Indian Journal of Agronomy **61** (1): 53–58 (March 2016)

Research Paper

Effect of irrigation scheduling and nutrient management on productivity, profitability and nutrient uptake of wheat (*Triticum aestivum*) grown under zero-tilled condition in south-eastern Rajasthan

R.S. NAROLIA[1], HARPHOOL MEENA[2], PRATAP SINGH[3], B.S. MEENA[4] AND BALDEV RAM[5]

Agricultural Research Station, Ummedganj, Agriculture University, Kota, Rajasthan 324 001

Received : April 2015; Revised accepted : February 2016

ABSTRACT

A field experiment was conducted at Agricultural Research Station, Kota, Rajasthan, during the winter (*rabi*) seasons of 2011–12, 2012–13 and 2013–14, to evaluate effect of irrigation scheduling and nutrient management practices on productivity, profitability and nutrient uptake of wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.] grown under zero-tillage condition in south eastern Rajasthan. Treatments comparised irrigation schedules in main plots, viz. irrigation water: cumulative pan evaporation (IW: CPE) 0.8 and IW: CPE 1.0, and nutrient-management practices in sub plots, viz. 100% recommended dose of fertilizers (RDF 120 kg/ha nitrogen, 40 kg/ha P_2O_5 and 30 kg/ha potash), 125% RDF and 150% RDF, were laid out in split-plot design with 4 replication. Irrigation at an IW: CPE of 1.0 significantly increased plant height (85.3 cm), leaf-area index (3.64) and dry-matter accumulation (894.2 g/m^2) at 90 days after sowing (DAS), effective tillers/m^2 (489), ear length (9.27 cm), grains/ear (45.3) and 1,000-seed weight (36.82g), grain yield (4.16 t/ha), straw yield (6.50 t/ha), N (69.6 and 44.0 kg/ha), P (15.7 and 3.52 kg/ha) and K (20.6 and 153.1 kg/ha) uptake by grain and straw, respectively, protein content (10.5%), net returns (₹56,004/ha) and benefit: cost ratio (3.30), production efficiency (28.7 kg/ha/day) and economic efficiency (₹386/ha/day) and water-use efficiency (80.1 kg/ha-cm)) than the irrigation at IW:CPE of 0.8. However, maximum harvest index and water productivity were observed with the irrigation at an IW: CPE ratio of 0.8. Among nutrient-management practices, 125% RDF registered significantly higher growth and yield attributes, grain yield (4.04 t/ha), net returns (₹54,058/ha) and all the efficiency indices, N, P and K uptake by grain and straw. However, significant improvement in straw yield was observed up to 150% RDF. Maximum harvest index and benefit: cost ratio were found only with 100% RDF.

Key words : Irrigation schedule, Nutrient management, Profitability, Uptake, Water productivity, Wheat, Zero-tillage

Rice–wheat cropping system is a dominant cropping system on fertile and irrigated Vertisols of humid south-eastern plain zone of Rajasthan. In this region, conventional crop-establishment practice in rice involves manual transplanting of of rice in puddle soil, whereas wheat is seeded in well-prepared fine seedbed. These practices involve excessive tillage and hence, result not only in high-energy consumption but also in deterioration of soil structure (Jha *et al*., 2011). Rice stubbles create a problem to complete tillage operation with in short period. Under this situation, zero tillage offers the benefit of saving of fuel, time, labour, retained surface residue, improve organic carbon, nutrients, reduced soil water, protect the soil from the sun, rain, wind and allows soil micro-organisms, fauna, reduces the breakdown of the soil structure, involves protection of the soil compaction by machinery and from changes to its chemistry through acidification or salinization (Jha *et al*., 2011; Shekhar *et al*., 2014). Zero tillage with proper irrigation management can help mitigate the adverse effect of conventional farming practices by increasing soil organic carbon, increased soil-moisture availability and sustainability of production system in a long run. Growing of 2 cereal crops in a year involves heavy removal of plant nutrients, which diminishes the soil fertility. It is, therefore, necessary to manage the inflow of organic sources of nutrient optimally through residue management under zero-tillage condition and their integration with fertilizers. However, wheat grown under zero-tilled condition requires more inorganic fertilization as compared to conventionally tilled field of rice–wheat

