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Efficacy of Different Herbicides and its Combination against the Weed Flora of Transplanted Rice: A Review

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A B S T R A C T

Rice is an important food crop extensively grown in India. Several factors are responsible for reducing the yield of transplant rice. However, weed infestation is the major threat to productivity of transplanted rice. Normally the loss in yield ranges between 16-20%, yet in severe cases the yield losses can be more than 50%, depending upon the species and intensity of weeds. Weed flora under transplanted condition is very much diverse and consists of grasses, sedges and broad-leaved weeds causing yield reduction of rice crop up to 76 %. These weeds could be controlled through manual and chemical methods. Manual method is though very common but cost intensive and chemical weed control is used to overcome weeds infestation which is easy, quick, time saving, cost effective and the most reliable method to control weeds in rice. Herbicides when applied alone is although economical but may have limitation of resistance development, shift in weed flora etc. Therefore, presently there is a need to use high efficacy herbicides in combination coupled with broad spectrum nature to control the complex weed flora in transplanted rice.

Introduction

Rice is the world's most important food and more than half of the world's population depends on rice for food, calories and protein, especially in developing countries among all staple food crops More than 90% of the world rice is produced and consumed in Asia, which is a native for 60% of the earth's population. With the increasing food demand by the growing population, rice will continue to be primary source of food. Rice is primary food crop of India and therefore, national food security system largely depends on productivity of rice ecosystems. The world's total area under rice is 161.1 mha and production is about 480.3 mt along with the productivity of 2.98 t/ha. Rice is the first most important crop in India where it is grown in an area of 44.1 mha with an annual production of 106.7 mt and average productivity is 2.4 t/ha. Rice is grown in both

kharif and Rabi seasons under diverse ecological and climatic conditions apart from socio-economic diversities of the state. 33% of total rice land has got irrigation facilities and rest is totally dependent upon rainfall. Among various depressing factors, abiotic stress i.e. water and nutrient stress and biotic stress i.e. weed infestations in the field are the most crucial factors due to which rice production is unpredictable and considerably low. Weeds are the most important biological constraint to decrease yields wherever rice is grown. It has been estimated that without weed control, at a yield level of 7 to 8 $t.ha^{-1}$, yield loss can be as high as about 90% (Ferrero and Tinarelli, 2007). Various methods like cultural, mechanical, biological and chemicals are used for weed control. The chemical weed control method is becoming popular among the farmers because it is the most efficient means of reducing weeds competition with minimum labour cost (Baloch, 1994). Chemical weed management becomes a competitive and promising way to control weeds in transplanted rice, at least for first few weeks after transplanting of crop. The use of herbicides, therefore appears to be the only alternative (Alstorm, 1990) and in the present context, it is most preferable and farmer can easily go for it, because day-by-day labour scarcity increased. The yield of transplanted rice in India is much lower than that of transplanted rice in other rice growing countries. Therefore, proper weed management is essential for satisfactory rice production in India. Weed free period during the critical period of competition is essential for obtaining optimum rice yield. This can be achieved by removing the weeds by mechanical, cultural or chemical means or by their combinations. Subsistence farmers in India spend more time and energy on weed control than any other aspects of rice cultivation. Chemical weed control has been gaining popularity in India in recent years. In addition, during peak period, the availability of labour is becoming a serious problem by time. So, herbicides are used successfully for weed control in rice fields for rapid effect, easier to application and lower cost involvement in comparison to the traditional methods of hand weeding (Mian and Al-Mamun, 1969). Both pre-emergence and Post-emergence herbicides can be used in rice fields and they are effective. But weeds are the most severe constraints and timely weed management is crucial for increasing the productivity of rice. In such situation, the application of pre-emergence herbicides like Pendimethalin plays significant role in controlling weeds (Singh and Singh, 2010). Similarly, several authors reported to Azimsulfuron (Singh *et al.,* 2009), Pyrazosulfuron, Penoxsulam (Chauhan & Seth, 2013) and post emergence Bispyribac (Khaliq *et al.,* 2012) herbicides which are considered to be an alternative/ supplement to hand weeding. Most of the pre-emergence herbicides viz., butachlor, pretilachlor and thiobencarb were applied in large quantities for weed management in transplanted rice. These herbicides are very effective for grasses and less effective against sedges and broad-leaved weeds (Singh*et al.,* 2009). Further, these herbicides are very effective for controlling weeds up to 20 DAT. Application of herbicide mixtures or sequential application of herbicides may be useful for broad-spectrum control of weeds in rice. Recent trend of herbicide use is to find out an alternative and effective weed management by using low dose high efficiency herbicides, which will not only reduce the total volume of herbicide per unit area, but also application becomes easier and economical to the farmer. Repeated use of same herbicide in the same field had often led to the occurrence of herbicide resistant weeds (Kim, 1996) and therefore, selection of herbicides with different mode of actions is also necessary for alternate application to avoid development of herbicide resistance in weeds. Herbicide

