Agronomic Management for Improving the Water Productivity under Sri Ram Sagar Project Command, Andhra Pradesh, India

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Abstract

On-farm trials (OFT) to assess the water productivity and to suggest alternative agronomic measures for its improvement during 2008-09 and 2009-10 were conducted under D51 distributory of Kakatiya Canal, Sri Ram Sagar Project, Andhra Pradesh. The grain yield and field water use productivity improved by adoption of ridge and furrow method of irrigation in place of flat bed for maize, rotational irrigation/alternate wetting and drying and by maintaining 44 hills m^{-2} in rice during *rabi*. Adopting these agronomic techniques there will be a saving of 122-162 mm of water in maize and 8-12% water in rice over farmer's practice of flat bed in maize and daily irrigation (continuous submergence of 5-10 cm), respectively. Further, application of higher levels of N than recommended has improved grain yield of rice and thereby field water use efficiency. Application of 90 kg N ha^{-1} improved yield and water productivity of sesame. The irrigation rate (quantity of water) applied was more under canal irrigation compared to well irrigation. Farmers adjusted their cropping pattern by crop diversification from rice to green gram and ground nut and used we11 water in conjunction with rain and canal when water scarcity observed during 2009-10 compared to 2008-09 under D51 canal command area of Sri Ram Sagar Project.

1. Introduction

Water scarcity for agricultural production is becoming a serious problem, but development of new water resources is very costly. Thus more efficient use of water is essential for future food security. Food production is the largest water user and is directly constrained by water scarcity. In India, 84% of the water resources are used for agriculture. Absolute water stress and relative water scarcity across economic sectors has increased the need for demand side management and improving water use efficiency in agriculture. There is a need to produce as much as 325-350 mt of food grains by 2025 to meet the food, feed, fodder and fiber requirements of India. To meet this estimate of food grain requirement it is assumed that the overall irrigation efficiencies will be in the order of 50% for surface water systems and 72% for groundwater systems, compared to the present level of 35-40% (FAO, 2010). The project irrigation efficiencies are low in Andhra Pradesh compared to that in Indian average. Kakatiya Canal of Sri Ram Sagar Project (SRSP) is having total cultivable command area (CCA) of 0.369 mha besides meeting the drinking water needs of Warangal town and also water needs of Super Thermal Power Station, Ramagundam. Reconnaissance survey of Kakatiya canal command area indicated that non-adoption of recommended agronomic practices and inefficient irrigation methods were main constraints among other constraints in realizing the agricultural production potential. As a result, the water productivity of Kakatiya canal, SRSP command area in turn is low. Alternatives for increasing water productivity can be applied at the crop, farm system and basin levels (Molden et al., 2001). There is an obvious need for agronomic solutions to close the common and often large gap between actual and attainable yield $unit^{-1}$ of water use. The particular practices required to close the gap between attainable and actual yield $unit^{-1}$ water use are specific for a given crop and cropping system. Water productivity can be improved by increasing the yield of crops and decreasing water use by cops under a system or at farm level. Hence, an attempt was made to assess the present water productivity and to suggest alternative agronomic measures for its improvement during 2008-09 and 2009-10 under canal commands of SRSP, Andhra Pradesh.

2. Material and Methods

2.1. Study area

Based on the survey, the command area of 2R-2R minor of D51 distributory, Kakatiya canal, SRSP at Mythapur village, Raikal mandal of Karimnagar District (Figure 1) was selected to assess the present water productivity and for carrying out on-farm trials on agronomic measures for its improvement during 2008-09 and 2009-10. The 2R-2R minor takes off at 4.7 km away from the off take of 2R minor and runs over a distance of 0.882 km, irrigating an area of 43.2 ha (Figure 2). The size of the inlet structure is 300 mm with a discharge capacity of 0.04 Cubic meters second^{-1}. There are two pipes on this minor to irrigate the study area.

