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RESEARCH PAPER

Effect of nitrogen levels and K:N ratios on growth, yield and economics of Bt cotton

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Abstract: A field experiment was carried out at University of Agricultural Sciences, Dharwad for two years (2012-13 and 2013-14) on effect of nitrogen levels and potassium ratios on growth, yield and economics of Bt cotton. The experiment was laid out in Randomized Block Design (factorial) with three replications. Three nitrogen levels *viz.,* N_1: 120 kg N ha^{-1}, N_2: 150 kg N ha^{-1} and N_3:180 kg N ha^{-1} and Four potassium nitrogen ratios (K:N) *i.e.*, K_1: 0.25, K_2: 0.50, K_3: 0.75 and K_4:1.00. Application of 180 kg N ha^{-1} recorded significantly higher seed cotton yield (3249 kg ha^{-1}), Seed cotton yield per plant (207.1 g), total dry matter production (294.5 g plant^{-1}), higher gross returns (₹146222 ha^{-1}), net returns (₹ 97, 765 ha^{-1}) and B: C ratio (3.01) over other nitrogen levels. K:N ratio of 1.00 recorded significantly higher seed cotton yield (3223 kg ha^{-1}), seed cotton yield per plant (208.7 g), total dry matter production (298.1 g plant^{-1}), higher gross returns (₹ 145026 ha^{-1}), net returns (₹ 96,166 ha^{-1}) and B: C ratio (2.96 ha^{-1}) as compared to other K:N ratios, However, it was on par with 0.75 K:N ratio. Application of 180 kg N ha^{-1} with K;N ratio of 1.00 (180 : 180 kg NK ha^{-1}) recorded significantly higher seed cotton yield (3501 kg ha^{-1}), net returns (₹ 1,06,523ha^{-1}) and B:C ratio (3.08).

Keywords: Economics, Nitrogen levels, Potassium, Seed cotton

Introduction

Cotton (*Gossypium* spp.) is an important fibre crop of India contributing 85 per cent of raw materials to textile industry. India ranks first in global cotton cultivation with an area of 12.17 m ha accounting 33% of the world cotton area and stands second in production (353 lakh bales) next to China. However, the average productivity (494 kg lint ha^{-1}) is low compared to the world average of 725 kg lint ha^{-1} (Anon., 2012). There are many reasons for the reduction in the Bt cotton productivity. The major cause being area under rainfed conditions which predominate over irrigated area particularly in the state and country as a whole. More than 50 per cent of rainfed cotton is grown under erratic and low rainfall, without proper fertilization and plant protection measures. Thus, low yield levels prevailing in the country could be attributed to the genetic, physiological and agronomic factor. The main agronomic factors are improper tillage, non incorporation of residue, decline in soil fertility and nutrient imbalance in the soil. Compared to desi, American cotton varieties and other hybrids, nutrient removal is higher in Bt cotton hybrids. In general, a rainfed crop removes about 6–7 kg N, 2–2.5 kg P, 7–8 kg K per 100 kg seed cotton (Blaise *et al.,* 2014). Further, nutrient recommendation varies with crop response, genotypes, soil and climatic conditions. Balanced fertilization is a dynamic, site and situation-specific concept. Balanced dose of N, P and K is usually applied to the soil in the ratio of 2:1:1 ($N:P_2O_5:K_2O$) for obtaining greater efficiency. Among the major nutrients, nitrogen (N) is critical because it is a component of proteins, enzymes, nucleic acids and chlorophyll. Deficiency of nitrogen has negative effects on the number of fruiting parts produced and ultimately the yield.

Earlier, use of potash fertilizers in cotton was negligible. This was because most of the cotton growing soils had medium to high available K and response to K application was either low or inconsistent. Shift in cotton cultivation to Bt cotton demands revisit to potassium nutrition. Response to higher levels of potassium in the Bt hybrids than the conventional hybrids especially during the boll-development phase has been observed in both irrigated as well as under rainfed conditions (Blaise, 2012). Potassium plays an important role in fibre development and the turgor driven expansion of fibre cells ultimately determines the fibre length and strength (Bailey and Gwathmey, 2007).

