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Foliar nitrogen application for enhancing growth, productivity and nitrogen use efficiency in sunflower (*Helianthus annuus*)

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Sunflower (*Helianthus annuus* L.) is the world's fourth largest oilseed crop after soybean, rapeseed and groundnut. Its seed has high oil content (45-50%) and high amount of poly-unsaturated fatty acid, i.e. linolieic acid (70%). The seeds are easily digestible and are popular baby foods. Sunflower is also used in making salad dressings, for cooking and in the manufacturing of margarine and shortening (Kunduraci *et al*. 2010). Annually 12000 ha area is grown under sunflower in Afghanistan, yet the domestically grown oil crops contribute even <10% of the cooking oil consumed. The huge demand of edible oil (3.45 lakh tons) in Afghanistan is met out by imports (Anonymous 2018). The prospects of higher sunflower production in Afghanistan are very high, if various production limiting factors, viz. poor soil fertility and faulty nutrient management practices can be addressed. Among nutrient management, nitrogen (N) is the most important element for sunflower production, where 4-R stewardship, i.e. use of right rate, amount, time and form are very crucial. N fertilization and foliar spray at different stage growth can overcome soil fertility limitation and improves sunflower yield as well as nutrient use efficiency (Gafori 2014).

The experiment was laid down at the research farm of ANASTU, Kandahar, Afghanistan during summer season of 2017. The soil was sandy clay loam (*p*H=8.1), low in oxidizable N (175 kg/ha), medium in available P (19 kg/ha) and high in available K (290 kg/ha). The experiment was laid out in randomized block design (RBD) with treatments, viz. T_1: control, T_2: 25 kg N/ha as basal, T_3: 50 kg N/ha as basal, T_4: 25 N kg/ha N as basal + 12.5 kg 20 and 40 DAS, T_5: 25 kg N/ha N as basal+1.5% urea foliar spray at 20 DAS, T_6: 25 kg N/ha N as basal+1.5% urea foliar spray at 40 DAS, T_7: 25 kg N/ha N as basal+1.5% urea foliar spray at 20 and40 DAS, T_8: 25 kg N/ha N as basal+12.5 kg N at 20 DAS+1.5% foliar spray at 40 DAS, T_9: 25 kg N/ha N as basal+1.5% urea foliar spray at 20 DAS+12.5 kg N at 40 DAS, T_{10}: 50 kg N/ha N as basal+1.5% urea foliar spray at 20 DAS, T_{11}: 50 kg N/ha N as basal+1.5% urea foliar spray at 40 DAS and T_{12}: 50 kg N/ha N as basal + 1.5% urea foliar spray at 20 and 40 DAS and replicated thrice. Sunflower Canadian cultivar was sown on 10 June with 60 cm × 30 cm spacing. The plant height and dry matter accumulation was measured from three randomly selected plants. The area of single leaf was determined by multiplying leaf length and maximum breadth by correction factors 0.75 (i.e. 0.75 × leaf length × maximum breadth) at 30, 60 and 75 DAS. The day on which 50% ray florets opened in a given treatment was recorded. The whole sampled plants were air-dried and then oven-dried at 70˚C+5˚C for 48 h to ger dry weight. The data were subjected to the analysis of variance (ANOVA) by using MSTATC software (CIMMYT, Mexico City, Mexico), and the significance was tested by the variance ratio (i.e. f-value) at 5% level (Gomez and Gomez 1984).

Leaf area, dry matter accumulation, root length and days to 50% flowering: The various growth parameters in sunflower were significantly influenced by foliar application of N (Table 1). The results showed that 50 kg N/has basal + 1.5% urea foliar spray at 20 and 40 DAS recorded highest LAI (2.18 and 2.9 at 60 and 75 DAS, respectively) and 50 kg N/ha application as basal + 1.5% urea foliar spray at 20 DAS remained at par with it (2.06 and 2.75 at 60 and 75 DAS, respectively). A 29.8 and 22.6% increase in the LAI of sunflower was recorded with 50 kg N as basal+ foliar application at 60 and 75 DAS, respectively. The highest dry matter accumulation at 60 DAS (461.4 g/m^2) and at harvest (579.6 g/m^2) was recorded when 50 kg N/ha as basal + 1.5% urea foliar spray at 20 and 40 DAS was applied. The 50 kg N/ha as basal with foliar application at 20 and 40 DAS resulted in an increase of 31.4 and 30% dry matter accumulation at 60 DAS and at harvest, respectively over 50 kg N/ha as basal. The days to 50% flowering varied from 54-58 days among various treatments. It delayed significantly where 50 kg N/has basal + 1.5% urea foliar

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Table 1 Effect of foliar application of nitrogen on leaf area index and dry matter accumulation (g/m^2) of sunflower