[1]**Corresponding author Email:** narolia2007@gmail.com
[1,2,4,5]Assistant Professor (Agronomy), [3]Professor and Zonal Director Research, Agricultural Research Station, Kota, Rajasthan 324 001

cropping system (Singh, 2006). Rapid and wide spread of rice–wheat 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 NPK in this region. This declining trend has been attributed to multiple nutrient deficiencies and imbalances of nutrients which poses a serious threat to long-term sustainability of crop production (Paul *et al.,* 2014). Considering this, the present investigation was undertaken to study the effect of irrigation scheduling and nutrient management on yield, nutrient uptake and economics of wheat grown under zero-tillage condition in humid south eastern plain zone of Rajasthan.

MATERIALS AND METHODS

A field experiment was carried out during the winter (*rabi*) seasons of 2011–12 to 2013–14 at Agricultural Research Station, Kota (26º N, 76º-6' E and 260 m above mean sea-level), Rajasthan. The soil was Vertisols having bulk density 1.53 Mg/m^3, *p*H 7.79 and cation-exchange capacity 35 C mol/kg. The soil had a very low infiltration rate (0.25 cm/hr) on surface but at deeper layers (1.2 to 1.5 m) was impermeable. The potential moisture-retention capacity of soil was 120 mm of water at 1 m soil depth. The soil was medium in organic carbon 5.6 g/kg, available nitrogen (320 kg/ha) and available phosphorus (23.6 kg/ha) and high in available potash (281 kg K_2O /ha). The experiment was laid out in split-plot design with 4 replications. The treatments of the experiments comprised 6 factorial combinations of 2 irrigation schedules, i.e. irrigation at 0.8 irrigation water: cumulative pan evaporation (IW: CPE) and irrigation at 1.0 IW: CPE and 3 nutrient management practices, i.e. 100% recommended dose of fertilizers (RDF): 120 kg/ha nitrogen, 40 kg/ha P_2O_5 and 30 kg/ha potash), 125% RDF and 150% RDF. The recommended practices of weed control, viz. application of isoproturon 0.75 kg/ha and 2, 4-D @ 0.8 kg/ha at 30 days after sowing was used. Wheat variety 'Raj 3765' was sown on 28, 30 and 29 November of 2011, 2012 and 2013 and harvested on 20, 21 and 25 April of 2012, 2013 and 2014 respectively. Seed @ 100 kg/ha was taken. Crop was planted by direct seeding using zero-tilled ferti-seed drill at 23 cm row spacing. Crop was raised with recommended package of practices, viz. seed treatment and weed management. The field plots of size 4.6 m × 5 m were separated from each other by using 1 m buffer rows. Irrigations were applied as per treatment on the basis of IW: CPE ratio approach using 6 cm depth of irrigation water. Four irrigations in IW: CPE of 1.0 and 3 in IW: CPE of 0.8 were applied during crop-growing seasons of experimentation. Basal application as per treatment, half doses of nitrogen and full dose of P and K were applied through, *diammonium* phosphate and muriate of potash respectively. The remaining N was top-dressed as urea in 2 equal splits at crown-root initiation (CRI) and tillering stage. A common basal dose of zinc sulphate (21% Zn) @ 25 kg/ha was applied uniformly to all plots only during the first year of experimentation. The annual rainfall received during growing seasons was 531 mm in 2011–12, 758 mm in 2012–13 and 683 mm in 2013–14. Observations of growth and yield-attributing characters were recorded 90 days after sowing and harvesting of wheat under different treatments. Plant height was recorded from each plot at 10 different selected plants. Dry-matter accumulation from the sample plants in each plot were recorded 90 days after sowing (DAS) and converted into meter square area. The plant material was first air dried, then chopped and oven dried at 70ºC for 72 hr to a constant weight. Leaf-area index (LAI) was recorded by using the Sun Scan Canopy Analyzer. Ear-bearing tillers from 1 m row length of each net plot at maturity were counted and recorded as number of effective tillers/m row length at harvesting. Five ears were selected at random from each plot to compute ear length and number of grain/ear. For test weight, 1,000 grains were counted from each treatment and then their weight was recorded. The crop was harvested manually with the help of sickle when grain almost matured and straw had turned yellow and data on grain and straw yields were recorded. The sun-dried bundles were threshed and winnowed and seed so obtained was weighed. The straw yield was obtained by subtracting the seed yield from the biological yield. Year-wise consumptive use of water was worked out using the formula described by Dastane (1972) and then mean of 3 years was used for calculating water-use efficiency. Evapotranpiration observed during growing seasons of 2011–12, 2012–13 and 2013–14 were 514 mm, 525 and 520 respectively. Nutrient uptake by crop in each plot was estimated by multiplying the seed and stover yields at harvesting with their respective percentage of nutrients in grains and straw. Colorimetric method and vanaomolybdo phosphoric acid yellow colour methods were used for determination of N and P (Jackson, 1973). Potassium was determined by flame photometer (Richards, 1954). The per cent protein content in seed of each plot was worked out by multiplying the nitrogen content in seed with conversion factor 6.25 (AOAC, 1960). All the observations were statistically analyzed for their test of significance of the individual years and then pooled analysis was done over the years. Water-use efficiency (WUE) and water productivity (WP) were worked out as per standard procedures (Devasenapathy *et al*., 2008; Singh and Kumar, 2011).

