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Research Paper

Effect of irrigation schedule, residue incorporation and nutrient management on system productivity and profitability of soybean (*Glycine max*)–wheat (*Triticum aestivum*) cropping system in Vertisols of Rajasthan

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ABSTRACT

A 3-year field experiment was carried out at Kota, Rajasthan during 2015–16 to 2017–18, to study the effect of irrigation schedule, residue incorporation and nutrient management on system productivity and profitability of soybean [*Glycine max* (L.) Merr.]–wheat (*Triticum aestivum* L.) cropping system in Vertisols of Rajasthan. The treatments consisted of 24 combinations of 2 irrigation schedules in soybean, viz. 1 irrigation at flowering stage and 2 irrigations at flowering and other pod-development stages -in main plots; 4 wheat residue-management practices, viz. sowing of soybean after wheat-residue burning, wheat-residue incorporation without irrigation, residue incorporation with irrigation and application of urea @ 25 kg/ha and residue incorporation with irrigation and application of urea @ 25 kg/ha + cellulolytic microbes @ 2.0 kg/ha in subplots; and 3 nutrient-management practices, viz. 75% recommended dose of fertilizers (RDF), 100% RDF (20 kg N, 40 kg P_2O_5, 40 kg K_2O/ha) and 125% RDF in sub-subplots. The experiment was laid out in a split split-plot design with 3 replications. Wheat crop was sown every year with the adoption of recommended package of practices. Pooled data of 3 years revealed that 2 irrigations at flowering and other at pod development stages-in soybean crop significantly increased dry-matter production, unit-area efficiency, branches/plant, pods/plant, seeds/pod, seed index, seed and straw yields and net returns of soybean, grain yield of wheat, soybean-equivalent yield (SEY), profitability, production- and economic-efficiency of system, available N, P and K status of soil after harvesting of wheat and soybean as compared to 1 irrigation at flowering stage. However, available K status of soil after harvesting of soybean was found non-significant in relation to irrigation. Wheat-residue incorporation with irrigation and application of urea @ 25 kg/ha + cellulolytic microbes @ 2.0 kg/ha resulted in the highest growth and yield attributes, seed and straw yields and net returns of soybean, water-use efficiency (WUE), water productivity (WP), soybean-equivalent yield (4.51 t/ha), system profitability (₹96,520/ha), production (12.35 kg/ha/day) and economic (264₹/ha/day) efficiency of system, organic carbon, bulk density of soil after harvesting of soybean and N, P and K status of soil after harvesting of both soybean as well as wheat over wheat-residue burning. Application of 125% RDF resulted in the maximum growth and yield attributes, seed (1.51 t/ha) and straw (2.17 t/ha) yield, net returns (₹25,700), benefit: cost ratio (1.09) of soybean and SEY (4.44 t/ha), system profitability (₹95,740/ha), production (12.15 kg/ha/day) and economic efficiency (262₹/ha/day), bulk density (1.42 Mg/m^3), N (282, 288 kg/ha) P_2O_5 (24.6,25.9 kg/ha) and K_2O (293, 299 kg/ha) of soil after harvesting of wheat and soybean respectively.

Key words : Cropping system, Irrigation schedule, Residue incorporation, Soil fertility, System productivity Soybean, Wheat

Soybean–wheat is by and large the most important cropping system in south eastern Rajasthan and occupies 55–60% of total cultivated area. Wide adoptability of soybean–wheat cropping system is mainly owing to high productivity and less element of risk. Rapid and wide spreading of this cropping system in irrigated area caused an eclipse on sustainability of soil productivity. Unsustainable high yields have been noticed in spite of liberal application of N, P and K in this region. This declining or stagnating yield trend has been attributed to multiple-nutrient deficiencies and imbalances of nutrients, which poses a serious threat to the long-term sustainability of crop production (Karunakaran and Behera, 2013). There is a close relationship between cropping system productivity, economics, energy and environment (Tuti *et al*., 2013). Wheat is one of the most important staple food crops of India and occupies

