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Longterm Irrigation scheduling with different irrigated land modules and *insitu* green manuring effects on growth and yield of Sunflower in *Vertisol* of Malaprabha command area

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Abstract
A long-term field experiment was conducted during 2014-15 to 2017-18 to evaluate the interaction between different irrigated ecosystems *viz.*, rainfed (I_1) and irrigated (I_2-0.8 IW/CPE and I_3 -0.6 IW/CPE) with different land modules (*i.e.*, T_1 and T_2 Compartment bunding without and with sunhemp, T_3 and T_4 Broad bed furrows without and with sunhemp and T_5 and T_6 Furrows without and with sunhemp) in Sunflower. The pooled results indicated that among irrigated ecosystems, irrigation at 0.8 IW/CPE ratio recorded significantly higher sunflower (17.15 q ha^{-1}) as compared to rainfed ecosystem (14.19 q ha^{-1}). Among the land modules, broad bed furrows with *in-situ* sunhemp green manuring showed significant differences on sunflower yield (17.63 q ha^{-1}) and higher water use efficiency of 4.83 kg ha.mm^{-1}, respectively. Economic analysis states that, the net returns and B:C ratio were significantly influenced due to irrigation and land modules**.** The pooled data reveals that, irrigation @ 0.8 IW/CPE ratio recorded significantly higher net returns of Rs.26,399 ha^{-1}and among the different *insitu* moisture conservation systems, significantly higher net returns (Rs.27,864 Rs.) and B:C ratio (2.42) were recorded with the broad bed furrows with sun hemp (T_4) as compared to rest of the treatments. Among interactions, irrigation at 0.8 IW/CPE with land module broad bed furrows with sunhemp recorded significantly higher B:C ratio of 2.51.

Keywords: land modules, irrigated ecosystems, WUE, IW/CPE ratio, *in-situ*, B:C ratio

Introduction

Water scarcity and unpredictable rainfall constrain crop production in *Vertisol* dominated command areas. Seasonal, erratic monsoon rainfall and limited reservoir releases create moisture stress during crop critical stages, reducing yield and water productivity. Rainfed areas can be made productive and profitable by adopting improved technologies for rainwater conservation and harvesting and commensurate agricultural production technologies. Soil management practices are tailored to store and conserve as much rainfall as possible by reducing runoff and increasing storage capacity of soil profile (Muthamilselvan *et al.*, 2006) [11]. Sunflower crop is highly sensitive to water stress between flowering and grain filling stages and is the most established system in Malaprabha command area. Sunflower (*Helianthus annuus* L.) is one of the important oil seed crop in the world and belongs to the family *Asteraceae*. India's contribution to the total global sunflower oil production is around one per cent. In India, sunflower is being cultivated in the states of Karnataka, Maharashtra and Andhra Pradesh of which Karnataka occupies an area of 0.89 lakh hectares with a production of 0.80 lakh tonnes and productivity of 899 kg ha^{-1}(Anon., 2023) [1].Though many factors contribute for increasing the potential yield of crops, soil moisture is considered to be vital as the crop response to all other inputs depends on the availability of soil water in the profile from sowing to harvest especially at critical stages of crop growth in drylands (Ardeshna *et al.*, 2013; Paulpandi *et al.*, 2009; Reddy *et al.*, 2005) [2, 12, 13]. Hence, effective use of rainwater through conservation measures at farmers' field is becoming important due to frequent droughts and predicted moisture deficits situations in future due to changing climatic situations (Deutsch *et al.*, 2010;

Lal *et al.*, 2011) [3, 8]. The continuous application of inorganic fertilizers without complementary organic amendments leads to deterioration of soil properties and contributes to environmental pollution. Incorporating green manure into the soil is an effective strategy to enhance soil quality and sustainability. The importance of organic manures and crop residues in supplying nutrients and maintaining soil health is well established. Therefore, greater emphasis must be placed on farming systems that promote organic matter management through efficient recycling of organic resources. In addition, *insitu* rainwater conservation increases water and nutrient availability besides improving soil health and sustaining sunflower productivity (Hegde and Sudhakara Babu, 2009; Madhurendra *et al.*, 2009; Maruthi Sankar *et al.*, 2008; Paulpandi *et al.*, 2009) [5, 9, 10, 12]. Keeping these points in view the present investigation was undertaken to ascertain the yield of sunflower by conjoint use of different irrigated land module ecosystems and green manuring.

