J Krishi Vigyan 2022, 11 (1) : 410-418 DOI : 10.5958/2349-4433.2022.00167.2

Yield of Sunflower (*Helianthus annuus* L) Influenced by Irrigation and Potassium Levels

Anusha L.* and S S Angadi

Department of Agronomy
University of Agricultural Sciences, Dharwad 580 005 (Karnataka)

ABSTRACT

The field experiment was conducted during summer 2019 and 2021 at the Main Agriculture Research Station (MARS), University of Agricultural Sciences, Dharwad, Karnataka on medium deep black clayey soils to evaluate the effect of irrigation and potassium levels on sunflower. The treatments included four irrigation regimes (Irrigation at 0.4, 06, 08 and 1.0 IW/CPE ratio) and four potassium levels (application of potassium @ 0, 45, 60 and 75 kg/ha). Results revealed that scheduling of irrigation at 1.0 IW/CPE (2144 kg/ha) and 0.8 IW/CPE (2067 kg/ha) recorded significantly higher on par grain yield as compared to other irrigation levels. Further, application of potassium @ 75 kg/ha (2031 kg/ha) and 60 kg/ha (1983 kg/ha) recorded significantly higher and on par grain yield over other treatments. The combined effect of irrigation at 1.0 IW/CPE with application of potassium @ 75, 60 and 45 kg/ha enhanced the yield attributes and yield as compared to rest of the treatment combination. Irrigation at 0.4 IW/CPE ratio with no potassium application recorded significantly lower growth and yield parameters of sunflower.

Key Words: Sunflower, irrigation regime, potassium, IW/CPE ratio

INTRODUCTION

Sunflower is one among the seven edible oilseeds with 48 to 53 per cent edible oil and 16 per cent proteins, making it both an oil and protein species. It competes on both vegetable oils market led by palm oil and the other driven by soybean for vegetable protein-rich products. India accounts for about 15 to 20 per cent of the global oilseeds area, 6 to 7 per cent of vegetable oils production and 9 to 10 per cent of the total edible oils consumption (Kumar and Tiwari, 2020). However, the average national productivity is much lower (931 kg/ha). The reasons for the low productivity of sunflower in India are due to unavailability of adequate soil moisture and nutrients especially during winter and summer, erratic rainfall, poor nutrient management, low solar radiation and bud necrosis during the rainy season. In India, the majority of the oilseeds are cultivated under rainfed ecosystem (70%). However, the crop is often subjected to moisture stress and only 28 per cent of the area is covered under irrigation. As agricultural land area is inelastic, the enhancement of productivity is the only alternative. Hence, special attention is needed to achieve the goal of increasing and stabilizing agricultural production in moisture deficit areas.

Under emerging water scarcities in the face of global warming, optimization of irrigation and nutrient inputs is essential to maximize input use efficiency. Scheduling irrigation based on data of pan evaporation is likely to increase agricultural production at least by 15 to 20 per cent (Dastane, 1972). Considering the strong relationship between the pan evaporation and crop evapotranspiration, particularly in semi-arid tropics, the IW/CPE ratio has been suggested as a practical approach for irrigation scheduling, as it integrates all the weather parameters giving their natural weightage in a given soil-water plant continuum (Parihar *et al*, 1975). Further, nutrients are the essential elemental

Corresponding Author's Email: anooppathy@gmail.com

components of soil required for plant growth and architecture. Among macro-nutrients, potassium is an essential nutrient and plays a key role in improving crop yield and quality of the produce.

