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Water conservation through precise irrigation & sowing methods under paddy eco-system in upper Krishna project command area

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Abstract
Adoption of precise irrigation water application methods in paddy cultivation could increase the water productivity by minimizing the seepage and percolation water losses. A field demonstration were conducted at five different locations under five selected farmers filed to assess Direct Seeded Rice (DSR) and Alternate Wetting and Drying (AWD) method on water saving, water productivity and yield under paddy crop during *kharif* season of 2020 and 2021 under Upper Krishna Project command area (Karnataka) against farmers practices such as Traditional Transplanted Rice (TTR) and Submerged Irrigation (SI). The average paddy yield under DSR+AWD was 6503.5 (kg ha^{-1}) which is 13.61% higher than TTR+SI of 5724.0 (kg ha^{-1}) among selected farmers field. The lowest average quantity of water applied was in DSR+AWD (942.6 mm) which is 27.66% lesser than TTR+SI method (1203.4 mm). Significant difference was observed in water productivity during both the season in all the five location. The highest pooled water productivity of two seasons was in DSR+AWD (6.9 kg ha^{-1} mm^{-1}) which is 46.8% higher than the TTR+SI (4.7 kg ha^{-1} mm^{-1}). Therefore, paddy growing farmers should adopt AWD under DSR method instead of continuous submergence to minimize water losses and solve water scarcity problems in UKP command area. The study has demonstrated that integrated extension approach in technology dissemination and scaling-out through stakeholder integration is crucial. However, a mission mode framework is needed for technology up scaling at system level.

Keywords: AWD method, Paddy, Irrigation, command area and water productivity

1. Introduction

Rice (*Oryza sativa* L.) is the staple food of more than 50% of the world's population and method of rice production plays major role on both production and cost of cultivation (Chaudhary *et al*., 2022) [3]. In India, it is grown on about 42.5 million ha with a total production of 105.5 million tons and productivity of 3632.9 kg ha^{-1} (Mishra *et al.*, 2021, Gill *et al*., 2014) [20, 5]. Traditional transplanted rice (TTR) system is still the predominant method of rice establishment in Indian sub-continent (Dattu *et al*., 2017; Bhatt *et al.*, 2021) [1]. The traditional rice production become less profitable due to major constraints such as climate change and variability, declining water tables with increasing water scarcity, water, labour- and energy-intensive nature of TTR (Rizwan *et al.*, 2018) [25]. The adverse effects of puddling on soil health and succeeding crops, and high methane emissions, unscientific irrigation & fertilizer application, emerging energy crisis and hike in fuel prices and multiplying cost of cultivation also negetivelly impacted on rice production (Islam, 2021) [8]. The intensive cultivation of rice under traditional method, unscientific irrigation & fertilizer application with 20 to 25% higher fertilizers than the recommended dose led to conversion of 40% of fertile land to soil salinization and acidity problems in many irrigations projects command area across the country (Joshi *et al.*, 2013; Singh *et al.*, 2019) [30]. Good agronomic management practices and innovations in technology are required to overcome these problems and increase the both production & profitability under rice-based production sytem (Gonçalves *et al.*, 2022) [6].

Rice is the major traditional crop cultivating fewer than 97584 ha with 57% of net irrigated area under Upper Krishna Project (UKP) command area in Yadgir district of Karnataka (Umesh *et al.*, 2020). The cultivation of paddy in both *kharif* and *rabi* seasons by upper end farmers in UKP command area leads to water scarcity problems for tail end farmers & they could able to get sufficient water in *kharif* seasons only. The uneven rainfall distribution in Yadgir district and water scarcity in canal irrigation have restricted major crop yield in the season. The judicious use of irrigation water and nutrient management not only increase the crop yield but also increaes the water & fertilizer efficiencies (Kakumanu *et al.*,

2019) [10]. The problems of water logging & soil salinity leads to less water productivity & low yield in present day paddy cultivation (Kaur and Singh, 2017) [36]. There is a need to adaptation of judicious irrigation water application methods & sowing methods in UKP command area to minimize excess irrigation and water losses. In paddy cultivation, sufficient soil moisture should be maintained during planting to panicle initiation (PI), panicle initiation to flowering and flowering to crop maturity (Shahid *et al.*, 2022) [26]. In transplanted paddy cultivation, it is suggested to maintain 2.5 cm for first 10 days and thereafter 5.0 cm is to be maintained up 10 days before the crop harvest (Kaur and Mahal, 2015) [11]. However, farmers are maintaining 15 cm depth of water throughout the crop growing period which leads to bring ground water table (GWT) near to soil surface which causes the poor crop productivity (Vinaykumar *et al.,* 2018).

