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RESEARCH ARTICLE

Study the Irrigation Scheduling and Intercrop Practices on Yield Attributes, Yield, Water Use Efficiency and Economics of Aerobic Rice

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ABSTRACT

Field trial conducted 'at the Central farm, Department of Agronomy, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai' during 'Kharif' 2019-2020 to study the irrigation scheduling and intercrop practices on yield attributes, yield, water use efficiency and economics of aerobic rice. The field experiment was laid out in strip plot design with three replications. The results concluded that scheduling irrigation at (Irrigation water/Cumulative Pan Evaporation) IW/CPE ratio 0.8 up to panicle initiation thereafter 1.2 showed higher yield attributes viz, panicle number (12.3), panicle length (24.4 cm), filled grains panicle^{-1} (176), grain yield (5373 kg ha^{-1}), straw yield (7829 kg ha^{-1}), net income (82062 ₹ ha^{-1}) and B: C ratio (2.25). However, the highest water use efficiency (80.4 kg m^{-3}) was recorded in the treatment with IW/CPE ratio 1.0 up to maturity. Lower yield attributes, yield, water use efficiency, net income, and B: C ratio was noted with IW/CPE ratio 0.8 up to panicle initiation thereafter IW/CPE 1.0. Whereas, intercrop practices, rice alone noted higher yield attributes viz., panicle number (12.6), panicle length (24.1 cm), filled grains panicle^{-1} (191), grain yield (5467 kg ha^{-1}), straw yield (8002 kg ha^{-1}) and WUE (86.6 kg m^{-3}). Rice + green gram (2:1 ratio) intercropping system registered lower yield attributes, yield and water use efficiency. However, the economics of the intercropping system was found higher in rice + black gram (2:1 ratio) with net income of ₹ 92404 ha^{-1} and B: C ratio (2.43).

Keywords: *Aerobic Rice; Irrigation Scheduling; Intercrop; Water Use Efficiency; Economics.*

INTRODUCTION

Rice is the most extensively growing cereal crop on earth and is the essential food for over half of its population. In India, rice is cultivated in areas of 43.1 million ha with a total production of 112.9 million tons and its average productivity is 2.6 tons ha^{-1}. In Tamil Nadu, rice is cultivated in an area of 1.82 million ha with a production of 8.0 million tons and productivity of 3.5 tons ha^{-1} (India stat, 2017 - 2018). Asia's food security mostly depends on irrigated low land rice fields. Rice consumes about 90% of the fresh water resources in Asia used for Agriculture. About 80% of the world's rice grown under irrigated (55%) and rainfed lowland (25%) ecosystems, both of which depend on fresh-water resources. In this, irrigated lowland consuming an additional amount of water for the practices of raising nursery, puddling and transplanting. However, seepage, percolation and evaporation are the major sources for water loss in irrigated lowland condition. Transplanting is the traditional rice cultivation system in this region, in which the farmer's transplant seedlings in paddies that are kept flooded with about 2 to 7 centimeters of standing water throughout the growing season. Now the global "water crisis" threatens the sustainability of irrigated rice production. (Subramanian *et al.* (2008). The lowland rice system not only leads to wastage of water but also causes environmental degradation. Hence, shifting gradually from the traditional rice production system to an aerobic rice system can mitigate the occurrence of water -related problems (Nayak *et al.,* 2015). Aerobic rice is one of the water- saving technology for growing of rice by direct seeding of high yielding varieties in unpuddled condition without standing water and irrigated similar to other upland crops (Bouman *et al.,* 2005). The irrigation regime plays an important role in attaining higher yield and higher water use efficiency. In contrast, the aerobic rice alone under the irrigation regime would not be much cost- effective to the rice growers. Intercropping is an alternate strategy to increase the income of the farmers.

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So, to increase the farm productivity and overall income for the farmers, a short duration suitable crop was introduced as intercrop. Intercropping in rice increases the productivity, profitability, and effective utilization of soil, water, nutrients and sunlight compared to sole crop (Subramanian et al., 2020). Thus, it is believed that efficient utilization of resources results in yield advantages. Keeping these points a field experiment conducted to study the irrigation scheduling and intercrop practices on yield attributes, yield, water use efficiency and economics of aerobic rice.

