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Short Communications

Influence of applied nitrogen on productivity, profitability and resource-use efficiency in winter barley (*Hordeum vulgare*) under semi–arid conditions of Afghanistan

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Barley (*Hordeum vulgare* L.) is the major cereal in majority of global drylands and thus, vital for the livelihoods of resource-poor farmers of such harsh agro-ecologies (Rana *et al.* 2014). Barley is such an annual cereal crop grown in environments ranging from the deserts of the Middle East to the higher elevation of Himalayas (Hayes *et al.* 2003). Barley has the ability to replace the wheat as the dominant crop due to its tolerance to drought and salinity in dryland areas (Rana *et al*. 2014), thus, it is a potential alternate cereal crop for wheat under changing climate scenario. Barley is more productive under adverse environments than other cereals. That's why; the barley is cultivated in all the provinces of Afghanistan in a wide range of agro-climatic conditions. The major barley growing provinces of Afghanistan are Takhar, Balkh, Faryab, Jawzjan and Ghazni (Afghanistan Statistical Yearbook 2016–17). According to Afghanistan Statistical Yearbook (2016–2017), the area, production and productivity of barley is drastically reducing in Afghanistan year after year due to poor productivity of the crop. At present, the area under barley cultivation is 219208 ha with the production of 301856 metric tons and average productivity of 1.38 t ha^{-1} (Afghanistan Statistical Yearbook 2016–17). The major constraints for low barley productivity in the nation are poor nitrogen (N) management and rainfed agro-ecologies (Omran *et al.* 2018). Since, the development of irrigation infrastructure needs huge investments in the nation, however, the precise N management strategy may still abridge the production gaps upto some extend and may result in large economic benefits to Afghan farmers. The rate of uptake and partition of N is largely determined by supply and demand during various stages of plant growth. Soil N supply, for example, must be high at tillering, stem elongation, booting, heading and grain filling requiring a greater amount for the development and growth of its reproductive organs and for an enhanced and high accumulation of proteins in the kernel (Choudhary *et al.* 2010). Moreover, nitrogen is considered as one of the most important factors affecting crop morphology. Thus, keeping in view above facts an investigation was undertaken by in winter barley.

The field experimentation was conducted during winter season of 2014–2015 at Research Farm of Afghanistan National Agricultural Science and Technology University (ANASTU), Kandahar, Afghanistan ($31^0 30'$ N Longitude; $65^0 50'$ E Latitude; 1010 m Altitude) to study the effect of different levels of nitrogen (N) nutrition *viz*. 0, 40, 60, 80, 100, 120 and 140 kg N ha^{-1} (N_0, N_{40}, N_{60}, N_{80}, N_{100}, N_{120} & N_{140}) on productivity, profitability and resource-use efficiency (RUE) in winter barley (*Hordeum vulgare* L.) under semi–arid conditions of Afghanistan in a randomized block design (RBD) 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 P_2O_5 and high in K_2O content. The 100% recommended dose of phosphorus (P_2O_5) and potassium (K_2O) at the rate of 60 and 30 kg ha^{-1} respectively, was added to all the above treatments (N_0 to N_{140}). Half amount of N with full amount of phosphorus and potassium were applied as basal at the time of sowing through urea, potassium sulphate and diammonium phosphate (DAP), respectively. Remaining half N dose was top dressed in two equal split doses after first irrigation and second irrigation. In control plots, the phosphorus was applied through triple super phosphate instead of DAP as it contains N. Geographically, Kandahar is situated in southern part of Afghanistan having semi-arid hot climate with annual rainfall of about 190.6 mm received mostly during January, February and March months. Its climate is semi–arid to subtropical with extreme cold and hot situations.

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The weather data were recorded during crop season from *Meteorological Observatory* located at Research Farm of ANASTU, Kandahar. During the crop growth season, the mean weekly maximum temperature varied from 12^0C to 31.3^0C with April as the hottest month while mean weekly minimum temperature varied from 0^0C to 14^0C with January as the coldest month. The average weekly relative humidity during crop growth period varied from 39.1 to 60.8% while average seasonal rainfall was 49.8 mm.

