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# Response of morphological and biological characteristics of two sunflowers (*Helianthus annuus* L.) hybrid against the application of nitrogen and phosphorous under the rainfed conditions of Rawalakot Azad Jammu and Kashmir

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## Abstract

The sunflower (*Helianthus annuus* L.) is an important oil seed crop of subtropical and temperate zones. Among the all other nutrients required by sunflower, nitrogen and phosphorus are the more essential. In this study effectiveness of these nutrients on the yield, quality and nutrient uptake of two sunflower hybrids (Parsaun-3 and Super-2216) was explored. Results demonstrated that the application of nitrogen and phosphorus or their combinations significantly increased growth, yield and NP-uptake as compared to the control. Among different N levels, the maximum plant height, head diameter and stem girth (186.1, 19.34 and 6.69 cm, respectively) was recorded for the treatment receiving N at the rate of N180 kg ha-1. Similarly, by the application of phosphorus @130 kg $P_2O_5$ $ha^{-1}$ highest plant height, head diameter and stem girth of 180.2, 18.90 and 6.55 cm, were recorded respectively. For combined NP treatments, the plant height, head diameter and stem girth did not show significant improvement as compared to the control ($N_oP_o$). Application of N, P and their combined use significantly increased seed weight between 98.7-117.3, 103.2-106.1 and 106.9-127.8 g, respectively and maximum values were recorded for NP combination of 180+130 kg $ha^{-1}$. The number of achene's $head^{-1}$ and thousand grain weight were also significantly improved by applying N and P individually. However, combine effect was non-significant. The achene, biological and dry matter yields were significantly improved in all manners. Combined use of N+P @180+130 kg $ha^{-1}$ increased achene, biological and dry matter yields by 36.99, 31.81 and 29.90 percent, respectively over the $N_oP_o$ treatment combination. It is concluded that these nutrient in different combination would be helpful for improving yields of sunflower in nutrient exhaustive/ eroded area of Rawalakot, Azad Jammu and Kashmir.

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## Introduction

Sunflower (*Helianthus annuus* L.) is an important oil seed crop of subtropical and temperate zones because of its possible significant contribution in the edible oil production and wide adaptability (Demir, 2012). Among the cultivated oilseed crops after soybean, palm oil and canola crops sunflower (*Helianthus annus* L.) comes at fourth position (Fernandez *et al.*, 2004). It has well-developed branched root system, helps to extract water from deeper soil layers and results in better adaptability under prevailing drought conditions (Ahmed, 2001). Without replacing any other major crop sunflower can be grown well in an existing cropping system (Ahmad *et al.*, 2009). It has 40-50% oil contents and 20-30% seed protein contents. Sunflower oil cake contains 40-44% of protein and is used as livestock feed (Hussain *et al.*, 2000; Balasubramaniyan and Palaniappan, 2001). Being exhaustive crop, sunflower react very well to the applied nutrients. Among the all other nutrients required by sunflower, nitrogen and phosphorus are the essential development constraining supplements under general situations (Baldev *et al.*, 1999). Dark green color of plants is due to the presence of nitrogen, as it is an integral component of chlorophyll. Yield quality and quantity is also improved by nitrogen (Khan *et al.*, 2008). The major source of nitrogen in today's faming system is compound manures. By the addition of these manures agriculture production may expand up to 50 percent. (Fixon and West, 2002). The sustainability of intensive agricultural biological communities' extent relies upon the use of nitrogen fertilizers. While the availability of nitrogen is deficient from organic and other natural sources. Similarly Phosphorous is the second most frequently growth limiting macronutrient. A sufficient supply of phosphorous is essential for ideal growth and reproduction and its deficiency is associated with stunted plant and root growth, purplish discoloration of leaves and reduced flowering. Phosphorus deficiency also affect transformation of sugars, movement of nutrients, vitality exchange and photosynthesis (Alberta and Saskatchewan, 1999). Likewise, it affects flowering, fruit and seed formation (Aduayi*et al.,* 2002). Shaheen *et al.,* 2007 documented that a sufficient supply of phosphorous is essential to contribute the resistance to root disease. The estimates have shown that only 1.0-2.5% of the total soil phosphorus (0.04-0.10%) becomes available to the plants in a growing season (Lin, 1990). This low accessibility of phosphorus nutrition in soils terminates plant and root development (Borch*et al.,* 1999; Kanako *et al.,* 2004) especially when plants are supplied with sufficient nitrogen (Woolmanse and Duncan, 1980) and demands for additional P supply from other sources. Phosphorous that applied to the soil is quickly immobilized due to phosphate fixation by iron, calcium, magnesium and aluminium (Dainel *et al.,* 1999). Due to utmost importance of these two nutrients, the present study was design to explore the effectiveness of nitrogen and phosphorus application on the yield, quality and nutrient uptake of sunflower hybrids under rainfed conditions.

## Materials and methods

*Pre-sowing soil analysis*

Research was conducted in the field area of university of Poonch Rawalakot which is about 5500ft above from the sea level. Before sowing the seeds of two hybrid cultivar of sunflower in the field, soil analysis was done. For soil analysis, soil samples were taken from the depth of 0 to 15 cm followed by air dry, grind and sieved through a 2mm sieve to evacuate coarse particles of rocks and other deposit product. Soil samples were analysed for the critical soil properties by utilizing standard systematic strategies (Table 1).

