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Assessment of Yield, Consumptive Use and Water Use Efficiency of Dry sown Rice (*Oryza sativa* L.) Influenced by Irrigation Schedules And Weed Management Options

P. Haindavi*, K. Chandrasekhar, N. Venkata Lakshmi and P. Ratna Prasad
Department of Agronomy (Water Management), APGC, Lam, Guntur-522034, Andhra Pradesh
Corresponding author's e-mail: haindavi017@gmail.com

ABSTRACT
A field experiment was carried out during the year 2016-17 at Agricultural Research Station, Jangamaheshwarapuram. Guntur, Andhra Pradesh to study the growth and yield attributes of dry sown rice (oryza sativa L.) which was influenced by irrigation schedules and weed management options. The treatments consisted of four irrigation schedules (I_1-1.5 IW/CPE ratio, I_2-2.0 IW/CPE ratio, I_3-3.0 IW/CPE ratio and I_4- continuous submergence) assigned to main plots and four weed management treatments (W_1-control, W_2 -hand weeding at 20 DAS and 35 DAS, W_3 - pendimethalin @ 1 kg a.i. ha^{-1} (PE) fb. hand weeding at 25 DAS, W_4 - pendimethalin @ 1kg a.i. ha^{-1} (PE) fb. bispyribac sodium 25 g a.i. ha^{-1} at 15- 20 DAS, W_5 - pendimethalin @ 1 kg a.i. ha^{-1} (PE) fb. bispyribac sodium 25 g a.i. ha^{-1} at 15 – 20 DAS fb. metsulfuron methyl + chlorimuron ethyl 8 g a.i. ha^{-1} at 35 – 40 DAS as sub plots. The effect of irrigation schedules found to be significant on increasing consumptive of water, whereas the effect of weed management options and their interaction was not significant.Consumptive use of water increased with increasing irrigation frequency. It was significantly the lowest of 374.8 mm with irrigation at 1.5 IW/CPE and increased to 488.9 mm with 2.0 IW/CPE and 631.7 mm at irrigation with 3.0 IW/CPE. This was because of increased soil moisture supply due to increase in number of irrigations facilitated more moisture availability for evapotranspiration.The highest WUE of 14.5 was obtained from five irrigations given under 1.5 IW/CPE ratio which was significantly higher than 23.0 and 3.0 IW/CPE ratios.In general aerobic rice requires less water compared to transplanted puddle rice (123 cm ha^{-1}) and subsequent increase in WUE efficiency under aerobic rice. More water consumptively used under 3.0 IW/CPE ration might have lowered the WUE significantly compared to higher frequency irrigations. Continuous flooding (CF) provides a favorable water and nutrient supply under anaerobic conditions. However, the conventional system consumes a large amount of water approximately 1900 to 5000 liters of water to produce 1 kg of grain. However, irrigation at 3.0 IW/CPE found equally effective as that of continuous submergence in increasing grain yield and higher harvest index was observed under in irrigation schedules based on IW/CPE over continuous submergence. This clearly demonstrates that submerged paddy field is not necessarily the only solution for optimum production.Among the weed control treatments, the highest grain yield (6555 kg ha^{-1}) and straw yield (9470 kg ha^{-1}) recorded with two hand weedings (W_2)were found to be significantly higher over all other treatments. It was followed by the treatment W_3 (pendimethalin + hand weeding) which recorded significantly higher grain yield over W_4 and W_5.
Key words: *Dry sown rice, IW/CPE ratio, Consumptive use, Water use efficiency*

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INTRODUCTION

Rice (*Oryza sativa* L.) is the most important, staple and extensively grown food crop in world as well as India, occupying an area of 44.1 million hectares with a production of 105.5 million tonnes and productivity of 2500 kg ha^{-1}. It is grown in an area of 25.84 lakh hectares with a production of 9.18 million tonnes and productivity of 3.7 t ha^{-1} (Agriculture action plan 2015-16, Department of Agriculture, A.P).
In the present scenario, increasing scarcity of water and labour due to population explosion and urbanization, poses a serious threat to sustainability of traditional methods of rice production. Direct-seeded rice (DSR) can address these problems, as it is economically feasible and technically viable alternative to transplanted rice, as cost of cultivation was 15% less in DSR. Moreover, technical efficiency of DSR was found to be 92% whereas it was 87% in case of TPR. It was observed that farmers could save

55% human labour, 10% machine labour and 33% irrigation water in DSR compared to transplanted rice (Mehala *et al*., 2016).