Soils were mostly red sandy loams of shallow depth, light textured (red sandy loams) with high infiltration rate and hydraulic conductivity, low water holding capacity, low to medium organic carbon, low in available N (130-180 kg ha^{-1}), medium to high in P (28-76 kg ha^{-1}) and K (169-421 kg ha^{-1}). Prevailing farming situation in the study area was canal irrigation and canal supported by well irrigation. There were 24 open wells but no bore wells in the pilot area. The depth of wells ranges from 5.8 to 8 m and shape of wells was either square or rectangular. Each well commands an area of 1.2 ha during rainy season and 0.3 ha during *rabi*/summer season. Rice is the predominant crop followed by maize, turmeric and groundnut. Normal rainfall of Raikal mandal (study area) was 909 mm. Most of the rainfall (80%) received during south-west monsoon period and little rainfall received during rest of the period. Generally, south-west monsoon establishes during last week of June and length of growing period ranges from 100 to 110 days. The monsoon was weak in the month of September, during which dry spells of 1-3 weeks may occur. Thereafter occasional showers occur during north-east monsoon period.

2.2. *On-farm trials (OFT)*

OFT on ridge and furrow method of sowing for maize, rotational irrigation to rice, plant stand influence on rice, effect of nitrogen levels on rice and sesame were conducted during 2008-09 and 2009-10 as detailed below.

2.2.1. Maize

OFT were conducted on farmers' fields on ridge and furrow method of sowing for maize in an area of 1.65 and 0.9 ha and

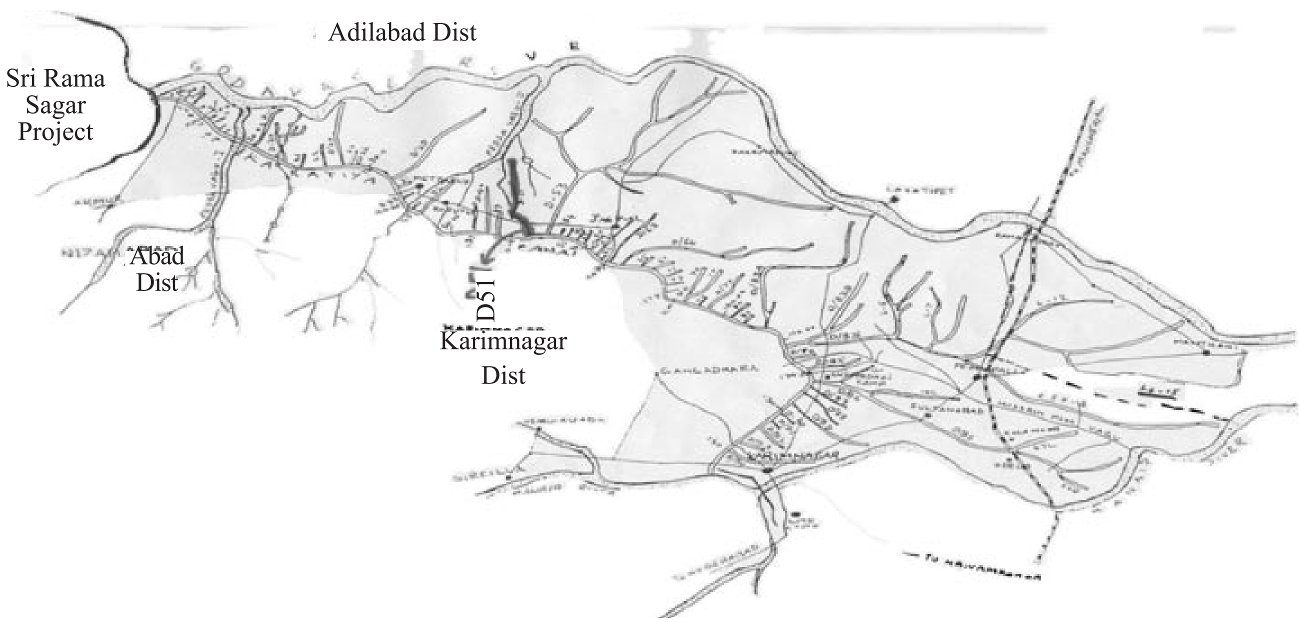


Figure 1: Map of Sri Ram Sagar Project, Kakatiya canal command area and D51 distributory

