Indian Journal of Agricultural Sciences **89** (12): 2069–73, December 2019/Article
https://doi.org/10.56093/ijas.v89i12.96276

Nitrogen fertilizer management for enhancing productivity and nitrogen-use efficiency in Bt cotton

RAMANJIT KAUR[1], V P VERMA[2], Y S SHIVAY[3], ANCHAL DASS[4] and SEEMA SEPAT[5]

ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India

Received: 15 November 2018; Accepted: 31 May 2019

ABSTRACT

A field experiment was conducted at ICAR–Indian Agricultural Research Institute (IARI), New Delhi during *kharif* 2013–14 to study the effect of four nitrogen (N) levels on crop productivity and nitrogen-use efficiency in Bt cotton in a factorial randomised complete block design (RCBD). There were nine treatments, viz. (i) 4-N rates (100, 125, 150, and 175 kg/ha as urea), (ii) two rates of N application at sowing (0 and 30 kg N/ha) and (iii) one absolute control. Significantly higher seed cotton and lint yields were obtained with application of 175 kg N/ha along with basal application of 30 kg N/ha compared to remaining treatment combinations. Total N-uptake, N-harvest index and normalized difference vegetative index (NDVI) of *Bt*-cotton were significantly higher at 175 kg N/ha compared with rest of N levels. However, highest N-use efficiency indices were recorded with 150 kg N/ha. A strong and positive correlation (r^2=0.804-0.835) was observed between yield and NDVI indicating that NDVI could be used for predicting the potential yield of Bt cotton in semi-arid north Indian plains.

Key words: Bt cotton, Correlation, N-use efficiency, NDVI, Productivity

Cotton (*Gossypium hirsutum* L.) is the most important fibre and cash crop in India occupying 12.5 million ha area with a production of 0.34 million bales (Choudhary *et al.* 2015). Bt-cotton accounts for more than 90% of cotton area in India. Its cultivars differ from traditional cotton cultivars w.r.t. indeterminate growth habits where both vegetative and reproductive growth phases progress simultaneously. Therefore, production practices cannot be generalized for Bt-cotton and traditional cotton cultivars (Blaise *et al.* 2014, Noori *et al.* 2019). Both under-fertilization and over-fertilization with N can adversely affect the fibre quality and, reduce the seed cotton and lint yields of cotton (Rajpoot *et al.* 2018 and 2019). A large temporal and spatial variability of soil N-supply lowers the N-use efficiency (NUE) (Dass *et al.* 2014a and 2014b). N-application, which fails to match the cotton N-demand, can have significant physiological, environmental, and financial implications (Boquet and Breitenbeck 2000). Rochester (2006) reported that N enhances the *cry*-protein concentration in the plant which in turn increases the resistance against pest incidence. Thus, N management in Bt-cotton assumes greater importance to boost its productivity and quality. It has been estimated that 50–70% of the N applied to the soil is lost (Hodge *et al.* 2000). Thus, site-specific N management can be effectively used for achieving high NUE (Dass *et al.* 2014b). N-application by taking care of the spatial (soil test based) and temporal (plant based) variability of the N-demand of crops and soil increases NUE and simultaneously reduce the environmental pollution (Dass *et al.* 2014b). Optical sensors like GreenSeeker or chlorophyll meter can be used for precise N-applications in Bt-cotton and has been shown to optimize N-use of rice (*Oryza sativa*), wheat (*Triticum aestivum*) and maize crops without yield reductions. Such studies have not yet been reported in cotton in general and Bt-cotton in particular. Thus, current experiment was planned to optimise the appropriate N-rate for Bt-cotton in semi-arid north Indian plains.

