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Integration of chemical and manual control methods for sustainable weed management in inbred and hybrid rice

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Abstract

Herbicidal weed control is gaining popularity in the developing countries but its efficacy still remains unclear. Therefore, an experiment was conducted to find out appropriate weed management practices for inbred and hybrid rice. The experiment comprised of inbred and hybrid varieties (two of each), and eight weed control treatments arranged in randomized complete block design with three replicates. Hybrid varieties performed better in terms of yield attributes and yield than inbred varieties. The highest grain yield (5.3 t ha^{-1}) was obtained from the hybrid Agrodhan-12 and the lowest one (4.3 t ha^{-1}) was from inbred Binadhan-7. Weed free treatment resulted in the highest grain yield (6.1 t ha^{-1}) and the lowest one was with weedy treatment (1.96 t ha^{-1}). The highest grain yield was obtained from Agrodhan-12 in weed free condition (6.9 t ha^{-1}), while the lowest value was in inbred BRRI dhan49 under weedy condition (1.73 t ha^{-1}). Weed-free treatment and the treatments of Pretilachlor fb Penoxsolum, Pretilachlor fb hand weeding, and Pendimethalin fb hand weeding showed similar performances in reducing weed density and eventually resulted in similar and the highest grain yield. Based on these results it may conclude that Pretilachlor applied at 2 days after transplanting (DAT) fb Penoxsolum at 21 DAT is the best weed management option. But from sustainability viewpoint, Pretilachlor or Pendimethalin applied at 2 DAT along with one hand weeding at 35 DAT may be recommended for effective weed management in inbred and hybrid rice during monsoon season.

Introduction

Weeds are endemic in crops, and the most important biotic constraint in rice production. Worldwide approximately 10% of total crop yields are lost every year by the effects of 1800 kind of weeds (Li *et al*., 2003). Studies reported that uncontrolled growth of weeds causing 16–48% reduction in monsoon rice yield (Mamun, 1990; Rashid *et al*., 2007). Manual weeding is mainly practiced here in Bangladesh, which is laborious and time consuming (Mamun, 1990). But this is becoming less common in Asian countries because of labour scarcity at critical time of weeding and increasing labour costs (Kumar and Ladha, 2011; Chauhan, 2012). Moreover, mimic nature of some grassy weeds like *Echinochloa crusgalli* L. makes hand weeding more tedious, difficult, and less effective (Rao and Moody, 1988). Therefore, use of herbicides may be an alternative method in controlling weeds more easily and effectively at low cost (Rashid *et al*., 2007; Hussain *et al*., 2008). Additionally, the application of herbicide can increased 60–82% rice yield compared with season-long weedy plots (Ahmed and Chauhan, 2014). Anwar *et al*. (2012) reported herbicide as the most efficient and cost-effective tool for weed management in rice.

Although weed management is mostly herbicide dependent in many rice growing areas but, concern over herbicide resistance in weeds and herbicide toxicity to crops (Blackshaw *et al*., 2005) may change the scenario in future (Bastiaans *et al*., 2000). Moreover, herbicides are often blamed for environmental hazard and considered as one of the threats to biodiversity (Marshall *et al*., 2003). Farmers are now very much concerned about herbicide resistance and environmental hazard of using herbicides, and hence they are becoming more interested in less herbicide dependent weed management approach (Mahmood *et al*., 2009). Integrated weed management (IWM) is now becoming very popular among the rice farmers (Anwar *et al*., 2013; 2014) which includes various agronomic tools like manual weeding, tillage, competitive cultivar, crop rotation, seeding date, seeding density, fertilizer management and so on for managing weeds in an integrated way (Juraimi *et al*., 2013).

In this backdrop, current study was undertaken to evaluate the efficacy of different pre- and post-emergence herbicides with/without manual weeding in controlling weed and increasing yield performance of inbred and hybrid rice varieties in monsoon season.