to study the amount of water applied to maize during *rabi* to study water use efficiency of maize under well and canal irrigation in an area of one ha. The crop was sown during first week of November and harvested during second fortnight of March in both years. Effective rainfall was 35.5 mm estimated by CRIWAR model out of total rainfall of 37.2 mm during crop growth period during 2009-10 and there was no rainfall during 2008-09. The crop was fertilized with 22 kg N and 60 kg P_2O_5 as basal in the form of di-ammonium phosphate (DAP) and the crop was top dressed twice with 57 kg N ha^{-1} each time at knee height and tasseling stages. Hand weeding at 20 days after sowing (DAS) and earthing up at 35 DAS was carried out in addition to pre-emergence application of atrazine @ 1 kg ai ha^{-1} 2 DAS. The crop was harvested at maturity.

2.2.2. Rice

OFT was conducted on rotational irrigation to rice in an area of

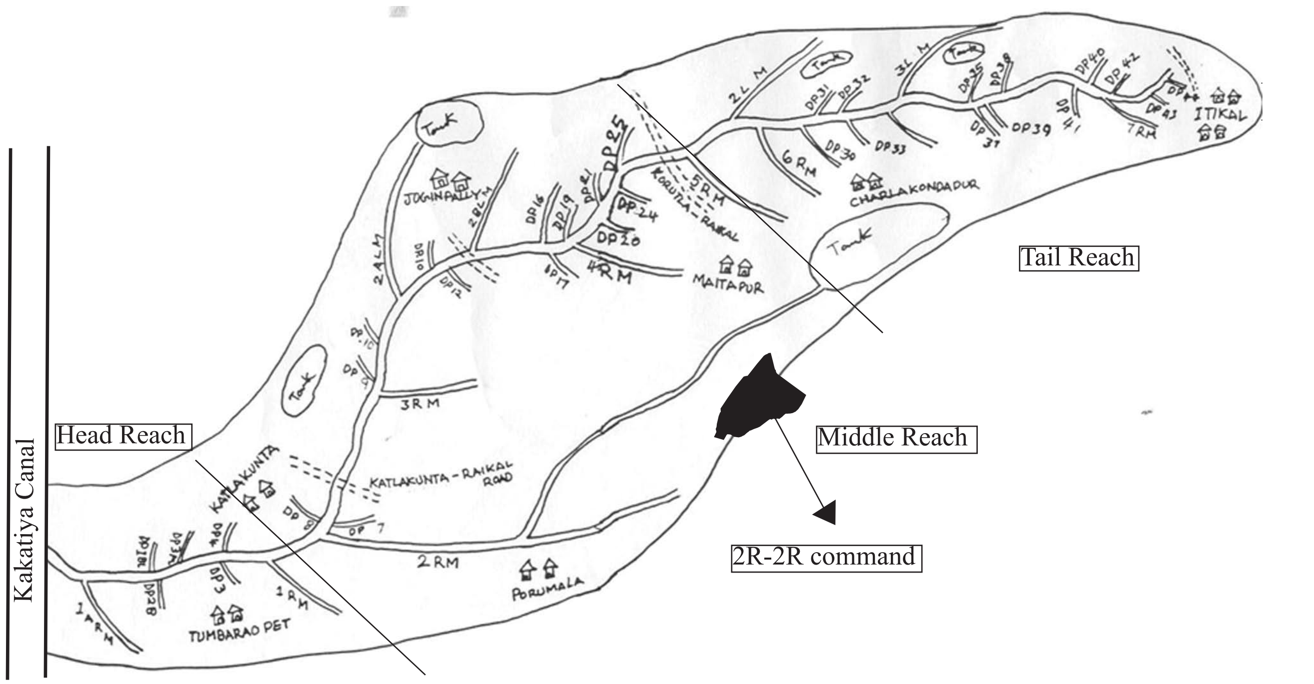


Figure 2: D51distributory command area and study area (2R-2R command area).

