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A study on chemical weed management in *boro* rice: A review

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ABSTRACT

Characteristically *boro* rice is winter season, photo-insensitive, transplanted rice cultivated on supplemental irrigation, often under conditions, where farmers' are not able to take any other *rabi* season crop. Butachlor, pretilachlor, bispyribac-sodium and anilofos are the most commonly used herbicides for control of weeds in *boro* rice. Weed competition is one of the prime yield limiting biotic constraints resulting in yield reduction to the tune of 28 to 45%. *Echinochloa* spp., *Cynodon dactylon*, *Portulaca quadrifida* and *Cyperus* spp. are the major weeds responsible for yield reduction in *boro* rice. However, continuous and indiscriminate use of herbicides for a longer period may result in buildup of problematic weeds and also development of herbicide resistance in weeds. It is therefore, necessary to review the performance of promising herbicides for chemical weed management to improve the production and productivity of *boro* rice under the climate change scenario.

Key words: *Boro* rice, Economics, Herbicides, Weed management, Weed flora.

Rice (*Oryza sativa* L.) is the staple food for more than half of the world's population (Kumar *et al.,* 2016a). It provides 27 per cent dietary energy and 20 per cent dietary protein for the developing world (Kumar *et al.,* 2016b). *Boro* rice pertains to rice cultivation in water logged low lying or medium land with irrigation grown during month of November to May in eastern states of India (West Bengal, eastern Uttar Pradesh, Orissa, Bihar and Jharkhand) and North eastern India (Assam, Tripura and others) has got great potential to bring in additional rice to our food basket (Kumar *et al.,* 2016c). Its cultivation not only depends on assured irrigation but also in modern inputs. *Boro* rice is an ancient system of cultivation in non-productive water logged area in winter season from October-November to May-June. *Boro* is a Bengali term originated from Sanskrit word "BOROB'. Due to larger sunshine hours and less incidence of pests and diseases, *boro* rice usually gives better yield as compared to *kharif* season.

Weeds are considered to be one of the major biotic constraints in achieving the higher crop productivity that cause a reduction of ~10-90 per cent grain yield in Indian rice field (Singh *et al.,* 2004a, Kumar *et al.,* 2016d, Kumar *et al.,* 2016e, Kumar *et al.,* 2016f, Kumar *et al.,* 2016g, Chatterjee *et al.,* 2016). Weeds not only cause huge reduction in yield but also increases the cost of cultivation, reduce the input use efficiency, loss of potentially productive lands, loss of grazing areas and livestock production (Kumar *et al.,* 2015c) . Besides yield reduction, weeds also deplete the nutrients from soil to the tune of 11, 3 and 10 kg ha^{-1} of N, P_2O_5 and K_2O respectively (Gautam and Mishra, 1995). Among the modern weed management practices, effective weed management through chemical methods plays a vital role in the era of conservation agriculture (Pal *et al.,* 2013, Prakash *et al.,* 2014, Singh *et al.,* 2017). In case of *boro* rice, weed infestation is the most important causative factors for its low yields. Uncontrolled weed growth caused ~33-45% reduction in yield of rice (Manhas *et al.,* 2012). Now-a-days, manual weeding in rice becomes difficult because of problems in differentiating grassy weeds, labour scarcity and time consuming and costly. In addition, during peak period availability of labor is also becoming a serious problem by time. Chemical control using herbicide alone or mixtures result in control of higher number of weed species. Use of herbicide offers an economic and efficient control of weeds at right from beginning and providing crop better establishment and competitive ability. It is well known fact that weeds competes with rice for space, light, moisture and nutrients (Mandal *et al.,* 2011a; Mandal *et al.,* 2011b, Bohra and Kumar 2015, Mishra *et al.,* 2016). Therefore, weed control with minimum cost and lowest energy input is of prime importance. However, herbicides are used successfully for weed control in rice fields for rapid effect, easier to application and low cost involvement in comparison to traditional methods of hand weeding. Therefore, this review

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will help to understand the different herbicides used for weed control and their effect on growth, yield and nutrient uptake of *boro* rice.

