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Management of weeds in aerobic rice under different agro ecologies of North East India

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Abstract

The field experiment was carried out to study the importance of weed management and efficiency of different weed management practices both chemical and nonchemical method in aerobic rice. The field experiment was carried out in a randomized block design with twelve treatments and three replication. In the experiment chemical and nonchemical methods are used either alone or in combination. Rice variety NDR-97 was taken for the purpose. The upland rice was fertilized as per recommended package of practices in Tripura. Weed counts at different stages (15, 30, 60 and at harvest stage) was taken by placing quadrat at random from three sites in each plot and calculating the average. Weed sample from each of the quadrat was taken, grouped into grasses, broad leaved weed and sedges, dried and weighed. Weed dry matter was expressed category wise in g m^{-2} . Data on growth parameters, yield attributes and yield of rice were taken. Economics of different weed management practices was also calculated. The data generated from the experiment were subject to analysis of variance (ANOVA) as applied to randomized block design. Among the various weed management practices, hand weeding at 15, 30 and 45 DAS has recorded the lowest weed dry weight, highest weed control efficiency, highest grain and straw yield followed by pendimethalin @ 1.0 kg ha^{-1} + one hand weeding at 30 DAS and pendimethalin @ 1.0 kg ha^{-1} at 2 DAS + bispyribac sodium @ 25 g ha^{-1} at 20 DAS. Highest dry weight of weed, lowest weed control efficiency, lowest grain and straw yield was obtained with weedy check where weed management practices were not adopted. Though the rice yield and gross return were the highest under hand weeding at 15, 30 and 45 DAS, net income and return per rupee invested showed that it was less remunerative than pendimethalin @ 1.0 kg ha^{-1} at 2 DAS + bispyribac sodium @ 25 g ha^{-1} at 20 DAS and pendimethalin @ 1.0 kg ha^{-1} + one manual weeding at 30 DAS. For successful crop production adoption of weed management practices is very much necessary. Acceptance of any weed management practices depends on the economic viability of the practices. The net return and B C ratio obtained with hand weeding at 15, 30 and 45 DAS implied that it was uneconomic and unnecessary to give three hand weeding during the entire crop growth.

Keywords: Aerobic rice, fenoxaprop, weed management, yield, weed control efficiency, weed dry weight

Introduction

Meeting food demand for the burgeoning population has become a major challenge now than ever before. Agriculture is in the fore front of national and international agenda to assume food security and sound management of natural resources. Cereal plays major role in our food economy and is the most important part of diet throughout the world. Rice (*Oryza sativa*) is the leading cereal of the world (Ashraf *et al.*, 2006) ^[1], and more than half of the human race depend on rice for their daily sustenance (Chauhan and Jhonson, 2011) ^[5]. It is the primary source of income and employment for more than 100 million household for Asia and Africa (FAO, 2004) ^[9]. World's rice demands is projected to be increased by 25% from 2001 to 2025 to keep pace with population growth (Maclean *et al.*, 2002) ^[17], and therefore, meeting ever increasing rice demand in a sustainable way with shrinking natural resources is a great challenge.

In North east India rice is cultivated in a wide range of agro ecosystem from irrigated to shallow lowlands, mid-deep lowlands, deep water to uplands. Based on the hydrology and topography of land, the rice area is divided into various ecologies viz., rainfed upland (16%), irrigated medium land (45%) and rainfed low land including shallow, intermediate, semi deep and deep (39%). Out of 61.3% of total rice area in eastern India 20% (5.2 M ha) are rainfed upland, 28.5% (7.8 Mha) medium land and 51.5% (14.0 mha) are rainfed lowland (Mahapatra *et al.*, 2012) ^[16].

Transplanting is the major method of rice cultivation in India. However, it is becoming increasingly difficult due to shortage and high cost of labour, scarcity of water, and reduced profit. The practice of direct seeding of rice is gaining importance. Conventional puddled transplanted rice is a major source of greenhouse gas (GHG), particularly methane, causing global warming (Brye *et al.*, 2013)^[4]. The advantages of direct seeding also include more efficient use of water, higher tolerance of water deficit through less soil cracking and percolation and leaching losses upon re-flooding, less methane emission, earlier crop maturity (7-15 days) and often higher profit in areas with an assured water supply.

