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Research Paper

Effect of nutrition management and irrigation methods and schedule on productivity, economics and water-use efficiency in soybean (*Glycine max*)–chickpea (*Cicer arietinum*) cropping sequence in alluvial soil

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ABSTRACT

A field experiment was conducted during 2011–12 and 2012–13 at Morena, Madhya Pradesh, to study the effect of nutrition management, and methods and scheduling of irrigation on soybean **[***Glycine max* (L.) Merr.]–chickpea (*Cicer arietinum* L.) cropping sequence. An irrigation at 0.6 irrigation water:cumulative pan evaporation (IW:CPE) ratio resulted in significantly higher growth, yield attributes, seed yield, economic benefits and water productivity of soybean compared with 0.4 and 0.8 IW:CPE. Similarly, an irrigation at 0.4 IW:CPE ratio significantly influenced the yield-attributing characters, seed and straw yields, economic benefits and water productivity of chickpea compared with 0.6 and 0.8 IW:CPE ratios, whereas height and number of branches increased with increasing IW:CPE ratio. Sprinkler irrigation resulted in significantly higher growth and yield attributes, seed and straw yields, economic benefits and water productivity of both the crops. The irrigation at 0.6 IW:CPE ratio showed 51.3% and 39.0% higher seed of soybean over 0.4 and 0.8 IW:CPE ratio, whereas 0.4 IW:CPE of irrigation yielded 14.5% and 32.5% higher seed of chickpea compared with 0.6 and 0.8 IW:CPE. Mean response of sprinkler irrigation was recorded 8.3% in soybean and 11.7% in chickpea higher seed yield over check basin irrigation. Likewise, increases in growth and yield attributes, seed yield, water productivity and protein production of soybean and chickpea were noticed with application of 75% recommended dose of fertilizer (RDF) + 2.5 t FYM/ha compared with other nutrition treatments. Addition of 75% RDF + 2.5 t FYM/ha also achieved higher system productivity, net profit and production and economic efficacy. After harvesting of the second crop of chickpea, maximum availability of N, P, K and S was recorded under 0.4 IW:CPE ratio, sprinkler irrigation and application of 75% RDF + 2.5 t FYM/ha compared to other treatments.

Key words: Chickpea, Irrigation methods and schedules, Nutrition management, Soybean

In spite of high yield potential (4.5 t/ha) of soybean, its productivity is much less in India (0.798 t/ha) than the world average of 2.66 t/ha during 2014–15 (USDA, 2016). Similarly in pulses, productivity of chickpea in India (0.73 t/ha) is too below with the world average (0.91 t/ha), whereas demand of pulses and vegetable oils is increasing at a very high rate (Singh and Singh, 2016). The wide yield gap between actual and potential of soybean and chickpea is due to intensive tillage, monocropping, imbalanced use of nutrients coupled with limited use of organic manures, less recycling and burning of crop residues in soil, soil erosion, undulated topography, indiscriminate irrigation systems etc. Likewise biotic factors are also obstacle in yield potential of both the crop. Integrated nutrient management plays an important role in maintaining soil fertility in long run. Soybean is an energy-rich crop and hence the requirement of major nutrients including secondary and micronutrients is high (Saste *et al*., 2015). Legumes are known to fix atmospheric N and enrich soil fertility and therefore could help in sustaining the long-term productivity. Besides, inclusion of legumes in the cropping system improves nutrient use-efficiency, soil organic matter content and soil physical condition along with microbial activity.