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a notable position among the food grain crops not only in area and production but also in versatility in adaptation to wide range of agro-climatic conditions. A substantial area under this cropping sequence is combine harvested, leaving enormous quantities of wheat residue (5–6 t/ha) which is burnt in the field prior to sowing of soybean, especially in south-eastern parts of Rajasthan. The physical removal of combine-harvested material is no longer feasible because of increased labour cost and scarce labour availability. So, farmers prefer complete burning of crop residue in the field. The wheat-residue recycling may be one of the alternative practices of replenishing the depleted fertility from the soil as complementary to integrated nutrient management (INM) in soybean–wheat cropping system. Crop residues are renewable and readily available resource and their recycling is a viable strategy to meet at least a part of nutrient requirement of crop. Direct incorporation of wheat residue in soil having a wide C : N ratio creates enormous problem in the establishment and growth of succeeding soybean crop and also leads to decrease in crop yield due to production of microbial phytotoxins and immobilization of available N. The potential phytotoxins production can be reduced if the straw is decomposed before sowing of succeeding soybean crop. Inoculation of residue with efficient cellulolytic microbes produced enough simple sugars for growth and multiplication of beneficial soil micro-flora. To enhance the process of residue management in the soil and to provide supplemental N, the use of starter dose in the form of fertilizer N to the decomposing residues can partially offset the mobilization process. Since no single-residue-management practice is superior under all the conditions, it becomes imperative to determine the benefits and adverse effects of residue management options in soybean–wheat cropping system. Development of appropriate residue-management practice is, therefore, very important for its successful use as INM component. Keeping in view these emerging challenges, present study was undertaken to study the effect of irrigation schedule, residue incorporation and nutrient management on system productivity and profitability of soybean–wheat cropping system in *Vertisols* of Rajasthan.

MATERIALS AND METHODS

The field experiment was conducted during 2015–16 to 2017–18 at Agricultural Research Station, Agriculture University Kota (26° N, 76°–6' E and 260 m above mean sea-level), Rajasthan. The study area falls under humid south-eastern plain zone of Rajasthan. Soil of the experimental field belongs to Vertisols, having *p*H 7.56, electrical conductivity 0.30 dS/m and cation-exchange capacity 35 Cmol/kg. Soil had a very low infiltration rate (0.25 cm/h) on surface, but at deeper layer (1.2 to 1.5 m) soil was impermeable. The potential moisture-retention capacity of soil was 120 mm of water in 1 m depth. Soil samples were taken initially after harvesting of wheat in winter (*rabi*) season of 2015–16 under soybean–wheat cropping system. Soil of the experimental field was medium in organic C 4.7 g/kg, available N (272.5 kg/ha), available P (23.23 kg P_2O_5/ha) and high in available K (282.3 kg P_2O_5/ha). The bulk density of soil was 1.47 Mg/m^3. The treatments of the fixed layout of experiment consisted of 24 factorial combinations of 2 irrigation scheduling in soybean, viz. one irrigation at flowering stage and 2 irrigations–at flowering and other at pod development stages-in main plots; 4 residue-management practices, viz. sowing of soybean after wheat-residue burning, wheat-residue incorporation without irrigation, wheat residue incorporation with irrigation and application of urea @ 25 kg/ha and residue incorporation with irrigation and application of urea @ 25 kg/ha + cellulolytic microbes @ 2.0 kg/ha in subplots; and 3 nutrient-management practices, viz. 75% recommended dose of fertilizer (RDF)–N : P : K : 20 : 40 : 40 kg/ha), RDF and 125% RDF in sub-subplot. The experiment was laid out in split split-plot design with 3 replications. Wheat variety 'Raj 4037' was sown on 20, 18 and 22 November during 2015, 2016 and 2017, respectively, with the adoption of recommended package of practices and harvested on 13, 15 and 17 April in 2016, 2017 and 2018 respectivey. Wheat residue (70% of the height) left after harvesting with combine machine was incorporated by harrowing and soybean crop was raised as per treatments having a gross plot size of 4.2 m × 5.0 m. Cellulolytic fungi, viz. *Aspergillus* sp., *Penicillium sp., Trichoderma viride, Trichoderma spiralis,* and lignolytic fungi, viz. *Pleurotus sajor-caju*, *Poyporus versicolor,* were used as cellulolytic microbes. Recommended package of practices, viz. High-yielding variety 'RKS-45', crop geometry (30 cm × 15 cm), seed rate (80 kg/ha), seed treatment with @ 2 g/kg seed were used to raise soybean crop. Soybean crop was sown in well-prepared soil on 15, 8 and 3 July and harvested on 20, 10 and 8 October in 2016, 2017 and 2018 respectively.

