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EFFECT OF VARIOUS LEVELS OF NPK ON CROP GROWTH AND YIELD OF SUNFLOWER HYBRIDS GROWN UNDER AUTUMN SEASONS

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Abstract

The present study investigates the effect of various doses of N, P and K (0, 50, 100 and 150 kg ha^{-1}) on sunflower hybrids (SF-187 and Parsun-1. The data indicated that different parameters (plant height, head diameter, number of seeds $head^{-1}$, 100 seed weight and biological yield) were significantly ($p \leq 0.05$) affected by an increase in fertilizer level in all combinations when compared with the control. Maximum seed yield (2813 kg ha^{-1}) was produced by fertilizer combinations of 150:100:100 NPK kg ha^{-1} and minimum in control plot (1813 kg ha^{-1}). Hybrid Parsun-1 produced less yield than SF-187. Oil content also varied with different combinations of NPK fertilizers, which ranged from 37 to 39%.during both the seasons. Maximum biological yield (15.8 tons ha^{-1}) was produced in NPK combination of 150:100:100 kg ha^{-1}.

Key words: Growth, Yield, Sunflower, NPK, Autumn

Introduction

Sunflower is widely distributed and adoptable oil seed crop of the world. It is fourth oil grain crop grown worldwide by area (Allam *et al*., 2003; Koutroubas *et al*., 2008; Bakht *et al*., 2010a,b; Ullah *et al.,* 2011; Siddique *et al*., 2012; Shafi *et al.,* 2013; Taran *et al.,* 2013; Hakim *et al.,* 2013; Nasreen *et al*., 2015). Sunflower contains high oil contents of about 34.26-39.13% in non irrigated conditions and 38.50-42.73% in irrigated conditions (Nasim *et al*., 2011). Pakistan is constantly limited in the production of edible oil and the situation is becoming worst each day due to alarming increase in population growth (Asif *et al*., 2001; Iqbal *et al*., 2007; Munir *et al*., 2007). Sunflower is considered a major non-conventional oilseed crop of Pakistan which has the potential to meet the growing demand of the country (Hu *et al*., 2008). The soils of Pakistan exhibit deficiency of nitrogen, while 80-90% of them have inadequate phosphorous and 40-50% are responding to potash application (Bajwa, 1995). Major nutrients like NPK play a very important role in the growth and development of a crop and its yield is more often restricted by their availability (Khan *et al.,* 2013; Ali *et al*., 2014; Zhang *et al*., 2014; Al-Juhaim *et al*., 2014; Shabbir *et al*., 2015). Fertilizer containing major nutrients is usually applied to meet the nutrient deficiencies of the soil, however, uptake of N is often low (50%) which possess serious environmental consequences (Scheiner *et al.,* 2002). The effect of N application on the growth and yield of sunflower has been extensively investigated and oil yield was found to be determined by the number of achenes per capitulum and single achene mass, while oil concentration is considered to be of minor importance. Different approaches for the proper diagnosis and management of crop nutrition is often focused on individual nutrients, there is an increasing demand for the integrated nutrient management and development of early empirical models of crop to multiple nutrients (NPK). Prasad *et al.,* (2001) reported more comprehensive theoretical and experimental approaches to understand and manage crop responses to multiple nutrients. Several researchers have reported significant responses of seed oil yield to increased level of NPK fertilizers (Bahl *et al.,* 1997; El-Kalla *et al.,* 1992; Zahid *et al.,* 1998; Abu Ghazala *et al.,* 2001). However, Kene *et al.,* (1992) found that seed oil percentage was not affected by N or P levels while El-Kalla *et al.,* (1992) found a decreased of oil %age with increased N level. The present study investigates the optimum nutrient needs of the two sunflower hybrids in term of NPK for their yield and yield components.

