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Weed management practices effect on weed dynamics of different rice varieties under aerobic rice system

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Abstract
Experiment was carried out at Banaras Hindu University, Varanasi. The results indicated that, weed flora of the experiment plot comprised of fourteen weed species belonging to seven families. Sedges and grasses were the most dominant species at early growth stage of rice, but with the advancement of time, sedges and grasses were gradually replaced by broadleaf weeds. Weed density and weed dry matter was lower in weed-free up to 60 DAS (W_3). Weedy check (W_4) showed the highest weed density and weed dry matter. Among cultivars, significantly lower weed population and weed dry matter was recorded in DRR Dhan-44 (V_1) and higher weed density and weed dry matter was recorded in DRR Dhan-46 (V_5). Weed control efficiency was recorded to the tune of 76.17 – 100 %, with highest in weed-free up to 60 DAS (W_3) (100 %) and lowest in weed-free up to 30 DAS (W_1) (76.17 %). Among cultivars, Weed control efficiency was to the tune of 61.39 – 67.87 %, with highest in DRR Dhan-44 (V_1) (67.87) and lowest in DRR Dhan-46 (V_5) (61.39 %). Weed free up to 60 DAS (W_3) and Weed free up to 45 DAS (W_2) were statistically on par and Weed free up to 45 DAS (W_2) is effective in arresting weeds and to prevent yield losses as compared to other weed management treatments and among different varieties, DRR Dhan-44 (V_1) is found most competitive and effective in minimizing the population of weeds, weed dry weight and nutrient depletion by weeds.

Keywords: B:C ratio, competitive, nutrient depletion, weed density

1. Introduction
Rice (*Oryza sativa* L.) is the most important cereal crop of the world and is predominantly grown by transplanting seedlings, this practice consumes about 150 ha-cm of water and engagement of labour for transplanting and weeding (Mahajan and Chauhan 2016). With increasing water scarcity, the conventionally flooded rice system is losing its sustainability and economic viability (Bhushan *et al.*, 2007) [1]. 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) [11].
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) [2]. But, intensive herbicide use can cause environmental contamination and the development of herbicide resistance (Labrada, 2003 and Zhao *et al*., 2006) [6, 12]. Recently, attention has shifted to integrate non-chemical methods of weeds control into the current farming systems to reduce herbicide use (Mcdonald, 2003) [7], such as the development of competitive rice cultivars which provide a safe and environmentally benign tool for integrated weed management (Fischer *et al*., 2001). Differences between rice cultivars in response to weed competition have been recognized (Suzuki et al., 2002; Estorninos et al., 2005; Zhao et al., 2007) [9, 3, 13]. The present study was undertaken to evaluate the competitive ability of rice varieties against weeds under aerobic condition to select suitable rice varieties.

2. Material and Methods

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. 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. 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). At sampling time for estimating weed count, 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 oven dried at 70°C for 72 hours. Weed density (WD) and weed dry weight (WDW) were expressed as no m^{-2} and g m^{-2}, respectively. Weed control efficiency (%) was calculated by using the formula given by Tripathi and Mishra (1971.

3. Results and discussion.

3.1. Weed Composition.

Weed flora of the experiment plot comprised of fourteen weed species belonging to seven families. Among grasses, *Cynodon dactylon* (L.), *Echinochloa colona* (L.) and *Echinochloa crusgalli* (L.) were the prominent weeds. Among sedges, *Cyperus rotund*us (L.), *Cyperus difformis* (L.), *cyperus iria* (L.) and *Fimbristylis maliaceae* (L.) were most dominant. In broad-leaved weeds, *Caesulia axillaris* (L.), *Phyllanthus niruri* (L.) and *Anagallis arvensis* (L.) were dominant weeds during the investigation period (Table 1).

3.2. Weed Species Dominance Pattern.

In general, the total population of weeds increased gradually up to 60 DAS and thereafter it decreased. *Cyperus rotund*us (L.), *Cyperus difformis* (L.), *cyperus iria* (L.) and *Fimbristylis maliaceae* (L.) representing sedge group and *Echinochloa crusgalli* (L.) among grasses group, were the most dominant species at early growth stage of rice, But with the advancement of time, sedges and grasses were gradually replaced by broadleaf weeds. *Caesulia axillaris* (L.) and *Anagallis arvensis* (L.) were the broadleaf weeds started dominating the community from mid growth stage of rice till maturity.

