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RESEARCH ARTICLE

Management of invasive aquatic weeds *Limnocharis* and *Monochoria* in wetland rice

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ABSTRACT

Aquatic weeds often pose a serious threat to wetland rice production. An experiment was conducted at All India Coordinated Research Project (AICRP) on Weed Management, Kerala Agricultural University, India to evaluate the performance of post-emergence herbicides for the management of two broad-leaf aquatic weeds *Limnocharis flava* and *Monochoria vaginalis* during the rainy *(Kharif)* and winter *(Rabi)* seasons of 2022. The experiment was laid out with eleven treatments, consisting of recommended dose of 2,4-D-sodium salt, penoxsulam + butachlor, penoxsulam + pendimethalin, metsulfuron-methyl + chlorimuron-ethyl, florpyrauxifen-benzyl, bispyribac-sodium, penoxsulam + cyhalofop-butyl, carfentrazone-ethyl, pretilachlor + pyrazosulfuron-ethyl, hand weeding at 20 and 40 days after transplanting and un-weeded control. Weed management treatments had significant effect on the weed density, weed dry matter, and crop yield. Post-emergence application of 2,4-D-sodium salt and florpyrauxifen-benzyl as well as hand weeding twice resulted in total control of both *Limnocharis falva* and *Monochoria vaginalis*. All the herbicides applied along with a wetting agent recorded 70-100% weed control efficiency. 2,4-D Na salt and hand weeding twice produced the highest grain yield and straw yields followed by florpyrauxifen-benzyl. Season-long weed competition caused 68% reduction in the grain yield in un-weeded plot. The findings provide an array of herbicides which can be included in herbicide rotation for broad-spectrum weed control, especially *Limnocharis* and *Monochoria* in wetland rice fields

Keywords: Correlation, Florpyrauxifen, Rice herbicides, Principal component analysis, Weed control efficiency

INTRODUCTION

A wide variety of aquatic weeds infest rice fields, including submerged, emergent, and floating species. Their rapid growth rates, efficient reproduction, and highly competitive ability reduce crop yield and impair ecosystem services. *Limnocharis flava* (L.) Buchenau, commonly known as water cabbage or yellow burr head, is an emergent aquatic plant belonging to the family Limnocharitaceae. It is native to tropical and subtropical America, and it has become naturalized in Southern and Southeast Asia, including parts of India. *L. flava* inhabits shallow swamps, ditches, and wet rice fields, occurring usually in stagnant fresh water. *Monochoria vaginalis* (Burm. f.) Kunth commonly called as oval-leaf pond weed or heartleaf false pickerel weed, is a submerged or emergent weed that features slender stems and lilac flowers. It is also a native of Southeast Asia and Africa, and now common in tropical and subtropical regions and reproduces both through seeds and vegetative means. It readily adapts to various water depths and thrives in nutrient-rich environments. Its rapid vegetative spread and high seed production facilitate its establishment and dominance in wetland rice fields (Brooks *et al*. 2008). In Iran, *Monochoria* reduced rice yields to the tune of 32% when the infestation lasted throughout the season (Hazrati *et al*. 2003). It is often gregarious and highly competitive because of its discontinuous germination, rapid growth, and high plasticity (Athira *et al*. 2019).

Severe infestation of these two weeds has been observed recently in the wetland rice ecosystems of Kerala. *L. flava* exhibits vigorous vegetative growth, smothering the rice crop by the time of harvest. During mechanized harvesting, weeds get along with the harvested rice grains, increasing their moisture content, creating conditions conducive for fungal growth. The mouldy appearance on the grains significantly impacts the quality and marketability of the produce.

Management of these aquatic weeds is not easy and varied strategies have to be adopted depending on the agro-ecology. Chemical management using herbicides is an easy and cost-effective option for managing aquatic weeds in wetland rice. Several herbicides such as paraquat, glyphosate, glufosinate ammonium, carfentrazone-ethyl, imazethapyr, 2,4-D, endothall, diquat, fluoridone, florpyrauxifen-benzyl,

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penoxsulam, cyhalofop-butyl, butachlor, and imazamox have been evaluated in different countries for management of these weeds with varying degree of success in tank cultures (Wersal and Madsen 2012, Garlich *et al*. 2021). The present study was conducted to evaluate the efficacy of new herbicide molecules against aquatic weeds *L. flava* and *M. vaginalis* in transplanted rice under wetland ecology of Kerala.