$$\text{Water-use efficiency} = \frac{\text{Economic crop yield (kg/ha)}}{\text{Evapotranspiration (ha-cm)}}$$

$$\text{Water productivity} = \frac{\text{Net returns (₹/ha)}}{\text{Water applied (m}^3\text{)}}$$

Economics of the treatments was carried out on the basis of prevailing market price of inputs and output.

RESULTS AND DISCUSSION

Growth and yield attributes

Irrigation schedules had significant effect on growth and yield attributes, viz. plant height, leaf-area index and dry-matter accumulation/m^2 at 90 days after sowing (DAS), effective tillers/m^2, ear length, grains/ear and 1,000-seed weight (Table 1). Irrigation applied at IW:CPE 1.0 registered significant increase in plant height, leaf-area index and dry-matter accumulation/m^2 by 4.3, 7.7 and 18.2% and in effective tillers/m^2, ear length, grains/ear and 1,000-seed weight by 14.5, 2.3, 11.3 and 2.8% over IW: CPE of 0.8. This might be owing adequate availability of water and better conductive rhizosphere environment for higher uptake of nutrients and in turn boost the growth, leading to the development of higher yield attributes through supply of more photosynthates towards the sink. Stress during the reproductive phase might have hampered the supply of photosynthates towards the sink resulting in poor yield attributes obtained in irrigation at IW: CPE of 0.8. The results are in close conformity with the finding of Ranjita *et al*. (2007) and Gurjar (2014).

Among nutrient management treatments, plant height and leaf-area index recorded in 125% recommended dose of fertilizers (RDF) and 150% recommended dose of fertilizers was statistically at par (Table 1), where as 125% RDF recorded significantly higher plant height and leaf-area index than the 100% RDF. However, significant improvement in dry-matter accumulation/m^2 was observed up to 150% RDF. Nitrogen application might have resulted in beneficial effect on cell-division and cell-elongation and it resulted in increased chlorophyll content and net photosynthetic rate and phosphorus supply on the other hand stored the solar energy obtained from photosynthesis and metabolism of carbohydrates into phosphate compounds for subsequent use in growth and reproductive processes which might be attributed to the increased plant height. Greater meristematic activity under the influence of inorganic fertilization might have promoted greater canopy development in terms of leaf-area index. Thus, increased LAI as a result of inorganic fertilization seem to have resulted in better interception, absorption and utilization of solar energy with greater CO_2 fixation and thereby increased the photosynthetic efficiency considerably.

