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On-farm assessment of resources utilized in wet-DSR through paddy drum seeder and its practicability

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ABSTRACT

High labor requirement in rice transplantation is major concern of the farmers in north India. Direct seeding of rice can save labor resource effectively through manual paddy drum seeder (PDS). An on-farm trial (OFT) was carried out to evaluate the labor and other resources used and its impact on farmer's income by the use of PDS as T_2 in comparison to the prevailing rice transplantation practice as T_1 . The trial was conducted at 19 locations (farmer's field) of Unnao district, Uttar Pradesh, India and data were collected and analyzed for three years from 2020 to 2022.

Groundwater pumping was monitored to assess the water need of rice other than rainfall. It was 138 hr.ha^{-1} in T_2 against 114 hr.ha^{-1} in T_1 during the whole crop period which resulted 686.8 mm irrigation by applied in T_2 against 564.9 mm in T_1 . In T_2 , rice was seeded 25-40 days before the onset of monsoon in T_2 therefore it required 24 hr.ha^{-1} (121.9 mm) more pumping of water to meet out the moisture requirement of the crop at the initial level. Observations revealed that 48-52 more man-days/ha were required in T_1 for uprooting and transplanting of rice seedlings than T_2 . Weed infestation suppressed the yield by 0.2 to 3.5 qt.ha^{-1} in T_2 . Less labor, more water pumping and low yield summed up the benefit cost ratio to 1.66 in T_2 than 1.51 in T_1 . Economically, it was revealed that farmer can save 4000 to 9000 INR per ha by the use of PDS. PDS can proved to be beneficial and cost-effective to the farmers of north India if the sufficient irrigation facility is available at seeding time with proper weed management and facing high labor wages problems.

Keywords: Paddy Drum Seeder, Wet Direct Seeder Rice (DSR), Water Productivity, Resource Conservation, Labor Intensive

Introduction

Resource conservation technologies (RCT) are developed for optimizing the available resources and inputs to produce the maximum outputs from the agricultural land. Many of these technologies are realized and adopted by the farmers as per the projections of that region. Encouragement to adopt the new technology and its optimization to the small stakeholder is still need more attention to sustain the agriculture in remunerative way. On farm trials and demonstrations are more effective tools used by extension system of India as well as by Krishi Vigyan Kendra (KVKs) to extend the RCTs. Land, labor and water are the critical resources for agriculture production (Sharma *et al.*, 2018) [1] and it is extremely important to use these resources wisely to reduce cultivation costs, increases crop yields and achieve maximum benefits.

Rice-wheat cropping system is most common in Indo-Gangetic plains specially. Rice is cultivated through conventional method (transplantation) which involves high man-days for bed preparation, nursery growing and transplanting as well as high demand of water resources. High labor requirements in rice affect the input cost thus results low benefit-cost-ratio (BCR). Only puddling and transplanting accounts 42-49% of labor costs in rice cultivation and rest for other activities like weeding, harvesting, and threshing etc. (Hoki, 1977, Singh *et al.*, 2017) [2]. The size of workforce in the agriculture is declined by 30.57 million between the year 2004-2012 and about 28% agricultural workforces were reduced from 43.3 million in 2004 to 34.83 million in 2012 in Uttar Pradesh and having a declining trend (FICCI *et al.*, 2015) [3]. The studies conducted in Andhra Pradesh showed that there was a declining trend in all three types of agricultural labor (family, casual and attached) during 2005-2011 with dramatically 4-fold increment in their wages in rice cultivation (Reddy *et al.*, 2013) [4]. The availability of labor at nominal cost during the peak period of transplanting rice is also a major concern in the region. The scarce availability of labor at peak season of rice transplanting (TR) results the late transplanting/establishment of rice and which in-turn results the late sowing of wheat in Rabi. Therefore, it is important that farmers should be motivated by providing direct seeded rice technology (DSR) either wet or dry to resolve the labor shortage during the peak season of TR and find out the possibility and feasibility of its adaptation in the district.

Rice, the high-water demanding crop can produce only 0.35-0.37 kg of physical rice in 1-meter cube water (Sharma *et al.*, 2018 and Mishra, 2020) [1]. Gross irrigation water requirement for rice is in between 1192.3 to 1386 mm (Jangre *et al.*, 2022 & Vibhute *et al.*, 2016) [5]. About 70% of rice and wheat cropping pattern is depending on 60% groundwater irrigated area (SIA 2017) which substantially depleted the groundwater

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level and put them under over-exploited category. A declining trend in groundwater is also reported in Unnao district (Agarwal *et al.*, 2017) [6]. There is an immense scope for bringing down wasteful use of water and enhancing agricultural productivity by employing on-farm water management solutions (SIA 2017). Water intensive irrigation practices for rice cultivation result in the consumption of about one-third of total water required for agriculture in India (Sharma *et al.*, 2018) [1].