MATERIALS AND METHODS

The study was conducted at the State Seed Farm, Mannuthy (10°32’27"N 76°15’46"E), Kerala, India during rainy *(Kharif)* and early winter *(Rabi)* seasons of 2022. The study period extended from June to September and September to December. The average maximum temperature and minimum temperature were 30.2 °C and 23.6°C for *Kharif*, and 31.8°C and 23.4°C for early *Rabi*, respectively. The corresponding weather data are illustrated in **Figure 1**. The soil of the experimental field was clay loam (20.5% sand, 22.3% silt, and 57.28% clay) with a pH of 5.10, EC 0.004 dS/m, OC 0.82%, available N 265 kg/ha, available P 35 kg/ha, and available K 214 kg/ha.

The experiment was laid out in a randomized block design with eleven treatments replicated thrice. The treatments were 2,4-D Na salt (80 WP) 1000 g/ha (2,4-D); penoxsulam + butachlor (0.97+38.8 SE) 820 g/ha (PX + BU); penoxsulam + pendimethalin (1+24 SE) 625 g/ha (PX + PE); metsulfuron-ethyl + chlorimuron-ethyl (10+10WP) 4 g/ha (ME + CE); florpyrauxifen-benzyl (25 EC) 31.5 g/ha (FB); bispyribac-sodium (10SC) 25 g/ha (BS); cyhalofop-butyl + penoxsulam (5.1+1.02 OD) 150 g/ha (CY + PX); carfentrazone-ethyl (40 DF) 25 g/ha (CZE); pretilachlor + pyrazosulfuron-ethyl (30+0.75 WG) 600 + 15 g/ha (PR + PY); hand weeding at 20 and 40 DAT (HW); unweeded control (UWC). In the case of combination sprays, premix herbicides were used.

The rice variety ‘*Jyothi*’ (a short-duration high-yielding variety released from Kerala Agricultural University) was chosen for the experiment. The crop was transplanted at a spacing of 20 x 10 cm. FYM (5 t/ha) was incorporated at the time of the last ploughing. Fertilizers were applied 70:35:35kg/ha (N:P:K kg/ha). All the herbicides were applied as post-emergence at 18 DAT along with wetting agent 2ml/L. The spray volume used was 500 L/ha and backpack sprayer fitted with flat-fan nozzle was used for spraying.

Observations on density and dry weight of *L. flava* and *M. vaginalis* were recorded separately at 20, 40, and 60 DAT and at harvest. Weed control efficiency (WCE) was also computed. Yield and yield attributes were recorded at harvest.

Data on weed count and dry weight were subjected to square root transformation. The data generated were subjected to analysis of variance of RBD using the statistical package GRAPES (General R-shiny based Analysis Platform Empowered by Statistics) (Gopinath *et al*., 2023).

RESULTS AND DISCUSSION

Weed spectrum

The weed spectrum constituted *Limnocharis flava* (70%), *Monochoria vaginalis* (20%) and other weeds (10%) including *Echinochloa* spp., *Ludwigia parviflora* and *Sagittaria* sp.

Weed density and dry weight

Limnocharis flava

Treatments had significant effect on the density and dry weight of *L. flava* at 40 and 60 DAT and at harvest (**Table 1** and **2**). Post-emergence application of 2,4-D Na salt 1000 g/ha recorded the lowest weed density at 40 DAT during both seasons (1.00 and 1.67/m^2, respectively). However, at 60 DAT and