*Morphological and yield parameters analysis of sunflower*

Five sunflower plants of various heights were arbitrarily chosen from focal columns of standing crop in every plot from each treatment for measuring morphological qualities including height of plant, Disc diameter and stem breath. Shoot length was measure by measuring tape at vegetative stage. Take the measurements from each treatment and then found the average value.Similarly head diameter was measure at the developed stage and found their average. Formeasuring number of achene per head grains from each of the five removed heads were separated manually and their number was accounted accordingly. After that seed weight per head was measured by threshing the seed from flower followed by weighing through digital balance. Similarly for thousand grain weight, weigh the seeds of eachplots (1000 seeds) and take the mean value.

*Yield parameters*

Yield parameter include achene yield, biological yield, dry matter yield and harvest index. Subsequent to shelling, achenes from each plot were taken, the aggregate weight of this yield from each treatment was noted with a balance and achene yield were figured on hectare premise. For biological yield total crop was dried for ten days in sunlight. Followed sun drying biomass yield of each plot was measure by balance. Dry matter yield and harvest index were measured by following equations.

$$\text{Dry matter yield} = \text{Biological yield} - \text{Grain yield}$$

$$\text{Harvest Index (HI)} = \frac{\text{Grain yield (kgha}^{-1}\text{)}}{\text{Biological yield (kgha}^{-1}\text{)}} \times 100$$

*Experimental description and statistical analysis*

There were three nitrogen ($N_0$ = 0 kg nitrogen ha$^{-1}$, $N_1$ = 130 kg nitrogen ha$^{-1}$, $N_2$ = 180 kg nitrogen ha$^{-1}$) and three phosphorous ($P_0$= 0 kg phosphorous ha$^{-1}$, $P_1$= 90 kg phosphorous ha$^{-1}$ and $P_2$= 130 kg phosphorous ha$^{-1}$) levels and two sunflower hybrids ($H_1$= Parsaun-3 and $H_2$= Super-2216), comprising of a total of eighteen possible treatment combinations ($N_0P_0H_1$, $N_0P_0H_2$, $N_0P_1H_1$, $N_0P_1H_2$, $N_0P_2H_1$, $N_0P_2H_2$, $N_1P_0H_1$, $N_1P_0H_2$, $N_1P_1H_1$, $N_1P_1H_2$, $N_1P_2H_1$, $N_1P_2H_2$, $N_2P_0H_1$, $N_2P_0H_2$, $N_2P_1H_1$, $N_2P_1H_2$, $N_2P_2H_1$, $N_2P_2H_2$ in each replication. The seed of two sunflower hybrids namely, Parsaun-3 and Super 2216 were used in experiment. The treatments were arranged under three factors in randomized complete block design (RCBD) with three replications. Experimental data was analysed in SPSS 16 software. The individual plotted area was 4m$^2$ (2m× 2m). The entire amounts of nitrogen and phosphorous were applied from urea and single super phosphate (SSP) at planting to the respective plots while the potassium was applied 60 kg ha$^{-1}$ basal dose in the form of Sulphate of Potash (SOP) to all experimental units including control.

The plants were thinned after germination completion, by keeping up 25 cm interval. Add up to five lines for each plot were built up by keeping up 75 cm remove between them. The standard nearby cultural practices like thinning, weeding, hoeing and so forth was done according to prerequisite all through the development time frame.

## Results and discussion

*Morphological characteristics*

Plant height: Significant (*p*≤*0.05*) differences was observed in sunflower plant height as a result of nitrogen application while phosphorus levels and hybrid effects were non-significant. Similarly the effect of interaction among the variables (N×P, N×H and P×H) were also non-significant. (Tahir, 1996 and Subhash *et al.*, 2013). Application of nitrogen @ $N_{130}$ kg and $N_{180}$ kg ha$^{-1}$ increased plant height range from 180.43 cm to 186.14 cm compared to 166.52 cm in the control treatment ($N_0$) (Table 2).

**Table 1.** Pre-sowing soil analysis.

| Parameters | Values |
|---|---|
| Total Nitrogen (%) | 0.38 |
| Available Phosphorous (mg kg ha-1) | 4.97 |
| Organic matter (%) | 0.76 |
| Soil Ec (dS m-1) | 0.41 |
| Soil pH | 7.25 |
| Sand (%) | 28.40 |
| Silt (%) | 52.35 |
| Clay (%) | 19.25 |
| Soil textural class | Silt loam |

Plant height in treatments $N_{130}$ and $N_{180}$ was 8.35 and 11.78 percent higher over the control treatment ($N_0$). (Ali *et al.*, 2004,Rani and Reddy, 1993; Martinez *et al.*, 2010).Application of phosphorus didn't show significant effect on plant height and height range was recorded range from 173.41 to 181.77 cm. Height in sunflower hybrid super-2216 was recorded 180.19 cm compared to 175.20 cm recorded for the sunflower hybrid Parsun, shows the relative increase of 2.84 percent. Among the N×P, N×H and P×H interactions, the plant height varied between 177.07 to 192.35 cm, 177.03 to 190.23 cm, and 174.68 to 183.87 cm, respectively.