MATERIAL AND METHODS

A field experiment was conducted ‘at the Central farm, Department of Agronomy, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, during ‘*Kharif’* 2019-2020. The experimental field is located at the southern agro-climatic zone of Tamil Nadu with 9°54’ N latitude and 78°54’ E longitude with an altitude of 147 m above mean sea level. The experiment was laid out in a strip plot design with twelve treatment combinations and three replications. Horizantal plot had three treatments M_1- IW/CPE ratio 1 upto maturity, M_2 - IW/CPE ratio 0.8 upto PI thereafter IW/CPE ratio 1.0 and M_3 - IW/CPE ratio 0.8 upto PI thereafter IW/CPE ratio 1.20. Further, the Vertical plots had four treatments S_1 – Rice alone, S_2 – Rice + Green gram (2:1 ratio), S_3 - Rice + Black gram (2:1 ratio), S_4 – Rice + Coriander (2:1 ratio). The paddy variety used for this experiment was TKM 13 as the main crop and the intercrops were Green gram (Co 8), Black gram (VBN 6), Coriander (Co (CR) 4). The treated and sprouted paddy seeds were used for sowing at the seed rate of 40 kg ha^{-1}. The paddy seeds were sown an intra row spacing of 10 cm and an inter- row spacing of 20 cm. Intercrop seeds were sown after every two rows of rice in the replacement series with a plant-to-plant spacing of 10 cm for green gram, black gram and coriander. The soil of the test site was sandy clay loam with low and medium-range of N, P&K. The entire quantity of phosphate fertilizer applied in basal as a single dose, while nitrogen and potash fertilizers applied in four equal splits at 15 days after sowing (DAS) (20%), active tillering (AT) (30%), Panicle initiation (PI) (30%) and flowering (20%) as per the CPG, TNAU (2019). Irrigation water was measured through Parshall flume. The observation on yield parameters, yield and WUE noted and the economics were calculated. Gomez and Gomez, (1984) statistically analyzed the collected data. Whenever the treatment differences were found to be significant (F test), critical differences were worked out at five percent probability level and the values are furnished in the respective table. If the treatment differences were non-significant denoted as NS.

RESULTS AND DISCUSSION

Number of panicles hill^{-1}

Data pertaining to the number of panicles hill^{-1} of rice is presented in table 1. Among the irrigation scheduling, higher number of panicles (12.3) was observed with IW/CPE ratio 0.8 upto PI thereafter IW/CPE ratio 1.2 (M_3) which was significantly higher than the irrigation scheduled at IW/CPE ratio 1.0 upto maturity (M_1). The lower number of panicles (7.18) was recorded in IW/CPE ratio 0.8 upto PI thereafter IW/CPE 1.0 (M_2). This clearly indicates that aerobic rice was well responded to the irrigation water and revealed the importance of reduced irrigation level during early stages. Higher moisture regime influences to promote the higher number of tillers, higher dry matter production and nutrient uptake (Balamani *et al.,* 2012).

Under intercropping system, higher number of panicles (12.6) were noted in rice alone (S_1) followed by rice + coriander (2:1 ratio) (S_4) intercropping system. Rice + green gram (2:1 ratio) (S_2) produced a lesser number of panicles (8.04) which was statistically comparable rice + black gram (2:1 ratio) (S_3) intercropping system. These results were in conformity with the findings of Lawrence *et al.* (2011).

Panicle length

Irrigation scheduling and intercrop practices influence the panicle length under aerobic condition. (Table 1). Lengthier panicle (24.4 cm) was found in the irrigation scheduling of water at IW/CPE ratio 0.8 upto PI thereafter IW/CPE ratio 1.2 (M_3) followed by treatment M_1. Shorter panicle (20.3 cm) was observed in irrigation scheduling of IW/CPE ratio at 0.8 upto PI thereafter IW/CPE ratio at 1.0 (M_2). It is mainly due to the adequate moisture availability during the crop growth period and thereby the effective translocation of photosynthates to the sink, contributing to better development of yield attributes. Basha *et al*., (2017) gave similar findings.

Among the intercrop practices, the lengthier panicle (24.1 cm) were recorded in rice alone (S_1) compared to rice + coriander (S_4) intercropping system. Shorter panicle (20.8 cm) was registered in rice + green gram (S_2) intercropping system. It was comparable with rice + black gram (S_3) intercropping system. The results were in conformity with the finding of Lawrence *et al.,* (2017).

Panicle weight

Results of irrigation scheduling and intercrop practices on panicle weight under aerobic condition is exhibited in table 1. Regards to irrigation scheduling, higher panicle weight of (4.13 g) were noticed in scheduling irrigation at IW/CPE ratio

0.8 upto PI thereafter IW/CPE ratio 1.2 (M_3) over an irrigation scheduling of IW/CPE ratio 1.0 upto maturity (M_1). However, irrigation scheduling of IW/CPE ratio 0.8 upto PI thereafter IW/CPE ratio 1.0 (M_2) were recorded a lower panicle weight (3.28 g) of aerobic rice. The results were in conformity with finding of Basha *et al.* (2017).