Water is the key factor of agricultural production and development of different crops. Efficient irrigation water management is the solution to reap full benefit from the available water by adopting proper irrigation method, losses of water save in conveyance, regulation, distribu-

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tion, application and use of irrigation water for crops to conformity with the plant needs for optimum growth and yield. In contrary, excess soil moisture due to faulty irrigation or winter rains results in influencing excess growth of chickpea (Singh and Singh, 2016), while excess soil moisture or flooding significantly reduces root and shoot growth parameters of soybean. Wu (2017) reported that flooding reduced to soybean yields by 17 to 43% at the vegetative growth stage, and 50 to 56% at the reproductive stage. It is highly desirable to obtain potential yield using the least possible amount of water. Sprinkler method of irrigation saves up to 65% water compared with surface-irrigation methods and significantly influences yield, benefits, soil properties and saving natural resources. It is essential to use irrigation water and plant nutrients in a judicious way to minimize fertilizer use and at the same time sustain soil fertility and productivity in a long-term basis. Keeping in view these above aspects, present investigation was undertaken to study the effect nutrition management and methods and scheduling of irrigation on yield, economics, water productivity and soil properties in soybean–chickpea cropping system of alluvial plains.

MATERIALS AND METHODS

The field experiment was carried out during 2011–12 and 2012–13 at Zonal Agricultural Research Station, Morena, Madhya Pradesh. The soil of experimental field was alluvial, having sandy loam texture with *p*H 7.79. It was moderately fertile, being low in organic carbon (0.32%), available nitrogen (174 kg/ha), sulphur (9.9 kg/ha) and medium in available phosphorus (12.3 kg/ha) and potassium (253 kg/ha) (Table 4). The experiment was laid out in a split-plot design with 3 replications. Twenty four treatment combinations, comprising 3 irrigation schedules, viz. 0.4, 0.6 and 0.8 irrigation water: cumulative pan evaporation (IW: CPE) ratio in main plot; 2 irrigation methods, i.e. check basin and sprinkler in subplots, and 4 nutrition managements, viz. recommended dose of fertilizer for soybean and chickpea (30–60–20 kg N-P_2O_5-K_2O/ha), 125% recommended dose of fertilizer (RDF), 75% RDF + 2.5 t FYM/ha and 50% RDF + 5.0 t FYM/ha in sub-subplots. The nutrient content of FYM was 0.66% N, 0.37% P, 0.62% K, 47 mg/kg Cu, 9645 mg/kg Fe, 81 mg/kg Zn and 289 mg/kg Mg. Full doses of organic manure were applied as per treatments before sowing of both the crops, whereas inorganic fertilizer was placed at time of sowing. Soybean cultivar 'JS 9305' and chickpea 'JG-16' were sown in the first week of July and the first week of November and harvested in the fourth week of October and second week of March respectively. The crops were sown in rows, 30 cm apart, with a seed rate of 80 and 70 kg/ha to soybean and chickpea respectively. The soybean crop was grown in the rainy season, while 5 cm pre-sowing irrigation and irrigation was applied as per treatments to chickpea. The mean annual rainfall of the region is 700 mm, whereas annual rainfall received during 2011–12 and 2012–13 was 873 and 727 mm respectively. The other crop-management practices were followed as per standard recommendations.

The seed samples were analyzed for N content (Piper, 1967) and crude protein in seed was calculated by multiplying 6.25% N in seed. Soil samples (0–15 cm) were drawn before initiation of experiment and after the harvesting of the second crop of chickpea and analyzed for organic carbon (Walkley and Black, 1934), available N (Kjeltec-II auto analyzer), Olsen P, NH_4OAc K and S (Jackson, 1973). Production indices like chickpea-equivalent yield (CEY), system productivity of the soybean–chickpea cropping system was worked out to evaluate the system efficacy.

The total cost of cultivation of soybean and chickpea under all treatments were calculated on the basis of different operations performed and materials used for raising the crop, including the cost of fertilizers, irrigation, harvesting, threshing etc. Economics of treatments was computed taking all operations for crop production in account and the prevailing market prices for inputs. Gross returns were calculated by multiplying seed yield with minimum support price and the same for straw by prevailing market price. Net returns and benefit: cost ratio were calculated.

