, 1973) [4]. The S content was estimated from diacid extract turbidimetrically using Spectrophotometer (Chesnin and Yein, 1951) [1]. Versanate titration method was used for estimation of calcium and magnesium in diacid extract (Schwarzenbach, 1946) [11].

The weight of dry matter accumulated in plant is an index of plant growth. The plants uprooted for dry matter study, excluding root system, were air dried under sun for eight days and subsequently dried in the thermostatic oven at 65^0 C, till constant weight. The final constant dry weight was recorded as total dry matter accumulation per plant. Seed cotton yield was recorded from net plots in all the replications during each picking. Yield per plot and yield per hectare was calculated. The data thus generated were subjected to statistical analysis adopting standard protocol (Gomez and Gomez, 1984).

Results and Discussion

Seed cotton and cotton stalk yield

The data pertaining to seed cotton and cotton stalk yield as influenced by application of various nutrient management treatments are presented in the Table 1. The application of RDF 60:30:30 N, P_2O_5 and K_2O kg ha^{-1} with splits of nitrogen as Basal, 30 DAS, 60 DAS and 90 DAS, 100 per cent P_2O_5 at sowing and K_2O in two equal splits at basal and 60 DAS with foliar spray of 1% $MgSO_4$ at 60 DAS and 90 DAS recorded highest yield of seed cotton (17.16 q ha^{-1}) in Vertisol. Increasing splits of N and K fertilizer found beneficial for obtaining higher yield of Bt cotton over control. The seed cotton yield increased progressively with increasing splits of N and K fertilizer. However, the differences between two successive splits of N and K was non-significant. Whereas the lowest seed cotton yield (9.16 q ha^{-1}) was observed under treatment in absolute control. The highest stalk yield (21.84 q ha^{-1}) found in treatment receiving N at basal, 30 DAS, 60 DAS and 90 DAS, P-Basal, K–Basal + 60 DAS + foliar spray of 1% $MgSO_4$ at 60 DAS and 90 DAS. The yield data revealed that the Bt cotton responded to split application of RDF 60:30:30 kg N, P_2O_5 and K_2O ha^{-1} where the seed cotton yield and stalk yield was increase suggesting RDF 60:30:30 applied with splits of nitrogen at basal, 30 DAS, 60 DAS and 90 DAS, 100 per cent, P_2O_5 at basal and K_2O in two equal splits i.e. at basal and 60 DAS appears to be adequate and useful for obtaining higher yield of cotton. Split application of N produced maximum seed cotton yield.

The significant increase in yield over control could be attributed to availability of more nutrients in balance quantity to crop which ultimately produced higher seed cotton yield. The results are in close agreement with the findings reported by Modhvadia *et al*. (2012), Sattar *et al*. (2017) and Pandagale *et al*. (2018) [7, 10, 8]. However, Jadhao *et al.* [3] reported yield contributing parameters like number of bolls per plant were reported higher with the application of RDF along with 2% foliar spray of DAP followed by RDF along with recommended dose + 1.5 per cent urea spray.

Table 1: Effect of precise application of nutrients on dry matter, seed cotton and cotton stalk yield

Treatments		Dry matter yield (q ha^{-1})	Yield (q ha^{-1})	
			Seed Cotton	Cotton Stalk
T_1	Absolute control	14.48	9.16	11.21
T_2	N-Basal and 30 DAS, P & K Basal.	18.98	13.53	16.87
T_3	N-Basal and 30 DAS, P-Basal application, K–Basal and 60 DAS.	19.07	13.99	17.57
T_4	N–Basal, 30 DAS, 60 DAS, P & K–Basal application.	21.22	14.11	17.67
T_5	N–Basal, 30 DAS, 60 DAS, P–Basal application, K–Basal and 60 DAS.	22.05	14.40	18.20
T_6	N–Basal, 30 DAS, 60 DAS and 90 DAS, P & K–Basal application.	24.13	15.63	18.98
T_7	N–Basal, 30 DAS, 60 DAS and 90 DAS, P-Basal, K–Basal + 60 DAS.	25.06	16.33	21.02
T_8	T_7 + Foliar spray of 1% $MgSO_4$ at 60 DAS and 90 DAS.	25.94	17.16	21.84
SE (m) ±		0.95	0.83	1.03
CD at 5 %		2.88	2.51	3.11

Table 2: Effect of precise application of fertilizers on uptake of primary nutrients by cotton at harvest