mixtures may help prevent resistance problem as well as shift in weed population (Wrubel and Gressel, 1994). Proprietary mixture or tank mixture of different herbicides could often be preferred because they require less time, cost and increase the spectrum of weed control (Ooi *et al.,* 2000). Application of herbicide mixtures or sequential application of herbicides may be useful for broad-spectrum control of weeds in rice. Recent trend of herbicide use is to find out an alternative and effective weed management by using low dose high efficiency herbicides, which will not only reduce the total volume of herbicide per unit area, but also application becomes easier and economical to the farmer.

Important weed species in transplanted rice

A broad spectrum of weed flora infests rice crop. Diversified weed flora being noticed in paddy fields of different states (Table 1).

Yield reduction by weeds in rice

Weeds caused maximum yield reduction in direct seeded rice of dry seeded soil than puddle soil (Moody, 1977). Janiya (2002) stated that yield reduction by weeds was varied from 30-80 % in direct seeded and 20-60 % in transplanted rice. Kumar *et al.,* (2013) critically analysed the impact of weeds on yield reduction and found that reduction in rice yield was 15.3 kg ha^{-1} for increase in one weed per meter square and 32.5 kg ha^{-1} reduction in grain yield for each gram increase in weed biomass. Uncontrolled growth of weeds during early stage (20-45 days after planting) led to reduction in yield was up to 25-53 % (Subbaiah and Sreedevi, 2000). Reddy *et al.,* (2003) from Hyderabad noticed that *Cyperus spp., Paspalum spp., Caesulia axillaris, Rotala densiflora* and *Monocharia vaginalis* caused 28-40% reduction in yield of transplanted rice. Hossain *et al.,* (2010) from Ranchi reported that the weed population as well as dry matter was reduced in transplanted rice with higher weed control efficiency resulting in higher grain yield.

Crop-weed competition

Weed competition is one of the major causes for yield loss in lowland rice in India. Weeds compete with the crop aggressively because of their high growth rate, high potential to acclimatize changing environment and more efficient seed production (Kim and Moody, 1989). Competition between crop and weed begins when the supply of any of the growth factor is limiting and falls below the demand of both crop and weeds, when they grow in close proximity. Weeds having faster growth rate, accumulate large amount of biomass in a short period, which interferes with the growth of rice plants and ultimately affects the yield of rice crop. Grasses are usually the most dominant competitors during early season, while sedges and broad-leaved weeds dominate later in the season (Jiang, 1989). Most of the reports also agreed that grasses are vigorous competitors, exhausting greater portion of the fertilizer applied to the crop followed by sedges and broad-leaved weeds (Singh *et al.,* 2006). Similarly, sedges grow huge in number and cause serious competition for nutrients. The roots of the sedges also dominate the surface feeding zone and obstruct nutrient flow to crop roots. Generally, one-third duration of the crop period should be maintained weed free. The critical crop weed competition from 28-45 DAT in transplanted rice was reported by various workers (Singh *et al.,* 2003). Singh *et al.,* (2005) found that grasses constituted 14.1%, sedges 71.4% and broad-leaf weeds 14.5% of the total weed population in rice crop at 30 days stage. Dhammu and Sandhu (2002) observed that *Cyperus iria* competition for the first 30 days caused less than one-

fourth (12.9%) of the total yield loss in transplanted rice while competition for 40 days resulted in more than half (43.5%) of the total yield loss due to the weeds.

