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RESEARCH PAPER

Effect of irrigation scheduling and integrated nutrient management practices on oil yield, quality, water use efficiency and economics of sunflower in Vertisol of Malaprabha Command Area

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Abstract: A field experiment was conducted in calcarious *Vertisol* at the Irrigation Water Management Research Centre (IWMRC) Belavatgi, Navalgund taluk of Dharwad, Karnataka, during *kharif* 2016-17 and 2017-18. The experiment was laid out in split plot design. The main plot consisted of irrigation scheduling, whereas the sub-plot included integrated nutrients management levels with three replications. The pooled data on sunflower during 2016-17 and 2017-18 revealed that, irrigation scheduling at 0.8 IW/CPE and application of RPP + PSB + GM (one row of sunhemp between two rows of sunflower) has significantly noticed higher oil content (41.83), oil yield (764.88), protein content (20.47), gross returns (₹ 63935 ha^{-1}), net returns (₹ 26339 ha^{-1}) and BC ratio (1.70). However, the application of RPP + PSB + GM and 0.6 IW/CPE has significantly registered higher WUE (6.64 kg ha - mm^{-1}) of sunflower at harvest.

Key words: Irrigation scheduling, Nutrient management, Quality, Sunflower

Introduction

Sunflower (*Helianthus annuus* L.) is one of the important edible oilseed crops of India as well as worldwide because of its adequate supply of unsaturated fatty acids (900 g/kg) as reported by Burton *et al.* (2004). This crop occupies second place as source of edible oil next to the soybean. Thimmegowda *et al.* (2007) reported that sunflower has gained very popularity among all the oilseed crops, because of its high quality oil due to higher unsaturated fatty acids, anti-cholesterol property, wide adaptability to different soil types, short duration, and climatic conditions, drought tolerance, photo and thermo-insensitive and higher oil yield per unit area. Karnataka state is leading sunflower producing state in the country and contributes nearly about 62 per cent of total area and 48 per cent of total production in India.

Soil quality maintenance and improving for increasing and sustainable agricultural production is inevitable for India's nutritional and food security concern. Although, India is food surplus country at present with 277.49 mt of food grain production per annum, it will require about 4 mt of additional food grains each year, if the trend in rising population persists (Gajbhiye *et al.,* 2013). The maximum yields were obtained with sufficient irrigation which provide adequate soil moisture during flowering and seed formation periods. However, adequate supply of water at early stage of plant growth is important for responding to irrigations as shown by Tolga and Lokman (2003).

Material and methods

The field experiment was conducted at Irrigation Water Management Research Centre (IWMRC) Belavatgi, Navalgund taluk of Dharwad, Karnataka during *kharif* 2016-17 and 2017-18 to know the effect of integrated nutrient management (INM) in sunflower-chickpea cropping sequence under varied irrigation levels in *Vertisol* of Malaprabha Command Area. The experiment was laid out in split plot design with three replications. The experiment site was calcareous in nature and soil was clay in texture, alkaline in reaction, normal in salt content, low in available nitrogen, medium in available phosphorus and sulphur and high in available potassium status. The soil was high in DTPA extractable Cu, Zn and Mn but deficient in Fe. The main plot consisted of three irrigation levels (I_1-0.8 IW/CPE, I_2- 0.6 IW/CPE and I_3- Irrigation at critical stages-germination, flowering and seed filling stage) and the total amount of water applied during *kharif* 2016-17 was I_1- 329.3, I_2- 262.1 and I_3- 276.7 mm, respectively and 2016-17 was I_1- 385.8, I_2- 325.8 and I_3- 325.8 mm, respectively. The sub-plot consisted of five nutrient management treatments *viz.*,M_1-RPP, M_2- RPP + PSB, M_3- RPP + PSB + GM (one row of sunhemp between two rows of sunflower), M_4-75 per cent RPP + PSB + GM (one row of sunhemp between two rows of sunflower) + sunflower stalk incorporation @ 5 t / ha with cellulolytic culture and M_5 = 50 per cent RPP + PSB + GM (one row of sunhemp between two rows of sunflower) +sunflower stalk incorporation @ 5 t ha^{-1} with cellulolytic culture with net plot size 3.0 × 2.4 m. However, RPP comprised of 90 kg N: 90 kg P_2O_5: 60 kg K_2O: 10 kg $ZnSO_4$ ha^{-1} +0.5 % borax foliar spray at ray floret stage + FYM @ 8 t ha^{-1} + *Azospirillum* @ 500 g/ha.