Materials and Methods

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University (24°75' N latitude, 90°50' E longitude). The experimental area was characterized by non-calcareous dark grey floodplain soil belonging to the Sonatola Soil Series under Old Brahmaputra Floodplain (Agro-Ecological Zone 9) of Bangladesh (Islam *et al*., 2011). The experiment included two factors. Factor A comprising

four rice varieties: two inbred (BRRI dhan49 and Binadhan-7) and two hybrids (Dhani gold and Agrodhan-12). Factor B comprising six different combinations of herbicides and hand weeding including season-long weed-free check and season-long weedy check (Table 1). Common names, chemical families, selectivity, modes of application and manufacturer names of the herbicides used in this experiment are described in Table 2. All herbicides were applied using 500 L water per hectare with a 2L hand sprayer. The experiment was conducted in a randomized complete block design with three replications. The size of the unit plot was 4.0 m×2.5 m.

For inbred varieties, the plots were fertilized with urea, triple super phosphate (TSP), muriate of potash (MoP) and gypsum at the rate of 125, 81, 52 and 60 kg ha^{-1}, respectively (BRRI, 2015) and those for hybrids were 220, 123, 86 and 62 kg ha^{-1}, respectively (as recommended by Petrochem Agro Industries Ltd.). In both cases the whole amount of fertilizers except urea were applied as basal dose at the time of final land preparation. Urea was top dressed in three equal splits at 15, 30 and 45 days after transplanting (DAT). In addition, hybrid varieties were top dressed with 10 kg ha^{-1} zinc sulphate at 15 DAT (as recommended by Petrochem Agro Industries Ltd.). Seedlings were transplanted in the plots according to the layout @ 3 seedlings $hill^{-1}$ maintaining 25 × 15 cm spacing. Intercultural operations *e.g.*, gap filling, irrigation and drainage was done as per requirement.

Weed species grown in the experimental field were identified and the summed dominance ratio (SDR) was calculated as per Janiya and Moody (1989). The yield parameters and yield were collected and processed as per Ray *et al*. (2015). Analysis of variance was done with the help of computer package MSTAT-C. The mean differences among the treatments were performed by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

Results and Discussion

Weed Parameters

Weed composition: The weed species found in the weedy plots of the experimental field are shown in Table 3. Eleven weed species comprising four grasses, four sedges and three broad leaves were identified in weedy plots. Based on the summed dominance ratio (SDR) values, grass weed species of *Echinochloa crusgalli* (30.7) was the predominant species in the experimental plot followed by sedge weed species of *Scirpus juncoides* (25.8) and broadleaf weed of *Monochoria vaginalis* (14.2) (Fig. 1). On the other hand, the least dominant weeds species of the experimental plot was sedge weed *Fimbristylis miliaceae* (0.2) followed by broadleaf weed species *Marsilea quadrifolia* (0.6) (Fig. 1).

Percent reduction in weed density and biomass: Variation in weed density and biomass reduction over control was observed among the weed control treatments at different DATs (Table 4). At all sampling dates, season long weed free treatments gave the complete reduction in weed density and biomass over control (weedy). The lowest percentage of weed density and biomass reduction was noted in plots where weeds were allowed to compete with crop plants without adopting any control measure i.e. in weedy treatments. Apart from the season long weed free and weedy treatments, the highest percentage of reduction in weed density and biomass was observed in Pretilachlor fb with one hand weeding, and the lowest was in Pendimethalin fb 2,4-D dimethyl amine at 45 DAT (Table 4). Whereas, at 60 DAT, the highest percentage of reduction in weed density and biomass was observed in Pendimethalin fb with one hand weeding, and the lowest weed density in Pretilachlor fb 2,4-D dimethyl amine and biomass in Pendimethalin fb 2,4-D dimethyl amine. On the other hand, at 75 DAT Pretilachlor fb with one hand weeding reduced the highest percentage of weed density and biomass, and Pretilachlor fb 2,4-D dimethyl amine and Pendimethalin fb 2,4-D dimethyl amine reduced the lowest weed density and biomass, respectively (Table 4).Weed density and biomass at earlier stage of crop growth are more critical than later stage. Several researchers (Kropff *et al*., 1993; Frantik, 1994; Bedmar *et al*., 1999) established the importance of time of emergence of the weeds. Generally, weeds that emerge simultaneously with the crop or shortly after the crop cause severe yields losses at very low densities. Therefore, the treatments that can control weed more effectively at earlier stage of crop growth.