Weeds are the greatest yield-limiting constraint in upland rice (WARDA, 1996)^[31]. Weed pose serious threat to the crop through its competition for the factors like nutrients, water, sunlight and space which causes considerable reduction in grain yield. It is estimated that every year, weeds cause yield losses from 15 to 76% in rice crop (Mishra *et al.*, 2008)^[21]. The risk of yield loss from weeds in direct seeded rice is greater than transplanted rice (Rao *et al.*, 2007)^[25]. Aerobic rice is subjected to much higher weed pressure with a broader weed spectrum than flood irrigated rice (Balasubramanian and Hill, 2002)^[3]. Relatively safe, economic and easily acceptable weed management system is imperative for effective weed control and higher productivity. In light of this a weed management packages was designed for aerobic rice to study the effectiveness of the management packages in controlling weeds of upland rice of north eastern region with special reference to Tripura.

Materials and Methods

The field experiment was conducted in the villages of South Tripura district during the kharif season of 2013-2014 and 2014-2015 to study the effect of different weed management practices on direct seeded upland rice under Tripura condition. The farm is situated at about 22°57' and 23°45' N latitude and 91°19' and 91°53'E longitude with an average altitude of 120 m above the mean sea level. The Agricultural farm is located in the Mid tropical Plain zone (NEH-6) of Tripura. The experimental site is situated in the semi-arid and sub-humid lateritic belt of South Tripura District. The soil of the experimental field was sandy loam in texture, having low fertility with acidic reaction. The average maximum and minimum temperature during the crop growing period from June 2013 to March 2014 varied from 25.2°C to 34.2°C and 10.1°C to 25.3°C respectively in the first year and 25.8°C to 35.9°C and 12.2°C to 25.4°C respectively in the second year. Variation in relative humidity was also observed during the cropping season of 2013-14 and 2014-15 which varied from 55 to 86% in 2013-14 and 72 to 90% in 2014-15. The South -West monsoon sets in South Tripura during middle of June and continues to the month of October with occasional dry spell. More than 80% of the total rainfall occurred during monsoon months (June to September). The total rainfall during the rice growing season in 2013 was 1156.1 mm whereas it was 1461.8 mm in 2014.

The field experiment was carried out in a randomized block design with twelve treatments and three replication. The detail of the treatments were pendimethalin @ 1.0 kg ha⁻¹ at 2 DAS, bispyribac sodium @ 25 g ha⁻¹ at 25 DAS, pendimethalin @ 1.0 kg ha⁻¹ at 2 DAS + one hand weeding at 30 DAS, pendimethalin @ 1.0 kg ha⁻¹ at 2 DAS + bispyribac sodium @ 25 g ha⁻¹ at 20 DAS, metsulfuron methyl + chlorimuron ethyl (Almix) @ 4 g at 10 DAS followed by bispyribac sodium @ 25 g at 20 DAS, pyrazosulfuron ethyl @ 25 g ha⁻¹ at 3 DAS followed by bispyribac sodium @ 25 g at 20 DAS, fenoxaprop-p-ethyl @ 60

g ha⁻¹ + metsulfuron methyl + chlorimuron ethyl (Almix) @ 4 g ha⁻¹ at 15 DAS, stale seed bed + smother crop (cowpea) in between two rows of rice, stale seed bed + one hand weeding at 30 DAS, sesbania (broadcast) @ 25 kg ha⁻¹ during sowing of rice + 2,4-D @ 500 g ha⁻¹ at 25 DAS, hand weeding at 15, 30 and 45 DAS, weedy check were assigned in a randomized block design replicated thrice. Rice variety NDR-97 was used for the experimental purpose. The upland rice was fertilized as per recommended package of practices in Tripura. Five tonnes of Farm Yard Manure were applied at the time of field preparation for both the crop. Chemical fertilizers were applied to meet 60 kg nitrogen in the form of urea, 40 kg phosphorus in the form of single superphosphate and 40 kg potassium in the form of muriate of potash in the rice.

Weed counts at different stages (15, 30, 60 and at harvest stage) was taken by placing quadrat at random from three sites in each plot and calculating the average. Weed sample from each of the quadrat was taken, grouped into grasses, broad leaved weed and sedges, dried and weighed. Weed dry matter was expressed category wise in g m⁻². Data on growth parameters, yield attributes and yield of rice were taken. Economics of different weed management practices was also calculated.