Treatments	Nutrient uptake by cotton (kg ha^{-1})								
	Cotton seed	Cotton stalk	Total uptake	Cotton seed	Cotton stalk	Total uptake	Cotton seed	Cotton stalk	Total uptake
	Nitrogen			Phosphorus			Potassium		
T1-Absolute control	21.46	6.34	27.81	4.18	1.65	5.83	8.21	11.57	19.78
T2-N-Basal and 30 DAS, P & K Basal	36.30	10.16	46.46	7.58	3.02	10.60	13.94	18.06	32.00
T3-N-Basal and 30 DAS, P-Basal application, K–Basal and 60 DAS	38.81	10.77	49.58	8.18	3.26	11.44	15.26	19.73	34.99
T4- N–Basal, 30 DAS, 60 DAS, P & K–Basal application	40.00	11.50	51.51	8.65	3.41	12.06	15.17	20.61	35.79
T5-N–Basal, 30 DAS, 60 DAS, P–Basal application, K–Basal and 60 DAS	41.89	12.07	53.96	9.40	3.58	12.98	16.39	21.67	38.06
T6-N–Basal, 30 DAS, 60 DAS and 90 DAS, P & K–Basal application	46.20	13.75	59.95	9.82	4.24	14.05	16.60	22.69	39.28
T7-N–Basal, 30 DAS, 60 DAS and 90 DAS, P-Basal, K–Basal + 60 DAS	51.93	14.28	66.21	11.82	4.55	16.37	18.75	24.98	43.73
T8- T_7 + Foliar spray of 1% $MgSO_4$ at 60 DAS and 90 DAS	55.91	17.10	73.01	12.82	5.15	17.97	22.18	25.65	47.83
SE (m) ±	2.14	0.96	2.91	1.08	0.49	1.29	1.39	1.18	2.39
CD at 5 %	6.48	2.90	8.84	3.29	1.49	3.91	4.20	3.59	7.24

Table 3: Effect of precise application of fertilizers on uptake of secondary nutrients by cotton at harvest

Treatments	Nutrient uptake by cotton (kg ha^{-1})								
	Cotton seed	Cotton stalk	Total uptake	Cotton seed	Cotton stalk	Total uptake	Cotton seed	Cotton stalk	Total uptake
	Calcium			Magnesium			Sulphur		
T1-Absolute control	6.92	5.17	12.09	4.78	3.62	8.39	5.10	2.98	8.07
T2-N-Basal and 30 DAS, P & K Basal	12.26	8.46	20.73	10.43	7.68	18.11	8.78	5.73	14.51
T3-N-Basal and 30 DAS, P-Basal application, K–Basal and 60 DAS	13.28	9.15	22.43	10.57	8.08	18.65	9.64	5.77	15.42
T4- N–Basal, 30 DAS, 60 DAS, P & K–Basal application	13.30	9.28	22.58	10.48	8.06	18.54	9.25	6.27	15.51
T5-N–Basal, 30 DAS, 60 DAS, P–Basal application, K–Basal and 60 DAS	14.73	9.28	24.01	11.48	8.79	20.27	10.41	6.50	16.91
T6-N–Basal, 30 DAS, 60 DAS and 90 DAS, P & K–Basal application	15.03	10.55	25.57	12.34	9.37	21.71	10.64	6.97	17.61
T7-N–Basal, 30 DAS, 60 DAS and 90 DAS, P-Basal, K–Basal + 60 DAS	17.42	11.81	29.24	13.96	10.08	24.04	12.31	8.44	20.75
T8- T_7 + Foliar spray of 1% $MgSO_4$ at 60 DAS and 90 DAS	18.80	13.01	31.81	17.27	12.20	29.46	13.84	9.35	23.19
SE (m) ±	1.47	0.95	2.05	1.32	0.94	1.92	1.38	0.63	1.62
CD at 5 %	4.46	2.88	6.23	3.99	2.86	5.82	4.17	1.90	4.92

