RESPONSE OF SUNFLOWER TO VARYING LEVELS OF MINERAL FERTILIZERS AND IRRIGATION SCHEDULING

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ABSTRACT

In order to examine the effect of mineral fertilizers and irrigation levels on the growth and yield of sunflower crop, the experiment was conducted at Arid Zone Research Institute (PARC), Umerkot during 2013 in Randomized Complete Block Design (RCBD) three replications with a plot size of 3m x 5m ($15m^2$). Using four levels of mineral fertilizers (F_1=80-40 N-P kg ha^{-1}, F_2=100-50 N-P kg ha^{-1}, F_3=120-50 N-P kg ha^{-1}, F_4=140-50 N-P kg ha^{-1}) and four irrigation levels (I_1=1 irrigation, I_2=2 irrigations, I_3=3 irrigations, I_4=4 irrigations). The results revealed that all sunflower traits studied were significantly ($P<0.05$) affected by varying levels of mineral fertilizers (NP) and irrigation levels. The crop given N-P @ 140-50 kg ha^{-1} resulted in maximum values for all the traits examined taking 72.67 days to 75% flowering, 110.75 days to 90% maturity, 169.38 cm plant height, 5.19 cm stem girth, 21.38 cm head diameter, 1602.93 seeds $head^{-1}$, 65.92 g seed index and 1465.90 kg ha^{-1} seed yield. The crop receiving N-P @ 120-50 kg ha^{-1} took 69.50 days to 75% flowering, 106.10 days to 90% maturity, 161.80 cm plant height, 5.04 cm stem girth, 20.44 cm head diameter, 1533.08 seeds $head^{-1}$, 63.05 g seed index and 1380.90 kg ha^{-1} seed yield. The crop performance was adversely affected under N-P fertilizers @ 100-50 kg ha^{-1} and 80-40 kg ha^{-1}. The effect of number of irrigations indicated that the crop irrigated four times throughout the growing season took 73.92 days to 75% flowering, 112.99 days to 90% maturity, 177.61 cm plant height, 5.31 cm stem girth, 21.77 cm head diameter, 1632.30 seeds $head^{-1}$, 67.13 g seed index and 1585.50 kg ha^{-1} seed yield. The sunflower crop given three irrigations took 69.25 days to 75% flowering, 105.70 days to 90% maturity, 166.19 cm plant height, 5.00 cm stem girth, 20.37 cm head diameter, 1540.08 seeds $head^{-1}$, 63.32 g seed index and 1362.80 kg ha^{-1} seed yield. The crop irrigated two times and receiving only one irrigation throughout the growing period showed least performance. It was concluded that highest N-P level of 140-50 kg ha^{-1} produced highest sunflower seed yield, and seed yield decreased with curtailing the rate of mineral fertilizers. Similarly, four irrigations resulted in improved growth and highest seed yield as compared to lower irrigation levels. For profitable cultivation of sunflower the crop may be fertilized with NP @ 140-50 kg ha^{-1} and given 4 irrigations, because reduction in the dose of mineral fertilizers and water stress impacted the crop yields adversely.

Key words: Sunflower, mineral fertilizers, irrigation scheduling, growth, seed yield ha^{-1}

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INTRODUCTION

Sunflower is most important crop that is high yielding, short duration, and non-conventional oilseed crop. It fits well in existing cropping systems and can be grown without replacing any major crop (Ahmad *et al*., 2009). Sunflower oil is quite palatable and contains soluble vitamins A, D, E and K. It is used in manufacturing of margarine; and sunflower cake is used as cattle feed (Hussain *et al*., 2000). Sunflower being the most important oil crop and due to its high content of unsaturated fatty acids and a lack of cholesterol, the oil benefits are well recognized for human health (Razi and Assad, 1998; (Nezami *et al.* 2008). Sunflower has the potential to bridge up the gap between demand and supply of edible oil and it is well adapted to agro-ecological conditions of Pakistan. During the year 2011-12, the total availability of edible oil was 2.748 million tons. Local production of edible oil is remained 0.636 million tons while imports were 2.148 million tons. The import bill during 2011-12 stood at Rs. 216.4 billion. During the year 2012-13, 1.738 million tons of edible oil valued at Rs. 153.3 billion has been imported. The local production during 2012-13 was 0.612 million tons. Total availability of edible oil from all sources is provisionally estimated at 2.35 million tons during 2012-13 (GOP, 2013).

