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Response of Sunflower (*Helianthus annuus* L.) to Sulphur and Seasonal Variations

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ABSTRACT

Field experiments were conducted during spring and autumn to evaluate the effects of sulphur and seasonal variations on sunflower. Four sunflower hybrids (SAL-105, Mehran-II, G-101 & Parsun-II) and four sulphur levels (0, 10, 15 & 20 kg ha^{-1}) were arranged in a randomized complete block design with four replications. Amongst hybrids, SAL-105 produced the highest achene yield during both the seasons. Yield and yield attributes were significantly affected by sulphur levels and seasons. Overall performance of spring crop was found to be better than that of autumn crop. Sulphur (20 kg ha^{-1}) affected yield and yield attributes positively as compared to rest of the treatments. Sulphur levels and hybrids exhibited significant differences for oil content during both the seasons. Interactive effects of sulphur and hybrids on achene yield were found to be significant.

Key Words: *Helianthus annuus* L.*;* Sulphur; Seasons; Achene yield; Oil content

INTRODUCTION

The major sources of edible oil production in Pakistan are the conventional oilseeds crops (cottonseed, rapeseed, mustard & sesame) and non-conventional oilseed crops (sunflower & soybean). Among the non-conventional oilseed crops sunflower has the potential to narrow the existing gap between production and consumption of edible oil.

Apart from climatic conditions, nutrients available for growth and development may influence the overall plant structure and yield. Sulphur is the fourth major nutrient in crop production. Most of the crops require as much sulphur as phosphorus. Sulphur is the component of the amino acids, cystin, cystein and methionine, needed for chlorophyll (Marschner, 1995). Sulphur also plays an important role in the chemical composition of seeds. It increases the percentage of oil (Saron & Giri, 1990). Poonia (2000) recorded significant increase in dry matter, plant height, head diameter, number and weight of seeds, test weight, seed and biological yields of sunflower when sulphur was applied at 25 kg S ha^{-1}. The increase in seed yield was observed up to 50 kg S ha^{-1}. Similarly, Wani *et al.* (2001) observed significant increase in seed yield and protein content of sunflower with the increase in sulphur level. Sulphur takes time to become available to plants, thus affects the succeeding crop. Babu and Hegde (2002) studied the residual response of sulphur on rice-sunflower and sunflower-groundnut cropping systems. The residual effect on succeeding sunflower crop resulted in 37% increase in seed yield and 45% increase in oil yield.

Though sunflower is a temperate zone crop, it can perform well under various climatic and soil conditions. The wider adaptability of the crop and wide range of climatic conditions of Pakistan make it possible to have two crops of sunflower in a year. Khalifa *et al.* (2000) concluded that wide geographic, morphological and habitat wise diversity of sunflower extending from very hot to very cold areas might have developed the unique characteristics of sunflower tolerance to both low and high temperatures and accounted for wide adaptation of the crop.

Temperature being the major determinant of plant growth and development has been widely studied for different crops. Rondanini *et al.* (2003) concluded that brief periods of high temperature reduced grain weight and quality in temperate cereals but the nature of sunflower grain growth and oil quality responses to exposure to high temperature are differential. However, they observed that brief periods of heat stress produced sunflower grains with a lower weight, a greater percentage of pericarp, a lower oil content and an altered fatty acid composition. Similarly, Roche *et al.* (2004) reported that environmental factors, mainly temperature and water availability, play a major role in oil quality of sunflower. Delayed sowing improved protein content and seed weight but decreased yield, whereas oil content was not depressed.

Sunflower can successfully be grown in two seasons (spring i.e., February/March & autumn i.e., July/August) in Pakistan due to its wide range of adaptability. Thus, two opposite sets of environmental conditions prevail from germination to maturity of sunflower when it is grown in two seasons i.e., spring and autumn. Overall length of crop life cycle is affected accordingly. Germination and vegetative stage of spring crops take relatively longer time due to lower temperature as compared to autumn crop, where germination and vegetative growth take place under high temperature taking less time and complete its cycle very shortly.