All the plant-protection measures were adopted to ensure healthy crop. Basal application of N and full doses of P and K were applied in soybean crop as per treatments through diammonium phosphate and muriate of potash respectively. The remaining N was top-dressed as urea before flowering stage. A common basal dose of sulphur @ 25 kg/ha was applied uniformely to all the plots. The required quantity of herbicide to control weeds and insecticides to control insects were applied with manually operated knapsack sprayer using a spray volume of 500 litres water/ha. The maximum and minimum temperature during the soybean crop period were 36.3°C and 21.9°C in 2016, 34.6°C and 15.3 °C in 2017 and 35.7 and 17.3°C in 2018 respectively. The effective rainfall received and evapo-transpiration during the growing seasons of soybean were 823 mm and 404.5 mm, 341 mm and 754.4 mm and 360 and 735.0 mm in 2016, 2017 and 2018 respectively. Irrigation requirement of the crop as per treatment was fulfilled by groundwater irrespective of rainfall. Plant height of soybean and wheat was measured from the base of the plant at ground surface to the tip of the plant using a meter scale. Dry-matter accumulation 60 days after sowing (DAS) was recorded every year from each plot for both crops. These samples were sun-dried and further oven-dried at 70°C till constant weight. For dry matter accumulation at harvest in soybean, the sun dried bundles were threshed, winnowed and seed and straw so obtained were weighed. Branches/plant, pods/plant, seeds/pod and 100-seed weight were noted by counting from sampling unit at harvesting stage. Similarly, yield attributes of wheat were also measured. Gross and net returns were calculated based on the grain and straw yields and prevailing market prices of soybean in respective seasons. The benefit: cost ratio of soybean was calculated by dividing the net returns from the total cost of cultivation. Dry-matter efficiency is the per cent of total dry- matter production (seed yield + straw yield) accumulated in seed/day. Unit-area efficiency is expressed as the quantum of seed yield produced over a unit land area for growth period. These growth analysis parameters were calculated as:

$$\text{Dry-matter efficiency} = \frac{\text{Seed yield}}{\text{Total dry-matter production}} \times \frac{100}{\text{Duration of crop}}$$

$$\text{Unit area efficiency} = \frac{\text{Seed yield}}{\text{Land area}} \times \frac{1}{\text{Duration of crop}}$$

System productivity in terms of soybean-equivalent yield (SEY) was calculated as; SEY= soybean yield +[(Yield of wheat × price of wheat)/price of soybean]. Production efficiency was expressed as the ratio of system productivity in terms of soybean-equivalent yield in kg/ha to total duration of the cropping system in days. Likewise, economic efficiency was expressed as the ratio of net returns from the cropping system in ₹/ha to total duration of the cropping system in days. Mean selling price of soybean and wheat was ₹32.66 and ₹17.46/kg, respectively. Soil samples (0–15 cm) were collected from the each plot and analysed for electrical conductivity (EC), *p*H, organic carbon and bulk density after harvesting of soybean and available N, P and K status of soil after harvesting of both wheat and soybean crops. Standard methods as described by Jackson (1973) were used to estimate available nutrient status of soil. Bulk density was estimated by core sampler method (Bodman, 1942).