Table 1. Weed control treatments used in the experiment

Treatment	Application rate and time
Weedy (control)	No hand weeding or herbicides were used till harvest
Weed-free	Frequent manual weeding to keep field weed free
Pretilachlor fb Penoxsolum	80 g *a.i.* ha^{-1} at 2 DAT fb 18 g *a.i.* ha^{-1} at 21 DAT
Pretilachlor fb 2,4-D dimethyl amine	80 g *a.i.* ha^{-1} at 2 DAT fb 500 g *a.i.* ha^{-1} at 21 DAT
Pendimethalin fb Penoxsolum	850 g *a.i.* ha^{-1} at 2 DAT fb 18 g *a.i.* ha^{-1} at 21 DAT
Pendimethalin fb 2,4-D dimethyl amine	850 g *a.i.* ha^{-1} at 2 DAT fb 500 g *a.i.* ha^{-1} at 21 DAT
Pretilachlor fb one hand weeding	80 g *a.i.* ha^{-1} at 2 DAT fb HW at 35 DAT
Pendimethalin fb one hand weeding	850 g *a.i.* ha^{-1} at 2 DAT fb HW at 35 DAT

a.i.: active ingredient, fb: followed by, DAT: days after transplanting, HW: hand weeding.

Table 2. Description of the herbicides used in the experiment

Common name	Chemical family	Target weeds	Mode of application	Manufacturer
Pretilachlor	Chloroacetamide	Grass and sedge	Pre-emergence	Syngenta India Ltd.
Pendimethalin	Dinitroaniline	Grass, sedge and broadleaf		Auto Crop Care Ltd.
2,4-D dimethyl amine	Aryloxyalkanoic acid	Sedge and broadleaf	Post-emergence	HALEX (M) SDN, BHD, Malaysia
Penoxsolum	Triazolopyrimidine Sulfonamide	Grass, sedge and broadleaf		DAO Agrolicence LLC, USA

Table 3. Weed species composition in weedy plots

Sl. No.	Scientific name	Family name	Weed type
1.	*Monochoria vaginalis* (Burn. F.) C. Presl.	Pontederiaceae	Perennial broad leaf
2.	*Nymphaea nouchali* Burm. f.	Nymphaeaceae	Perennial broad leaf
3.	*Marsilea quadrifolia* L.	Marsileaceae	Annual broad leaf
4.	*Scirpus juncoides* Roxb.	Cyperaceae	Perennial sedge
5.	*Cyperus iria* L.	Cyperaceae	Annual sedge
6.	*Cyperus difformis* L.	Cyperaceae	Perennial sedge
7.	*Fimbristylis miliaceae* L.	Cyperaceae	Annual sedge
8.	*Echinochloa crusgalli* (L.) P. Beauv.	Gramineae	Annual grass
9.	*Digitaria sanguinalis* (L.) Scop.	Gramineae	Annual grass
10.	*Leersia hexandra* Swartz.	Gramineae	Annual grass
11.	*Panicum repens* L.	Gramineae	Perennial grass

Table 4. Per cent reduction in weed density and biomass over control due to different weed control treatments

	Weed density			Weed biomass		
	45 DAT	60 DAT	75 DAT	45 DAT	60 DAT	75 DAT
Weedy	0	0	0	0	0	0
Weed free	100	100	100	100	100	100
Pretilachlor fb Penoxsolum	64.7	65.2	73.9	81.8	77.9	72.2
Pretilachlor fb 2,4-D dimethyl amine	62.0	64.2	68.2	74.8	73.9	70.7
Pendimethalin fb Penoxsolum	63.5	65.8	71.4	75.5	74.8	71.8
Pendimethalin fb 2,4-D dimethyl amine	59.5	65.8	68.9	71.0	71.6	66.0
Pretilachlor fb one hand weeding	68.1	70.8	77.0	83.2	79.1	76.8
Pendimethalin fb one hand weeding	65.6	72.7	73.2	80.2	78.7	75.7