Effect of crop-weed competition on rice

Any weed growing in association with the crop will reduce vegetative potential of the crop and ultimately resulted in loss of yield (Moody, 1978). Many workers reported the effects of weed competition on rice growth and yield. Severe infestation of weeds suppressed the plant height (Bhargavi and Yellamanda Reddy, 1994) increased tiller mortality, decreased shoot and grain production (Srinivasan and Palaniappan, 1994). Singh *et al.,* (2002) reported a reduction in grain yield in weedy check to the tune of 50.1 %. They also observed that maintaining weed free condition till maturity significantly reduced the density and dry weight of weeds and enhanced the grain yield due to a greater number of panicles m^{-2}. Moorthy and Sanjoy Saha (2005) reported that losses in grain yield due to weed free condition upto 30, 60 and 90 DAT were 17.7, 11.8 and 5.0 % respectively. The overall effect of crop weed competition is the reduction in the economic as well as biological yield of rice. In India, due to uncontrolled weed growth, yield of lowland rice was reduced by 17 to 73 % (Choudhury and Thakuria, 1998). According to Tamil Selvan and Budhar (2001), weeds alone have been reported to reduce the yield by 50 to 60 % in direct sown rice.

Effect of herbicides on weeds in rice field

Herbicides effectively controlled the weed population. Dixit and Varshney (2008) conducted a field trail to evaluate the post-emergence herbicides in direct seeded rice during the rainy season of 2001 and 2002 and reported that the post-emergence application of Pyrazosulfuron 25 g/ha effectively controlled the infestation of *Phyllanthus niruri, Alternanther asessilis, Commelina benghalensis, Physalis minima* and *Cyperusiria* followed by one hand weeding. Incorporation of Dhaincha by spraying 2, 4-D resulted in 78% reduction in total weed count and 59 % in weed dry matter production. Singh *et al.,* (2004) observed that application of butachlor alone @ 1.25 kg a.i. ha^{-1} was effective against annual grasses. According to Rajkhowa and Gogoi (2004) application of butachlor @ 1.5 kg a.i. ha^{-1} as pre-emergence herbicide recorded significantly lower weed density and dry matter accumulation over weedy check. Hussain, *et al.,* (2008)carried out a field experiment at Lahore, Pakistan. They found that bispyribacsodium proved the best weedicide with 90.5 % weed control efficiency and paddy yield with 3.61 t/ha which was comparatively higher than other weedicides. Singh *et al.,* (2005a) observed that bensulfuron methyl (Londax) at different doses (40 g a.i. ha^{-1} and 50 g a.i. ha^{-1}) applied alone or as tank mixture with butachlor @ 1000 g a.i. ha^{-1} reduced the density of all the sedges and broad-leaved weeds and increased the grain yield. Ramana *et al.,* (2008) reported that pre-emergence application of metsulfuron methyl + chlorimuron ethyl at 8 g a.i. ha^{-1} resulted in effective weed control as compared to other weed control treatments. Singh *et al.,* (2008) reported that the density of sedges and broad-leaved weeds in almix treated plots were less as compared to application of butachlor, anilofos and pretilachlor alone.

Prakash *et al.,* (2013) reported that the highest weed control was achieved with manual hand weeding (64-82%). However, the hand weeding is laborious, tedious, expensive and time-consuming, hence it cannot be practicable on a large scale. Among the weedicides, bispyribac-sodium 50 g/ha at 15-20 DAT gave the highest weed control (58-75%). Bispyribac-sodium at 25 and 35 g/ha at 15-20 DAT reduced the weed density. The

weed control efficiency with bispyribac-sodium 50 g/ha at 15- 20 DAT ranged between 58 and 75% The weed control efficiency with butachlor 1.5 kg/ha at 5-7 DAT ranged between 28 and 47%, which was comparatively lower than other treatments.