Water saving techniques like alternate wet and dry (AWD) (Carrijo, 2011, Muhammad *et al.*, 2020), SRI (Geethalakshmi *et al.*, 2011) [7] and DSR (Kumar & Ladha, 2011; Chaudhary *et al.*, 2023) [9, 8] are well known techniques for improving the water productivity in rice cultivation. Farmer's interaction with these technologies under a controlled environment may be difficult except with DSR as the possibility of adoption of DSR is much easier than AWD and SRI techniques. Water productivity in DDSR and WDSR ranged from 0.4 to 0.46 and 0.3 to 0.4 respectively in comparison of 0.29 to 0.39 kg of grain m⁻³ irrigation water in TR which accounted about 24% higher than TR under a proper management practice (Gill *et al.*, 2006; Kumar *et al.*, 2017; Nayak *et al.*, 2020) [10, 11, 12]. Wet-DSR (WDSR) requires significantly higher irrigation input than Dry-DSR (DDSR) because it required more water for puddling and bed preparations at the beginning of rice establishment (Yadav *et al.*, 2014; Kumar & Katagami, 2016) [13] which is 10-15 days earlier the onset of monsoon (Kamboj *et al.*, 2012) [14]. Other than rainfall, Weirs, flumes etc. are important structures for the assessment of water input to the field. The quantification of irrigation can be recorded in terms of water pumping hours (WPH) in rice field and the water resources can be assessed and analyzed for wet DSR and transplantation methodology. At farmer's field, on-farm assessment of irrigation inputs by recording WPH, is easy and accurate practice for that particular pump installed at their fields.

The scarcity or involvement of expensive labor and intensive water requirement has become a challenge and it is pressurizing on the cost of rice cultivation in Unnao district as well as the GHGs emissions. Paddy drum seeder (Wet-DSR) tool in the field may prove to be a good substitute for saving labor and cost of rice cultivation in the district with the marginal increment of grain yield (Hobbs *et al.*, 2002; Sharma *et al.*, 2004; Kumar & Ladha 2011) [15, 16, 9].

The main objective of the trial was to assess and analyze the on-farm data for the water utilization, labor saving, effects on yield, cost of cultivation and BCR value of farmers of Unnao district and the farmers perspective about wet DSR.

2. Material and methods

2.1 Site description

During the *kharif* season (2020-2022), an on-farm trial (OFT) was carried out in farmer's field located at 19 sites in 14 different villages of Unnao district of Uttar Pradesh (26°48' N and 80°39' E). The district lies in central plain agro-ecological sub zone.

2.2 Climate

Unnao is having sub-tropical humid climate with hot summer and falls in Upper Indo Ganagatic Plains (UIGP) agro-climatic zone. May is generally the hottest month with mean daily maximum at 40.6 °C and the mean daily minimum at 25.5 °C whereas January is usually the coldest month with the mean daily maximum at 22.8 °C and mean daily minimum at 8.6 °C (Maurya *et al.*, 2019) [17]. The normal rainfall in the district is about 840 mm in which more than 86% occurs during monsoon season (June-Sept). The month of highest relative humidity is August (81.22 %) and with the lowest relative humidity is April (29.58 %).

2.3 Soil status

Soil samples were collected and analyzed in soil laboratory of Krishi Vigyan Kendra, Unnao to check the soil properties and status (Table 1). Overall, soil in the experimental field was deep, fine associated with loamy clay soils having high sodicity waterlogging condition.

2.4 Treatments

Two basic treatments were selected viz. farmers practice i.e., transplanted rice as T₁ and wet direct seeded rice (Wet-DSR) through paddy drum seeder (PDS) as T₂. There are 14 replications of the experiments during the *kharif* season of years 2020, 2021, and 2022, respectively. Each replication was carried out on about 0.50 ha of farmers' land, in which 0.25 ha was allotted to each of the T₁ and T₂ treatments.

2.5 Bed preparation

Farmer's practice (T₁): - A small plot was prepared for growing rice seedlings nursery during second fortnight of May to 1st week of June. The size of the nursery plot was selected as 1/20th of the experimental area. For the transplanting of rice seedlings, the field was prepared at the onset of monsoons or during mid of June to last week of July. Farmers typically used harrows or rotavators to prepare the bed or puddle the soil. They then performed one or two irrigations to ensure adequate standing water in the field for reducing the germination of weeds.