MATERIALS AND METHODS

A field experiment was conducted at ICAR-Indian Agricultural Research Institute, New Delhi (Latitude 28°38’N; Longitude 77°10’E; Altitude 229 m) during *kharif* 2013–14. Soil of the experimental site comes under semi-arid and sub-tropical climate with very hot dry summers. It is characterized as sandy-loam, medium in organic carbon (0.43%), P (11.6 kg/ha) and K (178.5 kg/ha) with *p*H 7.6 and EC 0.33 dS/m. Maximum temperature ranged from 25.8–41°C and 27.2– 44.2°C and minimum temperature ranged from 7.4–27.9°C and 7.3–28.5°C during 2013–14, respectively. A total of 1350.2 mm rainfall received during

[1,3,4]Principal Scientist (ramaan180103@yahoo.com, ysshivay@hotmail.com, anchal_d@rediffmail.com), [2]Ph D Scholar (virendrapratap7399@gmail.com), [5]Scientist (seemasepat12@gmail.com), Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi.

the crop growth period in 2013 with monthly rainfall of 151 mm in June, 459.8 mm in July, 518.3 mm in August, 111.7 mm in September and 109 mm in October. The crop received a total of 547.1 mm rainfall (June-December) in 2014, which was almost 60% lower than that in 2013. The month-wise distribution was 56.4, 227.8, 138.6, and 124.3 mm for the month of June, July, August, and September, respectively. There was no rain during October–December in 2014.

Experiment was laid-out in a factorial randomised complete block design with nine treatments consisting of (i) 4-N rates (100, 125, 150, and 175 kg/ha as urea), (ii) two rates of N application at sowing (0 and 30 kg N/ha) and (iii) one absolute control [(4×2) + 1= 9] and 4 replications. In treatments, that included application of 30 kg N/ha at sowing, the same amount of N was subtracted from each of the 4-N rates and the remaining quantities of fertilizer-N were applied in two equal splits. In case of no-N at sowing, whole quantity of fertilizer N was applied in two equal splits (first split, 30 days after sowing/at thinning and second split at the appearance of the first flower, by side dressing through urea). In absolute control, no-N was applied. Recommended doses of P (26 kg P/ha) as single super phosphate and K (50 kg K/ha) as muriate of potash were applied basally. A medium duration Bt cotton variety MRC-7017 was sown manually by dibbling method on 5th June in 2013 and 7th June in 2014 at 75 cm × 60 cm spacing. Crop was harvested by manual picking of the matured bolls on 115 and 117 and 140 and 142 days after seeding and the final (third) picking was done on 24th and 26th of November in 2013 and 2014, respectively. Seed cotton yield from the three pickings from a net-plot size of 16.2 m^2 was weighed separately and summed up to get total seed cotton yield for each treatment. After ginning, seed and lint yields were recorded separately. The plants were sun-dried to a moisture content of 16% and weighed to calculate stalk yield. All yields were recorded at 14% moisture content.

At harvest, cotton stalk, cotton seed, and lint were analyzed for total N content by Kjeldahl's digestion and distillation method (Rana *et al.* 2014). Total N uptake by the cotton was calculated by multiplying N concentrations in the plant parts with their respective dry matter yields. Different indices of N-use efficiencies (NUE), such as apparent recovery of N, agronomic N-use efficiency of N and physiological N use efficiency were computed using the expressions suggested by Fageria and Baligar (2003), Dobermann (2005) and Fageria (2014). Spectral reflectance of crop was recorded at a weekly interval starting from 30 days after sowing using a GreenSeeker (Dass 2018).

Data for different parameters were subjected to analysis of variance (ANOVA) for a factorial RBD (pooled analysis) using PROC-GLM in the statistical software package SAS 9.4 version. The treatment effects for different treatments were tested at the 5% probability level of significance.