MATERIALS AND METHODS

The field experiment was conducted during summer 2019 and 2021 at the Main Agriculture Research Station (MARS), University of Agricultural Sciences, Dharwad (Karnataka), situated at 15°26' N latitude, 75°07' E longitude and at an altitude of 678 m above mean sea level. The research station comes under Northern Transition Zone (Zone-8) of Karnataka. The soil type of the experimental site was medium black (vertisols) and clayey in texture. The soil was neutral to slightly alkaline in reaction (7.78) with normal in electrical conductivity (0.36 dS m^{-1}), medium in organic carbon content (0.49 %), medium in available of nitrogen (272.4 kg/ha) and phosphorus (32.1 kg/ha) and high in available potassium (318.8 kg/ha). The bulk density of top soil (30 cm) was 1.24 g cc^{-1}, with field capacity of 32.40 per cent and permanent wilting point of 18.00 per cent. The mean maximum temperatures recorded during crop growth period were highest in April first fortnight (37.1 °C during 2019 and 35.8 °C during 2021) and lowest were in February first fortnight (31.6 °C during 2019 and 30.0 °C during 2021). The total rainfall received during crop period in 2019 and 2021 were 54.50 mm with 6 rainy days and 113.04 mm with 9 rainy days, respectively. The average evaporation rate during the crop period was 7.64 mm/day during 2019 and 5.79 mm/day during 2021.

The experiment was laid out in split plot design with three replications and sixteen treatment combinations. The main plot consisted of four irrigation regimes *viz*., I_1: Irrigation at 0.4 IW/CPE ratio, I_2: Irrigation at 0.6 IW/CPE ratio, I_3: Irrigation at 0.8 IW/CPE ratio and I_4: Irrigation at 1.0 IW/CPE ratio. Whereas, sub plot consisted of four potassium levels *viz*., K_1: no potassium application, K_2: application of potassium @ 45 kg/ha, K_3: application of potassium @ 60 kg/ha and K_4: application of potassium @ 75 kg/ha. The net plot area was 4.2 m × 3.0 m and hybrid grown was DSFH-3 at the recommended spacing of 60 cm × 30 cm. Crop was planted on February 11th and harvested on May 13th in 2019 and planted on January 21st and harvested on April 27th in 2021.

To ensure uniform germination and establishment of the crop, immediately after sowing the field was irrigated with sprinkler and two more general irrigations were given at 5 to 6d interval. Furrows were made twenty days after sowing (DAS) and irrigation was scheduled based on IW/CPE ratio approach. The depth of irrigation water was fixed to 60 mm. The quantity of water discharged was measured by volumetric method and the volume of water required to apply 60 mm of water was calculated by formula,

$W = A \times d \times 1000$

Where,

W = Quantity of water (L)

A = Plot area in (m^2)

d = Depth of irrigation water (m)

Irrigation was scheduled using daily pan evaporation data recorded from USWB Class-A open pan evaporimeter from the meteorological observatory, MARS, Dharwad during cropping period. Irrigation was scheduled with cumulative pan evaporation (CPE) of 150, 100, 75 and 60 mm in I_1, I_2, I_3 and I_4, respectively. The nitrogen (90 kg/ha), phosphorus (90 kg/ha), potassium (0, 45, 60 and 75 kg/ha in K_1, K_2, K_3 and K_4, respectively), zinc (10 kg/ha) and boron (0.5 %) were applied in the form of urea, diammonium phosphate (DAP), muriate of potash (MOP), zinc sulphate and borax, respectively. 50 per cent of recommended dose of nitrogen and potassium along with 100 per cent of phosphorous and zinc were applied as per the treatments at the time of sowing. The remaining nitrogen and potassium were applied as top dressing at 45 DAS. Foliar application of borax @ 0.5 per cent at ray floret initiation stage (50 DAS).

Table 1. Capitulum diameter of sunflower as influenced by irrigation regimes and potassium levels.

