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Integrated Weed Management in Transplanted Rice-An Effective Approach

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A B S T R A C T

Rice production has an important role in Indian economy and transplanting being most common practice adopted in the country. Transplanted rice encounters diverse type of weed flora consisting of grasses, sedges and broad-leafed weeds as well as sedges. Effective control of these weeds at initial stages can ensure in increasing the productivity of this crop. Weed control in transplanted rice by mechanical and cultural methods is quiet expensive. At peak period of crop weed competition due to labour crises weeding gets delayed. In contrast use of herbicides is an effective measure for weed control in transplanted rice. In India, the widely used herbicides are butachlor, anilofos, thiobencarb and pretilachlor, which provide effective control of annual grasses when applied as pre-emergence. However, these are not effective against annual sedges and broad leaf weeds. Further, due to continuous use of these herbicides a shift in weed flora from grassy to non-grassy and annual sedges has been observed in transplanted rice fields. Therefore, to overcome such problems, adoption of integrated weed management practices is a powerful tool, which can manage the weeds in standing crop more effectively in a sustainable way.

Introduction

Rice (*Oryza sativa* L.) is one of the most important food crops in Asia, where 90% of this crop is grown and consumed. In India, it contributes to about 40 per cent of the total food grain production. It provides 43 per cent of calorie requirement for more than 70 per cent of Indian population. The rice production in India in 2015-16 was 104.32 MT (Directorate of Economics and Statistics 2016-17). India has to produce about 130 MT of rice by 2025 to feed the ever growing population (Hugar *et al.*, 2009), which is a challenging task. Rice yield is affected by several factors *viz.*, weeds, insects, diseases and other management practices. Among several production constraints, weeds are most important, causing enormous losses in yield and quality of rice crop (Kropff, 1993; Raju and Reddy, 1995; Singh *et al.*, 2003). Weeds not only cause huge reductions in crop yield but also increase cost of cultivation, reduce input efficiency, interfere with agricultural operations, impair quality, act as alternate hosts for several insect-pests and diseases and above all affects human and animal health.

Weed free period during the critical period of competition is essential for obtaining optimum rice yield. This can be achieved by removing weeds manually, mechanically and through chemical sprays or by their combinations. This can be achieved by removing weeds manually, mechanically and through chemical sprays or by their combinations. Manual weeding is although effective and most common method, however, scarcity and high wages of labour particularly during peak period of agricultural operations make this method uneconomic. Further, mechanical method of weed management is also time taking, cost intensive, much tedious and also does not remove all the weeds. Weed management through herbicide application may be the best suited option. It also save valuable time by covering more area in short period and is also cost effective. Raising cost of labour and their reduced availability has led to search for alternative methods such as herbicide use either alone or in combination with manual or mechanical weeding. The integration of chemical followed by mechanical weeding are cheaper and effective than hand weeding alone (Ali and Bhanumurthy, 1985). The integrated weed management (IWM) thus can play a vital role in transplanted rice cultivation, in order to reduce dependence on excessive chemical use, avoid environmental pollution and reduce weeding costs.

Weed flora associated with transplanted rice

Major weed species in transplanted rice at Pantnagar were *Echinochloa colona* (80.2%), *Ischaemum rugosum* (3.2%), *Cyperus iria* (6.5%), *Fimbristylis miliacea* (3.9%) and others (6.2%) viz. *Caesulia* spp., *Panicum* spp., *Leptochloa chinensis* and *Commelina* spp. Singh *et al.,* (2004a). Sah *et al.,* (2012) observed that the major weed flora in the experimental field in rice was *Echinochloa crus-galli* L., *Echinochloa colonum* L., *Cynodon dactylon* L., in grasses, *Eclipta alba* L., *Ammania baccifera* L., *Celosia argentia* L., in broad leaf weeds and *Cyperus difformis* L., *C. iria* L., *C. rotundus* L., and *Fimbristylis miliacea* (L.) in sedges at Palamau, Jharkhand.

Crop -weed competition

Weed competition is one of the most important factors in limiting yield of rice. The rice and weeds compete for the same resources. Among the different weed species, grassy weeds pose greater competition. They have an extensive and fibrous root system. Similarly, sedges grow huge in number and cause serious competition for nutrients.

