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Growth and nutrient uptake of sunflower hybrids as influenced by irrigation methods and sulphur nutrition

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Abstract
A field experiment was conducted at Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana to evaluate the performance of sunflower hybrids in response to irrigation methods and sulphur fertilization during spring 2016 and 2017. The experiment was laid out in Randomized Complete Block Design with two sunflower hybrids (PSH 1962 and PSH 996), two methods of irrigation (drip and furrow irrigation) and four levels of sulphur *viz*. 0, 20, 40 and 60 kg S ha^{-1} with three replications. The results of the study revealed that among the hybrids, PSH 1962 recorded significantly higher growth and yield attributes *viz*. plant height, stem girth, capitulum diameter, seed per capitulum and 1000-seed weight. The hybrid PSH 1962 recorded 17.9 and 7.5% significant higher yield than PSH 996 during 2016 and 2017, respectively. Among the methods of irrigation, drip irrigation resulted in significantly better growth and uptake over furrow irrigation during both the years and sunflower seed yield was 13.9 and 16.2% more in drip irrigation over furrow irrigation in 2016 and 2017, respectively. Application of sulphur resulted in significant increase in growth and yield attributes up to 60 kg S ha^{-1}. Sulphur application @ 60 kg ha^{-1} gave 6.8, 14.5 and 22.0% higher seed yield over 40, 20 and 0 kg S ha^{-1} during 2016 and 9.4, 24.2 and 42.8% during 2017. Application of 60 kg S/ha recorded 33.9 and 58.1% of significantly higher sulphur uptake over control during 2016 and 2017, respectively.

Keywords: Methods of irrigation, nutrient uptake, sunflower hybrids, sulphur nutrition

Introduction
Oilseeds constitute a very important group of commercial crops in India. The oil extracted from oilseeds form an important component of our diet and is used as raw material for manufacturing large number of products like paints, varnishes, hydrogenated oil, soaps, perfumery, lubricants, etc. Oil-cake after oil extraction from the oilseeds also used as cattle-feed and manure. In India there are two major group of oilseed crop namely edible and non-edible. Groundnut, rapeseed and mustard, sesame, safflower, Niger, soybean and sunflower form the edible while linseed and castor categorizing under non-edible group. India import edible oil of worth rupees 59094.76 crore during 2014-15, which is a big drain on Indian economy. So, sulphur nutrition being a perspective management practice to be followed to enhance the oil content of oilseed crops, as well as to meet the increasing demands of edible oils and also check country's import exchanges.

Sunflower (*Helianthus annuus* L.) commonly known as '*surajmukhi*' belongs to family compositae and is a native of North America. Sunflower ranks third amongst the oil producing crops next to soybean, rapeseed and mustard in the world. Sunflower mainly cultivated in Argentina, Bolvia, Bulgaria, China, Croatia, France, Hungry, India, Israel, Italy, Kajakistan, Moldova, Mayanmar, Pakistan, Paraguay, Romania, Russia, Serbia, South Africa, Spain, Sudan, Turkey, Uganda, Ukraine, USA and Switzerland for edible oils. In India sunflower is being cultivated in Karnataka, Andhra Pradesh, Maharashtra, Punjab, Haryana, Uttar Pradesh, Bihar, West Bengal and Odisha. In Punjab, sunflower was cultivated on 5000 hectare with total production of 9700 tonnes at productivity levels of 1933 kg ha^{-1} (Anonymous 2016) [1].

Sunflower is a short duration, thermo and photo insensitive plant with wide range of climatic adaptability. In Punjab, sunflower crop is being cultivated during spring season (end of January to first week of February), as honey bees remain available in abundance during this season and help in pollination. However, high evaporative demand of spring season makes its water requirement quite high despite a short duration crop. Spring sunflower generally requires 6-9 irrigations depending upon the soil type, rain and weather prevalent. The crop uses only 20-25 percent of its total water requirement during the first 30 days and major portion required during the reproduction stage (Ghani *et al.*, 2000) [5].

