Internat. J. agric. Sci. Vol.2 No.2 July 2006 : (639-643)

A Review

Weed control in rice through micro herbicidal approach

Dhiman Mukherjee

Department of Agronomy, Regional Research Station, Uttar Banga Krishi Viswavidyalaya, KALIMPONG(W. B.) INDIA

ABSTRACT

Successful weed management for rice crop becomes much more important in order to exploit its maximum production potential as it is a serious constraint. Herbicides are effective tools in man's eternal struggle with weeds in rice field. When properly used, herbicide can safely and effectively accomplish their objective. An array of integrated and selective herbicides provide farmer with a wide choice of practices to control a broad spectrum of weeds in continuously shifting weed population. The use of herbicides is likely to remain an important component in the overall control strategy, as much of the progress in crop protection has been made possible through use of highly effective agrochemicals. The intensive use of high doses herbicides is held responsible for environmental pollution, shift in weed flora and evolution of resistant weed biotypes, which jeopardize herbicides utility, availability and longevity and impose the threat to productivity of world agriculture. However, selective micro herbicide of eco-friendly nature will to be a key ingredient in effective weed management system. Use of low dose high efficiency herbicide of sulfonylurea group is relatively new group of compound, which control grassy, non-grassy and sedges in cereals. Further, an environmental advantage derives from their very low application rates, which markedly reduce the **"Chemical load"** in the environment resulting from herbicide usage. Also most of low doses herbicides are non toxic to animals (both vertebrate and invertebrate) and soil micro-organisms.

Key words : Weed, Rice, Herbicide, Weed control.

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important cereal crop and extensively grown in tropical and subtropical regions of the world, and is staple food for more than 60 per cent of the world population. Rice plays unique role in providing calories to the majority of Asian and Latin American countries. It is grown in 112 countries in the world, covering every continent, and is consumed by 2500 million people in developing countries. Among cereals, rice is the major source of calories for about 40% of the world population and every third person on earth eats rice every day in one form or other (Datta and Khushi, 2002; Mukherjee,2002). In India rice is cultivated on an area of 43.40 million hectares with an annual production of 86 million tons. Its production is found to be distributed as 73 million tons in *kharif* and 13 million tons in *rabi* season. However, rice productivity in India is very low (1,780 kg ha^{-1}) as compared to other rice growing countries like Japan (6,352 kg ha^{-1}), Australia (6,220 kg ha^{-1}), Spain (6,160 kg ha^{-1}), Egypt (5,000 kg ha^{-1}) and China (5,200 kg ha^{-1}). There are several reasons for it's low productivity, and out of that losses caused due to weeds is one of the most important (GOI, 2003).

The yield losses due to uncontrolled weed growth in rice ranges from 12 to 81 per cent from low land to upland situation (Chopra and Chopra, 2003). Weed infestation reducing grain yield directly and indirectly. Rice and rice–weeds have similar requirements for growth and development. Competition occurs when one of the resources (nutrients, light, moisture and space) fall short of total requirement of rice and weeds. Weeds by virtue of their high adaptability and faster growth dominate the crop habitat and reduce the yield potential. The degree of rice-weeds competition depends on crop factors cultivars, crop density, crop age, plant spacing etc. (Moody, 1990). In general, weed problem in transplanted rice is slightly lower than that of direct seeds dry sown rice. But in some cases where continuous standing water cannot be maintained particularly for the first 45 days, weed infestation may be as high as direct seeded dry sown rice. Again continuous flooding controls grassy weeds but invites the infestation of sedge and broad leaved weeds (Mukherjee and Singh, 2005). The dwarf rice plants (high yielding variety) with it erect leaf habit promotes more weed growth and suffers yield losses relatively more than the tall variety (traditional variety) of rice in transplanted condition.

