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Influence of integrated nutrient management on seed cotton yield, nutrient use efficiency and economics of Bt cotton (*Gossypium hirsutum* L.)

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Abstract
A field experiment entitled "Influence of Integrated Nutrient Management on Seed Cotton Yield, Uptake of NPK and Economics of Bt Cotton (*Gossypium hirsutum* L.)" was conducted during three consecutive *Kharif* seasons of 2017-18, 2018-19 and 2019-20 at experimental farm, Regional Agricultural Research Station, Lam, Guntur. to evaluate the influence of different nitrogen (N) management strategies on the growth and yield attributes of cotton. The experiment comprised seven treatments including a control (no nitrogen), full and partial recommended doses of nitrogen (RDN), and various methods of fertilizer application such as banding, spot placement, split doses, foliar urea sprays, and incorporation of green manure through *sunnhemp* intercropping. The pooled analysis of the three years experimental results showed that the maximum seed cotton yield of Bt cotton was recorded with application of 75% RDN (Placement as spot application in 4 splits- Basal, Squaring, Flowering & boll development) + Foliar application of 1% urea (Squaring, Flowering & boll development) + Raising of *sunhemp* and incorporation before flowering (T_7). Similarly, the growth and yield attributes *viz.*, plant height, total number of sympodial branches per plant, total number of bolls per m^2 at harvest and uptake of NPK and economics of cotton crop were recorded significantly higher under this treatment.

Keywords: Cotton, integrated nutrient management, cotton yield, nutrient use efficiency

Introduction
Cotton, known as "the king of apparel fibers," is a significant cash crop that provides a major portion of the raw materials used in the textile industry. BT cotton is the only genetically modified (GM) crop that has been approved for commercial cultivation in 2002 by the Genetic Engineering Appraisal Committee (GEAC) of the Ministry of Environment, Forest and Climate Change. In India, cotton occupies an area of 125.55 lakh ha and production 316.76 lakh bales with a yield of 429 kg ha^{-1}during 2023-24 (Anonymous, 2024) [1]. After Bt cotton was initially introduced in India in 2002, both the area planted to the crop and the number of farmers using the technique grew dramatically each year. Farmers are responding favourably to growing Bt cotton, displacing conventional kinds and hybrids at the same time in order to avoid the bollworm threat and maximize production (Liaqat *et al.*, 2018) [4].

Regrettably, there is currently no definitive agronomic package available for Bt cotton, despite its significant yield potential. This potential arises from its resistance to bollworm and its exceptional canopy architecture, which facilitates the production of a large number of bolls. The necessity for fertilizers is paramount in the context of cotton cultivation, particularly due to the extended growth period of this crop in black cotton soils, whether under rainfed or irrigated conditions (Parmar *et al*., 2019) [8].

The careless application of these chemical fertilizers can lead to a number of environmental issues, such as declining soil health and pollution of the environment. For the crop to grow properly, both organic and inorganic fertilizer must be applied in sufficient amounts and on time (Singh *et al*., 2020) [10]. Both vegetative and reproductive growth are impacted by nutritional stressors and imbalances, which ultimately reduce average seed cotton yields, fiber content, and seed quality. Therefore, an integration of sources has to be done. The utilization of organic manures in conjunction with inorganic fertilizers contributes to the restoration of degraded soils

and promotes sustainability in agricultural production. Therefore, keeping the above facts in view a field experiment entitled "Influence of Integrated Nutrient Management on Seed Cotton Yield, Uptake of NPK and Economics of Bt Cotton (*Gossypium hirsutum L.*)" was designed and conducted on Experimental Farm of RARS, Lam, Guntur.

Materials and method

Field experiment was conducted under rainfed conditions during *kharif* seasons of 2017,2018 & 2019 at the experimental farm of RARS, Lam, Guntur (Andhra Pradesh) on deep black soil having 218, 35 and 645 kg ha^{-1} of available N, P_2O_5 and K_2O respectively with pH of 8.2 and organic matter content of 0.40 per cent. The experiment was laid out in randomised block design and replicated thrice. There were seven treatments consisting of T_1: Control; T_2: 100% RDN (Band application in 2 splits- Basal & Flowering); T_3: 75% RDN (Band application in 2 splits- Basal & Flowering); T_4: 75% RDN (Placement as spot application in 2 splits- Basal & Flowering); T_5: 75% RDN (Placement as spot application in 4 splits- Basal, squaring, Flowering & Boll development); T_6: T_5 + Foliar application 1% urea (squaring, Flowering & boll development); T_7: T_6 + Raising of *sunhemp* and incorporation before flowering. The nutrients N, P, and K were applied by using sources of urea, single super phosphate and muriate of potash. The recommended dose of phosphorus and potassium was applied as per standard recommendation to all the treatments. The nitrogen was applied as per the treatments. The cotton variety "Jadoo" was planted during the years of the study with spacing of 105 cm × 60 cm. The crop was raised with all the standard package of practices and timely protection measures were carried out as and when required. The experimental data recorded for growth, yield parameters, seed cotton yield and economic parameters were statistically analyzed for level of significance and the pooled data was presented.

