Effect of Irrigation, Tillage and Residue Retention on Performance and Economics of Soybean – Wheat Cropping System

Abstract

A field experiment on "Conservation agriculture for improving crop productivity and water use efficiency in soybean–wheat cropping system under deficit irrigation" was conducted during 2017-18 and 2018-19 at Post Graduate Institute Research Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahilyanagar Maharashtra (India). The soil of experimental field was sandy loam in texture with low in available nitrogen (181.25 kg ha^{-1}), medium in available phosphorous (15.70 kg ha^{-1}) and very high in potassium (470.40 kg ha^{-1}). The soil organic carbon content, pH and EC were 0.55 %, 8.04, and 0.32 dSm^{-1}, respectively.The physical properties of soil *viz.*, field capacity (33.35 %), permanent wilting point (16.67 %) and bulk density (1.28 g cm^{-3}) indicates that soil was good in water retention capacity. The experiment was laid out in split plot design during *kharif* season and split-split plot design during *rabi* season with three replications. The treatment consists of four main plot treatments of irrigation scheduling i.e. DASM- depletion of available soil moisture*viz.*, I_1 – 40 % of DASM, I_2 – 50 % of DASM, I_3 – 60 % of DASM and I_4 – As per CGS (critical growth stages) and two sub plot treatments of tillage practices *viz.*, T_1 – Zero tillage, T_2 – Conventional tillage for *kharif* soybean. During *rabi* season the main and sub plot treatments remain same but the sub plot treatments were divided into three sub plot treatments of crop residue management *viz.*, R_1 – No crop residue, R_2 – Crop residue, R_3 - Crop residue + composting culture to wheat crop as a sub-sub plot treatment.The conventional tillage practice and scheduling of irrigation at 40 per cent of DASM to *kharif* soybean followed by cultivation of *rabi* wheat under conventional tillage practice with scheduling of irrigation at 40 per cent of DASM and application of soybean crop residue + composting culture obtained higher system productivity, production efficiency and economic efficiency, gross monetary returns, net monetary returns and B:C ratio in soybean-wheat cropping system.

Keywords: Irrigation, tillage, residue management, soybean-wheat cropping system

Introduction

Conservation agriculture a concept evolved as a response to concerns of sustainability of agriculture globally has steadily increased worldwide. Conservation agriculture is characterized by minimal soil disturbance, diversified crop rotations, and surface crop residue retention to reduce soil and environmental degradation while sustaining crop production. Tillage systems affect soil physical properties differently, because of their varied tillage intensities, which in turn affect infiltration characteristics. Surface residues maintained under zero tillage (ZT) systems moderate the temperature and moisture fluctuations and thus reduce both evaporation and runoff. It is characterized by higher soil organic carbon sequestration, better aggregation and improved pore size distribution. Infiltration rate of the soil is influenced by soil properties, vegetation, antecedent soil moisture and slope. Water scarcity is a real threat to food production for millions of people in arid and semi-arid areas, hence the available water resources needs to be used very efficiently to increase water productivity. Deficit irrigation has been suggested as an alternative strategy for making better use of irrigation water. More crops per drop of water is a challenging task during the forthcoming decades. The Soybean (*Glycine max* L. Merill) - Wheat (*Triticum aestivum* L.) is a predominant cropping system in Maharashtra. Soybean potentially high yielding crop can play a greater role in oil seed production in the country. Similarly, Wheat is one of the major cereal crop next to rice. However, the productivity of both the crops are less than the national acreage, even though both the crops are going to play important role in the food, nutritional and vegetable oil security as well as in agro based industries of the country in future. At present the increasing area, production and productivity under these crops indicating that the soybean – wheat is emerging as an alternative option for replacing less profitable cropping systems in Maharashtra. Hence, the present study on conservation agriculture for improving crop productivity and water use efficiency in soybean–wheat cropping system under deficit irrigationwas conductedto improve the soil health and crop productivity on sustainable basis with efficient utilization of available water resources.