Constraints in *boro* rice production: This region is characterized by heavy and erratic rain causing recurrent floods. Inherent poor response of local land races to high dose of fertilizer, its poor recovery due to various type of losses restrain the farmer from investing more on fertilizer. Development of full irrigation potential has not been done properly due to various reasons. The following are the important constraints in *boro* areas:

- Lack of suitable weed management techniques
- Lack of weed competitive cultivars
- Predominance of poor small and marginal farmers
- Preponderance of traditional customs and practices among *boro* rice farmers
- Lack of location specific typical high yielding *boro* varieties with tolerance to low temperatures (5-10°C) during seedling to vegetative phase and to heat at ripening stage
- Lack of genotypes with efficient root system for quick crop establishment after transplanting
- Inadequate utilization of indigenous/local varieties in the breeding programs
- Lack of precise production package to different locations of *boro* i.e. *boro*-deep water, *boro* irrigated medium land, short duration, paddy-cum-fish culture etc.
- Lack of resistance in varieties to major biotic stresses
- Inadequate extension activities in percolating the improved technologies to farmers

Dominant weed flora in *boro* rice: For the successful weed control, survey of weed flora is an important parameter. A common knowledge of weed flora, their time of emergence, density and growth duration is essential for formulating sound weed control measures. Weeds belonging to various species of grasses, sedges and broadleaved were found to be associated with rice culture. Madhu and Nanjappa (1997) found that rice field consisted of *Echinochloa crusgalli, Echinochloa glabrascens, Leptochloa chinensis, Panicum repens* in grasses and *Eclipta alba, Marsilea qadrifoliata* in broad leaved weeds (BLWs) and *Cyperus iria, Cyperus difformis* and *Fimbristylis miliacea* in sedges. Singh *et al*., (2004b) observed that *Echinochloa colona* L., *Paspalum disticum* L., *Cynodon dactylon* L., *Cyperus rotundus* L., *Siripus erectus* L., *Marsiles minuta* L., *Eclipta alba* L., *Ipomoea aquatica* Forsk, *Pistia stratiotes* L., *Nymphea nouchali* Burn *and Isoetes lacustris* L. were major weed flora of *boro* rice at Varanasi. The major weed flora associated with the transplanted summer rice at Gayeshpur, West Bengal, during dry season mainly comprised *E. crusgalli* (30%), *Cyperus difformis* (20%), *Monochoria vaginalis* (30%) and *Ludwigia parviflora* (30%) (Banerjee *et al.*, 2008a). Prashanth *et al.,* (2016) reported that major weeds found in *boro* rice i.e. *Cyperus difformis, Cyperus iria, Fimbristylis woodrowii* (sedges); *Panicum repens, Echinochloa colona, Echinochloa crusgalli, Cynodon doctylon* (grasses); *Rotala densiflora, Eclipta alba, Portulaca quadrifida* (BLWs).

Losses caused by weeds: Weeds are major yield limiting factor in rice production (Bastiaans *et al.,* 1997). Its infestation causes considerable reduction in yield, which depends upon the type of weed species, severity and intensity of infestation and time of occurrence under different agro-climatic condition. Globally, actual rice yield losses due to pest have been estimated ~40% of which weeds have highest loss potential of ~32%. The worldwide estimated loss in rice yield is ~10% of the total production (Oerke and Dehne, 2004). Moorthy and Saha (2005) observed that losses in yield due to weed competitions were 17.7, 11.8 and 5% for 50, 60 and 90 days, respectively.