The experimental data related to each character of crop and weed were analysed statistically by the technique of "Analysis of variance" and significance was tested by variance ratio i.e. value at 5% level of significance as described by Gomez and Gomez (2010)^[10]. The standard error of means (S.E.m.±), the value of critical differences (C. D.) to compare the differences between means, and co-efficient of variability (C.V.) have been provided in the tables.

Results and Discussion

Weed spectrum

The degree and nature of competition between crop and weeds is dependent on the weed species growing in association with the crop (Kim and Moody, 1980)^[15]. The experimental field was infested with three categories of weeds under eight families. The total number of weed species was eight, out of which *Digitaria sanguinalis* among grasses, *Cyperus iria* among sedges and *Amaranthus viridis*, *Oldenlandia corymbosa*, *Spilanthes acmella*, *Ludwigia parviflora*, *Cleome rutidosperma*, *Malvestrum coromondaliense* among the broad leaved weeds were present as major weeds (Table-1). Similar weed flora in direct seeded rice was also reported by many workers like Duary *et al.* (2005)^[8], Maity and Mukherjee (2009)^[19], Chauhan and Opena (2012)^[6] and Kashid *et al.* (2015)^[13].

Table 1: Major weeds present in the experimental field

Botanical Name	Family	English Name/Common name
Grasses		
<i>Digitaria sanguinalis</i>	Poaceae	Crab grass
Sedges		
<i>Cyperus iria</i> L.	Cyperaceae	Flat sedge
Broadleaved		
<i>Amaranthus viridis</i>	Amaranthaceae	Slender Amaranth
<i>Oldenlandia corymbosa</i>	Rubiaceae	Diamond Flower
<i>Spilanthes acmella</i> L.	Asteraceae	Toothache plant
<i>Ludwigia parviflora</i> (L.) Roxb.	Onagraceae	Water purslane
<i>Cleome rutidosperma</i> (Dc.)	Cleomaceae	Fringed Spider Flower
<i>Malvastrum coromondelianum</i>	Malvaceae	Broom weed/clock plant

Weed Dry matter accumulation

The impact of different weed management practices on dry weight of grassy, broadleaf and sedges at 90 days after sowing

was significant and are depicted in Table 2. The dry matter accumulated by the weed was the highest under weedy check throughout the crop growth period (255.88 g m⁻² in 1st year and 243.66 g m⁻² in 2nd year) which was followed by Stale seed bed + smother crop and Sesbania (broadcast) + 2,4-D @ 500 g ha⁻¹ at 25 DAS during both the years. Unchecked weed growth exploited the available nutrients and water resulting in better

growth and dry matter production. Similar observations have been made by Singh *et al.* (2014)^[29] and Kashid *et al.* (2015)^[13] who reported that maximum dry weight of weed was found in weedy check or unweeded control in upland rice. Hand weeding at 15, 30 and 45 DAS recorded the lowest dry weight (49.88 g m⁻² and 37.20 g m⁻²).

Table 2: Effect of treatments on weed dry weight at 90 DAS

Treatment	Weed dry weight (g m ⁻²) at 90 DAS							
	1 st year				2 nd year			
	Grasses	BLW	Sedges	Total	Grasses	BLW	Sedges	Total
Pendimethalin @ 1.0 kg ha ⁻¹ at 2 DAS (T ₁)	76.90	39.88	29.71	146.48	71.69	35.31	27.12	134.12
Bispyribac sodium @25 g ha ⁻¹ at 20 DAS (T ₂)	95.77	43.59	9.47	148.83	90.47	39.55	6.90	136.91
Pendimethalin @ 1.0 kg ha ⁻¹ + one hand weeding at 30 DAS (T ₃)	27.96	23.31	8.93	60.21	22.13	18.58	5.97	46.68
Pendimethalin @ 1.0 kg ha ⁻¹ at 2 DAS + bispyribac sodium @ 25 g ha ⁻¹ at 20 DAS (T ₄)	28.48	24.96	10.08	63.52	23.90	20.28	7.90	52.09
Metsulfuron + chlorimuron (Almix) @ 4 g at 10 DAS followed by bispyribac sodium @ 25 g at 20 DAS (T ₅)	89.32	43.73	9.36	142.41	83.81	40.05	6.17	130.03
Pyrazosulfuron ethyl @ 25 g ha ⁻¹ at 3 DAS followed by bispyribac sodium @ 25 g at 20 DAS (T ₆)	79.05	37.95	17.24	134.24	73.68	33.88	14.46	122.03
Fenoxaprop @ 60 g ha ⁻¹ + metsulfuron + chlorimuron (Almix) @ 4 g ha ⁻¹ at 15 DAS (T ₇)	82.34	41.74	12.54	136.62	76.77	37.84	13.13	127.75
Stale seed bed + smother crop (cowpea) (T ₈)	117.07	41.45	30.66	189.18	110.84	37.59	27.70	176.14
Stale seed bed + one hand weeding at 30 DAS (T ₉)	97.40	42.41	23.22	163.03	91.85	38.74	20.68	151.27
Sesbania (broadcast) + 2,4-D @ 500 g ha ⁻¹ at 25 DAS (T ₁₀)	114.42	37.86	30.00	182.28	108.36	34.33	27.42	170.11
Hand weeding at 15, 30 and 45 DAS (T ₁₁)	25.21	18.77	5.90	49.88	19.42	14.91	2.87	37.20
Weedy check (T ₁₂)	142.85	69.02	44.01	255.88	137.14	65.48	41.03	243.66
S.Em (±)	2.29	1.24	1.20	2.50	2.30	1.29	1.15	2.50
CD(P=0.05)	6.72	3.65	3.53	7.33	6.75	3.77	3.36	7.34
CV (%)	4.88	5.56	10.83	3.11	5.26	6.44	11.84	3.40

