



Influence of varying nitrogen levels on crop productivity, profitability and resource-use efficiency in *Bt*-cotton (*Gossypium hirsutum*) in semi-arid region of Afghanistan

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Cotton (*Gossypium hirsutum* L.) is one of the most important commercial crops of Afghanistan mainly grown for fiber production; however, its seeds are used as source of edible oil while cotton cake is used as animal feed. With the collapse of the cotton industry in the last four decades due to war, cotton planting has declined drastically in the country resulting in low cotton production (Noori 2018). There are many production constraints resulting in low cotton productivity in the country like poor irrigation infrastructure, low rainfall, less availability of improved variety seeds, sub-optimal fertilizer use especially nitrogen (N) and poor weed management practices etc. (Ibrahimi *et al.* 2017; Noorzai *et al.* 2017; Noorzai and Choudhary 2017). At present, the Afghan government is giving prime emphasis to cotton cultivation keeping in view its quality production and congenial agro-climatic conditions in some parts of the country. However, this crop is grown extensively using conventional local cultivars with sub-optimal or over-doses of fertilizer N which adversely affects the cotton productivity and profitability. Moreover, the optimum N application dose for conventional cotton in general and *Bt*-cotton in particular has not yet been standardized so for cotton growing areas in Afghanistan. Thus, to promote the cotton cultivation with enhanced productivity in Afghanistan we need to use high yielding cultivars like *Bt*-cotton with redesigned agronomic practices specifically fertilizer N management (Blaise *et al.* 2014). Therefore, an attempt was made to assess the optimum N dose for *Bt*-cotton besides its yield performance vis-à-vis resource-use efficiency under varying N levels in semi-arid region of Afghanistan.

A field experiment was conducted during *kharif* 2017 at Research Farm of Afghanistan National Agricultural Science and Technology University (ANASTU), Kandahar, Afghanistan (31°30' N Longitude; 65°50' E Latitude; 1010 m Altitude) to study the effect of varying N levels viz. 0, 30, 60, 90, 120, 150, 180 and 210 kg N ha⁻¹ (N₀, N₃₀, N₆₀, N₉₀, N₁₂₀, N₁₅₀, N₁₈₀, and N₂₁₀) on productivity, profitability and

resource-use efficiency of *Bt*-cotton (*Gossypium hirsutum* L.) in semi-arid conditions of Afghanistan. Geographically, Kandahar is situated in southern Afghanistan having semi-arid hot climate with extreme cold and hot situations. The mean weather data were recorded from *Meteorological Observatory* located at ANASTU, Kandahar during crop season (Fig. 1). The experiment was conducted in randomized block design replicated thrice in a sandy-clay loam soil having slightly alkaline pH (7.2). Using LaMotte Garden Guide Soil Test Kit-5679-01 (LaMotte Soil Testing Kit, Chestertown, Maryland, USA), the soil was characterized as low in available N, medium in P₂O₅ and high in K₂O content. The size of each gross and net-plot was 6.0 m × 4.5 m (27 m²) and 4.5 m × 3.6 m (16.2 m²), respectively. The N was supplied through urea (46% N) in two equal splits i.e. first at sowing and remaining half N at appearance of flowering in *Bt*-cotton. A blanket dose of 60 kg P₂O₅/ha was applied through triple super phosphate (45% P₂O₅) and 40 kg K₂O/ha through potassium sulphate (50% K₂O) applied at sowing time in direct-seeded *Bt*-cotton. The *Bt*-cotton cultivar Bt-3700 was sown manually using seed @ 5 kg ha⁻¹ with plant spacing of 75 cm × 45 cm at 3–4 cm depth on 21st May, 2017 and harvested on 21st October, 2017. The seedlings of the cotton emerged out within 5–6 days after sowing (DAS) and the gap filling was done at 12 DAS. Different intercultural operations were done as and when necessary following standard package of practices (Choudhary *et al.* 2015). Two hand-weeding were done during growing season at 30 and 50 DAS. Pre-sowing irrigation was given to aid land preparation for cotton seed sowing. The crop yield, production-efficiency and monetary-efficiency were estimated using standard procedures (Rana *et al.* 2014, Kumar *et al.* 2015). Optimum economic N dose was calculated through the formula [optimum N dose = [(q/p-b)/2c]; where, q is the unit cost of fertilizer used in AFN/kg (AFN 43.8 kg⁻¹), p is the unit price of economic yield of cotton i.e. seed cotton yield in AFN/kg (AFN 40.8 kg⁻¹) and b and c are the constants determined from the