Irrigation water applied to chickpea crop was measured by using water meter. Soil water content was measured gravimetrically in 0–150 cm soil profile at 15 cm increments for first 2 layers, and at 30 cm subsequently. Soil moisture (%) was determined by thermo-gravimetrically. During cropping period of soybean and chickpea rainfall received was 710 and 19 mm during the first and 626 and 60 mm during the second year respectively. The surface drainage recorded during the rainy cropping season was 55 mm during the first and 145 mm during the second year of experimentation. The total water use was calculated as sum of effective rainfall, amount of water (input water) applied plus change in soil water storage (0–150 cm) between sowing and harvesting of each season. Irrigation water productivity was calculated as: Water-use efficiency (kg seed m^3) = Grain yield of crop (kg/ha)/Total water use (m^3/ha).

RESULTS AND DISCUSSION

Growth, yield attributes and yield

Soybean: The growth, yield components and yield of soybean varied significantly due to irrigation schedules and methods of irrigation pooled over 2 years (Table 1). The maximum, growth and yield attributes of soybean

were observed with 0.6 IW:CPE ratio and sprinkler method of irrigation except plant height, which was maximum under 0.8 IW:CPE ratio. Such increase in growth and yield attributes were owing to adequate and timely supply of water with 0.6 IW:CPE ratio and sprinkler method of irrigation providing congenial growth environment with improved cell turgidity, opening of stomata and finally the partitioning of photosynthesis efficiency to the sink (Chauhan *et al*., 2002). On the other hand, significantly lowest growth and yield attributes were recorded under 0.4 IW:CPE ratio and check basin irrigation method, which might have exposed the crop to relatively more water stress and pulled down the growth and yield components when compared with irrigation scheduling of 0.6 and 0.8 IW:CPE ratios and sprinkler methods of irrigation (Yadav *et al*., 2010)

Significant improvement in seed yield as well as in straw yield of soybean was recorded with schedule and method of irrigation (Table 2). The mean response due to 0.6 IW:CPE ratio was 51.3 and 39.0% in seed and 32.3 and 5.2% in straw yield over 0.4 and 0.8 IW:CPE ratio respectively. However with sprinkler irrigation increase of 8.3 and 5.3% in seed and straw yield was noticed over check basin method of irrigation which might be ascribed to adequate supply of the moisture to the crop growth and development phase that favourably induced number of physiological process which resulted in higher production when compared with 0.4 and 0.8 IW:CPE ratio and check basin method of irrigation. Yadav *et al*. (2009) also obtained similar results in sunflower crop.

Nutrient-management method had significant effect on growth and yield-contributing characters of soybean (Table 1). The maximum growth and yield-contributing characters were recorded with application of 75% RDF + 2.5 t FYM/ha over the other nutrient-management treatments. The higher values of these growth and yield attributes with this nutrient-management practice might be owing to supply of all the essential mineral nutrients in a balanced amount which resulted in better growth and development of the plants. Several workers have reported the positive response of organic and inorganic sources of application on different growth and yield attributes of soybean (Dabhi *et al*., 2010; Singh and Saxena, 2010; Singh *et al*., 2013). Significantly lowest growth and yield parameters were obtained under recommended doses fertilizers added through only chemical fertilizers.

The pooled seed yield and straw yields of soybean improved markedly owing to application of higher doses of nutrients through only chemical sources or in combinations of organic and inorganic sources as compared with

Table 1. Effect of nutrition management, methods and scheduling of irrigation on growth and yield of soybean–chickpea cropping sequence (pooled data of 2 years)