Treatment	Capitulum diameter (cm)														
	2019					2021					Pooled				
K/I	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
K_1	11.8^{g}	11.7^{g}	14.1^{c-e}	14.4^{b-e}	13.0^{c}	10.4^{j}	10.3^{j}	13.0^{c-f}	13.4^{b-e}	11.8^{c}	11.1^{j}	11.0^{j}	13.6^{d-f}	13.9^{c-f}	12.4^{cd}
K_2	11.9^{g}	12.3^{fg}	14.2^{c-e}	14.6^{a-d}	13.2^{c}	10.6^{ij}	11.4^{h-j}	13.4^{c-e}	13.8^{b-d}	12.3^{c}	11.2^{ij}	11.8^{h-j}	13.8^{c-f}	14.2^{c-e}	12.8^{c}
K_3	12.4^{fg}	13.4^{d-g}	14.8^{a-d}	15.9^{ab}	14.1^{ab}	11.7^{g-i}	12.6^{e-h}	14.0^{bc}	15.3^{a}	13.4^{ab}	12.0^{g-j}	13.0^{e-h}	14.4^{b-d}	15.6^{ab}	13.7^{ab}
K_4	12.9^{e-g}	13.6^{d-f}	15.3^{a-c}	16.0^{a}	14.4^{a}	12.2^{f-h}	12.8^{d-g}	14.6^{ab}	15.6^{a}	13.8^{a}	12.5^{f-i}	13.2^{d-g}	14.9^{a-c}	15.8^{a}	14.1^{a}
Mean	12.2^{c}	12.7^{c}	14.6^{ab}	15.2^{a}		11.2^{c}	11.7^{c}	13.8^{ab}	14.5^{a}		11.7^{cd}	12.2^{c}	14.2^{ab}	14.9^{a}	
S.V.			S.Em. ±					S.Em. ±					S.Em. ±		
I			0.4					0.4					0.3		
K			0.3					0.3					0.2		
I × K			0.7					0.6					0.5		

RESULTS AND DISCUSSION

The two years (pooled) data revealed that yield attributes and yield of sunflower differed significantly due to irrigation and potassium levels and their interaction effects. Irrigation at 1.0 IW/CPE ratio recorded significantly higher capitulum diameter (14.9 cm) and number of seeds capitulum^{-1} (1242) as compared to other treatments. Maintenance of desired soil moisture status throughout the growing period helped in maintaining a higher leaf water energy and photosynthetic efficiency leading to production of larger capitulum which held more number of grains. Peak consumptive water use in sunflower was noticed at reproductive phase. Ensuring the soil moisture status to meet the evapotranspiration demands and not exposing crop to any sort of moisture stress during this phase resulted in better floral development, pollination and fertilization. Hence, the size of sink was sufficient enough for translocation and assimilation of photosynthates from the source. Increase in the size of capitulum and number of seeds capitulum^{-1} with increasing irrigation regimes were also recorded by Hittinahalli (1998) and Gurumurthy *et al* (2008). Further, significantly higher and on par 100 seed weight was recorded with scheduling of irrigation at 1.0 (4.12 g) and 0.8 (4.10 g) IW/CPE ratio. Higher test weight was associated with the favourable soil moisture throughout the crop growth period than other irrigation regimes. The increased test weight with increase in the water supply was also reported by Abdou *et al* (2011), Moitra *et al* (2012) and Brar *et al* (2016). The better yield attributes resulted in significantly higher grain yield of 43.6 and 42.1 g/plant with irrigation at 1.0 and 0.8 IW/CPE ratio, respectively. With the higher yield attributes with irrigation at 1.0 and 0.8 IW/CPE ratio recorded significantly higher and on par grain yield 2144 and 2067 kg/ha. These results were in conformity with the findings of Meti *et al* (2004), Ramamoorthy *et al* (2009) and Dar *et al* (2021). On the contrary, scheduling of irrigation at 0.4 IW/CPE recorded significantly the lowest grain yield (1643 kg/ha). The yield reduction was due to

Table 2. Number of seeds capitulum^{-1} of sunflower as influenced by irrigation regimes and potassium levels