Wet DSR (T₂):- The plots for DSR were prepared during 1st to 20th June. Before sowing, these were irrigated to attain some moisture so that the harrow and rotavator could be used easily for bed preparation. The pre-emergence weedicide was sprayed on the field for reducing the effect of weeds.

2.6 Seeding and transplanting

For seeding purposes, local rice seed of farmers choice (generally named as *Ganga Cauvery*) was soaked in the water for 6-7 hours and dried in a shade in such a way that seeds should fell in a plunging manner. Manually operated paddy drum seeder with four drum was used for seeding the rice in the field (Figure-1). In paddy drum seeder, the seeds were equally filled in all the drum in such a manner that it should neither be more than 2/3rd nor less than 1/4th volume of the drum to maintain the proper contact pressure to drop the seed from the holes of the drum. Seeder was then run over the prepared field for seeding rice in rows (Figure 1). To ensure proper soil moisture, a flush irrigation of 32.8 to 47.6 mm was applied to each of the experimental plots. The water was applied to the experimental field in such a manner that the soil surface was just get wet, without any standing water, to prevent seed rotting. (Kumar *et al.*, 2016; Balasubramanian *et al.*, 2002) [13, 18]. This continuous wetting process lasted up to seedlings grew up to 4-5 inches. While transplanting the seedlings in T₁, 5-6 kilograms of rice seeds were broadcasted to grow a rice nursery in a well-prepared and irrigated land.

2.7 Data collection

Data were collected under the head of resources used (water and labor), economical (input cost and benefit-cost ratio value) and outcome (yield) parameters. Water resources (groundwater and rainfall) for irrigation were assessed through water pumping hours monitored by farmer and effective rainfall. In present study, the rainfall data were collected for the respective year of trials and presented in Table 2 (Yadav *et al.*, 2021; Yadav *et al.*, 2022; Bhan *et al.*, 2023) [19, 20, 21].

Effective rainfall was estimated by Brouwer *et al.* (1986) [22] as follows: -

If $P > 75$ mm/month	
$P_e = 0.8P - 25$	
If $P < 75$ mm/month	
$P_e = 0.6P - 10$	

Source: FAO training Manual no. 3

Groundwater drafted for irrigation were averaged yearly and summed up with effective rainfall of respective year for assessing the total wa

ter utilization. Discharge of individual pumping set was calculated by volume-duration method which was in the range of 41.78 to 56.81 m³

hr⁻¹ (Table 1). Similarly, the depth of Irrigation was calculated as

$$\text{depth of irrigation (mm)} = \frac{\text{Discharge (m}^3\text{hr}^{-1}) \times \text{water pumping hours (hr)}}{\text{area covered under irrigation (m}^2\text{)}} \times 1000$$

The input cost and benefit-cost ratio (BCR) were calculated on the basis of cost involved for different inputs and resources at local level. The data and observations collected from the trial fields were integrated for 1 ha land and represented in this paper. The results of the study were analyzed statistically to check the significance among the trials through single factor ANOVA.

2.8 Weed and disease control

Weed is the primary concern in rice cultivation using DSR technology. To effectively manage weeds, weedicides were sprayed to control both pre-emergence and post-emergence weeds.

Further, leaf folder (LF) was observed in most of the trials along with the brown plant hopper (BPH) as presented in Table 4. It was also sprayed in all the trials as the preventive measure.

3. Results and discussion

3.1 Water pumping hours

Number of pumping hours were recorded for evaluating the utilization of on-farm water resource other than rainfall. Table 5 exhibits the number of irrigations, duration for irrigation in terms of average pumping hours and corresponding irrigation depth for the crop period in each trial field for both the treatments. During the rice crop period, there were 7-9 irrigation events in *T*₁ after transplanting rice seedlings, while *T*₂ experienced the same irrigation events (Vibhute *et al.*, 2016) [23] except 3-4 more irrigation has to be given for establishment of crop before onset of monsoon. On an average, pumping hours in *T*₂ is high i.e., 138 hr.ha⁻¹ as compared to the *T*₁ i.e., 114 hr.ha⁻¹ which causes 21.05 % more water pumping in *T*₂ which concludes high water application in *T*₂ as 686.8 mm in comparison of *T*₁, that is 564.9 mm through pumping sets.

Initially, the area prepared for rice cultivation in *T*₂ was more than *T*₁, as the whole area was to be seeded for rice cultivation while in *T*₁ only 1/20th area was to be prepared for growing nursery to cover the same area. Therefore, paleo irrigation and frequent wetting spells (4-6 days interval) required 22.9-30 hr more water pumping in *T*₂ with the comparison of *T*₁. At the initial level, groundwater pumping was conducted for 8-14 hr.ha⁻¹ per wetting spell in *T*₂ to maintain adequate moisture up to crop establishment. In contrast, during the growing nursery phase in *T*₁, the pumping time was significantly shorter, typically lasting only 3/4 hours for the same interval. *T*₂ experienced a total of 3-4 frequent wetting spells, which necessitated increased water pumping activities. (Figure 3). Geethalakshmi *et al.* (2011) [7] found higher no of irrigation events against the conventional rice cultivation practice which causes more water requirement at field level in wet DSR.

