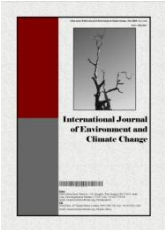

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Yield and Economics as Influenced by Irrigation and Weed Management Practices in Rice

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted to study the effect of irrigation and weed management practices weed seed bank at college farm situated in College of Agriculture, PJTSAU, Hyderabad, during *kharif* 2019 and 2020. The experiment consisted of two main plot treatments and nine subplot treatments laid out in Split plot design replicated thrice. Two irrigation practices (Alternate wetting and drying irrigation and continuous submergence) and nine weed management practices (pretilachloar 50 EC 660 g ha^{-1}(PE) *fb* mechanical weeding twice, pyrazosulfuron ethyl + pretilachloar 6.15 GR 615 g ha^{-1} (PE) *fb* penoxsulam + cyhalofop p butyl 6.12 OD 125 g ha^{-1} (POE), orthosulfamuron + pretilachloar 6.6 GR 600 g ha^{-1} (PE) *fb* mechanical weeding twice, penoxsulam + butachloar 39.77 SE 820 g ha^{-1} (PE) *fb* mechanical weeding, flucetosulfuron 10% WG 25 g ha^{-1}(Early PoE) *fb* mechanical weeding, bispyribac sodium + 2, 4-D sodium salt 56.3 SP 703.75 g ha^{-1} (PoE) *fb* mechanical weeding once, florpyrauxifen benzyl + cyhalofop p butyl 12 EC 150 g ha^{-1} (PoE) *fb* mechanical weeding once, hand weeding twice and unweeded control). There was no significant difference observed in irrigation practices for grain yield. With respect to weed managements, significantly higher grain yield was recorded in hand weeding and integrated weed management (IWM) involving penoxsulam + butachloar *fb* mechanical weeding. As an economics

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aspect is concerned, continuous submergence recorded higher cost of cultivation and higher grass return. Among weed management practices, hand weeding and IWM involving penoxsulam + butachloar *fb* mechanical weeding recorded higher cost of cultivation and higher gross return. As net return is concerned, IWM involving penoxsulam + butachloar *fb* mechanical weeding recorded higher, whereas B: C ratio in chemical weed control.

Keywords: Irrigation; weed management; grain yield; cost of cultivation; profit; B: C ratio.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is considered as the "global grain" and is the staple food for Asia and for more than half of the global population. In India, it contributes to about 40 per cent of the total food grain production. It plays a vital role in food security and livelihood for almost every household. It provides 43 per cent of calorie requirement for more than 70 per cent of Indian population [1]. In world, rice is grown in 169.5 million hectares with production of 761.50 million tones and average productivity of 4501 kg ha^{-1} [2]. India ranks first in rice area and second in production and is grown in almost all the states of the country. Total estimated area under rice in India in 2019-20 is 43.6 million hectares with a production of 118.8 million tones and average productivity of 2722 kg ha^{-1} [3]. Telangana state contributes 2.01 million hectare area with a production of 7.43 million tonnes, at an average productivity of 3694 kg ha^{-1} during 2019-20 [3]. The country has to produce about 130 million tonnes of rice by 2025 to meet the food requirement of the ever growing population (Kumar, 2015).

Alternate wetting and drying (AWD) technique is a necessity for modern farming of rice as it is profitable over the continuous flooding irrigation system which prevents the wastage of scarce and vital water resources, irrigation cost and protects the environment from degradation. It helps to enhance food security by increasing the production, nutrient content and minimizing the toxic elements in rice. This method of managing the water in which water will not be wasted rather it will aid the root growth; facilitate higher nutrient uptake, and increase land and water productivity [4].

Herbicides when applied alone is although economical but may have limitations like resistance development shift in weed flora *etc*. Therefore, presently there is a need to use high efficacy herbicide mixtures coupled with broad spectrum nature to control the complex weed flora in transplanted rice and to reduce the risk of resistance development in weeds due to their multiple modes of action. Also, the combination of herbicides save time of application and reduces the cost of cultivation [5]. Herbicides with different mode of action when mixed together bind with different target sites of the weeds and prevent probability of resistance development in weed species [6]. Tank-mix application leads to reduced accuracy of application by illiterate farmers. Therefore, pre-mix herbicide with broad spectrum of weed control is preferable. Mechanical weed control is one of the classical weed management methods. Although it is an ancient method, but recent advances like development of power operated weeders, motorized rotary tillers had rendered it as an effective and viable weed management tool [7].