Yield Contributing Parameters and Yield

Number of effective tillers hill^{-1}: Number of effective tillers hill^{-1} was significantly influenced by variety, weed control treatments and their interactions (Table 5 and 6). The number of effective tillers hill^{-1} ranged from 6.6 to 8.7. The highest number of tillers hill^{-1} (8.7) was found in inbred rice Binadhan-7. The lowest effective tillers hill^{-1} (6.6) was found in hybrid rice Agrodhan-12 that was statistically similar with Dhani gold (Table 5). The highest number of effective tillers hill^{-1} (8.6) was found in weed-free treatment followed by Petilachlor fb one hand weeding, whereas, the lowest number (5.3) was found in weedy treatment (Table 5). In interaction, highest number of effective tillers hill^{-1} (10.1) was produced in Binadhan-7 under weed-free condition, which was statistically similar with BRRI dhan49 under weed-free treatment and Binadhan-7 applied with Pretilachlor fb one hand weeding (Table 6). The lowest number of effective tillers hill^{-1} (4.6) was found in BRRI dhan49 under weedy treatment.

Table 5. Effect of variety and weed control treatments on yield contributing characters of inbred and hybrid rice

Treatments	No. of effective tillers hill^{-1}	No. of total spikelets panicle^{-1}	No. of grains panicle^{-1}	Weight of 1000-grain (g)
Variety				
BRRI dhan49	8.4ab	122.9c	107.9c	19.4c
Binadhan-7	8.7a	98.6d	98.2d	21.7b
Dhani gold	6.6b	140.6b	118.6b	22.1b
Agrodhan-12	6.6b	146.5a	125.6a	23.8a
CV (%)	7.5	5.7	5.7	3.3
Level of significance	**	**	**	**
Weed control treatments				
Weedy	5.3f	109.0e	74.9f	18.9c
Weed free	8.6a	137.8a	124.4a	22.2a
Pretilachlor fb Penoxsolum	7.9bc	131.1b	114.8c	22.2a
Pretilachlor fb 2,4-D dimethyl amine	7.5de	123.9d	106.6e	22.0b
Pendimethalin fb Penoxsolum	7.8cd	127.0c	111.0d	22.1b
Pendimethalin fb 2,4-D dimethyl amine	7.3e	122.6d	106.1e	22.1b
Pretilachlor fb one hand weeding	8.1b	136.3a	120.7b	22.2a
Pendimethalin fb one hand weeding	8.0bc	129.5b	114.0c	22.2ab
CV (%)	7.5	5.7	5.7	3.3
Level of significance	**	**	**	**

In a column, figures with same letters or without letters do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT). **= Significant at 1% level of probability.

Table 6. Interaction effect of variety and weed control treatments on yield contributing characters and yield of inbred and hybrid rice