The water pumping hours used for irrigation in growing nursery were also recorded and included in the table in *T*₁. Statistical analysis shows that water pumping hours used in *T*₂ is significantly low (*p* < 0.05) (Table 8).

Number of irrigation and working hours of pumping set with respect to the crop is illustrated by Figure 4. The length of the strips describes the crop duration and its thickness defines the area of the field. The length of the strip is divided according to the crop stages (Allen *et al.*, 1998) [24]. The color changing in strips represents the rate of change of vegetative or greenery cover over the field. The lines over the strips, exhibit the water pumping hours during the irrigation. In *T*₁, thickness of the strip up to 38 days was very small as compared to *T*₂. The smaller area represents over which the rice nursery was growing up for transplantation. The spikes over this segment of strip shows the pumping hours used to irrigate the nursery. On 38th day, rice seedlings were uprooted and transplanted to the main field and there-

fore thickness of the strip has widened. The figure clearly elucidates comparatively higher pumping required in *T*₂. Initial watering in *T*₂ causes high water pumping in pre-monsoon season. In contrast of *T*₂, bed preparation and puddling for transplanting was mostly rainfed in *T*₁, and water pumping was low or negligible.

3.2 Water utilization

The effective rainfall was also calculated to quantify the total water utilized in the trials. Table 6 concludes that in *T*₂ utilized 792 mm of groundwater against 593.7 mm used in *T*₁ which was 25% lower than *T*₂. Total water utilization in *T*₂ and *T*₁ was 946.2 mm and 826.4 mm respectively and concluded that the *T*₂ utilized about 14.4 % more water than *T*₁. These findings are close to the study of Vibhute *et al.*, 2016 [23] that concluded about 970 mm surface irrigation for rice establishment under *T*₁. Statistical approaches indicates that total water utilized for *T*₂ is significantly higher (*p* < 0.05) than that of *T*₁. Bhuiyan *et al.* (1995) reported high water use in Wet DSR, ranging from 3.8 to 2.5% in *T*₂ under control conditions with precise water measurement setup at the experimental sites. Many authors also reported low or negligible water saving in Wet DSR (Gill *et al.*, 2006; Kumar *et al.*, 2017; Nayak *et al.*, 2020) [10, 11, 12].

3.3 Labor resource

Labor involved in rice cultivation in different stages were assessed as shown in Table 8. The labor requirement in *T*₁ was higher in comparison of *T*₂. There is high labor requirement during uprooting and transplantation of rice seedling in puddled field. The labor used in all other activity like irrigation, fertilization, weeding, and harvesting were remained almost same except the bed preparation for nursery growing at earlier stages in *T*₁. It was observed about 48-50 labor are needed together for uprooting and transplanting in *T*₁. However, the total labor requirement in *T*₁ was recorded 111 and in *T*₂, it was 63 that was about 43 % less labor used in *T*₂. The labor-saving in *T*₂ was close to the finding reported in all the related studies as 12-35% (Chaudhary *et al.*, 2023) [8], 50% (Marasini *et al.*, 2017) [25], 37% (Kaur *et al.*, 2017) [26].

3.4 Yield

Results revealed that there is significant difference (*p* < 0.05) in yield in *T*₁ and *T*₂. The crop yield was recorded as 40.7 and 38.3 quintal per hectare (qt. ha⁻¹) in *T*₁ and *T*₂, respectively (Table 8 & 9). Drum seeder drops 5-8 sprouted rice seeds from the hole which in-turn makes a heavy bunch of rice plants at development stage than that of *T*₁ as 2-3 seedlings were transplanted together which showed good crop establishment but later on (30-35 DAS) dominance of weed in *T*₂ against the weed control measure, suppressed the yield of rice by 2.4 qt. ha⁻¹ about 5.89 %. Kumar *et al.* (2011) [9] assessed significantly lower yield by 1.9% in 35 studies across India. The yield data in this trial has the close conformity with the findings of Chaudhary *et al.*, 2023 [8]; Marasini *et al.*, 2017 [25] and Kaur *et al.*, 2017 [26] by 5-6% low yield.