Treatment	Number of leaves			Leaf area index			Dry matter (g/m^2)		
	30 DAS	60 DAS	75 DAS	30 DAS	60 DAS	75 DAS	30 DAS	60 DAS	At harvest
T_1	6.1	14.3	21.3	0.08	0.65	1.35	6.78	81.1	240.6
T_2	6.4	16.2	23.4	0.11	1.13	1.81	7.8	163.8	306
T_3	6.4	19.6	25.8	0.11	1.64	2.3	9.6	346.8	445.8
T_4	6.8	20.3	27.3	0.12	1.74	2.5	10.8	378	479.4
T_5	6.4	19.3	25	0.11	1.61	2.4	9.0	345	421.8
T_6	6.4	19.2	25.1	0.11	1.6	2.23	9.0	343.8	420.6
T_7	6.8	20.7	27.2	0.13	1.8	2.5	10.8	379.2	480.6
T_8	6.4	19.2	26	0.11	1.61	2.33	9.6	370.2	453
T_9	6.5	20.1	26	0.11	1.71	2.34	9.6	370.8	452.4
T_{10}	7.1	23.3	28.5	0.15	2.13	2.82	13.2	456	571.8
T_{11}	6.9	23	28.2	0.15	2.06	2.75	13.2	451.8	571.8
T_{12}	7.1	23.4	28.6	0.15	2.18	2.9	13.8	461.4	579.6
SEm ±	0.22	1.03	0.6	0.047	0.087	0.056	1.56	25.6	29.8
CD (P≤ 0.05)	NS	3.03	1.8	NS	0.26	0.16	NS	75.6	88.1

spray at 20 and 40 DAS was applied, followed by 50 kg N/ha applied as basal + 1.5% urea foliar spray at 20 and 40 DAS. The longest tap root (25.7 cm) was recorded where 50 kg N/ha was applied as basal+1.5% urea foliar spray at 20 and 40 DAS, however it was found on par (25.3 cm) with 50 kg N/has basal + 1.5% urea foliar spray at 20 DAS. The higher LAI, dry matter accumulation and yield attributes of sunflower in response to foliar application as per the crop demand increases the seed yield (El-kady *et al*. 2007, Bakery *et al*. 2009).

Yield: The highest seed yield (2461 kg/ha) of sunflower were recorded with the application of 50 kg N as basal and foliar application 1.5% N at 20 and 40 DAS, followed by 50 kg N/ha as basal + 1.5% of foliar application of urea at 20 DAS (Table 2). A 39.4% increase in the seed yield was obtained over 50 kg N/ha as basal alone (Nelson *et al*. 2005) have also reported yield, seed weight and seed N concentration increase with the application of liquid fertilizers in sunflower. The maximum nutrient requirement for sunflower remains between 25-30 DAS, thus optimizing the N fertilizer application as per the crop demand improved the seed yield. A foliar spray or topdressing at 40-45 DAS is useful as it coincides with the flower initiation stage. At 20 and 40 DAS, the internode elongation and the button stage commences, respectively. At 20 DAS, the sunflower arrives at the phenological stage S-1, i.e. leaf development, where 9 or more leaves remain unfolded. Any N application till 40 DAS is more useful in sunflower, probably because of N accumulation stage for bud formation (Shekhawat *et al.* 2008). The relative advantage of N foliar spray at 20 DAS over 40 DAS was recorded possibly due to more active and N receptive sites. Also, the N application as 50 kg N/ha basal followed by 1.5% N foliar spray at 20 DAS suffice the crop requirement.

A linear response was obtained in seed yield with various N application strategies in sunflower (Fig 1). The intercept in the figure indicates the soil native nutrient supplying capacity. A 937.3 kg/ha seed yield of sunflower

