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Studies on effect of weed management practices on growth and yield of different rice varieties under aerobic rice system

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Abstract
The experiment was laid out in a split-plot design with three replications and comprises two factors. Four weed management practices viz., weed-free up to 30 DAS (W_1), weed-free up to 45 DAS (W_2), weed-free up to 60 DAS (W_3) and unweeded control (W_4) in main plot and six rice varieties viz., 'DRR Dhan-44' (V_1), 'Sahabhagidhan' (V_2), 'DRR Dhan-41' (V_3), 'DRR Dhan-42' (V_4), 'DRR Dhan-46' (V_5) and 'HUR-3022' (V_6) in sub plots. The results showed that among weed management practices, weed-free up to 60 DAS (W_3) which was at par with weed-free up to 45 DAS (W_2) significantly enhanced growth attributes of rice, yield attributes, yield [grain and straw yield] and nutrient content and uptake as compared to weedy throughout the season (W_4). And among cultivars significantly higher under DRR Dhan-44 (V_1) which was at par with HUR-3022 (V_6) and was minimum in DRR Dhan-46 (V_5). Among different treatment combinations the minimum cost of cultivation and higher B:C ratio obtained under W_2V_1 (weed free up to 45 DAS + DRR Dhan-44) over others.

Keywords: Competitive, B:C ratio, cultivars, un-weeded

1. Introduction

Rice (*Oryza sativa* L.) is the most important cereal crop of the world, particularly in East and South East Asia, as it forms the staple diet for nearly 70 percent of the world's population. Rice is mainly grown by transplanting 25-30 days-old seedlings into puddled fields and requires a huge amount of water and labour during transplanting. Due to urbanization and industrialization, the availability of water and labour for agriculture is declining steadily. With increasing water scarcity, the conventionally flooded rice system is losing its sustainability and economic viability (Guerra *et al.*, 1998, Bhushan *et al.*, 2007) [9, 3]. Therefore there is a need to develop alternate systems which are technically viable and economically feasible for growing rice in this area; result of it is development of aerobic rice concept. This is an irrigated system in which rice is direct-seeded in dry soil and irrigation is applied to keep the soil sufficiently moist for crop growth but not saturated (Tuong and Bouman, 2003) [22]. Compared with lowland rice, aerobic rice can reduce water use by as much as 50% while maintaining a moderately high yield (Tuong and Bouman, 2003) [22].

The major impediment to the successful cultivation of aerobic rice is a heavy infestation of weed. This invites severe competition between weeds and rice thus reducing the crop yield on an average of 50-60 percent. Early weed control is essential in aerobic rice. Therefore, any effort to mitigate the ill effect of crop-weed competition in the early stages of crop growth will go a long way in increasing resource use efficiency and to achieve higher yields in aerobic rice.

Upland rice growers usually hand-weed their crop two or three times per season, Hand weeding is environment-friendly but it is labour-intensive. Though mechanical weeding is possible in aerobic rice, it leads to loss of seedlings at an early stage of crop growth. The herbicides have been proven effective in many cases (De Datta and Lagas, 1984) [5]. But, intensive herbicide use can cause environmental contamination and the development of herbicide resistance (Fischer *et al*., 1993, Labrada, 2003 and Zhao *et al*., 2006) [7, 11, 25]. Recently, attention has shifted to integrate non-chemical methods of weeds control into the current farming systems to reduce herbicide use (Mcdonald, 2003) [12], such as the development of competitive rice cultivars which provide a safe and environmentally benign tool for integrated weed management (Fischer *et al*., 1993) [7]. Differences between rice cultivars in response to weed competition have been recognized (Suzuki *et al*., 2002; Estorninos *et al*., 2005; Zhao *et al*., 2007) [20, 6, 24]. The present study was undertaken to evaluate the competitive ability of several rice varieties against weeds under aerobic condition to select suitable rice varieties.

2. Material and Methods

2.1 Experimental site

A field experiment was conducted during *kharif* season of 2017 at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. This region falls in semi-arid to the sub-humid type of climate. Normally, the period for the start of monsoon in this region is the third week of June and it lasts up to the end of September or sometimes extends up to the first week of October. Long-term average (over 1941 to 2004) of annual rainfall for this region amounts to 1081.5 mm, out of which 944.5 mm (87.33 percent) is received during the summer monsoon or rainy season (June to September) and 137.0 mm (12.67 percent) during the post-monsoon season or post rainy season. The soil type at the experimental site is sandy clay loam in texture with 7.3 pH, 0.44% organic carbon and 189, 26 and 204 kg/ha of available N, P and K, respectively.