A single application of (pre (or) post emergence) herbicide does not provide satisfactory weed control throughout the crop season as some of the broad - leaf weeds and sedges are not controlled effectively [8]. Hence there is need to depend on other methods of weed management as a part of integrated weed management for effective control of weeds.

2. MATERIALS AND METHODS

The present experiment was carried out at College Farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad, Telangana State. The farm is geographically situated at an altitude of 542.3 m above mean sea level at 17°19' N latitude and 78°23' E longitude in the Southern Telangana agro-climatic zone of Telangana and it is classified under semi-arid tropics (SAT) according to Troll's classification. The average annual temperature is 26.6ºC and monthly mean maximum and minimum temperatures range between 21 - 33ºC. Summers (March – June) are hot and humid, with a 30ºC. Maximum temperatures often exceed 40ºC between April and May. The coolest temperatures occur in December and January. Temperature occasionally drops to

Chart 1. List of different treatments used for the study

Symbol	Treatments
Main plots - Irrigation methods (2)	
I_1	Alternate wetting and drying irrigation of 5 cm, when water level falls below 5 cm from soil surface in perforated pipe
I_2	Recommended submergence of 2 - 5 cm water level as per crop stage
Sub plots - Weed management options (9)	
W_1	Pretilachloar 50 EC 660 g ha^{-1} (PE) fb mechanical weeding twice at 25 and 45 DAT
W_2	Pyrazosulfuron ethyl + pretilachloar 6.15 GR 615 g ha^{-1} (PE) *fb* penoxsulam + cyhalofop p butyl 6.12 OD 125 g ha^{-1} (POE)
W_3	Orthosulfamuron + pretilachloar 6.6 GR 600 g ha^{-1} (PE) *fb* mechanical weeding twice at 25 and 45 DAT
W_4	Penoxsulam + butachloar 39.77 SE 820 g ha^{-1} (PE) *fb* mechanical weeding at 25 and 45 DAT
W_5	Flucetosulfuron 10 WG 25 g ha^{-1} (Early PoE) *fb* mechanical weeding at 45DAT
W_6	Bispyribac sodium + 2, 4-D sodium salt 56.3 SP 25.0 + 678.75 g ha^{-1} (PoE) *fb* mechanical weeding at 45 DAT
W_7	Florpyrauxifen benzyl + cyhalofop p butyl 12 EC 150 g ha^{-1}(PoE) *fb* mechanical weeding at 45 DAT
W_8	Hand weeding at 25 and 45 DAT (weed free)
W_9	Control (Unweeded)

DAT: Days after transplanting

10°C. More than 75% of rainfall is due to south-west monsoon and occurs between June to September. The location receives 2,731 hours of sunshine per year. The rainfall during experimental period was 603.6 and 744.6 mm received in 18 and 23 rainy days in 2019 and 2020 respectively. Late onset of monsoon was observed and rainfall mostly received in September (297.4 and 384.8 mm) and October (129.0 and 344.6 mm) months.

The soil of the experimental was sandy loam in texture (70.4 sand, 11.8% silt, and 17.8% clay) with an average bulk density of 1.59 Mg m^3 for 0-60 cm depth and is slightly alkaline in reaction with pH around 7.96 and Ec ranging from 1.24 (ds m^{-1}). The available N, P, and K was 153.56, 20.2, and 272.3 kg ha^{-1}. The experiment consisted of two main plot treatments and nine subplot treatments laid out in Split plot design (SPD) replicated thrice, details on treatments as follows.

Data on yield and economics was subjected to analysis of variance procedures as outlined for split plot design [9]. Statistical significance was tested by F-value at 0.05 level of probability and critical difference was worked out where ever the effects were significant. As the observation on emergence on weed seedlings, normality of distribution was not seen and hence, the values were subjected to square root transformation ($\sqrt{x+0.5}$) prior to statistical analysis to normalize their distribution as suggested by Gomez and Gomez (1984).

3. RESULTS AND DISCUSSION

A. Grain yield (kg ha^{-1})

Grain is the final product of growth and development which is controlled by growth and yield attributing characters. Grain yield depicts the amount of dry matter converted as economic produce which is always influenced by many crop production aspects and in particular weed management. Grain yield was significantly influenced by irrigation and weed management practices and the data is presented in Table 1.