Materials and Methods

A long term field trial was carried out at Irrigation Water Management Reaserch Centre, Belavatagi during 2014-15 to 2017-18. The initial soil was clayey in nature with pH 8.30, Electrical conductivity 0.22 dsm^{-1}, organic carbon 0.52 per cent, available P_2O_5 22.00 kg ha^{-1} and available K_2O 768 kg ha^{-1}. The experiment was laid out in split plot design with three replications. The treatment consisted of three irrigation levels *i.e.*, I_1- Rainfed, I_2 and I_3 are 0.8 and 0.6 IW/CPE ratio and different land modules (*i.e.*, T_1 and T_2 Compartment bunding without and with sunhemp, T_3 and T_4 Broad bed furrows without and with sunhemp and T_5 and T_6 Furrows without and with sunhemp), respectively. Sunflower was grown in *kharif* and green manuring crop sunhemp was sown in between the rows of sunflower, later which were subsequently incorporated into the soil. The total water use was calculated as sum of effective rainfall and amount of water (input water) applied. Water use efficiency was calculated as: Seed yield of crop (kg ha^{-1}) / Total water use (kg ha.mm^{-1}).

Results and Discussion

Longterm effect of irrigation scheduling under different irrigated land module ecosystems and *insitu* green manuring on growth and yield attributes of sunflower

The pooled data of sunflower with respect to growth parameters *viz.,* plant height, head diameter, grain and stalk yield of sunflower is presented in Table.1.

The results reveal that the plant height at harvest was significantly influenced by the irrigation levels and land module ecosystems. Among irrigation levels, significantly higher plant height of 179.02 cm was recorded in irrigation level at I_2 (0.8 IW/CPE ratio) which was followed by 178.81 cm at irrigation level I_3 (0.6 IW/CPE ratio). However, the head diameter of sunflower was not significantly influenced among irrigation levels. Similarly, the pooled data indicates that significantly higher grain and stalk yield of 17.15 and 42.82 q ha^{-1} was observed in irrigation level at I_1 (0.8 IW/CPE ratio). This might be due to sufficient soil moisture from initial to harvest in field favouring growth and yield of the crop. Similar results were noticed by Tripathy and Bastia (2012) [15] and Eman *et al.* (2015) [4].

Among the different irrigated land module ecosystems, significantly higher plant height of 182.72 cm, head diameter of 18.41 cm, higher grain and stalk yield of 17.63 and 44.31q ha^{-1} were recorded in T_4 (Broad bed furrows with sunhemp) which was followed by T_6 (Furrows with sunhemp) which recorded plant height of 179.26 cm, head diameter of 17.75 cm, higher grain and stalk yield of 16.73 and 42.35q ha^{-1}, respectively compared all other treatments. Significant differences in interactions was observed in plant height whereas, nonsignificant differences on head diameter, grain and stalk yield of sunflower was noticed. This might be due to availablility of sufficient nitrogen through fertilizer and incorporated green manure and moisture in the broad bed furrow with sunhemp which might have enhanced the growth of the plant, inturn producing higher dry grain yield and stalk yield. Similar results were noticed by Venkatakrishnan, (1998) [16], Kadam *et al*. (2000) [7] and Hiremath *et al*. (2003) [6].

Longterm effect of irrigation scheduling under different irrigated land module ecosystems and *insitu* green manuring on water use efficiency and economics of growing sunflower

The pooled data of sunflower with respect to water use efficiency (kg hamm^{-1}.), Gross income (Rs.ha^{-1}), Net income (Rs ha^{-1}) and B:C ratio of Sunflower is presented in Table.2.

