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Research article

PLANT SPACING AND WEED MANAGEMENT TECHNIQUES INFLUENCE WEED COMPETITIVENESS OF DRUM SEEDED RICE (*Oryza sativa* L.)

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ABSTRACT: Direct wet seeded-rice sown through drum seeder, a potential wise rice production system in the present-day scenario, is subject to severe weed infestation and, therefore, development of a sustainable weed management strategy is crucial for its wide spread adoption. The present study was conducted in *kharif* 2012 at department of agronomy division with NLR-33358 (*SOMASILA)* using six planting densities under five weed management conditions. The plant spacing tried were: 20cm x 7cm, 20 cm x 10.5 cm, 20 cm x 14 cm, 20 cm x 17.5 cm and 20 cm x 24.5cm and 20 cm x15cm. with a plant density of 71, 47, 35, 28, 20 and 33 hills m^{-2}, respectively and five weed management practices *viz.*, weedy check (W_1), hand weeding at 20 and 40 DAS (W_2), cono weeding at 20 and 40 with modified cono weeder (W_3), pre-emergence application of anilofos @ 0.375 kg a.i ha^{-1} followed by post-emergence application of 2, 4 D sodium salt @ 1.0 kg a.i ha^{-1} 20-25 DAS (W_4), pre-emergence application of pendimethalin @1.0 kg a.i ha^{-1} followed by post-emergence application of bispyribac sodium @ 20 g a.i ha^{-1} 30 DAS (W_5). . The experiment was laid out in strip- plot design with three replications assigning weed management techniques in vertical factor and plant spacing in horizontal factor. Direct wet seeded rice field was infested with 12 and 22 weed species, kharif -2012 season having *Echinochloa colona, Leptochloa chinensis, Digitaria aescendens, Cyperus iriaand Eleusine indicaas* the predominant weeds. Rice spacing exerted significant influence on both weed pressure and yield performance of crop. With the increase in plant spacing weed dry matter decreased but rice yield increased. In this season, among different plant densities, the highest density of 71 hills m^{-2}(D_1) resulted in minimum weed density, weed drymatter, and more number of tillers m^{-2} and maximum drymatter production at all stages of plant growth. closest spacing resulted in maximum weed suppression, but among various rice plant densities, a medium level population of 47 hills m^{-2} (D_2) significantly increased the paddy yield over all other treatments except D_1 treatments with a plant density of 71 hills m^{-2} .The highest grain yield of 3476 kg ha^{-1} was observed with a plant density of 47 hills m^{-2} and it was significantly superior to 71, 35, 28, 20 hills m^{-2}drum seeded and 33 hills m^{-2} transplant paddies. which ultimately produced the highest rice yield. Weed inflicted relative yield loss was also minimized by the closest spacing. Present findings imply rice spacing mostly determines rice-weed competition, and can play a decisive role to minimize weed pressure. Therefore, closer spacing could be considered as a vital tool in the integrated weed management program for direct wet-seeded rice sown through drum seeder.

Key words: Weed competitiveness, wet- seeded rice, drum seeder, spacing, weed density.

INTRODUCTION

Rice (*Oryza sativa* L.) is the dominant staple food for many countries in Asia and Pacific, South and North America as well as Africa (Mobasser *et. al.* 2007) and also is a staple food for nearly half of the world's seven billion population. However, more than 90 per cent of rice is consumed in Asia, where it is a staple food for a majority of the population, including the 560 million hungry people in the region (Mohanty, 2013). Globally, India stands first in rice area and second in production after China. It is also a staple food for more than 65 per cent of the Indian population and accounts for more than 42 per cent of food production. The area under direct - seeded rice is increasing as farmers in India seek higher productivity and profitability to overcome increasing costs and scarcity of farm labour.

One of the major reasons for non-remunerative rice production in recent times is augmented cost of cultivation because of scarce and costly farm labour during the peak period of farm operations. Establishing rice by transplanting is labour intensive and increasingly difficult due to higher cost and shortage of labour. Inadequate plant population with hired labour for transplanting is the major lacuna in this method (Ram *et al.* 2006).

Drum seeding is an alternative method to transplanting. It reduces labour requirement and performs as good as transplanting method at many places (Yadav and Singh, 2006). However, drum seeding method is subjected to severe weed infestation than conventionally puddled transplanted rice that leads to because of the absence of the size disparity between the crop and weed plants and the suppressive effect of standing water on weed growth at crop establishment.