Table 1. Scheduling of irrigation and intercrop practices on yield parameters and water use efficiency of aerobic rice

Treatments	No. of. Panicles hill^{-1}	Panicle length (cm)	Panicle weight (g)	Filled grains panicle^{-1}	Ill filled grains panicle^{-1}	WUE (kg m^{-3})
Horizontal plot: Irrigation scheduling						
M_1	10.4	22.6	3.52	139	25.2	80.4
M_2	7.18	20.3	3.28	115	30.0	76.7
M_3	12.3	24.4	4.13	176	17.0	77.2
SEd	0.35	0.50	0.08	3.93	1.15	*
CD (p=0.05)	0.97	1.39	0.22	10.9	3.18	*
Vertical plot: Intercrop practices						
S_1	12.6	24.1	4.04	191	16.7	86.6
S_2	8.04	20.8	3.31	106	31.3	69.3
S_3	8.99	22.1	3.54	129	26.3	76.0
S_4	10.2	22.7	3.68	148	22.0	80.5
SEd	0.42	0.54	0.10	4.40	1.49	*
CD (p=0.05)	1.02	1.33	0.25	10.8	3.66	*

Interaction was non - significant; *Data not statistically analyzed.

M_1 – IW/CPE ratio 1 upto maturity; M_2 – IW/CPE ratio 0.8 upto PI thereafter IW/CPE ratio 1.0; M_3 – IW/CPE ratio 0.8 upto PI thereafter IW/CPE ratio 1.20; S_1 – Rice alone; S_2 – Rice + Green gram (2:1 ratio) ; S_3 – Rice + Black gram (2:1 ratio); S_4 – Rice + Coriander (2:1 ratio)

About intercrop practices, rice alone (S_1) recorded higher panicle weight (4.04 g) than rice + coriander (S_4) intercropping system. Whereas rice + green gram (S_2) intercropping system, registered lower panicle weight 3.31 g that of rice + black gram (S_3) intercropping system.

Number of filled grains panicle^{-1}

In the present investigation, the number of filled grains greatly influenced by the irrigation scheduling and intercropping system (Table 1). The data shows that maximum filled grains (176) per panicle was registered in the M_3 treatment where the irrigation was scheduled at the IW/CPE ratio of 0.8 upto PI and 1.2 thereafter till maturity. The lower number of filled grains (115) was noted in IW/CPE ratio 0.8 upto PI thereafter IW/CPE 1.0 (M_2). While scheduling irrigation at IW/CPE ratio 1.0 (M_1) showed higher yield compared to M_2 and significantly lower than M_3. This is in accordance with the results of Belder *et al.* (2005) who also demonstrated the optima of irrigation scheduling.

Table 2. Irrigation scheduling and intercrop practices on yield of aerobic rice

Treatment	Grain yield (kg ha^{-1})				Mean	Straw yield (kg ha^{-1})				Mean	Rice Equivalent Yield (kg ha^{-1})				Mean
	S_1	S_2	S_3	S_4		S_1	S_2	S_3	S_4		S_1	S_2	S_3	S_4	
M_1	5635	4488	4648	4848	4905	8253	6453	6755	7067	7132	5635	6961	7341	6688	6656
M_2	5067	3632	4564	4917	4545	7433	5395	6651	7181	6665	5067	6251	7432	6852	6400
M_3	5700	5088	5202	5503	5373	8320	7422	7549	8026	7829	5700	7845	8229	7663	7359
Mean	5467	4403	4805	5089		8002	6424	6985	7425		5467	7019	7667	7068	
	M	S			M XS	M	S			M XS	M	S			M XS
SEd	125	160			218	200	221			298	*	*			*
CD (p=0.05)	346	392			475	555	541			649	*	*			*

* Data not statistically analyzed

M_1 – IW/CPE ratio 1 upto maturity ; M_2 – IW/CPE ratio 0.8 upto PI there after IW/CPE ratio 1.0 ; M_3 – IW/CPE ratio 0.8 upto PI there after IW/CPE ratio 1.20

S_1 – Rice alone; S_2 – Rice + Green gram (2:1 ratio) ; S_3 – Rice + Black gram (2:1 ratio); S_4 – Rice + Coriander (2:1 ratio)

Regarding intercropping practices, a higher number of filled grains (191) per panicle was recorded in rice alone (S_1) followed by rice + coriander (2:1 ratio) (S_4) intercropping system. Relatively, rice + green gram (2:1 ratio) (S_2) showed a lesser number of filled grains (106). A higher number of filled grains panicle^{-1} recorded may be due to a better environment for plant growth, higher plant dry matter production and higher photosynthates available for grain filling. All these characters positively correlated to grain filling. These results are in conformity with the finding of Venkatesha *et al.,* (2015).