2.2 Experimental design and treatments

The experiment was laid out in a split-plot design with three replications and comprises two factors. Four weed management practices viz., weed-free up to 30 DAS (W_1), weed-free up to 45 DAS (W_2), weed-free up to 60 DAS (W_3) and unweeded control (W_4) were assigned to main plot and six rice varieties viz., 'DRR Dhan-44' (V_1), 'Sahabhagidhan' (V_2), 'DRR Dhan-41' (V_3), 'DRR Dhan-42' (V_4), 'DRR Dhan-46' (V_5) and 'HUR-3022' (V_6) were assigned in sub plots.

2.3 Crop management

The experimental area was ploughed with a tractor just after harvest of winter crop and ploughed again in the last week of May month. Thereafter, the field was ploughed, levelled and well prepared. The main plot weed management treatments were kept weed-free by manual weeding and seeds of each variety were sown manually by dibbling in each plot at 20-cm row spacing, on 15 June 2017. A uniform dose of 90 kg N + 40 kg P_2O_5 + 40 kg K_2O + 5 kg $ZnSO_4$ ha^{-1} was applied in all the treatments in the form of Urea, DAP, MOP and $ZnSO_4$, respectively. Half of total N and a full dose of P_2O_5, K_2O and $ZnSO_4$ were applied as basal and remaining half dose of N was top dressed in two equal splits at active tillering (30 DAS) and panicle initiation stage (55 DAS).

2.4 Data collection

A weed count for estimating weed density and weed dry weight were recorded with the help of a quadrate of 1 m^2 placed randomly in each plot. Weeds were clipped to ground level, identified and counted by species, and separately oven dried at 70°C for 72 hours. Weed density (WD) and weed dry weight (WDW) were expressed as number/m^2 and g m^{-2}, respectively. Weed control efficiency (%) was calculated by using the formula given by Tripathi and Mishra (1971) [21]. The height of five randomly selected plants were measured at 30, 60, 90 DAS and at harvest from the soil surface to the tip of the fully opened leaf. For dry matter accumulation of crop, 100 cm area was randomly selected from the sampling rows (leaving aside two border rows from each side) at a regular interval (30, 60, 90 DAS and at harvest). The plants were cut at collar region. The collected samples were oven dried at 70°C for 48 hours and weighed after 6 hrs. The weight thus obtained was recorded as the dry matter accumulation in gram per running meter. At maturity, yield components like panicle/m^2, fertility ratio and thousand-seed weight were recorded from five randomly selected plants. Each plot was hand harvested to record grain yield and straw yield.

3. Result and Discussion

3.1 Growth attributes

The data on plant height, number of tillers per m^{-2} and Dry matter accumulation (g) m^{-1} row length was influenced by weed management practices and varieties at throughout the crop stage and observations recorded at harvest are presented in Table 1.

In case of weed management practices, maximum plant height was recorded in weed-free up to 60 DAS (W_3) which was at par with weed-free up to 45 DAS (W_2) and 30 DAS (W_1) compared to weedy throughout the crop season. Taller plants in weed-free up to 60 DAS (W_3) was due to lesser weed density and weed dry matter which provide a suitable environment for vegetative growth. Maximum number of tillers m^{-2} and dry matter accumulation was recorded in weed-free up to 60 DAS (W_3) which was at par with weed-free up to 45 DAS (W_2) followed by weed-free up to 30 DAS (W_1) and minimum number of tillers m^{-2} and dry matter accumulation was recorded in Un weeded control (W_4) at all the stages of observations.

Among the varieties DRR Dhan-42 (V_4) attained maximum plant height which was at par with DRR Dhan-44 (V_1) followed by DRR Dhan-45 (V_5) and Saghabhagi Dhan (V_2).The minimum plant height was recorded with DRR Dhan-41 (V_3). Taller plants in DRR Dhan-44 (V_1) was probably due to lower weed infestation, better initial emergence and suitable environment of growth which might have resulted in more cell division and cell elongation in the meristematic tissues of plants which led to significant increase in the plant height. Similar findings have also reported by Mukherjee *et al.* (2008) [13], Anwar *et al.* (2012) [2] and Rahman *et al.* (2014).