Results and discussion

Water use efficiency of sunflower as influenced by application of nutrients and irrigation levels and their interactions during individual years as well as pooled data is presented in Table 1. Among the different irrigation scheduling treatments, the higher water use efficiency (5.96 kg ha- mm^{-1}) was observed in I_2 (0.6 IW/CPE ratio irrigation) and lower water use efficiency (5.15 kg ha - mm^{-1}) of sunflower was recorded in I_1 treatment (0.8 IW/CPE ratio irrigation).

The pooled data on WUE indicated that, there was a significant variation in the water use efficiency with respect to different INM treatments. The M_3 treatment (100 % RPP + PSB + GM) recorded significantly higher water use efficiency (6.17 kg

Table 1. Effect of irrigation and INM levels on WUE, oil content, oil yield and protein content in sunflower

	WUE (kg ha - mm^{-1})			Oil content (%)			Oil yield (kg ha^{-1})			Protein content (%)		
	2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
Main plot - Irrigation levels												
I_1-0.8 IW/CPE	5.08	5.23	5.15	39.45	38.41	38.93	662.79	632.77	647.78	20.00	19.98	19.99
I_2- 0.6 IW/CPE	5.99	5.94	5.96	38.11	38.37	38.24	602.21	603.49	602.85	20.35	20.08	20.18
I_3- = Irrigation at critical stages	5.65	5.63	5.64	38.53	37.87	38.20	605.89	568.35	587.12	20.21	21.14	20.67
S.Em.±	0.04	0.06	0.04	0.36	0.86	0.42	7.28	20.43	10.20	0.16	0.40	0.27
C.D. (P=0.05)	0.10	0.15	0.13	1.02	NS	NS	20.57	53.22	27.45	NS	NS	NS
Sub-plot - INM levels												
M_1 - RPP	5.88	5.80	5.84	39.52	39.00	39.26	667.56	640.65	654.11	20.62	20.15	20.38
M_2 - RPP + PSB	5.94	5.85	5.90	40.06	38.46	39.60	683.84	637.13	660.49	20.94	20.36	20.65
M_3 - RPP + PSB + GM	6.21	6.13	6.17	41.26	39.88	40.57	736.08	693.00	714.54	20.79	20.56	20.68
M_4 - 75 % RPP + PSB + GM + SSI @ 5 t / ha	5.39	5.33	5.36	36.89	37.72	37.31	572.58	569.90	571.24	18.75	19.66	19.20
M_5 - 50 % RPP + PSB + GM + SSI @ 5 t / ha	4.44	4.89	4.66	35.76	36.02	35.89	458.08	467.00	462.54	19.83	21.12	20.47
S.Em.±	0.06	0.07	0.05	0.54	0.51	0.42	11.84	11.38	8.81	0.57	0.43	0.62
C.D. (P=0.05)	0.18	0.21	0.14	1.57	1.49	1.23	34.56	33.21	25.71	NS	NS	NS
Interaction												
I_1M_1	5.27	5.29	5.28	39.77	38.87	39.32	690.06	670.83	680.44	20.58	19.73	20.16
I_1M_2	5.30	5.33	5.31	40.84	38.53	39.69	712.22	668.80	690.51	20.83	20.08	20.46
I_1M_3	5.58	5.56	5.57	42.40	41.27	41.83	779.52	750.24	764.88	20.24	20.70	20.47
I_1M_4	5.02	4.88	4.95	37.53	37.43	37.48	619.82	595.42	607.62	19.20	18.80	19.00
I_1M_5	4.23	5.05	4.64	36.70	35.93	36.32	512.33	478.57	495.45	19.13	20.64	19.88
I_2M_1	6.36	6.15	6.25	38.73	38.70	38.72	645.72	627.72	636.72	20.83	19.92	20.38
I_2M_2	6.47	6.20	6.33	39.57	38.73	39.15	671.03	633.57	652.30	21.09	20.25	20.67
I_2M_3	6.68	6.61	6.64	40.63	39.63	40.13	711.35	690.60	700.98	21.00	19.99	20.50
I_2M_4	5.74	5.83	5.78	36.37	39.00	37.68	547.31	600.12	573.71	18.63	18.80	18.71
I_2M_5	4.72	4.89	4.81	35.23	35.77	35.50	435.63	465.46	450.55	20.19	21.05	20.62
I_3M_1	6.02	5.96	5.99	40.07	39.43	39.75	666.91	623.40	645.15	20.44	20.81	20.62
I_3M_2	6.07	6.02	6.05	39.77	38.10	38.93	668.27	609.03	638.65	20.90	20.76	20.83
I_3M_3	6.36	6.20	6.28	40.73	38.73	39.73	717.37	638.18	677.77	21.12	20.99	21.06
I_3M_4	5.41	5.27	5.34	36.77	36.73	36.75	550.62	514.17	532.39	18.42	21.38	19.90
I_3M_5	4.36	4.73	4.55	35.33	36.37	35.85	426.28	456.96	441.62	20.16	21.68	20.92
S.Em.±	0.11	0.12	0.09	0.93	0.88	0.73	20.51	19.71	15.25	0.98	0.82	1.24
C.D. (P=0.05)	0.31	0.36	0.25	2.72	2.58	2.13	59.87	57.52	44.53	NS	NS	NS