Materials and methods:

The field experiments wereconducted during 2017-18 and 2018-19 at Post Graduate Institute Research Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahilyanagar Maharashtra (India). The soil of experimental field was sandy loam in texture with low in available nitrogen (181.25 kg ha^{-1}), medium in available phosphorous (15.70 kg ha^{-1}) and very high in potassium (470.40 kg ha^{-1}). The soil organic carbon content, pH and EC were 0.55 %, 8.04 and 0.32 dSm^{-1}, respectively.The physical properties of soil *viz.*, field capacity (33.35 %), permanent wilting point (16.67 %) and bulk density (1.28 g cm^{-3}) indicates that soil was good in water retention capacity. The experiment was conducted in fixed layout in split plot design during *kharif* season and split-split plot design during *rabi* season with three replications. The treatment consists of four main plot treatments of irrigation scheduling *viz.*, I_1 – 40 % of DASM (depletion of available soil moisture), I_2 – 50 % of DASM, I_3 – 60 % of DASM, I_4 – As per CGS (critical growth stages) and two sub plot treatments of tillage practices *viz.*, T_1 – Zero tillage, T_2 – Conventional tillage for *kharif* soybean. During *rabi* season the main and sub plot treatments remains same but the sub plot treatments were divided into three sub plot treatment of crop residue management *viz.*, R_1 – No crop residue, R_2 – Crop residue, R_3 - Crop residue + composting culture to wheat crop as a sub-sub plot treatment.The soybean variety 'KDS – 344'was sown with the seed rate of 75 kg ha^{-1} during *kharif* season at spacing of 30 x 10 cm and wheat variety 'NIAW- 1994'was sown at the seed rate of 100 kg ha^{-1} during *rabi* season at spacing of 22.5 cm between line. The N, P and K were given in the form of urea, single super phosphate and muriate of potash, respectively in soybean @ 15 t FYM + 50:75:45 kg N, P_2O_5 and K_2O ha^{-1} and in wheat 10 t FYM + 120:60:40 kg N, P_2O_5 and K_2O ha^{-1}. After harvesting of soybean crop, remaining crop residue was added in respective plot as per the treatments and then compost culture (lignin base) was applied on crop residue @ 1 litre for 4 tonof crop residue as per treatment and kept for decomposition upto sowing of wheat crop. Experimental field was kept free from weeds by performing two hand weeding in conventional tillage plots of soybean and wheat crops and in zero tillage plots of both the crops, pre-emergence herbicide Pendimethalin 30 EC was applied, while post emergence herbicide Imazethapyr 10 % SL in soybean and Metasulfuron Methyl 20 % WP in wheat were applied during both the years.

Irrigation scheduling was done on the basis of the depletion of available soil moisture and critical growth stages of crops (soybean and wheat). The depletion of available soil moisture was measured by soil moisture meter. The periodical depletion was monitored as per irrigation treatment. Based on percent depletion of available moisture the depth of irrigation at each irrigation was worked out. The volume of water was calculated based on area to be irrigated (m^2) as per treatment. After knowing the total volume of water, the discharge rate was measured by using 90^0V Notch weir and worked out time required for irrigation by using fallowing formula.

$$\text{Time (Sec.)} = \frac{\text{Area } (m^2) \times \text{Depth of irrigation (m)}}{\text{Discharge (lit. Sec.)}}$$

The observations of yield parameter were recorded after harvesting of soybean and wheat crop during both the years of experiment. For evaluation of performance of soybean-wheat cropping system soybean grain equivalent yield of wheat (q ha^{-1}), system productivity (q ha^{-1}), production efficiency (q ha^{-1} day^{-1}) and economic efficiency (₹ ha^{-1} day^{-1}) were worked out by using fallowing formula.

$$\text{Soybean grain equivalent yield of wheat } (q\ ha^{-1}) = \frac{\text{Wheat grain yield } (q\ ha^{-1}) \times \text{Price of wheat } (₹\ q^{-1})}{\text{Price of soybean grain } (₹\ q^{-1})}$$

$$\text{System productivity } (q\ ha^{-1}) = \text{Soybean yield of respective treatment } (q\ ha^{-1}) + \text{soybean grain equivalent yield of wheat of respective treatment } (q\ ha^{-1})$$

$$\text{Production efficiency } (q\ ha^{-1}\ day^{-1}) = \frac{\text{System productivity of respective treatment } (q\ ha^{-1})}{\text{Duration of cropping system}}$$

$$\text{Economic efficiency } (₹\ ha^{-1}\ day^{-1}) = \frac{\text{Net monetary returns over the year of respective treatment } (₹\ ha^{-1})}{\text{Duration of cropping system}}$$

The cost of cultivation (₹ ha^{-1}) was worked out by considering prevailing market prices of inputs as well as wages and charges of respective cultural operations. Gross monetary returns (₹ ha^{-1}) of respective crop were worked out by considering the prevailing prices of the farm produce (main and by produce) of respective years.