Many interrelated factors, both natural and managerial, cause soil fertility decline. Among the factors, inefficient use of fertilizers is the major constraint for low productivity. Organic inputs can alleviate constraints of crop productivity by improving the use efficiency of mineral fertilizers (Jackson, 2001). The use of heavy amount of fertilizers not only increases the cost of inputs, but also creates soil and environmental pollution. It was reported that application of adequate fertilizers led to enhance nutrient uptake in plant and nutrient balance in soil ultimately increasing production of crops (Adediran *et al.,* 2004). Mineral fertilizers are inorganic substances, primarily salts, containing nutrients required by plants and greatly affect the soil (its physical, chemical, and biologic properties) as well as plants. In soil, mineral fertilizers undergo various changes that influence the solubility of their nutrients, their permeability, and their availability to plants. Bogdanovic *et al.* (1999) observed that the application of increasing P rates did not decrease the content of available Zn in the soil. For getting maximum production, it is necessary to apply 181- 40 NP kg ha^{-1} due to increased P use efficiency of the applied nitrogen (Zubillaga *et al*., 2002).

Similarly, irrigation management in relation to number of irrigations and scheduling of its application has very crucial role in crop production. Studies have demonstrated that avoiding irrigation during the vegetative growth stages could result decrease yields substantially and proper irrigation management could lead to improved irrigation water use efficiency (Garcia *et al*. 2010). Most of the crops in Pakistan are produced under irrigated conditions; thus, it is essential to determine the water regimes leading to improved crop yields and irrigation efficiency.

Substantially high yields can be obtained from irrigated sunflowers, provided suitable varieties and watering techniques are used and the crop can be very profitable. Hybrid cultivars having high seed cost give the highest yield only when irrigated (Flagella *et al*., 2002). One of the needs of the hour is to adopt management techniques and technologies available for increasing irrigation efficiency (Khan, 2005). The purpose of irrigation scheduling is to determine the exact amount of water to apply to the field and the exact timing for application. The amount of water applied is determined by using a criterion to determine irrigation need and a strategy to prescribe how much water to apply in any situation (Broner, 2005). Irregular and inadequate water supply reduce growth, yield, and quality of crop produce, however some cultivars responded to irrigation better than others (Tan, 1990). Taha *et al.* (2001) reported that scheduling of irrigation at IW/CPE of 1.0 resulted in significantly maximum seed yield of 1391.7 kg ha^{-1} and stover yield of 2832.7 kg ha^{-1} in sunflower. In view of the factors stated above, the study was carried out to investigate the effect of mineral fertilizers and irrigation scheduling on the growth and yield of sunflower.

MATERIAL AND METHODS

This experiment was conducted during 2013 in a randomized complete block design (RCBD) in three replications, one sunflower variety Parsun-3 with factorial arrangements keeping plot size of 3.0 x 5m ($15m^2$), at experimental field of Arid Zone Research Institute (PARC), Umerkot on 6th February, 2013. The treatments included four levels of NP fertilizers and four irrigation levels. The land was prepared by giving two dry plowings followed by precision land leveling. After soaking dose, when soil came in condition two plowings with crosswise cultivator followed by planking was applied to achieve the fine seed bed. The

sowing was done by means of single coulter hand drill at the row distance of 60 cm, keeping 45 cm distance between plants. The above row and plant spacing was maintained by thinning, 15 days after completion of the germination.