The field data obtained for 3 years were analysed yearly and pooled over 3 years and statistically analysed using ‘F’ (Gomez and Gomez, 1984). The test of significance of treatments differences were done on the basis of ‘t’ test. The treatment means were compared for significant differences using critical difference value at 5% level of probability The significant.

RESULTS AND DISCUSSION

Growth characters

Growth parameters, viz. dry-matter production at 60 DAS and at harvesting, and unit-area efficiency were significantly influenced by irrigations schedule (Table 1). Two irrigations at flowering and other at pod development stage-increased the dry-matter production at 60 DAS and at harvesting and unit-area efficiency by 1.9, 9.3 and 29.6%, respectively, over 1 irrigation at the flowering stage. The maximum plant height, nodules/plant and nodule dry weight were also observed with irrigation at flowering and pod-development stages. Increase in plant height, dry-matter production at 60 DAS and at harvesting under irrigation applied at flowering and pod-development stage might be owing to adequate availability of moisture and more conductive rhizosphere environment for higher uptake of nutrients and in turn, which boosted the growth of soybean crop.

All the residue-management practices significantly increased the growth parameters as compared to residue burning (Table 1). Wheat-residue incorporation with irrigation and application of urea @ 25 kg/ha + cellulolytic microbes @ 2.0 kg/ha resulted in the maximum plant height, dry-matter production at 60 DAS and at harvesting, dry-matter efficiency and unit area efficiency, nodules/plant and nodule dry weight. Residue incorporation with irrigation and application of urea @ 25 kg/ha resulted in 18.6 and 14.8% higher plant height, 13.5 and 9.8% higher dry-matter production at 60 DAS and 8.0 and 5.4% at harvesting and 8.4 and 5.5% higher unit-area efficiency than residue burning and residue incorporation without irrigation respectively. Overall improvement in crop growth under the influence of residue incorporation with irrigation and application of urea @ 25 kg/ha + cellulolytic microbes seems to be due to better nutritional environment in the root zone for growth and development of the crop and increased availability of all essential nutrients to the plant system. Wheat-residue incorporation after harvesting add sufficient amount of organic matter that results in improved physical and biological properties of soil. The improved physical and biological properties of soil might have improved soil-moisture conservation, rate of native and applied soil-nutrient mineralization and higher N, P and K availability. This in turn increased nutrient uptake and stimulated growth of the plant (Choudhary *et al*., 2016).

Nutrient-management practices also had significant influence on growth parameters. Significantly higher plant height, dry-matter production at 60 DAS and at harvesting, dry-matter efficiency and unit-area efficiency, nodules/plant and nodule dry weight with application of 125% recommended dose of fertilizer (RDF). The use of 125% RDF resulted 22.0, 13.3, 11.5 and 11.1% higher plant height dry-matter production at 60 DAS and at harvesting, and unit-area efficiency compared to 75% RDF (Table 1). Nitrogen application might have resulted in increased chlorophyll content and net photosynthetic rate ensuing continuous supply of evapo-hydrates to growing and phosphorus supply on the other hand stored the solar energy obtained from the photosynthesis and metabolism of carbohydrates in to phosphate compounds for subsequent use in growth and reproductive process which might have attributed to the increased plant height. Greater meristematic activity under the influence of inorganic fertilization might have promoted greater canopy development in term of leaf-area index. Thus, increased LAI as a result of inorganic fertilization seems to have resulted in better interception, absorption and utilization of solar energy with greater CO_2 fixation and thereby increase the photosynthetic efficiency considerably.

Yield attributes and yields

The irrigation applied at flowering and pod-development stages resulted in higher branches/plant, pods/plant, seeds/pod, 100-seed weight, seed and straw yield over 1 irrigation at flowering stage, representing an increase of 12.1, 8.8, 12.8, 21.1, 8.8 and 8.6% respectively (Table 2). The increase in yield attributes and yields might be owing to better nutritional environment in the root zone throughout the growing period, which turn, boosted the growth, leading to development of larger yield attributes through supply of more photosynthates towards the sink. Stress during the reproductive phase might have hampered the supply of photosynthate towards the sink resulting in poor yield attributes and ultimately yields obtained in irrigation applied at flowering stage. (Karunakaran and Behera, 2013 and Choudhary *et al*., 2016).