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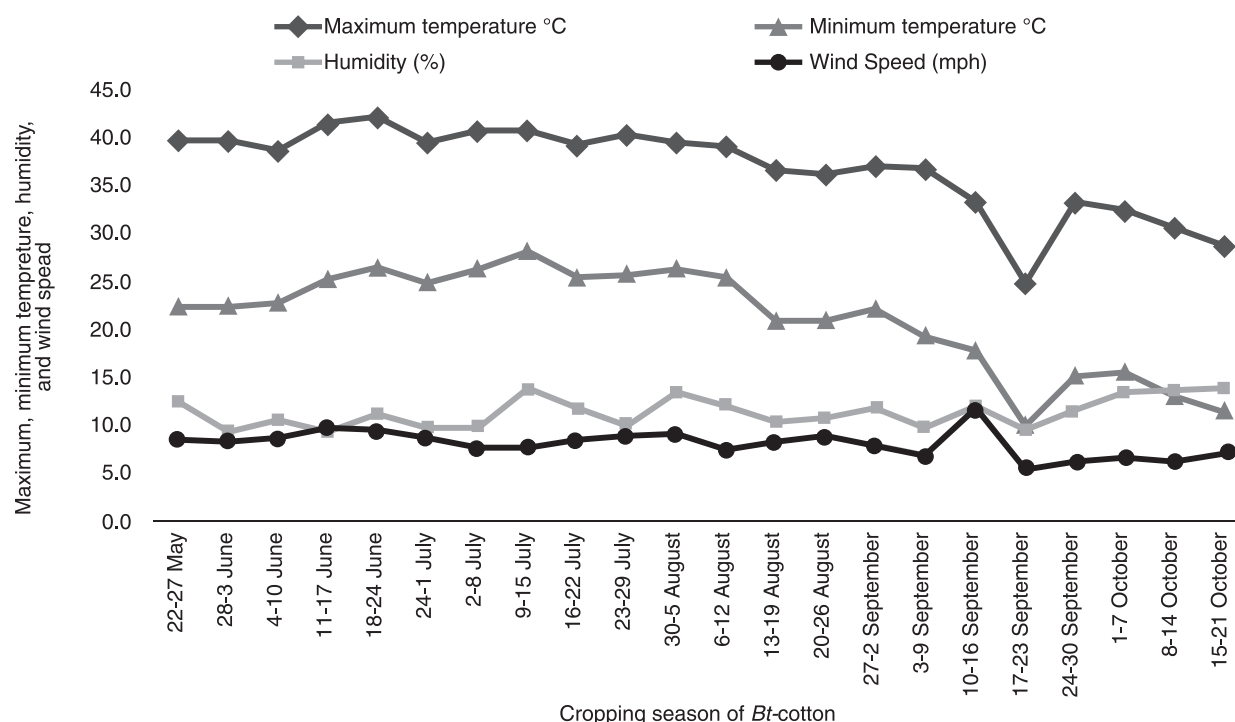


Fig 1 Meteorological details of the experimental site.

resultant regression equation. The regression equation was fitted for the yield variation in cotton in relation to different N-levels. The regression equation was quadratic in nature ($Y = -0.0421 x^2 + 18.132 x + 2017.1$; $R^2 = 0.7625$). The economic study *w.r.t.* cost of cultivation, gross returns, net returns, benefit: cost ratio (B: C ratio) were computed using standard procedures as suggested by Jalali and Choudhary (2018). The gross returns were calculated using prevalent market price of the seed (AFN 78 kg⁻¹), lint (AFN 27 kg⁻¹) and stalk (AFN 5 kg⁻¹) using standard procedures. A total of 18 irrigations 60 mm depth each were applied to the crop. The profile water contribution was not taken into consideration for seasonal water-use estimation in current study. Thus, total seasonal water-use for Bt-cotton was 1080 mm [effective rainfall (0.0 mm) + irrigational water use (1080 mm)]. Water-use efficiency (WUE) was computed using standard procedures (Choudhary *et al.* 2006). Partial factor productivity (PFP) (kg ha⁻¹ kg⁻¹) of applied (N, P, K) was calculated using formula as suggested by Choudhary and Suri (2018). The experimental data were subjected to statistical analysis as per standard methods suggested by Rana *et al.* (2014).

The data in Table 1 revealed that the highest seed cotton yield (3175.3 kg ha⁻¹) was recorded using N @ 210 kg ha⁻¹ which was followed by N₁₈₀, N₁₅₀, N₁₂₀, N₉₀, N₆₀, N₃₀ and N₀, respectively (Table 1). Since, N fertilization plays an important role in growth and yield enhancement (Choudhary *et al.* 2006), thus, increase in N levels led to enhanced seed cotton yield (Paul *et al.* 2016, Rajpoot *et al.* 2016a, 2016b, 2018). In current study, the cost of cultivation (COC) consistently increased with increase in N levels with highest COC under 210 kg N ha⁻¹ (Table 1).