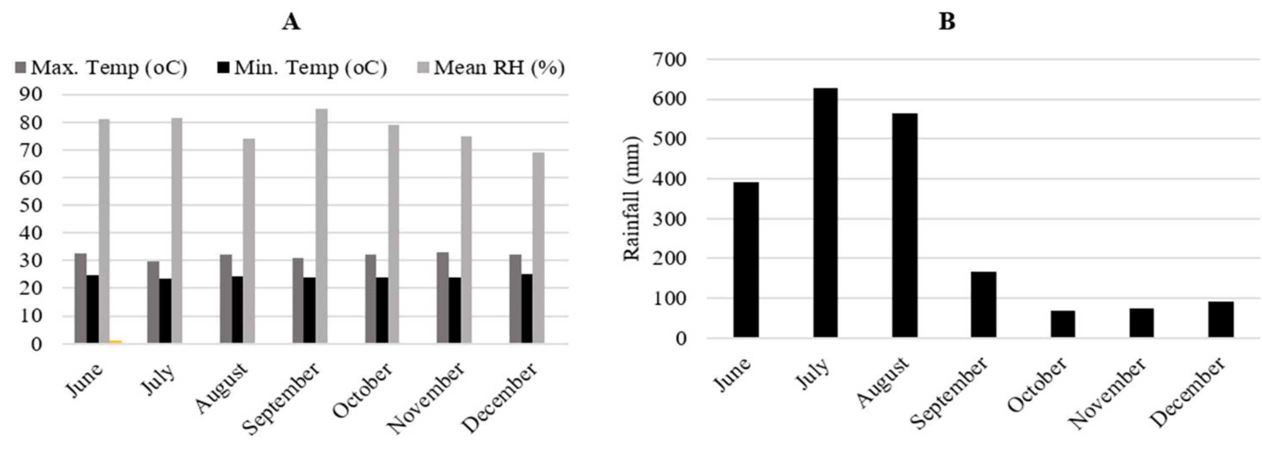


Figure 1. Monthly weather data - maximum and minimum temperature, mean relative humidity (A) and rainfall (B) during 2022

harvest, hand weeding twice registered the lowest weed density. All the herbicidal treatments were statistically comparable during both seasons at 40 DAT in terms of weed density. Un-weeded control had the highest weed density irrespective of the growth stages and seasons.

Post-emergence application of 2,4-D Na salt 1000 g/ha and florpyrauxifen-benzyl 31.5 g/ha registered negligible dry matter production of *L. flava* at 40 DAT during both the seasons, recording less than 1 g/m^2. At 60 DAT, all the herbicidal treatments recorded statistically comparable dry matter of weed during both seasons. HW twice at 20 and 40 DAT had a lower dry weight at all stages. The dry weight of *L. flava* was the highest in the unweeded control at all growth stages. Notably, the dry weight at harvest in the unweeded control was three times greater than that observed at 20 DAT

Monochoria vaginalis

The occurrence of *M. vaginalis* was observed exclusively during the *Kharif* season, attributed to the substantial rainfall from June to August (**Figure 1**). This weed was absent in the field during the later stages of the *Kharif* crop as well as during the *Rabi* season due to low rainfall. Chen and Kuo (1999) reported that flooding conditions and seasonal variation in light and temperature affected the seed germination of *Monochoria*. However, as *Limnocharis* can survive under wide regime of soil moisture and temperature (Lakitan *et al.* 2018); it was present in both seasons.

In the *Kharif* season, treatments had a significant effect on the density and dry weight of *M. vaginalis.* The weed density ranged from a maximum of 13 plants per square meter to a minimum of one plant per square meter. By 40 DAT, the post-emergence application of 2,4-D Na salt at 1000 g/ha resulted in the lowest density, while the un-weeded control exhibited the highest (**Figure 2**). All the herbicides were comparable with respect to weed density. In all the treatments the weed dry matter was less by 70 % over un-weeded plot.