Among the residue-management practices, the maximum branches/plant, pods/plant, seeds/pod and 100-seed weight were obtained under residue incorporation with irrigation and application of urea @ 25 kg/ha + cellulolytic microbes (Table 2). Residue incorporation with irrigation and application of urea @ 25 kg/ha + cellulolytic microbes increased branches/plant, pods/plant, seeds/pod and 100-seed weight by 19.5, 19.9, 22.2, 17.6%, over residue burn-

Table 1. Effect of irrigation schedule, residue incorporation and nutrient management on growth attributes of soybean (pooled data of 3 years)

Treatment	Plant height (cm)	Dry matter production at 60 DAS (g/plant)	Dry matter production at harvest (t/ha)	Dry matter efficiency (%/day)	Unit area efficiency (kg/ha/day	Nodules/ plant	Nodule dry weight (mg/plant)
Irrigation schedule							
One irrigation at flowering stage	52.1	15.9	3.32	0.438	14.5	49.6	85.1
Two irrigation at flowering and pod development stages	58.1	16.2	3.63	0.437	18.8	50.1	86.6
SEm±	0.70	0.219	0.022	-	0.205	0.145	0.468
CD (P=0.05)	NS	0.76	0.08	-	0.71	NS	NS
Residue management							
Residue burning	50.4	14.8	3.26	0.438	14.2	48.8	84.3
Residue incorporation without irrigation	52.1	15.3	3.34	0.437	14.6	49.2	84.8
Residue incorporation with irrigation and application of urea @ 25 kg/ha	58.1	16.8	3.52	0.437	15.4	50.5	86.7
Residue incorporation with irrigation and application of urea @ 25 kg/ha + Cellulolytic microbes @ 2.0 kg/ha	59.8	17.3	3.79	0.437	16.5	50.9	87.7
SEm±	0.64	0.315	0.032	-	0.169	0.185	0.401
CD (P=0.05)	1.8	0.90	0.09	-	0.48	0.53	1.15
Nutrient management							
75% RDF	49.9	15.0	3.29	0.438	14.4	48.6	84.5
100% RDF	54.0	16.2	3.47	0.438	15.2	50.	86.1
125% RDF	61.4	17.0	3.67	0.438	16.0	51.0	87.0
SEm±	0.57	0.198	0.031	-	0.158	0.292	0.310
CD (P=0.05)	1.6	0.56	0.09	-	0.44	0.82	0.87

ing. However, residue incorporation with irrigation and application of urea @ 25 kg/ha and residue incorporation with irrigation and application of urea @ 25 kg/ha + cellulolytic microbes remained statistically at par with each other in relation to branches/plant. Moreover, residue incorporation without irrigation did not influence significantly the branches/plant and straw yield as compared to residue burning. The seed yield, being a function primarily of cumulative effect of yield parameters and straw yield of growth parameters, increased significantly by 210 kg/ha and 310 kg/ha over residue burning. This could also be as a result of better yield-contributing characters with the residue- management practices. The results of this study are in close agreement with the findings of Das and Dkhar (2011) and Sinha (2015).

Yield attributes and yields showed progressive improvement with the increasing levels of fertilizers from 75% to 125 RDF. Applying resulted in 125% RDF significantly higher branches/plant, pods/plant, seeds/pod and 100-seed weight, the increase being 24.3, 13.3, 28.3 and 17.4% over 75% RDF. Seed and straw yields increased significantly with the 125% RDF by160, 80 kg/ha and 220, 120 kg/ha over 75% and 100% RDF, respectively. An adequate supply of N in the life of plant under residue management system is considered important in promoting rapid vegetative growth in terms of plant height and dry-matter production and of phosphorus in root proliferation and laying down primordial for its reproductive growth and seed formation.