Materials and Methods

Field trials were conducted to study the efect of NPK fertilizer on sunflower hybrids at NARC Islamabad Pakistan. A sub plot size of 4.5 m x 5 m, with six rows, 5 m long with row-to-row distance of 75 cm and plant to plant distance of 20 cm was used for four replications. Urea was used as a source of N; single super phosphate as P and Muriate of potash as of K in the trial. Full dose of P and K were applied at the time of planting and half dose of N was applied at planting time and the remaining half at bud initiation stage. Planting was done with the help of dibbler by dropping two to three seeds $hill^{-1}$ covered with soil. Later on it was thinned to one plant $hill^{-1}$ at two leaves stage (67000 plants ha^{-1}). A factorial design with split plot arrangement was used during the experiment using 11 NPK treatments in the main plots and two hybrids in sub plots with four replications. Different NPK levels included T1 (0-0-0 NPK); T2 (0-100-100 NPK), T3 (50-100-100 NPK), T4 (100-100-100 NPK), T5 (150-100-100 NPK), T6 (100-0-100 NPK), T7 (100-50-100 NPK),T8 (100-150-100 NPK), T9 (100-100-0), T10 (100-100-50 NPK) and T11 (100-100-150 NPK) were allotted to main plots and sub-plot contained two hybrids (Parsun-1 and SF-187).

Climate and soil characteristics of experimental sites: Climatically Islamabad falls under sub-humid to humid conditions and is a part of Pothwar area. Annual rainfall ranges from 517 to 1550 mm. About 54% of the rainfall occurs during summer monsoon (July to August). Average annual temperature ranges between 03 (minimum) to 41°C (maximum). Climatic data of the experimental site of year 1 and year 2 is shown in Tables 1 and 2. The soils are alkaline (pH, 7.0 to 8.2), non saline (EC, 0.09 –0.76 ds m^{-2}) and slightly to moderately calcareous. Organic matter ranges between 0.31 to 2.50 % in the surface soils and 0.15 to 2.50 % in sub surface. The physio-chemical characteristics of the experimental sites showed that 2.56 mg NO_3-N, 1.15 mg kg^{-1} P, 100.8 mg kg^{-1} K and 0.69 % organic matter at 0-15 cm depth. Soil at the experimental sites was loamy in texture.

Statistical analysis: Analysis of variance (ANOVA) was calculated statistically as described by Gomez & Gomaz (1984). For statistical analysis MSTATC computer software was used (Russel & Eisensmith, 1983). Least Significant Difference (LSD) test was employed upon obtaining significance differences among means (Steel & Torrie, 1997).

Table 1. Climate data of NARC field station during the period of study (Year 1).

Month/Year	Max. Temp. (°C)	Min. Temp. (°C)	R.H (%) 800 hrs	R.H (%) 1400 hrs	Sunshine (hrs)	Wind Speed (km/d)	Rainfall (mm)
Jan. (2001) Avg.	17.0	3.0	91.0	56.0	4.7	59.0	136
Feb	18.0	4.0	91.0	52.0	6.8	66.0	51
Mar	24.0	13.0	75.0	52.0	7.7	85.0	19.0
Apr	33.0	14.0	56.0	32.0	9.5	92.0	5.0
May	40.0	22.0	48.0	26.0	9.6	100.0	8.0
Jun	39.0	24.0	52.0	34.0	8.5	123.0	109.0
Jul	34.0	24.0	82.0	59.0	6.9	56.9	250.0
Aug	33.0	23.0	86.0	63.0	8.3	56.0	279.0
Sep.	32.0	20.0	82.0	55.0	8.7	54.0	55.0
Oct.	32.0	14.0	77.0	33.0	8.9	50.0	0.0
Nov.	26.0	8.0	79.0	33.0	7.0	51.0	0.0
Dec.	22.0	3.0	83.0	31.0	6.6	49.0	12.0

Table 2. Climate data of NARC field station during the period of study (Year 2).

Month/Year	Max temp (°C)	Min temp. (°C)	R.H (%) 800 hrs	R.H (%) 1400 hrs	Sunshine (hrs)	Wind speed (km/d)	Pan Evap. (mm/d)	Rainfall (mm)
Jan. (2001)	19.0	1.1	81.0	36.7	7.1	57.9	2.2	0
Feb	23.3	4.3	68.6	25.1	7.8	78.8	3.5	1
Mar	27.5	9.2	70.7	25.9	9.2	90.4	5.1	27.0
Apr	31.5	15.1	60.6	35.2	8.0	83.4	6.0	10.0
May	39.0	21.3	50.6	26.1	10.3	93.6	9.1	46.0
Jun	35.6	23.5	74.0	49.5	7.9	76.4	6.0	157.0
Jul	33.2	23.7	88.1	66.1	7.1	56.9	4.9	591.0
Aug	33.9	23.7	86.5	65.6	8.3	46.2	4.8	141.0
Sep	33.6	18.8	77.9	47.3	9.1	52.6	5.0	29.0
Oct	31.4	13.9	78.0	41.1	8.0	38.5	3.4	23.0
Nov	26.1	7.5	78.1	33.2	7.8	34.3	2.4	4.0
Dec	21.2	3.9	86.8	40.6	7.5	35.4	1.5	1.0