Interactions		No. of effective tillers hill^{-1}	No. of total spikelets panicle^{-1}	No. of grains panicle^{-1}	Weight of 1000-grain (g)	Grain yield (t ha^{-1})
Variety	**Weed control treatments**					
BRRI dhan 49	Weedy	4.6m	107.1kl	86.4j	16.59	1.7n
	Weed free	9.9ab	133.0gh	123.0e	19.86	6.4b
	Pretilachlor fb Penoxsolum	9.2cde	127.3i	111.0g	19.72	5.4efg
	Pretilachlor fb 2,4-D dimethyl amine	8.6fg	114.7j	101.7h	19.48	4.51jk
	Pendimethalin fb Penoxsolum	8.3g	126.3i	110.0g	19.63	4.8hij
	Pendimethalin fb 2,4-D dimethyl amine	8.22g	114.7j	100.0h	19.69	4.3kl
	Pretilachlor fb one hand weeding	9.1c-f	131.3hi	116.7f	19.88	5.6cde
	Pendimethalin fb one hand weeding	9.0def	128.7hi	114.3fg	19.97	5.5def
Binadhan-7	Weedy	5.7l	92.7p	68.3l	19.05	2.0mn
	Weed free	10.1a	104.3lm	100.3h	22.31	5.6cde
	Pretilachlor fb Penoxsolum	9.0def	99.7mno	98.3i	22.24	4.6ijk
	Pretilachlor fb 2,4-D dimethyl amine	8.7efg	96.7nop	94.7k	22.26	4.1l
	Pendimethalin fb Penoxsolum	8.8d-g	99.0no	97.3j	22.00	4.5jk
	Pendimethalin fb 2,4-D dimethyl amine	8.6fg	95.3op	93.0k	21.97	4.0l
	Pretilachlor fb one hand weeding	9.7abc	101.3mn	98.0i	22.10	5.1fgh
	Pendimethalin fb one hand weeding	9.3bcd	100.0mno	97.7j	22.01	4.8hij
Dhanigold	Weedy	5.44l	126.7i	78.3k	19.23	2.2m
	Weed free	7.11hi	147.7c	132.3c	22.58	5.7cde
	Pretilachlor fb Penoxsolum	6.9hij	142.0dr	124.7de	22.43	5.1fgh
	Pretilachlor fb 2,4-D dimethyl amine	6.3jk	136.3fg	114.0fg	22.17	4.3kl
	Pendimethalin fb Penoxsolum	6.9hij	143.0cde	124.3de	22.53	5.1fgh
	Pendimethalin fb 2,4-D dimethyl amine	6.33jk	140.3ef	122.0e	22.43	4.6ijk
	Pretilachlor fb one hand weeding	7.00hi	146.0cd	128.3cd	22.64	5.4efg
	Pendimethalin fb one hand weeding	6.8h-k	143.0cde	124.7de	22.60	5.1gh
Agro dhan 12	Weedy	5.33l	109.7k	66.7l	20.78	2.0mn
	Weed free	7.22h	166.3a	149.0a	24.23	6.9a
	Pretilachlor fb Penoxsolum	6.6ijk	155.3b	137.3b	24.41	5.8c
	Pretilachlor fb 2,4-D dimethyl amine	6.6ijk	148.0c	130.0c	24.13	5.5def
	Pendimethalin fb Penoxsolum	7.00hi	139.7ef	122.3e	24.21	5.5cde
	Pendimethalin fb 2,4-D dimethyl amine	6.22k	140.0ef	122.3e	24.21	4.9hi
	Pretilachlor fb one hand weeding	6.6ijk	166.7a	147.7a	24.29	6.3b
	Pendimethalin fb one hand weeding	7.0hi	146.3cd	129.3cd	24.05	5.8cd
CV (%)		7.5	5.7	5.7	3.29	5.4
Level of significance		**	**	**	NS	**

NS= non-significant, other details are same as Table 5

Number of total spikelets panicle^{-1}: Number of total spikelets panicle^{-1} was significantly influenced by variety, weed control treatments and their interaction (Table 5 and 6). Agrodhan-12 produced the highest total number of spikelets panicle^{-1} (146.5) and the lowest one (98.6) was produced by Binadhan-7 (Table 5). Among the weed control treatments, the highest number of total spikelets panicle^{-1} (137.8) was produced in weed-free treatment, which was statistically similar with Pretilachlor fb with one hand weeding (Table 5). The lowest number of total spikelets panicle^{-1} (109.0) was found in weedy treatment. In their interaction, the highest total spikelets panicle^{-1} (166.7) was produced in Agrodhan-12 under Pretilachlor fb with one hand weeding treatment, which was statistically similar with Agrodhan-12 under weed-free condition (Table 6). The lowest number (92.7) was found in Binadhan-7 under weedy condition. Study revealed that number of total spikelets panicle^{-1} were higher in hybrid rice. Hossain *et al*. (2014) found from a study that hybrid rice produced higher spikelets panicle^{-1} than inbred rice varieties. Similar type of results was also found from a study conducted by Haque *et al*. (2015). They found that hybrids exhibited significantly lower number of panicles m^{-2} and on average 33.95% higher number of spikelets panicle^{-1}compared to the tested inbred.

Number of grains panicle^{-1}: Variety, weed control treatments and their interaction had significant effect on number of grains panicle^{-1} (Table 5 and 6). The highest number of grains panicle^{-1} (125.6) was found in Agrodhan-12 and the lowest one was (84.2) was observed in Binadhan-7 (Table 5). The highest number of grains panicle^{-1} (124.4) was found in weed-free treatment and the lowest (74.9) was found in weedy treatment (Table 6). In interaction, the highest number of grains panicle^{-1} (149.0) was produced in Agrodhan-12 under weed-free condition, which was statistically similar with Agrodhan-12 when applied with Pretilachlor fb with one hand weeding. The lowest number of grains panicle^{-1} (66.7) was found in Agrodhan-12 under weedy condition, which was statistically similar with Binadhan-7 under the same condition (Table 6). Parvez *et al*. (2013) observed the