Results and Discussion

Growth parameters: The data revealed that the maximum plant height (203 cm) was obtained with treatment receiving 100% RDN (Band application- 2 splits- Basal & Flowering) which was on par with all the other treatments under study but significantly superior over control.

The data on the number of monopodial branches $plant^{-1}$ recorded at harvest was found to be non-significant. The treatment of application of 75% RDN (Placement spot application- 4 splits- Basal, squaring, Flowering & boll development) + Foliar application 1% urea (squaring, Flowering & boll development) + Raising of *sunhemp* and incorporation before flowering produced significantly a greater number of sympodial branches $plant^{-1}$ (24.3), which was statistically at par with treatments T_3, T_4, T_5 and T_6 (Table 1). This may be due to the fact that organic manure in the form of *sunhemp* increase the absorptive power of soil for cation and anion. These adsorbed ions are increased slowly for the entire growth period resulted in better increases observed in plant height, number of sympodial branches per plant is the reflection of overall improvement in plant performance (Sattar *et al.*, 2017) [9].

Yield parameters and seed cotton yield

A perusal of data (Table 1) revealed that different nutrient management practices significantly influenced the number of bolls per square meter at harvest. Application of 75% RDN (Placement spot application- 4 splits- Basal, squaring, Flowering & boll development) + Foliar application 1% urea (squaring, Flowering & boll development) + Raising of *sunhemp* and incorporation before flowering (T_7) produced significantly higher bolls per m^2 (101.2) and it was found on par with treatments T_5 and T_6. Organic manures (Green manure) had many advantages in increasing root growth, soil micro flora by providing congenial rhizosphere. It might have induced cell division, expansion of cell wall, meristmatic activity photosynthetic efficiency and regulation of translocation of sugar resulting in the enhancement of yield related parameters like, number of bolls per plant and boll weight.

Various practices of nutrient management significantly influenced the seed cotton yield (Table 1). Application of 75% RDN (Placement spot application- 4 splits- Basal, squaring, Flowering & boll development) + Foliar application 1% urea (squaring, Flowering & boll development) + Raising of sunhemp and incorporation before flowering (T_7) recorded significantly the higher seed cotton yield of 4225 kg ha^{-1} which was statistically at par with corresponding seed cotton yield of 4130 kg ha^{-1} recorded by 75% RDN (Placement spot application- 4 splits- Basal, squaring, Flowering & boll development) + Foliar application 1% urea (squaring, Flowering & boll development) (T_6). Enhancement in yield attributing characters of cotton in this treatment (T_7), more over important yield components like number of bolls per plant also showed significant positive correlation with seed cotton yield which might have resulted higher seed cotton yield. Improvement in yield due to combined application of inorganic fertilizer and organic manure might be attributed to control release of nutrient in the soil through mineralization of organic manure which might have facilitated better crop growth. Similar findings were also reported by Hirapara *et al.*, 2023 [14], Yadav *et.al*. (2021) [11], Megha *et al*. (2017) [6] and Ashwini *et al*. (2017) [2].

Uptake of NPK: NPK uptake and Nutrient Use efficiency were significantly higher with *sunhemp in-situ* green manuring over no manuring practices (Table 2). This increased uptake may be attributed to the increased availability of nutrients in soil. Increased nutrient uptake with green manure treatments inturn resulted in higher dry matter production. Similar results were reported by Badole and More, 2000 [13] and also by Katkar, *et. al.*, 2002 [12] who reported higher NPK uptake by cotton with *sunhemp* and dhaincha with green leaf and green manuring practices. Among different nutrient management practices, application of 75% RDN (Placement spot application- 4 splits- Basal, squaring, Flowering & boll development) + Foliar application 1% urea (squaring, Flowering & boll development) + Raising of *sunhemp* and incorporation before flowering (T_7) recorded significantly higher NPK uptake (38.0, 14.0 and 43.3 kg ha^{-1}) and NUE (37.56 kg kapas/kg N) as compared to control (24.2, 8.9 and 27.6 kg ha^{-1}). In the present investigation, green manuring with *sunhemp* increased the N, P and K availability. This might be due to direct addition of nutrients through organics to the available pool of soil and greater multiplication of soil microbes for the conversion of organically bound form to inorganic form particularly for nitrogen. These results are in agreement with the findings of Muthu and Rao, 2023, and Mahapatra *et al*., 2018 [5].