DRR Dhan-44 (V_1) produced maximum number of tillers m^{-2} which was at par with DRR Dhan-42 (V_4) followed by HUR-3022 (V_6) and DRR Dhan-45 (V_5) and the minimum number of tillers m^{-2} was recorded with Sahabhagidhan (V_2). DRR Dhan-44 (V_1) had an opportunity of lowering weed infestation, better use of plant growth factors to increase the tillers per unit area. Reduced number of tillers under Sahabhagidhan (V_2) might have been due to the heavy occurrence of weeds resulting in a more crop-weed competition thereby lower number of tillers m^{-2}. Similar findings have also reported by Anwar *et al*. (2010) [1]. Higher dry matter accumulation was recorded with DRR Dhan-44 (V_1), It is owing to more number of tillers per unit area and plant height. As dry matter accumulation is positively related to a number of plants per unit row and a number of tillers m^{-2} and treatment which had higher both these attributes had more dry matter accumulation over other varieties and DRR Dhan-46 (V_5) resulted in lower dry matter accumulation. Similar findings have also reported by Anwar *et al*. (2010) [1].

3.2 Yield attributes

The yield attributes *viz*., a number of panicle m^{-2}, panicle length (cm), panicle weight (g), fertility ratio (%) and test weight (g) as influenced by weed management practices and different varieties are presented in Table (2).

Among weed management practices Significantly higher number of panicle m^{-2}, panicle length, panicle weight and test weight were recorded with weed-free up to 60 DAS (W_3) which was at par with weed-free up to 45 DAS (W_2) followed by weed-free up to 30 DAS (W_1) and lower with weedy throughout the crop season (W_4). The result indicated that increase in yield contributing characters was owing to low weed growth, minimum weed competition during the critical growth period. As a result, these conditions enabled the crop to make maximum use of inputs for the crop growth, and thereby for the formation and development of yield attributes. Yaduraju and Mishra (2004) [23], Mukherjee *et al.* (2008) [13], Khaliq *et al*. (2011) [10], Anwar *et al.* (2012) [2] and Rahman *et al.* (2014) have reported that the crop which had minimum weed growth during the critical period of crop growth had better growth and yield attributes.

Among different varieties significantly higher values of a number of panicles m^{-2}, panicle length, panicle weight (g) were recorded under DRR Dhan-42 (V_4) which was at par with DRR Dhan-44 (V_1) and HUR-3022 (V_6) (Table 4) and higher fertility ratio and test weight recorded under DRR Dhan-44 (V_1). Even though DRR Dhan-42 (V_4) recorded longer panicle length and higher panicle weight, but it has failed to produce a higher number of filled grains due to lack of photosynthates accumulation during vegetative phase of crop growth. Yield attributing characters are the function of growth and development that developed during vegetative phase of the plant. A higher value of yield attributes under DRR Dhan-44 (V_1) is perhaps due to the better partitioning of photosynthates from source to sink as a result of lower crop-weed competition and better crop growth (Table 2) which was obtained owing to the favourable growing condition. The result is in close proximity to those obtained by Prasad *et al*. (2001) [14], Subbalakshmi and Pandian (2002) [18], and Sunyob *et al*. (2015) [19].

3.3 Grain and straw yield

Yield is the result of the coordinated interplay of growth characters *viz*., plant height, number of tiller $hill^{-1}$, dry matter accumulation m^{-1} row, and yield attributes *viz*., number of panicles m^{-2}, grains per panicle, panicle length, panicle weight and 1000-grain matter. Grain and straw yield (Table 3) were significantly influenced by weed management practices and different varieties and these values were significantly higher under weed-free up to 60 DAS (W_3) which was at par with weed-free up to 45 DAS (W_2) followed by weed-free up to 30 DAS (W_1) and lowest values were observed in weedy throughout the crop season (W_4). The increased grain and straw yield was perhaps the result of reduced weed population and their dry matter under weed-free up to 60 DAS (W_3).

Among different varieties, these values were higher under DRR Dhan-44 (V_1) which was at par with HUR-3022 (V_6). The increased grain and straw yield in DRR Dhan-44 (V_1) and HUR-3022 (V_6) was due to better weed competitive ability, weed suppression and the improvement of yield attributes like number of panicle bearing tillers, number of grains per panicle, panicle length, test weight and more nutrient uptake by crop. The minimum grain and straw yield was recorded under DRR Dhan-46 (V_5). This might be due to less weed competitive ability, higher weed population and their dry matter, crop-weed competition and lower yield attributes. These findings are in conformity with that of Singh *et al.* (2005) [17] and Singh *et al.* (2006) [16].

3.2.4 Nutrient content, uptake by grain and straw

Nutrient uptake by grain and straw is the function of N, P and K content with its corresponding yield. Weed management practices significantly influenced N, P and K content and uptake by varieties. It is apparent from data that in case of weed management practices significantly maximum N content was recorded under weed-free up to 60 DAS (W_3) which was at par with weed-free up to 30 DAS (W_1) and 45 DAS (W_2) in both grain and straw (Table 4) and significantly maximum P and K content was recorded under weed-free up to 60 DAS (W_3) which is at par with weed-free up to 45 DAS (W_2) in both grain and straw (Table 4).