Barley variety Wotan seed was sown manually @ 100 kg ha^{-1} in rows at 20 cm distance at 3-4 cm depth on 28th December, 2014 and harvested on 30th April, 2015. Gross plot size was 3 m × 4 m while net plot size was 3.6 m × 2.4 m. Different intercultural operations were done as and when necessary following standard package of practices. To reduce crop-weed competition, the 2, 4- D and Isoproturon were mixed and sprayed as post-emergence herbicides at rate of 1.0 kg a.i. + 0.75 kg a.i. per ha, respectively at 35 DAS using 750 liter water/ha. First irrigation was given at the CRI stage, and the five additional irrigations were given to the crop with 15 days interval. The number of effective tillers or spike bearing shoots were counted at crop maturity in three demarcated one meter row length observational units already used for determination of number of tillers per m^2 and then mean value was converted as number of effective tillers or spikes per m^2. The number of grains per spike, grains weight per spike, 1000-grains weight, grain and straw yield and harvest index were computed using standard procedures suggested by Rana *et al*. (2014). The grain yield was recorded at 12% moisture content. Finally, the production efficiency (PE) (kg ha^{-1} day^{-1}) and monetary efficiency (ME) (AFN ha^{-1} day^{-1}) were computed using standard procedure (Kumar *et al*. 2015). The gross returns were calculated using prevalent market price of the barley grains (AFN 20000 t^{-1}) and straw (AFN 7700 t^{-1}) in the market using standard procedure. The net returns and net benefit: cost ratio (B: C ratio) were then calculated using respective cost of cultivation. The *seasonal water use* was computed from profile water contribution (CS), effective rainfall (ER) and irrigation water applied (I) using procedure suggested by Choudhary *et al*. (2006a). The profile water contribution (CS) was not taken into consideration in current study. Thus, the effective rainfall (49.8 mm) and irrigational water use (360 mm) was considered as the seasonal total water use (409.8 mm) in the present study by taking into account the respective crop growth period by following the procedure as suggested by Choudhary *et al.* (2006a). Water use efficiency (WUE) and partial factor productivity (PFP) of applied-N through inorganic fertilizers were computed using procedure suggested by Rana *et al.* (2014). The statistical analysis of data was done as per standard method suggested by Rana *et al.* (2014). The significance of treatment effects were tested with the help of F-test and critical difference (CD) values at P=0.05 were used to determine the significant differences between treatment means.

There were significant differences among different N levels for number of effective tillers m^{-2} with significantly maximum number (285) under treatment 120 kg N ha^{-1} which though remained statistically at par with treatments *viz*. 60, 80, 100 and 140 kg N ha^{-1} (Table 1). The results showed that number of grains per spike was significantly highest under treatment 120 kg N ha^{-1} which remained at par with the treatments, viz. 100 and 140 kg N ha^{-1} (Table 1). It was observed that weight of grains per spike was significantly higher (2.07 g) with the application of 120 kg N ha^{-1} and lowest grain weight (1.49) was recorded in control treatment. The 1000–grain weight (g) of barley was significantly influenced by different N levels with highest values (34.3 g) in treatment 120 kg N ha^{-1} followed by 140, 100, 80, 60, 40 kg N ha^{-1} and control, respectively. Better growth and yield parameters, viz. weight of grains spike^{-1}, number of grains spike and spike weight obtained with the respective treatment could lead to higher thousand grains weight (Suri *et al*. 2011). The increased spike weight may be attributed to steady supply of nutrients which enhanced the dry matter production due to more availability of photosynthesis (Choudhary and Suri 2018). As a result of application of higher dose of nitrogen, bolder seeds were formed which in turn increased the test weight of barley (Sabir *et al*. 2002). Whereas, control plots resulted in significantly lower thousand grains weight which may be ascribed to poor vegetative growth, lower number of spikes with reduced number of grains per spike leading to lower thousand grains weight (Choudhary *et al*. 2006b).