Effect of herbicides on nutrient uptake by rice

Weeds usually grow faster than the crop plants and then they adsorb the available nutrients earlier, resulting in reduced availability to crop plants. Weeds being more vigorous competitors remove a greater portion of the fertilizer applied to the rice crop (Thirumurugan *et al.,* 1998). Effective weed control measure increased the uptake of nutrients by the crop and decreased their removal by weeds. Finally, the weed free crop absorbs higher quantity of nutrient from the soil than weedy check. However, in chemical weeding systems, lower depletion was recorded at early stage when steadily increased towards later stages of crop growth. Because of their persistence in soil, it controls the weeds over an extended period of time. Devi and Singh (2018) reported that among weed management practices, application of bispyribac at 25 g/ha + azimsulfuron at 17.5 g/ha at 15-20 DAS established their superiority in minimizing the nitrogen removable weeds which was significantly superior to other weed management treatments but it was next best to the hand weeding twice at 20 and 40 DAS.

Effect of herbicides on growth and yield of rice

Growth and yield also significantly influenced by herbicides. The higher grain yield was recorded with the pre-emergence application of butachlor followed by one hand weeding treatment and it was on par with butachlor followed by two hand weeding treatments (Madhavi and Reddy, 2002). Application of butachlor @ 1.5 kg a.i. ha^{-1} as pre-emergence + 2, 4-D @ 0.5 kg ha^{-1} as post-emergence herbicide produced grain yield similar to hand weeding twice at 30 and 50 DAT (Singh *et al.,* 2004). Among the herbicidal treatments, the lowest dry weight of weeds was recorded with butachlor @ 1.5 kg a.i. ha^{-1} + one handweeding, which was statistically similar to two hand weeding (Ramphoolpuniya *et al.,* 2007). Application of butachlor at 1.25 kg a.i. ha^{-1} gave the efficient weed control and ultimately gave the maximum number of effective tillers ha^{-1} (Mirza Hasanuzzaman *et al.,* 2008).Among the herbicidal treatments, application of oxadiargyl @ 70 g a.i. ha^{-1} recorded higher number of panicles, 1000 grain weight and grain yield of rice (Kumar *et al.,* 2004). Ramana *et al.,* (2008) noticed that pre-emergence application of oxadiargyl at 80 g a.i. ha^{-1} + mechanical weeding with star weeder resulted in improved weed control and higher grain and straw yield and proved economically remunerative over butachlor and pretilachlor treatments. The highest number of filled grains $panicle^{-1}$, 1000 grain weight and grain yield of rice were recorded with pre-emergence application of oxadiargyl @ 75 g a.i. ha^{-1}, which was on par with hand weeding twice at 20 and 40 DAT (Yadav *et al.,* 2009; Deepthi Kiran and Subramanyam, 2010). Application of almix @ 4 g ha^{-1} mixed with butachlor @ 938 g ha^{-1} at 3 DAT was at par with hand weeding twice at 20 and 40 DAT in controlling weeds and achieving higher grain yield (Patra *et al.,* 2006). Bensulfuron methyl at 60 g a.i. ha^{-1} tank mix with pretilachlor 450 g a.i. ha^{-1} applied at 20 DAS were found to be effective in controlling weeds with weed control efficiency of 92.2 % and produced 5.53 t ha^{-1} of grain yield and this herbicide treatment was at par with hand weeding twice at 20 and 40 DAS (Sanjoy Saha and Rao, 2010). Singh *et al.,* (2005b) reported that combination of pre-emergence application of pendimethalin @ 1.0 kg a.i. ha^{-}

[1] and post emergence application of 2, 4-D @ 500 g a.i. ha^{-1} recorded highest rice grain yield. Jacob and Syria (2005) noticed that post-emergence application of 2, 4-D Na salt @ 1.0 kg a.i. ha^{-1} at 20 DAT combined with pre-emergence application of anilofos @ 0.4 kg a.i. ha^{-1} generally favoured with increased yield.

Singh *et al.*, (2018) reported that maximum grain yield (5.05 t/ha) was obtained under T_{11}-weed free (2 hand weeding at 25 and 45 DAT), which was statistically at par with (4.84 t/ha cm) T_{10}-pendimithlin 750 g/ha (0-3 DAT) *fb* bispyribac-sodium 25 g/ha (25 DAT). This might be due to excellent performance of these treatments in terms of grain and straw yield due to better management practices and reduction in weed dry weight and its population (Table 2–4).