Nutrient-management practices also had significant influence on the yield attributes of the wheat. Significantly higher effective tillers/m^2, ear length, grains/ear and 1,000-seed weight was recorded with the application of 125% recommended dose of fertilizers. However, 125% RDF and 150% RDF remained statistically at par in relation to yield-attributing characters. The RDF of 125% resulted 12.6, 2.3, 8.7 and 2.2% higher effective tillers/m^2, ear length, grains/ear and 1,000-grain weight, respectively. Higher number of effective tillers/m^2 was probably recorded owing to more utilization and uptake of nutrients which had significant role to play in photosynthesis and tillering of wheat. These results are in accordance with the findings of Sepat and Rana, (2013) and Sepat *et al*. (2010).

Yields

The grain and straw yield and protein content of wheat significantly influenced by irrigation schedules. Maximum

Table 1. Effect of irrigation scheduling and nutrient management on growth and yield attributes of wheat grown under zero tillage condition (pooled data of 3 years)

Treatment	Plant height at 90 DAS (cm)	Dry-matter/m^2 (gm) at 90 DAS	Leaf-area index at 90 DAS	Effective tillers/ m^2	Ear length (cm)	Grains/ear	1,000-grain weight (g)
Irrigation schedule							
IW: CPE 0.8	81.8	756.5	3.38	427	9.06	40.7	35.78
IW: CPE 1.0	85.3	894.2	3.64	489	9.27	45.3	36.82
SEm±	0.71	21.8	0.04	9.9	0.03	0.92	0.19
CD (P=0.05)	2.27	69.8	0.12	31.6	0.11	2.94	0.60
Nutrient management							
100% RDF	81.7	743.5	3.40	419	9.00	40.0	35.61
125% RDF	84.0	839.1	3.54	467	9.21	43.5	36.42
150% RDF	84.9	893.5	3.60	488	9.30	45.5	36.86
SEm±	0.39	12.3	0.02	9.2	0.03	0.75	0.16
CD (P=0.05)	1.10	35.3	0.06	26.4	0.09	2.20	0.45

IW: CPE, Irrigation water: cumulative pan evaporation; RDF, recommended dose of fertilizer

grain and straw yields were obtained under irrigation applied at an IW: CPE of1.0 (Table 2). Irrigation at an IW: CPE of 1.0 gave significantly higher grain and straw yield and protein content by 8.9 and 10.7 and 6.4% respectively, than irrigation applied at an IW: CPE of 0.8. However, harvest index (HI) was significantly lower under irrigation at an IW: CPE of 1.0 (1.0%) than the irrigation at an IW: CPE of 0.8. Highest grain and straw yields could be due to better availability of soil moisture in the root zone which might have enhanced nutrient availability to plants when crop received 4 irrigations at an IW: CPE of 1.0. This might have helped the plants more in better synthesis and translocation of photosynthates to the new developing sinks (ears) compared to 3 irrigations an IW: CPE of 0.8. This may also be as a result of batter yield-contributing characters with the application of irrigation at an IW: CPE of 1.0. These results are in accordance with those of Mesbah (2009) and Dixit *et al*. (2014).