N as urea and P as SSP were applied and the crop was irrigated as per the treatment plan. All P alongwith 1/3rd of N were applied at the time of sowing and remaining N was applied in two splits at first irrigation and at grain formation stage, respectively. For recording observations on various agronomical traits, five plants in each plot were selected at random and labeled to record the observations on various parameters. The data thus obtained were subjected to statistical analysis using analysis of variance to observe the significance of the treatment effect on a certain parameter and DMRT (Duncan's Multiple Range Test) was applied to compare the means (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Days to 75% flowering

The sunflower took maximum number of days (72.67) to reach 75% flowering when the crop was fertilized with NP @ 140-50 kg ha^{-1}, and an earliness in 75% flowering was noted (69.50 and 67.00 days) when the crop was fertilized with NP @ 120-50 kg ha^{-1} and 100-50 kg ha^{-1}, respectively; while the minimum days to 75% flowering (64.67) were observed in plots fertilized with NP @ 80-40 kg ha^{-1}. In case of irrigation levels, the crop receiving four irrigations prolonged the 75% flowering (73.92 days), while sunflower irrigated 3 times and 2 times took 69.25 and 65.92 days to 75% flowering, respectively. The minimum days to 75% flowering (64.75) were observed in plots irrigated once only throughout the growing season. The interaction (NP @ 140-50 kg ha^{-1} × 4 irrigations) took maximum days (78.66) to 75% flowering and minimum days to 75% flowering (61.33) were noted in interaction (NP @ 80-40 kg ha^{-1} × 1 irrigation).

Days to 90% maturity

The crop took maximum days (110.75) to reach 90% maturity when the crop was fertilized with NP @ 140-50 kg ha^{-1}, followed by 90% maturity in 106.10 and 102.37 days in plots fertilized with NP @ 120-50 kg ha^{-1} and 100-50 kg ha^{-1}, respectively. The minimum days

taken to 90% maturity (98.75) were noted in plots fertilized with NP @ 80-40 kg ha^{-1}. In case of irrigation levels, the sunflower crop took maximum number of days (112.99) to reach 90 percent maturity when irrigated four times, while sunflower irrigated 3 times and 2 times took 105.70 and 100.78 days to reach 90% maturity, respectively. The minimum number of days (98.50) to 90% maturity was noted in plots given only one irrigation during the whole season. The interaction (NP @ 140-50 kg ha^{-1} × 4 irrigations) took maximum days (121.00) to reach 90% maturity and minimum days to 90% maturity (93.23) were noted in interaction (NP @ 80-40 kg ha^{-1} × 1 irrigation).

Plant height

It can be seen from the results (Table-3) that the crop fertilized with NP @ 140-50 kg ha^{-1} resulted in maximum plant height of 174.38 cm on average, while decreasing fertilizer rates i.e. NP @ 120-50 kg ha^{-1} and 100-50 kg ha^{-1} resulted average plant height of 166.80 cm and 160.80 cm, respectively. The lowest plant height (155.40 cm) was noted in plots fertilized with NP @ 80-40 kg ha^{-1}. In case of irrigation levels, the maximum plant height of 177.61 cm was recorded in plots receiving four irrigations, while the plant height reduced to 166.19 cm and 158.19 cm when the crop was given three and two irrigations, respectively. However, the minimum plant height (135.40 cm) was observed from the plots given only one irrigation. The interactive effect showed that the interaction (NP @ 140-50 kg ha^{-1} × 4 irrigations) resulted in maximum plant height (188.80 cm) and minimum plant height (127.20 cm) was observed in the interaction (NP @ 80-40 kg ha^{-1} × 1 irrigation).

Table 1. Effect of fertilizers and irrigation on number of days taken to 75% flowering

NP levels	**Number of irrigations**				**Mean**
	1 irrigation	**2 irrigations**	**3 irrigations**	**4 irrigations**	
F_1=80-40 kg ha^{-1}	61.33	62.67	64.67	70.00	**64.67 d**
F_2=100-50 kg ha^{-1}	63.33	64.33	68.00	72.33	**67.00 c**
F_3=120-50 kg ha^{-1}	65.67	67.00	70.67	74.67	**69.50 b**
F_4=140-50 kg ha^{-1}	67.66	69.67	73.67	78.66	**72.67 a**
Mean	**64.75 d**	**65.92 c**	**69.25 b**	**73.92 a**	**-**