Table.1 Major weed flora of transplanted rice in different regions (Priyanka *et al.*2018)

Major weed flora	Place	Reference
Echinochloa crus-galli, Paspalum distichum and Caesulia axillaris	Pantnagar	Sarkar (2001)
Cyperus iria, Sphenoclea zeylanica, Leptochloa chinensis, Fimbristylis miliacea and *Eclipta alba*	Karnal	Chopra andChopra(2003)
E.colona,E.crus-galli,Cyperusrotundus,Cyperusdifformis,Fimbristylis miliacea, Ludwigia parviflora, and Ammania baccifera	Varanasi	MukherjeeandSingh(2004)
E.crusgalli, Leersia hexandra, Marsilea quadrifolia	West Bengal	GhoshandGhosh (2005)
Echinochloa crusgalli,E.colona, Cyperusiria,C.rotundus,Fimbristylismiliacea, Ammania baccifera, Marsilea quadrifolia and*Potamogeton distinctus*	Kashmir	Singh *et al.*(2007)
Echinochloa glabrescens, *E.colona*(L.), *Ammania baccifera* (L), *Euphorbia spp., Fimbristylis miliacea* (L.), *Cyperus rotundus* (L.), *Cyperus iria* (L.) and *Cyperus difformis* (L.)	Karnal	Yadav *et al.*(2009)
Cyperus difformis, Fimbristylis miliacea, Scripus spp., C. procerus, Echinochola colona, Panicum tripheron, Ludwigia parviflora, Spinanthus acemella, Rotala verticillaris, Lindernia veronicaefolia and*Glinus oppositifolia*	Bangalore Karnataka	Ramchandra *et al.*(2010)
Echinochloa crusgalli, Cynodon dactylon, Echinochloa colona, Cyperus rotundus and *Amaranthus viridis*	Varanasi	SharmaandSingh(2010)
Digitaria sanguinalis, *Echinochola crus-galli*, *E.colona, Panicum repens*, *Fimbristylis miliacea, Cyperus rotundus*, *Cyperus iria*, *Cyperus difformis*, *Ammania baccifera*, *Ludwigia parviflora*, *Eclipt prostrate*, *Eclipta alba*, *Lippa nodiflora* Nich, *Marsilea quadrifolium*, *Sphenocleazeylanica*, and *Commelina benghalensis*	Orissa	Patra *et al.*(2011)
Cyperus rotundus, Cynodon dactylon, Echinochloa colonum, Ceasulia axillaris, Phyllanthus niruri and Parthenium hysterophorus	Varanasi	Singh *et al.*, (2014)
Echinochloa crusgalli, Echinochloa colonum, Leptochloa, ChinensisCyperus difformis, Cyperus iria, Fimbristylis miliacea, Eclipta alba, Ammania baccifera, Bergia capensis and Ludwigia parviflora	Tamil Nadu	ParthipanandRavi(2016)
Echinochloa sp., Panicum repens, Cynodon dactylon, Leptochloa chinensis, Eclipta alba, Ludwigia parviflora and Cyperus sp.	Raichur, Karnataka	Ramesh *et al.*, (2017)

Table.2 Effect of bispyribac-sodium on weed growth in transplanted rice

Treatment	Weed density (no./m^2)		Dry weight of weeds (g/m^2)		Weed persistence index		Weed competition index (%)		Weed control efficiency (%)		Herbicidal efficiency index	
	2009	2010	2010	2010	2009	2010	2009	2010	2009	2010	2009	**2010**
Butachlor 1.5 kg/ ha at 5-7 DAT	24	22	32.7	35.8	0.18	0.14	13.6	16.4	28.2	47.7	0.80	**0.97**
Bispyribac-sodium 25 g/ha at 15-20 DAT	27	25	35.2	39.2	0.22	0.18	15.0	20.2	24.8	43.8	0.70	**0.74**
Bispyribac-sodium 35 g/ha at 15-20 DAT	9	10	12.6	13.6	0.03	0.03	8.1	12.3	55.8	72.8	2.60	**2.96**
Bispyribac-sodium 50 g/ha at 15-20 DAT	7	8	10.4	11.0	0.02	0.02	5.7	11.5	58.7	75.7	3.39	**4.02**
Weed-free	-	-	-	-			-	-	-	-		
Two hand weedings (20 and 40 DAT)	4	4	6.3	4.8	0.01	0.00	2.2	4.8	64.3	82.8		
Unweeded control	59	62	73.0	88.2	1.00	1.00	36.5	4.0				
LSD (P=0.05)	**2.13**	**2.10**	**2.13**	**3.14**								