Increased cropping intensity, higher crop yield and greater depletion of soil K drives greater attention towards optimum management of K and indicate to signify N x K interaction especially in crops like corn and cotton which have high K requirement. Strong N × K interaction shows progressive improvement in yield and the quality of the produce (Aulakh and Malhi 2005). Cotton crop removes higher quantities of potassium than nitrogen in contrast to the amount added to soil resulting in heavy depletion. In context of prevailing K:N ratio and increased potassium demand in Bt cotton necessitates application of lower K:N ratios coupled with higher levels of nitrogen and potassium. Supplementation of higher potassium will improve the efficiency of the applied nitrogen. Further, rationalizing dose of nitrogen and potassium at different K:N ratios is critical for optimizing seed cotton yield and profit in Bt cotton production. Keeping this in view, the present investigation was carried out to assess the effect of nitrogen levels and K:N ratios on growth, yield and economics of Bt cotton.

Material and methods

The experiment was conducted at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during *kharif* season of 2012-13 and 2013-14. The soil was medium deep black clay having pH 7.0 and electrical conductivity (EC) of 0.20 dS m^{-1}. The soil had medium organic carbon (0.47 %), low available nitrogen (203.7 kg ha^{-1}), high available phosphorus (38.6 kg ha^{-1}) and high available potassium (320.3 kg ha^{-1}). The experiment was laid out in Randomized Block Design (factorial) with three replications. First factor consisted three nitrogen levels *viz.,* N_1: 120 kg N ha^1, N_2: 150 kg N ha^{-1} and N_3:180 kg N ha^{-1} and second factor consisted four Potassium nitrogen ratios (K:N) *i.e.,* K_1: 0.25, K_2: 0.50, K_3: 0.75 and K_4:1.00. Variable rates of nitrogen, and potash as per ratios and levels for different treatments were calculated based on the gross plot size. Fifty per cent of nitrogen fertilizer and full dose of phosphorus and potassium were applied at the time of sowing as basal and the remaining 50 per cent N was applied into two splits at 30 and 45 days after sowing (DAS). Experiment was sown during third week of June in both the year. Sowing of seed was done by hand dibbling with 90 cm × 60 cm spacing at 4 to 5 cm depth. Five plants were tagged randomly in net plots for recording growth and yield attributes of crop different treatments. Yield and yield parameters were recorded periodically till harvest during both the years. The data collected from the experiment were subjected to statistical analysis as described by Gomez and Gomez (1984).

Results and discussion

Effect of nitrogen levels

Seed cotton yield increased significantly with each level of nitrogen. Application of 180 kg N ha^{-1} recorded significantly higher seed cotton (3249 kg ha^{-1}) over other nitrogen levels and the increase in yield to the tune of 26.7 and 7.8 per cent over 120 and 150 kg N ha^{-1}, respectively (Table 2). Similar results were reported by Hallikeri (2008); Sree Rekha and Pradeep (2012) and they reported higher seed cotton yield with higher levels of nitrogen. Nitrogen is an essential element for canopy area development and photosynthesis. Providing the right N amount during the plant growth will provide healthy leaves with the photosynthetic capacity needed to support the growing of the reproductive components (Nour Ali, 2015). Positive effect of nitrogen on yield could be attribute to the fact that it controls new growth, nutrient

Table 1. Growth parameters of Bt cotton as influenced by nitrogen levels and K:N ratios

Treatments	Plant height (cm)	Leaf area (dm^2 $plant^{-1}$)	Leaf area index	No. of sympodia per plant	No. of monopodia per plant	Total dry matter production (g $plant^{-1}$)
Nitrogen levels (N)						
N_1: 120 kg ha^{-1}	138.5	133.5	2.47	22.1	2.9	263.0
N_2: 150 kg ha^{-1}	142.9	140.1	2.59	25.2	3.0	278.9
N_3: 180 kg ha^{-1}	151.5	145.7	2.70	26.6	3.1	294.5
S.Em±	2.9	1.2	0.02	0.5	0.1	4.0
C.D. at 5%	8.6	3.5	0.06	1.5	0.2	11.7
K:N ratio (K)						
K_1: K @ 0.25 K:N ratio	133.3	135.8	2.51	22.3	2.8	259.0
K_2: K @ 0.50 K:N ratio	139.8	138.3	2.56	23.9	2.9	272.7
K_3: K @ 0.75 K:N ratio	148.1	140.8	2.61	25.6	3.1	282.3
K_4: K @ 1.00 K:N ratio	156.1	144.1	2.67	26.8	3.2	298.1
S.Em±	3.4	1.4	0.03	0.6	0.1	4.6
C.D. at 5%	9.9	4.0	0.07	1.7	0.2	13.5
Interactions (N × K)						
N_1K_1	127.1	129.3	2.39	17.9	2.5	243.5
N_1K_2	135.9	132.7	2.46	21.3	2.8	256.9
N_1K_3	142.5	134.9	2.50	24.1	3.0	269.2
N_1K_4	148.4	137.0	2.54	25.3	3.1	282.3
N_2K_1	131.9	135.3	2.51	23.5	2.8	258.4
N_2K_2	137.7	137.6	2.55	24.6	2.9	271.8
N_2K_3	146.0	141.9	2.63	25.9	3.0	288.3
N_2K_4	156.1	145.5	2.69	26.9	3.2	297.2
N_3K_1	140.9	142.7	2.64	25.4	3.0	275.2
N_3K_2	145.7	144.4	2.67	25.8	3.0	289.4
N_3K_3	155.7	145.8	2.70	26.8	3.1	298.7
N_3K_4	163.7	149.9	2.78	28.2	3.2	314.7
S.Em±	5.9	2.4	0.04	1.0	0.1	7.9
C.D. at 5%	17.2	6.9	0.13	NS	NS	23.3