RESULTS AND DISCUSSION

Seed cotton, lint and cotton seed yield: Application of N @175 kg/ha resulted in 25.8, 14.5 and 3.3% greater seed cotton yield compared with 100, 125, and 150 kg N/ha, respectively (Table 1). Furthermore, basal application of N significantly increased the seed cotton yield as compared

Table 1 Effect of variable rate of N application on yields, N content and N uptake in Bt cotton

Treatment	Seed cotton yield (t/ha)	Lint yield (t/ha)	Seed yield (t/ha)	Stalk yield (t/ha)	N content (%)			N uptake (kg/ha)			
					Seed	Lint	Stalk	Seed	Lint	Stalk	Total
Nitrogen levels (kg N/ha)											
100	2.10	0.71	1.39	4.61	3.55	0.33	1.10	49.35	2.35	50.66	102.35
125	2.31	0.785	1.52	4.96	3.59	0.39	1.13	54.50	3.05	55.95	113.51
150	2.56	0.885	1.67	5.24	3.69	0.45	1.19	61.44	3.95	62.31	127.71
175	2.64	0.925	1.72	5.42	3.75	0.51	1.12	64.43	4.65	64.65	133.75
SEm±	0.014	0.005	0.008	0.021	0.006	0.005	0.004	0.291	0.051	0.321	0.531
LSD (P=0.05)	0.039	0.014	0.024	0.061	0.016	0.014	0.011	0.852	0.135	0.942	1.545
Time of application (T)											
No basal + 2 splits	2.34	0.81	1.54	4.98	3.62	0.41	1.14	55.81	3.25	57.10	116.11
Basal + 2 splits	2.46	0.85	1.61	5.12	3.66	0.43	1.16	59.10	3.75	59.71	122.50
SEm±	0.009	0.004	0.006	0.015	0.004	0.003	0.003	0.211	0.031	0.232	0.375
LSD (P=0.05)	0.027	0.011	0.016	0.043	0.012	0.009	0.008	0.612	0.095	0.665	1.091
N × T	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Control vs Rest											
Control	1.38	0.45	0.94	3.62	2.87	0.23	0.98	26.95	1.02	35.35	63.25
Rest	2.40	0.81	1.56	5.06	3.645	0.415	1.15	57.45	3.51	58.40	119.35
SEm±	0.02	0.008	0.013	0.031	0.0085	0.007	0.0055	0.44	0.07	0.48	0.795
LSD (P=0.05)	0.0415	0.015	0.027	0.065	0.0175	0.0145	0.0115	0.9	0.145	0.995	1.64

to non-basal application with an increase of about 5.1%. Similarly, highest and significantly different lint yield was recorded in 175 kg N/ha application which was found to be 30.2, 17.8, and 4.5% higher over 100, 125, and 150 kg N/ha, respectively. Basal application of N @30 kg/ha resulted in 4.94% additional lint yield over no-basal N-application. Also, a significant increase in seed yield was observed with N @175 kg/ha as compared to rest of the treatments. Basal N application increased the seed yield by 4.55% over non-basal application. Highest stalk yield (5.42 t/ha) was recorded when N was applied @175 kg/ha with per cent increase of 17.57, 9.27, 3.44 over N @100, 125 and 150 kg/ha, respectively. Application of 30 kg N/ha basally resulted in significantly higher stalk yield (5.12 t/ha) than non-basal N application. A non-significant interaction effect between N dose and basal N-application on the yield of seed cotton, lint and seed yield was recorded in the pooled yield data. A significant increase in yield parameters of Bt cotton can be attributed to production of higher number of bolls with heavier boll weight by increasing N-fertilization (Paul *et al.* 2016). Secondly, soil of the experimental site was low in organic carbon; hence, soils responded to higher N application (175 kg N/ha). N leads to enhancement in leaf area culminating in more number of sympodial branches (Noori *et al.* 2018 and 2019), resulting in production of higher numbers of bolls in cotton (Noori *et al.* 2019). Thus, the increased demand for nutrients led to higher uptake from soil and their accumulation in various plant parts, which was reflected in increased concentration of N in plant parts. Higher N rate assured optimum N availability causing an increase in plant height, leaf, monopodia, and sympodia production (Rajpoot *et al.* 2016a), ultimately leading to significant increase in stalk yield (Rajpoot *et al.* 2016b).