The roots of sedges also dominate the surface feeding zone and obstruct nutrient flow to crop roots. Broadleaf weeds being deep rooted explore the sub-surface zone for minerals and exert less competition for nutrients with rice (Raju and Reddy, 1986). Competition between crop and weeds begins when the supply of any necessary growth factor falls below the demand of both crop and weeds, when they grow in close proximity. Weeds are nourished by the same nutrients and environmental elements as needed by the crop.

Weeds interfere with rice growing by competing for one or more growth limiting resources, such as nutrients, water, space, light and CO_2; because of the limited supply of these vital elements, their association, therefore, leads to competition for these elements for their survival. Singh *et al.,* (2004) reported that uncontrolled weeds cause grain yield reduction upto 76 per cent under transplanted conditions. 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. Mukherjee *et al.,* (2008) noticed that 20-40 DAT were the most critical period of crop-weed competition and found that weedy situation throughout the crop growth caused yield reduction to the tune of 57 to 61% in transplanted rice.

Losses caused by weeds in rice

Considerable losses in the grain yield of rice due to infestation of weeds have been reported by different workers in the country. Without weed control yield losses ranges from 16-48% in transplanted aman rice (Mamun, 1990). Ananthakumari and Rao (1993) observed that transplanted rice crop faces diverse type of weed flora, consisting of grasses, broad leaved weeds and some sedges.

Competition of these weeds brought about reduction in yield by about 50%. Yield reductions in transplanted rice due to weeds have been reported to be 28-45% by several workers (Raju and Reddy, 1995; Nandal *et al.,* 1999; Singh *et al.,* 2003). Yaduraju *et al.,* (2006) found that uncontrolled weed growth might reduce yield to the tune of 65% in rice under Jabalpur conditions. Mishra *et al.,* (2007) reported that weed infestation reduce the grain yield of rice by 25.9%.

Halder and Patra (2007) found that due to weed infestation about 50% yield reduction occur in transplanted rice. Weeds caused 30 to 32% losses in grain yield in weedy check as compared to weed free treatment (Singh *et al.,* 2007). Rodenburg and Johnson (2009) observed that rice yield losses due to uncontrolled weed growth ranges from 28 to74% and 28 to 89% in transplanted lowland and direct-seeded lowland rice, respectively. 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.

Methods of weed control

Weed control methods are grouped into cultural, manual, mechanical, chemical and biological. Each of them has their own advantage and disadvantage, any single method is rarely found adequate and effective in controlling weeds. Summarized reviews have been given below particularly for manual, mechanical and chemical methods of weed control in transplanted rice.

Manual weeding

The earliest ways of weed control in rice were cultural methods. In spite of being labour intensive, hand weeding is still the most common direct weed control method in rice practiced by hands and small tools in India. This practice is effective only when weeds attain certain stature to provide better grip for uprooting (Bhan *et al.,* 1980).

Halder and Patra (2007) from Orissa noticed that twice hand weeding at 20 and 40 DAT resulted in minimum weed population and dry weight and the highest weed control efficiency at 30 and 60 days stage of crop growth. Hand weeding twice was found to be superior which was followed by herbicide application combined with hand weeding in suppressing weed density, dry matter and also significantly increased the productive tillers m^{-2}, panicle weight and grain yield (Rao *et al.,* 2007).

Hasanuzzaman *et al.,* (2008) from Bangladesh observed that hand weeding proved superior to other methods of weed control with regard to panicle length, 1000 grain weight, weed control efficiency, grain and straw yield under transplanted rice. Jayadeva *et al.,* (2009) from Karnataka observed that hand weeding twice (20 and 40 DAT) recorded lower weed dry weight and higher mean grain and straw yield in rice.