University of Agricultural Science, Raichur (Karnataka) has developed and modified many irrigation water management methods for paddy cultivation in Tunga Bandra Project (TBP) command areas (Narappa *et al.*, 2020). The Alternate Wetting and Drying (AWD) method in paddy for precise water application have been tested by UAS, Raichur and created awareness among paddy growing farmers. The AWD were developed by International Institute for Rice Research (IIRR), Philiphines and Indian Institute of Rice Research, Hyderabad (Marasini *et al.*, 2016) [19]. AWD is an irrigation management practicethat shown to reduce water use in paddy systems (Linquist *et al.*, 2014; Lampayan *et al.*, 2015) [17, 16]. In this method, fields are subjected to intermittent flooding (alternate cycles of saturated and unsaturated conditions) whereirrigation is interrupted and water is allowed to subside untilthe soil reaches a certain moisture level, after which the field isreflooded. AWD has been reported to reduce water inputs by 23% (Shantappa *et al*. 2014) [27] compared to continuously flooded rice systems. The alternate wetting and drying (AWD) not only saves the irrigation water, it also recorded significantly higher growth and yield parameters over the other traditional irrigation methods due to profuse root growth and aerated condition (Raghuvir *et al.* 2020). Increasing water scarcity is becoming real threat to rice cultivation in UKP command area now days due to acute rainfall and water scarcity in UKP project. Hence, water-saving technology which also maintains soil health and sustainability as well as economically beneficial, needs to be developed (Subramaniam *et al.*, 2013) [32]. The water stagnation or saturation irrigation with certain depth of irrigation in paddy throughout growth period results in water saving up to 30% over traditional method of irrigation due to the restriction of seepage and deep percolation losses by maintaining water level up to saturation attributing to lesser water use under saturation (Hussain *et al.*, 2021) [7]. Many water saving irrigation methods are available, farmers under UKP command area are still practicing traditional irrigation methods which increases the soil salinity problem and reduction in crop yield (Umesh *et al.,* 2020). The Direct Seeding Rice (DRS) is the method of direct sowing of paddy seeds in the main field rather than transplanting of seedlings from nursery (LaHue *et al.,* 2016; Soriano *et al.,* 2018) [14]. After good germination and seedling establishment, crop can be irrigated and water regimes maintained as for transplanted rice (Bishal Bista., 2018). This DSR technology has proved successfully on water saving and paddy yield enhancement throughout the world and presently it contributes 23% of rice productions under direct-seeding (Rao *et al*., 2007) [23]. Many researchers reported that, scanty rainfall, water scarcity and higher costs for labour are the major constraints for shifting from traditional transplanted method to DSR (Lal B *et al.*, 2016) [15]. The adaptation of DSR in paddy cultivation is expected to reduce the water use by 30% and 60% labour cost as it lacks raising of paddy nursery, transplanting, puddling and maintenance of standing water **(**Umesh *et al.,* 2020). The DSR increase the net profit by reducing the cost of production by US$ 9-125 ha^{-1} (Kumar and Ladha, 2011) [13]. The timely field operation, low crop inputs and water use has enhanced crop productivity up to 5-10% more than farmer's traditional practices (Manohar *et al.*, 2017) [18]. In Karnataka under Cauvery and Tunga Badra command areas, DSR technology has been introduced and farmers are successfully adopted. However, the farmers in the Upper Krishna Project (UKP) command areas are still practicing the traditional paddy cultivation which consumes more water and causes less crop yield as compared to DSR. Therefore, the present study is undertaken to assess the water conservation through AWD & DSR methods in paddy under UKP command area of Yadgir district of Karnataka.