Economics

Maximum net return and B: C ratio obtained under irrigation applied at flowering and pod development stages which were 15.4 and 11.1% higher than irrigation applied at flowering stage. This might be owing to higher production with proper moisture availability during critical stages of soybean. Similarly, under residue management practices, residue incorporation with irrigation and application of urea @ 25 kg/ha + Cellulolytic microbes showed higher net return and B: C ratio than residue burning. However, net return and B: C ratio in residue burning was found

Table 2. Effect of irrigation schedule, residue incorporation and nutrient management on yield attributes, yields, net return, Benefit: cost ratio and indices of water use of soybean (pooled data of 3 years)

Treatment	Yield attributes				Yield		Net returns (× 10³₹/ha)	Benefit: cost ratio	WUE (kg/ha-cm)	WP (₹/M³)
	Branches/ plant	Pods/ plant	Seeds/ Pod	Seed Index (g/100 seeds)	Seed yield (t/ha)	Straw yield (t/ha)				
Irrigation schedule										
One irrigation at flowering stage	3.29	30.8	2.88	8.42	1.37	1.97	22.1	0.99	36.2	5.19
Two irrigation at flowering and pod development stages	3.69	33.5	3.25	10.2	1.49	2.14	25.5	1.10	37.3	5.37
SEm±	0.051	0.44	0.058	0.35	0.019	0.029	0.642	-	0.83	0.12
CD (P=0.05)	0.18	1.52	0.20	1.2	0.07	0.10	2.22	-	NS	NS
Residue management										
Residue burning	3.18	29.1	2.75	8.50	1.34	1.93	23.7	1.18	35.8	5.18
Residue incorporation without irrigation	3.31	30.9	2.90	9.01	1.37	1.97	21.7	0.93	36.2	4.77
Residue incorporation with irrigation and application of urea @ 25 kg/ha	3.68	33.7	3.28	9.72	1.44	2.08	23.2	0.96	36.8	5.17
Residue incorporation with irrigation and application of urea @ 25 kg/ha + Cellulolytic microbes @ 2.0 kg/ha	3.80	34.9	3.36	10.0	1.55	2.24	26.6	1.09	38.2	6.01
SEm±	0.052	0.32	0.021	0.119	0.016	0.023	0.51	-	0.56	0.12
CD (P=0.05)	0.15	0.92	0.06	0.34	0.05	0.07	1.49	-	1.61	0.34
Nutrient management										
75% RDF	3.12	30.0	2.65	8.52	1.35	1.95	22.0	1.0	35.7	4.88
100% RDF	3.48	32.5	3.15	9.45	1.43	2.05	23.7	1.04	36.7	5.25
125% RDF	3.88	34.0	3.40	10.0	1.51	2.17	25.7	1.09	37.8	5.72
SEm±	0.062	0.43	0.053	0.135	0.015	0.021	0.469	-	0.65	0.10
CD (P=0.05)	0.18	1.22	0.15	0.38	0.04	0.06	1.32	-	1.83	0.28

WUE, water use-efficiency; WP, water productivity higher as compared to residue incorporation without irrigation due to less cost of cultivation under residue burning.

Net return and B: C ratio was positively influenced by nutrient management practices (Table 2). Significantly higher net return was obtained with 125% RDF compared to 75% RDF. This was mainly owing to higher seed and straw production and ultimately net return. The results confirm the findings Choudhary *et al*. (2016) and Sinha (2015).

Soybean–wheat cropping system

System productivity

The grain yield of soybean and wheat were significantly higher under soybean-wheat cropping system with irrigation applied in soybean at flowering and pod development stages as compared to irrigation applied at flowering stage only (Tables 2 and 4), which jointly contributed towards significant variation in system productivity. However, irrigation applied in soybean crop did not have any significant effect on growth and yield attributes of wheat grown after soybean except effective tillers. Production efficiency was also affected significantly by irrigation. Residue management practices significantly improved growth and yield attributes, grain yield of wheat and ultimately system productivity. Residue incorporation with irrigation and application of urea @ 25 kg/ha + cellulolytic microbes @ 2.0 kg/ha enhanced soybean equivalent yield by 7.9 and 6.4% and production efficiency by 7.8 and 6.3% as compared to residue burning and residue incorporation without irrigation, respectively. System productivity increased with increasing percentage of RDF; application of 125% RDF increased system productivity and production efficiency by 5.7 and 5.6% as compared to 75% RDF, respectively. Nutrient management practices did not show any significant effect on growth and yield attributes of wheat. These results are in conformity with the findings of Paul *et al*. (2015) and Ransing *et al.* (2019).