Treatment	Soybean					Chickpea				
	Plant height (cm)	Branches/ plant	Pods/ plant	Nodules/ plant 60 DAS (no.)	1,000-grain weight (g)	Plant height (cm)	Branches/ plant	Pods/ plant	Nodules/ plant 60 DAS (no.)	1,000-grain weight (g)
Irrigation schedule										
0.4 IW: CPE	71.3	7.99	26.9	29.4	132.7	38.8	8.15	57.4	34.4	193.6
0.6 IW: CPE	72.7	9.23	32.5	35.8	144.6	41.0	8.78	47.6	28.1	189.9
0.8 IW: CPE	74.1	8.99	29.1	32.1	140.4	48.4	9.54	41.3	23.8	188.3
SEm±	0.3	0.13	0.6	0.4	0.51	0.4	0.06	0.6	0.5	0.3
CD (P=0.05)	0.8	0.37	1.8	1.1	1.50	1.6	0.19	1.6	1.6	0.8
Method of irrigation										
Check basin	71.6	8.22	28.0	32.0	135.8	41.4	8.63	41.1	27.9	189.8
Sprinkler	73.7	9.25	31.0	32.8	142.7	44.0	9.02	43.1	29.6	191.6
SEm±	0.2	0.10	0.3	0.2	0.31	0.3	0.03	0.3	0.1	0.2
CD (P=0.05)	0.6	0.29	0.9	0.6	0.91	1.0	0.09	0.9	0.3	0.6
Nutrition management										
RDF	71.5	8.22	27.1	29.2	134.2	40.3	8.33	39.7	26.8	189.5
125% RDF	72.8	8.57	28.9	31.5	136.3	42.3	8.73	41.0	28.3	190.3
75% RDF + 2.5 t FYM/ha	73.9	9.33	31.7	35.3	148.8	44.8	9.23	45.2	30.8	192.2
50% RDF + 5.0 t FYM/ha	72.5	8.82	30.4	33.7	141.7	43.3	8.98	42.5	29.0	190.8
SEm±	0.3	0.10	0.4	0.3	0.39	0.6	0.08	0.4	0.3	0.2
CD (P=0.05)	0.9	0.31	1.1	1.0	1.18	1.9	0.24	1.1	0.8	0.7

DAS, Days after sowing; IW: CPE, irrigation water: cumulative pan evaporation; RDF, recommended dose of fertilizer

RDF. The mean increase in seed and straw yields of soybean with application of 125% RDF, 75% RDF + 2.5 t FYM/ha and 50% RDF + 5.0 t FYM/ha was 7.5, 13.3 and 10.4% and 7.6, 11.0 and 9.1% over RDF respectively. The maximum seed and straw yields were registered with 75% RDF + 2.5 t FYM/ha application. Addition of nutrient through organic and inorganic sources provided better conducive conditions for better uptake of nutrients and in turn helped the plants to boost their growth leading to the development of yield attributes through supply of more photosynthates towards the reproductive sink. Such increased trends were also noticed by Ramesh *et al*. (2009) and Saste *et al*. (2015).

Chickpea: Irrigation schedules and methods of irrigation significantly influenced the pooled data of growth and yield components and yields of chickpea (Table 1). The growth pods/plant, nodules and 1,000-seed weight), seed and straw yield of chickpea were significantly increased under 0.4 IW:CPE ratio compared with 0.6 and 0.8 IW:CPE ratio, whereas plant height and branching significantly increased with increasing irrigation regimes. Significant improvement in growth, yield-attributing characters, seed and straw yield of chickpea were recorded under sprinkler irrigation as compared to check basin irrigation method. Improvement in growth and yield parameters under these treatments was owing to timely and adequate supply of moisture which might have helped in better nutrient uptake by the crop which is in turn resulted in assimilation of photosynthates toward sink as well as higher dry matter accumulation. These results confirm that the findings of Pramanik *et al*. (2009) and Singh *et al*. (2009).

Pooled data revealed that chickpea recorded the maximum seed as well as straw yields, being significantly higher by 14.5 and 32.5% in seed yield over 0.4 and 0.8 IW:CPE ratio respectively (Table 2). Similarly, sprinkler method of irrigation resulted in significantly higher seed and straw yields by 11.7 and 7.5% over check basin method of irrigation. Likewise, almost similar trend of system productivity of chickpea equivalent was also observed with schedules and method of irrigation. Irrigation at 0.6 and 0.8 IW:CPE ratio favourably influenced the vegetative growth

Table 2. Effect of nutrition management, methods and scheduling of irrigation on productivity and economics of soybean–chickpea cropping sequence (pooled data of 2 years)