NS: Non Significant

N_1K_1 - 120:30 kg NK ha^{-1}	N_2K_1 – 150:37.5 kg NK ha^{-1}	N_3K_1 - 180:45 kg NK ha^{-1}
N_1K_2 - 120:60 kg NK ha^{-1}	N_2K_2 – 150:75 kg NK ha^{-1}	N_3K_2 - 180:90 kg NK ha^{-1}
N_1K_3 - 120:90 kg NK ha^{-1}	N_2K_3 – 150:112.5 kg NK ha^{-1}	N_3K_3 - 180:135 kg NK ha^{-1}
N_1K_4 - 120:120 kg NK ha^{-1}	N_2K_4 – 150:150 kg NK ha^{-1}	N_3K_4 - 180:180 kg NK ha^{-1}

Table 2. Seed cotton yield and its parameters of Bt cotton as influenced by nitrogen levels and K:N ratios

Treatments	Mean boll weight (g)	Total number of bolls plant^{-1}	Seed cotton yield plant^{-1} (g)	Seed cotton yield (kg ha^{-1})
Nitrogen levels (N)				
N_1: 120 kg ha^{-1}	4.63	39.2	183.7	2563
N_2: 150 kg ha^{-1}	5.32	42.4	200.0	3015
N_3: 180 kg ha^{-1}	5.89	46.3	207.1	3249
S.Em±	0.12	0.5	1.0	42
C.D. at 5%	0.34	1.6	3.1	122
K:N ratio (K)				
K_1: K @ 0.25 K:N ratio	4.73	35.6	179.8	2592
K_2: K @ 0.50 K:N ratio	5.14	41.1	193.4	2857
K_3: K @ 0.75 K:N ratio	5.46	45.7	205.7	3099
K_4: K @ 1.00 K:N ratio	5.79	48.1	208.7	3223
S.Em±	0.14	0.6	1.2	48
C.D. at 5%	0.40	1.9	3.5	141
Interactions (N × K)				
N_1K_1	4.11	33.5	165.4	2268
N_1K_2	4.30	37.0	182.1	2459
N_1K_3	4.69	42.4	191.6	2707
N_1K_4	5.41	43.8	195.6	2821
N_2K_1	4.87	34.7	181.1	2514
N_2K_2	5.25	41.1	195.0	2957
N_2K_3	5.50	45.0	211.5	3243
N_2K_4	5.67	49.1	212.4	3347
N_3K_1	5.20	38.5	192.9	2994
N_3K_2	5.88	44.9	203.3	3155
N_3K_3	6.19	49.8	213.9	3347
N_3K_4	6.28	51.8	218.2	3501
S.Em±	0.24	1.1	2.1	83
C.D. at 5%	0.69	3.3	6.1	244

N_1K_1 - 120:30 kg NK ha^{-1}	N_2K_1 – 150:37.5 kg NK ha^{-1}	N_3K_1 - 180:45 kg NK ha^{-1}
N_1K_2 - 120:60 kg NK ha^{-1}	N_2K_2 – 150:75 kg NK ha^{-1}	N_3K_2 - 180:90 kg NK ha^{-1}
N_1K_3 - 120:90 kg NK ha^{-1}	N_2K_3 – 150:112.5 kg NK ha^{-1}	N_3K_3 - 180:135 kg NK ha^{-1}
N_1K_4 - 120:120 kg NK ha^{-1}	N_2K_4 – 150:150 kg NK ha^{-1}	N_3K_4 - 180:180 kg NK ha^{-1}