2. Material and Methods

The study was conducted on water conservation through water saving irrigation methods and sowing methods in paddy crop under UKP command area in Karnataka (India) at five farmer's fields during *kharif* 2020 and 2021. The field demonstration was conducted at five farmers filed, two sowing methods like direct seeded rice (DSR) & traditional transplanting method (TTR) as main treatments, two irrigation methods *viz* alternative wetting & drying (AWD) and submerged irrigation (SI) as sub treatments. The locations were selected based on farmer's interest, soil type, cropping system. The size of the demonstrated plots was one acre each of DSR+AWD and TTR+SI at each farmer filed.

2.1 Sowing Methods

The paddy was sown with tractor operated paddy direct seed drill in demonstration field and transplanted paddy cultivation was selected as check for analysis of yield and economic feasibility. The direct seeded seed drill was provided by ICAR-KVK Yadgir for sowing of paddy and seeds, farm manure, balanced fertilizers and agro- chemicals were managed by farmers himself as per recommendation of package of practices of University of Agricultural Science, Raichur. The paddy nurseries were raised & transplanted to main field under traditional transplanting method.

2.2 Details of Irrigation Methods

Two irrigation methods were selected for assessing their suitability to save the irrigation water under paddy ecosystem under UKP command area. Alternate Wetting and Drying Method: The 5 cm irrigation water depth was maintained at each alternate wetting and drying by installing filed water tube (Pani Pipe) in all selected farmers field. A 30 cm length plastic pipe with a diameter of 15 cm was installed with 3 feet away from the bund in field for water measurement. Perforated holes were made up to 15 cm and that portion was inserted below the soil surface. The soil in Pani Pipe has removed to ensure both water levels in pipe and soil surface in equal level. When the water level has dropped to about 15 cm below the surface of the soil, irrigation has applied to reflood the field to a depth of 5 cm. From one week before to a week after flowering, the field was kept flooded, topping up to a depth of 5 cm as needed. After flowering, during grain filling and ripening, the water level was allowed to drop again to 15 cm below the soil surface before re-irrigation. AWD was started a few weeks (1-2 weeks) after transplanting. When many weeds are present, AWD was postponed for 2-3 weeks to assist suppression of the weeds by the ponded water and to improve the efficacy of herbicide. Traditional irrigation method: The farmers were followed their traditional practice for water application with a 5 cm irrigation water depth at each irrigation during growth period. Irrigation was stopped just 10 days before harvesting the crop.

2.3 Irrigation Scheduling
The details of irrigation schedule followed and quantity of irrigation water applied in each demonstrated field is presented in Table 01. Cut throat flume was installed to apply required depth of irrigation water in selected irrigation method as per irrigation scheduling.

2.4 Water Saving & Water Productivity (WUE)
The water productivity of each demonstrated was calculated which is the ratio of crop yield (kg) to the total quantity of irrigation water applied (Umesh *et al.*, 2022). Quantity of irrigation water saved (mm &%) are calculated against farmers practices and are presented in results section.

$$\text{Water productivity (kg ha}^{-1}\text{ mm}^{-1}) = \frac{\text{Crop yield (kg)}}{\text{Total quantity of irrigation water applied (ha mm)}}$$

2.5 Data collection
Field observation data during *kharif* 2020 and 2021 were collected on growth parameters such as plant height, tillers m^{-1}, and panicle m^{-1} were collected at maturity stage and pooled data was used for comparing the selected irrigation methods. Weight of 1000 grain and crop yield per hectare was calculated during crop harvest.

2.6 Extension Strategies
After the two years of demonstration, the best sowing & irrigation methods *viz.* DSR & AWD method were popularized through demonstration in 50 farmer field during *kharif* 2022 under UKP command area. The impact of adoptation of DSR &AWD methods among selected farmers in paddy crop were estimated through extension tools such as extension gap, technology gap, and technology index as suggested by (Chaudhary *et al.*, 2018).