*Head diameter*

The diameter of sunflower head was significantly ($p\leq0.05$) influenced by the application of nitrogen (Wajid *et al.*, 2012) and phosphorus while hybrid impact was non-significant. The head diameter of sunflower was significantly increased from 18.21 - 19.34 cm, following the application of nitrogen at 130 kg $ha^{-1}$ while control treatment shows smallest sunflower head diameter i.e. 16.10 cm. (Table 2). Among the P treatments, the application of 130 kg $P_2O_5$ $ha^{-1}$maximum head diameter of 19.02 cm was recorded and values were statistically at par with the treatment receiving the application of 90 kg $P_2O_5$ $ha^{-1}$ (18.12 cm) which means that further improvement in head diameter by the application of P @ 90 kg $ha^{-1}$was retarded.

There were non-significant differences were noticed between the head diameter of the two hybrids and values generally varied between 17.63 and 18.13 cm.In combined NP treatments, the interactive effects of N and P on head diameter were found non-significant and values ranged between 16.34 to 20.40 cm. Highest level of improvement was noticed in $N_{180}P_{130}$ and lowest in $N_0P_{90}$ combinations. For the N×H and P×H interactions, the head diameter varied between 18.13 to 19.61 and 17.96 to 19.28 cm, respectively.

*Stem girth*: Significant ($p\leq0.05$) differences in stem girth of sunflower were found for nitrogen and phosphorus levels while hybrid effect was non-significant. The interaction effects among the variables (N×P, N×H and P×H) were also non-significant. Application of N @ 130 kg $ha^{-1}$ and 180 kg $ha^{-1}$ was significantly increased stem girth of sunflower by 6.28 and 6.69 cm compared to the lowest of 5.45 cm in the control treatment (($N_0$)(Table 2). However, the difference between the latter two levels was found non-significant. The stem girth in N treatments ($N_{130}$ and $N_{180}$) was 15.2 and 22.7% higher over the control treatment ($N_0$). Among the P levels, the application of phosphorous @ 130 kg $P_2O_5$ $ha^{-1}$ increase the stem girth upto 6.55 cm and values were statistically at par with the treatment receiving the application of 90 kg $P_2O_5$ $ha^{-1}$.

In combined NP treatments, the interactive effects of N and P on stem girth were found non-significant and highest values (7.27 cm) was recorded in $N_{180}P_{130}$ treatment while lowest (5.54 to cm) was recorded in $N_0P_{90}$treatment. For the N×H and P×H interactions, the stem girth ranges varied between 6.34 to 6.52cm and 6.32 to 6.39 cm, respectively.

*Number of achene's per head*

Significant ($p\leq0.05$) differences in No. of achene˒s head$^{-1}$ of sunflower were recorded for nitrogen, phosphorus and hybrids. The interactive effects among the variables (N×P, N×H and P×H) were non-significant. Application of N @ 130 kg and 180 kg $ha^{-1}$ significantly increased number of achene˒s head$^{-1}$ of sunflower i.e. 830.2 and 1014.8 (Steer *et al.*, 1986 and Oyinlola *et al.*, 2010). Compared to the control ($N_0$) i.e. 625 (Table 3). Among the P levels, the amendment of 130 kg $P_2O_5$ $ha^{-1}$ recorded the maximum achene˒s number head$^{-1}$ of 898.50 that were statistically at par with the treatment receiving the application of 90 kg $P_2O_5$ $ha^{-1}$ (818.50), exhibiting that further application of P beyond 90 kg $ha^{-1}$ could not improve the number of achene˒s head$^{-1}$ of sunflower. There were significant differences between the achene˒s number head$^{-1}$ of the two hybrids. The achene˒s number head$^{-1}$ of hybrid super-2216 was 867.56 and in parsun-3 780.11 was recorded. In combined NP treatments, effects of N and P on number of achene˒s head$^{-1}$ were found non-significant and highest values (1102) was recorded in $N_{180}P_{130}$ and lowest (769.5) was observed in $N_0P_{90}$ combinations. For the N×H and P×H interactions, the number of achene s head$^{-1}$ varied between 787.3 to 1062 and 778.33 to 942, respectively.

**Table 2.** Comparative and interactive effects of nitrogen and phosphorus levels on morphological characteristics of two sunflower hybrids under rain-fed conditions of Rawalakot, Azad Jammu and Kashmir (AJK).