Nitrogen content and uptake: The highest N content in seed and lint (Table 1) was resulted by application of 175 kg N/ha which was significantly different from other treatments. The basal N @30 kg/ha recorded significantly higher N content in seed and lint compared to non-basal application. On the contrary, highest N content in stalk was recorded in N application @150 kg/ha which was significantly higher as compared to other treatments. Basal application of N significantly enhanced the N content in stalk relative to non-basal application. The N uptake of Bt cotton by seed, lint, and stalk increased with increasing N levels from 100–175 kg N/ha. The application of N @175 kg/ha resulted in 30.6, 18.2 and 4.9% higher N uptake in the seed as compared to 100, 125 and 150 kg N/ha, respectively. Similarly, higher total N uptake was recorded by N application @175 kg/ha. The time of application of N had a significant influence on N uptake and it was observed that the basal application of 30 kg N/ha recorded significantly higher N uptake by seed, lint and stalk as well as total N uptake compared to non-basal application. Enhancement in N content and uptake with increase in N dose could be attributed to increased availability of N (Kumar *et al.* 2015). Basal application of N might have made more N available to crop which enhanced N content and uptake as compared to non-basal application. Lack of N application in control treatment and low organic carbon content of soil could not meet the N demands of crop which consequently decreased the N content and N uptake.

Nitrogen-use efficiencies: The highest apparent recovery (Table 2) of 42.9% was at 150 kg N/ha, which was statistically higher than the remaining N rates. The apparent N recovery was similar at 100, 125 and 175 kg N/ha. The treatment having 30 kg N/ha as the basal dose recorded significantly higher apparent recovery (43.1%) compared with non-basal application of N (38.3%). The highest agronomic-use efficiency (AE) of 7.8 kg seed cotton kg/N applied was recorded with 150 kg N/ha followed by 125, 100, and 175 kg/ha. Basal application of N @30 kg/ha also significantly increased the AE of N over the non-basal application. The highest PE_N (18.5 kg per kg of N) was recorded at 100 kg N/ha, which was similar with 125 kg N/ha but significantly higher than 150 and 175 kg N/ha implying that crop could use absorbed N more efficiently in 100 and 125 kg/ha than other levels.. The highest nitrogen harvest index (NHI) NHI was recorded at 175 kg N/ha, which was significantly higher than 100 and 125 kg N/ha. Higher NHI indicates more accumulation of N in seed and lint per unit of N uptake by crop. Basal application of N @30 kg/ha resulted in significantly higher NHI over non-basal application. The Partial factor productivity (PFP_N) was significantly influenced by N rates and the time of N

Table 2 Effect of variable rate of N application on N-use efficiencies in Bt cotton

Treatment	AR	AE	PE	NHI	PFP
Nitrogen levels (kg N/ha)					
100	39.1	7.2	18.5	50.5	21.1
125	40.2	7.3	18.4	50.7	18.5
150	42.9	7.8	18.0	51.3	17.1
175	40.3	7.2	17.7	51.7	15.1
SEm±	0.39	0.11	0.14	0.16	0.1
LSD (P=0.05)	1.14	0.31	0.42	0.47	0.29
Time of application (T)					
No basal + 2 splits	38.3	6.9	18.2	50.8	17.5
Basal + 2 splits	43.1	7.8	18.2	51.3	18.4
SEm±	0.28	0.07	0.1	0.12	0.07
LSD (P=0.05)	0.81	0.21	NS	0.33	0.2
N×T	NS	NS	NS	NS	NS
Control vs Rest					
Control	-	-	-	44.2	-
Rest	40.7	7.4	18.2	51.1	17.9
SEm±	0.58	0.16	0.22	0.25	0.15

AR, Apparent recovery (%); AE, Agronomic use efficiency (kg seed cotton increased kg/N applied); PE, Physiological use efficiency (kg seed cotton kg/N uptake); NHI, Nitrogen harvest index (%); PFP, Partial factor productivity (kg seed cotton kg/N applied).