highest number of effective tillers hill^{-1}, highest number of grains panicle^{-1} and heaviest 1000-grain weight were observed in weed free treatment followed by application of Pretilachlor fb one hand weeding at 21 DAT treatment. The results obtained in our experiment might be due to the fact that severe weed infestation failed to produce more tillers in the experimental plot. Weeding reduce crop-weed competition and provides scope to the plants for efficient utilization of solar radiation and nutrients. This might be responsible to higher number of grains panicle^{-1} under weed free condition. Similar results were reported elsewhere by Chowdhury *et al*. (1994) and Islam *et al*. (2014).

Weight of 1000-grain: Weight of 1000-grain was significantly influenced by rice variety, weed control treatments but not significantly influenced by their interaction (Table 5 and 6). The heaviest 1000-grain weight (23.8 g) was found in Agrodhan-12 and the lowest one was found in BRRI dhan49 (19.4 g). In case of weed control treatments, the 1000-grain weight was highest (22.2 g) in weed free treatment, which was statistically similar with Pretilachlor fb with one hand weeding, Pretilachlor fb Penoxsolum and Pendimethalin fb and weeding. The lowest weight (18.9 g) was found in weedy treatment (Table 5). Study revealed that weight of 1000-grain was heavier in hybrid rice. Weed-free treatments are effective for heavier grain weight. Ganeshwor and Gadadhar (2000); Nahar *et al.* (2010) and Khan and Tarique (2011) also reported heavier grain weights from weed free plots, this is because 1000-grain weight is negatively related to weed density (Karim and Ferdous, 2010).

Grain yield: Grain yield varied significantly with the influence of rice variety, weed control treatments and their interactions (Figs. 2, 3 and Table 6). The highest grain yield (5.3 t ha^{-1}) was obtained from the hybrid variety Agrodhan-12 and the lowest was (4.3 t ha^{-1}) from the inbred variety Binadhan-7 (Fig. 2). Grain yield of rice becomes higher mainly due to the contribution of yield contributing characters such as number of effective tillers hill^{-1}, number of grains panicle^{-1}, weight of 1000-grain. The highest number of grains panicle^{-1} (125.6) and 1000-grain weight (23.8 g) was observed in hybrid rice Agrodhan-12 (Table 6). The highest number of effective tillers hill^{-1} was observed in Binadhan-7 but number of grains panicle^{-1} and weight of 1000-grain were lower in number in this variety, which results lower grain yield. Differences in grain yield due to varieties were also reported by Yoshida et al. (1994); Siddeque *et al.* (2002); Sarkar *et al.* (2007) and Ray *et al*. (2015).

The highest grain yield (6.1 t ha^{-1}) was obtained in weed free treatment because of its contribution on highest number of effective tillers hill^{-1}, grains panicle^{-1}, weight of 1000-grain (Fig. 3). The result of this treatment was followed by Pretilachlor fb hand weeding. The lowest grain yield (1.96 t ha^{-1}) was observed in weedy treatment (Fig. 3). The highest grain yield (6.9 t ha^{-1}) was found in Agrodhan-12 under weed-free condition, and the lowest grain yield (1.73 t ha^{-1}) was produced by BRRI dhan49 under weedy condition (Table 6). Similar results were also observed by Gogoi *et al.* (2000) and Islam *et al*. (2001). The highest grain yield was obtained in the treatment which was affected by comparatively less weed. The highest number of effective tiller hill^{-1}, grains panicle^{-1} and 1000-grain weight gave the highest grain yield in weed free plots. These might be due to the fact that in weed free rice field the soil was well aerated which facilitated the crop for absorption of greater amount of plant nutrients, moisture and greater reception of solar radiation for better growth. Manish *et al*. (2006) found that hand weeding at 15 and 30 DAT gave the highest grain yield.

Relationship between weed density and biomass at 75 DAT and grain yield of inbred and hybrid rice: Experimental results revealed that grain yield showed negative relationship (R^2 = 0.83) with weed density per square meter at 75 DAT (Fig. 4). This means a decrease in weed density will result in the corresponding increase in the grain yield of inbred and hybrid rice. Lowest grain yield (1.73 t ha^{-1}) was observed when weed density (45.33 m^{-2}) was highest at 75 DAT. This indicates weed density is a critical character in yielding ability of inbred and hybrid rice.