Transplanted rice under continuous submergence has recorded slightly higher grain (5368 and 4949 kg ha^{-1}) yield over rice under AWD (5172 and 44703 kg ha^{-1}). Among the weed management practices, significantly highest grain yield was recorded under hand weeding (W_8) (6041 and 5701 kg ha^{-1}) followed by IWM involving penoxsulam + butachloar *fb* mechanical weeding (W_4) (5916 and 5343 kg ha^{-1}), IWM involving orthosulfamuron + pretilachloar *fb* mechanical weeding (W_3) (5826 and 5336 kg ha^{-1}) and chemical weed control (W_2) (5786 and 5204 kg ha^{-1}) and these were on par with each other. Treatments W_1 (4728 and 4490 kg ha^{-1}) and W_6 (4726 and 4287 kg ha^{-1}) were found on par with each other Unweeded control (W_9)

reported the lowest grain yield (3725 and 3385 kg ha^{-1}). Hand weeding and IWM involving penoxsulam + butachloar (PE) *fb* mechanical weeding twice resulted in 165.1% and 158.3% increase of yield respectively over unweeded control. Interaction effect of irrigation and weed management practices was found to be non significant.

Non-significant difference in grain yield between continuous submerged and AWD condition may be due to presence of water depth by continuous occurrence of unconditional rainfall (603.6 in 2019 and 744.6 mm in 2020) during period of crop growth, which supposed to be meant to create aerobic conditions in AWD plots. Similar results were reported by Shantappa [10] and Zhang [11]. Higher yield under hand weeding and IWM involving penoxsulam + butachloar *fb* mechanical weeding might be due to effective control of weeds under hand weeding and IWM which produced more panicles m^{-2} and grains $panicle^{-1}$, which resulted in higher yield. Under chemical weed control lesser grain yield than IWM might be due to presence of late emerged weeds after herbicide treatment. Combined effect of favorable soil conditions in transplanted rice under continuous submergence and effective weed management helped in better nutrient availability to crop and resulted in higher yields. These results are in agreement with the findings of Srinithan, [12] and Yadav [13].

B. Economics

The irrigation practices followed and weed management practices adopted should also be economically reasonable for a farmer in order to reduce their input cost without sacrificing yields. The data with respect to cost of cultivation, gross return, net return and benefit cost ratio (B: C ratio) of rice are presented in Fig. 1 and Fig. 2.

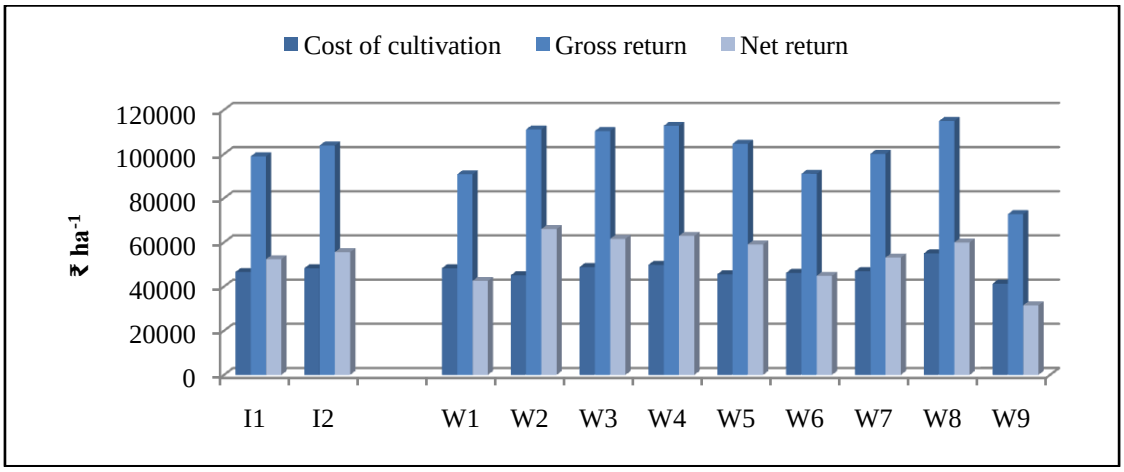

Fig. 1. Economics as influenced by irrigation and weed management practices in rice in *kharif* 2019