	N-P Levels (F)	**No. of Irrigations (I)**	**(F x I)**
S.E.±	0.2867	0.2867	0.5733
LSD 0.05	0.5854	0.5854	-
LSD 0.01	0.7883	0.7883	-

Table 2. Effect of fertilizers and irrigation on number of days taken to 90% maturity

NP levels	Number of irrigations				Mean
	1 irrigation	2 irrigations	3 irrigations	4 irrigations	
F_1=80-40 kg ha^{-1}	93.23	96.00	98.50	107.25	**98.75 d**
F_2=100-50 kg ha^{-1}	96.78	98.45	104.25	110.00	**102.37 c**
F_3=120-50 kg ha^{-1}	100.00	102.65	108.05	113.69	**106.10 b**
F_4=140-50 kg ha^{-1}	104.00	106.00	112.00	121.00	**110.75 a**
Mean	**98.50 c**	**100.78 c**	**105.70 b**	**112.99 a**	-

	N-P Levels (F)	No. of Irrigations (I)	(F x I)
S.E.±	1.6647	1.6647	3.3293
LSD 0.05	3.3997	3.3997	-
LSD 0.01	4.5778	4.5778	-

Table 3. Effect of fertilizers and irrigation on plant height (cm)

NP levels	Number of irrigations				Mean
	1 irrigation	2 irrigations	3 irrigations	4 irrigations	
F_1=80-40 kg ha^{-1}	127.20	150.40	155.20	168.80	**150.40 d**
F_2=100-50 kg ha^{-1}	132.00	154.40	163.20	173.60	**155.80 c**
F_3=120-50 kg ha^{-1}	137.60	160.80	169.60	179.20	**161.80 b**
F_4=140-50 kg ha^{-1}	144.73	167.20	176.80	188.80	**169.38 a**
Mean	**135.40 d**	**158.21 c**	**166.19 b**	**177.61 a**	-

	N-P Levels (F)	No. of Irrigations (I)	(F x I)
S.E.±	0.8813	0.8813	1.7625
LSD 0.05	1.7998	1.7998	-
LSD 0.01	2.4235	2.4235	-

Stem girth

The results (Table-4) showed that the crop fertilized with NP @ 140-50 kg ha^{-1} resulted in maximum stem girth of 5.19 cm on average, while decreasing fertilizer rates i.e. NP @ 120-50 and 100-50 kg ha^{-1} showed simultaneous decrease in stem girth upto 5.04 cm and 4.81 cm, respectively. The minimum stem girth (4.62 cm) was observed in plots fertilized with NP @ 80-40 kg ha^{-1}. In case of irrigation levels, the maximum stem girth of 5.31 cm was recorded in plots receiving four irrigations; while the stem girth reduced to 5.00 cm and 4.70 cm when the crop was given three and two irrigations, res. However, the minimum stem girth (4.65 cm) was noted from the plots given only one irrigation. The interaction (NP @ 140-50 kg ha^{-1} × 4

irrigations) resulted in maximum stem girth (5.62 cm) and minimum stem girth (4.38 cm) was noted in the interaction (NP @ 80-40 kg ha^{-1} × 1 irrigation).

Table 4. Effect of fertilizers and irrigation on stem girth

NP levels	Number of irrigations				Mean
	1 irrigation	2 irrigations	3 irrigations	4 irrigations	
F_1=80-40 kg ha^{-1}	4.38	4.48	4.62	5.02	**4.62 b**
F_2=100-50 kg ha^{-1}	4.62	4.59	4.86	5.16	**4.81 b**
F_3=120-50 kg ha^{-1}	4.69	4.79	5.24	5.44	**5.04 a**
F_4=140-50 kg ha^{-1}	4.91	4.98	5.26	5.62	**5.19 a**
Mean	**4.65 c**	**4.70 c**	**5.00 b**	**5.31 a**	**-**

	N-P Levels (F)	No. of Irrigations (I)	(F x I)
S.E.±	0.1009	0.1009	0.2018
LSD 0.05	0.2061	0.2061	-
LSD 0.01	0.2775	0.2775	-