3.5 Water productivity (WP)

Irrigation depth (m³) and yield (kg) were worked out to draft the water productivity. Table 8 presents the 16.4% lower water productivity in *T*₂, expressed as 0.411 kg.m⁻³, in contrast to *T*₁, which exhibits a productivity of 0.492 kg.m⁻³. This disparity arises from the increased water application in *T*₂, leading to a subsequent decrease in yield due to weed infestation. Geethalakshmi *et al.* (2011) [7] reported low water productivity (0.33 kg.m⁻³) in wet DSR than transplanted rice. Lower productivity in *T*₂ implies that 2433 liter water was used to produce 1 kg grain whereas it was 2032 liter in *T*₁. This revealed that

wet DSR required 390 liter more water to produce 1 kg grain. Statistically T_1 is having significantly higher ($p < 0.05$) water productivity than T_2 . Early seeding or transplantation reduces water productivity regardless of the method of sowing in rice cultivation as in the case of T_2 . (Das *et al.*, 2018) [27].

3.6 Economics

The cost breakup for transplanting and sowing with paddy drum seeder was calculated in the year 2022 and presented in Table 10. The input cost for rice cultivation in T_1 and T_2 was 57941 and 50342 INR respectively. High labor requirement during the transplantation time increases the cost of cultivation in T_1 in comparison of T_2 which increases the cost of cultivation through traditional methodology in T_1 . The cost of cultivation was reduced by ₹ 12000/- in wet DSR which was also reported to be ₹10500/- (Nayak *et al.*, 2021) [28]. However, the cost of irrigation was 32.1% high in T_2 because maintaining proper moisture during the early stage of the crop. The reduction in the cost of rice cultivation in T_2 was observed as the 13.1% in respective of T_1 , which is close to the finding of Bohra *et al.*, (2015) [29]. Net economic return value was higher in T_2 as ₹ 3729 (12.7%) in comparison of T_1 which is aligned to the findings of Chakraborty *et al.*, (2017) [30] and as 13%. Thus, the benefit-cost ratio (BCR) was high in T_2 i.e., 1.51 in comparison of T_1 i.e. 1.66.

4. Conclusions

On-farm trials revealed that more water was required in wet DSR for bed preparation and maintaining soil moisture to sustain the seeded seeds in the field. Following points can be concluded after the trials:-

1. High Water Requirement: - The water need of more than 119.8 mm was fulfilled with other source of water than rainfall i.e. blue water in wet DSR.

2. Labor Saving: - Wet DSR through paddy drum seeder is definitely a labor-saving technique as it required only 2-4 labors per hectare for rice seeding while it requires 48-52 for transplantation during the peak demand of labors.
3. High Weed Infestation: - Weed infestation was the major problem despite of recommended weedicide application in wet DSR field in contrast to transplanted rice field. Merely wetting of the field and weed infestation suppressed the yield of the rice by 2.4 qt. ha⁻¹ in T_2 which was 40.7 qt. ha⁻¹ in T_1 .
4. Low water productivity: - High water demand and low yield in wet DSR resulted lower water productivity of 0.411 kg.m⁻³ as compared to 0.492 kg.m⁻³ in transplanted rice.
5. Economic benefits: - A farmer can get the benefit about ₹ 3000/- to 5000/- per hectare by adopting wet DSR technology through paddy drum seeder at his farm with 1.66 BCR value.

Keeping in view the availability of the water, in Unnao and nearby districts, farmers may adopt wet direct seeded rice technology (DSR) through paddy drum seeder if frequent irrigation at the initial stage of rice cultivation could be done. This technology can address the high wages or labor shortage problem during the peak season of transplanting.

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Author contributions

R. Sahay: Soil data analysis, field experiment, writing, review & editing; J. K. Yadav: observation and recommendation of pesticide and insecticide in field experiment; A. Singh, A. K. Singh, M.Katiyaar and P. Srivastava: review & editing;

Conflict of interest

The authors declare no conflict of interest.

Data availability statement

Data can be made available on by the corresponding authors on receiving a reasonable request.

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Table 1. Locations of the trials, performing year and Soil fertility status

