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Impact of irrigation regimes on weed dynamics in various rice establishment methods

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Abstract
A field experiment conducted at IIRR, Hyderabad with three crop establishment methods (normal transplanted rice, mechanized SRI and wet DSR) as main plot treatments and sensor based irrigation management practices (alternate wetting and drying with 5, 10, 15 cm depletion of water level below the soil surface and continuous flooding) as subplot treatments in split plot design on clay loam soil. Significantly least weed abundance was observed in normal transplanted rice and with mechanized SRI with continuous flooding irrigated conditions during *rabi* seasons of 2021 and 2022. Wet direct seeded rice exhibited severe weed infestation (significantly high weed density and weed drymatter) under alternate wetting and drying conditions compared to mechanized SRI and normal transplanting method.

Keywords: Irrigation regimes, establishment methods of rice, weed dynamics

Introduction
For over one-third of the world's population, rice serves as the main source of calories each day (Ullah and Datta, 2018) [12]. Rice (*Oryza sativa* L.) and it is the second most important staple food crop of world and prime staple food crop of India. It occupied an area of 44.16 million hectares with an annual production of 120.32 million tonnes with a productivity of 2.64 t ha^{-1} whereas in Andhra Pradesh it is cultivated over an area of 2.21 million hectares with a production of 8.32 million tonnes with a productivity of 3.73 t ha^{-1}. Therefore, sustaining and improving the production potential of rice is essential for global food security. In India, rice is mainly cultivated by normal transplanting method. Puddling is done to reduce water infiltration and to maintain the continuous submerged conditions in the field, which helps in weed management and facilitates easier transplanting (Sharma and De Datta, 1986) [11]. The traditional method of transplanted rice cultivation with continual flooding leads to water wastage because of seepage and percolation due to the high hydrostatic pressure of stagnated water and demands the usage of more water, labour and energy, which raises the cost of cultivation. It causes numerous nitrogen losses (percolation, volatilization, and denitrification) that lower the efficacy of nitrogen utilization thereby reducing fertilizer use efficiency. Additionally, it contributes to 1.5% of the world's methane emissions and hastens environmental degradation. In addition, normal transplanting method of rice production on long run leads to destruction of soil aggregates and reduction in macro pore volume. Hence, the traditional way of lowland rice cultivation can no longer be sustained. In order to achieve stable and increased rice production with less irrigation water, it is essential to replace normal transplanted (NTP) rice with sustainable crop establishment techniques like direct seeded rice (DSR) and mechanized system of rice intensification (SRI). Wet DSR conditions help in lowering the expenditure of rice production through reduction in transplantation costs as it lacks nursery raising and it may be more environmentally sustainable (Farooq *et al*., 2011) [3]. The depth of the water influences the type and density of the weed flora (Kent and Johnson, 2001; Kumar and Latha, 2011) [5, 7]. Hussain *et al*. (2009) [4] found that, in AWD, effective weed management is only possible through herbicide application as weed infestation is closely related with soil moisture content and water level in the rice field. Continuous flooding can significantly reduce grass growth and as water levels drop below 15 cm and beyond, grass growth always increases in rice fields. In light of these facts, the present study was undertaken with the aim to evaluate the alternative crop establishment systems of rice and also to determine the differences in weed flora in addition to the weed density and weed drymatter in different rice crop establishment methods.