The most critical period of sunflower yield determinants are anthesis and grain filling (Chimenti and Hall 1992) [3]. Yield of sunflower is greatly influenced by fertilizer and irrigation practices. Potential seed yield can be achieved by adopting optimum fustigation and irrigation schedules.
Maintenance of adequate moisture in soil profile through irrigation is an important pre-requisite to reap the rich harvest of sunflower crop. Irrigation plays an important role in ripening and synchronous maturity of heads as it exhibits hydro positive features. There is also possibility of reducing crop water requirement by irrigating the crop by using drip irrigation which provides precise and site specific water and nutrient application near the root zone of plant. Water use efficiency and yield of crops can be improved greatly by using drip irrigation, under limited water applications by decreasing the leaching loses (El-Hendawy *et al.*, 2008) [4]. Drip irrigation improves the water use efficiency, nutrient uptake and quality of the produce (Kaur and Brar 2016) [6].
Optimum utilization of nutrients is an important factor which determines crop yield. Sulphur is an essential nutrient in oilseed production and sometimes called as 4th major nutrient and become more important as a limiting nutrient in crop production. Sulphur is involved in the synthesis of chlorophyll and is also required for synthesis of oil. It plays a major role in increasing the oil content of the seed and as is a major constitute of oil (Chaudhary *et al.*, 1992) [2]. Application of sulphur in oilseeds shows a great promise in promoting seed yield and oil content, which can be obtained by the proper adjustment of sulphur application. The central hypothesis of the study is to supply sulphur nutrition in oilseed crops in order to enhance the oil content as well as seed yield. To test the hypothesis different experiments were conducted at different regions, results were collected and studied further and finally the conclusion was drawn.

2. Materials and Methods
2.1 Location and Climate
Ludhiana is located in the central plain region of Punjab state, in the trans-gangetic agro-climatic zone of India, at 30^0 54' N latitude and 75^0 48' E longitudes, at an average rise of 247 m above mean sea level. This region's climate is subtropical and semi-arid, with a very hot and dry summer from April to June, a hot and humid summer from July to September, a cold winter from November to January, and a pleasant climate in February and March. During summer and winter, the mean minimum and maximum temperatures vary greatly. The average annual rainfall in Ludhiana is 755 mm, with the majority (> 75% of that) pouring during the summer monsoon season from July to September. During winter, the rains are scanty but a few showers of cyclonic rains are received during December-January or late spring. The spring season is distinguished by mild temperature during sowing and bright sunshine hours during the flowering or maturity stage of spring crops such as sunflower.

2.2 Methodology
The field experiment was conducted in randomized complete block design (RCBD) keeping combination of two hybrids (PSH-1962 and PSH-996), two methods of irrigation (drip and furrow) and four sulphur levels. (T_1: control [fertigation of recommended fertilizers and drip irrigation], T_2: T1+ 20 kg ha^{-1} elemental sulphur by fertigation, T_3: T_1+ 40 kg ha^{-1} elemental sulphur by fertigation, T_4: T1+ 60 kg ha^{-1} elemental sulphur by fertigation, T5: control (soil application of recommended fertilizers and furrow irrigation), T_6: T_5 + 20 kg ha^{-1} sulphur with gypsum + furrow irrigation, T_7: T_5 + 40 kg ha^{-1} sulphur with gypsum + furrow irrigation and T8: T5 + 60 kg ha^{-1} sulphur with gypsum + furrow irrigation) using 2 sunflower hybrids during 2016 and 2017. Recommended dose of 60 kg N (125 kg urea) and 30 kg P_2O_5 ha^{-1} through (single superphosphate) in furrow irrigated plot and 48 kg N (100 kg urea) and 24 kg P_2O_5 ha^{-1} through mono ammonium phosphate (MAP) in drip fustigated plot were applied. In furrow irrigated plots (half N, full P_2O_5 and gypsum) were applied as basal application and remaining N was applied one month after sowing as top dressing. In drip irrigated plots 1/5 N and 1/5 P_2O_5 were applied as basal and remaining (4/5 N, 4/5 P_2O_5 and full elemental sulphur) were applied in 5 splits, which was started at 30 DAS with an interval of 9 days on ventury system. Drip irrigations were applied at three days interval and depth of each irrigation kept equal to 80 percent of cumulative crop evapo-transpiration (ETc). Reference evapotranspiration (ET_0) was calculated with the help ET_0 calculator software developed by FAO using location specific meteorological data (maximum temperature, minimum temperature, maximum and minimum relative humidity, rainfall, sunshine hour and wind velocity).

3 Results and Discussion
3.1 Growth attributes
3.1.1 Plant height
The growth and development of a crop can be determined by recording the plant height, as height indicates the strength and vigor of a plant to the existing environmental conditions. Plant height of sunflower hybrids increased successively with passage of time and increase was maximum between 50-70 days after sowing (DAS). Thus 50-70 DAS period of sunflower hybrids can be called as grand growth period. Plant height of sunflower hybrids influence significantly with methods of irrigation and varying levels of sulphur during 2016 and 2017 (Table 1). PSH-1962 recorded significantly higher plant height at 30, 50, 70, 90 DAS and at harvest as compared to PSH-996 during both the years. At 70 days after sowing, PSH- 1962 produced 8.66 percent and 5.56 percent taller plant height than PSH-996 during, 2016 and 2017 respectively. The higher plant height of PSH- 1962 recorded due to genetic make-up of the hybrid.
Drip irrigated crop produced significantly taller plant than furrow irrigated at all the growth stages of crop during both the years except 30 and 50 DAS during 2017, irrespective of hybrids and sulphur levels. At 70 and 90 DAS drip irrigated crop recorded 3.80 and 2.94 percent and 9.05 and 8.61 percent taller plant than furrow during 2016 and 2017, respectively. Better plant height under drip irrigation was resulted from better and frequent availability of water and nutrient. Secondly, drip irrigation reduces the leaching loss of nutrients below the root zone. Thus, improve the availability of nutrients, which helps in efficient harvesting of solar energy.
Plant height of sunflower hybrids has influenced significantly with sulphur levels from 50 DAS to harvesting during both the years except at 70 DAS during 2017, where differences were non-significant (Table 1). Maximum plant height was recorded with 60 kg S ha^{-1}, which was statistically at par with 40 kg S ha^{-1}, but significantly better than lower levels at 50 DAS and at harvest during both the year. At 70 DAS during 2016 and at 90 DAS during 2017 plant height was