Net monetary return (₹ ha^{-1}) was calculated by using fallowing formula.

$$= \text{Gross monetary returns } (₹\ ha^{-1}) - \text{Cost of cultivation } (₹\ ha^{-1})$$

The Benefit : cost ratio for different treatment was calculated by using fallowing formula.

$$= \frac{\text{Gross monetary returns } (₹\ ha^{-1})}{\text{Cost of cultivation } (₹\ ha^{-1})}$$

The cropping system evaluation was assessed by using various indices *viz.*, crop equivalent yield, system productivity, production efficiencies and economic efficiencies were also statistically analyzed by using technique of 'Analysis of variance' (Fisher, 1950) and F test of significance for testing null hypothesis and appropriate standard error of mean (SEm.±). Treatment effects were worked out on the basis of critical difference (C.D) at % 5 per cent probability level (Panse and Sukhatme, 1967).

Result and Discussion

Cropping system performance

Maximum and significantly higher soybean equivalent yield of wheat (31.70, 33.10 and 32.40 q ha^{-1}), system productivity (60.46, 64.17 and 62.32 q ha^{-1}), production efficiency (16.57, 17.58 and 17.07 kg ha^{-1} day^{-1}) and economic efficiency (252.45, 302.95 and 277.70 ₹ ha^{-1} day^{-1}) in soybean-wheat cropping system were recorded by scheduling of irrigation at 40 % of DASM to *kharif* soybean and *rabi* wheat during both the years and on pooled mean (Table 1) than rest of the irrigation scheduling treatments and it might be due to retention of optimum soil moisture in root zone of both the crops obtained higher yield of soybean and wheat crop and assigned higher market price. Irrigation scheduling at 60 % of DASM to both the crops registered significantly minimum soybean seed equivalent yield of wheat (24.67, 25.67 and 25.67 q ha^{-1}, respectively), system productivity (42.85, 45.37 and 44.11 q ha^{-1}, respectively), production efficiency (11.74, 12.43 and 12.08 kg ha^{-1} day^{-1}, respectively) andeconomic efficiency (136.66, 170.31 and 153.99 ₹ ha^{-1} day^{-1}, respectively) of soybean-wheat cropping system during both the years and on pooled mean. These results are confirmed by Naroliа*et al*. (2016), Robel Admasu *et al*. (2019) andHayashi and Dogliotti (2021).

Data presented in Table 1 showed that the conventional tillage practice to *kharif* soybean and *rabi* wheat recorded significantly higher soybean equivalent yield of wheat (28.29, 29.38 and 28.84 q ha^{-1}), system productivity (52.48, 55.40 and 53.94 q ha^{-1}), production efficiency (14.38, 15.18 and 14.78 kg ha^{-1} day^{-1}) andeconomic efficiency (196.63 and 189.11 ₹ ha^{-1} day^{-1}) than zero tillage practice in soybean-wheat cropping system during both the years and on pooled mean. The conventional and zero tillage practices were found to be non-significant in respect of economic efficiency in soybean-wheat cropping system during second year and on pooled mean. These findings are supported by Karunakaran and Behera (2016), Nayak *et al*. (2018) and Parshotam Kumar *et al*. (2018).

Application of crop residue + composting culture to wheat crop recorded significantly higher soybean equivalent yield of wheat (28.83, 30.13 and 29.48 q ha^{-1}), system productivity (52.31, 55.57 and 53.94 q ha^{-1}), production efficiency (14.33, 15.22 and 14.78 kg ha^{-1} day^{-1}) and economic efficiency (198.63, 240.96 and 219.79 ₹ ha^{-1} day^{-1}) in soybean-wheat cropping system than application of crop residue alone and no crop residue treatments during both the years and on pooled mean. (Table 1) Application of crop residue + composting culture to wheat creates favorable soil environment for crop growth and development resulted in higher system productivity and production efficiency These results are confirmed by Dashrath Prasad *et al*. (2014), Karunakaran and Behera (2016). Narolia *et al*. (2016), Parshotam Kumar *et al*. (2018) and Kiran Kumar *et al*. (2019), Narolia *et al*. (2020)and Kaduwal (2022).