The overall observation on the effect of weed management on weed dry matter accumulation indicated that next to hand weeding at 15, 30 and 45 DAS, pendimethalin @ 1.0 kg ha⁻¹ + one hand weeding at 30 DAS was the best treatment for reducing dry matter accumulation by weeds throughout the growth period. This is in conformity with the findings of Valverde *et al.* (2005)^[30], and Singh *et al.* (2005)^[27].

Dry matter accumulation of rice

The perusal of data showed that the highest dry matter accumulation of rice was registered with hand weeding at 15, 30 and 45 DAS which was at par with pendimethalin @ 1.0 kg ha⁻¹

+ one hand weeding at 30 DAS and pendimethalin @ 1.0 kg ha⁻¹ at 2 DAS + bispyribac sodium @ 25 g ha⁻¹ at 20 DAS (Table 3). This was mainly due to higher weed control efficiency of these treatments which maintained lower weed density as well as dry weight thus least crop weed competition from the very early stage of the crop till maturity facilitating higher nutrient and water uptake, accelerated photosynthetic activity, availability of optimum space for better crop growth resulting into higher dry matter accumulation and thus led to higher crop growth rate. This was in corroboration with the findings of Yadav (2004)^[32], Singh *et al.* (2008)^[28], Maity and Mukherjee (2009)^[19], Gopal *et al.* (2010)^[11].

Table 3: Effect of treatments on dry matter accumulation of rice

Treatment	Dry matter accumulation (g m ⁻²) of rice					
	30 DAS		60 DAS		90 DAS	
	1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year
Pendimethalin @ 1.0 kg ha ⁻¹ at 2 DAS (T ₁)	223.97	293.33	418.67	492.67	729.33	835.67
Bispyribac sodium @25 g ha ⁻¹ at 20 DAS (T ₂)	179.33	252.33	409.00	504.33	750.00	839.00
Pendimethalin @ 1.0 kg ha ⁻¹ + one hand weeding at 30 DAS (T ₃)	233.83	303.00	505.67	581.70	915.67	989.67
Pendimethalin @ 1.0 kg ha ⁻¹ at 2 DAS + bispyribac sodium @ 25 g ha ⁻¹ at 20 DAS (T ₄)	236.00	294.50	501.67	584.67	921.83	1001.67
Metsulfuron + chlorimuron (Almix) @ 4 g at 10 DAS followed by bispyribac sodium @ 25 g at 20 DAS (T ₅)	183.67	259.97	410.13	510.00	761.33	876.67
Pyrazosulfuron ethyl @ 25 g ha ⁻¹ at 3 DAS followed by bispyribac sodium @ 25 g at 20 DAS (T ₆)	200.00	266.83	464.67	539.33	853.00	934.10
Fenoxaprop @ 60 g ha ⁻¹ + metsulfuron + chlorimuron (Almix) @ 4 g ha ⁻¹ at 15 DAS (T ₇)	190.63	236.48	354.37	402.31	701.00	765.00
Stale seed bed + smother crop (cowpea) (T ₈)	182.00	243.60	369.50	446.33	709.00	799.33
Stale seed bed + one hand weeding at 30 DAS (T ₉)	184.23	258.70	411.17	501.58	759.67	880.67
Sesbania (broadcast) + 2,4-D @ 500 g ha ⁻¹ at 25 DAS (T ₁₀)	168.30	240.57	348.83	465.60	687.67	840.00
Hand weeding at 15, 30 and 45 DAS (T ₁₁)	244.67	306.67	518.20	595.07	959.83	1014.67
Weedy check (T ₁₂)	125.83	115.00	272.67	266.00	489.17	470.00
S. Em (±)	9.97	8.51	8.47	9.85	14.01	16.03
CD(P=0.05)	29.22	24.95	24.85	28.89	41.08	47.03
CV (%)	8.80	5.76	3.53	3.48	3.15	3.25