Field No.	Village	Block	Pump Discharge m ³ .hr ⁻¹	Trail Year				Soil status before trials					Recommended dose of fertilizer				
				2020	2021	2022	No. of Trials	pH	EC ds/cm	N	P	K	Zinc	N	P	K	Zinc
F1	Pilakhna	Hasanganj	54.11		√		1	8.6	0.26	185	12	240	0.2	130	65	40	25
F2	Dhaura	Hasanganj	56.59	√			1	8.5	0.32	194	14	245	0.3	130	65	40	25
F3	Faridipur	Hasanganj	46.37		√		1	8.3	0.36	192	15	236	0.3	130	65	40	25
F4	Munshikheda	Auras	49.61		√	√	2	8.6	0.33	197	13	245	0.2	130	65	40	25
F5	Maakhi	Miyaganj	54.86			√	1	8.2	0.28	199	14	226	0.3	130	65	40	25
F6	Maakhi	Miyaganj	56.81	√	√	√	3	8.2	0.32	204	12	231	0.4	120	65	40	25
F7	Arerkalan	Miyaganj	47.88		√		1	7.8	0.27	230	18	215	0.6	120	60	40	25
F8	Arerkalan	Miyaganj	45.43			√	1	7.9	0.33	236	17	222	0.3	120	60	40	25
F9	Mavaibrahman	Safipur	44.32			√	1	8.0	0.34	204	15	234	0.4	120	65	40	25
F10	Maljha	Hasanganj	59.47			√	1	8.7	0.34	186	13	242	0.3	130	65	40	25
F11	Bibipur Chiryaari	Hasanganj	51.48		√		1	8.8	0.34	175	14	241	0.3	135	65	40	25
F12	Makahdoom Nagar	Safipur	43.54	√	√		2	7.5	0.19	241	19	226	0.5	120	60	40	25
F13	Mirjapur Ajhgaon	Auras	41.78	√			1	8.3	0.32	196	16	236	0.3	130	65	40	25
F14	Hilauli	Hasanganj	52.06			√	1	7.4	0.24	254	19	212	0.6	120	60	40	25

Table 2: Rainfall Data (mm)

Year	Jun	Jul	Aug	Sep	Oct
2020	44.3	118.3	161	33.5	0
2021	64.8	123.8	126.8	190.8	62
2022	13.7	118.7	105.7	100.5	111.7

Source: Indian Meteorology Department (IMD) New Delhi

Table 3. Weed Management

T1		T2	
Weedicide name / Recommended dose per ha	Application, Days after Transplanting (DAT)	Weedicide name / Recommended dose per ha	Application, Days after seeding (DAS)
Bispyribac Sodium 10 SC (250 ml) for wide and narrow leaf weeds	20-25	Pendimethalin 30% EC (3.75 L) + Pyrazosulfuron Ethyl 10 WP (80 gm) (Pre-emergence)	0-1
Bispyribac Sodium 10 SC (250 ml) for wide and narrow leaf weeds	45-55	Bispyribac Sodium 10 SC (250 ml) for wide and narrow leaf weeds	20-25
		Bispyribac Sodium 10 SC (250 ml) for wide and narrow leaf weeds	45-55

(continued on next page)

Table 4. Disease Management

Disease spotted in the field			
LF		BPH	
Plot	Control	Plot	Control
F1, F2, F5, F6, F7, F8, F10, F12, F14	Chloropyrifos 50% EC and cypermethrin 5% EC at the rate of 500-750 ml/ha	F5, F6, F7, F8, F9	Pymetrozine 50% WG at the rate of 300 gm/ha

Table 5: water pumping hours (hr.ha^{-1}) and irrigation depth (mm)

Year	Field No.	T_1				T_2					
		No. of Irrigation	Water Pumping Hours (hrs)	Pump Discharge $\text{m}^3.\text{hr}^{-1}$	Irrigation Depth (mm)	No. of Irrigation before crop establishment	No. of Irrigation after crop establishment	Water Pumping Hours (hrs) before crop establishment	Water Pumping Hours (hrs) after crop establishment	Water Pumping Hours (hrs)	Irrigation Depth (mm)
2020	F2	8	100.8	56.59	570	3	8	18.9	100.8	119.7	677
	F6	7	98	56.81	557	3	7	21	98	119	676
	F12	9	113.4	43.54	494	4	9	25.2	113.4	138.6	603
	F13	9	162	41.78	677	3	9	27	162	189	790
2021	F1	7	96.6	54.11	523	4	7	27.6	96.6	124.2	672
	F3	9	124.2	46.37	576	3	9	20.7	124.2	144.9	672
	F4	8	105.6	49.61	524	3	8	19.8	105.6	125.4	622
	F6	7	84	56.81	477	4	7	24	84	108	614
	F7	8	100.8	47.88	483	4	8	25.2	100.8	126	603
	F11	8	112	51.48	577	4	8	28	112	140	721
	F12	9	135	43.54	588	4	9	30	135	165	718
2022	F4	8	105.6	49.61	524	3	8	19.8	105.6	125.4	622
	F5	8	92.8	54.86	509	4	8	23.2	92.8	116	636
	F6	8	112	56.81	636	4	8	28	112	140	795
	F8	8	113.6	45.43	516	4	8	28.4	113.6	142	645
	F9	8	115.2	44.32	511	3	8	21.6	115.2	136.8	606
	F10	9	122.4	59.47	728	3	9	20.4	122.4	142.8	849
	F13	9	153	41.78	639	3	9	25.5	153	178.5	746
	F14	8	120	52.06	625	4	8	30	120	150	781
Mean			114		564.9	Mean				138	686.8