Grain and straw yields and protein content showed progressive improvement with the increasing levels of fertilizers from 100% recommended dose of fertilizes to 150% recommended dose of fertilizes. Improvement in grain yield with the application of 150% recommended dose of fertilizes over 100% recommended dose of fertilizers was marginal and not found statistically significant. Thus, 125% recommended dose of fertilizes gave significantly higher grain and protein content by 6.3 and 4.9% over 100% RDF, respectively. However, straw yield was found significantly superior up to 150% RDF being 17.5, 6.6% higher over 100% RDF and 125% RDF respectively. Harvest index was found significantly lower in 150% RDF than 100% RDF. An adequate supply of nitrogen in the life of a plant is considered important in promoting rapid vegetative growth in terms of plant height, number of tillers/plant, leaf-area index and dry-matter production and of phosphorus in root proliferation and laying down primordial for its reproductive growth and seed formation. Application of fertilizers to wheat crop stimulated seed setting and increased effective number of tillers, number of grains/ear and 1,000-seed weight significantly. The grain and straw yields being function of cumulative effect of growth and yield-attributing characters owing to fertilization. The results are in close agreement with the findings of Singh *et al*. (2011) and Prajapat *et al*. (2014).

Water use

Irrigation schedules had significant influence on indices for water use (Table 2). Water-use efficiency observed in irrigation at an IW: CPE of 1.0 which was significantly higher by 8.8% as compared to irrigation at IW: CPE of 0.8. However, water productivity was found lower in irrigation at an IW: CPE of 1.0 than irrigation with IW: CPE ratio of 0.8. Mesbah (2009) also reported similar results in wheat crop and Dixit *et al*. (2014) in chickpea.

Water-use efficiency and water productivity were positively influenced by nutrient-management practices (Table 2). Significantly higher water-use efficiency and water productivity were obtained with the 125% recommended dose of fertilizes than 100% RDF. However, 125% RDF and 150% RDF remained at par with each other. This was mainly owing to higher grain and straw production and ultimately net return per unit of water applied. The results confirm the findings of Jat *et al*. (2013).

Economics

Maximum net return, production efficiency and eco-

Table 2. Effect of irrigation scheduling and nutrient management on grain and straw yield, protein content and indices for water use of wheat grown under zero tillage condition (pooled data of 3 years)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)	Protein content (%)	Water-use efficiency (kg/ha-cm)	Water productivity (₹/ha/m³)
Irrigation schedule						
IW: CPE 0.8	3.82	5.87	39.5	9.87	73.6	28.0
IW: CPE 1.0	4.16	6.50	39.1	10.5	80.1	23.3
SEm±	0.06	0.05	0.07	0.09	1.08	0.49
CD (P=0.05)	0.18	0.16	0.23	0.30	3.46	1.55
Nutrient management						
100% RDF	3.80	5.66	40.2	9.82	73.1	24.5
125% RDF	4.04	6.24	39.3	10.3	77.8	26.1
150% RDF	4.14	6.55	38.4	10.4	79.6	26.5
SEm±	0.05	0.11	0.30	0.06	0.97	0.42
CD (P=0.05)	0.14	0.32	0.85	0.17	2.79	1.21

IW: CPE, Irrigation water: cumulative pan evaporation; RDF, recommended dose of fertilizer

nomics efficiency obtained with the irrigation at an IW: CPE of 1.0 which was significantly higher by 10.9, 8.7 and 10.9% over irrigation at IW: CPE of 0.8 (Table 3). Between 2 irrigation levels, maximum and significantly higher benefit: cost ratio of 3.3 was also observed under irrigation at an IW: CPE of 1.0. This might be owing to higher production of wheat grown under zero-tillage condition with proper moisture availability at an IW of CPE of 1.0 during crop-growing season.

Similarly, under nutrient-management practices, 125% recommended dose of fertilizes also showed higher net returns, production efficiency and economic efficiency than 100% RDF (Table 3). However, maximum benefit: cost ratio was found with 100% RDF. This might be owing to higher yields obtained under this treatment compared to the other treatments. These results are in conformity with those reported by Sepat *et al*. (2010) and Dixit *et al*. (2014).