Weed Control Efficiency (WCE)

Data in the Table no.4 and Fig 1 reveals that the treatment hand weeding at 15, 30 and 45 DAS showed highest weed control efficiency (80.51% in 1st year and 85.31% in 2nd year) during both the year (Table 4). This was in conformity with the report of Jhon *et al.* (2012) [12]. It was also evident that the weed

control efficiency was improved when the chemical was integrated with one manual weeding which implied that the persistence of the herbicide was short and for season long weed control, it has to be integrated with other control methods. This is in conformity with the report of Pannu *et al.* (1991) [23] and Anupam *et al.* (2022) [2].

Table 4: Effect of treatments on weed control efficiency at 90 DAS

Treatment	Weed control efficiency (%) at 90 DAS							
	1 st year				2 nd year			
	Grasses	BLW	Sedges	Total	Grasses	BLW	Sedges	Total
Pendimethalin @ 1.0 kg ha ⁻¹ at 2 DAS (T ₁)	46.17	42.22	32.50	42.75	49.42	48.44	36.98	47.04
Bispyribac sodium @25 g ha ⁻¹ at 20 DAS (T ₂)	32.96	36.85	78.48	41.84	36.17	42.25	83.97	45.94
Pendimethalin @ 1.0 kg ha ⁻¹ + one hand weeding at 30 DAS (T ₃)	80.43	66.22	79.70	76.47	84.39	72.87	86.12	81.57
Pendimethalin @ 1.0 kg ha ⁻¹ at 2 DAS + bispyribac sodium @ 25 g ha ⁻¹ at 20 DAS (T ₄)	80.06	63.84	77.09	75.17	83.14	70.38	81.63	79.43
Metsulfuron + chlorimuron (Almix) @ 4 g at 10 DAS followed by bispyribac sodium @ 25 g at 20 DAS (T ₅)	37.47	36.64	78.72	44.34	40.87	41.51	85.66	48.66
Pyrazosulfuron ethyl @ 25 g ha ⁻¹ at 3 DAS followed by bispyribac sodium @ 25 g at 20 DAS (T ₆)	44.66	45.01	60.83	47.54	48.02	50.53	66.39	51.82
Fenoxaprop @ 60 g ha ⁻¹ + metsulfuron + chlorimuron (Almix) @ 4 g ha ⁻¹ at 15 DAS (T ₇)	42.36	39.53	71.50	46.61	45.84	44.74	69.49	49.56
Stale seed bed + smother crop (cowpea) (T ₈)	18.05	39.94	30.33	26.07	21.80	45.11	35.62	30.45
Stale seed bed + one hand weeding at 30 DAS (T ₉)	31.81	38.56	47.23	36.29	35.20	43.43	51.95	40.27
Sesbania (broadcast) + 2,4-D @ 500 g ha ⁻¹ at 25 DAS (T ₁₀)	19.90	45.15	31.83	28.76	23.55	49.86	36.27	32.83
Hand weeding at 15, 30 and 45 DAS (T ₁₁)	82.35	72.80	86.59	80.51	86.30	78.23	93.34	85.31
Weedy check (T ₁₂)	0.00	0.00	0.00	0.00	3.25	4.38	4.65	3.79