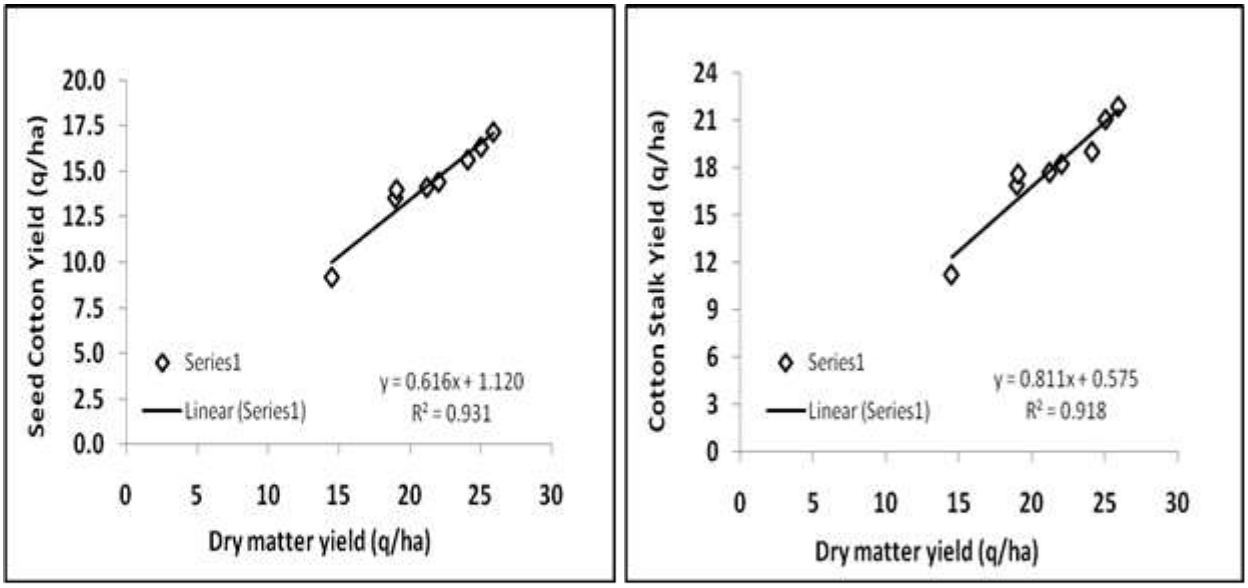

Fig 1: Relationship between dry matter yield and cotton yield parameters

Dry matter yield at boll development stage

The dry matter yield of cotton was significantly influenced by various treatments of nutrient management at boll development stage of cotton (Table 15). The split application of nitrogen and potassium recorded highest dry matter yield at boll development stage of cotton. The highest dry matter yield (25.94 q ha^{-1}) found under the treatment receiving N at basal, 30 DAS, 60 DAS and 90 DAS, P at basal, K at basal + 60 DAS + foliar spray of 1% $MgSO_4$ at 60 DAS and 90 DAS. Similar result was reported by Shankarnarayana *et al*. (2010) and Kulvir Singh (2015) [9, 6].

Correlation of dry matter yield and yield of cotton

The relationship among dry matter accumulation at boll development stage and seed cotton ($R = 0.93^{**}$) and stalk yield ($R = 0.90^{**}$) was significant. The higher dry matter accumulation at boll development stage resulted higher seed cotton yield followed by cotton stalk yield.

Effect of precise application of nutrients on nutrient uptake by cotton

The nitrogen uptake in cotton seed and cotton stalk was ranged from 21.46 to 55.91 and 6.34 to 17.10 kg ha^{-1}, respectively (Table). Split application of fertilizer treatment along with $MgSO_4$ spray where N at basal, 30 DAS, 60 DAS and 90 DAS, P at basal, K–Basal + 60 DAS + foliar spray of 1% $MgSO_4$ at 60 DAS and 90 DAS recorded significantly higher N uptake by cotton seed (55.91 kg ha^{-1}) and cotton stalk (17.10 kg ha^{-1}). The uptake of N by cotton seed and cotton stalk was significantly increased with splits application of fertilizer along with application of magnesium spray. Total uptake of N by cotton was the combined effect of their respective content and dry matter of various treatments. Significant increase in the total N uptake by cotton was observed with increasing split application of N and K fertilizer. The highest total N uptake (73.01 kg ha^{-1}) was found in treatment T_8 where N–Basal, 30 DAS, 60 DAS and 90 DAS, P-Basal, K–Basal + 60 DAS + foliar spray of 1% $MgSO_4$ at 60 DAS and 90 DAS. These findings are in close agreement with those obtained by Sisodia and Khamparia (2007) and Modhvadia *et al*. (2012) [12, 7].

The phosphorus uptake in cotton seed and cotton stalk was ranged from 4.18 to 12.82 and 1.65 to 5.15 kg ha^{-1}, respectively. Split application of fertilizer treatment where N–Basal, 30 DAS, 60 DAS and 90 DAS, P-Basal, K–Basal + 60 DAS along with foliar spray of 1% $MgSO_4$ at 60 DAS and 90 DAS recorded significantly higher P uptake in cotton seed (12.82 kg ha^{-1}) and cotton stalk (5.15 kg ha^{-1}). Increased uptake of P must be due to increased absorption of P by cotton crop. The uptake of P by cotton seed and cotton stalk was increased with increasing split application of fertilizer which was slightly increased with application of magnesium spray. Total uptake of P by cotton was the combined effect of their respective content and dry matter of various treatments. These findings are in close agreement with those obtained by Sisodia and Khamparia (2007) and Modhvadia *et al*. (2012) [12, 7].

The effect of various nutrient management treatments on K uptake by cotton seed and cotton stalk was found to be significant. The application of N at basal, 30 DAS, 60 DAS and 90 DAS, P at basal, K at basal + 60 DAS along with foliar spray of 1% $MgSO_4$ at 60 DAS and 90 DAS recorded higher K uptake by cotton seed (22.18 kg ha^{-1}) and cotton stalk (25.65 kg ha^{-1}). Increased uptake of K might be due to increased absorption of K by cotton crop. The uptake of K by cotton seed and cotton stalk was slightly increased with increasing split application of fertilizer along with application of magnesium spray.