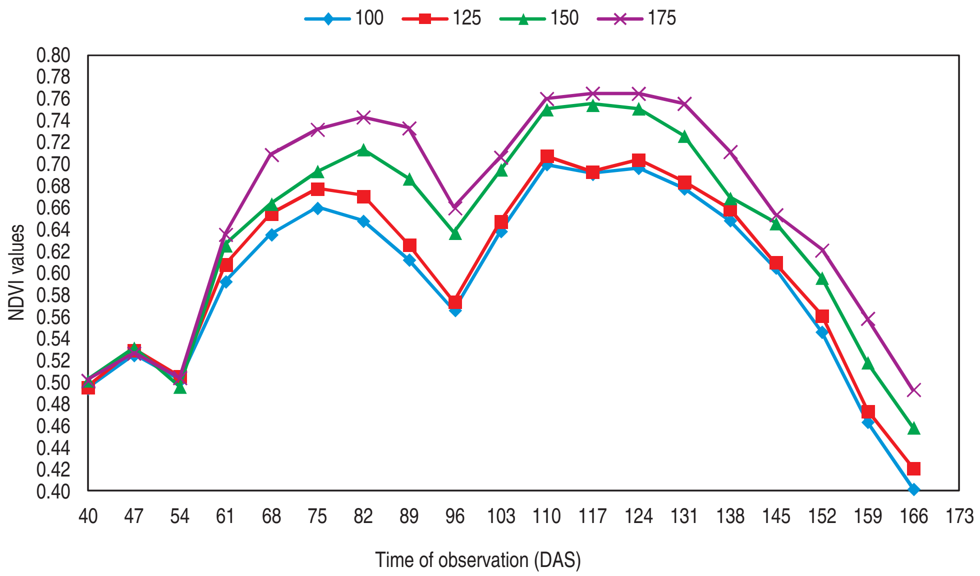

Fig 1 Effect of variable rate of nitrogen application on NDVI value of Bt cotton.

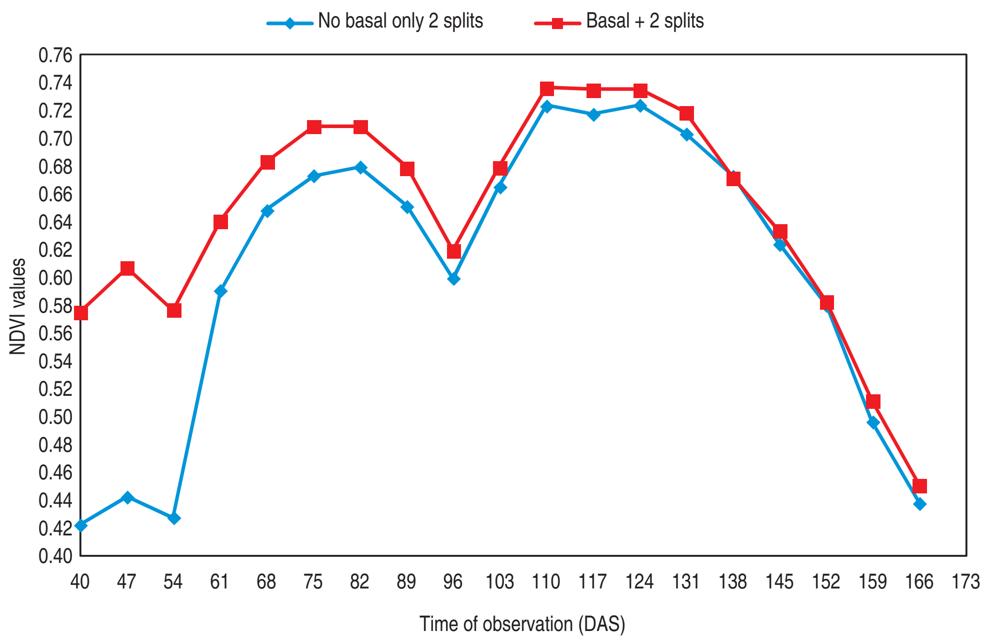

Fig 2 Effect of time of nitrogen application on NDVI value of Bt cotton.

application. The highest PFP_N of 21.1 kg seed cotton/kg N applied was recorded with 100 kg N/ha followed by 125, 100, and 175 kg N/ha. Applying 30 kg N as the basal dose recorded significantly higher PFP_N over the treatments with no basal application. The greater yield coupled with higher N-concentrations in plant parts led to higher N-uptake. The decrease in AE and PE with increased N dose was, because the increase in seed cotton yield was not in commensuration with the increase in N-dose. The decrease in recovery efficiency of N with increase in N fertilization was due to less increase in the rate of uptake compared to the increase in N dose. The increased seed yield coupled with more N concentration in seed with higher level of N fertilization led to higher NHI (Boquet and Breitenbeck 2000).