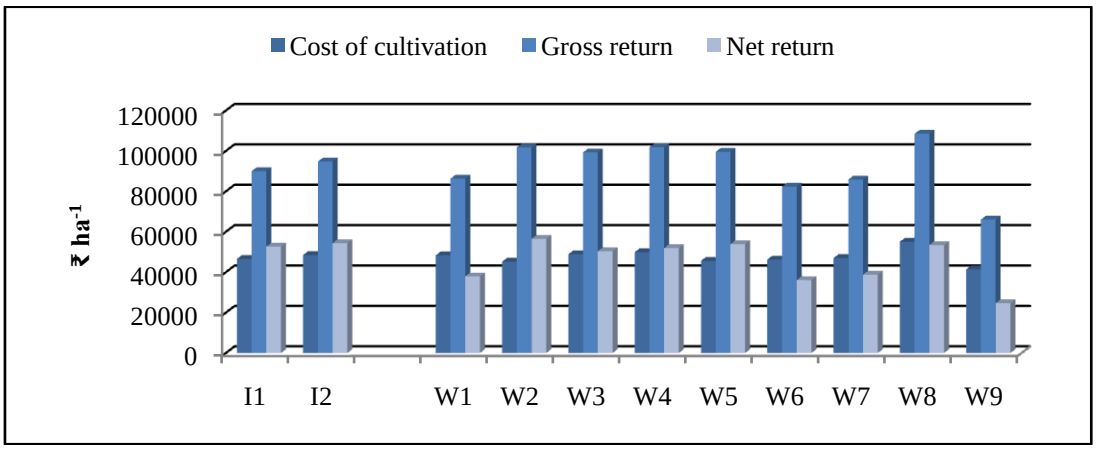

Fig. 2. Economics as influenced by irrigation and weed management practices in rice in khArif 2020

Table 1. Grain yield as influenced by irrigation and weed management in rice

Treatments	Grain yield		
	2019	2020	Mean
Main plots (Irrigation)			
I_1- Alternate wetting and drying irrigation	5172	4703	4936
I_2- continuous submergence as per crop stage	5368	4949	5159
S.E m±	88.49	74.79	
C.D (P=0.05)	NS	NS	
C.V (%)	5.89	5.69	
Sub-plots (Weed management)			
W_1 – Pretilachloar 50 EC 660 g ha^{-1}(PE) *fb* mechanical weeding twice at 25 and 45 DAT	4728	4490	4609
W_2 - Pyrazosulfuron ethyl + pretilachloar6.15 GR 615 g ha^{-1} (PE) *fb* penoxsulam + cyhalofop p butyl 6.12 OD 125 g ha^{-1} (POE)	5786	5204	5495
W_3- Orthosulfamuron + pretilachloar 6.6 GR 600 g ha^{-1} (PE) *fb* mechanical weeding twice at 25 and 45 DAT	5826	5336	5581
W_4- Penoxsulam + butachloar 39.77 SE 820 g ha^{-1} (PE) *fb* mechanical weeding at 25 and 45 DAT	5916	5343	5630
W_5- Flucetosulfuron 10 % WG 25 g ha^{-1}(Early PoE) *fb* mechanical weeding at 45DAT	5463	5218	5341
W_6 -Bispyribac sodium + 2, 4-D sodium salt 56.3 SP 703.75 g ha^{-1} (PoE) *fb* MW at 45 DAT	4726	4287	45.7
W_7- Florpyrauxifen benzyl + cyhalofop p butyl 12 EC 150 g ha^{-1} (PoE) *fb* mechanical weeding at 45 DAT	5222	4468	4845
W_8- Hand weeding at 25 and 45 DAT (weed free)	6041	5701	5871
W_9 – Control (Unweeded)	3725	3385	3555
S.E m±	172.40	154.26	
C.D (P=0.05)	351.16	314.22	
C.V (%)	5.67	5.54	
Interaction	NS	NS	

3.1 Cost of Cultivation (₹ ha^{-1})

The data on cost of irrigation and weed management practices of rice reveals that the higher cost of cultivation (₹ 48302 and 48541) was recorded under continuous submergence over AWD (₹ 46598 and 46559) in both the years. Among the weed management practices, significantly highest cost of cultivation was recorded under treatment hand weeding (W_8) (₹ 55019 and 55109) followed by IWM involving penoxsulam + butachloar *fb* mechanical weeding (W_4) (₹ 49829 and 49907), IWM involving orthosulfamuron + pretilachloar *fb* mechanical weeding (W_3) (₹ 48833 and 48921) and W_1 (₹ 48288 and 48376) and these were on par with each other. Treatments W_2 (₹ 45119 and 45225) and W_6 (₹ 45553 and 45650) were found on par with each other Unweeded control (W_9) reported the lowest cost of cultivation (₹ 41315 and 41414). Interaction effect of irrigation and weed management practices was found to be non significant.