Manipulation of different cultural practices could increase the competitiveness of a crop with weeds for aboveground and belowground resources and hence helps weed management 21, 36. Increasing crop density by narrowing row spacing enhances crop competitiveness against weeds 17, 40, 47 . Planting density of a crop determines solar radiation interception, canopy coverage and biomass accumulation which have cumulative effect on its weed suppressive ability 6. High planting density of a crop develops canopy rapidly and consequently suppresses weeds more effectively, and in contrast, widely spaced plants encourage weed growth 22. It is evident from literature that row spacing had no significant impact on grain yield of direct seeded rice under weed free condition but under weedy condition, grain yield reduced significantly in the widest spacing 3. Thus, it appears that narrow rows and higher plant density favour crop to compete with weeds and consequently produce higher yield 27, 37. Higher planting density up to 300 plants $m^{-2}$for better weed competitiveness has been suggested for aerobic rice 6. In addition to planting density, planting uniformity also has a positive impact on the competitive ability of a crop 13. Many researchers emphasized on the combination of increased crop density and more uniform plating to enable crops to compete more efficiently with weeds 6, 47. However, several studies reveal that higher planting density may bring about problems of mutual shading and intra specific competition that exacerbate problems like lodging 9, insect and disease infestation 43and rat damage 16. Therefore, planting density should be optimized considering different aspects of cropping in addition to weed suppression. Influence of plant spacing in reducing weed pressure in rice especially under aerobic soil conditions has not been given due to consideration and, therefore, a better understanding is necessary before suggesting planting geometry and spacing as a viable tool for sustainable weed management in aerobic rice. This research was therefore initiated to reveal the planting spacing and weed management techniques influence weed competitiveness of drum seeded rice.

MATERIAL AND METHODS

A field experiment entitled "Planspacing and Weed Management Techniques Influence Weed Competitiveness of drum Seeded Rice" was conducted at the Agricultural College Farm, Bapatla on sandy loam soil during *kharif* 2012. The treatments consisted of combination of five drum seeder spacings (20×7cm, 20×10.5cm, 20×14cm, 20×17.5cm, 20×24.5cm, and manual planting (20×15cm), with a rice plant population of 71, 47, 35, 28, 20 and 33 hills m^{-2}, respectively, and five weed management practices *viz.,* weedy check (W_1), hand weeding at 20 and 40 DAS (W_2), cono weeding twice at 20 and 40 DAS with modified cono weeder (W_3), pre-emergence application of anilofos @ 0.375 kg a.i ha^{-1} and post-emergence application of 2, 4 D salt @1.0 kg a.i ha^{-1} at 25 DAS (W_4), pre-emergence application of pendimethalin @1.0 kg a.i ha^{-1}post-emergence application of bispyribac sodium @ 20 g a.i ha^{-1} 30 DAS (W_5). The trail was laid out in strip plot design and replicated thrice. The rice variety used was NLR - 33358 (*SOMASILA*). Fertilizer was applied at the rate of 120:60:60 N: P_2O_5:K_2O kg ha^{-1}. Nitrogen was applied in two split doses at time of tillering and panicle initiation stage along with basal dose. Phosphorus and potassium was applied as basal.

Data collection on weed

The uniform representative samples of weeds and crop were randomly collected from each plot, dried processed and analysed to determine N,P,K content which in turn were multiplied by respective dry matter to determine uptake. Weed population determination was done by quadrant method described by Mishra and Mishra (1997). Based on the weed drymatter recorded according to treatments weed control efficiency (WCE) was calculated using the following formula (AICRPWC, 1988).

$$\text{WCE (\%)} = \frac{\text{DWC - DWT}}{\text{DWC}} \times 100$$

Where, DWC = weed dry matter in unweeded control plot, DWT = weed dry matter in treated plot.

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Predominant weed flora of the experimental field:

Botanical Name	Common Name	Family	Life Cycle	Mode of Propagation
Grasses				
Echinochloa colona	Jungle rice	Poaceae	Annual	Seed
Echinochloa crusgalli	Awned barnyard grass	Poaceae		
Cynodon dactylon	Bermuda grass	Poaceae	Perennial	Grain and under ground stems
Sedges				
Cyperus rotundus	Purple nut sedge	Cyperaceae	Perennial	Seed like nuts/ under ground stems
Cyperus difformis	Umberella sedge	Cyperaceae	Annual	Seed
Fimbristylis miliacea	Hoorah grass	Cyperaceae	Annual	Seed
Broad leaf weeds				
Eclipta alba	False daisy	Asteraceae	Annual	Seed like achenes
Ludwigia parviflora	Winter primose	Onagraceae	Annual	Seed
Ammania baccifera	Red stem	Lathraceae	Annual	Seed
Euphorbia hirta	Garden spurge	Euphorbiaceae	Annual	Seed

Data collection of crop characters

Data were collected from five hills per plot and then averaged.. Grains obtained from randomly selected five hills were sun dried and weighed carefully. Then it was averaged to get grain weight hill^{-1}. Straw obtained from randomly selected five sample hills of respective plot was dried in sun and weighed and then averaged. Grains obtained from each unit plot were sun dried and weighed carefully. The dry weights of grains from the panicle of the sample hills were added to the respective plot yield to record the grain yield plot^{-1}. Straw obtained from each unit plot including the straw of five sample hills of respective plot was dried in sun and weighed to record the straw yield plot^{-1}. The grain and straw yields per plot were subsequently converted to ha^{-1}and recorded. Data recorded for different crop parameters were compiled and tabulated in proper form for statistical analysis. The experimental data are statistically analyses by using Fisher's method of analysis of variance as outlined by Panse and Sukhatme (1978). Critical Difference (CD) was calculated wherever F-test was found significant. The level of significance used in F-test was five per cent.