Results and Discussion

Plant growth: Fertilizer treatments and year had a significant ($p \leq 0.05$) effect on plant height and non-significant differences were observed due to hybrids and their all possible interactions (Table 3). Between years, maximum plant height (118.0 cm) was attained during year 1 compared with year 2. In case of hybrids, maximum plant height (109.8 cm) was observed for Parsun-1 when compared with SF-187 (108.6 cm). Our results also showed that plant height was more (115.3 cm) in the fertilizer combinations of 100:100:50 NPK kg ha^{-1}. The data also suggested that plant height was significantly ($p \leq 0.05$) increased with an increase in N and P levels. Plant height increased at the rate of 0.041 and 0.01 cm with increase of 1 kg NP ha^{-1}, whereas plant height decreased with the higher dose of potash. Similar results are also concluded by Mahal *et al.,* (1998), Tomar *et al.,* (1999), Poonia, (2000), Khot & Patil (2002) and Hakoomat *et al.,* (2004), who reported taller plants with increasing nitrogen rates up to 150 kg ha^{-1}. On the contrary, Ozer *et al.,* (2004) observed that plant height increased by nitrogen up to 80 kg ha^{-1} and decreased with further increase in nitrogen.

Significant differences ($p \leq 0.05$) were also observed for the number of leaves plant^{-1} due to years and hybrids while the effect of NPK fertilizer and all possible interactions were non-significant (Table 4). Maximum number of leaves plant^{-1} was produced during year 1 compared with year 2. Similarly, number of leaves plant^{-1} was more in Parsun-1 compared with SF-187. Among fertilizer levels, plots treated with 100:100:0 NPK kg ha^{-1} produced maximum number of leaves plant^{-1} which was closely followed by plot fertilized with 100:50:100 NPK kg ha^{-1}. Year x hybrid x fertilizer interaction though non significant ($p>0.05$) revealed maximum number of leaves plant^{-1} for Parsun-1 at fertilizer level of 150:100:100 NPK kg ha^{-1} during 2001. Number of leaves plant^{-1} significantly ($p \leq 0.05$) increased with an increase of NP for Parsun-1 compared with hybrid SF-187. While the same treatment showed a negative effect on Parsun-1. These results are in confirmatory with Murad *et al.,* (2000) who reported that numbers of leaves plant^{-1} in hybrids were different due to differences in their genetic characteristic to grow tall and produce more leaves plant^{-1}. Ozer *et al*., (2004) indicated that leaf area index was increased with an increasing level of N rates up to 80 kg ha^{-1} and decreased with further increase in the N rate. Increasing level of N up to 150 kg ha^{-1} increased the leaf area. Bruginisky & Pissaia (2005) investigated that application of nitrogen fertilizer did not affect leaf area index.

Table 3. Effect of NPK treatments on plant height (cm) of sunflower hybrids (Parsun-I and SF-187) grown at NARC.

Fertilizers treatments	Parsun-1			SF-187			Mean (NPK)
NPK (kg ha^{-1})	Year 1	Year 2	**Mean (Parsun-1)**	Year 1	Year 2	**Mean (SF-187)**	
00:00:00 (Control)	106.3	93.8	100.0	120.0	90.8	105.4	102.7
00:100:100	119.0	93.3	106.1	108.5	99.8	104.1	105.1
50:100:100	109.3	94.0	101.6	113.0	97.5	105.3	103.4
100:100:100	116.5	97.8	107.1	118.5	99.8	109.1	108.1
150:100:100	119.8	104.5	112.1	120.0	97.0	108.5	110.3
100:00:100	114.3	106.0	110.1	114.3	93.3	103.8	106.9
100:50:100	118.8	101.8	110.3	124.3	99.5	111.9	111.1
100:150:00	118.0	101.8	109.9	121.8	96.8	109.3	109.6
100:100:00	127.5	102.8	115.1	120.8	105.0	112.9	114.0
100:100:50	121.5	110.5	116.0	123.8	105.3	114.5	115.3
100:100:150	114.5	104.8	109.6	116.3	96.0	106.1	107.9