Table 6: Water Utilization for Rice Cultivation (mm)

Year	Effective Rainfall						Groundwater (B)		Total Water Utilized (A+B)	
	Jun	Jul	Aug	Sep	Oct	Total (A)	T1	T2	T1	T2
2020	16.6	69.6	103.8	10.1	0	200.1	574.4	686.6	774.5	886.7
2021	28.9	74	76.4	127.6	27.2	334.2	535.2	658.3	869.4	992.5
2022	0	70	59.6	55.4	64.4	249.3	586	710.1	835.3	959.4
Mean							565.2	685.0	826.4	946.2

Table 7. Labor used in Rice Cultivation

S.No.	Crop Stage	Duration	Particular	T1 (Transplantation)	T2 (DSR)
A	Labor				

(continued on next page)

S.No.	Crop Stage	Duration	Particular	T1 (Transplantation)	T2 (DSR)
1	Initial Stage	0-20 Days	Bed preparation	2	2
			Weed Control (Spray pre-emergence herbicide)	-	2
2			Bed preparation for Nursery Raising	1	-
3			Nursery Raising	2	-
4			Sowing by DSR	0	2
5			Irrigation for nursery plot and rice sown field	1	2
6			Seedling uprooting	16	-
7			Transplantation	32	-
			Weed Control (Spray post-emergence herbicide)	2	4
8	Developing Stage	21-45	Irrigation	2	2
9			Fertilizer Application	1	1
10			Weedicide	1	6
11	Mid Stage	46-90	Irrigation	6	6
12			Fertilizer Application	2	2
13			Insecticide Spray (if any)	2	4
14	Final Stage	90-115	Irrigation	2	2
15			Harvesting (by hand)	16	16
16			Threshing	12	12
17			Total	111	63

Table 8. Major parameters and its significance

Parameters	T1	T2	Significance Level	
			(<i>p</i> < 0.05)	(<i>p</i> < 0.01)
Water Pumping Hours (hr)	118.7 ± 3.8	158.4 ± 4.8	s	s
Total Water Utilization (mm)	859.9 ± 16.4	1055.7 ± 16.0	s	s
Yield (q.ha)	40.7 ± 0.33	38.3 ± 0.34	s	s
Water Productivity (kg.m ⁻³)	0.492 ± 0.010	0.411 ± 0.007	s	s

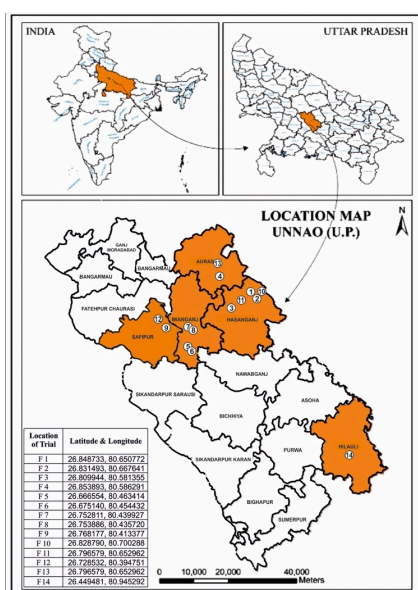
Table 9. Crop yield (qt ha⁻¹)

Year	Field No.	T1	T2
2020	F2	39.2	36.2
	F6	40.3	40.1
	F12	39.4	37.9
	F13	42.2	40.1
2021	F1	40.2	38.4
	F3	42.3	38.8
	F4	39.3	37.1
	F6	39.8	37.5
	F7	40.4	37.3
	F11	41.1	39.2
	F12	39.3	38.1
2022	F4	43.2	40.3
	F5	40.2	36.9
	F6	41.7	38.2
	F8	38.1	35.6
	F9	42.4	39.1
	F10	40.8	38.3
	F13	43.1	41.3
	F14	40	37.1
Mean		40.7	38.3

(continued on next page)