RESULT AND DISCUSSION

Weed population (no. m^{-2}):

The data pertaining to weed density recorded at different intervals are presented in Table 4.2 and depicted in Fig.4.1 to 4.4.The data revealed that weed density was significantly influenced by plant density and weed management practices. The interaction effect of these management practices on weed density was also significant during all the growth stages.

Effect of plant density

Average over all weed management practices, at 20 days after sowing, weed density was significantly lowest (76.1 m^{-2}) with higher plant density of 71 hills m^{-2} (D_1) over all other plant density treatments D_2 (47 hills m^{-2}) , D_3 (35 hills m^{-2}), D_4 (28 hills m^{-2}), D_5 (20 hills m^{-2}), D_6 (33 hills m^{-2}). An increase in plant density decreased the weed density in direct seeded rice from 47 to 71 plants m^{-2} which was also significantly lower than that recorded in traditional rice transplant system. An interesting fact to note is that a plant density of 35 hills m^{-2} either in direct seeded or transplant condition shown similar level of weed density clearly depicted that rice plant density surely had effect of suppression the weed growth by limiting the passage of sunlight, rain and changing climate. Similar trend was noticed at all other stages of crop growth *i.e.*, 40, 60 and at harvest. However the effective of weed growth suppression was seen up to 40 DAS, thereafter a marginal increase in weed density was noticed indicating that even rice canopy could not prevent new weed seed germination and during those stages higher rice plant density of 71 hills m^{-2} was effective in controlling new weed seed germination.

Effect of weed control treatments

Among different weed management practices averaged over rice plant population treatments, at 20 days after sowing, significantly lower (59.9 m^{-2}) weed population was recorded with pre-emergence application of pendimethalin followed by post-emergence application of bispyribac-sodium (W_5) (or) pre-emergence application of anilofos followed by post-emergence application of 2, 4.D sodium salt (W_4).

These two treatments significantly reduced the weed population as compared to W_1, W_2, and W_3 treatments. W_4 and W_5 treatments were at a par in reducing weed population. This effect was seen only up to 20 DAS. During the advanced stages of crop growth hand weeding twice (W_2), weeding twice with cono weeder (W_3) showed excellent effect on reducing weed population and all these treatments significantly reduced the weed population in comparison to weedy check. Among all weed control treatments the efficacy of W_4 treatment reduced to some extent during the advanced stages of crop growth as grassy weeds dominated the broad leaved weeds particularly during 60 DAS and at maturity stages of crop. These observations at 20 DAS might be due to the fact that pre-emergence application of pendimethalin in W_5 and anilofos inW_4 effectively prohibited the emergence of wide spectrum flora, as compared to rest of the treatments (W_1, W_2 and W_3). These results are in correlation with the findings of Bhowmick *et al.* (2000), Moorthy and Saha (2002) and Walia *et al.* (2008a).

Interaction effect on plant density and weed control treatments

The interaction between rice plant densities and weed management treatments was significant in reducing weed population during all the stages of crop growth, at 20 DAS a treatment combination of higher rice plant population 71 plants m^{-2} or 47 plants m^{-2} with pre-emergence application of pendimethalin or anilofos post-emergence application of bispyribac sodium or 2, 4 D sodium salt ($D_1 \times W_5$), ($D_2 \times W_5$), ($D_1 \times W_4$), showed significant reduction in weed population over weedy check treatments. The effects of these transplanted rice treatments was though found better than that seen in transplanted rice treatment but were at a par with this treatment. These results clearly show that high rice population with pre and post emergence herbicide combination under direct seeded condition is the better option even over traditional compulsive transplanted system to control the weeds in this eco system of rice cultivation.

Weed Dry matter Production

Effect of plant density

Average over all weed management practices the weed dry matter production was significantly influenced by varying rice plant densities at 20, 40, 60 DAS and at harvest. Weed dry matter was linearly decreased with an increase in rice plant density from 20 to 71 hills m^{-2} at all stages of crop growth. The lowest weed dry matter production was recorded when rice plant density was maintained at 71 hills m^{-2}, followed by a rice density of 47 and 35 hills m^{-2} at all crop growth stages. High plant density developed wider crop canopy and consequently suppressed weed growth more effectively resulting in lower weed dry matter. In contrast, widely spaced rice plants due to movisim of wider space encouraged congenial weed growth. These results are in conformation with the finding of Guillermo *et al.* (2009). Weed dry matter recorded in D_3 (35 hills m^{-2}) was statistically on par with manual transplant (D_6). The lower weed dry matter recorded in transplanted system might be due to puddling and anaerobic conditions prevailed in field which might have reduced the weed growth and its dry matter production. Similar to transplant system drum seeding on puddle soil also treated similar condition that might have reduced the weed problem considerably. Earlier Singh *et al.* (2003) and Singh *et al.* (2004a) also reported similar observations.