LSD value for NPK at $p \leq 0.05$ = 7.301

	Hybrids		
	Parsun-I	**SF-187**	**Means (Y†)**
Year 1	117.9	118.1	118.0 a
Year 2	101.7	99.0	100.4 b
Means (H††)	109.8	108.6	

† Years †† Hybrids

Means of the same category followed by different letters are significantly different using LSD test ($p \leq 0.05$)

Table 4. Effect of NPK treatments on number of leaves plant^{-1} of sunflower hybrids (Parsun-I and SF-187) grown at NARC.

Fertilizers treatments	Parsun-1			SF-187			Mean (NPK)
NPK (kg ha^{-1})	Year 1	Year 2	Mean (Parsun-1)	Year 1	Year 2	Mean (SF-187)	
00:00:00 (Control)	24.0	27.8	25.9	23.3	25.3	24.3	25.1
00:100:100	25.0	25.5	25.3	23.0	23.5	23.3	24.3
50:100:100	24.5	26.5	25.5	22.5	25.5	24.0	24.8
100:100:100	23.0	25.3	24.1	23.5	26.0	24.8	24.4
150:100:100	25.3	29.3	27.3	21.8	23.3	22.5	24.9
100:00:100	25.0	26.8	25.9	24.8	24.5	24.6	25.3
100:50:100	26.5	27.3	26.9	25.0	24.3	24.6	25.8
100:150:00	25.8	28.0	26.9	22.8	25.5	24.1	25.5
100:100:00	28.0	27.0	27.5	22.0	26.5	24.3	25.9
100:100:50	25.3	27.0	26.1	23.0	26.5	24.8	25.4
100:100:150	23.5	27.5	25.5	22.0	28.0	25.0	25.3

LSD value for NPK at $p \leq 0.05$ = 1.394

	Hybrids		
	Parsun-I	SF-187	Means (Y†)
Year 1	25.2	23.0	24.1 b
Year 2	27.0	25.4	26.2 a
Means (H††)	26.1 a	24.2 b	

† Years †† Hybrids

Means of the same category followed by different letters are significantly different using LSD test ($p \leq 0.05$)

Significant ($p \leq 0.05$) differences were also observed for head diameter due to year and hybrids while the effect of fertilizer and their all interactions with year and hybrids were non-significant (Table 5). Between years, maximum head diameter was recorded during year1 compared with year 2. Similarly, bigger heads were produced by SF-187 (17.3 cm) when compared with Parsun-1. Our results indicated that head diameter was non significantly ($p > 0.05$) increased by fertilizer treatments of 100:100:50 NPK kg ha^{-1} compared with other treatments. Year x hybrid x fertilizer interaction indicated that maximum head diameter was recorded for SF-187 at fertilizer combinations of 100:50:100 N-P-K kg ha^{-1} during year 1 compared with other treatments under study. Venkatarkrishnan *et al.,* (2001) investigated that application of 100 kg NPK kg ha^{-1} produced maximum head diameter. Kadar *et al.* (2001) indicated that head diameter increased at the rate of 100 kg N ha^{-1}, 120-150 kg P ha^{-1} and 150-200 kg K ha^{-1}. Sarkar *et al.,* (1995) reported that application of 100 kg ha^{-1} P_2O_5 produced maximum head diameter than 75 kg ha^{-1}. Similarly, Sephere *et al.,* (2002) concluded that head diameter was more when K was applied at the rate of 200 kg ha^{-1}.

Yield and yield components: Our results indicated significant ($p \leq 0.05$) effect of years on number of seeds head^{-1} while the effect of fertilizer, hybrids and their possible interactions with years was non significant (Table 6). Maximum number of seeds head^{-1} was produced during year 1 when compared with year 2. Among hybrids, SF-187 produced more seeds head^{-1} compared with Parsun-1. Similarly, among fertilizer levels, maximum number of seeds head^{-1} was noted for fertilizer treatments of 100:100:50 NPK kg ha^{-1}. In case of year x hybrid x fertilizer interactions, maximum number of 1140.5 seeds head^{-1} was recorded for SF-187 at fertilizer treatment of 150:100:100NPK kg ha^{-1} during 2000. These results agree with Vega *et al.,* (2001) who observed increase in number of seeds head^{-1} due to the application of N and P. Moreover, Surendra *et al.,* (2003) found that number of seeds head^{-1} was increased with the combination of 120 kg N and 60 kg P ha^{-1}.