System profitability

Irrigation schedule in soybean under soybean–wheat cropping system had significant effect on system profitability and economic efficiency (Table 4). Irrigation applied in soybean at flowering and pod development stages increased bothsystem profitability and economic efficiency by about 2% over irrigation applied at flowering stage. Residue incorporation with irrigation and application of urea @ 25 kg/ha + cellulolytic microbes @ 2.0 kg/ha registered significantly higher system profitability (₹95,870/ha) and economic efficiency (263₹/ha/day) as compared to residue burning. These of 100% RDF in soybean crop also

Table 3. Effect of irrigation schedule, residue incorporation and nutrient management on chemical properties of soil in soybean–wheat cropping systems (pooled data of 3 years)

Treatment	Organic carbon (%)	Bulk density (Mg/m^3)	*p*H	EC (dS/m)	Available nutrient status of soil after harvesting: Wheat (kg/ha) N	Wheat P_2O_5	Wheat K_2O	Soybean (kg/ha) N	Soybean P_2O_5	Soybean K_2O
Irrigation schedule										
One irrigation at flowering stage	0.52	1.43	7.57	0.29	277	23.7	288	279	23.9	292
Two irrigation at flowering and pod development stages	0.55	1.42	7.52	0.28	282	24.4	293	289	25.3	299
SEm±	0.010	0.006	0.072	0.058	0.98	0.11	0.99	1.96	0.33	2.06
CD (P=0.05)	NS	NS	NS	NS	3.40	0.38	3.40	6.80	1.5	NS
Residue management										
Residue burning	0.49	1.50	7.56	0.30	273	22.9	284	273	22.7	286
Residue incorporation without irrigation	0.50	1.43	7.56	0.29	276	23.7	287	279	23.9	291
Residue incorporation with irrigation and application of urea @ 25 kg/ha	0.57	1.40	7.55	0.28	284	24.7	295	291	25.5	301
Residue incorporation with irrigation and application of urea @ 25 kg/ha + Cellulolytic microbes @ 2.0 kg/ha	0.59	1.37	7.54	0.28	285	25.1	296	293	26.4	303
SEm±	0.012	0.008	0.066	0.052	1.19	0.23	1.50	1.52	0.31	2.31
CD (P=0.05)	0.04	0.02	NS	NS	3.40	0.65	4.29	4.37	0.90	6.62
Nutrient management										
75% RDF	0.52	1.45	7.56	0.30	276	23.3	287	280	23.3	290
100% RDF	0.54	1.43	7.54	0.29	280	24.3	292	284	24.6	297
125% RDF	0.55	1.42	7.54	0.28	282	24.6	293	288	25.9	299
SEm±	0.010	0.005	0.052	0.048	1.28	0.19	1.16	1.02	0.22	1.56
CD (P=0.05)	NS	0.01	NS	NS	3.6	0.53	3.25	2.87	0.63	4.37

Table 4. Effect of irrigation schedule, residue incorporation and nutrient management on growth, yield attributes and yield of wheat, productivity and profitability of soybean - wheat cropping system (Pooled data of 3 years)