WEED MANAGEMENT PRACTICES IN *BORO* RICE

Weed population and dry weight: Bhattacharya *et al.,*(2000) conducted a field experiment reported that hand weeding (HW) twice at 20 and 40 days after transplanting (DAT) significantly reduced weed population and it was at par with quinclorac SC 15 at 0.12 kg *a.i.* ha^{-1} + 1 HW at 40 DAT and quinclorac 15 SC at 0.075 kg a.i. ha^{-1} + 1 HW at 40 DAT. Singh *et al.,*(2003) conducted a field on *boro* rice and reported that twice HW recorded the lowest weed population and weed dry matter among all the treatments. However, twice HW, Anilofos + 2, 4-DEE, and anilofos + 2, 4-DEE + HW were at par with each other respect to weed population and weed dry matter. Bhattacharya *et al.,*(2005) working on *boro* rice noted among herbicidal treatments, Oxizdiargyl 80% WP @ 100 g a.i. ha^{-1} and Butachlor 50% EC @ 1.25 kg a.i. ha^{-1} significantly reduced weed density and weed dry weight as compared to other weed control treatments. Banerjee *et al.,*(2005) during *boro* season reported that among the different treatment of herbicides, application of Bensulfuron methyl + Butachlor @ 0.05+0.938 kg a.i. ha^{-1} as pre-emergence and gave the lowest dry weight (3.10, 8.14 and 10.31 g m^{-2} at 30, 60 and 90 DAT, respectively), weed density (7.33, 18.33 and 23.66 m^{-2} at 30, 60 and 90 DAT, respectively), weed index (5.49%) and also recorded highest weed control efficiency (75.21, 54.77 and 58.95% at 30, 60 and 90 DAT, respectively). Similarly, next best treatment combination was found Bensulfuron methyl + Butachlor @ 0.04 + 0.938 kg a.i. ha^{-1} as pre-emergence.

Maiti and Ghosh (2007) field experiment was conducted during the *boro* season of 2002-03 and 2003-04 and observed that HW twice at 25 and 45 DAT and Pyrazosulfuron ethyl @ 25 g a.i. ha^{-1} at 7 DAT were equally effective in decreasing growth of weeds. Banerjee *et al.,* (2008b) reported that application of Triasulfuron 20 WSG at 0.006 kg ha^{-1} at 5-7 DAT was the most effective in controlling all types of weed population and their growth.

Saha and Rao (2009) concluded that amongst herbicides, application of Bensulfuron methyl (60 g ha^{-1}) at 20 DAS was found to be the most effective in controlling weeds and maximum WCE (95.2%) and it was at par with HW twice at 20 and 40 DAS. Roy *et al.,*(2009) concluded lowest total number of weed (18.9 m^{-2}) and weed weight (17.99 g m^{-2}) obtained with Machete 5 G @ 25 kg ha^{-1}, which were applied at 4 DAT as compared to Ronstar 25 EC herbicide. Saha and Rao (2010) results showed Bensulfuron-methyl either alone at 60 g ha^{-1} or as tank mixture with pretilachlor (50+450 g ha^{-1}) applied at 20 DAS were noted equally effective in controlling weeds (WCE 90 and 92.2%, respectively). Both these herbicide treatments were at par with recommended practice of HW twice at 20 and 40 DAS in terms of weed control efficiency (WCE). Bensulfuron-methyl at 30 to 60 g ha^{-1} applied alone or as tank mixture with Pretilachlor at 450 g ha^{-1} was noted superior in reducing total weed population and dry matter production with WCE of 80-92.2%, when compared to the recommended herbicides Pretilachlor and Pyrazosulfuron-ethyl with WCE of 74 and 75.8%, respectively. Bari (2010) reported that herbicides of Pretilachlor @ 1 lit. ha^{-1} control weeds by 86% in *boro* season.