uptake and preventing abscission of squares and bolls there by retaining higher bolls (Hallikeri *et al.,* 2011). The seed cotton yield (SCY) in cotton depends on yield per plant, mean boll weight number of bolls, number of sympodia and monopodia per plant, Leaf area and leaf area index. In the present investigation application of 180 kg ha^{-1} recorded significantly higher seed cotton yield per plant (207.1 g), mean boll weight (5.89 g), total number of bolls (46.3), number of sympodia per plant (26.6), monopodia per plant (3.1), leaf area index (2.70) and plant height (151.7 cm) over other nitrogen levels. Saleem *et al.* (2010) indicated that total bolls per plant and mean boll weight were significantly more in the crop applied with higher levels of nitrogen. Increased nitrogen fertilizer level increased photosynthetic rate which might have resulted in higher accumulation of metabolites thus impacted on mean boll weight.The seed cotton yield is an end product, which obviously depends upon the total dry matter production at different stages of the crop growth and its partitioning in to different parts. The total dry matter production significantly higher with application of 180 kg N ha^{-1} (294.5 g) as compared to other nitrogen levels. Total dry matter production per plant depending on accumulation of dry matter in different plant parts *viz.,* leaf, stem and reproductive parts. Total dry matter production at 120 DAS increase was to the tune of 12.01 and 5.5 per cent over 120 and 150 kg N ha^{-1}. Borowski (2001) opined that the beneficial effects of nitrogen on cell division and elongation, formation of nucleotides and co-enzymes resulted in increased meristematic activity and photosynthetic area and hence more production and accumulation of photosynthates, which reflected in higher dry matter production. Reddy and Reddy (2012) indicated that the amount of dry matter production depends on photosynthesis which in turns depend on large and efficient assimilating area, adequate supply of solar radiation and carbon dioxide and favorable environment conditions.

Effect of potassium and nitrogen ratio (K:N ratio)

In the present investigation, increase in seed cotton yield was observed with increased potassium levels through nitrogen potassium ratios (Table 2). The data indicated K:N ratio of 1.0 recorded significantly higher seed cotton yield (3222 kg ha^{-1}) as compared to other K:N ratios. However, it was on par with

Table 3. Economics of Bt cotton as influenced by nitrogen levels and K:N ratios

Treatments	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
Nitrogen levels (N)			
N_1: 120 kg ha^{-1}	115354	71247	2.61
N_2: 150 kg ha^{-1}	135688	89028	2.90
N_3: 180 kg ha^{-1}	146222	97765	3.01
S.Em±	1871	1705	0.03
C.D. at 5%	5487	4999	0.09
K:N ratio (K)			
K_1: K @ 0.25 K:N ratio	116637	72964	2.66
K_2: K @ 0.50 K:N ratio	128560	82913	2.81
K_3: K @ 0.75 K:N ratio	139462	92010	2.93
K_4: K @ 1.00 K:N ratio	145026	96166	2.96
S.Em±	2160	1968	0.03
C.D. at 5%	6336	5773	0.10
Interactions (N × K)			
N_1K_1	102053	60178	2.44
N_1K_2	110640	67302	2.55
N_1K_3	121801	76770	2.70
N_1K_4	126923	80737	2.74
N_2K_1	113141	69856	2.61
N_2K_2	133065	87018	2.89
N_2K_3	145952	98001	3.04
N_2K_4	150593	101237	3.05
N_3K_1	134717	88858	2.94
N_3K_2	141975	94421	2.98
N_3K_3	150632	101258	3.05
N_3K_4	157563	106523	3.08
S.Em±	3880	3409	0.06
C.D. at 5%	11639	9998	0.17

N_1K_1 - 120:30 kg NK ha^{-1} N_2K_1 – 150:37.5 kg NK ha^{-1}
N_1K_2 - 120:60 kg NK ha^{-1} N_2K_2 – 150:75 kg NK ha^{-1}
N_1K_3 - 120:90 kg NK ha^{-1} N_2K_3 – 150:112.5 kg NK ha^{-1}
N_1K_4 - 120:120 kg NK ha^{-1} N_2K_4 – 150:150 kg NK ha^{-1}
N_3K_1 - 180:45 kg NK ha^{-1} N_3K_2 - 180:90 kg NK ha^{-1}
N_3K_3 - 180:135 kg NK ha^{-1} N_3K_4 - 180:180 kg NK ha^{-1}

0.75 K:N ratio (3099 kg ha^{-1}) and the yield increase was in the tune of 24.3, 12.8 and 4.0 per cent over 0.25, 0.50 and 0.75 of K:N ratio, respectively. Similar results were reported by Kaleem *et al.* (2009); Cocker *et al*. (2009). Increase in seed cotton yields of Bt cotton hybrids to an extent of 13–20 per cent was observed in the rainfed and irrigated conditions in Karnataka with application of potassium (Biradar *et al.,* 2011).