Treatment	Number of seeds capitulum^{-1}														
	2019					2021					Pooled				
K/I	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
K_1	1113^{f}	1120^{f}	1152^{d-f}	1188^{c-f}	1143^{c}	1042^{f}	1048^{f}	1077^{d-f}	1111^{b-f}	1070^{d}	1078^{e}	1084^{e}	1115^{de}	1150^{c-e}	**1106^{c}**
K_2	1129^{ef}	1182^{c-f}	1208^{b-f}	1268^{a-e}	1197^{bc}	1056^{ef}	1105^{b-f}	1129^{b-f}	1184^{a-d}	1119^{bc}	1093^{e}	1144^{c-e}	1169^{b-e}	1226^{a-d}	**1158^{bc}**
K_3	1156^{d-f}	1208^{b-f}	1274^{a-d}	1329^{ab}	1242^{ab}	1081^{c-f}	1129^{b-f}	1189^{a-c}	1240^{a}	1160^{ab}	1119^{de}	1169^{b-e}	1232^{a-d}	1285^{ab}	**1201^{ab}**
K_4	1180^{c-f}	1245^{a-f}	1299^{a-c}	1352^{a}	1269^{a}	1103^{c-f}	1163^{a-e}	1212^{ab}	1261^{a}	1185^{a}	1142^{c-e}	1204^{a-e}	1256^{a-c}	1307^{a}	**1227^{a}**
Mean	1145^{c}	1189^{bc}	1233^{ab}	1284^{a}		1071^{c}	1111^{bc}	1152^{ab}	1199^{a}		1108^{c}	1150^{bc}	1193^{ab}	**1242^{a}**	
S.V.	S.Em. ±					S.Em. ±					S.Em. ±				
I	37					33					25				
K	29					23					19				
I × K	63					52					41				

Main plot : Irrigation regime (I)	Sub plot : Potassium level (K)
I_1 : Furrow irrigation at 0.4 IW/CPE ratio	K_1 : Potassium @ 0 kg ha^{-1}
I_2 : Furrow irrigation at 0.6 IW/CPE ratio	K_2 : Potassium @ 45 kg ha^{-1}
I_3 : Furrow irrigation at 0.8 IW/CPE ratio	K_3 : Potassium @ 60 kg ha^{-1}
I_4 : Furrow irrigation at 1.0 IW/CPE ratio	K_4 : Potassium @ 75 kg ha^{-1}

Means followed by the same letter (s) within a column and row are not differed significantly by DMRT (P = 0.05); S.V.- Source of Variation; NS-Non Significant.

Table 3. 100 seed weight of sunflower as influenced by irrigation regimes and potassium levels

Treatment	100 seed weight (g)														
	2019					**2021**					**Pooled**				
K/I	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
K_1	3.67^{cd}	3.74^{cd}	3.99^{a-d}	4.07^{abc}	3.87^{a}	3.56^{cd}	3.58^{cd}	3.84^{a-d}	3.96^{ab}	3.73^{a}	3.61^{de}	3.66^{c-e}	3.92^{a-e}	4.01^{a-d}	3.80^{ab}
K_2	3.68^{cd}	3.79^{b-d}	4.43^{a}	4.26^{a}	4.04^{a}	3.51^{d}	3.57^{cd}	4.09^{a}	3.99^{ab}	3.79^{a}	3.59^{e}	3.68^{c-e}	4.26^{a}	4.13^{ab}	3.92^{a}
K_3	3.68^{cd}	3.79^{b-d}	4.24^{ab}	4.26^{a}	3.99^{a}	3.51^{d}	3.56^{cd}	4.10^{a}	3.95^{ab}	3.78^{a}	3.59^{e}	3.68^{c-e}	4.17^{ab}	4.10^{ab}	3.89^{a}
K_4	3.58^{d}	3.99^{a-d}	4.22^{ab}	4.37^{a}	4.04^{a}	3.54^{cd}	3.69^{b-d}	3.90^{a-c}	4.14^{a}	3.82^{a}	3.56^{e}	3.84^{b-e}	4.06^{a-c}	4.25^{a}	3.93^{a}
Mean	3.65^{c}	3.83^{c}	4.22^{ab}	4.24^{a}		3.53^{c}	3.60^{bc}	3.98^{ab}	4.01^{a}		3.59^{c}	3.71^{bc}	4.10^{ab}	4.12^{a}	
S.V.	S.Em. ±					S.Em. ±					S.Em. ±				
I	0.12					0.11					0.08				
K	0.10					0.08					0.06				
I × K	0.21					0.17					0.13				

considerable reduction in yield attributing traits such as capitulum diameter (11.7 cm), number of seeds capitulum^{-1} (1,108), 100 seed weight (3.59 g) and grain yield/plant (33.7 g). The significant reduction in yield attributes with irrigation at 0.4 IW/CPE might be related to prolonged and increased low moisture availability, which lowered the biomass accumulation and translocation of assimilates. These results fall in line with the findings of Reddy *et al* (2004), Alahdadi *et al* (2011), Geetha *et al* (2012) and Kassab *et al* (2012).