Weed control efficiency

Limnocharis flava

Application of 2,4-D Na salt 1000 g/ha registered the highest weed control efficiency (WCE) during both seasons at 40 DAT (94 and 96 %, respectively), followed by bispyribac-sodium 25 g/ha in *Kharif* (91%) and florpyrauxifen-benzyl 31.5 g/ha in *Rabi* (93 %). In Malaysia, Juraimi, *et al* (2012) reported that though 2, 4-D is effective against *L. flava*, resistant

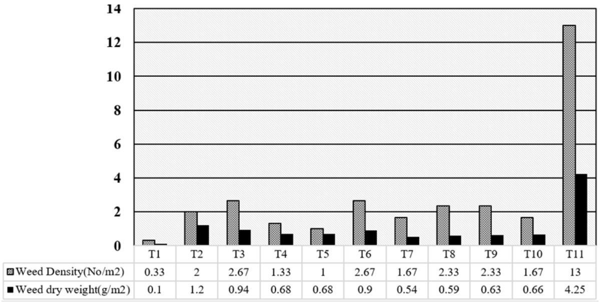
Table 1. Effect of weed management practices on density (no./m^2) of *L. flava* at different growth stages of rice

Treatment	20 DAT		40 DAT		60 DAT		Harvest	
	Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
2,4-D Na salt, 1000 g/ha	3.62 (12.67)	4.18 (17.00)	1.17^{c} (1.00)	1.25^{d} (1.67)	2.99^{b} (8.67)	3.29^{e} (10.33)	3.64^{b} (12.77)	3.75^{d} (13.67)
Penoxsulam + butachlor, 820g/ha	3.81 (14.00)	4.03 (16.00)	1.68^{bc} (2.33)	2.10^{bcd} (4.00)	3.02^{b} (8.67)	4.01^{bc} (15.67)	2.90^{cd} (7.97)	4.22^{bcd} (17.33)
Penoxsulam + pendimethalin, 625g/ha	3.38 (11.00)	4.13 (16.67)	1.56^{bc} (2.00)	2.74^{b} (7.00)	2.88^{bc} (8.00)	4.18^{b} (17.00)	3.23^{bc} (10.17)	4.37^{b} (18.67)
Metsulfuron-ethyl + chlorimuron-ethyl, 4 g/ha	3.39 (11.00)	4.15 (17.00)	1.95^{b} (3.33)	2.36^{bc} (5.33)	3.12^{b} (9.33)	3.87^{bcd} (14.67)	3.09^{bcd} (9.07)	4.25^{bcd} (17.67)
Florpyrauxifen-benzyl, 31.5 g/ha	3.21 (10.00)	3.99 (15.67)	1.39^{bc} (1.67)	1.54^{cd} (2.33)	3.06^{b} (9.00)	3.44^{de} (11.33)	3.19^{bc} (9.93)	3.80^{cd} (14.00)
Bispyribac sodium, 25 g/ha	3.44 (11.33)	4.05 (16.00)	1.17^{c} (1.00)	2.90^{b} (8.00)	3.18^{b} (9.67)	3.85^{bcd} (14.33)	3.07^{bcd} (9.00)	4.37^{b} (18.67)
Cyhalofop-butyl + penoxsulam, 150 g/ha	3.23 (10.00)	4.41 (19.00)	1.46^{bc} (1.67)	2.54^{b} (6.00)	3.06^{b} (9.00)	3.89^{b} (14.67)	2.57^{cd} (6.13)	4.22^{bcd} (17.33)
Carfentrazone-ethyl, 25g/ha	3.28 (10.33)	3.96 (15.33)	1.47^{bc} (2.00)	2.46^{bc} (5.67)	3.11^{b} (9.33)	3.72^{cde} (13.33)	3.20^{bc} (9.93)	4.34^{b} (18.33)
Pretilachlor + pyrazosulfuron-ethyl, 600 + 15 g/ha	2.91 (8.00)	4.06 (16.33)	1.39^{bc} (1.67)	2.67^{b} (6.67)	2.72^{bc} (7.00)	4.14^{b} (16.67)	2.79^{cd} (7.43)	4.30^{bc} (18.00)
Hand weeding at 20 and 40 DAT	3.38 (11.00)	4.14 (16.67)	1.94^{b} (3.33)	2.59^{b} (6.33)	2.29^{c} (5.00)	2.47^{f} (5.67)	2.48^{d} (5.67)	3.23^{e} (10.00)
Un-weeded control	3.44 (11.33)	3.90 (15.00)	3.72^{a} (13.33)	4.00^{a} (15.67)	7.66^{a} (58.33)	9.28^{a} (85.67)	7.03^{a} (49.0)	8.94^{a} (79.67)
LSD (p=0.05)	NS	NS	0.749	0.92	0.667	0.444	0.665	0.519