Technology gap = Potential yield - Demonstrated yield
Extension gap = Demonstrated yield - Yield under existing practice

$$\text{Technology index} = \frac{\text{Potential yield} - \text{Demonstrated yield}}{\text{Potential yield}} \times 100$$

2.7 Cost Economics
The benefit cost ratio was calculated using total expenditure which includes crop inputs incurred during crop production and their net profit with respect to crop yield. The labor cost was calculated for every selected location of rice cultivation in each of the field operation *viz*., land preparation, seeding, irrigation, fertilizer and pesticide application, weeding, harvesting, transporting, threshing, and drying. Eight hours human labor work was treated as one man-day. Farm inputs *viz*., seed, fertilizers, herbicides, and pesticides used in both the systems of rice cultivation were recorded and the cost was estimated based on the prevailing local market rates. Local rate was used in computing the cost of hiring human labor and machines for different field operations. The net returns (Rs. ha^{-1}) was computed by subtracting the gross returns or sales of produce based on the average local market price of paddy in the last three years and total cost of production. The ratio of the net returns or benefits and total cost of production was also computed and presented.

3. Results and Discussions
The results on paddy grain yield & water productivity under DSR+ AWD methods are presented & discussed under this section.

3.1 Paddy grain yield
The two years *kharif* data was pooled and used for statistically analysis and results are presented in the table 01. The pooled data of paddy grain yield indicated that, yield was significantly higher in DSR+AWD method in all the 05 location as compared to TTR+SI method. The average paddy yield in DSR+AWD was 6503.5 (kg ha^{-1}) which is 13.61% higher than TTR+SI of 5724.0 (ka ha^{-1}) from all the 05 location. The quantity of water applied in each location during both the season indicated that, the lowest average quantity of water applied was in DSR+AWD (942.6 mm) which is 27.66% lesser than TTR+SI method (1203.4 mm). Significant difference was observed in water productivity during both the season in all the five location. The highest pooled water productivity of two seasons was in DSR+AWD (6.9 kg ha^{-1} mm^{-1}) which is 46.8% higher than the TTR+SI (4.7 kg ha^{-1} mm^{-1}). The p-values clearly indicated that, there is a significant difference in quantity of water applied and water productivity in DSR+AWD as compared to TTR+SI method. However, the paddy grain yield was less in TTR+SI method but it was on par with DSR+AWD method in all the selected locations. The present study results are inline with Kaur and Singh, (2017) [36] and they reported that, there was 20% higher paddy yield than the traditional transplanted paddy. Cultivation of paddy under DSR method could increase the paddy yield by 15 to 20% depending up on the soil type and management practices (LaHue *et al.*, 2016; Marasini *et al.*, 2016 and Vinaykumar *et al.*, 2018) [14, 19].

3.2 Paddy Yield Gap: The paddy yield gap in DSR and Transplanting practices is presented in Table 02 and it is observed that, the technology gap during *kharif* 2020 and 2021 was 1.65 and 1.30 $t.ha^{-1}$ respectively. The extension gap and technology index was 0.62 to 0.75 $t.ha^{-1}$ and 22.00 and 17.33 during *kharif* 2020 and 2021 respectively. These results clearly indicated that, DSR & AWD is positively impact on crop yield up to 8 to 10%. DSR & AWD methods helps in minimizing crop inputs like seeds, fertilizer, labour and mainly water without declining crop yield. DSR & AWD method would be more useful for command area farmers to solve water scarcity problem and sustain the soil health management without effect on crop yield. This indicated that, farmers need to be educating on use of DSR & AWD for resource conservation and judicious use of crop inputs for minimizing paddy cost of cultivation under UKP command area.