Similarly, application of potassium @ 75 and 60 kg/ha recorded significantly higher capitulum diameter (14.1 cm), number of seeds capitulum^{-1} (1227), grain weight (41.3 g/plant), 100 seed weight (3.93 g), grain yield (2031 kg/ha) and stalk yield (3987 kg/ha) as compared to other potassium levels. However, it remained on par with application of potassium @ 60 kg/ha . Potassium being an essential nutrient affects most of the biochemical and physiological processes that influence plant growth and metabolism. The uptake rate of potassium reaches its maximum during the late vegetative phase and early reproductive phase. Hence, the split application of potassium synchronised peak uptake demand, which aided in capitulum expansion and higher number of seeds capitulum^{-1}. Further, the transpiration influences the translocation of carbon and nitrogen compounds from source to sink. Potassium through its effect on stomatal function controls the rate of transpiration and consequently the root-shoot transport of mineral salts, nitrate and amino acids (Marschner, 1995; Schobert *et al*, 1998). The potassium concentration controls the membrane potential of sieve tube (Wright and Fischer, 1981) and phloem loading of sucrose. Potassium regulates activation and functioning of invertase in sink organs (Oparka, 1990). It also provides the energy needed for the transmembrane phloem reloading process (Gajdanowicz *et al*, 2011). Hence, application of potassium @ 75 and 60 kg/ha enhanced channelization of photosynthates to reproductive parts during grain filling period, resulting in higher grain yield/plant and increased

Table 4. Grain yield plant^{-1} of sunflower as influenced by irrigation regimes and potassium levels

Treatment	Grain yield plant^{-1} (g)														
	2019					**2021**					**Pooled**				
K/I	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
K_1	33.5^{d}	34.5^{d}	38.1^{cd}	40.0^{c}	36.5^{d}	32.1^{h}	32.7^{gh}	$36.2^{e\text{-}g}$	$38.4^{c\text{-}e}$	34.9^{d}	32.8^{f}	33.6^{ef}	$37.1^{c\text{-}e}$	39.2^{bc}	35.7^{d}
K_2	34.3^{d}	37.1^{cd}	44.6^{ab}	45.2^{ab}	40.3^{bc}	32.4^{h}	$34.6^{f\text{-}h}$	$40.5^{b\text{-}d}$	$41.7^{a\text{-}c}$	37.3^{bc}	33.3^{ef}	$35.8^{c\text{-}f}$	42.5^{ab}	43.4^{a}	38.8^{c}
K_3	35.2^{d}	40.1^{c}	45.2^{ab}	47.5^{a}	42.0^{ab}	33.2^{gh}	$35.7^{e\text{-}h}$	42.6^{ab}	43.5^{ab}	38.8^{ab}	$34.2^{d\text{-}f}$	37.9^{cd}	43.9^{a}	45.5^{a}	40.4^{ab}
K_4	35.1^{d}	41.3^{bc}	46.1^{a}	48.1^{a}	42.6^{a}	34.2^{gh}	$37.8^{d\text{-}f}$	43.4^{ab}	44.3^{a}	39.9^{a}	$34.7^{d\text{-}f}$	39.6^{bc}	44.7^{a}	46.2^{a}	41.3^{a}
Mean	34.5^{d}	38.2^{c}	43.5^{ab}	45.2^{a}		33.0^{cd}	35.2^{c}	40.7^{ab}	42.0^{a}		33.7^{cd}	36.7^{c}	42.1^{ab}	43.6^{a}	
S.V.	S.Em. ±					S.Em. ±					S.Em. ±				
I	1.2					1.1					0.8				
K	1.0					0.8					0.6				
I × K	2.1					1.7					1.4				

Main plot : Irrigation regime (I)	**Sub plot : Potassium level (K)**
I_1 : Furrow irrigation at 0.4 IW/CPE ratio	K_1 : Potassium @ 0 kg ha^{-1}
I_2 : Furrow irrigation at 0.6 IW/CPE ratio	K_2 : Potassium @ 45 kg ha^{-1}
I_3 : Furrow irrigation at 0.8 IW/CPE ratio	K_3 : Potassium @ 60 kg ha^{-1}
I_4 : Furrow irrigation at 1.0 IW/CPE ratio	K_4 : Potassium @ 75 kg ha^{-1}

Means followed by the same letter (s) within a column and row are not differed significantly by DMRT (P = 0.05); S.V.- Source of Variation; NS-Non Significant.