Effect of weed control treatments

Among various weed management practices, weed dry matter production trend differed at different stages of crop growth. At 20 DAS, lowest weed dry matter production was reduced in pre-emergence application of pendimethalin followed by post-emergence application of bispyribac sodium (W_5) followed by pre-emergence application of anilofos followed by post-emergence application of 2,4 D sodium salt (W_4). The treatment hand weeding twice (W_2) and cono weeding (W_3) are on a par with weedy check (W_1). This clearly indicated that pre-emergence herbicide application helped in suppression of weed growth up to 20 DAS. Whereas at 40 DAS, the efficacy of pre-emergence herbicides got reduced and only post emergence (W_4 or W_5) helped in reducing weed growth compared to weedy check (W_1). At this stage mechanical weeding with cono weeder twice at 20 and 40 DAS (W_3) and hand weeding twice at 20 and 40 DAS outperformed other weed management practices though all these practices are significantly superior to weedy check with varying degree of weed growth reduction. This trend was seen even during the subsequent stages of crop growth. Moorthy and Saha (2002), Singh *et al.* (2007), Ladha *et al.* (2008) and Walia *et al.* (2008b) also reported similar results.

Interaction effect on plant density and weed control treatments

A significant interaction between rice plant density and weed management practices showed that all the treatments were significantly superior over weedy check in reducing weed dry matter production at all the crop growth stages. However, W_2, W_3 or W_5 with higher rice plant densities performed excellently compared to other treatment combination.

Weed Control Efficiency (%)
Effect of plant density

At 20 DAS, there is no significant difference with respect to weed control efficiency among various rice plant population treatments. Among various weed management practices, weed control efficiency at this stage of crop growth was highest (46%) with W_5 which significantly superior over all other weed management practices. A significant interaction between rice plant population and weed management practices showed that at all rice plant densities W_5 showed superiority in enhancing the weed control efficiency as a result of effective weed control right from emerging stage of rice crop. These results are akin to the findings of Moorthy and Saha, (2002).

Table no.1: Plant spacing and weed management techniques influence weed competitiveness of drum seeded rice

Rice plant densities	20 DAS		40 DAS		60 DAS		Harvest	
	Weed density per m^2							
D_1	76.1		30.4		41.5		45.9	
D_2	87.0		39.6		50.0		50.9	
D_3	95.1		43.5		53.9		52.5	
D_4	110.5		50.5		56.7		58.3	
D_5	121.9		55.1		58.5		60.9	
D_6	98.1		41.5		47.7		51.3	
SEm±	1.99		1.45		1.7		1.0	
D (P=0.05)	6.2		4.5		5.5		3.3	
CV (%)	7.7		12		13		7.6	
Weed management practices								
W_1	129.4		112.3		134.7		124.9	
W_2	123.9		22.4		25.7		33.3	
W_3	125.2		20.8		21.7		38.4	
W_4	62.9		35.3		39.6		42.5	
W_5	59.9		31.1		37.6		32.3	
SEm±	4.44		1.8		3.5		2.9	
D (P=0.05)	14.5		6.0		11.1		9.8	
CV (%)	18.8		17		28.9		23.0	
Interaction	D×W	W×D	D×W	W×D	D×W	W×D	D×W	W×D
SEm±	10.9	6.4	4.9	2.9	4.6	4.3	3.7	2.9
CD(P=0.05)	31.7	19.2	14.5	8.9	13.8	13.2	10.8	9.0
CV (%)	10.5		11.0		13.2		7.0	

Table.2.Weed dry matter as influenced by varied rice plant densities and weed management practices in drum seeded rice.

Rice plant densities	20 DAS		40 DAS		60 DAS		Harvest	
	Weed dry matter (g.m^{-2})							
D_1	35.1		26.6		36.0		44.1	
D_2	42.1		32.5		45.4		50.9	
D_3	44.4		36.9		52.4		64.5	
D_4	52.4		43.8		59.7		67.6	
D_5	54.2		47.5		76.2		81.9	
D_6	48.3		39.1		53.4		62.5	
SEm±	1.8		0.9		0.9		1.2	
CD (P=0.05)	5.7		2.8		2.9		4.0	
CV (%)	15.3		9.4		6.8		8.0	
Weed management practices								
W_1	54.3		75.5		86.8		94.2	
W_2	51.3		26.5		46.7		54.0	
W_3	53.2		19.4		40.5		51.0	
W_4	36.4		33.9		53.7		61.7	
W_5	30.2		33.4		41.5		50.5	
SEm±	1.6		1.4		1.0		2.0	
CD (P=0.05)	5.3		4.7		3.4		6.3	
CV (%)	15.1		16.2		8.2		13.6	
Interaction	D×W	W×D	D×W	W×D	D×W	W×D	D×W	W×D
SEm±	4.2	2.9	5.6	2.1	9.7	1.8	9.2	2.6
CD (P=0.05)	12.5	8.8	16.4	6.3	28.6	5.3	27.1	8.0
CV (%)	11.3		9.3		5.8		6.7	