*DAT – days after transplanting; In a column, means followed by common alphabet do not differ significantly at 5 % level in DMRT biotypes can tolerates four times the recommended dose. Nishan and George (2018) also noted the efficacy of ALS inhibiting herbicides like metsulfuron-methyl + chlorimuron-ethyl 6 g/ha or bispyribac-sodium 30 g/ha as substitutes for 2,4-D in managing *L. flava*. However, bispyribac-sodium 25 g/ha recorded the lowest WCE of 79% and 82% at 60 DAT among the herbicidal treatments during during *Kharif* and *Rabi*, respectively*)*. At 60 DAT, HW twice at 20 and 40 DAT resulted in the highest WCE of 91 and 94% during *Kharif* and *Rabi* respectively. All the herbicidal treatments recorded more than 70% WCE at harvest during both seasons (**Table 3**). Raj and Syriac (2015) reported good control of *Limnocharis w*ith the pre-mix herbicide (cyhalofop-butyl + penoxsulam, 130-135 g/ha). Penoxsulam and bispyribac-sodium were effective for management of *L. flava* where it showed resistance to 2,4-D (Zakaria 2018)

Monochoria vaginalis

Weed control efficiency of various herbicides ranged from 72-98 %, 2,4-D being the superior treatment. All other herbicides registered weed control efficiency in the range of 72-86%. Pooled WCE data of *M. vaginalis* (**Table 4**) revealed that post-emergent application of 2,4-D Na salt



[Treatments : post-emergent application of -T_1 2,4-D Na salt, 1000 g/ha; T_2 : penoxsulam + butachlor, 820g/ha; T_3 : penoxsulam + pendimethalin, 625 g/ha; T_4 : metsulfuron-ethyl + chlorimuron-ethyl 4 g/ha; T5 : florpyrauxifen-benzyl 31.5 g/ha; T_6 : bispyribac sodium 25 g/ha; T_7 : cyhalofop-butyl + penoxsulam 150 g/ha; T_8 : carfentrazone-ethyl 25g/ha; T_9 : pretilachlor + pyrazosulfuron-ethyl 600 + 15 g/ha; T_{10} : hand weeding at 20 and 40 DAT; T_{10} : un-weeded control]

(LSD (p=0.05)- Weed density-2.66; Weed dry weight-0.95)

Figure 2. Effect of weed management practices on density (no./m^2) and dry weight (g/m^2) of *Monochoria vaginalis* at 40 DAT

registered the highest WCE of 95 % at 40 DAT followed by florpyrauxifen-benzyl (88 %). Premix herbicides (cyhalofop-butyl + penoxsulam) and (pretilachlor + pyrazosulfuron) were also effective. All the herbicidal treatments recorded 70-80 % WCE.

Crop yield

Application of 2,4-D Na salt 1000 g/ha and HW twice at 20 and 40 DAT produced higher and

Table 2. Effect of weed management practices on weed dry weight (g/m^2) of *L. flava* at different growth stages of rice