Treatment	Seed yield soybean (t/ha)	Grain yield chickpea (t/ha)	Chickpea equivalent (t/ha)	System productivity (t/ha)	Total duration (days)	Production efficiency (kg/ha/day)	Cost of cultivation (×10³ ₹/ha)	Economic efficiency (₹/ha/day)	Net returns (×10³ ₹/ha)	Benefit: cost ratio
Irrigation schedule										
0.4 IW: CPE	1.58 (1.98)	2.77 (3.49)	1.07	3.83	239	16.0	30.2	512	92.2	3.0
0.6 IW: CPE	2.39 (2.62)	2.42 (3.80)	1.62	4.03	240	16.8	32.5	534	95.6	2.9
0.8 IW: CPE	1.72 (2.49)	2.09 (3.92)	1.17	3.27	243	13.5	33.9	489	77.6	2.3
SEm±	0.02 (0.01)	0.01 (0.01)	0.02	0.05	3	–	–	–	–	–
CD (P=0.05)	0.05 (0.03)	0.03 (0.04)	0.06	0.16	NS	–	–	–	–	–
Method of irrigation										
Check basin	1.80 (2.25)	2.30 (3.22)	1.22	3.51	242	14.5	33.2	471	80.8	2.4
Sprinkler	1.95 (2.37)	2.57 (3.46)	1.32	3.89	240	16.2	35.2	523	90.3	2.6
SEm±	0.01 (0.01)	0.01 (0.01)	0.02	0.03	2	–	–	–	–	–
CD (P=0.05)	0.02 (0.02)	0.02 (0.03)	0.05	0.10	NS	–	–	–	–	–
Nutrition management										
RDF	1.73 (2.10)	2.20 (3.16)	1.17	3.37	241	14.0	31.4	454	78.1	2.5
125% RDF	1.86 (2.26)	2.34 (3.37)	1.26	3.60	241	14.9	33.1	484	83.5	2.5
75% RDF + 2.5t FYM/ha	1.96 (2.33)	2.66 (3.42)	1.33	3.98	241	16.5	34.5	531	93.5	2.7
50% RDF + 5.0t FYM/ha	1.91 (2.29)	2.35 (3.40)	1.29	3.65	240	15.2	37.8	491	82.4	2.2
SEm±	0.01 (0.01)	0.01 (0.02)	0.03	0.05	3	–	–	–	–	–
CD (P=0.05)	0.03 (0.02)	0.03 (0.05)	0.08	0.14	NS	–	–	–	–	–

DAS, Days after sowing; IW: CPE, irrigation water: cumulative pan evaporation; RDF, recommended dose of fertilizer
Minimum support price of seed of soybean and chickpea ₹16,900 and 28,000/t for 2011–12 and ₹22,400 and 30,000/t for 2012–13 and local market rate of straw ₹1,750 and 2,500/t for 2011–12 and ₹2,250 and 3,000/t for 2012–13 respectively

but did not influence the yield attributes and hence did not improve the yield significantly. Pramanik *et al*. (2009) and Yadav *et al*. (2009) also reported such increase in chickpea.

The growth and yield contributing characters and yield of chickpea were influenced significantly with nutrient management pooled over two years. Application of 75% RDF + 2.5 t FYM/ha significantly increased the plant height, branches/plant, pods/plant, nodules and 1000-seed weight when compared with other nutrient management treatments (Table 1). The significantly lowest values of all these characters and yield were noted under recommended doses of nutrients. The mean data showed that application of nutrient at 75% RDF + 2.5 t FYM/ha resulted in 20.9%, 13.7% and 13.2% increased in seed yield over 100% RDF, 125% RDF and 50% RDF + 5.0 t FYM/ha, respectively (Table 2). Similar trend was also obtained in system productivity of chickpea equivalent. These results corroborate with the results of Tiwari (2002) and Sammuria *et al*. (2009). The better yield attributes and yield with the application of 75% RDF + 2.5 t FYM/ha might be due to its key role in root development, energy translocation and metabolic process of plant growth which increased translocation of photosynthetic towards sink.