Number of achenes head^{-1} was significantly affected by nitrogen application along with phosphorus.

Table 5. Effect of NPK treatments on head diameter (cm) of sunflower hybrids (Parsun-I and SF-187) grown at NARC.

Fertilizers treatments	Parsun-1			SF-187			
NPK (kg ha^{-1})	Year 1	Year 2	Mean (Parsun-1)	Year 1	Year 2	Mean (SF-187)	Mean (NPK)
00:00:00 (Control)	15.2	15.2	15.2	18.4	14.4	16.4	15.8
00:100:100	16.4	14.7	15.5	17.9	16.5	17.2	16.4
50:100:100	16.1	14.7	15.4	17.7	16.3	17.0	16.2
100:100:100	18.0	16.3	17.1	17.5	14.8	16.1	16.6
150:100:100	19.0	15.7	17.3	19.3	16.4	17.8	17.6
100:00:100	16.4	14.8	15.6	16.3	15.5	15.9	15.7
100:50:100	17.0	15.3	16.2	19.4	15.7	17.6	16.9
100:150:00	17.2	15.8	16.5	17.8	17.3	17.5	17.0
100:100:00	18.1	16.5	17.3	19.2	16.0	17.6	17.4
100:100:50	18.0	17.0	17.5	18.6	17.5	18.0	17.8
100:100:150	17.6	16.5	17.0	18.5	17.4	17.9	17.5

LSD value for NPK at $p \leq 0.05$ = 1.021

	Hybrids		
	Parsun-I	SF-187	Means (Y†)
Year 1	17.4	18.2	17.8 a
Year 2	15.7	16.3	16.0 b
Means (H††)	16.6 b	17.3 a	

† Years †† Hybrids

Means of the same category followed by different letters are significantly different using LSD test ($p< 0.05$)

Table 6. Effect of NPK treatments on number of seeds head^{-1} of sunflower hybrids (Parsun-I and SF-187) grown at NARC.

Fertilizers treatments	Parsun-1			SF-187			Mean (NPK)
NPK (kg ha^{-1})	Year 1	Year 2	Mean (Parsun-1)	Year 1	Year 2	Mean (SF-187)	
00:00:00 (Control)	1020.0	723.5	871.8	950.0	648.3	799.1	835.4
00:100:100	983.0	693.8	838.4	967.8	689.5	828.6	833.5
50:100:100	931.0	672.8	801.9	912.0	745.0	828.5	815.2
100:100:100	980.8	785.8	883.3	1075.8	740.5	908.1	895.7
150:100:100	1020.0	750.0	885.0	1140.5	663.8	902.1	893.6
100:00:100	842.8	656.5	749.6	1057.0	701.5	879.3	814.4
100:50:100	895.0	600.5	747.8	956.3	711.3	833.8	790.8
100:150:00	1015.8	601.8	808.8	1067.0	677.5	872.3	840.5
100:100:00	1018.0	820.5	919.3	1071.8	640.5	856.1	887.7
100:100:50	998.3	836.3	917.3	1013.0	839.3	926.1	921.7
100:100:150	1016.0	842.3	929.1	971.3	778.5	874.9	902.0

LSD value for NPK at $p \leq 0.05$ = 102.1

	Hybrids			
	Parsun-I	SF-187	Means (Y†)	
Year 1	970.1	1023.2	996.7 a	
Year 2	726.0	718.7	722.4 b	
Means (H††)	848.1	871.0		

† Years †† Hybrids

Means of the same category followed by different letters are significantly different using LSD test ($p \leq 0.05$)