Table 1: Effect of DSR & AWD methods on paddy yield during study period

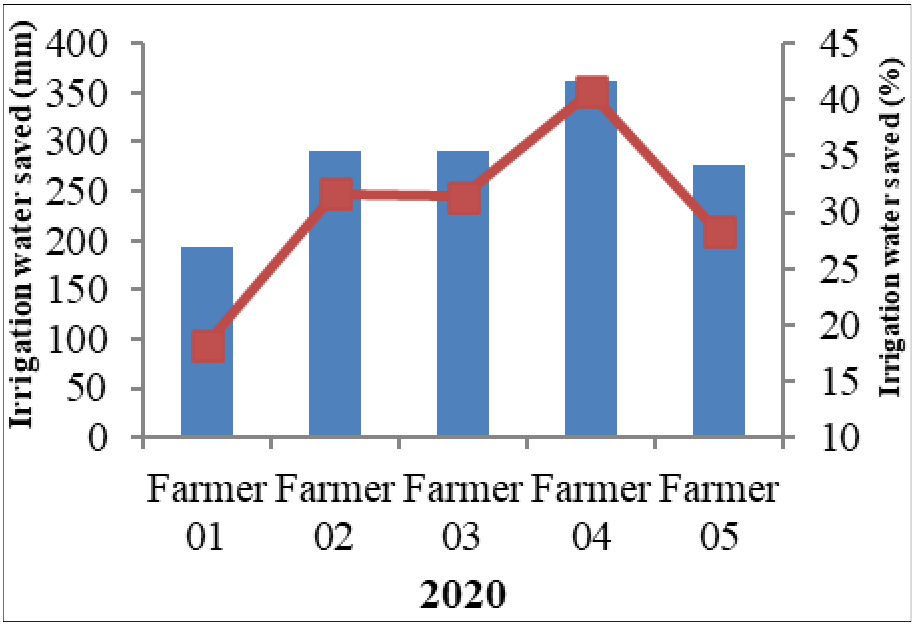
Treatments	Yield (kg ha^{-1})			Quantity of water applied, (mm)			WP (kg ha^{-1} mm^{-1})		
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
Farmer 01									
DSR+AWD	6100.0	6166.4	6133.2	1057	1078.1	1067.5	5.8	5.7	5.7
TTR+SI	5834.3	5605.5	5719.9	1250.3	1214.5	1232.4	4.7	4.6	4.6
Farmer 02									
DSR+AWD	6346.0	6424.9	6385.5	914.9	905.7	910.3	6.9	7.1	7.0
TTR+SI	5512.7	5467.3	5490.0	1204.8	1198.8	1201.8	4.6	4.6	4.6
Farmer 03									
DSR+AWD	6796.6	6670.4	6733.5	926.9	917.6	922.25	7.3	7.3	7.3
TTR+SI	5957.4	6218.5	6088.0	1217.4	1225.6	1221.5	4.9	5.1	5.0
Farmer 04									
DSR+AWD	6420.2	6824.0	6622.1	887	824.9	855.95	7.2	8.3	7.7
TTR+SI	5956.7	6035.5	5996.1	1247.8	1179.8	1213.8	4.8	5.1	4.9
Farmer 05									
DSR+AWD	6535.2	6751.5	6643.3	976.7	937.6	957.15	6.7	7.2	6.9
TTR+SI	5213.8	5438.1	5325.9	1252.6	1198.4	1225.5	4.2	4.5	4.3
Mean									
DSR+AWD	6439.6	6567.4	6503.5	952.5	932.8	942.6	6.8	7.1	6.9
TTR+SI	5695.0	5753.0	5724.0	1234.6	1234.6	1203.4	4.6	4.8	4.7
t-value			5.9938			0.7912			3.8565
p-value			1.393			0.4447			0.0012

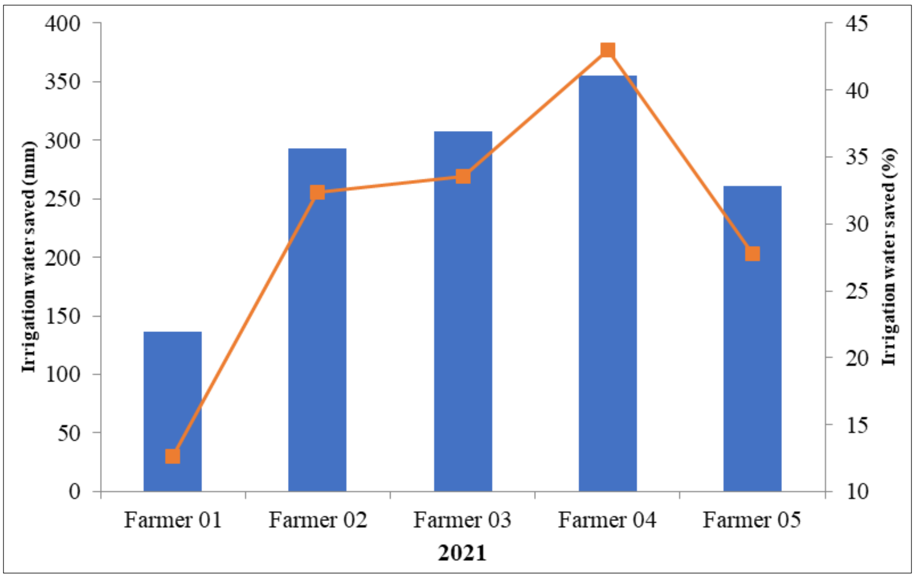
Table 2: Details of paddy yield gap under DSR+AWD in comparision with TTR+SI