Normalised Difference Vegetative Index (NDVI): Application of different doses of N significantly affected the crop vigour which is reflected in relatively higher NDVI values and maximum value was recorded at 175 kg N/ha and the lowest at 100 kg N/ha (Fig 1). During initial crop growth stages, the difference in NDVI values of different treatments was non-significant as similar quantity of N was applied as basal dose. With the advancement of crop growth, NDVI values decreased as represented by a dip in the NDVI value curve (Fig 1) at 54 days after sowing (DAS).

With application of N at 54 DAS, NDVI values regained an upward trend. NDVI values decreased again as reflected in the second dip in the graph at 96 DAS. After second top-dressing of N at 96 DAS, NDVI values showed increasing trend and towards maturity it showed a decline. Although same amount of fertilizer was applied but the application of 30 kg/ha N applied as basal recorded higher NDVI values especially during the initial growth stage. However, NDVI values at 89 DAS and thereafter decreased with small differences between the two treatments until maturity (Fig 2). A strong correlation (r^2 =0.92) was observed between the seed cotton yield and NDVI values. An increased NDVI with increased dose of N from 100–175 kg/ha might be due to the increase in N availability to plants maintaining an adequate leaf N concentration. This increased foliage and greenness of cotton plants along with better crop vigour. With the advancement in age of crop towards maturity, greenness of leaves declined due to translocation of N from leaves towards reproductive organs and also senescence of leaves resulted in a decrease in NDVI values (Kaur *et al.* 2015). The strong and positive correlation observed between seed cotton yield and NDVI values showed that the NDVI values can serve as a good indicator of plant growth and can be used as a tool in predicting/forecasting the potential yield of crop. Active growth stage, i.e. 90–110 DAS is better for predicting the yield potential in cotton crop.

The study demonstrated that for obtaining optimum yields of seed cotton and lint, Bt cotton needed 175 kg N/ha which should be applied in three splits, first 30 kg N/ha as basal and remaining 145 kg N/ha in two equal splits, first at thinning of cotton, 30 days after sowing and second, on the appearance of first flower. Basal application of 30 kg N /ha at the time of sowing is necessary to optimize seed cotton yield and nitrogen-use efficiency in Bt cotton.

REFERENCES

Boquet D J and Breitenbeck G A. 2000. Nitrogen rate effect on partitioning of nitrogen and dry matter by cotton. *Crop Science* **40**: 1685–93.

Choudhary A K, Rana D S, Bana R S, Pooniya V, Dass A, Kaur R and Rana K S. 2015. *Agronomy of Oilseed and Pulse Crops*. Post Graduate School, IARI, New Delhi and ICAR, DARE, New Delhi, India, pp 218 p.

Dass A, Kaur R and Vyas A K. 2014a. Nitrogen management in Precision Farming by soil plant analysis development meter. *Indian Farming* **3**(12): 33–5.

Dass A, Suri V K and Choudhary A K. 2014b. Site-specific nutrient management approaches for enhanced nutrient-use efficiency in agricultural crops. *Research and Reviews*: *Journal of Crop Science and Technology* **3**(3): 1–6.

Dass A. 2018. Plant sensor assisted precision nitrogen management in cereal crops. (In) Proceedings of National Conference on managing natural resources for sustainable agriculture, GKV Society, Agra, Uttar Pradesh, December 8–9.

Dobermann A R. 2005. *Nitrogen-se Efficiency – State of the Art*". Agronomy and Horticulture - Faculty Publications, 316 p.