In direct seeding, there are two methods (dry and wet seeding) based on the physical condition of seedbed and seed (pre germinated or dry). Direct seeding of rice however, offers certain advantages timely sowing, less drudgery, early crop maturity by 7-10 days, high tolerance to water deficit, low production cost, less methane emission etc., It also preserves natural resources especially underground water and maintains physical properties of soil. Whenever, hairline cracks appear on the soil, it is the criteria for irrigation scheduling in DSR. However, exact time interval for irrigation depends on particular soil type and evaporation demand in the atmosphere at that place. Weeds are the major hurdle for cultivation of direct-seeded rice. Weeds compete with direct-sown rice and reduce yield up to 30.17 per cent (Singh *et al*., 2005). The simultaneous emergence of weeds with rice seedlings makes weed control in dry sown rice a complex phenomenon due to over lapping of planting and need for weed control. Manual weeding in direct-seeded rice fields is labour oriented and expensive. The traditional hand weeding practice needs to be substituted by herbicides to control weeds timely and economically.

MATERIAL AND METHODS

A field study was conducted during *kharif*, 2016-17, experiment was laid out in the B - block of Agricultural Research Station, Jangamaheswarapuram, Gurazala, Guntur district, Andhra Pradesh. The experimental site was situated at an altitude of 349 m above mean sea level, 16^0 31' Northern latitude and 79^0 38' Eastern longitude. It is located in the Krishna Agro-climatic zone of Andhra Pradesh. The experimental soil was sandy loam in texture, strongly alkaline (p^H 8.57) in reaction with low organic carbon (0.49%) and available nitrogen (142 kg $ha^{-1)}$, high in available phosphorus (56 kg ha^{-1}) and available potassium (435 kg ha^{-1}). The experiment was laid out in split plot design with irrigation schedules in main plots and weed management options in sub plots using three replications. The treatments consisted of I_1-1.5 IW/CPE ratio, I_2-2.0 IW/CPE ratio, I_3-3.0 IW/CPE ratio and I_4- continuous submergence) as main plots and W_1- control, W_2 - hand weeding at 20 DAS and 35 DAS, W_3 - pendimethalin @ 1 kg a.i. ha^{-1} (PE) *fb.* hand weeding at 25 DAS, W_4 - pendimethalin @ 1kg a.i. ha^{-1} (PE) *fb.* bispyribac sodium 25 g a.i. ha^{-1} at 15- 20 DAS, W_5 - pendimethalin @ 1 kg a.i. ha^{-1} (PE) *fb.* bispyribac sodium 25 g a.i. ha^{-1} at 15 – 20 DAS *fb.* metsulfuron methyl + chlorimuron ethyl 8 g a.i. ha^{-1} at 35 – 40 DAS as sub plots. The rice variety BPT 5204 (Samba Mashuri) was sown on 2nd August 2016. A total of 905.7 mm rainfall received during crop growth period. Sowing was done manually by dibbling. The irrigation water was applied on the basis of pan evaporation data using (USWB class A pan evaporimeter). Irrigation was given as and when the Cumulative Pan Evaporimeter (CPE) reached 40mm, 30mm and 20mm in the treatments 1.5, 2.0 and 3.0 IW/CPE ratios, respectively. The depth of irrigation water applied at each irrigation was fixed at 60mm. Under continuous submergence treatment 5 cm depth of water was maintained throughout the crop growth period. Pendimethalin @ 1kg a.i. ha^{-1} was applied immediately after sowing as pre-emergence application; bispyribac sodium @ 25g a.i. ha^{-1} was applied as post emergence application at 15-20 DAS and metsulfuron methyl + chlorimuron ethyl @ 8 g a.i. ha^{-1} at 35-40 DAS. Hand weeding operation was also carried at 20, 25 and 35 DAS as per treatment. The data on plant height, drymatter accumulation, tillers per m^{-2} and yield attributes were recorded as per standard statistical procedures adopting Gomez and Gomez (1984) standard procedures.