Results also showed that grain yield has negative correlation (R^2 = 0.819) with weed dry weight (g m^{-2}) at 75 DAT (Fig. 4). This means a decrease in weed dry weight will result in the corresponding increase in the grain yield of inbred and hybrid rice. Second lowest grain yield (1.96 t ha^{-1}) was observed when weed dry weight (54.03 g m^{-2}) was highest at 75 DAT. This indicates weed dry weight might be critical characteristics in yield performance of inbred and hybrid rice.

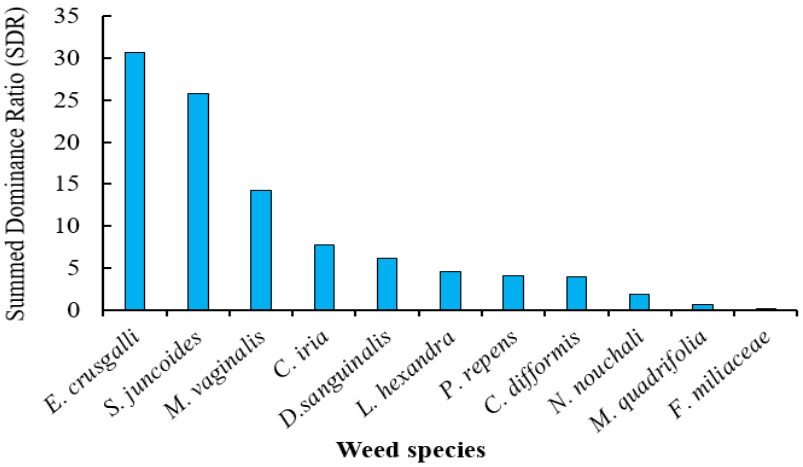

Fig. 1. Summed dominance ratio (SDR) of the major weeds found in weedy plots

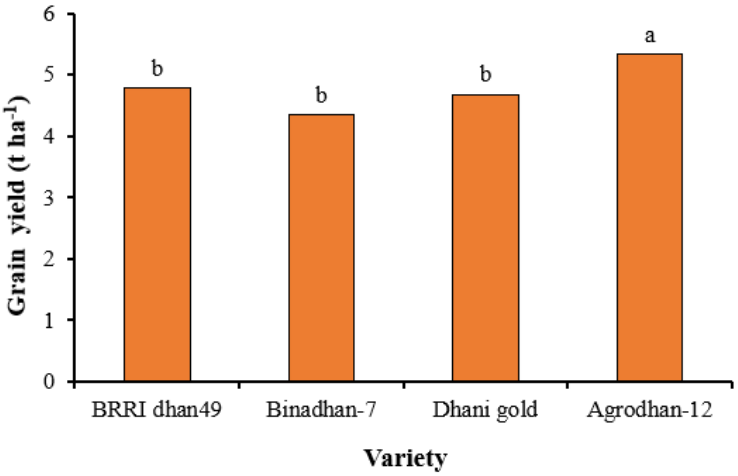

Fig. 2. Effect of variety on grain yield of inbred and hybrid rice

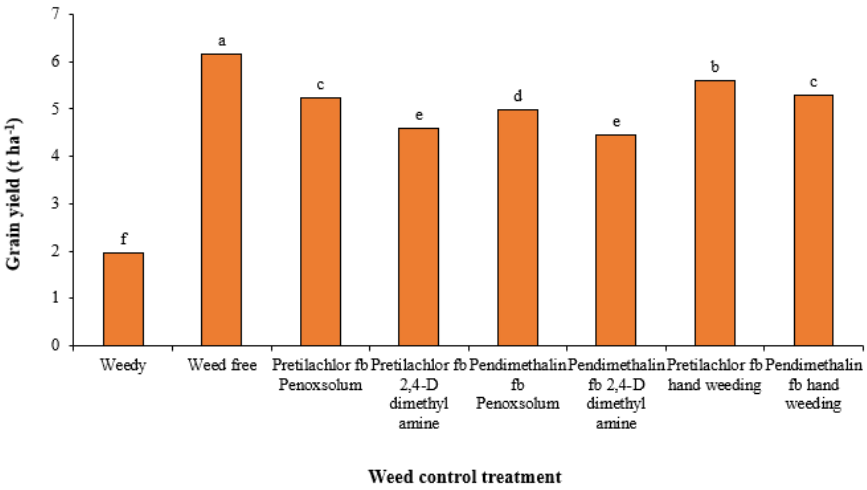

Fig. 3. Effect of weed control treatments on grain yield of inbred and hybrid rice