Materials and Methods

The field experiment was carried out at conducted at the B block, Agronomy unit of Indian Institute of Rice Research, Rajendranagar, Hyderabad, Telangana which is geographically situated at an altitude of 542.3 m above mean sea level and located at 17.19° N latitude and 78.23° E longitude during the *rabi* seasons of 2021 to 2023. The soil of the experimental field was sandy clay loam with a pH of 7.6, organic carbon content of 0.5%, and bulk density of 1.32 Mg m^{-3}. The soil was low in N (217 kg ha^{-1}), contained intermediate levels of P (22.3 kg P_2O_5 ha^{-1}) and medium levels of K (227 kg K_2O ha^{-1}). The variety used in the experiment was RNR 15048 (Telangana Sona). The experiment was laid out in split plot design with three replications. The treatments consisted of three establishment methods of rice *viz*., normal transplanted rice, wet direct seeded rice and Mechanized SRI as main plots and irrigation treatments *viz*., continuous flooding and alternate wetting and drying (AWD) when the water level reaches 5 cm, 10 cm and 15 cm below the ground level. The recommended dose of nutrients of 120 kg N, 60 kg P_2O_5 and 40 kg K_2O $ha^{-1}$was applied in the form of urea, single super phosphate and muriate of potash, respectively to all the plots. Nitrogen was applied in three equal splits *viz*., 1/3rd as basal, 1/3rd at 50 DAS and the remaining 1/3rdat 75 DAS. Full dose of phosphorus and potassium was applied as basal dose at the time of sowing. Irrigation was given to the plots according to the treatments. Irrigation was with held and water from the field was drained for 10 days before harvesting in all the treatments. Weed flora was identified twice at 30 and 60 DAS during the period of experimentation. Weed flora such as grasses, sedges and broadleaved weeds from experimental plots were recorded at tillering and panicle initation stages from randomly selected quadrants of 0.5 m × 0.5 m size. The total weed density was arrived by adding all the three weed groups and expressed as number m^{-2}. Weeds were collected from the quadrant (0.5 × 0.5 m) at 30 and 60 DAS/T. The weed samples so collected were shade dried initially followed by oven drying to attain constant weight and expressed in gm^{-2}. Weed density and weed drymatter were reduced after panicle initation stage as hand weeding was done for 2 times at critical crop period where weed competition is high. Therefore weed density and weed drymatter were recorded upto panicle initiation stage.

Results and Discussion

Weed flora

Prominent weed flora found in the experimental field were *Cyperus rotundus* L., *Cyperus difformis* (sedges); *Dactyloctenium aegyptium* (L.), *Echinochloa crusgalli* (Grasses); *Commelina benghalensis*, *Commelina diffusa*, *Eclipta prostrate* (herbs) *and Marsilea quadrifolia* (Aquatic fern). Continuous water-submergence for 20 days reduced the emergence of *Cyperus rotundus*, *Dactyloctenium aegyptium* and *Echinochloa crusgalli* (L.) in all crop establishment methods compared to alternate wetting and drying irrigation. Similiar weed flora was reported by Kumar *et al*. (2017) [6] and Chhokar *et al*. (2014) [1]. Algae were always present in continuous flooding irrigation treatment.

Table 1: Weed flora of the experimental field

S. No	Botanical Name	Common Name	Family	Life Cycle
Grasses				
1	*Dactyloctenium aegyptium*	Crow foot grass	Poaceae	Annual
2	*Echinochloa crusgalli*	Barnyard grass	Poaceae	Annual
Sedges				
1	*Cyperus rotundus*	Purple nutsedge	Cyperaceae	Perennial
2	*Cyperus difformis*	Variable flat sedge	Cyperaceae	Perennial
Broad leaved weeds				
1	*Commelina benghalensis*	Tropical spider wart	Commelinaceae	Annual
2	*Commelina diffusa*	Speading day flower	Commelinaceae	Annual
3	*Eclipta prostrate*	False daisy	Asteraceae	Annual
Aquatic weeds				
1	*Marsilea quadrifolia*	European water clover	Marsileaceae	Perennial

Weed density

Composition of weed flora varied significantly across the establishment methods. During both the years, wet DSR and MSRI recorded a higher number of BLW and sedges. However, in the transplanted method, grasses dominated over sedges and BLW at tillering stage (Figure 1a, b). With the advancement in number of days from sowing, weed flora also changed. At panicle initiation stage, weed flora in WDSR was different from MSRI and the transplanted method. In WDSR, sedges dominated over BLW and grasses at panicle initiation stage. In WDSR and puddled transplanting method, BLW dominated the weed flora during both years (Figure 1c,d). Irrespective of establishment methods, the number of weeds increased from tillering to panicle initiation stage. Among the establishment methods, weed density followed the order of WDSR > MSRI > PTR. Weeds that are appeared following flooding are disappeared once surface water receded in AWD irrigation treatments (Shaibu *et al*., 2015) [10]. Continuous standing water of 5 cm can effectively suppress grasses (Fig. 2; Hussain *et al*., 2009) [4]. Sedge infestation, however, is severe under alternately wet and dry situations and varies substantially with the depth of standing water. Rice fields that are regularly wet typically have less weed growth than rice fields that are not (Fig. 3, De Datta, 1981) [2]. Permanently flooded rice field tends to have less weed growth than rice field that is not permanently flooded (Mortimer and Hill, 1999) [8]. Among the irrigation treatments, weed density followed the order of AWD -5 cm > AWD -10 cm > AWD -15 cm depletion.