Irrigation levels significantly influenced on water use efficiency. The land module ecosystems had a significant influence on water use efficiency, significantly higher water use efficiency of 4.83 kg ha.mm^{-1} was recorded in T_4 (broad bed furrows with sunhemp) which was followed by T_3 (Broad bed furrows without sunhemp) which recorded 4.58 kg ha.mm^{-1} and lower water use efficiency of 3.94 kg ha.mm^{-1} in T_1 (Compartment bunding without sunhemp). Non significant differences were observed on water use efficiency in interactions (Table.2). This might be due to modified land configuration like broad bed furrows with *insitu* green manuring of sunhemp resulted in decreased bulk density, increased porosity, thereby helping to store more moisture and even to drain excess water in the root zone. This could also be supported by better physical conditions of soil such as better aeration and lower mechanical impedance making the soil to remain soft and moist due to the *insitu* rainwater harvesting by reducing runoff losses and finally all this supported the crop growth and yield and increased the WUE of sunflower. Similar results were noticed by Singh *et al* (1997) [14].

Table 1: Longterm effect of irrigation scheduling under different irrigated land module ecosystems and *insitu* green manuring on plant height, head diameter, grain and stalk yield of Sunflower (Pooled over 4 years 2014-15 to 2017-18)

Treatments	Plant height (cm) at harvest				Head diameter (cm)				Grain yield (q ha^{-1})				Stalk yield (q ha^{-1})			
	I_1 = Rainfed	I_2 = 0.8 IW / CPE	I_3 = 0.6 IW / CPE	Mean	I_1 = Rainfed	I_2 = 0.8 IW / CPE	I_3 = 0.6 IW / CPE	Mean	I_1 = Rainfed	I_2 = 0.8 IW / CPE	I_3 = 0.6 IW / CPE	Mean	I_1 = Rainfed	I_2 = 0.8 IW / CPE	I_3 = 0.6 IW / CPE	Mean
T_1 - Compartment bunding without sunhemp	168.54	173.63	173.02	171.73	15.49	16.29	15.86	15.87	12.50	15.36	13.91	13.92	36.36	39.91	39.66	38.64
T_2 - Compartment bunding with sunhemp	169.61	175.13	174.06	172.93	16.44	17.14	16.29	16.63	13.22	16.32	14.37	14.64	37.97	41.19	39.82	39.66

T_3 - Broad bed furrows without sunhemp	172.12	180.57	180.62	177.77	16.57	17.68	17.37	17.19	14.83	17.89	17.48	16.73	40.87	43.59	42.59	42.35
T_4 - Broad bed furrows with sunhemp	178.38	184.57	185.21	182.72	17.95	18.64	18.63	18.41	16.21	18.69	18.00	17.63	42.51	45.72	44.71	44.31
T_5 - Furrows without sunhemp	170.85	180.23	178.93	176.67	17.02	17.41	17.55	17.32	13.93	17.04	15.91	15.63	40.33	42.75	42.07	41.72
T_6 - Furrows with sunhemp	176.81	179.98	181.01	179.26	17.32	17.95	18.00	17.75	14.48	17.61	17.22	16.43	42.23	43.79	43.83	43.28
Mean	172.71	179.02	178.81	176.84	16.80	17.52	17.20	17.19	14.20	17.15	16.15	15.83	40.04	42.82	42.11	41.66
Irrigation	SEm±		CD(0.05)		SEm±		CD(0.05)		SEm±		CD(0.05)		SEm±		CD(0.05)	
	1.12		3.90		0.19		NS		0.42		1.46		0.62		2.17	
Land modules	0.43		1.23		0.12		0.35		0.31		1.46		0.30		0.85	
I X L	0.74		2.13		0.22		NS		0.53		NS		0.52		NS	

Table 2: Longterm effect of irrigation scheduling under different irrigated land module ecosystems and *insitu* green manuring on water use efficiency and economics of growing Sunflower (Pooled over 4 years 2014-15 to 2017-18).