Table 10: Cost analysis of rice cultivation for three years

Particulars			Unit	T1 No. of unit used	T2 No. of unit used	Rate (₹/ Unit)	T1 Cost (₹)	T2 Cost (₹)
A	Input (per hectare)							
1	Bed preparation and Seeding	Rotavator for puddling	Hr	5	2.5	900	4500	2250
		Drum Seeder	Day	-	4	300	0	1200
2		Seed	Kg	20	24	40	800	960
3		Irrigation (Water Pumping)	Hr	119	158	94	11186	14852
4	Fertilizer	DAP	Kg	130	130	25	3250	3250
		Urea	Kg	210	210	5.5	1155	1155
		MoP	Kg	60	60	30	1800	1800
		Zinc Sulphate	Kg	25	25	12	300	300
5		Labor	Number	111	63	250	27750	15750
6	Weedicide	Pre-emergence						
		Pendimethalin 30% EC	L		2.5	450	0	1125
		Pyrazosulfuron Ethyl 10 WP	gm		200	200	0	500
	Insecticide	Post-emergence						
		Bispyribac Sodium 10 SC	mL	250	250	300	1500	1500
7		Chloropyrifos 50% EC and cypermethrin 5% EC	L	1000	1000	280	700	700
		Pymetrozine	gm	300	300	800	2000	2000
8		Threshing	hr	4	4	750	3000	3000
Total							57941	50342
B	Yield (quintal/hectare)						40.6	38.8
C	Output Cost (Rs 2150/- per quintal)						87290	83420
D	Net return						29349	33078
D	Benefit-Cost Ratio (BCR)						1.51	1.66

**Figure 1.** Location of the trials in Unnao District**Figure 2.** Sowing of rice through rice drum seeder at farmer's field**Figure 3.** Crop germination after 20 DAS by rice drum seeder

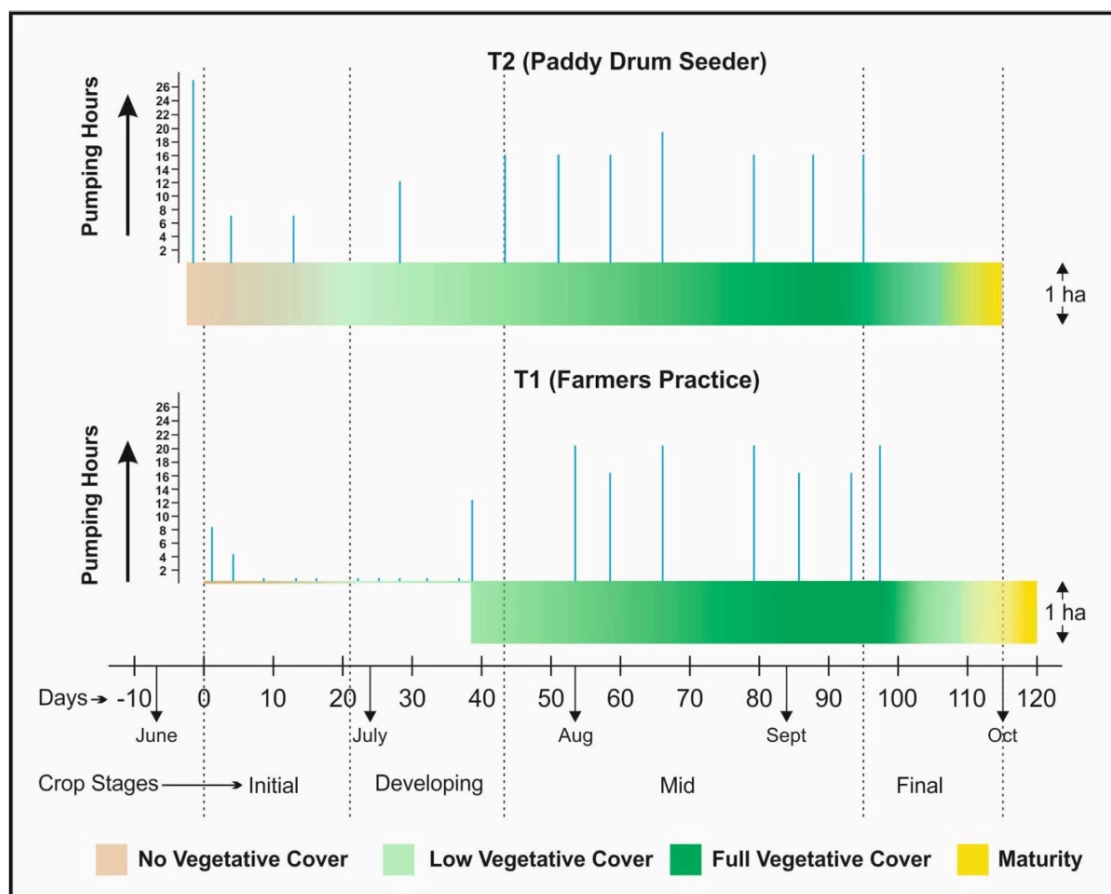


Figure 4. Irrigation by pumping set (hrs) V/s Crop Duration



Figure 5. Transplanting of rice

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