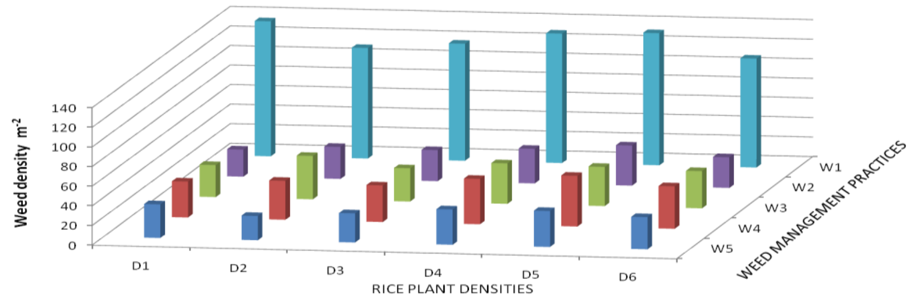
Effect of weed control treatments

At later stages of crop growth *i.e.* from 40 DAS to till harvest any weed management practices coupled with higher rice plant population played a pivotal role in improving the weed control efficiency as seen from very a significant interaction among various treatments combination. These results evaluated that higher plant population played favourable role in reducing the weed number and growth of varying weed fauna, added to that application of manual, mechanical or herbicidal treatments further improved, the suppressive effect on weeds there by increasing the weed control efficiency. These results are well supported by Walia *et al.* (2008b) and Yadav *et al.* (2009).

Table 3.Weed control efficiency (WEC) as influenced by varied rice plant densities and weed management practices in drum seeded rice.

Rice plant densities								
	20 DAS		40 DAS		60 DAS		Harvest	
Weed control efficiency (%)								
D_1	25.0		59.8		52.8		45.2	
D_2	15.3		50.1		41.7		42.0	
D_3	19.6		48.8		35.8		31.8	
D_4	19.3		46.3		34.5		15.3	
D_5	20.2		43.6		31.3		32.9	
D_6	10.6		53.4		35.7		35.5	
SEm±	0.3		0.2		0.8		1.9	
CD (p=0.05)	NS		NS		NS		NS	
CV (%)	10.6		10.1		14.2		10.4	
Weed management practices								
W_1	0		0		0		0	
W_2	7.0		65.3		47.4		42.7	
W_3	3.7		74.6		54.4		45.9	
W_4	35.2		55.3		38.6		34.5	
W_5	46.0		56.4		52.8		46.4	
SEm±	1.4		1.7		1.2		1.2	
CD(p=0.05)	3.2		5.5		4.0		4.1	
CV (%)	16.9		14.7		13.7		14.7	
Interaction	D×W	W×D	D×W	W×D	D×W	W×D	D×W	W×D
SEm±	4.4	3.1	4.5	2.2	5.7	1.9	6.0	3.2
CD (p= 0.05)	12.6	9.2	13	6.7	17.0	5.8	18.0	12.6
CV (%)	23.5		6.9		8.5		7.3	

Table.4: Plant spacing and weed management techniques influence weed competitiveness of drum seeded rice