Being grown in diverse environmental conditions all phases are affected accordingly. Thus, availability of nutrients to plants is also affected. The present study was contemplated to evaluate sulphur and seasonal variation impacts on yield, yield attributes and oil accumulation of sunflower hybrids.

MATERIALS AND METHODS

The present experiments were conducted at the farm area of the University of Arid Agriculture, Rawalpindi, Pakistan, during spring and autumn 2004. The experimental area lies 33^o 38' N and 73^o 04 E. The Physio-chemical properties of the experimental site are given in Table I.

The experiments were laid out in randomized complete block design with four sunflower hybrids (SAL-105, Mehran-II, G-101 & Parsun-II) and four levels of sulphur (S_1 = 0, S_2 = 10, S_3 = 15, S_4 = 20, kg ha^{-1} elemental S) replicated thrice. There were five rows of five meter length, 75 cm apart in each plot making a plot size of 5 m x 3 m with plant to plant distance of 25 cm. A uniform dose of fertilizer was applied (120 kg N, 60 kg P_2O_5) per hectare in the form of Urea and DAP and mixed with soil during land preparation. Elemental Sulphur was added in plots immediately after sowing. Sowing was done on 27.03.2004 of spring and on 23.08.2004 of autumn crops respectively. Planting was done with dibbler placing 3 - 4 seeds per hill at a depth of 3 - 5 cm in the soil. At three leaves stage thinning was done to maintain one plant per hill. At maturity central two rows were harvested on 16-07-04 and 19-11-04 of spring and autumn crops, respectively. For recording achene yield per plot harvested heads were sun dried for ten days before threshing. Dried heads were threshed manually and yield per hectare was calculated. Head diameter was recorded by taking average of randomly selected ten plants per plot. Thousand achene weight (g) was recorded on the basis of average by selecting three random samples of 1000-seeds from the produce of each plot. Oil contents were determined by following the Nuclear Magnetic Resonance technique. The data collected were subjected to statistical analysis appropriate to Randomized Complete Block Design by using M. Stat. C (Freed & Eisensmith, 1986). Means were compared for significance using LSD at 5% level of probability (Steel & Torrie, 1980).

RESULTS

Sulphur treatments significantly affected head diameter during both the seasons i.e., spring and autumn. The maximum head diameter of 17.3 cm was recorded in S_4 (20 kg ha^{-1}) treatment followed by S_2 with head diameter of 16.0 cm during spring season, while the smallest (15.0 cm) heads were observed in S_1 (control) (Table II). In case of autumn season, the maximum head diameter of 16.0 cm was again observed for treatment S_4, while S_2 and S_3 showed statistically at par values i.e., (14.4 cm) and (15.0 cm), respectively. The smallest (13.4 cm) head diameter was recorded for S_I again. Head size decreased for all the treatments during autumn than that observed during spring. However, reduction in S_4 was the least. Sulphur treatment S_4 showed better performance during both the cropping seasons.

The hybrids differed significantly for head diameter during both the seasons i.e., spring and autumn. Sunflower hybrid SAL-105 produced the biggest (17.7 cm) head diameter followed by Parsun-II (16.4 cm) during spring and were statistically at par with each other but significantly differed from rest of the hybrids. The smallest head was observed from Mehran-II with diameter of 14.8 cm during spring season. Head diameter of all the hybrids decreased in autumn than that of spring. During autumn season, again hybrid SAL-105 produced the largest head with diameter of 15.6 cm, while the smallest was observed from G-101 with diameter of 15.1 cm.

Interactive effects of sulphur and hybrids remained statistically non-significant (Table II). Similar to head diameter, thousand achene weight (TAW) was significantly affected by Sulphur treatments. The maximum (46.1 g) TAW was recorded for S_4 followed by S_3 those were at par with each other, but significantly different from S_1 and S_2 (Table II) during spring. The minimum (43.7 g) TAW was recorded in S_1. Thousand achene weight during autumn increased for all the sulphur treatments. The maximum (53.3 g) was recorded for S_3 followed by S_4 and S_2 those were statistically at par with each other. Thus significance level was narrow during autumn. The minimum (51.2 g) value of TAW was again recorded for S_1.