Economics: Gross returns, net returns and B:C ratio of Bt cotton was significantly affected by various nutrient management practices. Among the treatments, application of 75% RDN (Placement spot application- 4 splits- Basal, squaring, Flowering & boll development) + Foliar application 1% urea (squaring, Flowering & boll development) + Raising of *sunhemp* and

incorporation before flowering (T_7) recorded significantly higher gross returns, net returns and benefit cost ratio (186209 ₹ ha^{-1}, 112094 ₹ ha^{-1} and 2.51) followed by 75% RDN (Placement spot application- 4 splits- Basal, squaring, Flowering & boll development) + Foliar application 1% urea (squaring, Flowering & boll development) (T_6). Significantly lower gross return was noticed in control (T_1) (Table 3). Similar results were reported by Parmar *et al*., 2019 [8].

Conclusion

Application of organics (green manures) was found beneficial in improving the soil fertility when compared to application of RDF alone to obtain higher seed cotton yield. It is advisable to go for *in-situ* green manuring with *sunhemp* along with split application of nitrogen at critical growth stages of the crop reduces 25 per cent chemical fertilizer.

Table. 1: Influence of integrated nutrient management on growth, yield attributes and seed cotton yield of *Bt*. Cotton. (Pooled data)

Treatments	Plant height (cm) at harvest	No. of monopodia at harvest	No. of sympodia at harvest	No. of Bolls/ squaremetre	Boll weight (g)	Seed cotton Yield (kg/ha)
T_1.N_0 Control	161	1.73	16.0	68.99	4.49	2953
T_2.100% of RDN(Band application in 2 splits at Basal & Flowering)	203	1.73	23.4	101.01	4.69	3652
T_3.75% of RDN(Band application in 2 splits at Basal & Flowering)	196	1.67	22.8	101.23	4.92	3662
T_4.75% of RDN +Placement(Spot application in 2 splits at Basal & Flowering)	201	1.53	24.3	101.12	4.91	3659
T_5.75% of RDN + Placement (Spot application in 4 Split: Basal, Squaring, Flowering, Boll development)	189	1.47	22.8	90.80	4.83	4128
T_6.T_{5+} Foliar application of 1% urea (3 times: Squaring, Flowering, Boll development)	189	0.93	23.7	96.17	4.90	4130
T_7.T_6+raising of Sunnhemp between rows incorporated before flowering	185	1.53	18.9	100.07	4.89	4225
SE(m)±	5.07	0.19	0.90	5.31	0.16	143
CD (5%).	15.81	NS	2.80	16.54	NS	444
CV%	7.18	22.17	1.27	7.51	7.65	7.28

Table 2: Influence of integrated nutrient management in Bt cotton on Nitrogen Use Efficiency, Uptake of nitrogen (kg ha^{-1}), phosphorus (kg ha^{-1}) and potassium (kg ha^{-1}) and Economics

		Plant Uptake (kg ha^{-1})			Economics		
Treatments	Nitrogen Use Efficiency (kg kapas/kg N)	Nitrogen	Phosphorus	Potassium	Gross returns (₹/ha)	Net returns (₹/ha)	BCR
T_1.N0 Control	0.00	24.2	8.9	27.6	142342	77067	2.18
T_2.100% of RDN(Band application in 2 splits at Basal & Flowering)	27.53	35.5	13.0	40.5	160854	86534	2.16
T_3.75% of RDN(Band application in 2 splits at Basal & Flowering)	32.55	35.8	13.2	40.9	161399	91322	2.30
T_4.75% of RDN +Placement(Spot application in 2 splits at Basal & Flowering)	32.53	35.6	13.1	40.6	161263	89765	2.25
T_5.75% of RDN + Placement (Spot application in 4 Split: Basal, Squaring, Flowering, Boll development)	32.46	37.2	13.7	42.4	184209	102094	2.32
T_6.T5+ Foliar application of 1% urea (3 times: Squaring, Flowering, Boll development)	36.69	37.4	13.8	42.7	186073	107222	2.36
T_7.T6+raising of Sunnhemp between rows incorporated before flowering	37.56	38.0	14.0	43.3	186982	115275	2.51
SEm±	1.13	0.81	0.30	0.93	7779	6751	0.08
CD (5%)	3.54	2.54	0.93	2.89	24234	21033	0.11

MSP- ₹ 62.50/kg seed cotton

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