Hundred seed weight was also significantly ($p \leq 0.05$) affected by fertilizer, hybrids and interactions between year x fertilizer, year x hybrids and year x fertilizer x hybrid while the effect of fertilize x hybrid was non-significant (Table 7). Our results indicated that heavier seeds were produced during year 1 when compared with year 2. Similarly, maximum 100 seed weight was recorded for SF-187 compared with Parsun-1. Among fertilizers, 100 seed weight was more in fertilizer combinations of 150:100:100 NPK kg ha^{-1} compared with other treatments. In case of year x hybrid x fertilizer interaction, 100 seed weight was more in SF-187 at fertilizer treatments of 150:100:100 NPK kg ha^{-1} during 2000. Our data also suggested that hundred seed weight increased at the rate of 0.0032 and 0.035 g with kg^{-1} increase in the level of NK, whereas phosphorus had little effect on 100 seed weight. Sarkar *et al.,* (1995) and Vega *et al.,* (2001) reported that 100 seed weight was increased with increasing level of N and P at 100 kg ha^{-1}. These results are in contradiction with the findings of Vega *et al.,* (2001) and Mojiri & Arzani (2003) who reported that seed weight was not significantly affected by increasing level of nitrogen. It is well documented that increasing N rates produced sunflower plants with higher seed weight (Mahal *et al.,* 1998). Amjed *et al*., (2012) reported that with increasing nitrogen application phonological duration and achene's yield was increased. Similar results are also reported by Awais *et al*., (2013) and Khakwani *et al*., (2014).

Year and fertilizer interactions had a significant ($p \leq 0.01$) effect on seed yield, while the effect of hybrids and their possible interactions with year and fertilizer was non-significant (Table 8). Between years, maximum seed yield (2551 kg ha^{-1}) was obtained during year1 compared year 2 (2293 kg ha^{-1}). Significantly ($P<0.05$) maximum seed yield was produced by SF-187 (2439 kg ha^{-1}) when compared with Parsun-1 (2405 kg ha^{-1}). In case of fertilizer application, significantly ($P<0.05$) maximum seed yield (2813 kg ha^{-1}) was noted the for fertilizer treatment of 150:100:100 NPK kg ha^{-1} followed by 100:150:100 NPK kg ha^{-1} (2680 kg ha^{-1}). Minimum seed yield (1813 kg ha^{-1}) was recorded in control (no fertilizer). In case of year x hybrid x fertilizer interactions, maximum seed yield was recorded for Parsun-1 (3280 kg ha^{-1}) at fertilizer treatment of 150:100:100 NPK kg ha^{-1} during year 1 followed by the same treatment for SF-187 (2930 kg ha^{-1}). Seed yield increased at the rate of 5.45, 1.84 and 0.718 kg with kg^{-1} increase in the rate of NPK. These results are in conformity with El-Kalla *et al.,* (1992), Sathiyavelu *et al.,* (1994), Bahl *et al.,* (1997), Zahid *et al.,* (1998), Stulin (1999), Devi *et al.,* (1999), Abu Ghazala *et al.,* (2001), Ayyapan *et al.,* (2002), Hakoomat *et al.,* (2004), Khan *et al.,* (2008) and Bakht *et al.,* (2010a,b). Similarly, Mujiri & Arzani (2003) reported increase of seed yield with the application of N up to 150 kg ha^{-1}, whereas higher level of nitrogen decreased the seed yield. Kardar *et al.,* (2001) found maximum seed yield at the rate of 100 kg N ha^{-1}, 120 to 150 kg ha^{-1} P_2O_5 and 150 to 200 kg K ha^{-1}. On the other hand, Gajandra (2001) reported variations in seed yield due to application of N when applied at the rate of 40 and 80 kg ha^{-1}. Similarly, Iqbal *et al.,* (2008) reported a progressive increase in achene yield and yield components with increasing levels of N, P and K.

Table 7. Effect of NPK treatments on 100 seed weight (g) of sunflower hybrids (Parsun-I and SF-187) grown at NARC.

Fertilizers treatments	Parsun-1			SF-187			
NPK (kg ha^{-1})	Year 1	Year 2	Mean (Parsun-1)	Year 1	Year 2	Mean (SF-187)	Mean (NPK)
00:00:00 (Control)	4.7	5.1	4.9	4.6	5.7	5.2	5.0
00:100:100	5.9	5.1	5.5	5.5	5.2	5.4	5.4
50:100:100	5.5	5.1	5.3	5.2	5.5	5.4	5.3
100:100:100	6.0	4.9	5.5	6.4	5.1	5.8	5.6
150:100:100	6.6	4.7	5.7	6.7	5.4	6.1	5.9
100:00:100	5.2	5.1	5.2	5.4	5.8	5.6	5.4
100:50:100	5.8	5.8	5.8	6.2	4.5	5.4	5.6
100:150:00	6.0	4.8	5.4	5.8	5.3	5.6	5.5
100:100:00	5.9	4.1	5.0	6.0	5.6	5.8	5.4
100:100:50	5.6	4.8	5.2	5.9	5.4	5.7	5.4
100:100:150	6.3	5.2	5.8	6.4	5.8	6.1	5.9