The hybrids differed significantly for TAW during both the seasons i.e., spring and autumn. Hybrid SAL-105 gave the maximum (46.8 g) TAW followed by Parsun-II and G-101 with TAW of 45.8 g and 44.2 g, respectively during spring season. The minimum achene weight of 42.7 g was produced by Mehran-II during spring season. Thousand achene weights of all the hybrids increased during autumn. During autumn, again SAL-105 was at the top with 55.6 g TAW followed by Parsun-II (55.2 g), those were at par with each other (Table II). Hybrid Mehran-II again gave the minimum (48.0 g) TAW. Hybrids x sulphur interaction showed non-significant differences during both (spring & autumn) seasons.

Sulphur treatments showed significant effects on achene yield during both the seasons i.e., spring and autumn. During spring, the maximum achene yield (2018.3 kg ha^{-1}) was recorded for S_4 and the minimum (1820.4 kg ha^{-1}) from S_1. During autumn, achene yield of all the sulphur treatments decreased slightly. However, again S_4 and S_1 exhibited the maximum (1817.9 kg ha^{-1}) and the minimum (1681.7 kg ha^{-1}) achene yield respectively (Table II).

Table I. Physio-chemical properties of experimental site

Clay %	Silt %	Sand %	Bulk Density mg cm^{-3}	pH	ECe dSm^{-1}	Organic Matter (%)	N (%)	P (%)	K ppm	S
15	14	71	1.6	7.7	0.25	0.66%	3.84	6.5	130	0.6%

Table II. Effect of sulphur and seasonal variations on sunflower

Treatments	Seasons							
	Spring				Autumn			
Sulphur level(kg/ha)	HD (cm)	TAW (g)	AY (kg/ha)	OC (%)	HD (cm)	TAW (g)	AY (kg/ha)	OC (%)
S1 0	15.0	43.7	1820.4	42.3	13.4	51.2	1681.7	38.1
S2 10	16.0	44.3	1885.4	43.9	14.4	52.1	1719.8	40.7
S3 15	15.7	45.4	1937.1	46.8	15.0	53.3	1751.6	42.7
S4 20	17.3	46.1	2018.3	46.4	16.1	52.6	1817.9	45.1
Hybrids								
H1 (SAL-105	17.7	46.8	2187.1	48.2	15.6	55.6	2008.5	44.5
H2 (Mehran-II)	14.8	42.7	1406.1	41.6	14.2	48.0	1206.7	37.2
H3 (G-101)	15.1	44.2	2027.3	46.2	14.0	52.2	1815.5	43.8
H4 (Parsun-II)	16.4	45.8	2040.7	43.3	15.1	55.2	1940.3	40.9
Interaction								
H1x S1	16.5	45.9	2133.3	46.1	14.5	53.6	1798.3	39.8
H1x S2	17.5	46.6	2200.7	46.5	15.3	55.8	1915.7	43.3
V1 x S3	17.9	47.0	2204.3	48.8	15.9	56.4	2033.7	46.4
V1 x S4	18.8	47.6	2210.0	51.5	16.6	56.5	2286.3	48.54
H2 x S1	13.6	40.9	1127.3	39.5	12.7	46.3	1182.0	32.6
H2 x S2	15.7	41.6	1328.7	40.9	13.9	47.5	1212.0	35.4
H2 x S3	14.2	43.2	1505.0	42.2	14.2	48.5	1213.7	41.44
H2 x S4	15.5	45.1	1663.3	43.9	15.8	49.8	1219.0	39.64
H3 x S1	14.1	42.4	1986.0	43.3	13.3	50.7	1815.0	40.94
H3 x S2	14.5	43.2	2010.0	45.1	13.8	51.0	1815.7	43.74
H3 x S3	14.6	45.2	2027.7	51.3	14.2	53.5	1815.0	43.9
H3 x S4	17.4	46.0	2085.7	45.1	14.9	53.5	1816.3	46.9
H4 x S1	15.7	45.3	2085.7	40.4	12.9	54.1	1931.3	39.1
H4 x S2	16.2	45.9	2002.3	42.9	14.6	54.3	1936.0	40.4
H4 x S3	16.1	46.1	2011.3	45.0	15.6	55.0	1944.0	39.1
H4 x S4	17.5	45.7	2114.3	45.0	17.3	57.5	1950.0	45.3
LSD(p<0.05)								
Sulphur	1.31	1.71	93.910	0.92	0.96	2.54	103.39	0.87
Hybrids	1.29	1.73	93.890	0.89	0.97	2.53	103.40	0.86
Interaction	NS	NS	187.80	1.84	NS	NS	206.80	1.73