RESULTS AND DISCUSSION

Yield:

From the above field study, data on grain yield, straw yield and harvest index of dry sown rice presented in Table 1 revealed that variation in grain yield and straw yield due to irrigation schedules and weed management treatments was significant but their interaction was not significant. Whereas only the effect of irrigation levels was found significant on harvest index. Continuous submergence (I_4) recorded significantly the highest grain yield, (6307 kg ha^{-1}) though on a par with irrigation scheduled at 3.0 IW/CPE ratio (I_3) (6142 kg ha^{-1}) over other two irrigation levels. Difference between irrigation levels scheduled at IW/CPE ratio 1.5 (I_1) and 2.0 (I_2) was not significant in increasing the grain yield.

In the same way, the maximum straw yield (9604 kg ha^{-1}) obtained with (I_4) continuous submergence of irrigation was significantly superior to that of all other irrigation schedules. It was followed by irrigation at I_3 (3.0 IW/CPE) and found superior to other irrigation levels (I_2 and I_1). Alternatively, the lowest straw yield was recorded with (I_1) 1.5 IW/CPE ratio (7569 kg ha^{-1}) and was found to be on a par with that of irrigation with 2.0 IW/CPE (7890 kg ha^{-1}). On the other hand, continuous submergence observed with significantly lower harvest index compared to other IW/CPE based irrigation levels. The maximum harvest index was realized with 1.5 IW/CPE ratio; though the differences among the irrigation scheduled based on IW/CPE ratios were not significant with regard to harvest index. Continuous flooding (CF) provides a favorable water and nutrient supply under anaerobic conditions. However, the conventional system consumes a large amount of water approximately 1900 to 5000 liters of water to produce 1 kg of grain (Haefele *et al*., 2009). However, irrigation at 3.0 IW/CPE found equally effective as that of continuous submergence in increasing grain yield and higher harvest index was observed under in irrigation schedules based on IW/CPE over continuous submergence. This clearly demonstrates that submerged paddy field is not necessarily the only solution for optimum production. These findings are in corroboration with the findings of Oliver *et al*. (2008) and Balasubramanian and Krishnarajan (2001). Among the weed control treatments, the highest grain yield (6555 kg ha^{-1}) and straw yield (9470 kg ha^{-1}) recorded with two hand weedings (W_2) were found to be significantly higher over all other treatments. It was followed by the treatment W_3 (pendimethalin + hand weeding) which recorded significantly higher grain yield over W_4 and W_5. Whereas, the differences between the weed management options, i.e., sequential application of herbicide treatments (W_4 and W_5) were not significant in increasing grain and straw yields. Weedy check treatment (W_1) treatment recorded with the lowest grain yield which was significantly inferior to all other treatments. Whereas, the straw yield recorded with weedy check was found on a par with the application of pendimethalin + bispyribac sodium (W_4). Manual or mechanical method of weed control are the most efficient methods of weed control in DSR. Nevertheless, labour unavailability, increasing labour costs, and the pressing need to raise yields and maintain profit on a progressively limited land base have been major drivers for farmers to seek alternatives to manual weeding. Herbicides are one such alternative. For dry seeded rice, in general, two herbicide applications are recommended: one at the dry period either just before or after rice emergence and the other at the flood period. Post emergence herbicides protect the crop from subsequent flushes of weeds. For season long protection to dry sown rice from weeds sequential herbicides applications of either two or three herbicides may be needed. Earlier Helms *et al.,* (1995), Kim and Ha, (2005) and Mc Cauley *et al.*(2005) also expressed the importance of pre and post emergence herbicide application in DSR.

SOIL MOISTURE STUDIES

Soil moisture studies in the present experiment comprised of consumptive use of water (mm), water use efficiency (yield in kg/ mm of water used), daily moisture use rate (mm) and moisture extraction pattern.