In cotton, yield per plant is more important to achieve maximum yield per unit area. Mean boll weight and total number of bolls per plant greatly influence the yield per plant. In the present investigation K:N ratio of 1.0 recorded significantly higher seed cotton yield per plant (208.7 g), mean boll weight (5.79 g) and total bolls per plant (48.1) as compared to other K:N ratios. However, it was on par with 0.75 K:N ratio (205.7 g, 5.46 g and 45.7). Mohan Das *et al.* (2013) reported that seed cotton yield per plant and mean boll weight increased with increased levels of potassium. Potassium requirement of developing bolls is higher as bolls are the highest sinks of potassium (Oosterhuis, 2002). Increase in boll number and boll weight with the application of potassium was reported under loamy soil in Punjab (Brar and Brar, 2004). Potassium application had a significant effect on single boll weight as reported by Aladakatti *et al.* (2011). Yield is the result of growth and development as indicated by total dry matter production per plant, and its distribution in various parts. In the present investigation, total dry matter was significantly influenced by potassium levels through K:N ratios at all the growth stages (Table 1). Significantly higher total dry matter was recorded with K:N ratio of 1.0 as compared to other K:N ratios at all the growth stages. Total dry matter accumulation per plant may be due to higher dry matter accumulation in leaves, stem and reproductive parts. Potassium helps to translocates more assimilates to reproductive parts helpful in attaining accumulation of more dry matter in reproductive parts (Kaleem *et al.,* 2009).

Interaction effects

The significance of N × K interaction and its optimum management is to increasing cropping intensity, higher crop yield and greater depletion of soil K. Crops with a high requirement of K such as corn and cotton often show strong N × K interactions (Aulakh and Malhi 2005). In the present investigation, interaction effect of nitrogen levels and K:N ratio was found significant on seed cotton yield. Among the treatment combinations, application of 180 kg N ha^{-1} with K:N ratio of 1.0 (180:180 kg K:N ha^{-1}) recorded significantly higher seed cotton yield (3501 kg ha^{-1},) as compared to other treatment combinations. However, it was on par with 180 kg N ha^{-1} with 0.75 K:N ratio (180:135 kg NK ha^{-1}) and 150 kg N ha^{-1} with 1.0 K:N ratio (150:150 kg K:N ha^{-1}). In cotton, yield depend on yield attributing characters. In the present investigation, application of 180 kg N ha^{-1} with K:N ratio of 1.0 (180:180 kg K:N ha^{-1}) recorded significantly higher seed cotton yield per plant (218.2 g) and total bolls per plant (51.8) as compared to other treatment combinations. However, it was on par with 180 kg N ha^{-1} with 0.75 K:N ratio (180:135 kg NK ha^{-1}) and 150 kg N ha^{-1} with 0.75 (150:112.5 kg K:N ha^{-1}) and 1.0 K:N ratio (150:150 kg K:N ha^{-1}).

Economics

Economics of Bt-cotton production with the aim of better N management reveals that application of 180 kg N ha^{-1} resulted in significantly higher gross returns, net returns and B:C ratio (₹ 1,46,222, ₹ 97,765 ha^{-1} and 3.01, respectively) over other nitrogen levels. The higher gross and net returns were mainly due to higher economic yield (Table 3). Higher returns due to increased yield levels at higher application of nitrogen was reported by Hallikeri (2008). K:N ratio of 1.00 recorded significantly higher gross returns (₹ 145026 ha^{-1}), net returns (₹ 96,156 ha^{-1}) and B:C ratio (2.96) as compared to other K:N ratios. However, it was on par with 0.75 K:N ratio (₹ 139462, ₹ 92010 ha^{-1} and 2.93, respectively). The higher gross and net returns were mainly due to higher economic yield associated with that treatment. Among the treatment combinations, application of 180 kg N ha^{-1} with K:N ratio of 1.0 and 0.75 (180:180 and 180:135 kg K:N ha^{-1}) recorded significantly higher and comparable gross returns, net returns and B:C ratio as compared to other treatment combinations. However, it was on par with 150 kg N ha^{-1} with K:N ratio of 0.75 and 1.0.

Conclusion

Based on the results, it was concluded that application of 180 kg N ha^{-1} with K:N ratio of 1.0 and 0.75 (180:180 and 180:135 kg K:N ha^{-1} respectively) was found optimum for higher seed cotton, gross returns, net returns and B:C ratio.

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