Table 5. Effect of fertilizers and irrigation on head diameter

NP levels	Number of irrigations				Mean
	1 irrigation	2 irrigations	3 irrigations	4 irrigations	
F_1=80-40 kg ha^{-1}	17.01	18.43	19.02	20.68	**18.79 d**
F_2=100-50 kg ha^{-1}	18.63	18.93	20.00	21.28	**19.71 c**
F_3=120-50 kg ha^{-1}	19.31	19.71	20.78	21.96	**20.44 b**
F_4=140-50 kg ha^{-1}	19.20	21.49	21.67	23.14	**21.38 a**
Mean	**18.54 d**	**19.64 c**	**20.37 b**	**21.77 a**	**-**

	N-P Levels (F)	No. of Irrigations (I)	(F x I)
S.E.±	0.2325	0.2325	0.4650
LSD 0.05	0.4749	0.4749	-
LSD 0.01	0.6394	0.6394	-

Head diameter

It is evident that the sunflower receiving NP @ 140-50 kg ha^{-1} resulted in maximum head diameter of 21.38 cm on average, while decreasing fertilizer rates i.e. NP @ 120-50 kg ha^{-1} and 100-50 kg ha^{-1} followed a decreasing trend in head diameter i.e. 20.44 cm and 19.71 cm, respectively. The minimum head diameter (18.79 cm) was noted in plots fertilized with lowest NP @ 80-40 kg ha^{-1}. So far the irrigation levels are concerned, the maximum head diameter of 21.77 cm was noted from the plots receiving four irrigations; while the head diameter reduced to 20.37 cm and 19.64 cm when the crop was given three and two irrigations, respectively. However, the minimum head diameter (18.79 cm) was observed from the plots

given only one irrigation. The interactive effect indicated that the interaction (NP @ 140-50 kg ha^{-1} × 4 irrigations) produced maximum head diameter (23.14 cm) and minimum head diameter (17.01 cm) was noted in the interaction (NP @ 80-40 kg ha^{-1} × 1 irrigation).

Number of seeds $head^{-1}$

The sunflower fertilized with highest NP rate of 140-50 kg ha^{-1} resulted in highest number of seeds (1602.93) $head^{-1}$, followed by 1533.08 and 1477.90 average number of seeds $head^{-1}$ obtained from the plots fertilized with NP @ 120-50 kg ha^{-1} and 100-50 kg ha^{-1}, respectively. The lowest number of seeds $head^{-1}$ (1428.33) was noted in plots fertilized with lowest NP @ 80-40 kg ha^{-1}. In case of irrigations, the highest number of seeds $head^{-1}$ (1632.30) was observed in plots receiving four irrigations; followed by three irrigations and two irrigations with 1540.08 and 1454.00 seeds $head^{-1}$, respectively. However, the lowest number of seeds $head^{-1}$ (1415.80) was noted from the plots given only one irrigation. The interaction studies showed that interaction (NP @ 140-50 kg ha^{-1} × 4 irrigations) resulted in highest number of seeds $head^{-1}$ (1735.20) and minimum number of seeds $head^{-1}$ (1302.90) was found in the interaction (NP @ 80-40 kg ha^{-1} × 1 irrigation).

Table 6. Effect of fertilizers and irrigation on number of seeds $head^{-1}$

NP levels	Number of irrigations				Mean
	1 irrigation	2 irrigations	3 irrigations	4 irrigations	
F_1=80-40 kg ha^{-1}	1302.90	1382.40	1476.50	1551.50	**1428.33 c**
F_2=100-50 kg ha^{-1}	1397.10	1419.10	1500.00	1595.40	**1477.90 c**
F_3=120-50 kg ha^{-1}	1448.50	1477.90	1558.80	1647.10	**1533.08 b**
F_4=140-50 kg ha^{-1}	1514.70	1536.80	1625.00	1735.20	**1602.93 a**
Mean	**1415.8 c**	**1454.00 c**	**1540.08 b**	**1632.30 a**	**-**