0.52 and 0.37 ha, on irrigation water requirement to rice under well and canal situations in an area of 0.6 ha, plant stand of 33 and 44 hills m^{-2} effect and zigzag planting on yield of rice and nitrogen levels influence on rice yield and water use efficiency in an area of 0.6 and 0.43 ha were conducted to improve the crop yield and also the water use efficiency. The crop was transplanted during second fortnight of January and harvested during second fortnight of April. The field was plowed twice and puddled twice with tractor. Nursery seedlings of 25-30 days old were transplanted in zigzag method. Butachlor @ 2.51 ha^{-1} was applied 2-3 days after transplanting (DAT) and hand weeded twice at 25-30 and 45-60 DAT. The crop was fertilized with 22 kg N and 60 kg P_2O_5 ha^{-1} as basal in the form of DAP. The crop was top dressed in two splits with 50 kg N ha^{-1} each time at tillering and panicle initiation (PI) stages. In nitrogen levels trial, it was applied as treatment^{-1}, ⅓ each at planting, tillering and PI stages.

2.2.3. *Sesame*

OFT on effect of nitrogen levels on sesame were conducted at 2R-2R minor in an area of 0.3 ha during *raib*/summer. The crop was sown during second week of February and was harvested during first week of May. The seed @ 4.5 kg ha^{-1} was broadcasted after two times ploughing in sequence with turmeric. The crop was hand weeded twice and nitrogen was applied @ 60 kg ha^{-1} each at 10 DAS and flowering in farmers practice and according to treatments.

2.3. *Rainfall*

Effective rainfall estimated through CRIWAR computer model based on the rainfall recorded at nearby rain gauge and other metrological parameters recorded at Regional Agricultural Research Station, Jagtial were used. There was no rainfall during crop growth period during 2008-09 and rainfall of 37.2 mm was received during 2009-10.

2.4. *Quantification of irrigation water*

Irrigation volume from canal measured by portable RBC (Roplogle Bos Clements) flumes and from open wells was measured by fixing water meters (Dashmesh make) to delivery pipes of pumps installed at farmers' fields for the purpose. The water from SRSP was not released during 2009-10 due to shortage of water in the reservoir and water scarcity was observed in the study area. The water level in paddy fields was monitored daily through perforated plastic tubes that were inserted in to the soil to a depth of 0.3 m. Irrigation to maize and sesame was scheduled based on feel and appearance method followed by the farmers in the study area.

2.5. *Collection of data and analysis*

Cropped area of individual farmers was collected based on interview of individual farmers and the total area was confirmed with the mandal revenue records. The yield was recorded after harvest of individual crops, dried and expressed as kg ha^{-1} at 14% moisture. Field water productivity (kg grain m^{-3} water) was determined by dividing grain yield over sum volume of irrigation water and effective rainfall (m^{-3}). The data was analyzed statistically as per procedure suggested by Gomez and Gomez (1984).

3. Results and Discussion

3.1. Cropping pattern

During *kharif* 2008, 11 farmers of study area cultivated rice crop and among irrigated dry crops, maize was preferred by nine farmers, turmeric + maize intercropping by 13. While in *kharif* 2009, 16 farmers preferred rice crop among irrigated dry crops, maize was preferred by 20 farmers, turmeric + maize intercropping by 16. During *rabi*, 2008-09, 17 farmers preferred rice and among irrigated dry crops, preference was for maize (23 farmers) followed by groundnut (9) and green gram (7). Contrary to that during *rabi,* 2009-10, only three farmers preferred rice and among irrigated dry crops, the farmers preference was for maize (20 farmers) followed by groundnut (16) and green gram (13).

There was not significant change in the cropping pattern during *kharif*, while there was clear change in cropping pattern in 2009-10 compared to 2008-09. Rice cropped area not varied much during *kharif* in both the years (23 and 27%) during 2008-09 and 2009-10, respectively as the rice was preferred by the framers having ground water source (open wells) as a supplementary source of irrigation water (Figure 3).