Treatment	40 DAT		60 DAT		Harvest	
	Kharif	*Rabi*	*Kharif*	*rabi*	*Kharif*	*Rabi*
2,4-D Na salt, 1000 g/ha	0.81^{c}(0.17)	0.82^{d}(0.20)	2.86^{bc}(7.70)	3.23^{b}(10.03)	3.97^{b}(15.33)	4.70^{b}(21.93)
Penoxsulam + butachlor, 820 g/ha	1.38^{b}(1.47)	1.55^{c}(1.90)	2.96^{b}(8.36)	3.46^{b}(11.7)	3.25^{bcd}(10.20)	4.66^{b}(21.63)
Penoxsulam + pendimethalin, 625 g/ha	1.14^{bc}(0.80)	1.53^{c}(1.83)	2.77^{bc}(7.21)	3.50^{b}(12.07)	3.63^{bc}(12.97)	4.51^{b}(20.03)
Metsulfuron-ethyl + chlorimuron-ethyl,4 g/ha	1.10^{bc}(0.72)	1.61^{c}(2.10)	3.06^{b}(9.07)	3.52^{b}(12.00)	3.23^{cd}(10.00)	4.74^{b}(22.17)
Florpyrauxifen-benzyl, 31.5 g/ha	1.02^{bc}(0.61)	0.94^{d}(0.40)	2.95^{b}(8.25)	3.21^{b}(9.90)	3.62^{bc}(12.80)	4.56^{b}(20.77)
Bispyribac sodium, 25 g/ha	0.92^{c}(0.37)	1.86^{b}(2.97)	3.16^{b}(10.00)	3.63^{b}(12.83)	3.50^{bc}(11.80)	5.13^{b}(26.00)
Cyhalofop-butyl + penoxsulam, 150 g/ha	1.16^{bc}(0.87)	1.53^{c}(1.83)	2.99^{b}(8.60)	3.59^{b}(12.43)	2.70^{d}(6.87)	5.06^{b}(25.40)
Carfentrazone-ethyl, 25 g/ha	0.95^{bc}(0.43)	1.56^{c}(1.93)	3.00^{b}(8.50)	3.33^{b}(10.60)	3.48^{bc}(11.90)	4.75^{b}(22.50)
Pretilachlor + pyrazosulfuron-ethyl, 600 + 15 g/ha	1.02^{bc}(0.60)	1.58^{c}(2.00)	2.63^{bc}(6.45)	3.53^{b}(12.07)	3.09^{cd}(9.23)	4.73^{b}(21.93)
Hand weeding at 20 and 40 DAT	1.00^{bc}(0.57)	1.47^{c}(1.70)	2.17^{c}(4.28)	2.17 ^{c}(4.27)	2.62^{d}(6.47)	5.47^{b}(29.43)
Unweeded control	2.29^{a}(4.83)	2.57^{a}(6.100)	6.86^{a}(46.78)	8.41^{a}(70.17)	7.42^{a}(54.93)	10.0^{a}(99.47)
LSD (p=0.05)	0.432	0.226	0.715	0.725	0.729	1.001

*DAT – days after transplanting; In a column, means followed by common alphabet do not differ significantly at 5% level in DMRT

Table 3. Effect of treatments on weed control efficiency (%) of *L. flava*

Treatment	*Kharif*			*Rabi*		
	40 DAT	60 DAT	Harvest	40 DAT	60 DAT	Harvest
2,4-D Na salt, 1000 g/ha	94.44	83.59	71.97	96.15	85.60	77.70
Penoxsulam + butachlor, 820g/ha	71.57	81.79	80.93	68.30	83.15	78.05
Penoxsulam + pendimethalin, 625g/ha	80.81	84.14	75.47	71.97	82.89	79.98
Metsulfuron-ethyl + chlorimuron-ethyl, 4 g/ha	83.36	80.03	81.51	64.99	82.99	77.62
Florpyrauxifen-benzyl, 31.5 g/ha	82.60	82.41	76.98	93.21	85.77	78.87
Bispyribac sodium, 25 g/ha	91.27	78.58	78.06	50.38	81.67	73.95
Cyhalofop-butyl + penoxsulam, 150 g/ha	78.59	81.03	87.23	69.51	82.18	74.19
Carfentrazone-ethyl, 25g/ha	89.32	81.78	78.76	67.62	84.94	77.22
Pretilachlor + pyrazosulfuron-ethyl, 600 + 15 g/ha	87.57	85.89	82.55	66.53	82.75	77.79
Hand weeding at 20 and 40 DAT	88.10	90.63	88.35	70.94	93.90	70.28
Un-weeded control	0	0	0	0	0	0

*DAT – days after transplanting

statistically similar grain yield and straw yield followed by florpyrauxifen-benzyl 31.5 g/ha (**Table 5**). The grain yield ranged from 2765.73 to 3804.71 kg/ha in various treatments where herbicides were applied. The better yield in herbicide applied plots was the result of increased resource utilization by the crop due to decreased dry matter accumulation by the weeds. Season-long weed competition in unweeded check caused 68 % reduction in grain yield and 65 % reduction in straw yield compared to the treatments with the highest grain yield (HW twice at 20 and 40 DAT and 2,4-D Na salt 1000 g/ha). All other herbicidal treatments except florpyrauxifen-benzyl 31.5 g/ha were statistically comparable to each other in grain yield and straw yield.