Mechanical weeding

In transplanted rice, apart from manually, weeding is also done by using a mechanical hand weeder (rotating hoe or cono-weeder) with no herbicide use. Hand weeding, though efficient yet is a costly affair and is difficult due to continuous rain during *kharif* season and unavailability of labours during peak period. This practice incorporates the weeds into the soil which serve as green manure. Moreover, mechanical weeding becomes less hard in successive years as skill is gained in the methods and as better implements is developed. It eliminates the use of herbicides hence providing health benefits for all concerned persons like the farm worker and the consumer and there is no pollution of the environment and ground water. Hwang *et al.,* (2007) reported that control efficacy by cultivating weeder ranges from 82.3 to 82.5% by the one-time application (15 or 30 DAT), and 87.1% by the two times of 15 fb 30 days after transplanting (DAT) in transplanted rice. Kumar *et al.,* (2010) found that among the weed management practices, mechanical hoeing using cono weeder (twice at 15 and 30 DAT) reduced the total weed population and dry weight significantly at all the crop growth stages than weedy check but was at par with fenoxaprop-p-ethyl (0.06 kg ha^{-1}, 20 DAT) + 1 H.W (30 DAT) followed by metasulfuron methyl + chlorimuron ethyl (0.004 kg ha^{-1}, 20 DAT) + 1 H.W (30 DAT), fenoxaprop-p-ethyl (0.06 kg ha^{-1}, 20 DAT) and metasulfuron methyl + chlorimuron ethyl (0.004 kg ha^{-1}, 20 DAT) and also recorded maximum grain yield (4256 and 4393 kg ha^{-1}) during 2006 and 2007, respectively over other treatments under Jammu situations.

Chemical method of weed control

For effective weed management in transplanted rice, judicious application of herbicide as pre-emergence or post-emergence either applied alone or in sequence is essential. Chemical weed control can be considered as a better alternative (Singh and Singh, 1993). Use of chemical to control weed has been found effective and economical (Singh and Mani, 1981). Hence, a brief description has been mentioned below only regarding the use of pretilachlor, penoxsulam and bispyribac- Na.

Pretilachlor (2-chloro-2′,6′-diethyl- *N*- (2-propoxyethyl) acetanilide)

Pretilachlor is a chloracetanilide herbicide applied either pre-emergence or early post-emergence to control the annual grasses and broad leaf weeds but mainly used as a grass killer in transplanted rice. It is a selective broad spectrum pre-emergence herbicide for use in early season in transplanted rice with cell division inhibitor as its mode of action. It control grassy and sedges weed species viz. *E. crus-galli*, *E. colona*, *Leptochloa chinensis*, *C. iria*, *C. difformis* and *Fimbristylis millacea* in rice field. Pretilacholar is supplied with a surfactant under the trade name Sofit but the trade name Rifit does not contain extra surfactant. Pretilachlor affect the early development of susceptible plant by the inhibition of protein, nucleic acid and gibberellic acid synthesis (Das, 2008). It is easily taken up by the hypocotyls, mesocotyls, coleoptiles and to a lesser extent by the roots of germinating weeds which die shortly after emergence. Pretilachlor persists in paddy soils enough to give 30- 50 days residual weed control. Mahapatra *et al.,* (2002) from Bhubaneshwar (Orissa) observed that application of pretilachlor (50 EC) at 500 g ha^{-1} significantly reduced the weed density and weed dry matter at all the stages of crop growth having weed control efficiency of 82.0 per cent. Uncontrolled weeds reduced the yield of transplanted rice by 28.7 per cent. The grain yield obtained with pretilachlor (50 EC) at 750 g ha^{-1} (43.5 q ha^{-1}) was at par with its lower dose applied at 500 g ha^{-1}. Suganthi *et al.,* (2005) found that pretilachlor at 3 kg ha^{-1} were found effective in reducing the total weed population followed by twice hand weeding and pretilachlor at 1.5 kg ha^{-1} at panicle initiation stage. Shultana *et al.,* (2011) recorded lowest weed biomass and significantly highest weed control efficiency (86.01%) with the application of pretilachlor 50 EC at 1 l ha^{-1} under Gazipur, Bangladesh situation.