Fageria N K and Baligar V C. 2003. Methodology for evaluation of lowland rice genotypes for nitrogen use efficiency. *Journal of Plant Nutrition* **26**: 1315–33.

Fageria N K. 2014. Nitrogen harvest index and its association with crop yields. *Journal of Plant Nutrition* 3**7**: 795–810.

Hodge A, Robinson D and Fitter A. 2000. Are microorganisms more effective than plants at competing for nitrogen? *Trends in Plant Science* **5**: 304–8.

Kaur R, Deol J S, Brar A S, Jaidka M and Sepat S. 2015. Growth, reproductive physiology and spectral characteristics of Bt cotton under biotic and abiotic stresses. *Annals of Agriculture Research* ***3**6*: 92–7.

Kumar A, Choudhary A K and Suri V K. 2015. Influence of AM–fungi and applied phosphorus on growth indices, production efficiency, phosphorus–use efficiency and fruit–succulence in okra (*Abelmoschus esculentus*)–pea (*Pisum sativum*) cropping system in an acid Alfisol. *Indian Journal of Agricultural Sciences* **85**(8): 1030–37.

Noori A H, Choudhary A K and Dass A. 2019. Influence of varying nitrogen levels on crop productivity, profitability and resource-use efficiency in *Bt*-cotton (*Gossypium hirsutum*) in semi–arid region of Afghanistan. *Indian Journal of Agricultural Sciences* **89**(4): 745–8.

Noori A H, Choudhary A K, Dass A and Raihan O. 2018. Effect of varying nitrogen levels on growth, development and yield of *Bt*-cotton *(Gossypium hirsutum* L.*)* in semi-arid region of Afghanistan. *Annals of Agricultural Research* **39**(4): 390–7.

Noorzai A U and Choudhary A K. 2017. Influence of summer mungbean genotypes on grain yield and resource-use efficiency in Kandahar province of Afghanistan. *Annals of Agricultural Research* **38**(2): 194–9.

Paul T, Rana D S, Choudhary A K, Das T K and Rajpoot S. 2016. Crop establishment methods and Zn nutrition in *Bt*-cotton: Direct effects on system productivity, economic–efficiency and water–productivity in *Bt*-cotton–wheat cropping system and their residual effects on yield and Zn biofortification in wheat. *The Indian Journal of Agricultural Sciences* **86**(11): 1406–12.

Rajpoot S K, Rana D S and Choudhary A K. 2016a. Effect of crop establishment methods on seed germination, seedling mortality and growth of *Bt*–cotton (*Gossypium hirsutum*) based intercropping systems. *Annals of Agricultural Research* **37**(3): 316–20.

Rajpoot S K, Rana D S and Choudhary A K. 2016b. Influence of diverse crop management practices on weed suppression, crop and water productivity and nutrient dynamics in *Bt*–cotton (*Gossypium hirsutum*) based intercropping systems in a semi–arid Indo-Gangetic plains. *The Indian Journal of Agricultural Sciences* **86**(12): 1637–41.

Rajpoot S K, Rana D S and Choudhary A K. 2018. *Bt*-cotton–vegetable-based intercropping systems as influenced by crop establishment methods and planting geometry of *Bt*-cotton in Indo–Gangetic plains region. *Current Science* **115**(3): 516–22.

Rajpoot S K, Rana D S, Choudhary A K and Pande P. 2019. Cotton establishment methods' based system-intensification: Effects on *Bt*-cotton growth, weed suppression, system crop and water productivity, system-profitability and land–use efficiency in Indo–Gangetic plains region. *Indian Journal of Agricultural Sciences* **89**(2): 253–60.

Rana K S, Choudhary A K, Sepat S, Bana R S and Dass A. 2014. *Methodological and Analytical Agronomy,* IARI, New Delhi, 276 p.

Rochester I J. 2006. Effect of genotype, edaphic, environmental conditions and agronomic practices on Cry1ac protein expression in transgenic cotton. *The Journal of Cotton Science* **10**: 252–62.