	N-P Levels (F)	No. of Irrigations (I)	(F x I)
S.E.±	26.884	26.884	53.767
LSD 0.05	54.904	54.904	-
LSD 0.01	73.930	73.930	-

Seed index

The crop fertilized with highest NP rate of 140-50 kg ha^{-1} resulted in highest seed index value (65.92 g), followed by 63.05 g and 60.78 g average seed index value noted in plots fertilized with NP @ 120-50 kg ha^{-1} and 100-50 kg ha^{-1}, respectively. The lowest seed index value (58.74 g) was noted in plots fertilized with lowest NP @ 80-40 kg ha^{-1}. In case of

irrigations, the highest seed index value (67.13 g) was noted in plots receiving four irrigations; followed by 3 irrigations and 2 irrigations with average seed index value of 63.32 g and 60.05 g, respectively. However, the lowest seed index value (57.99 g) was observed in plots irrigated once only in whole season. The interaction studies showed that interaction (NP @ 140-50 kg ha^{-1} × 4 irrigations) resulted in highest seed index value (71.36 g) and minimum seed index value (52.64 g) was found in the interaction (NP @ 80-40 kg ha^{-1} × 1 irrigation).

Yield

The crop receiving highest NP dose of 140-50 kg ha^{-1} resulted in maximum seed yield (1465.90 kg ha^{-1}), followed by seed yield of 1380.90 and 1144.90 kg ha^{-1} achieved from the plots given NP @ 120-50 kg ha^{-1} and 100-50 kg ha^{-1}, respectively. The lowest seed yield ha^{-1} (1032.10 kg) was obtained in plots fertilized with lowest NP @ 80-40 kg ha^{-1}. In case of irrigation levels, the highest seed yield ha^{-1} (1585.50 kg) was achieved from the plots receiving four irrigations; followed by three irrigations and two irrigations with average seed yield of 1362.80 kg and 1184.70 kg ha^{-1}, respectively. However, the lowest seed yield ha^{-1} (890.70 kg) was noted from the plots given only one irrigation. The interaction studies showed that interaction (NP @ 140-50 kg ha^{-1} × 4 irrigations) resulted in highest seed yield ha^{-1} (1850.60 kg) and minimum seed yield ha^{-1} (732.00 kg) was noted in the interaction (NP @ 80-40 kg ha^{-1} × 1 irrigation). It was observed that reduction in the dose of mineral fertilizers, resulted severe adverse impact on the seed yield ha^{-1}. Similarly, adverse effects of water stress on sunflower were noted and decreasing the number of irrigations resulted in decline in crop yields.

Table 7. Effect of fertilizers and irrigation on seed index

NP levels	**Number of irrigations**				**Mean**
	1 irrigation	**2 irrigations**	**3 irrigations**	**4 irrigations**	
F_1=80-40 kg ha^{-1}	52.64	57.85	60.66	63.80	**58.74 c**
F_2=100-50 kg ha^{-1}	57.45	58.36	61.69	65.63	**60.78 b**
F_3=120-50 kg ha^{-1}	59.57	60.78	64.11	67.74	**63.05 b**
F_4=140-50 kg ha^{-1}	62.29	63.21	66.83	71.36	**65.92 a**
Mean	**57.99 c**	**60.05 b**	**63.32 b**	**67.13 a**	**-**

	N-P Levels (F)	**No. of Irrigations (I)**	**(F x I)**
S.E.±	1.3179	1.3179	2.6359
LSD 0.05	2.6916	2.6916	-
LSD 0.01	3.6243	3.6243	-

Table 8. Effect of fertilizers and irrigation on yield

NP levels	Number of irrigations				Mean
	1 irrigation	2 irrigations	3 irrigations	4 irrigations	
F_1=80-40 kg ha^{-1}	732.00	973.60	1120.00	1303.00	**1032.10 d**
F_2=100-50 kg ha^{-1}	812.00	1080.00	1242.40	1445.40	**1144.90 c**
F_3=120-50 kg ha^{-1}	979.30	1302.50	1498.40	1743.20	**1380.90 b**
F_4=140-50 kg ha^{-1}	1039.70	1382.80	1590.70	1850.60	**1465.90 a**
Mean	**890.70 d**	**1184.70 c**	**1362.80 b**	**1585.50 a**	-