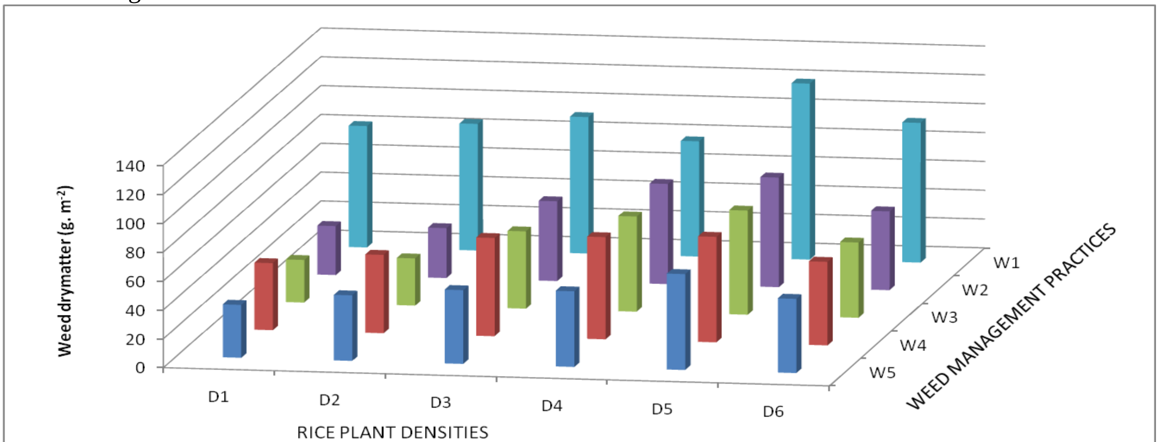


	D1	D2	D3	D4	D5	D6
W5	34.3	24.7	29.7	36	36.7	32.7
W4	36.7	39.7	37.3	46.3	51.7	43.3
W3	32.7	44.3	34	41.3	40	38
W2	27.7	32.7	31.7	35.3	41	31.3
W1	138	113	119.7	132.3	135	111.3

Fig. 1.Weed density at harvest as influenced by varied rice plant densities and weed management practices in drum seeded rice.

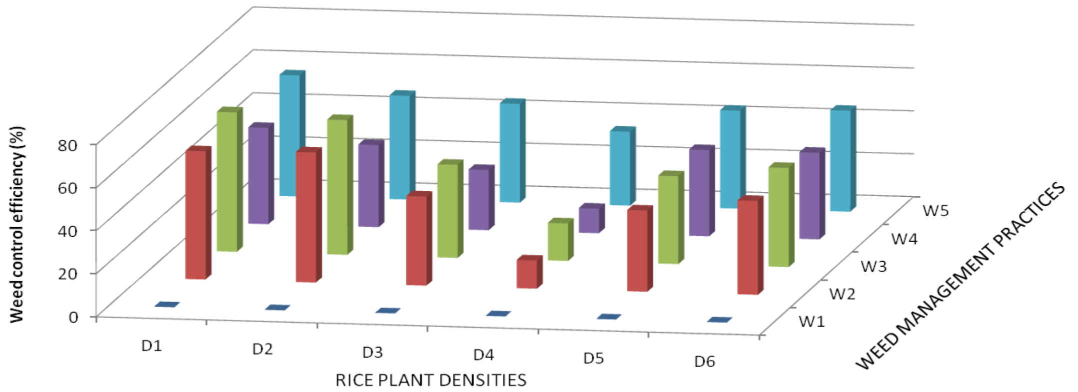
	TREATMENT	Weed density (m^2)	Weed Dry matter ($g\,m^{-2}$)	Weed control efficiency (%)	panicle length (Cm)	Number of grains panicle^{-1}	Test weight (g) 1000 grain weight	Grain yield (kg ha^{-1})
	PLANT DENSITY (D)							
D_1	20 ×7cm (71 hills m^{-2})	45.9	44.1	45.2	15.2	75.7	18.6	3154
D_2	20 ×10.5cm (47 hills m^{-2})	50.9	50.9	42.0	16.0	86.5	19.3	3476
D_3	20 ×14cm (35 hills m^{-2})	52.5	64.5	31.8	16.2	94.4	19.2	3060
D_4	20 ×17.5cm (28hills m^{-2})	58.3	67.6	15.3	16.7	96.6	19.8	2598
D_5	20 ×24.5cm (20 hills m^{-2})	60.9	81.9	32.9	17.7	108.9	20.3	2419
D_6	Manual transplanting 20 ×15cm (33 hills m^{-2})	51.3	62.5	35.5	17.2	101.7	19.8	3085
	SEm±	1.0	1.2	1.9	1.67	1.67	0.1	104
	CD (p = 0.05)	3.3	4.0	NS	5.2	5.2	0.4	328
	CV (%)	7.6	8.0	10.4	7.4	7.4	2.9	14
	WEED MANAGEMENT (W)							
W_1	Weedy check	124.9	94.2	0	14.5	50.4	18.4	1188
W_2	Hand weeding at 20 and 40 DAS	33.3	54.0	42.7	17.2	114.9	19.9	3570
W_3	Cono weeding at 20 and 40 DAS	38.4	51.0	45.9	18.2	132.5	20.2	3747
W_4	Anilofos @ 0.375 Kg a.i ha^{-1} (3-5 DAS) followed by 2, 4 D Salt 1.0 Kg a.i ha^{-1}	42.5	61.7	34.5	15.3	73.9	19.5	3004
W_5	Pendimethalin @1.0 Kg a.i ha^{-1} (3-5 DAS) followed by Bispyribac Sodium @ 20 g a.i ha^{-1} 30 DAS	32.3	50.5	46.4	16.4	103.1	20.0	3235
	SEm±	2.9	2.0	1.2	0.6	0.6	0.1	160
	CD (p = 0.05)	9.8	6.3	4.1	1.9	1.9	0.5	520
	CV(%)	23.0	13.6	14.7	2.9	2.9	3.6	23
	Interaction	WxC / CxW	W×C / CxW	WxC / CxW	WxC / CxW	WxC / CxW	WxC / CxW	WxC / CxW
	SEm±	3.7 / 2.9	14.7 / 2.6	6.0 / 3.2	7.2 / 2.5	7.2 / 2.5	0.3 / 0.2	18 / 14
	CD (p = 0.05)	10.8 / 9.0	27.1 / 8.0	18.0 / 12.6	21.5 / 7.4	21.5 / 7.4	0.6 / NS	53 / 43
	CV (%)	7.0	6.7	7.3	5.5	7.3	2.5	5.5