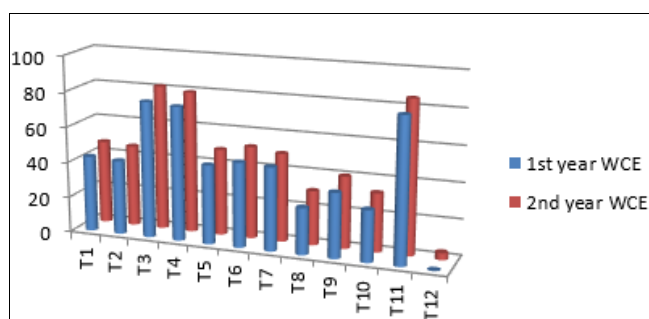


Fig 1: Weed Control efficiency of different weed management practices

Yield and Yield attributing characters of upland rice

From the data given in Table 5 it was evident that effective weed control did have a significant role in determining the grain yield, straw yield, harvest index and weed index. Among the various treatment, hand weeding at 15, 30 and 45 DAS recorded highest grain yield (3.45 t ha⁻¹ in 1st year and 3.60 t ha⁻¹ in 2nd year) and straw yield (5.16 t ha⁻¹ in 1st year and 5.43 t ha⁻¹ in 2nd year) which was either at par or closely followed by pendimethalin @ 1.0 kg ha⁻¹ + one hand weeding at 30 DAS and pendimethalin @ 1.0 kg ha⁻¹ at 2 DAS + bispyribac sodium @ 25 g ha⁻¹ at 20 DAS.

Table 5: Effect of treatments on grain and straw yield, harvest index and weed index

Treatment	Grain yield (t ha ⁻¹)		Straw yield (t ha ⁻¹)		Harvest index (%)		Weed Index (%)	
	1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year
Pendimethalin @ 1.0 kg ha ⁻¹ at 2 DAS (T ₁)	2.15	2.36	3.89	4.21	35.60	35.82	37.58	34.56
Bispyribac sodium @25 g ha ⁻¹ at 20 DAS (T ₂)	2.21	2.26	3.65	4.22	37.69	34.77	35.90	37.38
Pendimethalin @ 1.0 kg ha ⁻¹ + one hand weeding at 30 DAS (T ₃)	3.30	3.59	5.03	5.28	39.62	39.82	4.34	0.28
Pendimethalin @ 1.0 kg ha ⁻¹ at 2 DAS + bispyribac sodium at 25 g ha ⁻¹ at 20 DAS (T ₄)	3.26	3.41	4.87	5.17	40.14	39.73	5.48	5.48
Metsulfuron + chlorimuron (Almix) @ 4 g at 10 DAS followed by bispyribac sodium @ 25 g at 20 DAS (T ₅)	2.49	2.65	3.72	4.65	40.14	36.29	27.83	26.42
Pyrazosulfuron ethyl @ 25 g ha ⁻¹ at 3 DAS followed by bispyribac sodium @ 25 g at 20 DAS (T ₆)	2.71	2.80	4.04	4.81	40.15	36.68	21.35	22.38
Fenoxaprop @ 60 g ha ⁻¹ + metsulfuron + chlorimuron (Almix) @ 4 g ha ⁻¹ at 15 DAS (T ₇)	1.89	1.98	3.82	3.98	32.97	33.18	45.21	45.04
Stale seed bed + smother crop (cowpea) (T ₈)	1.86	2.01	3.79	4.01	32.92	33.27	46.06	44.23
Stale seed bed + one hand weeding at 30 DAS (T ₉)	1.86	2.10	3.71	3.89	33.42	35.10	46.15	41.53
Sesbania (broadcast) + 2,4-D @ 500 g ha ⁻¹ at 25 DAS (T ₁₀)	1.81	1.93	3.75	3.74	32.79	34.13	47.54	45.94
Hand weeding at 15, 30 and 45 DAS (T ₁₁)	3.45	3.60	5.16	5.43	40.33	40.57	0	0
Weedy check (T ₁₂)	0.58	0.74	2.90	2.80	16.85	20.76	83.12	79.49
S. Em (±)	0.11	0.13	0.22	0.17	1.33	0.80	-	-
CD (P=0.05)	0.34	0.37	0.64	0.49	3.88	2.35	-	-
CV (%)	8.62	8.93	9.40	6.70	6.52	3.97	-	-

The competition between rice and weed for nutrient, water, light and space was less under the above treatments, which facilitated greater utilization of sun light, higher synthesis of carbohydrate

and better partitioning of photosynthates towards grain formation and ultimately leading to higher grain yield of rice. The lowest grain yield (0.58 t ha⁻¹ in 1st year and 0.74 t ha⁻¹ in

2nd year) and straw yield (2.9 t ha⁻¹ in 1st year and 2.8 t ha⁻¹ in 2nd year) was observed under weedy check (Table 5 and fig 2). Similar results were observed by Kumar and Singh (2009) [14], Naresh *et al.* (2011) [22], Mathew *et al.* (2013) [20] and Choudhary *et al.* (2021) [7].