Nutrient uptake

Significant improvement in N, P and K uptake by grain and straw of wheat crop at harvesting was observed with irrigation levels of IW: CPE ratio of 0.8 and 1.0 (Table 4). The highest nitrogen, phosphorus and potassium uptake by grain and straw were observed with irrigation scheduled at IW/CPE ratio of 1.0 which were significantly higher than irrigation at an IW: CPE ratio of 0.8. Higher N, P and K uptake might be due to effective root-system and increased concentration of nutrients in soil solution. Our findings confirm with those of Dixit *et al*. (2014), who reported that nutrient uptake by crop at harvesting increased significantly due to fertilizers application.

Table 3. Effect of irrigation scheduling and nutrient management on net return, benefit: cost ratio, production and economic efficiency of wheat grown under zero tillage condition (pooled data of 3 years)

Treatment	Net returns (× 10^3 ₹/ha)	Benefit: cost ratio	Production efficiency (kg/ha/day)	Economic efficiency (₹ ha/day)
Irrigation schedule				
IW: CPE 0.8	50.5	3.10	26.4	348
IW: CPE 1.0	56.0	3.30	28.7	386
SEm±	0.9	0.05	0.38	6.90
CD (P=0.05)	3.0	0.17	1.23	22.1
Nutrient management				
100% RDF	50.7	3.30	26.2	349
125% RDF	54.1	3.23	27.9	372
150% RDF	54.9	3.06	28.5	379
SEm±	0.9	0.04	0.35	6.20
CD (P=0.05)	2.4	0.12	1.00	17.6

IW: CPE, Irrigation water: cumulative pan evaporation; RDF, recommended dose of fertilizer

Table 4. Effect of irrigation scheduling and nutrient management on nitrogen, phosphorus and potassium uptake by grain and straw of wheat grown under zero tillage condition (pooled data of 3 years)

Treatment	N uptake (kg/ha)		P uptake (kg/ha)		K uptake (kg/ha)	
	Grain	Straw	Grain	Straw	Grain	Straw
Irrigation schedule						
IW: CPE 0.8	60.5	35.6	14.1	3.17	18.7	136.3
IW: CPE 1.0	69.6	44.0	15.7	3.52	20.6	153.1
SEm±	1.40	1.64	0.32	0.05	0.37	3.24
CD (P=0.05)	4.47	5.27	1.0	0.18	1.20	10.4
Nutrient management						
100% RDF	59.7	33.5	14.0	3.06	18.6	131.2
125% RDF	66.7	40.1	15.2	3.38	19.9	147.3
150% RDF	68.7	45.8	15.6	3.60	20.5	155.5
SEm±	0.72	1.60	0.21	0.08	0.22	2.97
CD (P=0.05)	2.10	4.58	0.60	0.23	0.63	8.50

IW: CPE, Irrigation water: cumulative pan evaporation; RDF, recommended dose of fertilizer

Data further revealed that nutrient-management practices progressively increased N, P and K uptake by grain and straw up to the highest level of 150% RDF with comparable uptake under 125% RDF (Table 4). Additional application of fertilizers beyond 125% RDF did not increase the nutrient uptake any further significantly. However, N uptake by straw significantly increased up to 150% RDF. Increased grain and straw yields coupled with higher nutrient contents of these plant parts seem to be responsible for increased uptake of these nutrients by the crop due inorganic fertilization. The findings of this investigation are in conformity with those of Singh (2006) and Singh *et al*. (2011).

It was concluded that due to shortage of time between sowing of wheat and harvesting of rice, wheat can be grown under zero-tillage condition at an IW: CPE of 1.0 with 125% recommended dose of fertilizers for getting higher production and to save water in rice–wheat cropping system.

REFERENCES

AOAC. 1960. *Method of Analysis of the Association of Official Agricultural Chemists*. Edn 9. Association of Official Agricultural Chemists, Washington, DC, USA.

Dastane, N.G. 1972. *Practical Manual for Water Use Research in Agriculture*, end 2, Navbharat Prakashan, Poona, India.