Total uptake of K by cotton seed and cotton stalk was the combined effect of their respective content and dry matter of various treatments. The significant increase in the total K uptake by cotton was observed with increasing split application of N and K fertilizer. Balanced and optimum application of NPK increased the concentration and uptake of K by cotton plants. These findings are in close agreement with those obtained by Kote *et al*. (2005), Dhillon *et al*. (2006), Sisodia and Khamparia (2007) and Modhvadia *et al*. (2012) [5, 2, 12, 7].

Total uptake of calcium by cotton

The significantly highest uptake of Ca^{++} by cotton seed (18.80 kg ha^{-1}) and cotton stalk (13.01 kg ha^{-1}) was observed with split application of N as basal, 30, 60 and 90 DAS, P at basal, K at basal and 60 DAS along with $MgSO_4$ spray @ 1 % at 60 and 90 DAS.

Total uptake of Ca^{++} by cotton was the combined effect of their respective content and dry matter of various treatments. The significant increase in the total uptake of Ca^{++} by cotton was noticed with increasing splits of N and K fertilizers. The treatment (T_8) receiving split application of N as basal, 30, 60 and 90 DAS, P-Basal, K-Basal and 60 DAS along with $MgSO_4$ spray @ 1 % at 60 and 90 DAS recorded significantly highest total uptake of Ca^{++} (31.81 kg ha^{-1}) by cotton. These findings are in close agreement with those obtained by Kote *et al*. (2005), Dhillon *et al.* (2006), Sisodia and Khamparia (2007) and Modhvadia *et al*. (2012) [5, 2, 12, 7].

The effect of various nutrient management treatments on Mg^{++} uptake by cotton seed and cotton stalk was found to be significant. The treatment receiving $MgSO_4$ spray at 60 and 90 DAS along with split application of N as basal, 30, 60 and 90 DAS, P at basal, K at basal and 60 DAS recorded significantly highest uptake of Mg^{++} (17.27 kg ha^{-1} and 12.20 kg ha^{-1} by cotton seed and stalk respectively. Increased uptake of Mg^{++} might be due to increased absorption of nutrients by cotton crop. The uptake of Mg^{++} by cotton seed and cotton stalk was increased with increasing split application of fertilizer and which was slightly increased with application of magnesium spray over split application of N and K. These findings are in close agreement with those obtained by Kote *et al*. (2005), Dhillon *et al.* (2006), Sisodia and Khamparia (2007) and Modhvadia *et al*. (2012) [5, 2, 12, 7].

Total uptake of sulphur by cotton

The effect of various nutrient management treatments on sulphur uptake by cotton seed and cotton stalk was found to be significant. The treatment receiving split application of N at basal, 30 DAS, 60 DAS and 90 DAS, K at basal + 60 DAS and 100% P_2O_5 at basal along with foliar spray of $MgSO_4$ @ 1% at 60 and 90 DAS recorded significantly highest uptake of sulphur (13.84 and 9.35 kg ha^{-1} by cotton seed and cotton stalk, respectively). Increased uptake of sulphur might be due to increased absorption of sulphur by cotton crop. The uptake of sulphur by cotton seed and cotton stalk was increased with increasing splits of fertilizer and which was further slightly increased with application of magnesium spray.

Total uptake of sulphur by cotton was the combined effect of their respective content and dry matter of various treatments. Significant increase in the total uptake of sulphur by cotton was noted with increasing split application of N and K fertilizer. The significantly highest total uptake of S (23.19 kg ha^{-1}) by cotton was observed with split application of N at basal, 30 DAS, 60 DAS and 90 DAS, K at basal + 60 DAS and 100% P_2O_5 at basal along with foliar spray of $MgSO_4$ @ 1% at 60 and 90 DAS. Balanced and optimum application of NPK increased the concentration and uptake of S by cotton plants. These findings are in close agreement with those obtained by Kote *et al*. (2005), Dhillon *et al.* (2006), Sisodia and Khamparia (2007), Yin *et al*. (2012) and Modhvadia *et al*. (2012) [5, 2, 12, 14, 7].

Conclusion

On the basis of present study, it can be concluded that application of N in different splits viz; at basal, 30 DAS, 60 DAS and 90 DAS along with phosphorus application at basal, potassium application at basal and 60 DAS resulted higher uptake of primary and secondary nutrients as well as dry matter, seed cotton and stalk yield. The same treatment was further found effective when applied along with foliar spray of 1% $MgSO_4$ at 60 DAS and 90 DAS. The dry matter yield was closely related with the seed cotton and stalk yield of cotton indicating proper allocation of nutrients which ultimately reflected in higher yield of cotton.

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