Table.3 Effect of different weed management treatments on grain yield (t/ha), straw yield (t/ha) and weed population of transplanted rice

Treatments	Grain yield (t/ha)	Straw yield (t/ha)	Weed population at 90 DAT
Bispyribac- Sodium	4.01	4.88	18.44 (4.35)
Penoxsulam 24 % SC	4.05	4.93	18.94 (4.41)
Bispyribac – Sodium + Ethoxysulfuron	4.68	5.71	10.81 (3.36)
Bispyribac – Sodium + Chlorimuron + Metsulfuron (Almix)	4.31	5.53	12.33 (3.38)
Pretilachlor *fb* Ethoxysulfuron	4.30	5.37	13.94 (3.80)
Pretilachlor *fb* Chlorimuron + Metsulfuron (Almix)	4.37	5.62	13.58 (3.75)
Pyrazosulfuron *fb* Chlorimuron + Metsulfuron (Almix)	4.35	5.49	14.74 (3.90)
Penoxsulam + Cyhalofop 6 % OD	4.27	5.17	17.35 (4.22)
Triafamone + Ethoxysulfuron 30 % WG	4.18	5.09	16.83 (4.16)
Pendimethalin (38.7 % CS) *fb* Bispyribac –Sodium	4.84	5.83	8.44 (2.99)
Hand weeding at 25 and 45 DAT	5.05	6.35	5.11 (2.37)
Weedy check	2.92	3.62	34.41 (5.91)
***SEm*±**	0.113	0.14	0.831
LSD *(P=0.05)*	0.33	0.43	2.45

Table.4 Yield performance of transplanted rice as influenced by different treatments

Treatment	No. of panicles /m2		Panicle weight (g)		Grain yield (t/ha)		Straw yield (t/ha)		Harvest index (%)	
	2009	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**
Butachlor 1.5 kg /ha at 5-7 DAT	323	320	3.56	3.40	5. 22	5.48	7.45	7.47	41.2	**42.3**
Bispyribac-sodium 25 g/ha at 15-20 DAT	316	314	3.68	3.46	5. 14	5.23	7.24	7.05	41.5	**42.6**
Bispyribac-sodium 35 g/ha at 15-20 DAT	345	347	3.95	3.90	5. 56	5.75	7.68	7.87	42.0	**42.2**
Bispyribac-sodium 50 g/ha at 15-20 DAT	356	351	4.06	4.01	5. 70	5.92	8.13	8.45	41.2	**41.2**
Weed-free	382	385	4.41	4.32	6. 05	6.55	8.28	8.75	42.2	**42.8**
Two hand weedings (20 and 40 DAT)	371	374	4.30	4.25	5. 91	6.23	8.30	8.75	41.6	**41.6**
Unweeded control	268	270	3.12	3.10	3. 84	3.94	5.76	5.41	40.0	**42.1**
LSD (P=0.05)	**15.0**	**13.5**	**0.18**	**0.21**	**0. 20**	**0.23**	**3.60**	**3.90**	**2.3**	**2.3**

Prakash *et al.,* (2013) reported that all the weed control treatments significantly reduced the weed growth as compared to weedy check, and thus recorded higher grain yield of rice. The crop yield andweed control efficiency were positively correlated. It was revealed that all the herbicides showed significant effects on grain yield. The highest rice yield was recorded from weed-free plot, followed by two hand weedings treatment. Among the herbicides, bispyribacsodium 50 g/ha at 15-20 DAT resulted in the highest yield, which was at par with bispyribac-sodium 35 g/ha.