I- irrigation level, M- Management level, GM (one row of sunhemp between two rows of sunflower) and SSI-(Decomposed sunflower stalk incorporation @ 5 t/ha with cellulolytic culture)

Table 2. Economics of sunflower as influenced by irrigation and INM levels

	Cost of cultivation (₹)			Gross returns ₹ ha^{-1})			Net returns (₹ ha^{-1})			BC ratio		
	2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
Main plot - Irrigation levels												
I_1-0.8 IW/CPE	34974	35796	35385	56494	59394	57944	21520	23598	22559	1.62	1.66	1.64
I_2- 0.6 IW/CPE	34338	35160	34749	53163	56761	54962	18825	21601	20213	1.55	1.61	1.58
I_3-= Irrigation at critical stages	34338	35160	34749	52864	54404	53634	18526	19244	18885	1.54	1.55	1.54
S.Em.±	-	-	-	335	578	333	-	-	-	-	-	-
C.D. (P=0.05)	-	-	-	867	1623	821	-	-	-	-	-	-
Sub-plot - INM levels												
M_1 - RPP	36156	36974	36565	57004	59496	58250	20848	22522	21685	1.58	1.61	1.59
M_2 - RPP + PSB	36276	37094	36685	57581	60015	58798	21305	22921	22113	1.59	1.62	1.60
M_3 - RPP + PSB + GM	36760	37584	37172	60163	62964	61564	23403	25380	24392	1.64	1.68	1.66
M_4 -75 % RPP + PSB + GM + SSI @ 5 t / ha	33439	34263	33851	52515	54683	53599	19076	20420	19748	1.57	1.60	1.58
M_5 - 50 % RPP + PSB + GM + SSI @ 5 t / ha	30122	30946	30534	43606	47108	45357	13484	16162	14823	1.45	1.52	1.49
S.Em.±	-	-	-	564	696	467	-	-	-	-	-	-
C.D. (P=0.05)	-	-	-	1647	2032	1362	-	-	-	-	-	-
Interaction												
I_1M_1	36580	37398	36989	58523	62427	60475	21943	25029	23486	1.60	1.67	1.63
I_1M_2	36700	37518	37109	58842	62772	60807	22142	25254	23698	1.60	1.67	1.64
I_1M_3	37184	38008	37596	61988	65883	63935	24804	27875	26339	1.67	1.73	1.70
I_1M_4	33863	34687	34275	55833	57477	56655	21970	22790	22380	1.65	1.66	1.65
I_1M_5	30546	31370	30958	47284	48412	47848	16738	17042	16890	1.55	1.54	1.55
I_2M_1	35944	36762	36353	56275	58565	57420	20331	21803	21067	1.57	1.59	1.58
I_2M_2	36064	36882	36473	57181	59226	58204	21117	22344	21731	1.59	1.61	1.60
I_2M_3	36548	37372	36960	59090	63152	61121	22542	25780	24161	1.62	1.69	1.65
I_2M_4	33227	34051	33639	51015	55614	53314	17788	21563	19675	1.54	1.63	1.58
I_2M_5	29910	30734	30322	42255	47250	44753	12345	16516	14431	1.41	1.54	1.48
I_3M_1	35944	36762	36353	56214	57496	56855	20270	20734	20502	1.56	1.56	1.56
I_3M_2	36064	36882	36473	56719	58046	57382	20655	21164	20909	1.57	1.57	1.57
I_3M_3	36548	37372	36960	59410	59859	59634	22862	22487	22674	1.63	1.60	1.61
I_3M_4	33227	34051	33639	50696	50959	50827	17469	16908	17188	1.53	1.50	1.51
I_3M_5	29910	30734	30322	41280	45662	43471	11370	14928	13149	1.38	1.49	1.43
S.Em.±	-	-	-	977	1206	808	-	-	-	-	-	-
C.D. (P=0.05)	-	-	-	2852	3520	2359	-	-	-	-	-	-