Devasenapathy, P., Ramesh, T. and Gangwar, B. 2008. Efficiency indices for agriculture management research, pp. 1–143. Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu.

Dixit, A.K., Kumar, S., Rai, A.K. and Kumar, T.K. 2014. Tillage and irrigation management in chickpea–fodder sorghum cropping system under semi-arid conditions of India. *Indian Journal of Agronomy* **59**(4): 575–80.

Gurjar, N.S. 2014. Root characteristics and performance of different wheat genotypes under restricted irrigation in alluvial soil. *Indian Journal of Agronomy* **59**(2): 286–88.

Jackson, M.L. 1973. *Soil Chemical Analysis,* pp. 1–498. Prentic Hall of India. Pvt. Ltd, New Delhi.

Jat, L.K., Singh, S.K., Latare, A.M., Singh, R.S. and Patel, C.B. 2013. Effect of dates of sowing and fertilizer on growth and yield of wheat in an Inceptisols of Varanasi. *Indian Journal of Agronomy* **58**(4): 611–14.

Jha, A.K., Kewat, M.L., Upadhyay, V.B. and Vishwakarma, S.K. 2011. Effect of tillage and sowing methods on productivity, economics and energetic of rice–wheat cropping system. *Indian Journal of Agronomy* **56**(1): 35–40.

Mesbah, E.A.E. 2009. Effect of irrigation regimes and foliar spray of potassium on yield, yield attributes and water use efficiency of wheat in sandy soils. *World Journal of Agricultural Science* **5**(6): 662–69.

Paul, T., Bisht, P.S., Pandey, P.C., Barman, A., Bhattacharjya, S., Shaha, T. and Nath, C.P. 2014. Rice productivity and nutrient-use efficiency as influenced by nutrient management in long-term rice–wheat system. *Annals of Agricultural Research* **35**(2): 171–75.

Prajapat, K., Vyas, A.K. and Shiva Dhar. 2014. Productivity, profitability and land-use efficiency of soybean-based cropping systems under different nutrient-management practices. *Indian Journal of Agronomy* **59**(2): 229–34.

Ranjita, B., Janawade, A.D. and Palled, Y.B. 2007. Effect of irrigation schedule, mulch and anti transpirant on growth, yield and economy of wheat. *Karnataka Journal of Agricultural Science* **20**(1): 6–9.

Richard, L.A. 1954. *Diagnosis and Improvement of Saline and Alkaline soil*. USDA Hand Book No**. 60**.

Sepat, S. and Rana, D.S. 2013. Effect of double no tilled and permanent raised beds on productivity, profitability and physical properties of soil in maize–wheat cropping system under Indo-Gangatic Plain of India. *Indian Journal of Agronomy* **58**(4): 469–73.

Sepat, R.S., Rai, R.K. and Shiva Dhar. 2010. Planting system and integrated nutrient management for enhanced wheat productivity. *Indian Journal of Agronomy* **55**(2): 114–18.

Shekhar, C., Singh, D., Singh, A.K., Nepalia, V. and Choudhary, J. 2014. Weed dynamics, productivity and soil health under different tillage and weed control practices in wheat–maize cropping sequence. *Indian Journal of Agronomy* **59**(4): 561–67.

Singh, R. and Kumar, A. 2011. *Mannual on Enhancing Water Use Efficiency in Canal Command*. Directorate of Water Management (ICAR), Bhubaneshwar, pp. 47–62.

Singh, C.M., Sharma, R.K., Kishor, P., Mishra, P.K., Singh, A.P., Verma, R. and Raha, P. 2011. Impact of integrated nutrient management on growth, yield and nutrient uptake by wheat. *Asian Journal of Agricultural Research* **5**(1): 76–82.

Singh, V. 2006. Productivity and economics of rice–wheat cropping system under integrated nutrient supply system in recently reclaimed sodic soils. *Indian Journal of Agronomy* **51**(2): 81–84.