Note:
D×W=densities means at the same level of weed management means
W×D= weed management means at the same level of densities means



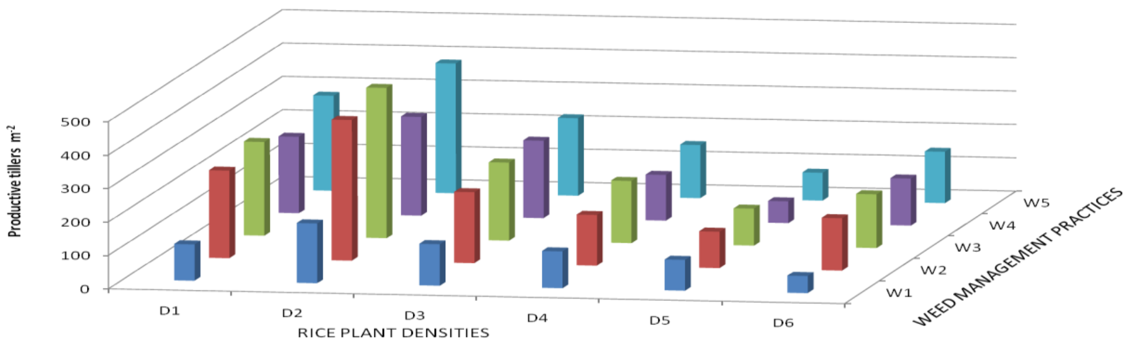
	D1	D2	D3	D4	D5	D6
W5	36.6	45.3	51	52.3	66.3	51.3
W4	46.4	54.2	68	70.7	73	57.8
W3	29.5	32.7	53.5	65.9	72.1	52.1
W2	33.9	34.6	55.3	69.4	75.9	54.6
W1	84.2	87.8	94.6	79.9	122	96.9

Fig: 2.Weed dry matter at harvest as influenced by varied rice plant densities and weed management practices in drum seeded rice



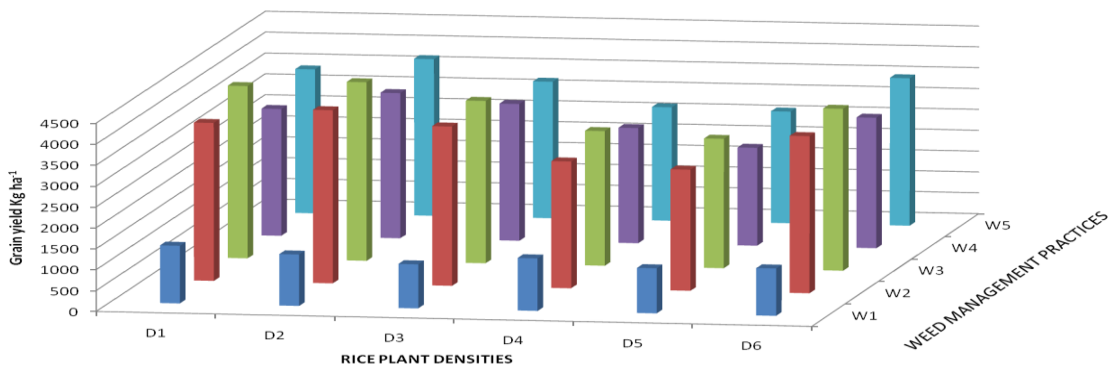
	D1	D2	D3	D4	D5	D6
W1	0	0	0	0	0	0
W2	59.7	60.6	41.5	13.1	37.8	43.7
W3	65	62.8	43.4	17.5	40.9	46.2
W4	44.9	38.3	28.1	11.5	40.2	40.4
W5	56.5	48.4	46.1	34.5	45.7	47.1

Fig.3.Weed control efficiency at harvest as influenced by varied rice plant densities and weed management practices in drum seeded rice



	D1	D2	D3	D4	D5	D6
W1	109	179	124	110	92	51
W2	262	421	212	152	109	157
W3	281	450	234	186	111	161
W4	229	296	232	137	65	141
W5	285	389	232	159	84	154

Fig.4.Rice productive tillers as influenced by varied rice plant densities and weed management practices in drum seeded rice



	D1	D2	D3	D4	D5	D6
W1	1378	1230	1054	1256	1078	1133
W2	3779	4142	3811	3034	2897	3759
W3	4124	4275	3887	3224	3098	3875
W4	3038	3478	3277	2759	2345	3124
W5	3451	3755	3273	2719	2675	3534