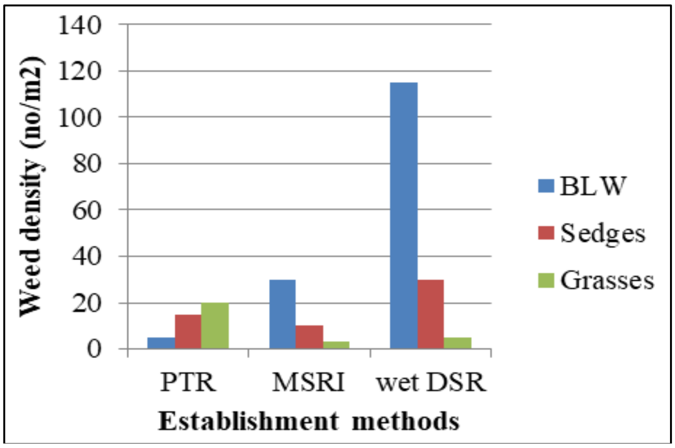

Fig 1(a): Tillering stage (2021)

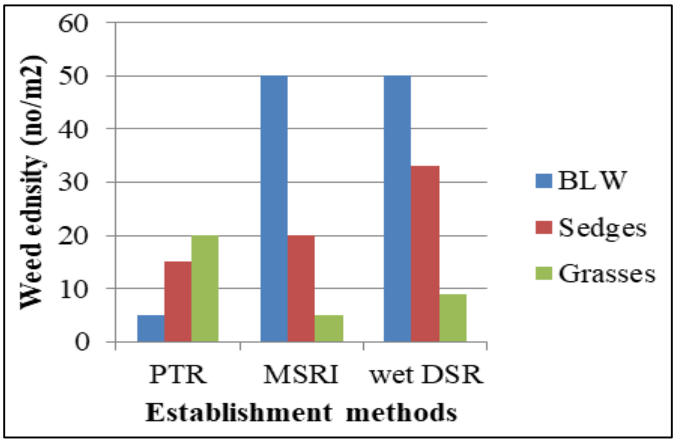

Fig 1(b): Panicle initiation stage (2022)

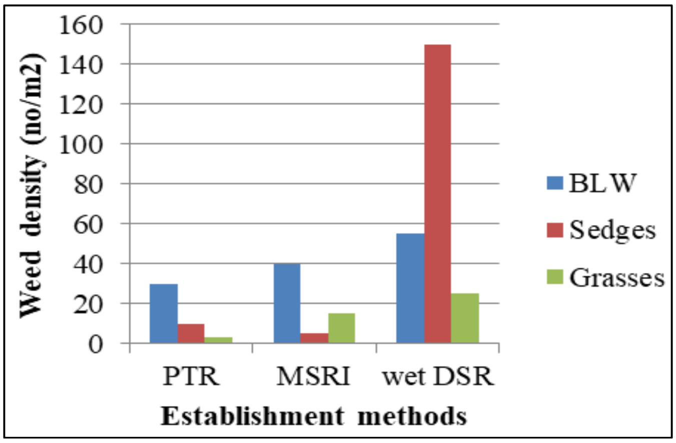

Fig 1(c): Tillering stage (2021)