| Treatments | Plant height (cm) | Head diameter (cm) | Stem girth (cm) |
|---|---|---|---|
| A= Nitrogen (N) | | | |
| $N_0$ (0 kg N ha$^{-1}$) | 166.52 b | 16.09 c | 5.45 b |
| $N_1$ (130 kg N ha$^{-1}$) | 180.43 a | 18.21 b | 6.28 a |
| $N_2$ (180 kg N ha$^{-1}$) | 186.14 a | 19.34 a | 6.69 a |
| LSD value ($p \leq 0.05$) | 10.61 | 0.76 | 0.51 |
| B= Phosphorus (P) | | | |
| $P_0$ (0 kg $P_2O_5$ ha$^{-1}$) | 173.41 $^{NS}$ | 16.49 c | 5.61 b |
| $P_1$ (90 kg $P_2O_5$ ha$^{-1}$) | 177.91 $^{NS}$ | 18.12 b | 6.26 a |
| $P_2$ (130 kg $P_2O_5$ ha$^{-1}$) | 181.77 $^{NS}$ | 19.02 a | 6.55 a |
| LSD value ($p \leq 0.05$) | ---- | 0.76 | 0.51 |
| C= Hybrids (H) | | | |
| $H_1$ (Parsun-3) | 175.20 $^{NS}$ | 17.63 $^{NS}$ | 6.22 $^{NS}$ |
| $H_2$ (Super-2216) | 180.19 $^{NS}$ | 18.13 $^{NS}$ | 6.07 $^{NS}$ |
| LSD value ($p \leq 0.05$) | ---- | ---- | ---- |
| Interaction (N×P) | | | |
| $N_0P_0$ | 162.25 $^{NS}$ | 15.43 $^{NS}$ | 5.08 $^{NS}$ |
| $N_0P_1$ | 167.18 $^{NS}$ | 15.73 $^{NS}$ | 5.54 $^{NS}$ |
| $N_0P_2$ | 170.12 $^{NS}$ | 17.11 $^{NS}$ | 5.73 $^{NS}$ |
| $N_1P_0$ | 177.07 $^{NS}$ | 16.35 $^{NS}$ | 5.80 $^{NS}$ |
| $N_1P_1$ | 181.38 $^{NS}$ | 18.72 $^{NS}$ | 6.38 $^{NS}$ |
| $N_1P_2$ | 182.83 $^{NS}$ | 19.57 $^{NS}$ | 6.67 $^{NS}$ |
| $N_2P_0$ | 180.90 $^{NS}$ | 17.73 $^{NS}$ | 5.95 $^{NS}$ |
| $N_2P_1$ | 185.17 $^{NS}$ | 19.90 $^{NS}$ | 6.86 $^{NS}$ |
| $N_2P_2$ | 192.35 $^{NS}$ | 20.39 $^{NS}$ | 7.27 $^{NS}$ |
| LSD value ($p \leq 0.05$) | ---- | ---- | ---- |
| Interaction (N×H) | | | |
| $N_0H_1$ | 166.52 $^{NS}$ | 15.69 $^{NS}$ | 5.44 $^{NS}$ |
| $N_0H_2$ | 166.51 $^{NS}$ | 16.48 $^{NS}$ | 5.46 $^{NS}$ |
| $N_1H_1$ | 177.03 $^{NS}$ | 18.13 $^{NS}$ | 6.34 $^{NS}$ |
| $N_1H_2$ | 183.82 $^{NS}$ | 18.2 $^{NS}$ | 6.23 $^{NS}$ |
| $N_2H_1$ | 182.04 $^{NS}$ | 19.07 $^{NS}$ | 6.86 $^{NS}$ |
| $N_2H_2$ | 190.23 $^{NS}$ | 19.61 $^{NS}$ | 6.52 $^{NS}$ |
| LSD value ($p \leq 0.05$) | ---- | ---- | ---- |
| Interaction (P×H) | | | |
| $P_0H_1$ | 171.26 $^{NS}$ | 16.17 $^{NS}$ | 5.60 $^{NS}$ |
| $P_0H_2$ | 175.56 $^{NS}$ | 16.83 $^{NS}$ | 5.62 $^{NS}$ |
| $P_1H_1$ | 174.68 $^{NS}$ | 17.96 $^{NS}$ | 6.32 $^{NS}$ |
| $P_1H_2$ | 181.14 $^{NS}$ | 18.27 $^{NS}$ | 6.20 $^{NS}$ |
| $P_2H_1$ | 179.67 $^{NS}$ | 18.77 $^{NS}$ | 6.72 $^{NS}$ |
| $P_2H_2$ | 183.87 $^{NS}$ | 19.28 $^{NS}$ | 6.39 $^{NS}$ |
| LSD value ($p \leq 0.05$) | ---- | ---- | ---- |

*Seed weight per head*

Seed weight head$^{-1}$ of sunflower hybrids was significantly ($p \leq 0.05$) influenced by the application of different concentration of nitrogen (N), phosphorus (P) and their interactions (N×P interactions). However, variation among the hybrids was found non-significant. Similarly, the interactive effects of hybrids with N, P and N+P in the first (N×H and

N×P) and second (N×P×H) order interactions were also non-significant.The seed weight head$^{-1}$ varied between 75.76 g to117.29 g among the N levels (Table 3). The maximum values were recorded for the treatment receiving 180 kg N ha$^{-1}$($N_{180}$) while the lowest yield was recorded for the $N_o$ level. The relative increase in $N_{180}$ amended treatment was 54.8 percent. The differential response of applied N fertilizer, high rain fall in spring and higher yield acquisition from unfertilized plots (75.76 g) could be the main reasons of low seed weight head$^{-1}$ increment in N fertilized plots in our experiment. Regarding the impact of phosphorus levels on sunflower yield, the results revealed that the treatment @ 90 and 130 kg $P_2O_5$ ha$^{-1}$($P_{90}$ and $P_{130}$) significantly increased seed weight head$^{-1}$ (103.17 g and 106.14 g, respectively).(Mohamed *et al.*, 2003),compared to the control (82.42 g). In P fertilized treatments, the seed weight head$^{-1}$ was 25.17 to 28.78 percent higher than the control ($P_o$). In combined treatments, the plots amended with NP combination of 130+90 ($N_{130}$+$P_{90}$) and 130+130 kg ha$^{-1}$ ($N_{130}$+$P_{130}$)having 106.90 and 111.50 gram seed weight head$^{-1}$, and was significantly ($p\leq0.05$) higher than that obtained from plots receiving P applications at 90 and 130 kg $P_2O_5$ ha$^{-1}$ (75.50 and 78.10 gram). The yield recorded for $N_{130}$+$P_{90}$ and $N_{130}$+$P_{130}$ fertilized plots was 37.87 and 42.76 percent higher than $P_{90}$ and $P_{130}$ fertilized treatments. The highest seed weight head$^{-1}$ of 128.82 gram was observed for the treatment receiving the NP combination of 180+130 kg ha$^{-1}$ ($N_{180}P_{130}$) followed by 127.12($N_{180}P_{90}$). The co-application of 180 kg N ha$^{-1}$ with P in $N_{180}$ $P_{90}$ and $N_{180}$ $P_{130}$ combinations resulted in 64.94 and 68.37 percent higher seed weight head$^{-1}$ compared to the individual application of 90 and 130 kg $P_2O_5$ ha$^{-1}$.