I- irrigation level, M- Management level, GM (one row of sunhemp between two rows of sunflower) and SSI-(Decomposed sunflower stalk incorporation @ 5 t/ha with cellulolytic culture)

ha - mm^{-1}) and the lesser water use efficiency (4.66 kg ha - mm^{-1}) was recorded in M_5 treatment (50 % RPP+PSB+GM+SSI @ 5 t ha^{-1}). The interaction effect was significant with regards to water use efficiency of sunflower. Significantly higher water use efficiency (6.64 kg ha - mm^{-1}) was observed with the treatment combination of I_2M_3 (0.6 IW/CPE ratio irrigation and 100 % RPP+PSB+GM) and lower water use efficiency (4.55 kg ha - mm^{-1}) was observed in I_3M_5 (50 % RPP+PSB+GM+SSI @ 5 t ha^{-1} + critical stages irrigation). This might be due to the balanced application of water, chemical fertilizers and organic manures which enriched the available nutrients status in the soil. Moreover, it enhanced growth promoting enzymes and improved in soil physical properties which led to increase in WUE of crop as concluded by Ramamoorthy *et al.* (2009).

The oil content of sunflower is shown in Table 1 as influenced by irrigation and INM levels. Among the different irrigation treatments, the oil content of sunflower was found to be non-significant. However, the higher oil content (38.93 %) was noticed in I_1 (0.8 IW/CPE ratio irrigation).The higher oil yield recorded with more frequent irrigation could be attributed to higher growth and yield parameters as reported by Sumathi and Koteswara Rao (2007). Significant variation in oil content was noticed with respect to different INM treatments in sunflower. The pooled data on oil content indicated that, the application of 100 % RPP+PSB+GM (M_3) registered significantly highest oil content (40.57 %) when compared to other treatments and lower oil content was found in the M_5 (35.89 %) treatment. Narendra (2017) reported that, increase in oil content might be due to the supply of sulphur (applied through gypsum and zinc sulphate) and its involvement in the synthesis of fatty acids and protein such as cystene, cysteine and methionine. It is evident from the results that sulphur had remarkable influence on protein and oil content as recorded by Chitale *et al*. (2004).

The interaction effect was found to be significant with regard to oil content in sunflower. The higher oil content (41.83 %) was observed in combination of I_1M_3 (0.8 IW/CPE ratio irrigation and 100 % RPP+PSB+GM) and was on par with I_2M_3 (40.13 %), I_3M_1 (39.75 %) and I_3M_3 (39.73 %). The lower oil content (35.50 %) of sunflower was observed in I_2M_5. It might be due to application of organic manures which might have enriched the mineral elements in the soil that resulted in better synthesis of chlorophyll in leaves, leading to higher photosynthesis and better translocation of food materials from source to sink and thus might have resulted in higher oil content in seeds as reported by Lokhande *et al.* (2018).