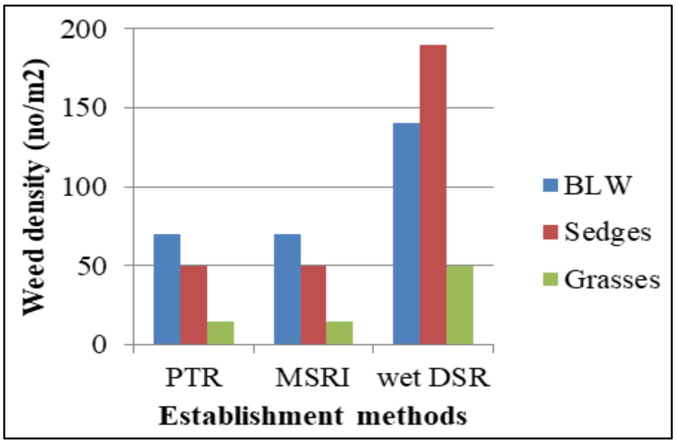

Fig 1(d): Panicle initiation stage (2022)

Effect of crop establishment methods on weed density (no. m^{-2}) as affected by crop at tillering stage 2021(a), tillering stage 2021 (b), Panicle initiation stage 2022 (c), Panicle initiation stage 2022 (d). WDSR - Wet direct seeding; PTR - Puddled transplanting; MSRI- Mechanised SRI, BLW—Broad-leaf weeds.

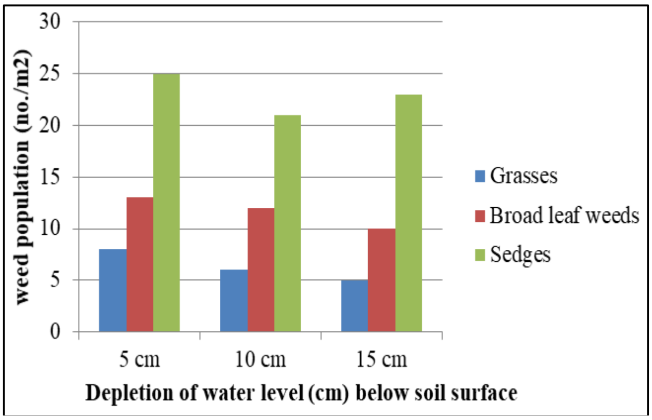

Fig 2: Weed density under various water depletion levels (Hussain *et al*., 2009) [4].

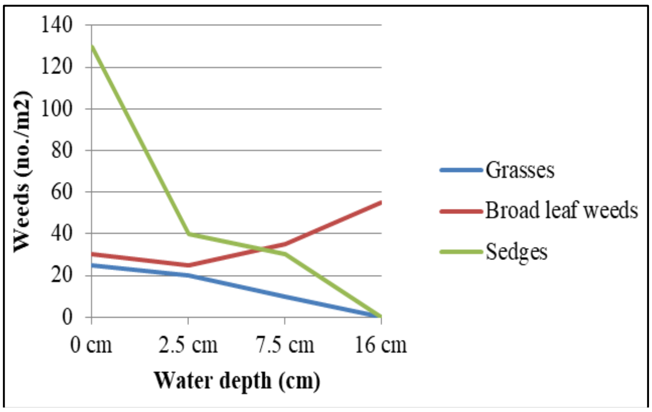

Fig 3: Weed population influenced by water depth in the rice

Table 2: Effect of establishment methods and sensor based irrigation management practices on drymatter of weeds (g m^{-2}) in rice.

Treatments	Drymatter of weeds (g m^{-2})					
	At tillering stage			At panicle initiation stage		
	2021	2022	Pooled	2021	2022	Pooled
Establishment methods (M)						
M_1 – Normal transplanting	9.45	9.07	9.26	24.22	20.67	22.45
M_2 – Mechanized SRI	12.90	12.15	12.53	27.74	25.53	26.64
M_3 – Wet direct seeded rice	18.18	21.69	19.94	33.09	41.59	37.34
S.Em±	0.26	0.28	0.27	0.27	0.46	0.37
C.D. at 5%	1.02	1.09	1.06	1.07	1.82	1.45
Sensor based irrigation regimes (I)						
I_1 – AWD at 5 cm depletion	20.33	18.69	19.51	38.66	37.89	38.28
I_2 – AWD at 10 cm depletion	13.19	14.00	13.59	28.61	28.61	28.61
I_3 – AWD at 15 cm depletion	12.08	12.84	12.46	23.89	29.50	26.69
I_4 – Flooded water management	8.43	11.68	10.10	22.24	21.06	21.65
S.Em.±	0.22	0.23	0.22	0.46	0.67	0.56
C.D. at 5%	0.64	0.69	0.667	1.36	1.98	1.68
Interactions (M×I)	NS	NS	NS	NS	NS	NS
General Mean	13.5	14.3	13.9	28.4	29.26	28.8

Weed drymatter (Table 2.)