Number of ill filled grains panicle^{-1}

Data on ill filled grains panicle^{-1} was depicted in Table 1. Among the irrigation scheduling, higher number of ill-filled grains (30) panicle^{-1} was noted in irrigation scheduling at IW/CPE ratio 0.8 upto PI thereafter IW/CPE ratio 1.0 (M_2) followed by irrigation scheduling at IW/CPE ratio 1.0 upto maturity (M_1). While, lesser ill–filled grains (17.0) panicle^{-1} was noticed in irrigation scheduling of IW/CPE ratio 0.8 upto PI thereafter IW/CPE ratio 1.2 (M_3). Basha *et al.* (2017) reported similar findings.

Regarding intercrop practices, rice + green gram (S_2) intercropping system, registered the highest number of ill-filled grains panicle^{-1} over a rice + black gram (S_3) system. However, rice alone (S_1) recorded a lower number of ill-filled grains panicle^{-1}. The lesser chaffy grains are recorded due to the favorable environment and available photosynthates. The results are in line with the findings of Venkatesha *et al.,* (2015).

Water use efficiency (WUE)

The irrigation water used for the crop was accounted including effective rainfall. The consumptive use of water varies with irrigation scheduling. Water use efficiency was worked out and presented in Table 1. In irrigation, scheduling of IW/CPE ratio 1.0 upto maturity (M_1) noted the highest water use efficiency of 80.4 kg m^{-3}. The lowest water use efficiency of 76.7 kg m^{-3} was observed in irrigation scheduling at IW/CPE ratio 0.8 upto PI thereafter IW/CPE ratio 1.0 (M_2). Higher WUE in this treatment was due to higher grain yield and reduced water consumption compared to other irrigation scheduling treatments. Keerthi *et al*. (2018) reported a similar finding.

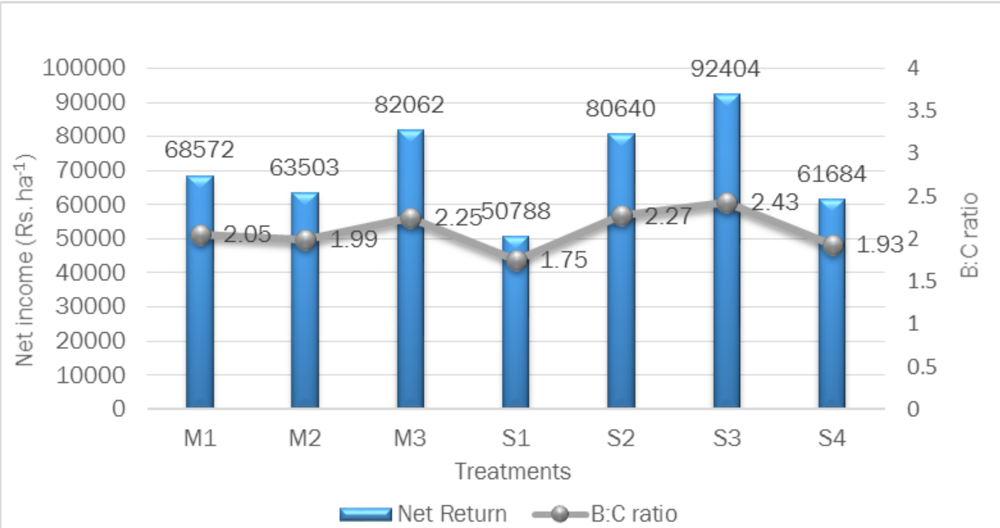

Figure 1. Economic analysis of irrigation scheduling and intercrop practices

Regards to intercrop practices, rice alone (S_1) recorded higher water use efficiency of 86.6 kg m^{-3} followed by rice + coriander (2:1 ratio) (S_4) intercropping system. With the lesser amount of water, the above system produced more yield than the other treatments. Lower water use efficiency of 69.3 kg m^{-3} recorded in the rice + green gram (2:1 ratio) (S_2) intercropping system.