Acharya and Bhattacharya (2013) carried out a field experiment at Patna and reported that application of Pyrazosulfuron ethyl @ 30 g a.i. ha^{-1} as pre-emergence recorded the maximum WCE (71.8%) and this treatment found most effective in controlling predominant weeds in comparison to Acetamide and Benzothiadiazinone herbicides. Sharif and Chauhan (2014) planned an experiment on weed management and reported that all evaluated herbicides reduced weed density and biomass upto a significant level. Among the herbicides, Pendimethalin, Oxadiargyl and Acetachlor + Bensulfuranmethyl performed well against grasses weeds, however broad leaves weeds (BLWs) best control by Oxadiargyl (65-85%). Best combination for weed control was Oxadiargyl 80 g a.i. ha^{-1} *fb* Ethoxysulfuron 18 g a.i. ha^{-1}. Morshed *et al.,*(2015) reported that application of post-emergence herbicide i.e. Pyrazosulfuran ethyl (150 g ha^{-1}) at 15 DAT recorded lowest weed population as well as WCE compared to pre-emergence herbicide i.e. Pretilachlor @ 1 lit ha^{-1}. Prashanth *et al.,*(2016) recorded application of Bispyribac sodium 35 g ha^{-1} at 15 DAT was recorded lower weed population (5.12 m^{-2}) and dry weight (2.3 g m^{-2}) and statistically at par with Bispyribac sodium 30 g ha^{-1} at 15 DAT and Bispyribac sodium 25 g ha^{-1} at 15 DAT. Bera *et al.,* (2016) observed that amongst non-chemical weed control methods; two hand weedings gave the lowest weed population and dry matter at 30 and 60 DAS, which was statistically comparable with mechanical-weeding with Japanese paddy weeders. Dash *et al.,*(2016b) conducted a field experiment at West Bangal and recorded that among the weed control practices, application of Bispyribac sodium @ 25 g a.i. ha^{-1} at 20 DAT, Bispyribac sodium @ 50 g a.i. ha^{-1} at 20 DAT and Butachlor @ 1 kg a.i. ha^{-1} at 3 DAT + HW at 20 DAT gave the lowest weed density and dry weight while, highest WCE as compared to weedy check.

Growth attributes: Singh *et al.,*(2004b) conducted a field study on *boro* rice and found that maximum plant height and tillers $hill^{-1}$ was recorded in Butachlor @ 1.5 kg PE + 2, 4-D @ 0.5 kg ha^{-1} PoE and it was at par with two HW and superior to weedy check. Kumar *et al.,*(2013) revealed that among different herbicide combination, application of Pretilachlor (pre-em) *fb* Azimsulfuron 15 DAT was effectively controlling *Echinochloa* spp. and lowest weed count and dry matter and highest WCE in *boro* rice. Similarly, lowest weed population of *Cyperus spp*. and weed count and its dry matter were recorded under Ethoxysulfuron + Fenoxaprop at 15 DAT. Application of Butachlor *fb* 2,4-D and pyrazosulfuron *fb* bispyribac was effective for control of *Cyperus spp*. Reddy and Bandyopadhyay (2015) reported that among weed management practices, weed-free *fb* Pretilachlor 50% EC at 1 DAT + HW at 40 DAT, HW twice at 20 and 40 DAT and Bispyribac sodium 10% SC at 20 DAT + HW at 40 DAT gave significantly higher plant height, no. of tillers m^{-2}, dry matter and LAI. Islam *et al.,*(2016) working on *boro* rice observed that among the different herbicides application of Pyrazosulfuron ethyl 10 WP at 125 g ha^{-1} gave higher plants height and effective tillers *fb* twice HW and significantly superior to control. From West Bangal, Dash *et al.,*(2016a) reported that application of Bispyribac sodium @ 25 g a.i. ha^{-1} at 20 DAT, Bispyribac sodium @ 50 g a.i. ha^{-1} at 20 DAT and Butachlor @ 1 kg a.i. ha^{-1} at 3 DAT + HW at 20 DAT recorded higher plant height and dry matter production and LAI in comparison to other treatments.