At the tillering stage

The results suggest that wet direct seeded rice recorded significantly highest dry matter of weeds, with values of 18.18 g m^{-2} in 2021 and 21.69 g m^{-2} in 2022 followed by Mechanized SRI rice which had slightly higher weed dry matter compared to normal transplanted rice, with values of 12.90 g m^{-2} in 2021 and 12.15 g m^{-2} in 2022. The pooled value of weed drymatter for wet direct seeded rice was 19.94 g m^{-2}. The Normal transplanting rice recorded significantly lowest dry matter of weeds (with values of 9.45 g m^{-2} in 2021 and 9.07 g m^{-2} in 2022). The pooled value for Normal transplanting was 9.26 g m^{-2}. Normal transplanting method was the most effective method for weed control during tillering stage as it resulted in the lowest weed growth during the tillering stage followed by mechanized SRI and wet direct seeded rice during both the years of study.

At the panicle initiation stage

Similar to the tillering stage, the Normal transplanting method recorded significantly the lowest dry matter of weeds (24.22 g m^{-2} in 2021 and 20.67 g m^{-2} in 2022) and the Wet direct seeded rice recorded highest dry matter of weeds (33.09 g m^{-2} in 2021 and 41.59 g m^{-2} in 2022). The pooled value for Normal transplanting method and wet direct seeded rice was 22.45 g m^{-2} and 37.34 g m^{-2}, respectively. Mechanized SRI had recorded higher weed dry matter compared to normal transplanting method, with values of 27.74 g m^{-2} in 2021 and 25.53 g m^{-2} in 2022. The pooled value for Mechanized SRI was 26.64 g m^{-2}. Similar to the tillering stage, the results indicate that normal transplanting method resulted in the lowest weed growth during the panicle initiation stage, followed by mechanized SRI and wet direct seeded rice.

The above results indicated that, among the crop establishment methods of rice, maximum weed drymatter recorded significantly higher in wet direct seeded rice followed by MSRI and puddled transplanted rice during both the years of study. This suggests that normal transplanting method was the most effective method for weed control during both stages of rice growth and during both the years of study. The reason behind the maximum weed density and maximum weed drymatter in wet DSR is due to the absence of continuous submergence.

Among the irrigation regimes, significantly higher weed drymatter recorded with alternate wetting and drying irrigation at 5 cm depletion followed by AWD-10 cm and AWD-15 cm depletion levels and lowest weed drymatter recorded with continuous flooding at all growth stages as continuous submergence reduces the availability of oxygen for growth of weeds. There is significant interaction between irrigation regimes and establishment methods at all growth stages and in both years. Significantly highest weed drymatter recorded with wet DSR irrigated with AWD 5 cm depletion level. These results are in accordance with Hussain *et al*. (2009) [4], Murugan *et al*. (2019) [9] and Shaibu *et al*. (2015) [10]. The lowest weed population and weed dry weight were obtained with normal transplanted rice irrigated with flooding throughout the crop growth period. The highest weed population and weed dry weight were recorded with wet direct seeded rice irrigated with AWD (Murugan *et al*., 2019) [9].

Conclusion

Mechanized SRI and normal transplanting method with continuous flooding were found to be superior in controlling weed growth compared to wet DSR establishment method irrigated with alternate wetting and drying method. Therefore, it was concluded that continuous flooding is the best irrigation practice for reducing the weed problem in rice.

Future scope

Normal transplanting method was the most effective method for weed control during both the tillering stage and panicle initiation stage of rice growth. Mechanized SRI showed slightly higher weed growth, while wet direct seeded rice exhibited the highest weed dry matter. These findings can be valuable for farmers and researchers in selecting appropriate establishment methods for weed management in rice cultivation.

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