Similarly the sesame area during summer also not varied much. The area under rice was drastically reduced during *rabi* 2009-10 compared to 2008-09 due to shortage of water. Similarly, there was reduction in area of maize also (Figure 4). This reduced area was compensated with low water requiring and green gram during *rabi* 2009-10 compared to 2008-09. Similar results of farmers adjustments with crop diversification and conjunctive use of water under canal commands was reported by Venot et al. (2010).When there was scarcity of water.

3.2. Performance of different agronomic practices

3.2.1. Ridge and furrow method of sowing for maize

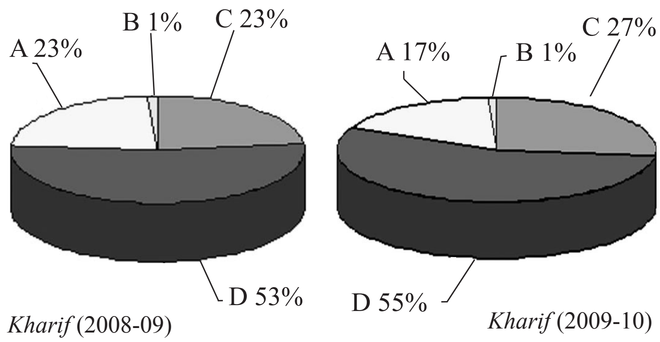
The crop growth of maize with in ridge and furrow method was better than that sown in flat beds and sowing of maize in ridges and furrows and border strips resulted in 29.2, 21.8, 20.3 and 14.4% higher grain yield than that of the crop sown in flat bed method during *rabi* 2008-09 and 2009-10, respectively (Table 1).

There was saving of 142 and 131 mm and 161.6 and 121.8 mm irrigation water under ridge and furrow method and border strip as compared to flat bed method of sowing during *rabi* 2008-09 and 2009-10, respectively. Further, water use efficiency (WUE) was also higher with ridge and furrow method of sowing followed by the border strip method as compared to flat bed. Similar results of higher yield in furrow irrigation were reported by Sepaskhah and Parand (2006), and Jin et al. (2010).

3.2.2. Field water productivity of maize under two farming situations

The farmers irrigated the maize crop with less water (189 mm) under wells as compared to crop under canal irrigation. Though the yield was higher under canal irrigation, the field water productivity was higher with well irrigation (Table 2). The water use was higher under canals irrigation compared to well irrigation as farmers were tempted irrigate crops with more water when the water availability was more under canal commands (Norman et al., 2008).

3.2.3. Alternate wetting and drying (AWD)/rotational irrigation to rice



A = Maize + Turmeric; B = Mango; C = Rice; D = Maize

Figure 3: Cropping pattern during *khaif* (2008-09 and 2009-10)

There was 3.8 and 3.6% increase in yield and 7.9% (127 mm) and 11.8% (151 mm) saving in irrigation water during *rabi* 2008-09 and 2009-10, respectively due to rotational irrigation/ alternate wetting and drying (AWD) of rice (Table 3).

The water productivity was also higher with rotational irrigation AWD over farmers practice. Bouman and Tuong (2001) also reported AWD resulted in decreased water input by 5-50%. In transplanted and wet seeded rice, keeping the soil moisture continuously a near saturation level, reduced yields by 5% and water input by 35% and increased water use efficiency by 45% compared with flooded condition (Tabbal et al., 2002). Water saving irrigation regimes and techniques (maintaining a thin layer of standing water in the field, saturated, or alternate wet and dry soil conditions) could save about 20-70% of irrigation water without significant yield loss as compared to continuous shallow submergence (Aslam et al., 2002). Intermitted flooding irrigation at two-day intervals was as effective as continuous flooding for grain yield showing high water use efficiency (Pi-ramoradian et al., 2004). Similarly, irrigation regime for rice that starts as conventional (flooded) and then changes to AWD can save water with little or no yield loss (Michiel et al., 2010).