Production and economic efficacy

Economics is the ultimate deciding factor to adopt a practice by the farmers. The production and economic efficacy, cost of cultivation, net returns and benefit: cost (B:C) ratio were affected by various irrigation and nutrient management treatments of soybean and chickpea (Table 2). The highest production and economic efficacy, net returns, of soybean–chickpea cropping system were registered with 0.6 IW:CPE ratio, whereas the highest B:C ratio registered with 0.4 IW:CPE ratio. Similar higher values were also obtained in case of sprinkler method of irrigation over check basin method. The treatment receiving 75% RDF + 2.5 t FYM/ha resulted in the maximum production and economic efficacy, net returns and B:C ratio of 2.7 of soybean and chickpea respectively. The highest monitory advantage under these irrigation and nutrient management treatments was mainly owing to better plant growth, yield components and yield when compared with other treatments. Ramesh *et al*. (2009); Paramanik *et al*. (2009); Yadav *et al*. (2009) and Singh *et al*. (2013) also reported similar findings.

Water productivity

The irrigation and nutrient-management treatments remarkably influenced total water use and water productivity of soybean and chickpea (Table 3). The maximum water productivity was obtained under 0.6 IW:CPE ratio 0.35 kg seed/m^3 water for soybean and 1.72 kg seed/m^3 water for chickpea under 0.4 IW:CPE ratio, respectively.

Table 3. Effect of nutrition management, methods and scheduling of irrigation on protein yield and water productivity of soybean–chickpea cropping sequence (pooled data of 2 years)

Treatment	Soybean			Chickpea		
	Protein yield (t/ha)	Total water use (m^3/ha)	Water productivity (kg seed/m^3 water)	Protein yield (t/ha)	Total water use (m^3/ha)	Water productivity (kg seed/m^3 water)
Irrigation schedule						
0.4 IW: CPE	0.64	7,261	0.33	0.60	1,612	1.72
0.6 IW: CPE	0.98	7,946	0.35	0.52	2,038	1.19
0.8 IW: CPE	0.72	8,642	0.24	0.45	2,453	0.85
SEm±	0.04	230	0.02	0.02	130	0.04
CD (P=0.05)	0.11	689	0.05	0.06	389	0.12
Method of irrigation						
Check basin	0.74	8,052	0.29	0.49	2,485	0.93
Sprinkler	0.81	7,834	0.33	0.55	2,427	1.06
SEm±	0.02	72	0.01	0.1	72	0.03
CD (P=0.05)	0.07	215	0.04	0.4	NS	0.09
Nutrition management						
RDF	0.70	7,997	0.28	0.44	2,451	0.90
125% RDF	0.77	8,005	0.29	0.50	2,490	0.94
75% RDF + 2.5 t FYM/ha	0.82	7,892	0.34	0.58	2,435	1.10
50% RDF + 5.0 t FYM/ha	0.80	7,878	0.30	0.51	2,448	0.96
SEm±	0.13	137	0.01	0.01	125	0.02
CD (P=0.05)	0.37	413	0.02	0.04	NS	0.06

DAS, Days after sowing; IW: CPE, irrigation water: cumulative pan evaporation; RDF, recommended dose of fertilizer

Yadav *et al*. (2009) and Pramanik *et al.* (2009) also reported similar results in sunflower and chickpea. However, sprinkler irrigation method resulted significantly highest water productivity over check basin. Total water use was increased with the increasing irrigation regime and maximum values were registered in both the crops at 0.8 IW:CPE ratio and check basin method of irrigation. Higher availability of water in upper and middle layers of soil in these treatments helps more moisture depletion and ultimately increases water use by the crop plants. The water productivity was recorded maximum under 75% RDF + 2.5 t FYM/ha (0.34 kg seed/m^3 water for soybean and 1.10 kg seed/m^3 water for chickpea) followed by at par with other fertility levels in both the crops (Pramanik *et al*., 2009).