Yield attributes and yields: Bhattacharya *et al.,*(1998) reported that highest grain yield was recorded in HW, which was noted on a par with Arozin + Ethoxysulfuron at 1.5 kg ha^{-1} applied at 10 DAT. Anwar *et al.,*(1998) observed that maximum grain yield (4.95 t ha^{-1}) was noted with weed free *fb* farmers practice i.e. 2 HW at 20 and 35 DAT (3.89 t ha^{-1}). Bhattacharya *et al.,*(2000) concluded that highest yield was found in 2 HW and this treatment was statistically equal to Quinclorac 15 SC at 0.72 kg a.i. ha^{-1} + 1 HW at 40 DAT and Quinclorac 15 SC at 0.075 kg a.i. ha^{-1}+ 1 HW at 40 DAT. Bhattacharya *et al.,*(2005) reported that among weed management treatments, 2 HW at 20 and 40 DAT recorded the highest grain yield of 4.5 t ha^{-1} but it was par with the Oxzdiargyl 80% WP @ 100 g a.i. ha^{-1} and Butachlor 50% EC @ 1250 g a.i ha^{-1} (4.3 and 4.2 t ha^{-1}, respectively). Banerjee *et al.,* (2005a) working on *boro* rice and reported that significantly highest grain yield was obtained in weed free *fb* HW twice (25 and 45 DAT), Pyrazosulfuron ethyl @ 25 g a.i. ha^{-1} at 7 DAT and Pretilachlor 400 g ha^{-1} 3 DAT and

recorded 24, 19.9, 16 and 14.7% higher yield over weedy check, respectively.

Maiti and Ghosh (2007) reported that application of Pyrazosulfuron ethyl @ 25 g a.i. ha^{-1} at 7 DAT at par with HW twice at 25 and 45 DAT significantly increased grain yield compared to other treatments. Banerjee *et al.,*(2008b) observed that Pyrazosulfuron ethyl 10% WP @ 25 g ha^{-1} at 7 DAT was produced highest yield, which was significantly superior over Pretilachlor. Saha and Rao (2009) carried out a field experiment and found that application of Bensulfuron methyl (60 g ha^{-1}) at 20 DAS was gave highest grain yield (5.82 t ha^{-1}) and which was at par with HW twice at 20 and 40 DAS. Similarly sulfonylurea group viz. Pyrazosulfuron ethyl (25 g ha^{-1}) applied at 10 DAS, Triasulfuran (9 g ha^{-1}) applied at 7 DAS and Almix (Metsulfuron methyl + Chlorimuron ethyl) + 0.2% surfactant (4 g ha^{-1}) applied at 20 DAS also showed better suppression of weeds and WCE (93.4, 91.7 and 88.6%, respectively). Roy *et al.,*(2009) reported higher yield attributes (effective tillers hill^{-1} and grains panicle^{-1}) and yield were recorded with application of Machete 5 G @ 25 kg ha^{-1}, which was significantly superior to Ronstar 25 EC herbicide. Saha and Rao (2010) indicated Bensulfuronmethyl either alone at 60 g ha^{-1} or as tank mixture with pretilachlor (50+450 g ha^{-1}) applied at 20 DAS were produced highest grain yield of 5.48 and 5.53 t ha^{-1}, respectively, but both treatments were at par with HW twice at 20 and 40 DAS. Al-Mamun *et al.,*(2011) found that higher yield attributes (panicles m^{-2} and grains panicle^{-1}) and grain yield was recorded with Remover 10 WP at 187 g ha^{-1} and being at par with HW. From Varanasi, Kumar *et al.,* (2012), results showed that Pretilachlor *fb* Azimsulfuron gave highest panicles hill^{-1}, panicle weight, grains panicle^{-1} and realizing 80.2% higher grain yield over unweeded control, which was statistically similar to HW twice. Ethoxysulfuron + Fenoxaprop combination was next to most effective herbicidal treatment obtaining an increase of 70.6% in grain yield over control. Parvin *et al.,*(2013) carried out a field study and noticed that three hand weedings at 30, 60 and 90 DAT produced the higher tillers hill^{-1}, effective tillers hill^{-1} and grains panicle^{-1} and yields of *boro* rice as compared to HW. Kumar *et al.,*(2013) observed that 1000-seed weight, tillers hill^{-1} and grain yield higher was recorded under Pretilachlor *fb* Azimsulfuron and realizing 80.2% higher yield over unweeded check, which was statistically similar to HW twice. Sudeshna *et al.,*(2014) results revealed that maximum grain yield was recorded in 2 HW at 20 and 40 DAT and it was *fb* HW at 20 DAT along with Oxadiargyl @ 0.1 kg^{-1}. Morshed *et al.,* (2015) reported that application of Pyrazosulfuran ethyl (150 g ha^{-1}) at 15 DAT along with N @ 200.4 kg ha^{-1} showed higher no. of tiller hill^{-1}, total dry matter, panicle hill^{-1}, filled grains panicle^{-1} (125.20) and grain yield (6.46 t ha^{-1}).