3.2.4. Water productivity of rice under two farming situations

Grain yield was 2.9% higher under well irrigation as compared to canal + well irrigation. Farmers applied 152 mm (9.4%) less water under well irrigation as compared to canal + well irrigation (Table 4).

Table 1: Effect of irrigation method on water use efficiency of maize under 2R-2R minor of D51 distributory, SRSP (*rabi*, 2008-09 and 2009-10)

Sl. No.	Method of irrigation	Grain yield (kg ha^{-1})			Water applied (mm)			Field water use efficiency					
								kg m^{-3}			₹ m^{-3}		
		a	b	Mean	a	b**	Mean	a	b	Mean	a	b	Mean
1.	Ridge and furrow	8853^{c}	7636^{c*}	8245^{c}	586	538	562	1.51	1.42	1.47	12.1	11.4	11.8
2.	Border strip	8344^{b}	7262^{b}	7803^{b}	606	579	593	1.38	1.26	1.32	11.0	10.1	10.6
3.	Farmers' practice (Flat bed)	6853^{a}	6348^{a}	6601^{a}	713	700	707	0.96	0.91	0.94	7.7	7.3	7.5

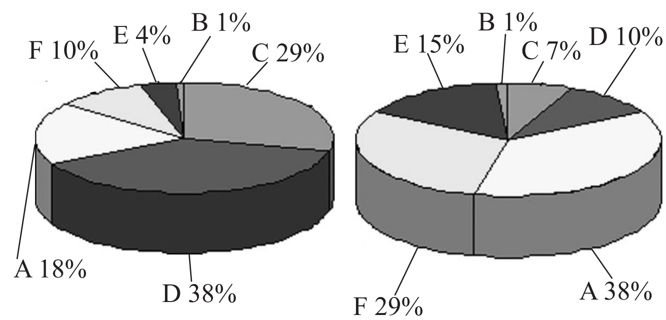
Grain price (₹ kg^{-1})=8; *Significant at 5% level of probability; **Inclusive of effective rainfall; a: 2008-09; b: 2009-10

Table 2: Water use efficiency of maize in two farming situations under 2R-2R minor of D51 distributory, SRSP (rabi, 2008-09) (mean of three farmers)

S1. No.	Farming situation	Grain yield (kg ha^{-1})	Water applied (mm)	Field water use efficiency	
				kg m^{-3}	₹ m^{-3}
1	Well irrigation	8080^{b}	609	1.33	10.6
2	Canal irrigation	8687^{a}	798	1.09	8.7

Grain price (₹ kg^{-1})=8; *Significant at 5% level of probability

The field water use efficiency was also greater with well irrigation than canal + well irrigation. The farmers tended to often increase the irrigation application rate when costs of getting water to the farm were relatively low or unrestricted so as to reduce their labor input for field water distribution and when the costs of getting water to the farm were high or water in scarce or limited, lower application rates were observed along with increased labor input with more efficient use of the resource (Norman et al., 2008).



Rabi, 2008-09 *Rabi*, 2009-10

A = Maize + Turmeric; B = Mango; C = Rice; D = Maize; E = Greengran; F = Groundnut

Figure 4: Cropping pattern during rabi (2008-09 and 2009-10)

Table 3: Performance of rice under rotational irrigation under 2R-2R minor of D51 distributory, SRSP (rabi, 2008-09 and 2009-10)

S1. No.	Irrigation method	Grain yield (kg ha^{-1})			Water applied (mm)			Field water use efficiency					
								Grain (kg m^{-3})			₹ m^{-3}		
		a	b	Mean	a	b	Mean	a	b	Mean	a	b	Mean
1	Rotational irrigation	7985^{b*}	5970^{b}	6978^{b}	1490	1129	1310	0.54	0.53	0.54	5.0	4.9	5.0
2	Farmers practice	7689^{a}	5760^{a}	6725^{a}	1617	1280	1549	0.48	0.45	0.47	4.5	4.4	4.4

Grain price (₹ kg^{-1})=9.3; *Significant at 5% level of probability; a: 2008-09; b: 2009-10

3.2.5. *Plant stand effect on yield of rice*

Yield recorded with 33 (20 × 15 cm^2) and 44 (15 × 15 cm^2) hills m^{-2} was 14.1% and 18.7% higher than that of 25 hills m^{-2} (6934 kg ha^{-1}) and field water use efficiency was higher with 33 and 44 plants m^{-2} than 25 plants m^{-2} (Table 5).