Higher cost of cultivation under continuous submergence was due to higher cost incurred in frequent irrigation compared to AWD. Among weed management practices higher cost in hand weeding treatment due to high labor costs for manual weeding and in IWMS involving pre-emeregent herbicides *fb* mechanical weeding twice due to cost of herbicides and fuel and labour involved in operating mechanical weeding. Similar findings were reported by Venkatesh [14].

3.2 Gross Returns (₹ ha^{-1})

Data on gross returns revealed that among the irrigation practices, the higher gross returns was recorded under higher gross return (₹ 103875 and 94792 ha^{-1}) was recorded under continuous submergence over AWD (₹ 98965 and 90009 ha^{-1}) in both the years. In case of weed management practices, significantly highest gross return was recorded under treatment hand weeding (W_8) (₹ 114983 and 108552 ha^{-1}) followed by IWM involving penoxsulam + butachloar *fb* mechanical weeding (W_4) (₹ 112789 and 101834 ha^{-1}), IWM involving orthosulfamuron + pretilachloar *fb* mechanical weeding (W_3) (₹ 111144 and 101732 ha^{-1}) and

chemical weed management (W_2) (₹ 110432 and 99311 ha^{-1}) and these were on par with each other. Treatments W_1 (₹ 90838 and 86290) and W_7 (₹ 91042 and 82407 ha^{-1}) were found on par with each other Unweeded control (W_9) reported the lowest gross return (₹ 72794 and 66060 ha^{-1}). Interaction effect of irrigation and weed management practices was found to be non significant.

3.3 Net Returns (₹ ha^{-1})

Net return was also influenced by irrigation and weed management practices. Among the irrigation practices, the higher gross return was recorded under higher gross return (₹ 55573 and 54367 ha^{-1}) was recorded under continuous submergence over AWD (₹ 52367 and 52660 ha^{-1}) in both the years. In case of weed management practices, significantly highest net return was recorded under chemical weeding (W_2) (₹ 65313 and 54086 ha^{-1}), followed by IWM involving penoxsulam + butachloar *fb* mechanical weeding (W_4) (₹ 62960 and 51927 ha^{-1}) and IWM involving orthosulfamuron + pretilachloar *fb* mechanical weeding (W_3) (₹ 62311 and 51927 ha^{-1}) and these were on par with each other. Treatments W_1 (₹ 42550 and 37914) and W_6 (₹ 44847 and 36108 ha^{-1}) were found on par with each other. Unweeded control (W_9) reported the lowest net return (₹ 31479 and 24646 ha^{-1}). Interaction effect of irrigation and weed management practices was found to be non significant.

A: C Ratio:

The data on B: C Ratio revealed that the B: C ratio under continuous submergence (2.05) and AWD (2.03) found to be on par with each other in both the years. Among the weed management practices, B: C was recorded under chemical weeding (W_2) (2.45 and 2.20), followed by IWM involving orthosulfamuron + pretilachloar *fb* mechanical weeding (W_3) (2.28 and 2.07) and IWM involving penoxsulam + butachloar *fb* mechanical weeding (W_4) (2.26 and 2.04). Treatments W_1 (1.88 and 1.78) and W_6 (1.97 and 1.78) were found equal each other. Unweeded control (W_9) reported the least B: C (1.76 and 1.59). Interaction effect of irrigation and weed management practices was found to be non significant.

Rice under continuous submerged condition recorded higher gross return over AWD condition despite of higher cost incurred in irrigation under previous one. This is due to higher grain yield and straw yield produced under continuously submerged rice. Although, B: C ratio is found to be comparable among irrigation practices. Among weed management practices, despite of higher gross return in treatment hand weeding, this could not realizes higher profit/ net return thus B: C ratio. Chemical weed control found to be proftitable as lower cost of cultivation and reasonably higher yield. Even though higher yield recorded under IWMs involving herbicides *fb* mechanical weeding, not found as highly profitable weed management options. This is due to higher cost of operation incurred in mechanical weeding. These results are in agreement with findings of Raviteja (2019) and Arya [16,17].

4. CONCLUSION

Based on the results obtained in the present investigation, it is concluded that irrigation practices do not have significant effect on yield and economics. Among weed management practices the treatment hand weeding and IWM involving penoxsulam + butachloar *fb* mechanical weeding found to be superior yield. As an economics aspect is concerned, these two treatments recorded higher cost of cultivation and higher gross return. As net return is concerned, IWM involving penoxsulam + butachloar *fb* mechanical weeding recorded higher, whereas B: C ratio in chemical weed control.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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