Economics of soybean-wheat cropping system

Irrigation scheduling at 40 % of DASM to *kharif* soybean and *rabi* wheat obtained significantly maximum gross monetary returns (194589, 215007 and 204798 ₹ ha^{-1}),cost of cultivation (102445 and 104429 ₹ ha^{-1}), net monetary returns (92144, 110577 and 101360 ₹ ha^{-1})and B:C ratio (1.90 and 2.06) in soybean-wheat cropping system than rest of the irrigation scheduling treatmentsduring both the years and on pooled mean (Table 2). Scheduling of irrigation at 40 % of DASM to both the crops obtained higher gross monetary returns, net monetary returns and B:C ratio because of maximum main and by produce yield of both the crops and higher market prices.Irrigation scheduling at 60 % of DASM obtained significantly minimum gross monetary returns (138371, 152560 and 145465 ₹ ha^{-1}, respectively), cost of cultivation in soybean-wheat cropping system (88124 and 90397 ₹ ha^{-1}), net monetary returns(50246, 62163 and 56204 ₹ ha^{-1}, respectively) and benefit: cost ratio(1.73 and 1.85) in soybean-wheat cropping system during both the year. These results are confirmed by Narolia*et al*. (2016).

The conventional tillage practice to *kharif* soybean and *rabi* wheat obtained significantly maximum gross monetary returns (169111, 185881 and 177496 ₹ ha^{-1}) and net monetary returns (71770, 85881 and 78826 ₹ ha^{-1}) in soybean-wheat cropping system during both the years and on pooled mean (Table 2). The maximum B:C ratio (1.73 and 1.85) was also reported under conventional tillage practice during both the years. These results are similar with Singh *et al.* (2008), Narola*et al*. (2016) and Nayak *et al*. (2018).

Application of crop residue + composting culture to wheat crop obtained significantly maximum gross monetary returns (168606, 186501 and 177496₹ ha^{-1}) and net monetary returns (72499, 87950 and 80224 ₹ ha^{-1}) in soybean-wheat cropping system during both the years and on pooled mean (Table 2).The maximum B:C ratio (1.75 and 18.9) was also reported under crop residue + composting culture to wheat crop during both the years.These results are in line of Karunakaran and Behara (2013) and Jaybhay*et al*. (2016).

Table 1. Soybean seed equivalent yield (SGEY), system productivity, production efficiency and economic efficiency of soybean- wheat cropping system

Treatments	Soybean seed equivalent yield(SGEY) (q ha^{-1})			System productivity (q ha^{-1})			Productionefficiency (kg ha^{-1} day^{-1})			Economicefficiency (₹ ha^{-1} day^{-1})		
	2017-18	**2018-19**	**Pooled mean**	**2017-18**	**2018-19**	**Pooled mean**	**2017-18**	**2018-19**	**Pooled mean**	**2017-18**	**2018-19**	**Pooled mean**
Irrigation scheduling – I												
I_1 : 40 % of DASM	31.70	33.10	32.40	60.46	64.17	62.32	16.57	17.58	17.07	252.45	302.95	277.70
I_2 : 50 % of DASM	28.10	29.29	28.69	53.42	56.64	55.03	14.64	15.52	15.08	203.01	245.79	224.40
I_3 : 60 % of DASM	24.67	25.67	25.17	42.85	45.37	44.11	11.74	12.43	12.08	136.66	170.31	153.99
I_4 : As per CGS	26.82	27.99	27.40	48.50	51.62	50.06	13.29	14.14	13.71	178.37	216.52	197.45
SE (m) ±	0.13	0.24	0.24	0.62	2.11	1.91	0.17	0.58	0.52	5.83	19.86	17.93
C.D. at 5 %	0.48	0.86	0.76	2.17	7.32	5.89	0.59	2.00	1.61	20.18	68.75	55.25
Tillage practices – T												
T_1 : Zero tillage	27.36	28.64	28.00	50.14	53.50	51.82	13.74	14.66	14.20	189.11	232.50	210.80
T_2 : Conventional tillage	28.29	29.38	28.84	52.48	55.40	53.94	14.38	15.18	14.78	196.63	235.29	215.96
SE (m) ±	0.05	0.08	0.08	0.19	0.15	0.21	0.05	0.04	0.06	1.96	1.41	2.09
C.D. at 5 %	0.17	0.28	0.26	0.64	0.51	0.65	0.17	0.14	0.18	6.41	NS	NS
Crop residue management-R												
R_1 : No crop residue	26.59	27.63	27.11	50.08	53.07	51.57	13.72	14.54	14.13	185.17	224.51	204.84
R_2 : Crop residue	28.05	29.28	28.66	51.54	54.72	53.13	14.12	14.99	14.56	194.82	236.21	215.52
R_3 : Crop residue + composting culture	28.83	30.13	29.48	52.31	55.57	53.94	14.33	15.22	14.78	198.63	240.96	219.79
SE (m) ±	0.02	0.10	0.09	0.02	0.10	0.09	0.005	0.03	0.02	0.22	0.98	0.87
C.D. at 5 %	0.05	0.31	0.27	0.05	0.31	0.27	0.01	0.08	0.07	0.65	2.84	2.47
Interactions												
I x T												
SE (m) ±	0.10	0.17	0.17	0.39	0.21	0.43	0.10	0.08	0.11	3.93	2.83	4.19
C.D. at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
I x R												
SE (m) ±	0.03	0.21	0.19	0.03	0.31	0.19	0.01	0.05	0.05	0.45	1.97	1.75
C.D. at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	5.68	NS
T x R												
SE (m) ±	0.02	0.15	0.13	0.02	0.15	0.13	0.007	0.04	0.03	0.32	1.39	1.24
C.D. at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
I x T x R												
SE (m) ±	0.05	0.30	0.27	0.05	0.30	0.27	0.01	0.08	0.07	0.64	2.79	2.48
C.D. at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
General mean	27.82	29.01	28.42	51.31	54.45	52.88	14.06	14.92	14.49	192.87	233.89	213.38