Protein production

Protein production of soybean and chickpea was significantly influenced by irrigation and nutrition management treatments (Table 3). The irrigation regime of 0.6 IW:CPE ratio resulted in maximum protein of seed 0.98 t/ha, whereas chickpea crop produced significantly higher protein of 0.60 t/ha under 0.4 IW:CPE ratio. Sprinkler method of irrigation significantly increased the protein production of seed of soybean and chickpea, compared with check basin irrigation method. Similar to irrigation treatments, 75% RDF + 2.5 t FYM/ha recorded the maximum seed protein production of 0.82 and 0.58 t/ha of soybean and chickpea, respectively. Dabhi *et al*. (2010) reported that integrated nutrition management increased crude protein in soybean crop. These findings are in line with that of Yadav *et al*. (2010).

Physicochemical properties

Electrical conductivity (EC), pH, organic carbon (OC), bulk density (BD), infiltration rate (IR) were not affected significantly by irrigation schedule and its method of irrigation and nutrient-management treatments after harvesting of second crop (Table 4). However, available N, P, K and S were significantly affected by irrigation schedule and its method of irrigation and nutrient-management treatments. Maximum value of available N, P, K and S were recorded under 0.4 IW:CPE ratio of irrigation compared with 0.6 and 0.8 IW:CPE ratio. Sprinkler-irrigation method significantly recorded higher available N and K over check basin method. Similarly availability of N, P, K, S were significantly higher under 75% RDF + 2.5 t FYM/ha than the other nutrition-management treatments. The maximum addition of available N after harvesting of the second crop of chickpea was 62 kg/ha with sprinkler method of irrigation followed by 0.4 IW:CPE ratio and 75% RDF + 2.5 t FYM/ha nutrition level compared with

Table 4. Effect of nutrition-management, methods and scheduling of irrigation on physico-chemical properties of soil of chickpea under soybean–chickpea cropping sequence

Treatment	Electrical conductivity (dS/m)	*p*H	Organic carbon (%)	Bulk density (Mg/m^3)	Infiltration rate (mm/hr)	Available nutrients (kg/ha)			
						N	P	K	S
Initial values	0.40	7.79	0.32	1.50	9	174	12.3	253	9.9
Irrigation schedule									
0.4 IW: CPE	0.43	7.84	0.38	1.47	13	228	15.1	267	12.1
0.6 IW: CPE	0.45	7.91	0.40	1.46	12	223	14.5	263	11.7
0.8 IW: CPE	0.48	7.94	0.40	1.46	12	218	14.8	261	11.9
SEm±	0.05	0.12	0.04	0.03	2	02	0.1	02	0.1
CD (P=0.05)	NS	NS	NS	NS	NS	05	0.3	06	0.2
Method of irrigation									
Check basin	0.44	7.88	0.38	1.47	11	210	14.7	260	11.8
Sprinkler	0.46	7.90	0.40	1.45	13	236	14.9	266	12.0
SEm±	0.02	0.06	0.02	0.01	1	01	0.1	01	0.1
CD (P=0.05)	NS	NS	NS	NS	NS	04	NS	03	NS
Nutrition management									
RDF	0.42	7.95	0.36	1.48	11	218	12.8	256	10.9
125% RDF	0.44	7.91	0.37	1.47	12	222	14.7	261	11.2
75% RDF + 2.5 t FYM/ha	0.46	7.86	0.41	1.45	13	227	15.6	266	12.5
50% RDF + 5.0 t FYM/ha	0.49	7.85	0.43	1.44	13	225	16.1	269	13.1
SEm±	0.04	0.10	0.03	0.02	2	01	0.1	01	0.1
CD (P=0.05)	NS	NS	NS	NS	NS	03	0.3	04	0.2

DAS, Days after sowing; IW: CPE, irrigation water: cumulative pan evaporation; RDF, recommended dose of fertilizer

initial value of available N (174 kg/ha). Similar findings were also reported by Yadav *et al*. (2009).

Thus, higher seed and straw yields, profitability, water productivity and improvement in physicochemical properties of soil obtained with irrigation regime of 0.6 IW:CPE ratio during dry spell for soybean grown in *kharif* (rainy) and 0.4 IW:CPE ratio for chickpea in *rabi* (winter) season crop, sprinkler method of irrigation and nutrition with addition of 75% RDF + 2.5 t FYM/ha is recommended to each crop.

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