3.2 Weed Density

Weed density of different weeds were recorded species wise at 50 and 70 DAS and Weed pressure of grasses, sedges and broad leaf weeds in terms of weed density is lower in weed-free up to 60 DAS (W_3) followed by weed free up to 45 (W_2) and 30 DAS (W_1). Weedy check (W_4) showed the highest weed density. Lower weed density in weed-free up to 60 DAS (W_3) might have been due to the field was kept weed-free up to 60 days. Among the cultivars, significantly higher weed population was recorded in DRR Dhan-46 (V_5) over other varieties. In contrast to this, lowest weed population was recorded in DRR Dhan-44 (V_1) followed by HUR-3022 (V_6) (Table 2). DRR Dhan-44 (V_1) cultivar showed better weed competitive ability and weed suppression because of its more vigorous growth and droopy lower leaves as compared to the other tested varieties. Vigorous crop growth and droopy lower leaves were responsible for curtailing the sunlight for profuse weed growth which ultimately reduced weed infestation Sunyob *et al.* (2015) [8].

3.3 Weed Dry matter

Dry weight of weeds was recorded at 60 DAS. In general total weed, dry matter increased up to 70 DAS and thereafter a decreasing trend was noticed irrespective of different varieties (Table 4). It might be due to the fact that at later stages, the growth of weeds ceased because of the fact that most of the weeds like *Phyllanthus niruri* and *Cyperus difformis* had completed their life cycle that resulted in reduced total weeds dry matter accumulation. The maximum dry matter of weeds was recorded in a un-weeded control (W_4) followed by weed-free up to 30 DAS (W_1) and lowest dry matter of weeds was found in weed-free up to 60 DAS (W_3). Highest weed dry matter was recorded under DRR-Dhan-46 (V_5) and lowest in DRR Dhan-44 (V_1) (Table 4). The occurrence of less number of weed species and lower population per $unit^{-2}$ area is due to more vigorous growth and droopy lower leaves as compared to the other tested varieties. This resulted in significant decrease of weed dry matter under DRR-Dhan-44 (V_1).

3.4 Weed control efficiency (%)

The results revealed that, among weed management practices, weed free up to 60 DAS (W_3) showed highest weed control efficiency, followed by weed free up to 45 DAS (W_1) and weed free up to 30 DAS (W_2). Un-weeded control (W_4) showed least weed control efficiency.

It is evident from the data presented in Table 4 among different varieties DRR Dhan-44 (V_1) showed higher weed control efficiency which was on par with HUR-3022 (V_6), DRR Dhan-41 (V_3) and DRR Dhan-42 (V_4) followed by Sahabhagi dhan (V_2). DRR Dhan-46 (V_5) showed the lower weed control efficiency.

3.5 Nutrient (N, P, K) depletion by weeds (kg ha^{-1})

The results revealed that, among weed management practices, unweeded control (W_4) depleted highest amount of nitrogen, phosphorus and potassium significantly over other treatments and weed free up to 60 DAS (W_3) depleted least. It is evident from the data presented in Table 4 that different varieties differed significantly in nitrogen, phosphorus and potassium depletion by weeds. Since the cultivar DRR Dhan-46 (V_5) promoted higher weeds growth and thereby removed significantly higher nitrogen, phosphorus and potassium by weeds as compared to other varieties. The minimum nitrogen, phosphorus and potassium were depleted by weeds in the treatment DRR Dhan-44 (V_1) (Table 4).

It is concluded that 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, weed density and weed biomass and higher weed control efficiency. Rice varieties DRR Dhan-44 (V_1) and HUR-3022(V_6) have better weed competitive ability and weed suppression.

Table 1: Weed flora of the experimental field.

Weeds	Botanical Name	English Name	Family
1. Grasses	*Cynodon ductylon* (L.)	Bermuda grass	Poaceae
	Echinochloa crusgalli (L.)	Barnyard grass	Poaceae
	Echinochloa colona (L.)	Jungle rice	Poaceae
	Eleusine indica (L.)	Goose grass	Poaceae
	Dactyloctenium aegyptium (L.)	Crow foot grass	Poaceae
2 Sedges	*Cyperus irria* (L.)	Yellow nut sedges	Cyperaceae
	Cyperus difformis (L.)	Umbrella sedge	Cyperaceae
	Fimbristylis miliaceae (L.)	Globe fringerush	Cyperaceae
3. Broad-leaved	*Amaranthus viridis* (L.)	Amarantha	Amaranthaceae
	Caesulia axillaris (L.)	Pink node flower	Compositae
	Commelina benghalensis (L.)	Day flower	Commelinaceae
	Corchorus acutangul (L.)	Wild jute	Tiliaceae
	Eclipta alba (L.)	Mukand	Compositae
	Phyllanthus niruri (L.)	Anwla	Euphorbiaceae

Table 2: Effect of weed management practices and varieties on the population of grasses, sedges and broad leaf weeds at different growth stages of rice.