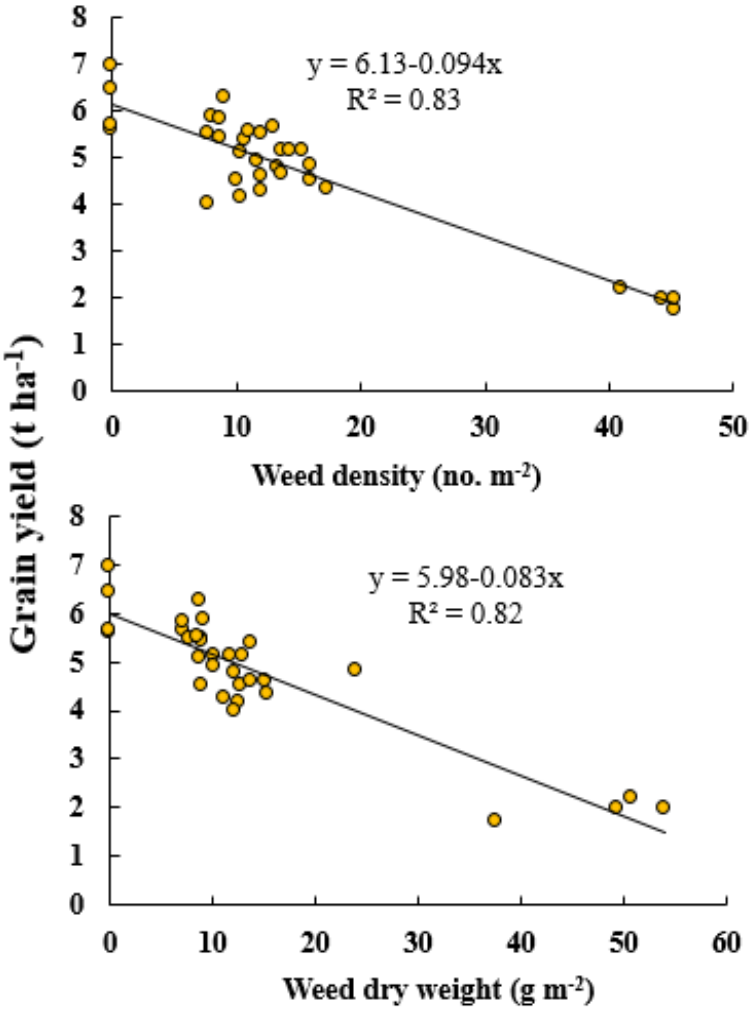

Fig. 4. Correlation between weed density and biomass at 75 DAT with grain yield of inbred and hybrid rice

Conclusion

Weed management has been a challenge in rice production. Manual weed control is environment friendly but not cost effective; herbicidal control, on the other hand, is highly efficient and cost effective but there is risk of environmental hazard and development of herbicide resistance in weeds. On the other hand, yield level of inbred rice reached the plateau, where hybrids have 15–30% yield advantage over inbred. In this situation, current study emphasized on finding out the most potential rice variety and an eco-friendly as well as efficient weed control methods to maximize rice yield in a sustainable way. Present study revealed that hybrid varieties gave higher yield performance than inbred ones. Season-long weed-free treatment and the treatments of Pretilachlor fb Penoxsolum or hand weeding and Pendimethalin fb with one hand weeding showed similar performances in reducing weed density and eventually resulted in similar and the highest grain yield. Therefore, from economic view point, Pretilachlor applied at 2 days after transplanting (DAT) fb Penoxsolum applied at 21 DAT is the best weed management option. But from sustainability view point, Pretilachlor or Pendimethalin applied at 2 DAT along with one hand weeding at 35 DAT may be recommended for effective weed management for inbred and hybrid rice during monsoon season.

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