It is apparent from data that in case of weed management practices significantly maximum N, P and K uptake was recorded under weed-free up to 60 DAS (W_3) in both grain and straw (Table 4).

Among different varieties it was higher under DRR Dhan-44 (V_1) as this cultivar reduced the weed population as well as led to minimum weed population, weed dry matter, more plant dry matter production and minimum nutrient depletion by weeds and subsequently more availability of these nutrients to the crop which ultimately increased NPK uptake by the crop as well as grain and straw. While minimum uptake of this nutrient was recorded in DRR Dhan-46 (V_5) due to higher losses of applied nutrients through associated weeds (Table 4). The results are in close proximity to Choubey *et al*. (1998).

3.5 Economics

The adoption of any technology in modern agriculture can only be feasible and acceptable to farmers if it is economically viable. Economic viability is a function of gain and loss. Thus, it is more important to justify the increase in economic yield with respect to expenditure involved.

The data on the economics of various weed management practices revealed that the higher net return and benefit: cost ratio was obtained with weed-free up to 60 DAS (W_3) which was at par with weed-free up to 45 DAS (W_2), respectively. The higher net return and benefit: cost ratio under this treatment was mainly due to lower weed infestation and more grain yield. Rahman *et al*. 2014 and Mukherjee *et al*., 2011 also had the similar findings.

DRR Dhan-44 (V_1) recorded maximum net return and benefit: cost ratio, which was at par with HUR-3022 (V_6). Higher net return and benefit: cost ratio might be due to more weed competitive ability, weed suppression and higher grain and straw yield under this treatment, which led to maximum net return and benefit: cost ratio. Minimum net return and benefit: cost ratio was obtained with DRR Dhan-46 (V_5), respectively. It might be due to higher weed infestation was pronounced in one hand and production of lower grain yield on another hand, which resulted in a lower net profit as compared to other varieties.

4. Conclusion

1. Weed-free up to 45 DAS (W_2) and 60 DAS (W_3) were statistically on par and weed free condition up to 45 DAS (W_2) was found sufficient to maintain lower weed competition, higher crop growth and grain yields.
2. Rice varieties DRR Dhan-44 (V_1) and HUR-3022(V_6) were found most effective in enhancing crop growth, yield attributes, grain yield and N, P, K uptake in grain and straw.
3. Among different treatment combinations the minimum cost of cultivation and higher B:C ratio obtained under W_2V_1 (weed free up to 45 DAS+DRR Dhan-44) over others.

Table 1: Effect of weed management practices and varieties on plant height, number of tillers m^{-2} and dry matter accumulation at harvest stage of rice.

Treatments	Plant height (cm)	No. of tillers m^{-2}	Dry matter accumulation (g)
Weed Management Practices			
W_1 (Weed free up to 30 DAS)	95.29	182.41	93.58
W_2 (Weed free up to 45 DAS)	97	199.5	99.82
W_3 (Weed free up to 60 DAS)	97.6	223.75	100.69
W_4 (Unweeded control)	93.32	137.5	86.7
SE.m±	0.63	7.04	1.39
C.D.(P=0.05)	2.82	39.41	6.28
Varieties			
V_1- DRR Dhan-44	103.06	206.25	111.73
V_2- Sahabhagidhan	95.15	148.75	91.95
V_3- DRR Dhan-41	84.075	156.25	98.61
V_4- DRR Dhan-42	105.35	222.87	102.82
V_5- DRR Dhan-46	96.91	192.5	82.12
V_6- HUR-3022	90.27	188.12	83.31
SE.m±	0.87	8.35	1.37
C.D.(P=0.05)	2.57	24.64	4.03

Table 2: Effect of weed management practices and varieties on different yield attributes of rice.

Treatments	No of panicle m^{-2}	Panicle length (cm)	Panicle weight (g)	Fertility ratio (%)	Test weight (g)
Weed Management Practices					
W_1 (Weed free up to 30 DAS)	149.42	26.13	2.42	74.45	22.50
W_2 (Weed free up to 45 DAS)	161.25	26.74	2.79	76.21	22.85
W_3 (Weed free up to 60 DAS)	170.92	28.38	2.95	81.15	23.09
W_4 (Unweeded control)	63.08	24.74	1.96	58.67	21.11
SE.m±	0.32	0.43	0.11	3.13	0.23
C.D.(P=0.05)	5.78	1.92	0.50	14.07	1.05
Varieties					
V_1- DRR Dhan-44	145.38	27.38	3.06	83.29	23.49
V_2- Sahabhagidhan	129.88	23.41	1.88	69.40	21.41
V_3- DRR Dhan-41	126.63	25.91	2.06	74.33	22.46
V_4- DRR Dhan-42	146.13	28.51	3.26	67.84	22.38
V_5- DRR Dhan-46	127.00	26.29	1.89	63.21	21.65
V_6- HUR-3022	142.00	27.48	3.04	77.65	22.95
SE.m±	1.99	0.41	0.10	3.09	0.34
C.D.(P=0.05)	5.86	1.22	0.29	12.03	1.02