Treatments	Grasses		Sedges		Broad leaf weeds	
	Density (No. m^{-2})		Density (No. m^{-2})		Density (No. m^{-2})	
	50 DAS	70 DAS	50 DAS	70 DAS	50 DAS	70 DAS
Weed Management Practices						
W1(Weed free up to 30 DAS)	(7.22)2.74	(1.50)1.37	(27.61)5.26	(24.89)5.01	(9.61)3.14	(3.50)1.97
W2(Weed free up to 45 DAS)	(5.94)2.49	(1.17)1.24	(23.06)4.76	(23.56)4.88	(7.06)2.69	(3.06)1.84
W3 (Weed free up to 60 DAS)	(4.83)2.25	(0.94)1.15	(16.89)4.04	(21.83)4.68	(6.33)2.53	(2.56)1.69
W4 (Unweeded control)	(8.28)2.90	(5.39)2.39	(30.33)5.47	(30.17)5.51	(10.61)3.28	(6.28)2.53
SE.m±	0.026	0.020	0.031	0.089	0.057	0.049
C.D.(P=0.05)	0.09	0.07	0.11	0.31	0.2	0.17
Cultivars						
V1- DRR Dhan-44	(5.08)2.31	(1.58)1.14	(21.33)4.60	(21.67)4.69	(7.08)2.69	(2.92)1.79
V2- Sahabhagi Dhan	(7.33)2.74	(2.50)1.62	(24.67)4.90	(27.33)5.24	(8.92)2.99	(4.42)2.10
V3- DRR Dhan-41	(6.33)2.57	(2.33)1.53	(22.50)4.67	(25.42)5.08	(7.92)2.83	(3.67)2.02
V4- DRR Dhan-42	(7.33)2.74	(2.50)1.61	(23.58)4.78	(25.50)5.07	(8.42)2.92	(3.83)2.02
V5- DRR Dhan-46	(7.42)2.75	(2.75)1.66	(34.42)5.67	(27.83)5.27	(10.83)3.32	(4.92)2.23
V6- HUR-3022	(5.92)2.46	(1.83)1.40	(22.33)4.66	(22.92)4.77	(7.25)2.70	(3.33)1.90
SE.m±	-	-	-	0.25	-	0.25
C.D.(P=0.05)	NS	NS	NS	0.85	NS	0.85

*Data subjected to square root transformation. Actual figures are given in parenthesis.

Table 3: Effect of weed management practices and varieties on dry matter accumulation of weeds and weed control efficiency.

Treatments	Dry matter accumulation (gm) (@70 DAS)	Weed control efficiency (%)
Weed Management Practices		
W_1 (Weed free up to 30 DAS)	4.86 (36.45)	76.17 (8.75)
W_2 (Weed free up to 45 DAS)	5.7 (20.62)	86.51 (9.32)
W_3 (Weed free up to 60 DAS)	2.87 (0)	100 (10.02)
W_4 (Un-weeded control)	8.21 (206.33)	0 (0.71)
SE.m±	0.30	0.19
C.D.(P=0.05)	1.05	2.02
Cultivars		
V_1- DRR Dhan-44	4.17 (47.9)	67.87 (7.32)
V_2- Sahabhagi Dhan	5.23 (77.65)	64.68 (7.15)
V_3- DRR Dhan-41	5.22 (65.43)	66.70 (7.26)
V_4- DRR Dhan-42	5.25 (68.67)	65.81 (7.21)
V_5- DRR Dhan-46	7.01 (87.31)	61.39 (6.96)
V_6- HUR-3022	5.57 (48.15)	67.54 (7.31)
SE.m±	0.42	0.16
C.D.(P=0.05)	1.23	2.11

*Data of subjected to square root transformation. Actual figures are given in parenthesis.

Table 4: Effect of weed management practices and varieties on N, P and K depletion (kg ha^{-1}) by weeds.

Treatments	N	P	K
Weed Management Practices			
W_1 (Weed free up to 30 DAS)	4.69	2.72	4.98
W_2 (Weed free up to 45 DAS)	4.24	2.69	4.83
W_3 (Weed free up to 60 DAS)	3.53	2.21	4.51
W_4 (Unweeded control)	5.4	3.39	5.54
SE.m±	0.16	0.15	0.12
C.D.(P=0.05)	0.70	0.65	0.53
Varieties			
V_1- DRR Dhan-44	4.13	2.53	4.62
V_2- Sahabhagidhan	4.43	2.79	4.94
V_3- DRR Dhan-41	4.38	2.68	4.85
V_4- DRR Dhan-42	4.43	2.74	4.99
V_5- DRR Dhan-46	5.03	2.96	5.22
V_6- HUR-3022	4.41	2.81	5.19
SE.m±	0.08	0.04	0.04
C.D.(P=0.05)	0.23	0.11	0.11

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