The effect of irrigation and INM levels on oil yield of sunflower is presented in Table 1. The oil yield as influenced by irrigation scheduling was found to be significant. The higher oil yield (647.78 kg ha^{-1}) in I_1 treatment (0.8 IW/CPE ratio irrigation) and the lower oil yield (587.12 kg ha^{-1}) in I_3 treatment (irrigation at critical stages)was noticed. The significant variation in oil yield was noticed with respect to different INM treatments. The pooled data on oil yield indicated that, the application of 100 per cent RPP+PSB+GM (M_3) registered significantly higher oil yield (714.54 kg ha^{-1}) of sunflower as compared to other treatments. Whereas, the lower oil yield (462.54 kg ha^{-1}) was noticed in the M_5 treatment. The interaction effect between irrigation and INM levels showed significant difference in the oil yield of sunflower. The higher oil yield of sunflower (764.88 kg ha^{-1}) was observed with the treatment combination of I_1M_3 (0.8 IW/CPE ratio irrigation and 100 % RPP+PSB+GM) and the lower oil yield (441.62 kg ha^{-1}) with I_3M_5.

The individual years (2016-17 and 2017-18) and pooled data on protein content of sunflower as influenced by irrigation, INM levels and their interaction was found to be non-significant (Table 1). However, among the different INM levels, higher protein content was observed in M_3 treatment (20.68 %) and in case of interaction treatments, I_3M_3 has recorded higher protein (21.06 %) content.

The results on cost of cultivation, gross returns, net returns and BC ratio of sunflower is presented in Table 2. The irrigation at 0.8 IW/CEP ratio (I_1) recorded higher gross returns (₹ 57944 ha^{-1}), net returns (₹ 22559 ha^{-1}) and BC ratio (1.64) over the other irrigation treatments and lower gross returns (₹ 53634 ha^{-1}), net returns (₹18885 ha^{-1}) and BC ratio (1.54) was found in I_3 treatment (irrigation at critical stages).The increase in irrigation frequency increased the total expense on cultivation accordingly *viz*., I_1 (0.8 IW/CPE), I_2 (0.6 IW/CPE) and I_3 (critical stage approach). The gross monetary return, net return and BC ratio per hectare increased with increase in the level of irrigation. The maximum gross return, net return and BC ratio was noticed in irrigation scheduling at 0.8 IW/CPE and it was higher under irrigation level as compared to critical stages approach. Moreover, the higher gross return, net return and BC ratio recorded at higher frequency of irrigation (I_1) was due to higher growth and yield of crop. The cost of irrigation schedule increased with the number of irrigations but the net profit was relatively higher because of the magnitude of increase in yield was more.

Among the different integrated nutrient management levels, the M_3 (100 % RPP+PSB+GM) treatment registered higher gross returns (₹ 61564 ha^{-1}), net returns (₹ 24392 ha^{-1}) and BC ratio (1.66) over the other irrigation treatments. The lower gross returns (45357 ha^{-1}), net returns (₹ 14823 ha^{-1}) and BC ratio (1.49) was found in M_5 treatment (50 % RPP+PSB+GM+SSI @ 5 t ha^{-1}). The interaction effect of treatments on economics of sunflower showed that, the combination of 100 per cent RPP+PSB+GM and 0.8 IW/CPE ratio irrigation (I_1M_3) showed higher gross returns (₹ 63935 ha^{-1}), net returns (₹ 26339 ha^{-1}) and BC ratio (1.70) as compared to other treatment combinations.

Conclusion

Irrigation scheduling at 0.8 IW/CPE and 100 per cent RPP+PSB+GM (one row of sunhemp between two rows of sunflower) resulted in higher oil content as well as oil yield, net returns and BC ratio. The above treatment was found most effective and ideal for increasing productivity of sunflower. Application of irrigation at 0.6 IW/CPE irrigation and 100 per cent RPP + PSB + GM (one row of sunhemp between two rows of sunflower) recorded higher WUE than other treatments.

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