Irrigation scheduling and intercrop practice on yield

The yield of rice and the intercrop was presented in Table 2. Among the irrigation scheduling, higher grain yield of 5373 kg ha^{-1} and straw yield 7829 kg ha^{-1} were recorded in IW/CPE ratio 0.8 upto PI thereafter IW/CPE 1.2 (M_3) followed by (M_1). Irrigation scheduling of IW/CPE ratio 0.8 upto PI thereafter IW/CPE 1.0 (M_2) recorded lesser grain yield (4545 kg ha^{-1}) and straw yield (6665 kg ha^{-1}). An increase in yield may be due to better availability of moisture, which in turn leads to efficient physiological activity. High level of dry matter production and efficient translocation of photosynthates from source to sink might be responsible for producing an increased level of yield. (Subramanian *et al.,* 2020). This result clearly indicated that irrigation with lesser IW/CPE during early stages followed by higher IW/CPE during later stages proved to be the irrigation strategies for the aerobic rice system.

Regarding intercropping practices, rice alone (S_1) recorded a higher grain yield of 5467 kg ha^{-1} and straw yield of 8002 kg ha^{-1} followed by rice + coriander (2:1 ratio) (S_4). Lesser grain yield of 4403 kg ha^{-1} and straw yield of 6424 kg ha^{-1} was recorded in rice + green gram (2:1 ratio) (S_2) intercropping system. However, rice + black gram (2:1 ratio) (S_3) did not differ from the above treatment. Lower grain and straw yield of rice were recorded in the intercropping system compared to the rice alone due to competition for light, space, moisture and nutrient with rice. Venkatesha *et al.,* (2015) also observed similar results.

The interaction effect between irrigation scheduling and intercrop practices were significant. The combination of irrigation scheduling at IW/CPE ratio 0.8 upto PI there after 1.2 (M_3) along with rice alone (S_1) significantly produced a higher grain yield (5700 kg ha^{-1}) and straw yield (8320 kg ha^{-1}). This might be due to the combined effect of soil moisture availability and competition-free environment in sole rice system.

Rice yield equivalent

Rice yield equivalent data is shown in Table 1. Among the treatments, scheduling irrigation at IW/CPE ratio 0.8 upto PI thereafter IW/CPE ratio 1.2 with a combination of rice + black gram (M_3 S_3) intercropping system produced a significantly higher rice yield equivalent (8229 kg ha^{-1}) compared to the other intercropping system. However, all the intercropping system resulted in higher rice yield equivalent than a sole crop of rice. This might be due to the intercropping system utilized agronomic resources more efficiently and effectively towards increased production. Ahmad *et al.* (2007) furnished comparable results.

Economic analysis of irrigation scheduling and intercrop practices

Economic analysis of irrigation scheduling and intercrop practices depicted in Fig. 1. Regards to irrigation scheduling, higher net income (₹ 82,062 ha^{-1}) and B:C ratio (2.25) was found in irrigation scheduling of IW/CPE ratio 0.8 upto PI thereafter IW/CPE ratio 1.2 (M_3) than irrigation scheduling of IW/CPE ratio 1.0 (M_1). It is due to higher grain and straw yield with higher level of IW/CPE ratio. This result of the present study was in orthodoxy with a finding of Keerthi *et al.,* (2018).

A net return provides an economic assessment of intercropping in terms of increased value per unit area of land. Among the intercrop practices, higher net income of (₹ 92,404 ha^{-1}) and B: C ratio (2.43) were obtained in Rice + Black gram (2:1 ratio) (S_3) followed by Rice + Green gram (2:1 ratio) (S_2) over the rice alone system. Among all the treatments, intercropping found higher net return and B: C ratio compared to sole rice. It is due to higher land equivalent ratio (LER) and higher market price of the crops. This result of the present study in conformity with the findings of Rana *et al.* (2013).

CONCLUSION

Under the present circumstances, it can be concluded that irrigation scheduling of IW/CPE ratio of 0.8 up to PI thereafter IW/CPE ratio of 1.2 noted higher yield attributes, yield, net income and B: C ratio. Whereas higher water use efficiency (80.4 kg m^{-3}) was recorded in irrigation scheduling of IW/CPE ratio 1.0 up to maturity. In intercrop practices, rice alone recorded higher yield attributes, yield and WUE. However, rice + black gram (2:1 ratio) intercropping system was noted in higher net income and B: C ratio. Hence, aerobic rice is highly suitable for low water resource areas. Adopting intercropping system in aerobic rice with irrigation scheduling of IW/CPE ratio of 0.8 upto PI thereafter IW/CPE ratio of 1.2 and rice + black gram intercrop system to obtain sustainable yield advantage over sole crop yield and increases the standard of living of the farmer through the higher yield in the water-limited condition.

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