Table 3: Effect of weed management practices and varieties on grain yield, straw yield and harvest index of rice.

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
Weed Management Practices			
W_1 (Weed free up to 30 DAS)	2.76	7.07	29.51
W_2 (Weed free up to 45 DAS)	3.46	8.71	28.43
W_3 (Weed free up to 60 DAS)	4.11	9.0	31.46
W_4 (Unweeded control)	1.02	4.29	19.15
SE.m±	0.15	0.37	1.54
C.D.(P=0.05)	0.66	1.69	6.91
Varieties			
V_1- DRR Dhan-44	3.69	9.58	27.12
V_2- Sahabhagidhan	2.29	6.09	26.22
V_3- DRR Dhan-41	2.70	8.19	22.89
V_4- DRR Dhan-42	2.53	7.69	23.34
V_5- DRR Dhan-46	2.27	5.21	29.10
V_6- HUR-3022	3.55	6.84	34.16
SE.m±	0.14	0.38	1.40
C.D.(P=0.05)	0.43	1.12	2.39

Table 4: Effect of weed management practices and varieties on N, P and K content in grain and straw.

Treatments	Nutrient content (%) in rice					
	Nitrogen		Phosphorus		Potassium	
	Grain	Straw	Grain	Straw	Grain	Straw
Weed Management Practices						
W_1 (Weed free up to 30 DAS)	1.162	0.54	0.4	0.22	0.23	0.96
W_2 (Weed free up to 45 DAS)	1.22	0.58	0.44	0.25	0.24	0.98
W_3 (Weed free up to 60 DAS)	1.23	0.59	0.47	0.26	0.25	1.17
W_4 (Unweeded control)	1.1	0.48	0.39	0.21	0.2	0.59

SE.m±	0.02	0.01	0.01	0.00	0.00	0.01
C.D.(P=0.05)	0.07	0.06	0.05	0.01	0.01	0.05
Varieties						
V_1- DRR Dhan-44	1.2	0.64	0.53	0.3	0.3	1.18
V_2- Sahabhagidhan	1.13	0.51	0.35	0.2	0.23	0.91
V_3- DRR Dhan-41	1.22	0.53	0.4	0.2	0.21	0.81
V_4- DRR Dhan-42	1.22	0.55	0.47	0.26	0.23	0.96
V_5- DRR Dhan-46	1.21	0.55	0.46	0.18	0.21	0.87
V_6- HUR-3022	1.07	0.52	0.34	0.27	0.21	0.79
SE.m±	0.02	0.01	0.01	0.00	0.00	0.01
C.D.(P=0.05)	0.05	0.02	0.02	0.00	0.01	0.03

Table 5: Effect of weed management practices and varieties on cost of cultivation, gross return, net return and B:C ratio.

Treatments	Cost of Cultivation (Rs)	Gross returns (Rs)	Net returns (Rs)	B:C ratio
Weed Management Practices				
W_1 (Weed free up to 30 DAS)	32169.4	67633.33	35463.95	2.10
W_2 (Weed free up to 45 DAS)	33909.4	84231.79	50322.41	2.48
W_3 (Weed free up to 60 DAS)	35649.4	95296.18	59646.8	2.67
W_4 (Unweeded control)	28689.4	30847.32	2157.94	1.08
SE.m±		2662.35	2662.35	0.08
C.D.(P=0.05)		11982.35	11982.35	0.36
Varieties				
V_1- DRR Dhan-44	28689.4	90746.82	58142.44	2.74
V_2- Sahabhagidhan	28689.4	56968.9	24364.52	1.72
V_3- DRR Dhan-41	28689.4	70601.28	37996.9	2.10
V_4- DRR Dhan-42	28689.4	66163.47	33559.09	1.98
V_5- DRR Dhan-46	28689.4	53482.26	20877.88	1.59
V_6- HUR-3022	28689.4	79050.21	46445.83	2.37
SE.m±		3218.05	3218.05	0.10
C.D.(P=0.05)		9493.24	9493.24	0.28

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