HD: Head diameter, TAW: Thousand Achene weight, AY: Achene's yield, OC: Oil content

The sunflower hybrids differed significantly for achene yield during both the seasons i.e., spring and autumn. In spring, the maximum achene yield of 2187.1 kg ha^{-1} was recorded for SAL-105 followed by Parsun-II with yield of 2040.8 kg ha^{-1}, these were statically at par with each other. The minimum achene yield of 1406.1 kg ha^{-1} was recorded for Mehran-II. Achene yield of all the hybrids decreased in autumn, however, again hybrid SAL-105 gave the maximum yield of 2008.5 kg ha^{-1} followed by Parsun-II with 1940.3 kg ha^{-1}. The lowest yield of 1206.7 kg ha^{-1} was recorded for Mehran-II (Table II). Reduction during achene yield of autumn crop ranged between 8 to 14% over spring crop.

Interaction of hybrids x sulphur resulted significant differences. The maximum achene yield of 2210 kg ha^{-1} was produced by $H_1 \times S_4$ and the minimum of 1127.3 kg ha^{-1} was given by $H_2 \times S_1$ during spring season. During autumn season, again the highest achene yield of 2286.3 kg ha^{-1} was exhibited by $H_1 \times S_4$ and the minimum achene yield of 1182 kg ha^{-1} was observed for $H_2 \times S_1$.

Sulphur treatments affected oil contents significantly (Table II). During spring, the maximum (46.8%) oil content was exhibited by S_3, which was at par with S_4. The minimum (42.3%) oil content was recorded in S_1. During autumn season, the maximum (45.1%) oil content was recorded with S_4, which was significantly different from all other treatments. However, S_1 again gave the minimum (38.1%) oil content. Oil content of all sulphur treatments decreased during autumn than that of spring in a range of 2.6 to 7.9%.

Significant variations were observed among hybrids for oil contents. The maximum (48.2%) oil content was observed in SAL-105, while the minimum (41.6%) oil content were recorded in Mehran-II during spring season. During autumn season, the maximum (44.5%) oil was again given by SAL-105 and the minimum (37.2%) by Mehran-II.

Interaction of sulphur x hybrids, resulted significant differences. The maximum (51.5%) oil contents were exhibited by H_1 x S_4 and the minimum (40.4%) in H_4 x S_1 during spring season. During autumn season, the highest oil contents (48.6%) were exhibited again by H_1 x S_4, however the minimum oil contents of (32.6%) were given by H_2 x S_1.