significantly higher in 60 kg ha^{-1} than all other levels of sulphur. Higher plant height in 60 kg S ha^{-1} and 40 kg S ha^{-1} than lower levels resulted from better availability of sulphur to plant, which helps in cell elongation, multiplication and expansion (Kumar *et al.,* 2011) [7] resulted in taller plants. All the interactions were found to be non-significant during both the year.

3.1.2 Stem girth

Stem girth of sunflower hybrids increased successively up to 90 days after sowing i.e. seed filling stages and at harvest girth decreases (Table 2). Stem girth of sunflower did not vary significantly between both the hybrids during both the years. Similarly methods of irrigation also have non-significant effect on stem girth sunflower at all growth stages except 90 DAS during both the year. At 90 DAS, drip irrigated crop resulted significantly 5.11 and 1.64 percent higher stem girth than furrow irrigated crop during 2016 and 2017, respectively. Sulphur levels also have non- significant effect on stem girth of the hybrids at all growth stages during 2016 and 2017.

3.1.3 Leaf area index

Leaf area index is the most important parameter to determine the plant growth. Leaf area index (LAI) substantially increased from 30 DAS to 70 DAS, afterwards LAI decreased during both the years. LAI of both the hybrids differs significantly from 30 to 70 DAS during both the year (Table 3). Hybrid PSH-1962 recorded significantly higher LAI as compared to PSH-996 at 30, 50 and 70 DAS during 2016 and 2017, except at 30 DAS during 2017. PSH-1962 recorded 3.71, 9.03 percent and 10.2, 5.63 percent significant higher LAI as compared to PSH-996 at 50 DAS and 70 DAS during 2016 and 2017, respectively. As per as genetic make-up of the hybrid, PSH-1962 have taller plant with more number of leaves, which leads to higher LAI.

Drip irrigated crop recorded significantly higher LAI as compared to furrow irrigated crop at 50 and 70 DAS during both the year, while at 50 DAS during 2017, drip and furrow irrigated crop produced statistically at par LAI. The maximum LAI was recorded at 70 DAS. Drip irrigated crop resulted in 3.57 and 6.91 percent higher LAI as compared to furrow irrigated crop at 70 DAS during 2016 and 2017 respectively. The reason behind higher LAI in drip irrigated crop is due to better and frequent availability of water and nutrient at root zone which leads to efficient availability of nutrient and water towards plant (Kaur and Brar 2016) [6]. At 90 DAS and at harvest LAI decreased due to senescence of leaves. So, methods of irrigation have no effect on these stages during both the year.

LAI of sunflower influenced significantly with sulphur levels from 50 DAS to 90 DAS during both the year, except at 90 DAS during 2016. Maximum LAI was recorded with 60 kg S ha-1 at 70 DAS which is significantly better than all other sulphur levels. At 70 and 60 DAS 60 kg S ha^{-1} recorded 35.7, 31.8 percent and 28.6, 27.4 percent significant higher LAI as compared to 0 kg S ha^{-1} during 2016 and 2017, respectively. At 50 and 70 DAS sunflower hybrids raised with 60 kg S ha^{-1} produced significantly higher LAI than lower levels during both the years except at 50 DAS during 2016. At 50 DAS during 2016 and 90 DAS during 2017, application of 40 kg S ha^{-1} resulted statistically at par LAI with 60 kg S ha-1 irrespective of methods of irrigation and sunflower hybrids. All the interactions were non-significant.