*Thousand grain weight*

Significant ($p\leq0.05$) differences in thousand grain weight of sunflower were found for nitrogen and phosphorus levels while hybrid effect was non-significant. The interaction effects among the variables (N×P, N×H and P×H) were also non-significant. Application of N @ 130 kg and 180 kg ha$^{-1}$ was significantly ($p\leq0.05$) increased thousand grain weight of sunflower from 46.63 and 52.20 g compared control treatment which remain 37.88 g as shown in Table 3. The thousand grain weight in N treatments ($N_{130}$ and $N_{180}$) was 23.10 and 37.80 percent higher over the control treatment ($N_o$).Among the P levels, the application of 130 kg $P_2O_5$ ha$^{-1}$ recorded the maximum thousand grain weight of 48.43 g and values were statistically at par with the treatment receiving the application of 90 kg $P_2O_5$ ha$^{-1}$ (45.11 g). There were non-significant differences between the thousand grain weight of the two hybrids and values generally varied between 46.43 and 44.71 g.In combined NP treatments, the interactive effects of N and P on thousand grain weight were found non-significant and values ranged between 33.84 to 53.10 g, highest in $N_{180}P_{130}$ and lowest in $N_oP_{90}$ combinations. For the N×H and P×H interactions, the thousand grain weight varied between 37.03 to 53.16 g and 42.40 to 49.14 g, respectively.

*Yield parameters*

Achene's yield: The achene's yield of sunflower hybrids was significantly ($p\leq0.05$) influenced by the application of different nitrogen (N) and phosphorus (P) rates as well as their combinations (N×P interactions) (Tahir, 1996) and Subhash *et al.*, (2013). However, variation between the hybrids was found non-significant. Similarly, the interactive effects of hybrids with N, P and N+P in the first (N×H and N×P) and second (N×P×H) order interactions were also non-significant. The achene's yield significantly varied between 2539.6 to 3166 kg ha$^{-1}$ among the N levels (Table 4). The maximum values were recorded for the treatment receiving 180 kg N ha$^{-1}$ ($N_{180}$) while the lowest yield was obtained from $N_o$ treatment. The relative increase over the control was 24.6 percent. The relative increase in yield of 24.6 percent recorded in our study for $N_{180}$ treatment was far below than that of 65.9 percent documented by (Nasim *et al.,* 2012) at the same N application rate (180 kg N ha$^{-1}$). The differential response of applied N fertilizer, seasonal variations and higher yield acquisition from unfertilized plots (2539.6 kg ha$^{-1}$) could be the main reasons of low yield increment in N fertilized plots in our experiment. Concerning to the effect of phosphorus levels on sunflower yield, the results revealed that the amendment of 90 and 130 kg $P_2O_5$ ha$^{-1}$($P_{90}$ and $P_{130}$) significantly *(p≤0.05)* increased achene,s yield (2931.8 and 3035.1 kg ha$^{-1}$, respectively) as compared to the control (2678.8 kg ha$^{-1}$). In P fertilized treatments, the achene's yield was 9.48 to 13.29 percent higher than the control ($P_0$). These results are supported by the findings of (Ali *et al.*, 2013) where they recorded significant effects of increasing P fertilization on achene yield of sunflower.

**Table 3.** Comparative and interactive effects of nitrogen and phosphorus levels on morphological characteristics of two sunflower hybrids under rain-fed conditions of Rawalakot, Ajk.