Correlation analysis

The correlation analysis of weed density, weed dry matter production, weed control efficiency and grain yield of rice was also performed. The weed density was significantly and positively correlated with weed dry weight (r = 0.999; p=0.01) (**Table 6**). It implies that the grain yield of rice decreased with proportional increase in weed interference. A highly significant and negative correlation was found between weed dry weight with WCE (r = -1) and grain yield (r = -0.869) at 1% significance level. A significant and positive correlation was observed between WCE and grain yield (r = 0.868; p = 0.01). Zhou *et al*. (2021) also

Table 4. Effect of weed management practices on weed control efficiency (%) (pooled) of *M. vaginalis*

Treatment	40 DAT	60 DAT	Harvest
2,4-D Na salt, 1 kg/ha	95	85	75
Penoxsulam + butachlor, 820g/ha	70	83	80
Penoxsulam + pendimethalin, 625g/ha	76	84	78
Metsulfuron-ethyl + chlorimuron-ethyl, 4 g/ha	74	82	80
Florpyrauxifen-benzyl, 31.5 g/ha	88	84	78
Bispyribac sodium, 25 g/ha	71	80	76
Cyhalofop-butyl + penoxsulam, 150 g/ha	74	82	81
Carfentrazone-ethyl, 25g/ha	79	83	78
Pretilachlor + pyrazosulfuron-ethyl, 600 + 15 g/ha	77	84	80
Hand weeding at 20 and 40 DAT	80	92	79
Unweeded control	0	0	0

reported that more than 45% reduction in gross returns from rice when the Monochoria population increased from 0 to 24 plants/m^2.

Principal component analysis (PCA)

To assess variation among different treatments, parameters such as weed density, weed dry weight, and WCE along with grain yield from eleven treatments underwent PCA. The scree plot revealed two principal components (Dim1 and Dim2) within the data. The subsequent PCA plot illustrated that the first two principal components captured a substantial amount of variance, with PC1 and PC2 collectively explaining 100% of the total variance. PC1, labelled "Dim1 (95.2%)," primarily contributed to the data variance (95.2%), while PC2, labelled "Dim2 (4.8%)," accounted for a smaller percentage (4.8%) (**Figure 3**).

The biplot depicted a discernible impact of herbicide treatments on wetland rice yield. PC1 (95.2%) indicated a positive correlation with weed density and weed dry weight and a negative correlation with WCE and grain yield.

In the scree plot, four distinct clusters emerged. Cluster I (2,4-D, HW) exhibited the lowest weed density and weed dry weight but the highest grain yield. Cluster II (FB) displayed a moderately lower weed population and weed dry matter, coupled with a moderately higher grain yield compared to the control. Cluster III (BS, CZE, ME+CE, PX+BU, PR+PY, PX+PE, CY+PX) showed higher WCE but a lower grain yield compared to Cluster I and II. Cluster IV (UWC) featured the highest weed population and weed dry matter, accompanied by the lowest grain yield.

The two troublesome aquatic weeds in wetland rice that is *Limnocharis flava* and *Monochoria vaginalis* can be managed through herbicidal application. The post-emergent application of herbicides 2,4-D-sodium salt, penoxsulam + butachlor, penoxsulam + pendimethalin, metsulfuron-methyl +