Table 5. Grain yield of sunflower as influenced by irrigation regimes and potassium levels

Treatment	Grain yield (kg ha^{-1})														
	2019					2021					Pooled				
K/I	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
K_1	1602^{d}	1654^{d}	1837^{cd}	1932^{c}	1756^{d}	1573^{h}	1608^{gh}	1786^{d-f}	1893^{cd}	1715^{d}	1588^{f}	1631^{ef}	1811^{c-e}	1912^{bc}	1736^{d}
K_2	1648^{d}	1791^{cd}	2158^{ab}	2195^{ab}	1948^{bc}	1594^{gh}	1709^{e-h}	2006^{bc}	2076^{ab}	1846^{c}	1621^{ef}	1750^{c-f}	2082^{ab}	2135^{a}	1897^{c}
K_3	1698^{d}	1937^{c}	2201^{ab}	2318^{a}	2039^{ab}	1635^{f-h}	1767^{d-g}	2129^{ab}	2179^{ab}	1928^{ab}	1667^{d-f}	1852^{cd}	2165^{a}	2249^{a}	1983^{ab}
K_4	1702^{d}	2002^{bc}	2249^{a}	2345^{a}	2074^{a}	1694^{f-h}	1875^{c-e}	2168^{ab}	2212^{a}	1987^{a}	1698^{d-f}	1939^{bc}	2209^{a}	2278^{a}	2031^{a}
Mean	1663^{d}	1846^{c}	2111^{ab}	2197^{a}		1624^{cd}	1740^{c}	2022^{ab}	2090^{a}		1643^{d}	1793^{c}	2067^{ab}	2144^{a}	
S.V.			S.Em. ±					S.Em. ±					S.Em. ±		
I			59					54					40		
K			48					38					31		
I × K			102					85					67		

100 seed weight. Thus, recorded significantly higher grain yield. These results are similar to the findings of Chaudhry and Mushtaq (1999), Siddiqui *et al* (2009) and Banerjee *et al* (2014).

Irrigation at 1.0 IW/CPE ratio with application of potassium @ 75 kg/ha recorded significantly higher capitulum diameter (15.8 cm), number of seeds capitulum^{-1} (1307), grain weight (46.2 g/plant), 100 seed weight (4.25 g), grain yield (2278 kg/ha) and stalk yield (4175 kg/ha) as compared to other treatment combinations. The next treatment in order was irrigation at 0.8 IW/CPE ratio with application of potassium @ 75 and 60 kg/ha. No moisture and nutrient stress at reproductive phase of the crop with irrigation at 1.0 and 0.8 IW/CPE along with application of potassium @ 75 and 60 kg/ha created a favourable environment for better development of sink (significantly higher capitulum diameter). Availability of optimum water in the rhizosphere along with optimum amount of potassium might have resulted in active photosynthetic area during grain filling stage. Further, the rate of translocation depends on transpiration rates. Potassium though not a major component of plant structure and any organic molecule, plays a significant role in functioning of stomata. Besides, with enough moisture in the rhizosphere potassium regulated stomatal movement in such a way to transpire more and thus increased the rate of translocation of assimilates from source to sink. This resulted in significantly more number of seeds capitulum^{-1} (Table 2), higher 100 seed weight (Table 3), grain yield.plant (Table 4), grain yield (Table 5) and stalk yield (Table 6). However, lower irrigation regimes (0.4 and 0.6 IW/CPE ratio) with no potassium application recorded significantly lower yield attributes and yield. The low soil moisture might have reduced the water energy in the guard cells and promoted stomatal closure, which was further aggravated by the abscisic acid synthesis and ethylene production due to potassium deficiency (Tanaka *et al*, 2005). This resulted in decreased CO_2 fixation rate (Lawlor and Cornic, 2002) and increased canopy temperature due to low gaseous