3.1.4 Dry matter accumulation

Dry matter accumulation (DMA) of a crop is an index to express the photosynthetic efficiency of the plant. DMA progressively increased with increase in age of sunflower hybrids during both the year (Table 4). The two hybrids differ significantly for DMA during both the year at all growth stages. Hybrid PSH- 1962 accumulated significantly higher dry matter as compared to PSH-996 at 30, 50, 70, 90 DAS and at harvest during both the year, except at 30 DAS during 2017. At 50, 70, 90 DAS and at harvest PSH-1962 recorded 54.2 and 12.9 percent, 22.6 and 17.6 percent, 27.3 and 8.93 percent and 11.9 and 7.32 percent significant higher DMA as compared to PSH-996 during 2016 and 2017, respectively. Better performance of PSH-1962 for DMA than PSH-996 resulted from higher plant height and LAI, which are responsible for better photosynthetic efficiency. Drip irrigated crop resulted in significantly higher DMA from 50 DAS to at harvest during both the year except at 50 DAS during 2017. At 70, 90 DAS and at harvest drip irrigated crop resulted in 20.6 and 4.33 percent, 38.6 and 3.87 percent and 8.90 and 7.41 percent of higher DMA over furrow irrigated crop during 2016 and 2017, respectively. Significantly higher DMA in drip than furrow irrigated crop resulted from better and frequent availability of nutrients at root zone, which leads to better uptake of nutrients and significantly higher plant height and LAI. DMA successively increased with each increment in sulphur dose from 50 DAS to till harvest (Table 4). Application of 60 kg S ha^{-1} resulted in significantly higher DMA as compared to lower dose at 50, 70, 90 DAS and at harvest except at 30 DAS. At 50 DAS during 2017, DMA recorded at 60 kg S ha^{-1} was statistically at par with 40 kg S ha^{-1} but significantly better than all other sulphur levels. At 50, 70, 90 DAS and at harvest 60 kg S ha^{-1} resulted in 52.8 and 27.2 percent, 27.7 and 34.7 percent, 23.4 and 20.2 percent and 16.2 and 20.3 percent of significantly higher DMA as compared to 0 kg S ha^{-1} during 2016 and 2017, respectively. Higher DMA with 40 kg S ha^{-1} to 60 kg S ha^{-1} might be due to improvement in cell multiplication, cell elongation and cell expansion in sunflower plant because of better availability of sulphur resulted in higher production of photosynthatesd and their translocation to sink (Kumar *et al.,* 2011) [7].

3.2 Yield parameters

3.2.1 Seed yield

Seed yield of sunflower significantly influenced between both the hybrids during both the year and in pooled data as well (Table 5). PSH-1962 recorded significantly higher seed yield as compared to PSH-996 during both the years and in pooled data. PSH-1962 recorded 17.9, 7.51 and 12.9 percent of significant higher seed yield over PSH-996 during 2016, 2017 and pooled data, respectively because of taller plant, higher dry matter accumulation, leaf area index, capitulum diameter, capitulum weight, seeds per head and 1000 seed weight. The increase in seed yield of drip irrigated crop over furrow irrigated crop was to the tune of 13.9, 16.2 and 14.6 percent during 2016, 2017 and pooled data, respectively. Higher seed yield in drip irrigated crop due to significantly higher LAI, plant height and dry matter accumulation, because drip irrigation provides light frequent irrigation near the root zone of plant, reduced evaporation and leaching of nutrients from root zone (Kaur and Brar 2016) [6].

Sulphur level of 60 kg S ha^{-1} resulted in a significantly higher seed yield as compared to the lower levels of sulphur during both the years and in pooled data. Increase in seed yield with 60 kg S ha^{-1} over lower levels of sulphur (40, 20 and 0 kg S ha^{-1}) are 6.76, 14.5 and 22.0 percent during 2016 and 9.37, 24.2 and 42.8 percent during 2017 and 8.04, 18.7 and 31.0 percent in pooled data. This could be attributed to better development of the vegetative parts of the plant (source) reflected by increased plant height, LAI and DMA and proportionate increase in reproductive parts (sink) of the plant as evidenced by larger disc diameter and number of seed per head resulting in a balanced source- sink relationship; this in turn was reflected in seed yield (Rani *et al.*, 2009) [8].

3.2.3 Harvest index

Sunflower hybrids differ significantly for harvest index during 2017, but during 2016 and pooled data hybrids had non-significant effect in harvest index (Table 5). PSH-1962 resulted in significantly higher harvest index than PSH-996 during 2017. PSH-1962 recorded 5.17 percent of higher harvest index as compared to PSH-996 due to taller plant height and higher LAI. Methods of irrigation had significant effect on harvest index during 2017 and pooled data but differences were non-significant during 2016. Drip irrigated crop resulted in significantly higher harvest index as compared to furrow irrigated crop during 2017 and in pooled data.