Table 1 Effect of varying N levels on yield attributes and yield in winter barley

Treatment	Effective tillers per m^2	Number of grains per spike	Grain weight per spike (g)	1000–grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
Control	151.0	31.7	1.49	26.3	1.89	3.43	34.98
40 kg N ha^{-1}	250.3	32.2	1.64	32.0	2.62	3.64	41.88
60 kg N ha^{-1}	267.0	33.6	1.69	32.5	2.83	3.87	42.28
80 kg N ha^{-1}	271.6	34.3	1.81	32.9	3.17	4.32	43.29
100 kg N ha^{-1}	274.3	38.6	1.92	33.1	3.31	4.16	43.41
120 kg N ha^{-1}	285.0	38.7	2.07	34.3	3.50	4.56	43.43
140 kg N ha^{-1}	282.0	38.1	1.82	33.8	3.35	4.81	41.22
SEm (±)	9.7	1.0	0.08	1.4	0.12	0.17	1.36
CD (P=0.05)	29.9	3.2	0.24	4.4	0.38	0.51	4.20

Table 2 Effect of varying N levels on resource-use efficiency in winter barley

Treatment	Crop profitability				Resource-use efficiency			
	Cost of cultivation (AFN ha^{-1})	Gross returns (AFN ha^{-1})	Net returns (AFN ha^{-1})	B: C ratio	Monetary efficiency (AFN ha^{-1} day^{-1})	Production efficiency (kg ha^{-1} day^{-1})	Water use efficiency (kg ha– mm^{-1})	Partial factor productivity of applied-N (kg ha^{-1} kg^{-1} of applied–N)
Control	23742	64210	40468	1.70	339.5	15.9	4.61	-
40 kg N ha^{-1}	26026	80457	54431	2.09	452.3	21.8	6.40	65.5
60 kg N ha^{-1}	26982	86487	59505	2.21	487.7	23.2	6.92	47.2
80 kg N ha^{-1}	27939	95487	67548	2.42	549.6	25.8	7.74	39.6
100 kg N ha^{-1}	28896	99504	70608	2.44	567.2	26.6	8.08	33.1
120 kg N ha^{-1}	29852	105076	75224	2.52	599.3	27.9	8.54	29.2
140 kg N ha^{-1}	30809	103997	73188	2.38	570.9	26.2	8.17	23.9
SEm (±)	-	3211	3211	0.13	24.8	1.1	0.30	2.1
CD (P=0.05)	-	9895	9895	0.41	76.3	3.4	0.93	6.3

*Note: 1 AFN (Afghani, the Afghanistan currency) = 0.94 INR (Indian Rupee); *One US Dollar = 72.82 AFN.*

Grain yield of barley was significantly highest (3.5 t ha^{-1}) in treatment 120 kg N ha^{-1} followed by 140, 100, 80, 60, 40 kg N ha^{-1} and control, respectively, though 120 kg N ha^{-1} was at par with 80, 100 and 140 kg N ha^{-1} (Table 1). It was observed that significantly highest straw yield (4.81 t ha^{-1}) was exhibited in treatment 140 kg N ha^{-1} followed by 120, 100, 80, 60, 40 kg N ha^{-1} and control, respectively; though application of 140 kg N ha^{-1} remained at par with the treatments, viz. 80, 100 and 120 kg N ha^{-1}. This significant increase in grain yield may be due to the higher yield attributing parameters like productive tillers, number of grains per spike and 1000-grains weight with higher N fertilization (Choudhary and Suri 2014). As a result, there was increase in both grain and straw yield. Also, higher leaf area was responsible for higher photosynthetic activity which promoted vegetative growth and dry matter production resulting in higher grain and straw yield of barley (Choudhary and Suri 2014). The dry matter production is an important determinant of the grain yield. Total dry matter production may reflect on the economic yield in view of the fact that, vegetative part of the plant serves as the source, whereas the grains as sink (Suri *et al.* 2011). During vegetative growth stage the dry matter production, and its distribution to yield attributes during reproductive stage through a process of translocation from source to sink finally determines the yield and harvest index at certain optimum nutrition level (Choudhary *et al.* 2007, Dass *et al.* 2014). That's why the application of 120 kg N ha^{-1} exhibited significantly highest harvest index and further increase to 140 kg N ha^{-1} led to decline in HI (Table 1). Such findings were also reported by Ram and Buttar (2012).