Effect of herbicides on economics of rice

Weed management should be practiced by least expensive available technology that does not interfere with other phases of crop production or human activities. Any weed control measure should be used only when its results are expected to be more economically beneficial then the results of not using any control measures (Moody, 1993). Chemical weed control always cost effective than other methods of weed controls this might be due to less cost involved in chemical treatment per unit of yield obtained. Pretilachlor and butachlor recorded good net return. Pretilachlor 625 g/ha was reported more economical as compared to butachlor 1250 g/ha getting good yield as well as cost benefit ratio (Sharma and Upadhyay, 2002). The highest net return (15,990 ha^{-1}) and B:C ratio (2.00) was recorded in Metsulfuron methyl at 8 g ha^{-1} (Sanjoy Saha and Rao, 2010). In transplanted rice, butachlor @ 1.0 kg ha^{-1} on 3 DAT and almix @ 4.0 g ha^{-1} on 20 DAT registered maximum monetary returns of 14,843 and 17,728 ha^{-1} as well as B:C ratio of 1.09 and 1.31 during 2006 and 2007 respectively (Mukherjee and Swapan Kumar Maity, 2011). Das., *et al.,* (2017)concluded that the post-emergence application of bispyribac-sodium 25 g/ha at 25 DAT proved economical herbicide for transplanted rice as compared to hand weeding twice and also other herbicides and weedy check. The highest net returns of 25,340 ha^{-1} and B:C ratio of 3.15 was recorded with application of almix at 4 g a.i. ha^{-1} followed by one hand weeding on 30 DAT (Yoga Lakshmi, 2001). The highest B: C ratio of 2.47 was recorded with 2, 4-D Na salt at 1.5 kg ha^{-1} applied at 10 DAS (Dani Tabin and Singh, 2008).

Hasanuzzaman *et al.,* (2008) reported that the maximum net return was found with the treatment T6 (two hand weeding) which was almost similar with *T2= Ronstar 25EC @ 1.25 L* ha^{-1} *+ IR5878 50 WP @ 120 g ha-1*followed by T_1*= Amchlor 5G @ 15 kg* ha^{-1} *+ IR5878 50 WP @ 120 g* ha^{-1},and T_5*= Set-off 20WG @ 50 g* ha^{-1} *+ IR5878 50 WP @ 120 g* ha^{-1}. Net profit was highest from the treatment T_2 (Ronstar 25EC @ 1.25 L ha^{-1} + IR5878 50 WP @ 120 g ha^{-1}) which was even higher than T_2 (two hand weeding). The application of T_2 maximized the profit and benefit-cost ratio (BCR) was the height (1.60) in the treatment. The second highest BCR (1.51) was obtained from the treatment T_1. Glyphosate application at 0.75 kg ha^{-1} on 15 days before transplanting of rice in combination with pre emergence application of bensulfuron methyl + pretilachlor at 5 DAT gave maximum profit in rice (Ramachandra *et al.,* 2014). Similarly, Manisankar *et al.,* (2019) found that pre plant application of glyphosate 2.5 kg ha^{-1} registered higher net return and B:C ratio of transplanted rice than control.

In conclusion the weeds are creating a major problem in rice production as they not only compete with crop but also hinder the quality of the rice produce. Control of weeds in rice crop is always a problematic task for effective crop production as their presence

causes severe reduction in yield and quality of crop thus reducing yield productivity and profitability. Herbicide applications is commonly used to overcome weed infestation which is easy, quick, time saving, cost effective and it is most reliable method to control weeds. Rice crop is grown in diverse agro ecosystem therefore, weed communities and its types associated to rice are having a huge variation. Hence, the use of a single herbicide cannot give satisfactory and cost-effective results of weed control. Integrated strategies on chemical weed management is the best option to control the diverse weeds flora and the competitive ability of weeds for the above and below ground resources. Regular monitoring and early detection of the evolution and mechanism of herbicide resistance is necessary. The adoption of suitable management strategies on herbicide is utmost important. Hence, in the future, researchers need to develop different combinations of effective herbicides which do not only favour crop yield and reduce weed infestation but also discourage the resistance of weed flora to the herbicides.

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