Sulphur levels had significant effect on harvest index during 2016, 2017 and in pooled data. The maximum harvest index was recorded at 60 kg S ha^{-1} which was statistically at par with 40 kg S ha-1, but significantly better than 20 and 0 kg S ha^{-1} during 2016, 2017 and in pooled data. There was increase of 14.6 and 22.1 percent and 11.1 and 18.4 percent in harvest index under 60 and 40 kg S ha^{-1} than 20 and 0 kg S ha^{-1} during 2016, respectively. The corresponding increase in harvest index was 5.58 and 16.3 percent and 5.07 and 15.5 percent during 2017 and 10.9 and 20.3 percent and 8.59 and 17.7 percent in pooled data.

3.3 N, P, K and S uptake in stalk

3.3.1 Nitrogen uptake

Sunflower hybrids showed significant effect on nitrogen uptake during both the years (Table 6). PSH-1962 had significantly higher nitrogen uptake as compared to PSH-996 during both the years. PSH-1962 recorded significantly 13.2 and 15.3% higher nitrogen uptake than PSH-996 during 2016 and 2017, respectively. Methods of irrigation had significant effect on the uptake of nitrogen during 2017 but it had non-significant effect during 2016 but had a significant effect during 20117. Drip irrigated crop had resulted in significantly higher amount of nitrogen uptake than furrow irrigated crop. Because of nutrient availability at the root zone, this had a synergetic effect on nitrogen uptake. Drip irrigated crop resulted in 5.41% of significantly higher nitrogen uptake as compared to furrow irrigated crop during 2017 and had non-significant effect during 2016. Sulphur levels also had significant effect on nitrogen uptake during 2017 and non-significant during 2016. Sulphur level of 60 kg S/ ha resulted in significantly higher nitrogen uptake than the lower levels during 2017 but non-significant during 2016. The reason behind this was the synergistic effects of S on availability of nitrogen, both the nutrients were said to increase the concentration and uptake of each other. Crop applied with 60 kg S ha^{-1} resulted in 17.8% of significantly higher nitrogen uptake than the control plot. Sulphur levels had no such significant effect on nitrogen uptake during 2016.

3.3.2 Phosphorous uptake

Sunflower hybrids had non-significant effect on phosphorous uptake in stalk during 2016 and 2017 (Table 6). Methods of irrigation also showed non-significant effect on phosphorous uptake in stalk of sunflower hybrids during both the years. Sulphur levels showed significant effect on phosphorous uptake in stalk during both the years. Maximum phosphorous uptake was recorded from the crop, raised with 60 kg S/ha. Increase in phosphorous uptake in stalk at 60 kg S ha^{-1} over 0 kg S ha^{-1} was 27.5 and 17.4% during 2016 and 2017, respectively. The increase in the P uptake in stalk with S application indicated the beneficial role of sulphur in mobilizing soil P and its utilization. Similar results were reported by Virmani and Gulati (1971) [9] in mustard.

3.3.3 Potassium uptake

Hybrids showed significant effect on potassium uptake in stalk during both the years (Table 6). PSH-1962 had significantly higher uptake as compared to PSH-996 during 2016 and 2017. PSH-1962 recorded 10.6 and 15.1% of higher potassium uptake over PSH-996 during 2016 and 2017, respectively. Methods of irrigation and sulphur levels had non-significant effect on potassium uptake during both the years.

3.3.4 Sulphur uptake

Sunflower hybrids had significant effect on sulphur uptake in stalk during both the years (Table 6). PSH-1962 recorded 12.5 and 17.9% significantly higher sulphur uptake in stalk as compared to PSH-996 during 2016 and 2017, respectively. Methods of irrigation showed significant effect on sulphur uptake during both the years. Drip irrigated crop resulted in significantly higher sulphur uptake as compared to furrow irrigated crop during both the years. Drip irrigated crop resulted in 27.3 and 32.7% of higher sulphur uptake as compared to furrow irrigated crop during 2016 and 2017, respectively. Sulphur levels had also significant effect on sulphur uptake during both the years. Application of 60 kg S ha^{-1} recorded 33.9 and 58.1% of significantly higher sulphur uptake over control during 2016 and 2017, respectively.

3.4 N, P, K and S uptake in seed

Sunflower hybrids had significant effect on nitrogen uptake in seed during both the years (Table 7). PSH-1962 recorded 18.8 & 7.70%, 20.6 & 41.3% and 28.7 &17.8% significantly higher nitrogen, potassium and sulphur uptake in seed as compared to PSH-996 during 2016 and 2017, respectively. Methods of irrigation showed significant effect on nitrogen uptake during both the years. Drip irrigated crop resulted in significantly higher nitrogen uptake as compared to furrow irrigated crop during both the years. Drip irrigated crop resulted in 30.2 & 31.7%, 22.2 & 24.7% and 16.3 &19.2% and 46.0 & 48.7% of higher N, P, K and S uptake as compared to furrow irrigated crop during 2016 and 2017, respectively.