Table 6. Stalk yield of sunflower as influenced by irrigation regimes and potassium levels

Treatment	Stalk yield (kg ha^{-1})														
	2019					**2021**					**Pooled**				
K/I	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
K_1	3526^{c}	3758^{a-c}	3946^{a-c}	4012^{ab}	3811^{a}	3470^{e}	3662^{b-e}	3788^{a-e}	4018^{ab}	3734^{c}	3498^{d}	3710^{b-d}	3867^{a-d}	4015^{ab}	3772^{c}
K_2	3672^{bc}	3750^{a-c}	4009^{ab}	4109^{ab}	3885^{a}	3532de	3659^{b-e}	3877^{a-d}	4039^{a}	3776^{bc}	3602^{cd}	3705^{b-d}	3943^{a-c}	4074^{ab}	3831^{bc}
K_3	3821^{a-c}	3864^{a-c}	4020^{ab}	4186^{a}	3973^{a}	3631^{c-e}	3866^{a-d}	4054^{a}	4053^{a}	3901^{ab}	3726^{b-d}	3865^{a-d}	4037^{ab}	4119^{ab}	3937^{ab}
K_4	3846^{a-c}	3937^{a-c}	4136^{a}	4210^{a}	4032^{a}	3603de	3990^{a-c}	4031^{a}	4141^{a}	3941^{a}	3724^{b-d}	3964^{a-c}	4083^{ab}	4175^{a}	3987^{a}
Mean	3716^{c}	3827^{bc}	4028^{ab}	4129^{a}		3559^{c}	3794^{a-c}	3937^{ab}	4063^{a}		3638^{c}	3811^{bc}	3983^{ab}	4096^{a}	
S.V.	**S.Em. ±**					**S.Em. ±**					**S.Em. ±**				
I	118					112					81				
K	96					77					61				
I × K	203					174					134				

Main plot : Irrigation regime (I)	**Sub plot : Potassium level (K)**
I_1 : Furrow irrigation at 0.4 IW/CPE ratio	K_1 : Potassium @ 0 kg ha^{-1}
I_2 : Furrow irrigation at 0.6 IW/CPE ratio	K_2 : Potassium @ 45 kg ha^{-1}
I_3 : Furrow irrigation at 0.8 IW/CPE ratio	K_3 : Potassium @ 60 kg ha^{-1}
I_4 : Furrow irrigation at 1.0 IW/CPE ratio	K_4 : Potassium @ 75 kg ha^{-1}

Means followed by the same letter (s) within a column and row are not differed significantly by DMRT (P = 0.05); S.V.- Source of Variation; NS-Non Significant exchange (especially water vapour). This might have resulted in lower rate of photosynthesis, translocation and assimilation of photosynthates, which led to significantly lower yield attributes and yield. These results fall in line with the findings of Dar *et al* (2021).

REFERENCES

Abdou S M M, Abd El- Latif K. M, Farrag R M F and Yousef K M R (2011). Response of sunflower yield and water relations to sowing dates and irrigation scheduling under middle Egypt condition. *Adv Appl Sci Res* **2** (3): 141-150.

Alahdadi I, Oraki H and Khajani F P (2011). Effect of water stress on yield and yield components of sunflower hybrids. *African J Biotechnol* **10**(34): 6504-6509.

Banerjee H, Dutta S K, Pramanik S J, Ray K, Phonglosa A and Bhattacharyya K (2014). Productivity and profitability of spring planted sunflower hybrid with nitrogen, phosphorus and potassium fertilizer. *Annals of Pl and Soil Res* **16**(3): 250-256.

Brar J S, Mahal S S, Saini K S and Brar N S (2016). Response of sunflower yield to planting methods and irrigation schedules. *Indian J Agric Res* **50**(1): 71-75.

Chaudhry A U and Mushtaq M (1999). Optimization of potassium in sunflower. *Pakistan J Biological Sci* **2**(3): 887-888.