LSD value for NPK at $p \leq 0.05$ = 0.317

	Hybrids			
	Parsun-I	SF-187	Means (Y†)	
Year 1	5.9	6.0	6.0 a	
Year 2	5.0	5.4	5.2 b	
Means (H††)	5.5 b	5.7 a		

† Years †† Hybrids

Means of the same category followed by different letters are significantly different using LSD test ($p \leq 0.05$)

Table 8. Effect of NPK treatments on seed yield kg ha^{-1} of sunflower hybrids (Parsun-I and SF-187) grown at NARC.

Fertilizers treatments	Parsun-1			SF-187			Mean (NPK)
NPK (kg ha^{-1})	Year 1	Year 2	Mean (Parsun-1)	Year 1	Year 2	Mean (SF-187)	
00:00:00 (Control)	1845	1915	1880	1693	1800	1747	1813
00:100:100	1863	1870	1867	1685	2260	1973	1920
50:100:100	2707	1827	2267	1985	2200	2093	2180
100:100:100	2453	2107	2280	2096	2250	2173	2227
150:100:100	3280	2293	2787	2930	2750	2840	2813
100:00:100	2453	2160	2307	2280	2200	2240	2273
100:50:100	2956	2190	2573	2580	2380	2480	2527
100:150:00	2800	2585	2693	2750	2584	2667	2680
100:100:00	2500	1820	2160	2780	2660	2720	2440
100:100:50	2606	2300	2453	2700	2420	2560	2507
100:100:150	2810	2520	2665	2800	2480	2640	2653

LSD value for NPK at $p \leq 0.05$ = 445.0

Hybrids

	Parsun-I	SF-187	Means (Y†)
Year 1	2643	2459	2551 a
Year 2	2167	2418	2293 b
Means (H††)	2405	2439	

† Years †† Hybrids

Means of the same category followed by different letters are significantly different using LSD test ($p \leq 0.05$)

Significant differences ($p \leq 0.05$) were noted for biological yield of sunflower due to years, hybrids and fertilizer levels while the effect of all possible combinations was non-significant (Table 9). Biological yield was more during year 1 compared year 2. The data also suggested that maximum biological yield was produced by SF-187 compared with Parsun-1. Fertilizer combinations of 150:100:100NPK kg ha^{-1} produced more biological yield when compared with other fertilizer levels. In case of year x hybrid x fertilizer interaction, maximum biological yield was observed in Parsun-1 at fertilizer treatments of 150:100:100 NPK kg ha^{-1} during year 1. Our results also suggested that biological yield increased with higher rate of nitrogen but application of high level of P and K did not enhance biological yield. Hakoomat *et al.,* (2004) reported that sunflower seeds sown with 150 kg N ha^{-1} produced the highest biological yield, whereas Mujiri & Arzani (2003) indicated that application of N up to 150 kg ha^{-1} increased the biological yield and was reduced when applied beyond 150 kg ha^{-1}. Surendra *et al.,* (2003) found that biological yield was increased with increasing level of N and P.

Significantly ($p \leq 0.01$) maximum oil content was recorded during year 2 compared with year 1 (Table 10). Application of 0:100:100 NPK kg ha^{-1} produced maximum oil content which was statistically at par with fertilizer level of 100:100:00 NPK kg ha^{-1} and 100:150:100 NPK kg ha^{-1}. Year x hybrid interaction indicated that maximum oil content was produced during 2001 in hybrid Parsun-1 compared with SF-187. The data further suggested that maximum oil content was observed for Parsun-1 at fertilizer treatment of 0:100:100 NPK kg ha^{-1} followed by the same hybrid at fertilizer level of 100:150:100 NPK kg ha^{-1}. In case of year x hybrid x fertilizer interaction, maximum oil content was recorded for Parsun-1 at fertilizer treatment of 0:100:100 NPK kg ha^{-1} during year 2, against minimum oil content produced by SF-187 at fertilizer combinations 150:100:100 NPK kg ha^{-1} during year 1. Our results further indicated that oil content decreased with increase in the level of NP while no effect on oil content was found due to the application of higher levels of K. These results are agree with Scheiner *et al.,* (2002) who concluded that reduction of seed oil content due to N addition was relatively small (2 to 5%) and was overcompensating by the seed yield at the responsive site. Syed *et al.,* (2003) also concluded that oil content was decreased significantly with increasing N levels, whereas increasing levels of N significantly increased the oil content. Aleman *et al.,* (2002) observed that application of 100 kg N ha^{-1} decreased the oil content. On the contrary, Ozer *et al.,* (2004) reported that oil content was increased with increasing rates of N up to 80 kg ha^{-1} and decreased with further increase in N rate. Sarkar *et al.,* (1995) observed that application of 100 kg P_2O_5 ha^{-1} produced higher oil content than 75 kg P_2O_5 ha^{-1}.