| Treatments | Number of achene's head $^{-1}$ | Seed weight head $^{-1}$ (g) | TGW(g) |
|---|---|---|---|
| A= Nitrogen (N) | | | |
| $N_0$ (0 kg N ha$^{-1}$) | 626.5 c | 75.76 c | 37.884 c |
| $N_1$ (130 kg N ha$^{-1}$) | 830.2 b | 98.68 b | 46.632 b |
| $N_2$ (180 kg N ha$^{-1}$) | 1014.8 a | 117.29 a | 52.204 a |
| LSD value (*p ≤ 0.05*) | 59.9 | 2.86 | 2.612 |
| B= Phosphorus (P) | | | |
| $P_0$ (0 kg $P_2O_5$ ha$^{-1}$) | 754.5 c | 82.42 c | 43.187 b |
| $P_1$ (90 kg $P_2O_5$ ha$^{-1}$) | 818.5 b | 103.17 b | 45.107 b |
| $P_2$ (130 kg $P_2O_5$ ha$^{-1}$) | 898.5 a | 106.14 a | 48.425 a |
| LSD value (*p ≤ 0.05*) | 59.9 | 2.86 | 2.612 |
| C= Hybrids (H) | | | |
| $H_1$ (Parsun-3) | 780.1 b | 97.55 $^{NS}$ | 46.433 $^{NS}$ |
| $H_2$ (Super-2216) | 867.6 a | 96.93 $^{NS}$ | 44.713 $^{NS}$ |
| LSD value (*p ≤ 0.05*) | 48.9 | ---- | ---- |
| Interaction (N×P) | | | |
| $N_0P_0$ | 550.0$^{NS}$ | 73.68 d | 33.838 $^{NS}$ |
| $N_0P_1$ | 630.0$^{NS}$ | 75.50 d | 36.993 $^{NS}$ |
| $N_0P_2$ | 699.5$^{NS}$ | 78.10 d | 42.820 $^{NS}$ |
| $N_1P_0$ | 769.5$^{NS}$ | 77.65 d | 44.308 $^{NS}$ |
| $N_1P_1$ | 827.0$^{NS}$ | 106.90 b | 46.207 $^{NS}$ |
| $N_1P_2$ | 894.0$^{NS}$ | 111.50 b | 49.380 $^{NS}$ |
| $N_2P_0$ | 944.0$^{NS}$ | 95.93 c | 51.415 $^{NS}$ |
| $N_2P_1$ | 998.5$^{NS}$ | 127.12 a | 52.122 $^{NS}$ |
| $N_2P_2$ | 1102.0$^{NS}$ | 128.82 a | 53.075 $^{NS}$ |
| LSD value (*p ≤ 0.05*) | ---- | 4.96 | ---- |
| Interaction (N×H) | | | |
| $N_0H_1$ | 585.3 $^{NS}$ | 76.18 $^{NS}$ | 37.033 $^{NS}$ |
| $N_0H_2$ | 667.7 $^{NS}$ | 75.34 $^{NS}$ | 38.734 $^{NS}$ |
| $N_1H_1$ | 787.3 $^{NS}$ | 98.94 $^{NS}$ | 45.859 $^{NS}$ |
| $N_1H_2$ | 873.0 $^{NS}$ | 98.42 $^{NS}$ | 47.404 $^{NS}$ |
| $N_2H_1$ | 967.7 $^{NS}$ | 117.53 $^{NS}$ | 51.247 $^{NS}$ |
| $N_2H_2$ | 1062.0 $^{NS}$ | 117.04 $^{NS}$ | 53.161 $^{NS}$ |
| LSD value (*p ≤ 0.05*) | ---- | ---- | ---- |
| Interaction (P×H) | | | |
| $P_0H_1$ | 707.0 $^{NS}$ | 82.41 $^{NS}$ | 42.406 $^{NS}$ |
| $P_0H_2$ | 802.0 $^{NS}$ | 82.43 $^{NS}$ | 43.969 $^{NS}$ |
| $P_1H_1$ | 778.3 $^{NS}$ | 103.66 $^{NS}$ | 44.027 $^{NS}$ |
| $P_1H_2$ | 858.6 $^{NS}$ | 102.69 $^{NS}$ | 46.188 $^{NS}$ |
| $P_2H_1$ | 855.0 $^{NS}$ | 106.59 $^{NS}$ | 47.707 $^{NS}$ |
| $P_2H_2$ | 942.0 $^{NS}$ | 105.69 $^{NS}$ | 49.143 $^{NS}$ |
| LSD value (*p ≤ 0.05*) | ---- | ---- | ---- |

In combined treatments, the plots amended with NP combination of 130+90 ($N_{130}$+$P_{90}$) and 130+130 kg ha$^{-1}$ ($N_{130}$+$P_{130}$)produced achene,s yield of 3098 and 3087 kg ha$^{-1}$, respectively and was significantly greater than obtained from plots receiving P applications at the rate of 90 and 130 kg $P_2O_5$ ha$^{-1}$ (2523.7 and 2596.8 kg yields ha$^{-1}$). The yield recorded for $N_{130}$+$P_{90}$ and $N_{130}$+$P_{130}$ fertilized plots was 22.7 and 18.86 percent higher than $P_{90}$ and $P_{130}$ fertilized treatments. The highest achene's yield of 3422 kg ha$^{-1}$ was recorded for the treatment receiving the NP combination of 180+130 kg ha$^{-1}$ ($N_{180}P_{130}$) followed by 3174 kg ha$^{-1}$ ($N_{180}P_{90}$). The co-application of 180 kg N ha$^{-1}$ with P in $N_{180}$ $P_{90}$ and $N_{180}$ $P_{130}$ combinations resulted in 8.14 and 11.3 percent higher achene yield compared to the individual application of 90 and 130 kg $P_2O_5$ ha$^{-1}$. The highest production values of 3422 kg ha$^{-1}$ recorded in our study for $N_{180}P_{130}$ combined treatment were 26.93% higher than those of 2696 kg $ha^{-1}$ reported by Ali *et al.* (2013) with the combined application of 135 kg N +75 kg $P_2O_5$ $ha^{-1}$. The improvements in light interception, higher NP availability and better root growth and proliferations could be responsible for this yield difference.