Bispyribac- sodium

Sodium 2,6-bis [(4,6-dimethoxy-2-pyrimidinyl)oxy] benzoate

Bispyribac-sodium belongs to the pyrimidinal thiobenzoates group of herbicide. It have the similar mode of action as the sulfonylureas. It is highly selective, post-emergence low mammalian toxic and low dose (15-40 g ha^{-1}) requiring herbicides so become popular now a days to weed control in rice growing area either transplanting or direct seeded (Das, 2008). Bispyribac-sodium is a pyrimidinyl carboxy herbicide, effectively controls many annual and perennial grasses, sedges and broad-leaved weeds in rice fields (Schmidt *et al.,* 1999 and Yun *et al.,* 2005). It is selective, systemic post-emergence herbicide, with ALS (acetolactate synthase) inhibition as its mode of action and absorbed by foliage and roots. Deepthi Kiran *et al.,* (2010) at Tirupati (A.P) recorded the highest grain yield, weed control efficiency and benefit: cost ratio with sequential application of oxadiargyl 75 g ha^{-1} and bispyribac-Na 30 g ha^{-1}, which were at par with H. W twice at 20 and 40 DAT in transplanted rice and found that sequential application of oxadiargyl 75 g ha^{-1} and bispyribac-Na 30 g ha^{-1} recorded the lowest density and dry weight of weeds with maximum weed control efficiency followed by oxadiargyl 75 g ha^{-1} and penoxulam 25 g ha^{-1}. Veeraputhiran and Balasubramanian (2012) conducted a experiment during 2010 and 2011 at Madurai (Tamil Nadu) recorded that the total weed population and dry weight under post emergence application of bispyribac- Na at 25 g ha^{-1} was on par with its higher doses of 35 and 50 g ha^{-1} while weed control efficiency and weed index at its lower dose (25 g ha^{-1}) were comparable with the higher doses i.e. 35 and 50 g ha^{-1}. Post-emergence application of bispyribac- Na at 25 g ha^{-1} recorded significantly higher grain yield (6838 and 6510 kg ha^{-1}) during 2010 and 2011, respectively over pre emergence application of butachlor at 1500 g ha^{-1} but remained at par with its higher doses *viz.,* 35 and 50 g ha^{-1}, twice hand weeding and weed free.

Penoxsulam (2-(2, 2-difluoroethoxy)-N-(5, 8-dimethoxy [1, 2, 4] triazolo [1,5-c]pyrimidin-2-yl)-6-trifluoromethyl) benzene sulfonamide)

Pal and Banerjee (2007) from Nadia (W.B) recorded the highest grain yield of rice (3.74 t ha^{-1}) with hand weeding twice at 20 and 40 DAT which was at par with penoxsulam 22.5 g ha^{-1} applied at 8-12 DAT (3.53 t ha^{-1}) and also recorded lowest weed index (5.61%) while penoxsulam 22.5 g ha^{-1} applied at 8-12 DAT resulting in 87% increase in grain yield of rice over unweeded control. Yadav *et al.,* (2010) from Karnal observed that penoxsulam at 25 g ha^{-1} as pre-emergence (3 DAT) and 22.5 g ha^{-1} as post-emergence (10-12 DAT) application provided satisfactory control of all types of weeds consequently resulting in grain yield of transplanted rice similar to weed free plot. Penoxsulam was particularly better against broad-leaf weeds and sedges than the application of butachlor and pretilachlor. Malik *et al.,* (2011) conducted an experiment at Pantnagar concluded that penoxsulam was more effective than pretilachlor and butachlor. Penoxsulam applied at pre-emergence (3 DAT) was effective against sedges and broad leaf weeds irrespective of the rate and found most effective against all the weeds at 60 DAT. The highest grain yield and benefit cost ratio were obtained with penoxsulam 25.0 g ha^{-1} applied at 3 or 10 DAT. No phytotoxicity symptoms were observed on rice treated with penoxsulam.

Integrated weed management

In rice, weed control by a single method is not remunerative because of higher infestation of weeds. For effective weed management, judicious combination of different weed control practices is essential. Integrated weed management is the long-term, economic and effective management of weed population without excessive reliance on only one method.