Significantly highest production-efficiency (PE) (27.9 kg ha^{-1}day–^{1}), monetary-efficiency (ME) and water-use efficiency (WUE) in barley were recorded in treatment 120 kg N ha^{-1} followed by 100, 140, 80, 60, 40 kg N ha^{-1} and control, respectively; however, the treatment 120 kg N ha^{-1} remained at par with the treatments, viz. 80, 100 and 140 kg N ha^{-1} with respect to above resource-use efficiency (RUE) indices (Table 2). The higher PE, ME and WUE at higher N doses were mainly due to higher grain yield of barley. The higher N application attributed to better N acquisition by the plants and hence growth and yield which led to better RUE indices in present study (Choudhary *et al.* 2006a, 2006b; Ehsan *et al.* 2017, Noorzai and Choudhary 2017). On the other hand, the partial factor productivity of applied–N (PFPn) was significantly highest under treatment 40 kg N ha^{-1} (65.8 kg ha^{-1} kg^{-1} of applied–N) while further increase in N levels upto 140 kg N ha^{-1} led to consistent and significant decline in the PFPn (Table 2) owing to decreasing rate of grain productivity in barley over the comparative incremental increase in N rates (Kumar *et al.* 2015, Choudhary and Suri 2018).

Economics of production is very important aspect to assess the efficiency of different production systems based on physical feasibility and its commercial viability. In current study, the cost of cultivation (COC) consistently increased with increase in N levels with highest COC under 140 kg N ha^{-1} (Table 2). It is apparent that high level of COC is always associated with high rates of farm inputs (Choudhary *et al.* 2007). Effect of nitrogen levels was significant on gross and net returns and benefit: cost ratio (B: C ratio)

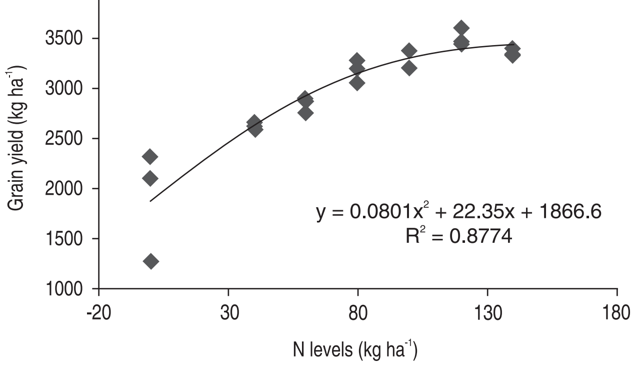

Fig 1 Estimation of economic optimum N dose for winter barley.

of barley with highest gross returns in treatment 120 kg N ha^{-1} followed by 140 kg N ha^{-1}. High gross and net returns and B: C ratio in barley might be due to higher grain and straw yield of barley treatment 120 kg N ha^{-1} (Choudhary *et al.* 2007, 2010; Ram and Buttar 2012). The regression equation was fitted for the yield variation in barley in relation to different N levels (Fig. 1). The regression equation was quadratic in nature ($Y = 0.0801\ x^2 + 22.35\ x + 1866.6$; $R_2 = 08774$) as per Fig. 1. Thus, the economic optimum N dose of seven N levels (0, 40, 60, 80, 100,120 and 140 kg ha^{-1}) was calculated through the formula of economic optimum dose = [(q/p-b)/2c] and the results showed that optimum N dose for barley was estimated as 132.6 kg ha^{-1} (Fig. 1).

Conclusion

Overall, it can be summarized that the application of N @ 120 kg ha^{-1} could be used as blanked recommendation for obtaining higher productivity, profitability as well as higher resource-use efficiency in winter barley. But as a site-specific recommendation, the economic optimum N dose for barley variety Wotan was estimated as 132.6 kg N ha^{-1} which may have great promises in enhancing the productivity and profitability in winter barley under semi-arid conditions of Kandahar, Afghanistan.

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