Treatment	Plant height (cm)	DM at 60 DAS (g/mrl)	Effective tillers/m^2	Grains/ ear	Wheat yield (t/ha)	System productivity (SEY, t/ha)	Production efficiency (kg/ha/day)	System profitability (×10^3 ₹/ha)	Economic efficiency (₹/ha/day)
Irrigation schedule									
One irrigation at flowering stage	81.7	78.57	97	30.7	5.37	4.24	11.61	93.81	257
Two irrigation at flowering and pod development stages	82.9	79.46	99	30.8	5.47	4.42	12.10	95.68	262
SEm±	0.69	0.80	0.51	0.19	0.02	0.032	0.087	0.401	1.10
CD (P=0.05)	NS	NS	1.76	NS	0.08	0.11	0.30	1.39	3.8
Residue management									
Residue burning	78.0	76.15	96	30.6	5.32	4.18	11.46	92.87	254
Residue incorporation without irrigation	78.8	77.50	96	30.7	5.36	4.24	11.62	93.73	257
Residue incorporation with irrigation and application of urea @ 25 kg/ha	86.7	80.53	99	30.8	5.48	4.38	11.99	95.87	263
Residue incorporation with irrigation and application of urea @ 25 kg/ha + Cellulolytic microbes @ 2.0 kg/ha	87.1	81.13	100	30.9	5.52	4.51	12.35	96.52	264
SEm±	1.82	2.00	1.03	.17	0.03	0.033	0.091	0.578	1.58
CD (P=0.05)	5.22	5.7	2.95	NS	0.09	0.10	0.26	1.66	4.5
Nutrient management									
75% RDF	81.3	77.40	96	30.7	5.33	4.20	11.51	93.13	255
100% RDF	83.1	80.25	98	30.8	5.45	4.34	11.90	95.35	261
125% RDF	83.6	80.82	98	30.8	5.48	4.44	12.15	95.74	262
SEm±	0.89	1.52	.67	.42	0.02	0.025	0.068	0.346	0.95
CD (P=0.05)	NS	NS	NS	NS	0.05	0.07	0.19	0.97	2.7

DM, Dry-matter accumulation/metre row length; SEY, soybean equivalent yield

induced perceptible increase in system profitability and economic efficiency, which were 2.38, 2.35% higher over control.

Water use and residual soil fertility

Irrigation at flowering and pod development stages gave maximum organic C, bulk density, available N, P and K status of soil after harvesting of wheat and soybean crop, water use efficiency (WUE) and water productivity (Table 2 and 3). Significant improvement with irrigation applied at flowering and pod development stages was found in available N, P and K status of soil after harvesting of wheat and only in N and P status of soil after harvesting of soybean over the one irrigation at flowering stage.

Among the residue management practices, residue incorporation with irrigation and application of urea @ 25 kg/ha + cellulolytic microbes @ 2.0 kg/ha resulted in the significantly maximum organic C, bulk density, available N, P and K status of soil after harvesting of wheat and soybean crops, water use efficiency (WUE) and water productivity. However, significant improvement in organic C, N, P and K status of soil after harvesting of soybean, wheat and WUE were found with residue incorporation with irrigation and application of urea @ 25 kg/ha as compared to residue burning. This was due to addition of organic matter to the soil through residue incorporation.

Data (Table 2 and 3) further revealed that nutrient management practices significantly increased N, P and K status of soil after harvesting of wheat and soybean crop and water productivity up to the highest level of 125% RDF with comparable status of soil under 100% RDF. Additional application of fertilizers beyond 100% RDF did not increase, bulk density, K and WUE any further significantly. This might be also due to addition of N, P and K in soil through fertilizers. Significant improvement due to irrigation, residue and nutrient management were not observed in relation to EC and *p*H. The findings of this investigation are in conformity with those of Girase *et al*. (2016), Gallani *et al*. (2013) and Ram *et al*. (2010).

Based on three years pooled data it may be concluded that system productivity, profitability and soil health under soybean–wheat cropping system can be enhanced through adoption of recommended package of practices for the wheat and its residue incorporation after harvest along with irrigation and application of urea @ 25 kg/ha + cellulolytic microbes @ 2.0 kg/ha; 125% RDF (25 kg N: 50 kg P_2O_5: 50 kg K_2O/ha) of soybean and then application of two irrigations at flowering and pod development stages.

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