Table 1: Effect of methods of irrigation and sulphur nutrition on plant height (cm) of sunflower hybrids during spring 2016 and 2017

Treatments	30 DAS		50 DAS		70 DAS		90 DAS		At harvest	
Hybrids	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
PSH-996	17.6^{b}	20.0^{b}	66.6^{b}	62.0^{b}	146.5^{b}	107.8^{b}	161.3^{b}	129.7^{b}	169.2^{b}	156.2^{b}
PSH-1962	21.8^{a}	24.6^{a}	86.0^{a}	74.3^{a}	159.2^{a}	113.8^{a}	169.9^{a}	143.9^{a}	177.3^{a}	174.8^{a}
Methods of irrigation										
Drip	19.7^{ns}	21.7^{ns}	79.9^{a}	68.7^{ns}	155.7^{a}	115.6^{a}	168.0^{a}	142.4^{a}	176.1^{a}	171.4^{a}
Furrow	19.7	23.0	72.7^{b}	67.6	150.0^{b}	106.0^{b}	163.2^{b}	131.1^{b}	170.4^{b}	159.5^{b}
Sulphur levels (kg ha^{-1})										
0	19.8^{ns}	21.7^{ns}	73.3^{b}	63.1^{b}	138.3^{d}	107.4^{ns}	154.9^{c}	128.3^{d}	163.2^{c}	161.2^{c}
20	20.4	22.0	74.9^{b}	68.5^{a}	150.2^{c}	110.2	164.1^{b}	133.6^{c}	171.1^{b}	164.9^{bc}
40	20.4	22.5	76.1^{b}	70.1^{a}	156.8^{b}	111.9	170.1^{ab}	136.4^{bc}	177.8^{a}	166.3^{ab}
60	21.1	23.1	80.9^{a}	70.9^{a}	166.2^{a}	113.6	173.5^{a}	148.9^{a}	180.8^{a}	169.4^{a}

Table 2: Effect of methods of irrigation and sulphur nutrition on stem girth (cm) of sunflower hybrids during spring 2016 and 2017

Treatments	30 DAS		50 DAS		70 DAS		90 DAS		At harvest	
Hybrids	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
PSH-996	2.48^{ns}	2.55^{ns}	8.26^{ns}	6.19^{ns}	9.62^{ns}	8.18^{ns}	9.80^{ns}	9.04^{ns}	8.92^{ns}	8.82^{ns}
PSH-1962	2.51	2.62	8.57	6.33	9.13	8.06	9.84	9.36	9.04	9.67
Methods of irrigation										
Drip	2.53^{ns}	2.60^{ns}	8.61^{ns}	6.49^{ns}	9.58^{ns}	8.19^{ns}	10.07^{a}	9.28^{a}	9.12^{ns}	9.47^{ns}
Furrow	2.46	2.57	8.22	6.04	9.18	8.05	9.58^{b}	9.13^{b}	8.84	9.01
Sulphur levels (kg ha^{-1})										
0	2.43^{ns}	2.48^{ns}	8.29^{ns}	6.20^{ns}	9.09^{ns}	7.84^{ns}	9.56^{ns}	9.13^{ns}	8.77^{ns}	9.18^{ns}
20	2.50	2.56	8.33	6.24	9.25	8.25	9.86	9.21	8.98	9.18
40	2.51	2.64	8.52	6.26	9.54	8.13	9.77	9.10	9.06	9.18
60	2.54	2.66	8.52	6.36	9.63	8.26	10.10	9.37	9.11	9.48

Table 3: Effect of methods of irrigation and sulphur nutrition on leaf area index of sunflower hybrids during spring 2016 and 2017

Treatments	30 DAS		50 DAS		70 DAS		90 DAS		At harvest	
Hybrids	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
PSH-996	0.74^{b}	0.74^{ns}	2.42^{b}	1.66^{b}	4.60^{b}	4.08^{b}	0.84^{ns}	0.88^{ns}	0.67^{ns}	0.66^{ns}
PSH-1962	0.94^{a}	0.83	2.51^{a}	1.81^{a}	5.07^{a}	4.31^{a}	0.93	0.92	0.76	0.68
Methods of irrigation										
Drip	0.81^{ns}	0.77^{ns}	2.63^{a}	1.79^{ns}	4.92^{a}	4.33^{a}	0.91^{ns}	0.91^{ns}	0.73^{ns}	0.67^{ns}
Furrow	0.86	0.81	2.30^{b}	1.68	4.75^{b}	4.05^{b}	0.85	0.88	0.69	0.67
Sulphur levels (kg ha^{-1})										
0	0.75^{ns}	0.71^{ns}	2.07^{c}	1.54^{b}	4.30^{d}	3.79^{c}	0.77^{ns}	0.76^{c}	0.61^{ns}	0.61^{ns}
20	0.81	0.79	2.37^{bc}	1.60^{b}	4.57^{c}	4.02^{bc}	0.86	0.86^{c}	0.68	0.66
40	0.86	0.82	2.61^{ab}	1.76^{b}	4.94^{b}	4.14^{b}	0.90	0.96^{bc}	0.74	0.69
60	0.94	0.84	2.81^{a}	2.03^{a}	5.53^{a}	4.83^{a}	1.00	1.02^{a}	0.82	0.72