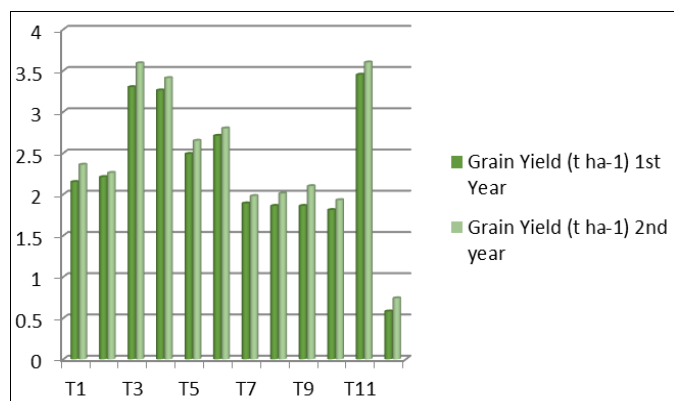


Fig 2: Grain yield of rice under different weed management practices

In the present study, the harvest index values were also higher in treatments which registered lower weed growth, and accordingly higher harvest index values were recorded with hand weeding at 15, 30 and 45 DAS (40.33 in 1st year and 40.57 in 2nd year), pendimethalin @ 1.0 kg ha⁻¹ at 2 DAS + bispyribac sodium @ 25 g ha⁻¹ at 20 DAS (40.14 in 1st year and 39.73 in 2nd year) and pendimethalin @ 1.0 kg ha⁻¹ + one manual weeding at 30 DAS

(39.62 in 1st year and 39.82 in 2nd year) respectively.

The weed indices give the extent of crop loss due to weed competition in rice, taking the crop yield from hand weeding at 15, 30 and 45 DAS as the reference. The yield loss was maximum under unweeded control that is 83.12% in the first year and 79.49% in the second year while it was the lowest in pendimethalin @ 1.0 kg ha⁻¹ + one hand weeding at 30 DAS. Such response indicated the direct correlation between intensity of weed competition and crop yield loss of upland rice.

Economics of the weed management

The result of the present study revealed that the remuneration from the rice crop was highly dependent on weed management practices adopted. Pendimethalin @ 1.0 kg ha⁻¹ at 2 DAS + bispyribac sodium @ 25 g ha⁻¹ at 20 DAS recorded the highest net return (Rs. 23847/- in the first year and Rs. 26010/- in the second year) and return per rupee invested (2.02 and 2.11) in both the years and was found to be the most remunerative weed management practices (Table 6). The herbicide pendimethalin @ 1.0 kg ha⁻¹ + one hand weeding at 30 DAS registered net return of Rs. 21427/- and 25573/- in the first year and second year respectively and was the next best treatment. This is simply due to higher grain and straw yield of the crop obtained from these treatments and comparatively lower cost involved in the cultivation of crop under these treatments. Similar result was reported by Yakadri *et al.* (2016) [33] and Maimunah *et al.* (2021) [18].