**Table 4.** Comparative and interactive effects of nitrogen and phosphorus levels on yield characteristics of two sunflower hybrids under rain-fed conditions of Rawalakot, AJK.

| Treatments | Achene's yield (kg $ha^{-1}$) | Biological yield (kg $ha^{-1}$) | Dry matter yield (kg $ha^{-1}$) | Harvest index (%) |
|---|---|---|---|---|
| A= Nitrogen (N) | | | | |
| $N_0$ (0 kg N $ha^{-1}$) | 2539.6 c | 9247 c | 6708.1 c | 27.5 $^{NS}$ |
| $N_1$ (130 kg N $ha^{-1}$) | 2939.8 b | 10515 b | 7575.0 b | 28.1 $^{NS}$ |
| $N_2$ (180 kg N $ha^{-1}$) | 3166.4 a | 11462 a | 8295.6 a | 27.6 $^{NS}$ |
| LSD value ($p \leq 0.05$) | 114.5 | 343.9 | 369.3 | ---- |
| B= Phosphorus (P) | | | | |
| $P_0$ (0 kg $P_2O_5$ $ha^{-1}$) | 2678.8 b | 9692 b | 7013.1 b | 27.8 $^{NS}$ |
| $P_1$ (90 kg $P_2O_5$ $ha^{-1}$) | 2931.8 a | 10607 a | 7675.2 a | 27.7 $^{NS}$ |
| $P_2$ (130 kg $P_2O_5$ $ha^{-1}$) | 3035.1 a | 10925 a | 7890.3 a | 27.9 $^{NS}$ |
| LSD value ($p \leq 0.05$) | 114.5 | 343.9 | 369.3 | ---- |
| C= Hybrids (H) | | | | |
| $H_1$ (Parsun-3) | 2867.4 $^{NS}$ | 10524 $^{NS}$ | 7657.1 $^{NS}$ | 27.3 $^{NS}$ |
| $H_2$ (Super-2216) | 2896.4 $^{NS}$ | 10292 $^{NS}$ | 7395.3 $^{NS}$ | 28.3 $^{NS}$ |
| LSD value ($p \leq 0.05$) | ---- | ---- | ---- | ---- |
| Interaction (N×P) | | | | |
| $N_0P_0$ | 2498.2 d | 9219 e | 6721.0 d | 27.2 $^{NS}$ |
| $N_0P_1$ | 2523.7 d | 9298 e | 6774.7 d | 27.3 $^{NS}$ |
| $N_0P_2$ | 2596.8 d | 9225 e | 6628.5 d | 28.3 $^{NS}$ |
| $N_1P_0$ | 2635.2 d | 9214 e | 6578.8 d | 28.7 $^{NS}$ |
| $N_1P_1$ | 3097.7 bc | 10932 cd | 7834.3 bc | 28.4 $^{NS}$ |
| $N_1P_2$ | 3086.5 bc | 11398 bc | 8311.8 abc | 27.2 $^{NS}$ |
| $N_2P_0$ | 2903.2 c | 10643 d | 7739.5 c | 27.4 $^{NS}$ |
| $N_2P_1$ | 3174.2 b | 11591 ab | 8416.7 ab | 27.4 $^{NS}$ |
| $N_2P_2$ | 3422.0 a | 12152 a | 8730.5 a | 28.2 $^{NS}$ |
| LSD value ($p \leq 0.05$) | 198.2 | 595.7 | 639.7 | ---- |
| Interaction (N×H) | | | | |
| $N_0H_1$ | 2531.8 $^{NS}$ | 9364 $^{NS}$ | 6832.8 $^{NS}$ | 27.1 $^{NS}$ |
| $N_0H_2$ | 2547.3 $^{NS}$ | 9131 $^{NS}$ | 6583.3 $^{NS}$ | 28. $^{NS}$ |
| $N_1H_1$ | 2915.0 $^{NS}$ | 10583 $^{NS}$ | 7668.3 $^{NS}$ | 27.7 $^{NS}$ |
| $N_1H_2$ | 2964.6 $^{NS}$ | 10446 $^{NS}$ | 7481.7 $^{NS}$ | 28.5 $^{NS}$ |
| $N_2H_1$ | 3155.6 $^{NS}$ | 11626 $^{NS}$ | 8470.2 $^{NS}$ | 27.1 $^{NS}$ |
| $N_2H_2$ | 3177.3 $^{NS}$ | 11298 $^{NS}$ | 8120.9 $^{NS}$ | 28.1 $^{NS}$ |
| LSD value ($p \leq 0.05$) | ---- | ---- | ---- | ---- |
| Interaction (P×H) | | | | |
| $P_0H_1$ | 2669.7 $^{NS}$ | 9764 $^{NS}$ | 7094.4 $^{NS}$ | 27.4 $^{NS}$ |
| $P_0H_2$ | 2688.0 $^{NS}$ | 9620 $^{NS}$ | 6931.8 $^{NS}$ | 28.1 $^{NS}$ |
| $P_1H_1$ | 2908.7 $^{NS}$ | 10700 $^{NS}$ | 7791.7 $^{NS}$ | 27.2 $^{NS}$ |
| $P_1H_2$ | 2955.0 $^{NS}$ | 10514 $^{NS}$ | 7558.8 $^{NS}$ | 28.1 $^{NS}$ |
| $P_2H_1$ | 3024.0 $^{NS}$ | 11109 $^{NS}$ | 8085.2 $^{NS}$ | 27.3 $^{NS}$ |
| $P_2H_2$ | 3046.2 $^{NS}$ | 10741 $^{NS}$ | 7695.3 $^{NS}$ | 28.4 $^{NS}$ |
| LSD value ($p \leq 0.05$) | --- | ---- | ---- | ---- |

*Biological yield*

Biological yield (BY) of sunflower hybrids was significantly ($p \leq 0.05$) influenced by the application of different nitrogen (N) and phosphorus (P) rates as well as their N×P interactions. However, the difference between the hybrids was found non-significant. Similarly, the first (N×H and N×P) and second (N×P×H) order interactions between the variables were also non-significant. The BY was significantly ($p \leq 0.05$) ranged between 9247 to 11462 kg $ha^{-1}$ among the N levels (Table 4).