Table 9. Effect of NPK treatments on biological yield (tons ha^{-1}) of sunflower hybrids (Parsun-I and SF-187) grown at NARC.

Fertilizers treatments	Parsun-1			SF-187			Mean (NPK)
NPK (kg ha^{-1})	Year 1	Year 2	Mean (Parsun-1)	Year 1	Year 2	Mean (SF-187)	
00:00:00 (Control)	11.5	5.0	8.3	11.2	7.2	9.2	8.7
00:100:100	8.2	5.7	7.0	13.3	6.5	9.9	8.4
50:100:100	11.3	8.3	9.8	17.3	5.2	11.3	10.5
100:100:100	11.3	7.5	9.4	14.8	7.1	11.0	10.2
150:100:100	20.8	11.8	16.3	19.0	11.7	15.4	15.8
100:00:100	13.0	7.2	10.1	14.5	9.8	12.2	11.1
100:50:100	14.3	8.7	11.5	14.8	6.2	10.5	11.0
100:150:00	12.3	7.0	9.7	15.2	10.7	13.0	11.3
100:100:00	14.6	8.7	11.7	11.8	9.5	10.7	11.2
100:100:50	15.0	9.4	12.2	16.0	8.3	12.2	12.2
100:100:150	10.3	8.5	9.4	14.8	7.2	11.0	10.2

LSD value for NPK at $p \leq 0.05$ =

Hybrids

	Parsun-I	SF-187	Means (Y†)	
Year 1	13.1	15.2	14.2 a	
Year 2	8.3	8.2	8.3 b	
Means (H††)	10.7 b	11.7 a		

† Years †† Hybrids

Means of the same category followed by different letters are significantly different using LSD test ($p \leq 0.05$)

Table 10. Effect of NPK treatments on oil content (%) of sunflower hybrids (Parsun-I and SF-187) grown at NARC.

Fertilizers treatments	Parsun-1			SF-187			Mean (NPK)
NPK (kg ha^{-1})	Year 1	Year 2	Mean (Parsun-1)	Year 1	Year 2	Mean (SF-187)	
00:00:00 (Control)	39.14	40.28	39.7	36.42	37.48	37.0	38.3
00:100:100	40.67	41.85	41.3	37.62	38.71	38.2	39.7
50:100:100	38.33	39.44	38.9	35.56	36.59	36.1	37.5
100:100:100	38.69	39.81	39.3	37.15	38.23	37.7	38.5
150:100:100	38.39	39.5	38.9	34.72	35.73	35.2	37.1
100:00:100	39.07	40.21	39.6	37.81	38.9	38.4	39.0
100:50:100	38.03	39.13	38.6	35.77	36.8	36.3	37.4
100:150:00	40.25	41.42	40.8	37.2	38.27	37.7	39.3
100:100:00	39.29	40.43	39.9	38.77	39.89	39.3	39.6
100:100:50	39.95	41.11	40.5	37.28	38.37	37.8	39.2
100:100:150	38.34	39.45	38.9	35.89	36.93	36.4	37.7

LSD value for NPK at $p \leq 0.05$ = 0.014

Hybrids

	Parsun-I	SF-187	Means (Y†)	
Year 1	39.10	36.80	37.95 b	
Year 2	40.20	37.80	39.00 a	
Means (H††)	39.65 a	37.30 b		

† Years †† Hybrids

Means of the same category followed by different letters are significantly different using LSD test ($p \leq 0.05$)

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