Dar J S, Cheema M A, Rehmani M I A, Khuhro S, Rajput S, Virk A L, Hussain S, Bashir M A, Alghanem S M, Al-Zuaibr F M, Ansari M J and Hessini K (2021). Potassium fertilization improves growth, yield and seed quality of sunflower (*Helianthus annuus* L.) under drought stress at different growth stages. *Plos One* **16** (9): 1-16.

Dastane N G (1972). *A practical manual for water use research in agriculture*. Nava Bharat Prakashan, Pune, India.

Gajdanowicz P, Michard E, Sandmann M, Rocha M, Dreyer I (2011). Potassium gradients serve as a mobile energy source in plant vascular tissues. *Proc National Acad Sci* 108 (2): 864–869.

Geetha A, Suresh J and Saidaiah P (2012). Study on response of sunflower (*Helianthus annuus* L.) genotypes for root and yield characters and water stress. *Current Biotica* **6**(1): 32-41.

Gurumurthy P, Rao M S, Reddy B B and Reddy B N (2008). Optimizing tillage and irrigation for sunflower cultivation in rice fallow alfisols of semiarid tropics. *HELIA* **31**(49): 91-102.

Hittinahalli N M (1998). *Effect of irrigation, nitrogen and sulphur fertilization on hybrid sunflower* (DSH-1). *M. Sc. (Agri.) Thesis*, University of Agricultural Sciences, Dharwad, Karnataka, India.

Kassab O M, Abo Ellil A A and Abo El-Kheir M S A (2012). Water use efficiency and productivity of two sunflower cultivars as influenced by three rates of drip irrigation water. *J Appl Sci Res* **8** (7): 3524-3529.

Kumar V and Tiwari A (2020). Sparking yellow revolution in India again. *Rural Pulse* 34: 1-4.

Lawlor D W and Cornic G (2002). Photosynthetic carbon assimilation and associated metabolism in relation to water deficits in higher plants. *Plant, Cell and Environ* **25**(2): 275-294.

Marschner H (1995). Marschner's mineral nutrition of higher plants, Waltham, M A, pp. 178-189.

Meti G S, Somanagouda G, Doddamani S and Meli S S (2004). Effect of irrigation, sources and levels of sulphur on sunflower yield and nutrient uptake. *Agri Sci Digest* **24**(3): 206 - 208.

Moitra A, Puste A M, Mandal T K, Gunri S K, Banerjee H and Pramanik B R (2012). Yield, water use and economics of summer sunflower (*Helianthus annuus* L.) as influenced by irrigation and integrated nutrient management. *World J Sci and Technol* **2**(7): 81-86.

Oparka K J (1990). What is phloem unloading?. *Plant Physiol* **94**(2): 393–396.

Parihar S S, Sahu B S and Singh N T (1975). A critical appraisal of research on irrigation scheduling to crops. *Proceedings of Second World Congress*, International Water Resources Association, New Delhi, India, 1: 343-51.

Ramamoorthy K, Arthanari M P and Subbian P (2009). Effect of irrigation scheduling and method of irrigation on productivity and water economy in hybrid sunflower (*Helianthus annuus* L.). *HELIA* **32**(50): 115-122.

Schobert C, Baker L, Komor E, Hayashi H, Chino M, Lucas W J (1998). Identification of immunologically related proteins in sieve-tube exudate collected from monocotyledonous and dicotyledonous plants. *Planta* **206**(2): 245–252.

Siddiqui M H, Oad F C, Abbasi M K and Gandahi A W (2009). Effect of NPK, micronutrients and N-placement on the Growth and Yield of Sunflower. *Sarhad J Agric* **25**(1): 45-52.

Tanaka Y, Sano T, Tamaoki M, Nakajima N, Kondo N and Hasezawa S (2005). Ethylene inhibits abscisic acid-induced stomatal closure in Arabidopsis. *Plant Physiol* **138**(4): 2337-2343.

Wright J P, Fisher, D B (1981). Measurement of the sieve tube membrane potential. *Plant Physiol* 67(4): 845–848.

Received on 29/7/2022 *Accepted on 22/10/2022*