It is apparent that high level of COC is always associated with high rates of farm inputs (Paul *et al.* 2016, Ibrahim *et al.* 2017, Rajpoot *et al.* 2018). Higher gross and net returns and B: C ratio were obtained when N was applied @ 210 kg ha⁻¹ followed by N₁₈₀, N₁₅₀, N₁₂₀, N₉₀, N₆₀, N₃₀ and N₀, respectively owing to differential yield trend as shown in Table 1. The optimum N dose for Bt-cotton was calculated as 206.7 kg N/ha from the resultant quadratic regression equation ($Y = -0.0421 x^2 + 18.132 x + 2017.1$; $R^2 = 0.7625$). The seasonal water-use was same in all the treatments (1080 mm). However, the WUE was maximum when N was applied @ 210 kg ha⁻¹ which was significantly higher over other treatments with least WUE values under control (Table 2). Production-efficiency (PE) and monetary-efficiency (ME) were significantly highest using N @ 210 kg ha⁻¹ which was followed by N₁₈₀, N₁₅₀, N₁₂₀, N₉₀, N₆₀, N₃₀ and N₀, respectively (Table 2). Since, higher N fertilization led to better crop yields and net returns which led to better resource-use efficiency indices *viz.* WUE, PE and ME in current study (Kumar *et al.* 2015, Choudhary and Rahi 2018, Rajpoot *et al.* 2019). Partial factor productivity of applied-N (PFP_N) was significantly higher when N was applied @ 30 kg ha⁻¹; thereafter, it showed a gradual decline till N @ 210 kg ha⁻¹ owing to decline in rate of seed cotton yield increase over per unit increase in N application rate (Table 2). Partial factor productivity of applied-P (PFP_P) and applied-K (PFP_K) were significantly higher in treatment N₂₁₀ while N₀ experienced lowest PFP_P and PFP_K. As high N fertilization led to better crop yields despite of same P and K doses, thus, resulting in better PFP_P and PFP_K in current study (Choudhary and Suri 2018).

Table 1 Effect of varying N levels on cost of cultivation, gross and net returns and B: C ratio of *Bt*-cotton

Treatment	Seed cotton yield (kg ha ⁻¹)	Cost of cultivation (AFN ha ⁻¹)	Gross returns (AFN ha ⁻¹)	Net returns (AFN ha ⁻¹)	B: C ratio
0 kg N ha ⁻¹ (Control)	1909.8	51616	90927	39311	0.76
30 kg N ha ⁻¹	2647.8	53420	124121	70701	1.32
60 kg N ha ⁻¹	3045.6	54725	144049	89324	1.63
90 kg N ha ⁻¹	3252.6	56029	154269	98241	1.75
120 kg N ha ⁻¹	3526.8	57333	167597	110264	1.92
150 kg N ha ⁻¹	3766.6	58638	180827	122189	2.08
180 kg N ha ⁻¹	3910.5	59942	188683	128741	2.15
210 kg N ha ⁻¹	4353.4	61246	212652	151406	2.47
SE(m)±	153.6		6899	6899	0.12
CD (<i>P</i> =0.05)	470.4		29044	29044	0.50

*Note: 1 AFN (Afghani, the Afghanistan currency) = 0.94 INR (Indian Rupee); One US dollar = 73.84 AFN.

Table 2 Effect of varying N levels on water-use efficiency, production-efficiency, monetary-efficiency and partial factor productivity (PFP) of *Bt*-cotton

Treatment	Water-use efficiency (kg ha ⁻¹ mm ⁻¹)	Production-efficiency (kg ha ⁻¹ day ⁻¹)	Monetary-efficiency (AFN ha ⁻¹ day ⁻¹)	Partial factor productivity (kg ha ⁻¹ kg ⁻¹ of applied nutrients)		
				PFP _N	PFP _P	PFP _K
0 kg N ha ⁻¹ (Control)	1.77	12.7	262.1	-	31.8	47.7
30 kg N ha ⁻¹	2.43	17.7	471.3	88.3	44.1	66.2
60 kg N ha ⁻¹	2.80	20.3	595.5	50.8	50.8	76.1
90 kg N ha ⁻¹	3.00	21.7	654.9	36.1	54.2	81.3
120 kg N ha ⁻¹	3.27	23.5	735.1	29.4	58.8	88.2
150 kg N ha ⁻¹	3.47	25.1	814.6	25.1	62.8	94.2
180 kg N ha ⁻¹	3.63	26.1	858.3	21.7	65.2	97.8
210 kg N ha ⁻¹	4.00	29.0	1009.4	20.7	72.6	108.8
SE(m)±	0.13	1.0	46.0	1.9	2.6	3.8
CD (<i>P</i> =0.05)	0.41	3.1	140.9	5.8	7.8	11.6

*PFP: Partial factor productivity; PFP_N: Partial factor productivity of nitrogen; PFP_P: Partial factor productivity of phosphorus; PFP_K: Partial factor productivity of potassium

Conclusion

Overall, it can be summarized that N application @ 210 kg ha⁻¹ can be used as a blanked recommendation for obtaining higher crop productivity and profitability as well as better resource-use efficiency in *Bt*-cotton in semi-arid region of Afghanistan. But as a site-specific recommendation, the economic optimum N dose for *Bt*-cotton was estimated ~206.7 kg N ha⁻¹ which may have great promises in enhancing the productivity, profitability and resource-use efficiency under semi-arid conditions of Afghanistan.

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