Table 4: Effect of methods of irrigation and sulphur nutrition on dry matter accumulation (g) of sunflower hybrids during spring 2016 and 2017

Treatments	30 DAS		50 DAS		70 DAS		90 DAS		At harvest	
Hybrids	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
PSH-996	1.32^{b}	1.13^{ns}	34.5^{b}	24.8^{b}	66.4^{b}	43.3^{b}	97.4^{b}	80.6^{b}	117.5^{b}	112.0^{b}
PSH-1962	1.54^{a}	1.19	53.2^{a}	28.0^{a}	67.9^{a}	50.9^{a}	124.0^{a}	87.8^{a}	131.3^{a}	120.2^{a}
Methods of irrigation										
Drip	1.41^{ns}	1.22^{ns}	47.9^{a}	26.8^{ns}	68.4^{a}	48.1^{a}	128.5^{a}	85.8^{a}	130.2^{a}	120.3^{a}
Furrow	1.45	1.12	39.9^{b}	26.1	56.7^{b}	46.1^{b}	92.9^{b}	82.6^{b}	118.6^{b}	112.0^{b}
Sulphur levels (kg ha^{-1})										
0	1.08^{ns}	1.05^{ns}	35.4^{c}	23.5^{c}	57.8^{c}	40.9^{d}	99.2^{d}	77.7^{c}	115.7^{c}	107.7^{d}
20	1.26	1.12	39.6^{c}	25.0^{b}	62.6^{c}	44.3^{c}	109.2^{c}	80.8^{c}	120.4^{c}	112.4^{cd}
40	1.44	1.19	46.3^{b}	27.3^{a}	65.3^{bc}	48.1^{b}	112.0^{b}	84.8^{b}	127.1^{b}	114.8^{bc}
60	1.98	1.31	54.1^{a}	29.9^{a}	73.8^{a}	55.1^{a}	122.5^{a}	93.4^{a}	134.4^{a}	129.6^{a}

Table 5: Effect of methods of irrigation and sulphur nutrition on seed yield (q/ha), stalk yield (q/ha) and harvest index of sunflower hybrids during spring 2016 and 2017

Hybrids	Seed yield			Harvest index		
	2016	2017	Pooled	2016	2017	Pooled
Hybrids						
PSH-996	18.4[b]	17.3[b]	17.8[b]	0.27[ns]	0.25[b]	0.26[ns]
PSH-1962	21.7[a]	18.6[a]	20.1[a]	0.28	0.26[a]	0.27
Methods of irrigation						
Drip	21.3[a]	19.3[a]	20.3[a]	0.28[ns]	0.27[a]	0.27[a]
Furrow	18.7[b]	16.6[b]	17.7[b]	0.26	24.9[b]	0.25[b]
Sulphur levels (kg ha^{-1})						
0	18.1[c]	14.7[d]	16.4[d]	0.24[c]	0.23[c]	0.24[c]
20	19.3[c]	16.9[c]	18.1[c]	0.26[bc]	0.26[b]	0.26[b]
40	20.7[b]	19.2[b]	19.9[b]	0.29[ab]	0.27[a]	0.28[a]
60	22.1[a]	21.0[a]	21.5[a]	0.30[a]	0.27[a]	0.28[a]

Table 6: Effect of methods of irrigation and sulphur nutrition on N, P, K and S uptake in stalk of sunflower hybrids during spring 2016 and 2017

Hybrids	N uptake		P uptake		K uptake		S uptake	
	2016	2017	2016	2017	2016	2017	2016	2017
PSH-996	24.6[b]	22.9[b]	3.65[ns]	3.39[ns]	54.8[b]	51.4[b]	18.4[b]	17.3[b]
PSH-1962	27.2[a]	26.4[a]	3.32	3.22	60.6[a]	59.2[a]	20.7[a]	20.4[a]
Methods of irrigation								
Drip	26.1[ns]	25.3[a]	3.35[ns]	3.27[ns]	58.7[ns]	57.2[ns]	21.9[a]	21.5[a]
Furrow	25.7	24.0[b]	3.62	3.40	56.7	53.4	17.2[b]	16.2[b]
Sulphur levels (kg/ha)								
0	23.6[b]	23.0[c]	2.98 [b]	3.17[b]	55.2[ns]	52.1[b]	17.1[b]	14.8[d]
20	26.6[ab]	23.6[bc]	3.57[a]	3.23[b]	55.9	52.3[b]	18.6[b]	17.3[c]
40	26.6[ab]	24.9[b]	3.67[a]	3.23[b]	58.6	57.7[ab]	19.6[b]	19.8 [b]
60	26.8[a]	27.1[a]	3.80[a]	3.72[a]	61.1	59.0[a]	22.9[a]	23.4[a]