Consumptive use of Water:

Consumptive use of water by dry sown rice was computed by summing up the values of soil moisture use from the profile and effective rainfall in during crop season. The effect of irrigation schedules found to be significant on increasing consumptive of water, whereas the effect of weed management options and their interaction was not significant. Data regarding the same are presented in Table 1 revealed that, Consumptive use of water increased with increasing irrigation frequency. It was significantly the lowest of 374.8 mm with irrigation at 1.5 IW/CPE and increased to 488.9 mm with 2.0 IW/CPE and 631.7 mm at irrigation with 3.0 IW/CPE. This was because of increased soil moisture supply due to increase in number of irrigations facilitated more moisture availability for evapotranspiration. Narolia *et al*. (2014) and Duttarganvi *et al*. (2016) have also reported amount of water used consumptively increased as supply of water increased.

Water Use Efficiency:

Computed data on water use efficiency (WUE) expressed as yield per unit of water used is presented in Table 1 Data reveals that influence of irrigation and weed management options both had significant effect on WUE in dry sown rice. The highest WUE of 14.5 was obtained from five irrigations given under 1.5 IW/CPE ratio which was significantly higher than 23.0 and 3.0 IW/CPE ratios. The lowest WUE was observed under 3.0 IW/CPE ratio which was significantly lower than other two irrigation schedules. In general aerobic rice requires less water compared to transplanted puddle rice (123 cm ha^{-1}) and subsequent increase in WUE efficiency under aerobic rice. More water consumptively used under 3.0 IW/CPE ratio might have lowered the WUE significantly compared to higher frequency irrigations. While reviewing the yield and WUE of rice, Jaffar basha and Sitha rama Sharma (2017) also expressed similar views. The maximum WUE was computed with two hand weedings (12.9) though the differences WUE obtained among the treatments W_3, W_5 and W_2 were not significantly varied. The weedy check (W_1) observed with lower WUE, which found to be at par with that of treatment W_4.

Table 1: Yield parameters, Consumptive use of water (mm) and Water use efficiency (kg- ha mm^{-1}) in dry sown rice influenced by irrigation schedules and weed management options

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index	Consumptive use of water (mm)	Water use efficiency (kg- ha mm^{-1})
Irrigation schedules					
I_1 -1.5 IW /CPE ratio	5431	7569	42.0	374.8	14.5
I_2 - 2.0 IW /CPE ratio	5632	7890	41.9	488.9	11.6
I_3 -3.0 IW /CPE ratio	6142	8606	41.9	631.7	9.7
I_4 -Continuous submergence	6307	9604	39.2	-	-
SEm±	**113.01**	**118.20**	**0.40**	**9.74**	**0.41**
CD (p=0.05)	**391**	**.409**	**1.4**	**38.1**	**1.6**
CV %	**7**	**5**	**3.7**	**7.5**	**13.4**
Weed management options					
W_1- Control	5298	7300	42.3	487.9	10.9
W_2 -2 HW at 20 & 35DAS	6555	9470	41.2	507.7	12.9
W_3 -PM + HW at 25 DAS	6061	8831	41.1	503.5	12.4
W_4 -PM + Bis. Sodium	5648	8143	41.1	497.6	11.5
W_5 -PM + Bis. sodium + Metsulfuron & Chlorimuron	5827	8342	41.4	496.0	12.0
SEm±	**95.89**	**162.78**	**0.60**	**9.13**	**0.37**
CD (p=0.05)	**275**	**467**	**NS**	**NS**	**1.09**
CV%	**5**	**6**	**5.8**	**5.4**	**9.4**
Interaction (I×W)	**NS**	**NS**	**NS**	**NS**	**NS**

CONCLUSIONS

In direct seeded rice the lowest Consumptive use and the highest Water use efficiency of were obtained from irrigation at 1.5 IW/CPE followed by higher frequency of irrigations (2.0 IW/CPE and 3.0 IW/CPE). Pre-emergence herbicide application along with manual weeding (W_3) or sequential application of herbicides (W_4 and W_5) along with irrigations based on 3.0 IW/CPE ratio were found advantageous. Irrigation schedule (I_1) 1.5 IW/CPE ratio was recorded significantly the maximum weed density and drymatter over rest of the treatments at all the stages of crop growth. Irrigation level at 3.0 IW/CPE was observed with higher WCE over lower frequency of irrigations.

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