The maximum values were recorded for the treatment receiving 180 kg N $ha^{-1}$($N_{180}$) while the lowest production i.e. 9247 kg $ha^{-1}$ was obtained from $N_0$ treatment. The relative increase (over the control) varied between 13.71 to 23.95 percent. Regarding the impact of phosphorus levels on sunflower yield, the results revealed that the application of 90 and 130 kg $P_2O_5$ $ha^{-1}$($P_{90}$ and $P_{130}$) significantly *($p \leq 0.05$)* increased BY (10607 and 10925 kg $ha^{-1}$, respectively) compared to the control (9692 kg $ha^{-1}$). In P fertilized treatments, the BY was 9.44 to 12.72 percent higher than the control ($P_0$).In combined treatments, the plots amended with NP combination of 130+90 ($N_{130}$+$P_{90}$) and 130+130 kg $ha^{-1}$ ($N_{130}$+$P_{130}$)having 10932 and 11398 kg ha $^{-1}$ biological yield (BY), and was significantly (*$p \leq 0.05$*) higher than that obtained from plots receiving P applications at 90 and 130 kg $P_2O_5$ $ha^{-1}$ (9298 and 9225 kg ha $^{-1}$). The BY recorded for $N_{130}$+$P_{90}$ and $N_{130}$+$P_{130}$ fertilized plots was 17.57 and 23.55 percent higher than $P_{90}$ and $P_{130}$ fertilized treatments. The highest BY of 12152 kg ha $^{-1}$ was recorded for the treatment receiving the NP combination of 180+130 kg $ha^{-1}$ ($N_{180}P_{130}$) followed by 11591 kg ha $^{-1}$ ($N_{180}P_{90}$). The co-application of 180 kg N $ha^{-1}$ with P in $N_{180}$ $P_{90}$ and $N_{180}$ $P_{130}$ combinations resulted in 24.66 and 31.72 percent higher BY compared to the individual application of 90 and 130 kg $P_2O_5$ $ha^{-1}$.

*Dry matter yield*

Impact of nitrogen and phosphorus levels and their N×P interactions on dry matter yield (DMY) of sunflower remain significant. However the differences between hybrids and remaining interactions were statistically found non-significant. The DMY obtained from $N_{130}$ and $N_{180}$ treatments was significantly higher (7575.0 and 8295.6 kg $ha^{-1}$, respectively) than that recorded in the control (6708.1 $kg^{-1}$). The relative increase in DMY varied between 12.92 to 23.66 percent among the N levels (Table 4).

With regards to the phosphorus effects the DMY was significantly varied between 7675.2 and 7890.3 $kg^{-1}$ with the application of 90 and 130 kg $P_2O_5$ $ha^{-1}$ - showing an increase of 9.44 to 12.50 percent over the control treatment i.e.7013.1percent. In combined treatments, the plots amended with NP combination of 130+90 ($N_{130}$+$P_{90}$) and 130+130 kg $ha^{-1}$ ($N_{130}$+$P_{130}$)having 17834.3 and 8311.8 kg ha $^{-1}$ dry matter yield (DMY), and was significantly higher than that obtained from plots receiving P applications at the rate of 90 and 130 kg $P_2O_5$ $ha^{-1}$ (6774.7 and 6628.5 kg ha $^{-1}$). The DMY recorded for $N_{130}$+$P_{90}$ and $N_{130}$+$P_{130}$ fertilized plots was 24.23 and 31.71 percent higher than $P_{90}$ and $P_{130}$ fertilized treatments. The highest DMY of 8730 kg ha $^{-1}$ was recorded for the treatment given the NP combination of 180+130 kg $ha^{-1}$ ($N_{180}P_{130}$) followed by 8416.7 kg ha $^{-1}$ ($N_{180}P_{90}$). The co-application of 180 kg N $ha^{-1}$ with P in $N_{180}$ $P_{90}$ and $N_{180}$ $P_{130}$ combinations resulted in 24.23 and 31.24 percent higher DMY compared to the individual application of 90 and 130 kg $P_2O_5$ $ha^{-1}$.

*Harvest index*

Non-significant differences were observed among the variables (nitrogen, phosphorus and hybrids) and their first and second order interactions for harvest index (HI). Application of nitrogen and phosphorus don't show any significant effect on HI that vary between 27.54 to 27.83 percent (Table 4). The sunflower hybrid super-2216 exhibited the HI of 28.20 that was 3.37 percent higher and in case of hybrid Parsun it was recorded 27.28 percent. Among the N×P, N×H and P×H interactions, the HI values varied between 27.20 to 28.66 percent, 27.08 to 28.48 percent and 27.37 to 28.41 percent, respectively.

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