Prashanth *et al.,*(2016) results revealed that application of Bispyribac sodium 25 g ha^{-1} at 15 DAT produced significantly higher grain yield (6.47 t ha^{-1}), but at par with Bensulfuronmethyl + Pretilachlor at 8 DAT. From Bangaldesh Islam *et al.,*(2016) found that highest number of filled grains panicle^{-1}, 1000-grain weight and grain yield were recorded with Pyrazosulfuron ethyl 10 WP at 125 g ha^{-1} *fb* HW. While lowest grain unfilled also was recorded in Pyrazosulfuron ethyl 10 WP at 125 g ha^{-1}. Dash *et al.,* (2016a) reported that application of Butachlor @ 1 kg a.i. ha^{-1} at 3 DAT + HW at 20 DAT statistically at par with Bispyribac sodium @ 25 g a.i. ha^{-1} at 20 DAT gave higher panicle and grains panicle^{-1}. Similarly, highest grain yield was recorded in Butachlor @ 1 kg a.i. ha^{-1} at 3 DAT + HW at 20 DAT, which was at par with Bispyribac sodium @ 25 g a.i. ha^{-1} at 20 DAT *fb* in Bispyribac Na @ 50 g a.i. ha^{-1} at 20 DAT. Reddy and Bandyopadhyay (2015) reported that weed-free *fb* Pretilachlor 50% EC on 1 DAT + HW on 40 DAT, HW twice on 20 and 40 DAT and Bispyribac Na 10% SC on 20 DAT + HW on 40 DAT recorded significantly highest yield attributes and grain yield. Bera *et al.,*(2016) reported that Japanese paddy weeder produced highest grain yields (6.1 t ha^{-1}), net return (Rs.29265) and B:C ratio (1.41).

Nutrient uptake by crop and weeds: Saha and Rao (2012) noted highest N-use efficiency (59.5%) with Azimsulfuron@ 35 g a.i. ha^{-1} treated plots compared to other treatments. Kumar *et al.,*(2012) reported that among the herbicidal treatment, Pretilachlor *fb* Azimsulfuron (36.2%) significantly superior to rest of herbicides in respect to N uptake and N-use efficiency *fb* Ethoxysulfuron+Fenoxaprop (34.57%) and Pyrazosulfuron *fb* Bispyribac (32.79%). Prashanth *et al.,*(2016) reported that lowest uptake (1.02, 0.21 and 1.62 kg ha^{-1}) of nutrients by weeds was noticed in Bispyribac sodium 35 g ha^{-1} at 15 DAT *fb* Bispyribac sodium 30 g ha^{-1} at 15 DAT and Bispyribac sodium 25 g ha^{-1} at 15 DAT. Similarly, application of bispyribac Na 35 g ha^{-1} at 15 DAT recorded significantly higher NPK uptake. However, it was statistically similar with Bensulfuron-methyl + Pretilachlor at 8 DAT. From another study, Dash *et al.,*(2016a) reported that highest N uptake by grain and straw was recorded in Bispyribac sodium @ 25 g a.i. ha^{-1} at 20 DAT, which was at par with Bispyribac Na @ 50 g a.i. ha^{-1} at 20 DAT and Butachlor @ 1 kg ha^{-1} at 3 DAT+HW at 20 DAT, whereas in case of K uptake by straw, except Orthosulfamuron @150 g ha^{-1} at 15 DAT and weedy check all the treatments were statistically at par with 2 HW at 20 and 40 DAS.