Ali *et al.,* (2008) at Dhaka (Bangladesh) observed that among the weed control treatments pretilachlor + one hand weeding was found the best for controlling weeds at 40 days after transplanting (DAT) (79.5%) and moderate for controlling weeds at 60 DAT (75.6%) that resulted in higher plant dry matter (23.6 g $hill^{-1}$) and total number of tillers $hill^{-1}$ at 60 DAT. Gnanavel and Anbhazhagan (2010) from Uganda observed that pre-emergence application of oxyfluorfen at 0.25kg ha^{-1} followed by post-emergence application of bispyribac-sodium 0.05 kg + metsulfuron methyl at 0.01kg ha^{-1} recorded the least weed count (11.0 m^{-2}) and weed dry matter production (114.65 kg ha^{-1}) and highest WCI (90.12%) favoring higher grain yield of transplanted aromatic rice (5.32 t ha^{-1}) which was at par with the pre-emergence application of butachlor at 1.25 kg ha^{-1} followed by post emergence application bispyribac sodium 0.05 kg + metsulfuron 0.01 kg ha^{-1} and the pre-emergence application of pendimethalin at 1.0 kg ha^{-1} followed by post-emergence application bispyribac Na 0.05 kg + metsulfuron 0.01 kg ha^{-1}. Application of pre-emergence and post-emergence herbicides alone were found to be less effective in reducing weed counts and weed dry matter production and increasing the grain yield of rice. Patra *et al.,* (2011) observed that application of almix 0.004 kg ha^{-1} mixed with butachlor 0.938 kg ha^{-1} at three days after transplanting (DAT) was at par with hand-weeding twice at 20 and 40 DAT in controlling weeds and higher grain yield. This application increased the grain yield by 45.1% over the unweeded check. There was a negative linear relationship between weed dry weight and grain yield. Koloor *et al.,* (2012) found that herbicide application + hand weeding once (35 DAT) recorded highest grain yield (4584 kg ha^{-1}) while lowest grain yield (2505 kg ha^{-1}) were observed in weedy check at Iran. Sah *et al.,* (2012) observed that pre-emergence application of almix (0.025 kg ha^{-1}) at 3 DAT fb sequential application of 2, 4-DEE (0.5 kg ha^{-1}) at 20 DAT was found most effective in minimizing weed population and their dry matter accumulation and increasing weed control efficiency & grain yield next to two hand-weedings. Both were at par. 80.1% & 77.7% increase in grain yield was recorded in two hand- weedings and almix fb 2, 4-DEE (0.025 + 0.5 kg ha^{-1}), respectively over weedy check.

Economics

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 measures should be used only when its results are expected to be more economically beneficial than the results it not using any control measures (Moody, 1993).

Therefore, choice of weed control inputs depends not only on its efficacy but also on its cost (De Dutta and Foster, 1977). Marginal benefits cost ratio and net returns are the best way to assess the economic viability of a particular weed control treatment. Hence, hand weeding is the predominant method of weed control. However low cost chemicals are being effectively used (De Dutta, 1974) often in combination with limited hand weeding, these appear to be economical in many situation. Pretilachlor and butachlor were also recorded good net return. Pretilachlor 625 g ha^{-1} was reported more economical as compared to butachlor 1250 g ha^{-1} getting good yield as well as cost benefit ratio (Sharma and Upadhyay, 2002). Almix fb 2, 4-DEE (0.025 fb 0.5 kg ha^{-1}) recorded highest net returns (Rs18070 ha^{-1}) and benefit: cost ratio (1.99). Two hand weedings although significantly reduced weed density and their biomass and increased the grain yield, owing to higher labour cost reduced the benefit: cost ratio (Sah *et al.,* 2012). Veeraputhiran and Balasubramanian (2012) recorded higher economic benefits like net income and benefit- cost ratio with the post emergence application of bispyribac-Na at 25 g ha^{-1} than all the other weed management treatments under Madurai situations.

The integrated weed management (IWM) thus can play a vital role in transplanted rice cultivation, in order to reduce dependence on excessive chemical use, avoid environmental pollution and reduce weeding costs. Therefore, to overcome such problems, there is need to develop of an alternative and effective weed management practice involving use of low dose high efficiency herbicides alone or sequential application with manual and mechanical weeding having wide spectrum weed control under transplanted rice.

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