Table 6: Economics of rice cultivation under different weed management practices

Treatment	Cost of cultivation (Rs. ha ⁻¹)	Gross Return (Rs. ha ⁻¹)		Net Return (Rs. ha ⁻¹)		Return Rupee ⁻¹ invested	
		2013	2014	2013	2014	2013	2014
Pendimethalin @ 1.0 kg ha ⁻¹ at 2 DAS (T ₁)	20550	31887	34847	11337	14297	1.55	1.70
Bispyribac sodium @ 25 g ha ⁻¹ at 20 DAS (T ₂)	21730	32380	33560	10650	11830	1.49	1.54
Pendimethalin @ 1.0 kg ha ⁻¹ + one hand weeding at 30 DAS (T ₃)	26550	47977	52123	21427	25573	1.81	1.96
Pendimethalin @ 1.0 kg ha ⁻¹ at 2 DAS + bispyribac sodium @ 25 g ha ⁻¹ at 20 DAS (T ₄)	23450	47297	49460	23847	26010	2.02	2.11
Metsulfuron + chlorimuron (Almix) @ 4 g at 10 DAS followed by bispyribac sodium @ 25 g at 20 DAS (T ₅)	22605	36093	39147	13488	16542	1.60	1.73
Pyrazosulfuron ethyl @ 25 g ha ⁻¹ at 3 DAS followed by bispyribac sodium @ 25 g at 20 DAS (T ₆)	22680	39317	41170	16637	18490	1.73	1.82
Fenoxaprop @ 60 g ha ⁻¹ + metsulfuron + chlorimuron (Almix) @ 4 g ha ⁻¹ at 15 DAS (T ₇)	20485	28393	29673	7908	9188	1.39	1.45
Stale seed bed + smother crop (cowpea) (T ₈)	23480	27973	30093	4493	6613	1.19	1.28
Stale seed bed + one hand weeding at 30 DAS (T ₉)	26030	27887	31233	1857	5203	1.07	1.20
Sesbania (broadcast) + 2,4-D @ 500 g ha ⁻¹ at 25 DAS (T ₁₀)	19790	27280	28873	7490	9083	1.38	1.46
Hand weeding at 15, 30 and 45 DAS (T ₁₁)	32430	50050	52143	17620	19713	1.54	1.61
Weedy check (T ₁₂)	15830	10483	12380	-5347	-3450	0.66	0.78
S. Em (±)	-	1609	1783	1609	1783	0.07	0.08
CD(P=0.05)	-	4719	5230	4719	5230	0.22	0.23
CV (%)	-	8.22	8.53	25.45	23.29	8.39	8.95

Though the rice yield and gross return were the highest under hand weeding at 15, 30 and 45 DAS, the data on net income and return per rupee invested showed that it was less remunerative than pendimethalin @ 1.0 kg ha⁻¹ at 2 DAS + bispyribac sodium @ 25 g ha⁻¹ at 20 DAS and pendimethalin @ 1.0 kg ha⁻¹ + one manual weeding at 30 DAS which implied that it was uneconomic and unnecessary to give three hand weeding during the entire crop growth (Table 6 and Fig 3). This is in conformity with the study conducted by Prashanth *et al.* (2016) [24]. Kashid

et al. (2015) [13] reported that significantly the highest net return and return per rupee invested was obtained with the pre-emergence application of herbicide integrating with one hand weeding or one post emergence herbicide. Sharma *et al.* (2004) [26] reported that pendimethalin + one hand weeding and pendimethalin + criss cross sowing + one hand weeding were better than the other treatments in terms of increasing grain, biomass yields and net returns.

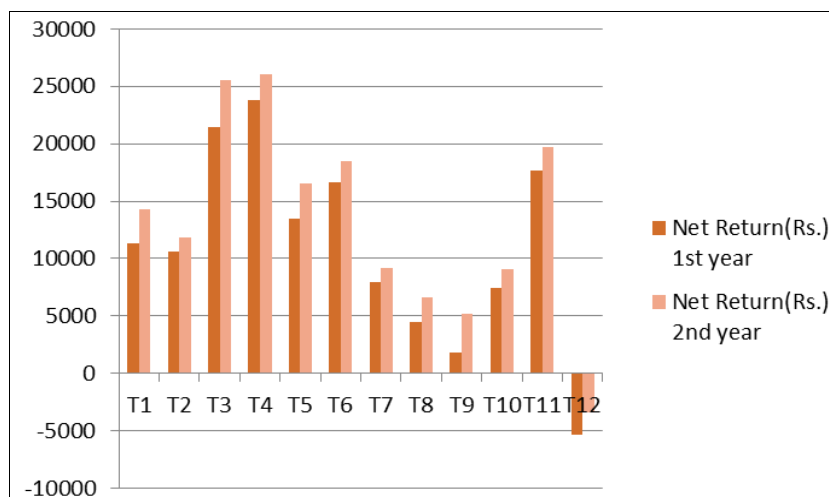


Fig 3: Net return of rice under different weed management practices

Conclusion

Acceptability of any farming practices essentially depends upon its economic viability. Hence it is concluded that among the different treatments tested, pendimethalin @ 1.0 kg ha⁻¹ at 2 DAS + bispyribac sodium @ 25 g ha⁻¹ at 20 DAS is the best treatment for managing weeds in aerobic rice followed by pendimethalin @ 1.0 kg ha⁻¹ + one hand weeding at 30 DAS. The net income was found negative under weedy check due to greater competition between rice and weed which led to poor growth of the crop, lower grain and straw yield. This again emphasized the importance of weed management in profitable rice production.

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