Year	Technology Demonstration	Technology gap (t.ha^{-1})	Extension gap (t.ha^{-1})	Technology index (%)
Kharif-2020	DSR	1.65	0.62	22.00
Kharif-2021	DSR	1.30	0.75	17.33

3.3 Quantity of irrigation water saved

The quantity of irrigation water saved (mm &%) under DSR+AWD as compared to farmers practices were calculated at selected demonstrated fields and are presented in fig 01. The quantity of irrigation water saved was ranged from 193.30 to 360.80 and 18.28 to 40.67 with an average of 282.08 to 30.04 (mm &%) respectively during *kharif* 2020. Similar trend was also observed during *kharif* 2021, the quantity of irrigation water saved was ranged from 136.40 to 354.90 and 12.65 to 43.02 with an average of 270.64 to 29.88 (mm &%) respectively. The two years average field data showed that, the quantity of irrigation water saved was ranged from 164.85 to 357.85 and 15.47 to 41.85 with an average of 276.36 to 29.96 (mm &%) respectively. Many researchers across the county reported that, shifting from traditional transplanting method to direct seeded rice alone saves 20 to 25% irrigation water under major & minor irrigation command areas (Kaur and Mahal, 2015; Kakumanu *et al* 2019; Chaudhary *et al*., 2022) [11, 3, 10]. Gonçalves *et al*., (2022) [6] reported that, AWD has potential to save about 10% of irrigation water with a reduced yield impact, allowing an additional period of about 10 to 29 days of dry soil. Adoption of AWD method in paddy cultivation uses 10- 15% of irrigation water as compared to continuous flood irrigation (Joshi *et al*., 2013; Hussain *et al*., 2021) [7]. Though many researchers worked independently on DSR & AWD cultivation methods, there is no sufficient study on combined effect of DSR & AWD on irrigation water saved in the country. The adoption of both DSR & AWD methods in paddy cultivation could able to save irrigation water 15 to 40% depending up on soil condition & rainfall amount.





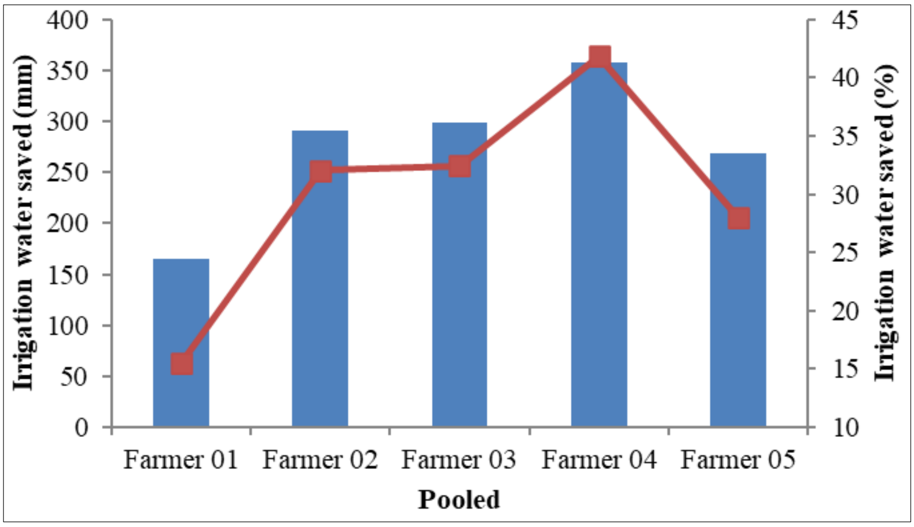


Fig 1: Quantity of irrigation water saved (mm &%) under DSR+AWD method during *kharif* 2020 & 2021 at selected demonstrated fields