Treatments	Water use efficiency (kg ha.mm^{-1})				Gross income (Rs. ha^{-1})				Net income (Rs ha^{-1})				B:C ratio			
	I_1 = Rainfed	I_2 = 0.8 IW / CPE	I_3 = 0.6 IW / CPE	Mean	I_1 = Rainfed	I_2 = 0.8 IW / CPE	I_3 = 0.6 IW / CPE	Mean	I_1 = Rainfed	I_2 = 0.8 IW / CPE	I_3 = 0.6 IW / CPE	Mean	I_1 = Rainfed	I_2 = 0.8 IW / CPE	I_3 = 0.6 IW / CPE	Mean
T_1 - Compartment bunding without sun hemp	4.28	3.82	3.71	3.94	34567	42229	38258	38351	16332	22651	18965	19316	1.95	2.19	2.02	2.06
T_2 - Compartment bunding with sun hemp	4.60	4.03	3.82	4.15	36061	44729	39348	40045	17605	24984	19929	20838	2.00	2.29	2.05	2.11
T_3 - Broad bed furrows without sun hemp	5.04	4.36	4.34	4.58	40719	48464	47036	45406	21871	28176	27281	25776	2.21	2.44	2.41	2.35
T_4 - Broad bed furrows with sun hemp	5.45	4.53	4.54	4.83	44041	50552	48195	47596	25070	30300	28223	27864	2.32	2.51	2.44	2.42
T_5 - Furrows without sun hemp	4.83	4.07	4.01	4.35	38151	46309	42766	42409	19629	24830	23231	22564	2.36	2.36	2.23	2.25
T_6 - Furrows with sun hemp	4.98	4.23	4.27	4.44	39599	47531	46355	44495	20847	27459	26753	24990	2.15	2.39	2.37	2.31
Mean	4.86	4.17	4.11	4.38	38856	46635	43659	43050	20225	26399	24063	23558	2.17	2.36	2.25	2.30
Irrigation	SEm±		CD(0.05)		SEm±		CD(0.05)		SEm±		CD(0.05)		SEm±		CD(0.05)	
	0.31		NS		1076		3725		1155		3997		0.07		NS	
Land modules	0.07		0.19		840		2389		823		2343		0.05		0.16	
I X L	0.11		NS		1454		NS		1425		NS		0.09		NS	

The pooled results on economics revealed that gross returns and net returns were significantly influenced by irrigated ecosystems and different land modules. Among irrigated ecosystems, significantly higher gross (46635 Rs. ha^{-1}) and net return (27864 Rs. ha^{-1}) were recorded in I_2 (0.8 IW/CPE ratio) which was followed by 43659 and 24063 Rs. ha^{-1}, respectively in I_3 (0.6 IW/CPE ratio). Among the different *insitu* moisture conservation systems, significantly higher gross (47596 Rs. ha^{-1}) and net returns (27864 Rs. ha^{-1}) was observed in T_4 (Broad bed furrows with sunhemp) as compared to rest of the treatments. B:C ratio was not significantly observed by irrigation levels. However, among the different *insitu* moisture conservation systems, significantly higher B:C ratio (2.42) was recorded in broad bed furrows with sun hemp (T_4) followed by T_3 (Broad bed furrows without sunhemp) which recorded 2.35, repectively. The lower B:C ratio of 2.06 was observed in T_1 (Compartment bunding without sunhemp) (Table.2). The higher benefits are attributed to higher yield and high market price of component crops. The results are in line with the findings of Paulpandi *et al*. (2009) [12].

Conclusion

The irrigated land-module ecosystems integrated with *in-situ* green manuring maintained favourable soil moisture levels throughout the crop growth period, which consequently enhanced the growth, yield and quality parameters of sunflower. Among the land configurations evaluated, the broad bed and furrow (BBF) system combined with sunhemp green manuring consistently recorded higher soil moisture content, superior water-use efficiency (WUE) and greater grain yield than the alternative land layout methods. Irrigation scheduled at an IW/CPE ratio of 0.8, in conjunction with the BBF moisture-conservation system and *in-situ* green manuring, significantly improved soil moisture availability, contributed to the buildup of soil organic matter and favourably enhanced the available nutrient status of the soil, thereby promoting sustained crop productivity

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