Economics: Bhattacharya *et al.,*(2000) observed that maximum gross returns and net profits were recorded in two hand weeding *fb* quinclorac 15 SC at 0.12 kg a.i. ha^{-1} + 1 HW at 40 DAT and quinclorac 15 SC at 0.075 kg a.i. ha^{-1} + 1 HW at 40 DAT, whereas highest B:C ratio was noticed in Quinclorac 15 SC at 0.12 kg a.i. ha^{-1} + 1 HW at 40 DAT.

Banerjee *et al.,*(2008a) found that maximum B:C ratio obtained in continuous submergence along with pre-emergence application of Pyrazosulfuron ethyl 10% WP @ 25 g ha^{-1} at 7 DAT combination *fb* continuous submergence + pre-emergence application of Pretilachlor @ 400 g ha^{-1} at 3 DAT combination. Al-Mamun *et al.,*(2011) reported that highest B:C ratio (2.77) was obtained with application of Bouncer 10WP @ 150g ha^{-1}. Whereas, maximum gross income was recorded with Remover 10WP at 187 g ha^{-1} and it was statistically similar with HW. Acharya and Bhattacharya(2013) working on *boro* rice found that application of application of pyrazosulfuron ethyl @ 20 g a.i. ha-1 gave highest gross and net returns compared to other weed control treatments. Kumar *et al.,*(2013) reported that among various herbicides, application of Pretilachlor 750 g ha^{-1} (pre-emergence) *fb* Azimsulfuron 35 g ha^{-1} + NIS (0.25%) at 15 DAT recorded significantly highest net returns (27,461 ha-1) and B:C ratio (1.32). Morshed *et al.,*(2015) found that application of Pyrazosulfuron ethyl @ 150 g ha^{-1} at 15 DAS + N @ 202 kg ha^{-1} fetched highest gross and net returns whereas, maximum B: C ratio in Pyrazosulfuron ethyl @ 150g ha^{-1} at 15 DAS + N @ 151.8 kg ha^{-1}. Prashanth *et al.,* (2016) reported that among the different herbicide treatments, application of Bispyribac Na @ 25 g ha^{-1} at 15 DAT has recorded maximum net returns and B:C ratio *fb* Bensulfuron-methyl + Pretilachlor @ 10 g ha^{-1} at 8 DAT. Islam *et al.,*(2016) carried out a field study on *boro* rice and observed that among the weed control treatments, application of Pyrazosulfuron ethyl 10 WP at 125 g ha^{-1} gave maximum gross returns *fb* in 2 HW. Dash *et al.,*(2016a) found that maximum net returns (and return/rupees investment) was recorded with application of Bispyribac sodium @ 25 g a.i. ha^{-1} at 20 *fb* Butachlor @ 1 kg a.i. ha^{-1} at 3 DAT + HW at 20 DAT.

FUTURE STRATEGIES

Effective training programmes should be organised for upgrading of knowledge and skill of farmers and useful literature related with cultivation of *boro* rice should be made available to the farmers. The farmers should be qualified with "know how" and "do how" of *boro* rice production technology. There is a need for a crop management package which may include nursery management, optimum planting time, plant population, planting geometry, fertilizer and irrigation requirements, weed management and integrated pest management (IPM). Develop appropriate water management techniques for varying low-lying water bodies help in better land utilization. Management of groundwater is equally important in medium lands. Proper drainage and pumping water from central portion to establish the crop and irrigation reduce menace of aquatic weeds.

CONCLUSION

Herbicides are applied to soil to manage weeds. While it is desirable for chemicals to control weeds and not desirable for them to persist and affect subsequent crop growth. Herbicides vary in their potential to persist in soil. Several factors like soil type, climatic conditions and herbicidal properties which determine the length of time herbicide persist.

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