DISCUSSION

An insufficient S supply can affect yield and quality of crops; caused by the S involved in protein and enzyme synthesis as well it is a constituent of the amino acids methionine, cystin and cystein. Sulphur depletion in soil is mainly caused by leaching. It takes place when the water moving vertical downward in soil profile is higher than that of the water uptake of the plants, evapo-transpiration and the amount of water necessary for the saturation of the soil (Scherer, 2001). Total S requirement mainly differs between crop species and the development stages of plant. In general S demand of oilseed crops are higher than those of cereal crops as they contain more S containing compounds needed for oil biosynthesis (Scherer, 2001). In present study, S application response was positive and consistent, which progressively improved the yield attributes, yield and oil contents. However, narrow range of difference may be due to relatively lower doses of S used in this study. Oilseeds have high demand of S, approximately 16 kg S is required to produce one ton of seed containing 91% dry matter (MacGrath & Zhao, 1996). Higher S demand of oilseed crops is related to oil biosynthesis. Significant variation among S treatments for oil content is concomitant with earlier findings. Reduction of oil content from higher doses of S in autumn crop was smaller as compared to other treatments. It is also pertinent to say, that presence of S had alleviated the impact of seasonal variations on (*Helianthus annuus*). However, in *Brassica* N: S ratio is considered to be responsible for an improvement of the oil content (Fismes *et al*., 2000).

Grain yield is the interplay of many components contributing towards final harvest. Yield depends on the ability of crop to capture resources (Monteith, 1994). Major resources are radiation, water and nutrient those also modulate leaf expansion and root growth, feeding back the ability of the crop to convert these into yield. Ground cover at anthesis may be a good measure of the capacity of the canopy to capture light and a measure of crop size that also reflects its ability to capture other resources (Mercau *et al*., 2001). Grain numbers have close association with yield, which was positively related to radiation and negatively to temperature (Cantagello, 1997). Larger head observed in spring crop in the present study would have developed more number of grains thus giving better yield than that of autumn crop; however, individual grain weight was affected negatively in autumn crop. Less number of grains developed on smaller heads would not have faced any competition for assimilates thus produced heavier individual grain weight. So, achene yield was affected accordingly. Significant relationship between head diameter and achene yield in spring (Fig. 1) and autumn (Fig. 2) support this view. Seasonal effects on yield attributes could also be related to the overall plant structure and length of crop life cycle. Spring crop matured late taking about 26 days more than that of autumn crop. Significant relationship between crop life cycle and dry matter accumulation in linseed has been reported by Hassan and Leitch (2001). This may also be the effect of temperature and moisture availability. Chapman and De La Vega (2002) observed significant relationship between rainfall, grain yield and oil content. They concluded that seasonal variation of total rainfall during months of reproductive phases was significantly correlated with crop characteristics. However, the influence of rainfall on sunflower yield is not straightforward. On one hand shortage of water reduces leaf expansion, light interception, growth and yield (Sadras *et al*., 1991). On the other hand abundant moisture favors many fungal diseases. In present study, reduction of yield and yield attributes of autumn crop are in line to above hypotheses. However, positive relationship between thousand achene weight and final yield in spring (Fig. 3) and autumn (Fig. 4) is in accordance with