Fig.5. Grain yield as influenced by varied rice plant densities and weed management practices in drum seeded rice

Grain yield (kg ha^{-1})

Effect of plant density

Among various rice plant densities, a medium level population of 47 hills $^{-2}$ (D_2) significantly increased the paddy over all other treatments except D_1 treatments with a plant population of 71 hills m^{-2} The highest grain yield of 3476 kg ha^{-1} was observed with a plant population of 47 hills m^{-2} and it was significantly superior to 35, 28, 20 drum seeded and 33 hills m^{-2} transplanting paddies. It was on a par with a grain yield of 3154 kg ha^{-1} in D_1. The manual transplant (D_6) gave yield of 3085 kg ha^{-1}which was on par with the plant population 71 and 35 hills m^{-2} drum seeded rice (D_3) with 3154 and 3060 kg ha^{-1} respectively. Mahajan *et.al.* (2010) also demonstrated that rice grain yield increased with an increase in plant population to a certain level, further increase of plant population beyond optimum level had a negative effect owing acute inter and intra plant competition for available resources. A lower plant population of 28 and 20 hills m^{-2} in D_4 and D_5 treatments reduced the paddy in adequate special occupation for optimal utilization of in situ and externally applied resources there by negating the phenomenon law of constant described by Bond *et. al.* (2005).

Effect of weed control treatments

Among the weed management practices, significantly higher paddy grain yield (3747 kg ha^{-1}) as compared to all other weed management practices was recorded by twice cono weeding (W_3) which was on a par with twice manual weeding W_2 treatment with 3570 kg ha^{-1}. The significant lowest plant grain yield (1188 kg ha^{-1}) was recorded by the weedy check (W_1) treatment. Among chemical methods of weed management pre-emergence application of pendimethalin followed by post-emergence application of bispyribac sodium at 30 DAS (W_5) was found better in increasing the yield over the pre-emergence application of anilofos followed by post-emergence application of 2,4.D sodium salt (W_4). The increase in paddy grain yield cono weeding (W_2), hand weeding twice (W_3), application of and pendimethalin followed by bispyribac-sodium (W_5) and application of anilofos followed by 2,4 D sodium salt (W_4) over weedy check (W_1) was 67.4, 66.4, 63 and 56 per cent, respectively. Sequential application of pre-emergence followed by post-emergence herbicide proved better for prolonged period of controlling weeds to realise higher yields in rice. These results are in conformity with the finding of Bhowmick *et al.* (2000). The superiority of weed control by cono weeder or manual means over remaining treatments might be due to effective control of weeds as well as providing congenial soil aeration which has helped in an increase in the yield attributes that ultimately led to higher paddy grain yield. Though controlling of weeds through chemicals is a cost effective approach, the results clearly indicated that the chemical control of weeds cannot be a substitute to either cono or hand weeding, as the yields obtained with herbicides was far lower than cono and hand weeding.

Mechanical weed control significantly increased grain yields. Weeder use alone increased the plant height and enhanced the grain yield as compared to manual weeding. The dry matter production during the growing season showed that the differences between the weed control treatments occurred primarily after flowering. The higher grain yield recorded in the use of mechanical weeder and continued stirring of soil could be attributed to prolonged active leaves leaf area index (LAI) and higher number of productive tillers. Incorporation of weed with mechanical weeder increased the root activity which stimulated the new cell division in roots by pruning of some upper roots that encouraged deeper root growth thereby increased the shoot: root ratio (Uphoff, 2001). This was in accordance to the theory that partial excision of roots of wheat seedlings resulted in an increase in the growth rate of the remaining root system (Hunt, 1975, Vysotskaya *et al.* 2001). The capacity of the plant to absorb water and nutrients is closely related to the total length of the root system (Yoshida, 1981) which subsequently increases higher assimilation which will favor higher yield attributes and yield.

Interaction effect on plant density and weed control treatments

A significant interaction between rice plant densities and weed management practices showed that a treatment combination of $D_2 \times W_3$ gave the highest paddy grain yield of 4275 kg ha^{-1} which was significantly superior to all the treatment combination. Next best treatment combination is $D_2 \times W_2$ and $D_1 \times W_3$ with a grain yield of 4142 kg ha^{-1} and 4124 kg ha^{-1} and superior to all other treatment combination even when compared with transplanted paddy system. These results clearly showed that medium to slightly higher plant densities above 33 hills m^{-2} with a combination of weed management technique which will serve the dual purpose of controlling first and second generation of both grassy and broad leaved weeds with an added advantage of soil pulverisation to enhance intermittent aeration would be the better option to extract higher rice productivity through direct seeded method of drum seeding which was even better than the traditional system of transplanted paddies particularly under the situation of depleting manual labour scenario.

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