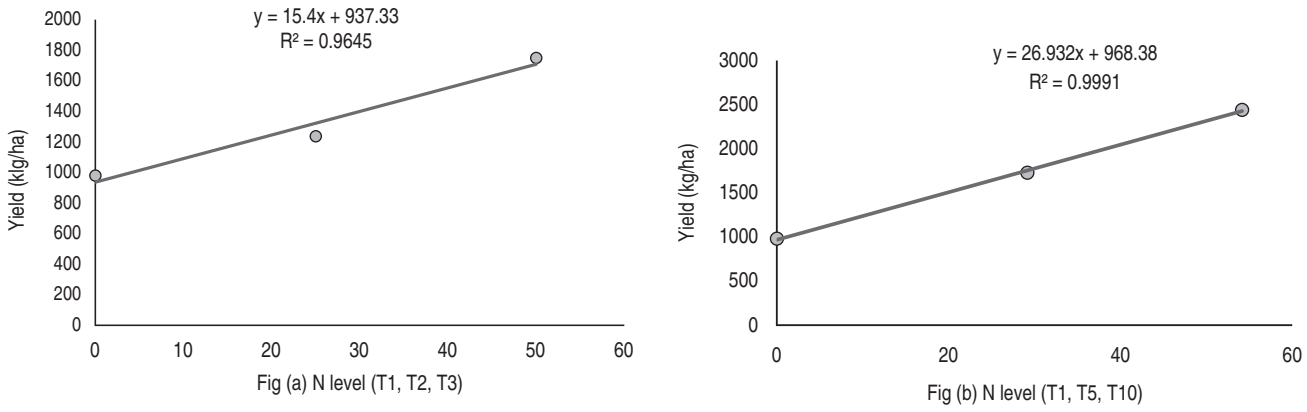

Fig 1 The yield response equation as influenced by various N application options in sunflower.

Table 2 Seed yield and nutrient use efficiency in sunflower as influenced by N foliar application.

Treatment	Seed yield (kg/ha)	NUE_A (kg/kg of applied N)	PFP_N	PFP_P
T_1 (Control)	980	-	-	24.5
T_2 (25 kg N basal)	1,237	10.3	49.5	30.9
T_3 (50 kg N basal)	1,750	13.4	33.0	41.3
T_4 (Split application of N)	1,950	12.4	32.0	40.0
T_5 (25 kg N basal + foliar at 20 DAS)	1,728	25.0	58.6	42.7
T_6 (25 kg N basal + foliar at 40 DAS)	1,703	17.9	51.6	37.6
T_7 (25 kg N basal + foliar at both)	1,954	26.3	55.7	46.4
T_8 (25 kg N basal + split + foliar)	1,763	18.8	42.3	44.1
T_9 (25 kg N basal + foliar + split)	1,785	17.7	41.2	42.9
T_{10} (50 kg N basal + foliar at 20 DAS)	2,440	27.0	45.1	61.0
T_{11} (50 kg N basal + foliar at 40 DAS)	2,375	23.9	42.0	56.9
T_{12} (50 kg N basal + foliar at both 20 and 40 DAS)	2,462	25.4	42.2	61.6
SEm ±/SD	141.1	6.04	8.45	9.84
CD ($P \leq 0.05$)	416.6	-	-	-

NUE_A, Agronomic nitrogen use efficiency; PFP_N, partial factor productivity of N; PFP_p, partial factor productivity of P.

obtained under the treatment combinations of control, 25 kg N/ha and 50 kg N/ha as basal indicates a low response of basal N application. However, the yield obtained with the treatment combinations of control, 25 kg N/ha and 50 kg N/ha as basal followed by one foliar spray at 20 DAS was 968.3 kg. A yield difference of 31 kg was obtained under basal application, either 25 or 50 kg N/ha followed by one foliar spray at 20 DAS over the sole basal treatments.

Nutrient use efficiency: The highest agronomic nitrogen use efficiency (27 kg/kg of N applied) was obtained where 50 kg N/ha as basal + 1.5% N foliar spray at 20 DAS (Table 2) was applied. However the NUE under T_5, T_7, T_{11} and T_{12} were comparable. The treatments receiving 25 or 50 kg N/ha along with 1.5% N foliar spray either at 20 or 40 DAS improved the partial factor productivity of N (PFP_N), the highest was obtained where 25 kg N was applied along with one foliar spray at 20 DAS. However, the highest PFP_N was obtained where 25 kg N/ha was applied followed by 2 sprays at 20 and 40 DAS. The application of 50 kg along with foliar sprays, either one or two sprays also improved PFP_N and PFP_P, followed by T_{12}, followed by 50 kg N/ha and one foliar sprays either at 20 and 40 DAS. The higher nutrient use efficiency due to foliar application is due to higher N translocation of optimum N dose (Qahar *et al*. 2010) and better utilization of applied N (Montemurro and Giogio 2005). The PFP_N declined at higher N application rates due to the diminishing rate of yield enhancement in response to N application. The synergistic relationship between N and P application improved the PFP_P at high N application.

SUMMARY

Sunflower (*Helianthus annuus* L.) is a promising oilseed crop of Afghanistan mainly grown under resource constraint situations. The poor nitrogen status of the soil makes nitrogen deficient for plants at the sensitive stages resulting in severe growth and yield decline. The present study compared the effect of nitrogen application as basal *vis-à-vis* in combination with foliar application at different crop growth stages on growth, productivity and nutrient use efficiency in sunflower. The application of 50 kg N/ha as basal along with two 1.5% foliar spray of N at 20 and 40 DAS resulted in higher growth parameters, yield and nutrient use efficiency in sunflower. Nitrogen application applied as basal met out the initial nitrogen demand and when supplemented with foliar application resulted in higher assimilating surface area, dry matter accumulation and higher yield attributes and yield in sunflower.

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