	N-P Levels (F)	No. of Irrigations (I)	(F x I)
S.E.±	36.945	36.945	73.889
LSD 0.05	75.451	75.451	-
LSD 0.01	101.60	101.60	-

DISCUSSION

The present study shows that sunflower traits examined in study were significantly ($P<0.05$) affected by varying levels of mineral fertilizers and irrigation levels. The crop given N-P @ 140-50 kg ha^{-1} resulted in maximum values for all the traits examined taking 72.67 days to 75% flowering, 110.75 days to 90% maturity, 169.38 cm plant height, 5.19 cm stem girth, 21.38 cm head diameter, 1602.93 seeds head^{-1}, 65.92 g seed index and 1465.90 kg ha^{-1} seed yield. The crop receiving N-P @ 120-50, 100-50 and 80-40 kg ha^{-1} followed an adverse trend for all the growth and yield traits and seed yields were declined considerably as compared to higher N-P level. These results are in agreement with those of Ajai Singh *et al.* (2000) reported that yield components and seed yields of sunflower increased with increasing N and P rates; while Reddy and Shaikh (2000) further reported that plant height and yield were increased by P application and were greatest with 100 kg N. Ayyappan *et al.* (2002) observed greatest head diameter, 100-seed weight, and seed yield which were obtained with 120 and 150 kg N ha^{-1}. N at 120 kg ha^{-1} gave the highest seed oil content, whereas N at 174 kg ha^{-1} gave the highest seed protein content. Thus, 120 kg N ha^{-1} was optimum for higher sunflower yield and oil content. Thavaprakash and Malligawad (2002) found higher sunflower seed yields (3554 and 3397 kg ha^{-1}), more gross returns (Rs. 35538 and 33967 ha^{-1}), more net returns (Rs. 24249 and 23336 ha^{-1}). Mojiri and Arzani (2003) reported that N fertilizer up to 150 kg ha^{-1} increased the grain yield and biological yield in sunflower. Siddiqui (2010) suggested NPK @ 90-45-45 kg ha^{-1} for achieving higher sunflower yields.

The present study further showed that four irrigations resulted in improved growth and highest seed yield as compared to lower irrigation levels and for profitable cultivation of sunflower the crop may be given 4 irrigations, because water stress impacted the crop yields negatively. These results are well comparable with the findings of Alahdadi *et al.* (2011) who suggested an irrigation interval of 10 days, equivalent to 60% depletion of available water, is optimum for reasonable sunflower production. Similarly, Bakhsh *et al.* (1999) evaluated the effect of irrigation frequencies i.e. 0, 2, 4, 6 and 8 and concluded that parameters like plant height, head diameter, number of grains per head, 1000-grain weight and grain yield per hectare were significantly affected by irrigation levels and six irrigations were found optimum for obtaining good yield of sunflower. On the basis of research findings, six irrigations are recommended for sunflower crop to obtain maximum seed yield under irrigated conditions. Bakht *et el.* (2010) reported that seed yield with three irrigations was 24.83% higher than the control plot. Maximum leaf area index was observed when irrigation was given at 90 day interval after emergence of the sunflower (third irrigation). The same trend was also observed in dry matter accumulation and crop growth rate. In another study, Abdou *et al.* (2011) reported that the highest water use efficiency, i.e. 0.470 and 0.486 kg seeds/m^3 water consumed.

Conclusions

It was concluded that highest N-P level of 140-50 kg ha^{-1} produced highest sunflower seed yield, and seed yield decreased with curtailing the rate of mineral fertilizers. Similarly, four irrigations resulted in improved growth and highest seed yield as compared to lower irrigation levels. For profitable cultivation of sunflower the crop may be fertilized with NP @ 140-50 kg ha^{-1} and given 4 irrigations, because reduction in the dose of mineral fertilizers and water stress impacted the crop yields adversely.

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