Table 7: Effect of methods of irrigation and sulphur nutrition on N, P, K and S uptake in seed of sunflower hybrids during spring 2016 and 2017

Hybrids	N uptake		P uptake		K uptake		S uptake	
	2016	2017	2016	2017	2016	2017	2016	2017
PSH-996	87.5[b]	83.1[b]	6.19[b]	5.84[ns]	15.9[b]	15.1[b]	39.3[b]	37.0[b]
PSH-1962	104.0[a]	89.5[a]	7.23[a]	6.25	19.8[a]	16.9[a]	50.6[a]	43.6[a]
Methods of irrigation								
Drip	108.8[a]	98.1[a]	7.38[a]	6.71[a]	19.2[a]	17.4[a]	53.3[a]	48.2[a]
Furrow	83.5[b]	74.5[b]	6.04[b]	5.38[b]	16.5[b]	14.6[b]	36.5[b]	32.4[b]
Sulphur levels (kg/ha)								
0	83.0[c]	67.9[c]	6.01[b]	4.92[c]	16.5[b]	13.3[c]	37.6[d]	30.6[d]
20	91.7[b]	80.9 [b]	6.37[b]	6.00[b]	17.3[b]	15.2[bc]	42.8[c]	37.6[c]
40	102.2[a]	95.5[a]	6.86[ab]	6.01[b]	17.7[b]	16.6[b]	47.6[b]	44.3[b]
60	106.1[a]	101.0[a]	7.60[a]	7.25[a]	19.9[a]	18.8[a]	51.5[a]	48.8[a]

Conclusion

PSH-1962 recorded significantly higher growth attributes, seed and nutrient uptake than PSH-996 during both the years and in pooled data as well. Drip irrigation resulted in significantly improved growth attributes, yield attributes and nutrient uptake than furrow irrigation during both the years and in pooled data as well. Sulphur nutrition at 60 kg S/ha recorded significantly better growth attributes, yield attributes and nutrient uptake as compared to lower levels. Increase in seed yield at 60 kg S /ha over lower levels of sulphur (40, 20 and 0 kg S/ha) were 6.9%, 14.5% and 22.0% respectively during 2016 and 9.3%, 24.3% and 42.8% respectively during 2017. The nitrogen, phosphorus, potassium, sulphur uptake in both seed and stalk were significantly higher in treatment with application of 60 kg S/ha as compared to 0, 20 40 kg S /ha.

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References

1. Anonymous. Spring sunflower. Package of practices for Rabi crops, Punjab Agricultural University, Ludhiana, India; c2016.
2. Chaudhary SK, Gogulwar NM, Singh AK. Effect of sulphur and nitrogen on seed yield and oil content of mustard (*Brassica juncea*). Indian Journal of Agronomy. 1992;37:839–40.
3. Chimenti CA, Hall AJ. Sensitivity number of fruits per chapter sunflower (*Helianthus annuus* L.) to changes in the radiation during ontogeny crop. Argentina Meeting of Plant Physiology Proceeding; c1992. p. 27-28.
4. El-Hendawy SE, El-Lattief EA, Ahmad AS, Schmidhalter U. Irrigation rate and plant density effects on yield and water use efficiency of drip-irrigated corn. Agriculture Water Management. 2008;95:836-44.
5. Ghani K, Hussain K, Qureshi MS. Effect of different irrigation regimes on the growth and yield of sunflower. International Journal of Agricultural Biology. 2000;2:334-35.
6. Kaur A, Brar AS. Influence of mulching and irrigation scheduling on productivity and water use of turmeric (*Curcuma longa* L.) in north-western India; c2016. DOI 10.1007/s00271-016-0501-0.

7. Kumar S, Tewari SK, Singh SS. Effect of sources and levels of sulphur and spacing on the growth, yield and quality of spring sunflower (*Helianthus annuus* L.). Indian Journal of Agronomy. 2011;56:242-46.
8. Rani KU, Sharma KL, Nagasri K, Srinivas K, Murthy TV, Maruthi SGR, *et al.* Response of sunflower to sources and levels of sulfur under rainfed semi-arid tropical conditions. Communication in Soil Science and Plant Analysis. 2009;40:2926-44.
9. Virmani SM, Gulati HC. Effect of sulphur on the response of Indian mustard (*Brassica juncea* (L.) Czem and Coss.) to phosphorus fertilization. Indian Journal of Agricultural Science. 1971;41:143-46.