These results corroborate the findings of Hayashi (2006), who reported that higher plant density resulted in higher grain yield under flooded fields and water productivity of rice increased with increasing plant density.

Table 4: Yield and water use efficiency of rice in two irrigation situations under 2R-2R minor of D51 distributory, SRSP (rabi, 2008-09)

Sl. No.	Farming situation	Yield (kg ha^{-1})		Water applied (mm)	Field water use efficiency	
		Grain	Straw		Grain (kg m^{-3})	₹ m^{-3}
1	Well irrigation	7780^{b*}	9258^{b}	1465	0.53	5.6
2	Canal + well irrigation	7558^{a}	9146^{a}	1617	0.47	4.9

Grain price (₹ kg^{-1})=9.3; Straw price (₹ kg^{-1})=1; *Significant at 5% level of probability

Table 5: Effect of plant stand (number m^{-2}) on rice yield and water use efficiency under 2R-2R minor of D51distributory, SRSP (*rabi*, 2008-09)

Sl. No.	Plant stand (no. in area, cm^2)	Yield (kg ha^{-1})		Water applied (mm)	Field water use efficiency	
		Grain	Straw		Grain (kg m^{-3})	₹ m^{-3}
1	44 (15 x 15)	8233[c*]	10292[c]	1617	0.51	5.4
2	33 (20 x 15)	7911[b]	9414[b]	1617	0.49	5.1
3	25 (zigzag)**	6934[a]	7974[a]	1617	0.43	4.5

**Farmers' practice; *Significant at 5% level of probability

3.2.6. Effect of N levels on yield and water productivity of rice

There was an increase in grain and straw yield of rice due to increased level of nitrogen application and the increase was up to 240 kg N ha^{-1}. The increase in yield was 0.7, 8.8, and 19.8% due to application of N @ 180, 210 and 240 kg ha^{-1}, respectively compared to 150kg ha^{-1} (FP) during 2008-09, while it was 3.7, 11.3, and 21.7% due to application of N @ 180, 210 and 240 kg ha^{-1}, respectively compared to 150 kg ha^{-1} (FP) during 2009-10. Application of N improved the water use efficiency of rice from 4.0 to 4.8 kg mm^{-1} and 5.1 to 6.2 kg mm^{-1} during 2008-09 and 2009-10, respectively as N level increased from 150 (FP) to 240 kg ha^{-1} (Table 6).

Yields increased as N level increased to higher than recommended level may be due to field to field irrigation there by higher leaching losses. Similar results of increased grain yield and dry matter as applied N rate was increased was reported by Zhong and Huang (2002). Similarly, Piramoradian et al. (2004) also reported increase in N application rate to 112-152 kg ha^{-1} increased grain yield under any irrigation conditions of flooding, intermittent flooding and sprinkler irrigation.

Table 6: Rice yield and water use efficiency as influenced by different nitrogen levels under 2R-2R minor of D51 distributory, SRSP (*rabi*, 2008-09 and 2009-10)

Sl. No.	Nitrogen (kg ha^{-1})	Grain yield (kg ha^{-1})			Water applied (mm)			Field water use efficiency					
								kg m^{-3}			₹ m^{-3}		
		2008-09	2009-10	mean	2008-09	2009-10	mean	2008-09	2009-10	mean	2008-09	2009-10	mean
1	180	6588[c*]	6077[c]	6333[c]	1617	1149	1383	0.41	0.53	0.47	3.81	4.9	4.4
2	210	7117[b]	6525[b]	6821[a]	1617	1149	1383	0.44	0.57	0.51	4.11	5.3	4.7
3	240	7838[a]	7135[a]	7487[a]	1617	1149	1383	0.48	0.62	0.55	4.45	5.8	5.1
4	FP (150)	6540[c]	5862[c]	6201[c]	1617	1149	1383	0.40	0.51	0.46	3.70	4.7	4.3