Table 5. Effect of treatments on yield of rice

Treatment	Grain yield (kg/ha)			Straw yield (kg/ha)		
	Kharif	*Rabi*	Pooled	*Kharif*	*Rabi*	Pooled
2,4-D Na salt, 1 kg/ha	2976.10	4597.67	3786.89	3967.33	5512.67	4740.00
Penoxsulam + butachlor, 820g/ha	2192.48	3498.00	2845.24	2921.00	4529.00	3725.00
Penoxsulam + pendimethalin,625g/ha	2107.78	3423.67	2765.73	2814.00	4481.00	3647.50
Metsulfuron-ethyl + chlorimuron-ethyl 4 g/ha	2133.13	3647.33	2890.23	2850.33	4484.33	3667.33
Florpyrauxifen-benzyl 31.5g/ha	2056.74	4555.67	3306.21	2741.33	5363.33	4052.33
Bispyribac-sodium 25 g/ha	2293.26	3541.00	2917.13	3055.67	4541.00	3798.34
Cyhalofop-butyl + penoxsulam 150 g/ha	1878.86	3597.67	2738.27	2503.67	4469.67	3486.67
Carfentrazone-ethyl 25 g/ha	2319.20	3544.67	2931.94	3092.67	4629.00	3860.84
Pretilachlor + pyrazosulfuron-ethyl 600 + 15 g/ha	2210.99	3409.33	2810.16	2949.00	4529.00	3739.00
Hand weeding at 20 and 40 DAT	3099.75	4509.67	3804.71	4130.67	5327.00	4728.84
Unweeded control	947.59	1476.33	1211.96	1173.67	2188.67	1681.17
LSD (p=0.05)	261.42	248.74	284.96	368.25	338.20	348.81

Table 6. Correlation matrix among weed parameters and grain yield

	Weed density	Weed dry weight	Weed control efficiency	Grain yield
Weed density	1	0.999***	-0.999***	-0.874***
Weed dry weight	0.999***	1	-1***	-0.869***
Weed control efficiency	-0.999***	-1***	1	0.868***
Grain yield	-0.874***	-0.869***	0.868***	1

The mean values of the two years' pooled data of the corresponding treatments were used
***indicates correlation is significant at 0.001 level (two tailed)

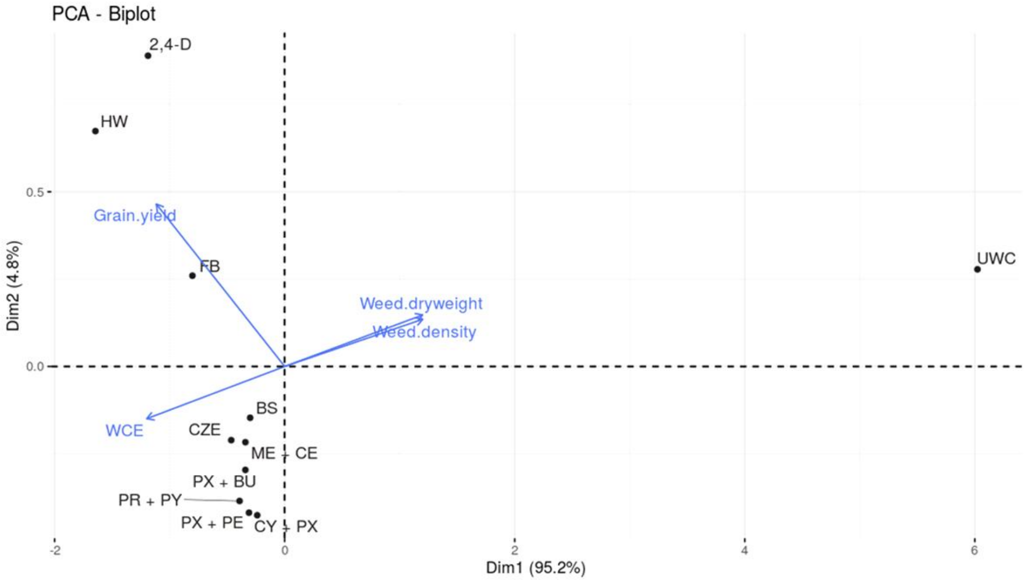


Figure 3. Principal component analysis of weed parameters and yield data. PC 1 and PC 2 jointly explained 100% of the total variation

chlorimuron-ethyl, florpyrauxifen-benzyl, bispyribac-sodium, penoxsulam + cyhalofop-butyl, carfentrazone-ethyl and pretilachlor + pyrazosulfuron- ethyl along with a wetting agent were effective in managing *Limnocharis flava* and *Monochoria vaginalis* in wetland rice.

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