3.4 Economic feasibility of DSR & AWD method in rice cultivation

Any new technologies in agriculture production will success only when it is economically viable. Economic analysis would indicate the success or failure of the new technology and in agriculture it is mainly depends on the crop inputs used for crop production. The total expenditure per hectare of traditional transplanting rice with saturation irrigation was Rs.50925.00 and Rs.56017.50 during *kharif*-2020 and 2021 respectively (Table 03). However, total expenditure per hectare in DSR with AWD irrigation method was Rs.27388.00 and Rs.30011.00 during *kharif*-2020 and 2021 respectively which enhance the net profit of Rs. 48,663.00 and 50,589.00 per hectare during *kharif*-2020 and 2021 respectively. The less use of crop inputs in DSR & AWD methods enhance the highest benefit cost ratio (B:C Ratio) of 2.77 and 2.68 during *kharif*-2020 and 2021respectively as compared to mere 1.26 in traditional transplanting rice. The highest B:C ration in DSR & AWD method was due to use less crop inputs such as seed, fertilizer and labour cost during crop growth period. The AWD irrigation method reduced the incidence of pest & disease in paddy leads to less number of spraying and saves the chemical cost. Similar results were also reported by Manohar *et al.,* (2017) [18] under TBP command areas for DSR paddy cultivation. In comparison with transplanted rice (TPR), in DSR, there was decrease in costs by Rs.16429 per ha with respect to input cost *viz*, nursery, seeds, fertilizers and PPC as well as labour operations. There was an additional net gain of Rs. 28226 per ha under DSR over TPR method of rice cultivation.

Table 3: Details on expenditure of crop inputs (Rs. ha^{-1}) and benefit cost ratio of selected irrigation & sowing methods

S.L No	Details	TTR & Saturation Irrigation		Direct Seeded Rice & AWD irrigation	
		2020	2021	2020	2021
01.	Seed (25 Kg)	1500	1650	700	730
02.	Fertilizer cost	15875	17462	8937	9334
03.	Herbicide and Pesticide	7800	8580	6500	6933
04.	Land Preparation	2500	2750	1250	1912
05.	Puddling	5000	5500	-	-
06.	Nursery rising and transplanting	6750	7425	750	787
07.	Fertiliser, Pesticide and Weedcide application	3750	4125	3250	3912
08.	Irrigation	2500	2750	750	887
09.	Harvest and transportation	5250	5775	5250	5512
10.	Total Expenditure	50,925	56017	27,388	30,011
11.	Crop Yield	5.23	5.45	5.85	6.2
12.	Grass returns	67990	70850	76050	80600
13.	Net Returns	17,065	14,833	48,663	50,589
14.	B:C Ratio	1.33	1.26	2.77	2.68

3.5 Extension Strategies

The aim of extension is to transfer the technology from scientists or farm university to farmers. During *kharif*-2020 when DSR method was introduced through Front Line Demonstration and only few farmers came to forward for adopting new technology. However, the success of technology created good impact in the command area and it could able to reach 50 farmers in next year and brought 200 acres of land under DSR cultivation. Organizing of training programmes and celebration of field days has given opportunity to other farmers to understand new technology. This shows that, the conducting front line demonstrations in farmers own field plays major role in building the confidence of the farmers to adopt new technologies.

Conclusion

There is a high time to introduce precise water application methods in paddy cultivation to minimize water losses and soil health related problems in UKP command area and solve water scarcity problem among tail end farmers. The alternative wetting and drying irrigation method is the solution water scarcity problem in command areas. The use of AWD irrigation method in paddy could able to save 44% of irrigation water as compared to farmers traditional practices and also possible to achieve water productivity of 7.27 (kg ha^{-1} mm^{-1}) over continuous submergence method without reduction in crop yield. The irrigation with 2 cm saturation of water has ability to save 41% of irrigation water as compared to traditional method. Better aeration and root growth under AWD practice provided sufficient nutrients for vegetative and reproductive growth which enhance the 10% increase in crop yield over traditional irrigation method. The intermittent application of irrigation water reduces quantity of fertilizer application and irrigation which enhanced the increase in B:C ration in AWD method. Therefore, paddy growing farmers should adopt AWD irrigation application method under DSR instead of continuous submergence to minimize water losses and solve water scarcity problems in UKP command area.

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