FP=Farmers' practice; Grain price (₹ kg^{-1})=9.3; *Same letter in each column are not significantly different at 5% level of probability

3.2.7. Nitrogen levels on yield and water productivity of sesame

Yield increase with sesame was 6.9, 7.6 and 11.9% higher during 2008-09, while it was 8.0, 15.0 and 20.9% higher during 2009-10 with 70, 80 and 90 kg N ha^{-1} over 60 kg N ha^{-1} (FP), respectively. The water use efficiency improved from 0.21 to 0.24 kg m^{-3} and 0.21 to 0.25 kg m^{-2} during 2008-09 and 2009-10, respectively (Table 7).

Table 7: Yield and water use efficiency of sesame as influenced by different nitrogen levels under 2R-2R minor of D51distributory, SRSP (summer, 2008-09 and 2009-10)

Sl. No.	Nitrogen (kg ha^{-1})	Seed yield (kg ha^{-1})			Water applied (mm)			Field water use efficiency					
								kg m^{-3}			₹ m^{-3}		
								A	B	Mean	A	B	Mean
		A	B	Mean	A	B	Mean	A	B	Mean	A	B	Mean
1	60 (FP)	1000[c*]	798[c]	899[c]	470	385	428	0.21	0.21	0.21	13.9	13.9	13.9
2	70	1061[b]	862[b]	961[b]	470	385	428	0.23	0.22	0.22	15.2	14.5	15.2
3	80	1076[b]	918[a]	997[b]	470	385	428	0.23	0.24	0.23	15.2	15.8	15.2
4	90	1119[a]	965[a]	1042[a]	470	385	428	0.24	0.25	0.24	15.8	16.5	15.8

FP=Farmers' practice; Seed price (₹ kg^{-1})=66; *Means with same letter in each column were not significant at 5% level of probability; A = 2008-09; B = 2009-10

Application of N significantly enhanced growth and yield attributes and seed yield up to 150 kg N ha^{-1} (Nahar et al. (2008). While, higher yield of sesame at 80 kg N ha^{-1} compared to 0 and 40 kg N ha^{-1} was reported by Sarkar et al. (2010). Contrary to that Haruna et al. (2011) concluded application of 120 kg N ha^{-1} along with 15 t ha^{-1} poultry manure and 13.2 kg P ha^{-1} recorded higher yield over 60 kg N ha^{-1} along with 15 t ha^{-1} poultry manure and 13.2 kg P ha^{-1}. Further, Jooyban and Moosavi (2012) found that increasing N fertilization to 200 kg ha^{-1} resulted in higher sesame seed yield as compared to 0 and 100 kg N ha^{-1}.

4. Conclusion

Results suggest that under Sri Ram Sagar Project (SRSP) canal command, the grain yield and field water productivity improved by adoption of ridge and furrow method of irrigation in place of flat bed for maize, rotational irrigation/alternate wetting and drying and by maintaining 44 hills m^{-2} in rice during *rabi*. By adoption these agronomic techniques there will be a saving of 122-162 mm of water in maize and 8-12% water in rice over farmer's practice of flat bed in maize and daily irrigation (continuous submergence of 5-10cm), respectively. Further, application of higher levels of N than recommended has improved grain yield of rice and thereby field water use efficiency. Application of 90 kg N ha^{-1} improved yield and water use efficiency of sesame. The irrigation rate (quantity of water) applied was more under canal irrigation compared to well irrigation. The farmers adjusted their cropping pattern by crop diversification from rice to green gram and ground nut and used well water in conjunction with rain and canal when water scarcity observed during 2009-10 compared to 2008-09 under D51 canal command area of SRSP.

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