Fig. 1. Relationship between Head diameter and achene yield in spring

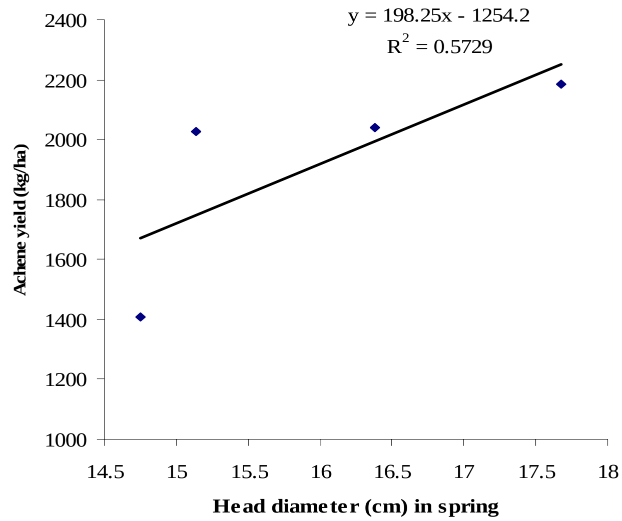


Fig. 2. Relationship between head diameter and achene yield in autumn

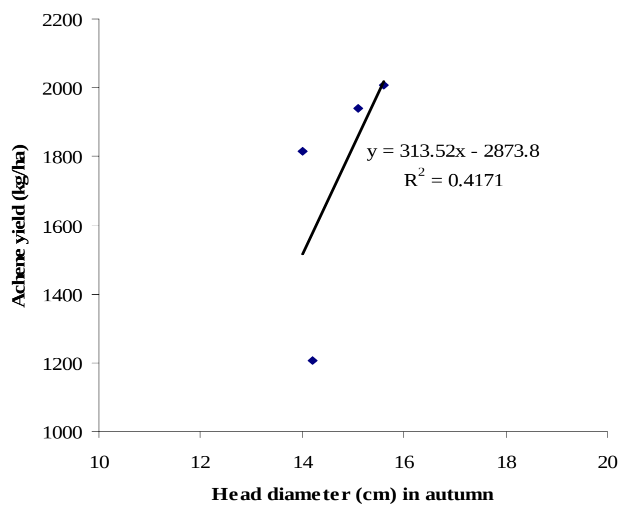


Fig. 3. Relationship between TAW and achene yield in spring

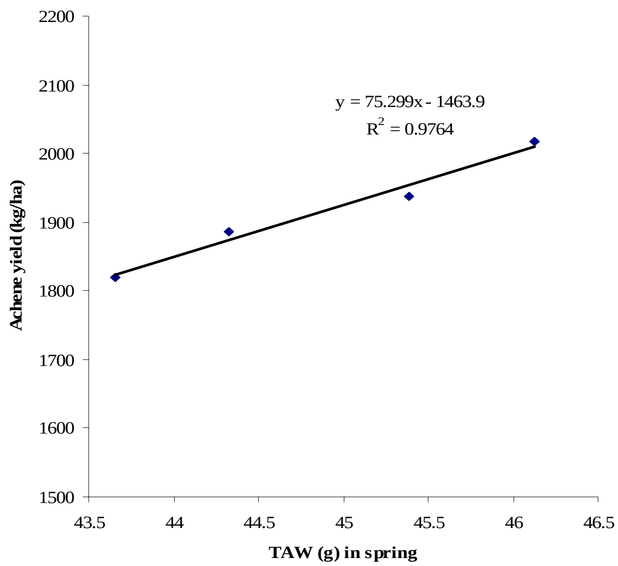
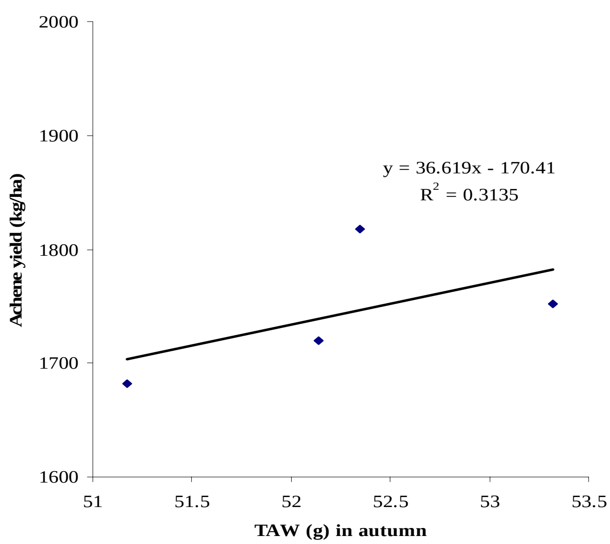


Fig. 4. Relationship between TAW and achene yield in autumn



findings of Mercau *et al*. (2001), they reported that most of variations in yield were accounted for grain number. Variation in oil content may be due to environmental factors especially temperature during seed development and maturation. Similar conclusion has been made by Seiler (1983), who concluded that oil accumulation in sunflower is affected by temperature.

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