Table 2. Economics of soybean- wheat cropping system as influenced by different treatments

Treatments		Gross monetary returns (₹ ha^{-1})			Cost of cultivation (₹ ha^{-1})			Net monetary returns (₹ ha^{-1})			B:C ratio		
		2017-18	2018-19	Pooled mean	2017-18	2018-19	Mean	2017-18	2018-19	Pooled mean	2017-18	2018-19	Mean
Irrigation scheduling – I													
I_1 :	40 % of DASM	194589	215007	204798	102445	104429	103437	92144	110577	101360	1.90	2.06	1.98
I_2 :	50 % of DASM	172020	189962	180991	97923	100248	99085	74097	89713	81905	1.76	1.90	1.83
I_3 :	60 % of DASM	138371	152560	145465	88124	90397	89260	50246	62163	56204	1.57	1.69	1.63
I_4 :	As per CGS	156398	173315	164857	91291	94284	92287	65106	79030	72068	1.71	1.84	1.78
	SE (m) ±	1999	7019	6320	-	-	-	2158	7251	6545	-	-	-
	C.D. at 5 %	6919	24290	19476	-	-	-	7365	25094	20167	-	-	-
Tillage practices – T													
T_1 :	Zero tillage	161578	179541	170559	92551	94680	93615	69026	84860	76943	1.74	1.89	1.81
T_2 :	Conventional tillage	169111	185881	177496	97341	99999	98670	71770	85881	78826	1.73	1.85	1.79
	SE (m) ±	628	529	711	-	-	-	717	517	766	-	-	-
	C.D. at 5 %	2048	1727	2133	-	-	-	2340	NS	NS	-	-	-
Crop residue management-R													
R_1 :	No crop residue	161338	178019	169679	93751	96072	94911	67586	81946	74766	1.72	1.85	1.78
R_2 :	Crop residue	166089	183612	174851	94979	97396	96187	71109	86216	78663	1.74	1.88	1.81
R_3 :	Crop residue + composting culture	168606	186501	177553	96107	98550	97328	72499	87950	80224	1.75	1.89	1.82
	SE (m) ±	67	368	324	-	-	-	83	360	320	-	-	-
	C.D. at 5 %	194	1061	916	-	-	-	239	1037	904	-	-	-
	Interactions												
	I x T												
	SE (m) ±	1256	1059	1423	-	-	-	1435	1034	1532	-	-	-
	C.D. at 5 %	NS	NS	NS	-	-	-	NS	NS	NS	-	-	-
	I x R												
	SE (m) ±	135	737	648	-	-	-	166	720	640	-	-	-
	C.D. at 5 %	NS	NS	NS	-	-	-	NS	2075	NS	-	-	-
	T x R												
	SE (m) ±	95	521	458	-	-	-	117	509	452	-	-	-
	C.D. at 5 %	NS	NS	NS	-	-	-	NS	NS	NS	-	-	-
	I x T x R												
	SE (m) ±	191	1042	917	-	-	-	235	1018	905	-	-	-
	C.D. at 5 %	NS	NS	NS	-	-	-	NS	NS	NS	-	-	-
	General mean	165344	182711	174028	94946	97339	96143	70398	85371	77884	1.74	1.87	1.80

Conclusion

At the end of two years of experimentation in soybean-wheat cropping system, the conventional tillage practice and scheduling of irrigation at 40 per cent of DASM to *kharif* soybean followed by cultivation of *rabi* wheat under conventional tillage practice with scheduling of irrigation at 40 per cent of DASM and application of soybean crop residue + composting culture obtained higher system productivity, production efficiency, economic efficiency, gross and net monetary returns in soybean-wheat cropping system.

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