In recent decades, the predominant weed control method in many parts of the world has been the use of effective and reliable chemical herbicide. Further it has been seen that hand weeding, which is in practice, is very effective if followed in time, though it is tedious, time consuming and costly. Whereas effective dose of herbicides not only save valuable time and money, but also allow coverage of more area in short period in carrying out timely weeding. However, repeated use of any single herbicide in crop generates a shift in the composition of weed flora with a result that secondary weeds become of primary concern. Thus, there is a great need for the use of wide spectrum herbicides. In addition their efficacy should be enough to cover the critical period of crop-weed competition. In this context, combination of different herbicides may widen the spectrum of weed control. However, most of herbicide which are commonly used in rice field were quite large amount of active ingredient such as butachlor (1-1.50 kg ha^{-1}), anilofos (0.60 kg ha^{-1}) and pretilachlor (1.00 kg ha^{-1}). Use of such huge amount of these herbicide increase chemical density into the environment and pollute soil and ground water resources, which ultimately distort whole ecology system. So, presently a new concept comes into existence i.e. micro herbicidal approach of weed management. In this approach herbicide dose are quite low usually 2-25 g ha^{-1} and they are very eco-friendly.

Weed flora in rice field

Rice field colonized by terrestrial, semi-aquatic or aquatic weeds depending on the types of rice culture and season. In recent years, rice production has increased with the introduction of high yielding varieties, but their maximum yield potential has not been fully realized owing to improper weed management. Weeds emerged three days to seven days after irrigation in wet seeded plots. However in upland situation it starts to grow at very early stage of crop growth. 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 broad-leaved weeds were found to be associated with rice culture. Mukherjee and Singh (2004 b) observed that transplanted paddy, fields were commonly infested with different types of grasses, viz. *Echinochloa colona* (L.) Link., *Echinochloa crusgalli* (L.) Beauv., *Cynodon dactylon* (L.) Pers., *Panicum repens* (L.), sedges viz., *Cyperus rotundus* (L.), *Cyperus iria* (L.), *Fimbristylis miliacea* (L.) Vahl. and broad-leaved weeds viz., *Caesulia axillaris* Roxb., *Phyllanthus niruri* (L.), *Ammania baccifera* (L.) Rottb., *Commelina benghalensis* (L.), *Amaranthus viridis* (L.), *Corchorus acutangulus* Lamk. Similar kind of observation was reported by Madhu and Nanjappa (1997) at Bangalore.

Crop – weed competition

Crops as well as weeds have the same requirement for the growth and development, and competition begins when crop and weeds grow in close proximity to each other and supply of a single necessary factor falls below the demand of both. Once this occurs, the other factors necessary for plant growth cannot be used effectively even though they may be present in abundance. The overall effect of competition would be a reduction in the biomass and reproductive potential of the competitors. The outcome of the competition would depend not only on the competing species but also on their density, duration and the level of fertility (Singh *et al*., 2003). As far as critical period of rice –weed competition is more effective know that will help to act easily low dose herbicide. Singh and Bhan (1986) noticed maximum emergence of weeds between 15 and 45 DAT (days after transplanting) and recommended a weed free situation in this period to obtain maximum productivity. The most critical period for competition between rice and weeds is when the rice is in the vegetative phase and the yield components of rice are being differentiated. The critical period of crop-weed competition varies considerably with the crop cultivar, weed flora, weed incidence, climatic and edaphic condition. Crop yield losses from weeds usually on proportional to the amount of nutrients, light and water used by the weeds at the expense of the crop (Singh *et. al.,* 2004). Other factors for which crops and weeds are said to compete are space, oxygen, carbon dioxide, air and heat energy, but there is little evidence to support many of these claims. Weed competes with crop plant mainly for nutrients, light moisture and space (Mukherjee and Singh , 2003).

Chemical methods of weed control

In general, cultural and mechanical methods of weed control are time consuming, cumbersome and laborious apart from being less effective because of chance of escape and or regeneration of weeds from roots or rhizome that are left behind. The morphological similarity between the crop and certain grassy weeds makes hand weeding difficult, if not impossible. The use of herbicides therefore, appears to be the only alternative. According to Aurora and De Datta (1992) effective herbicide treatments are those that provide 80 percent weed control, not more than 30 per cent initial injury to rice from which rice should be eventually recoverd, and yields higher than unweeded plots. Under puddled sown rice culture, chemical method of weed control is the efficient method for controlling grasses, sedges and broad-leaved weeds, and reducing the labour cost and achieving higher grain yield. Chemical weed control increased the grain yield by 0.50 t ha^{-1} over weedy check (Mukherjee and Singh, 2004a).

Judicious selection of herbicide, correct times of application, proper dose and method of application are important criteria for higher weed control efficiency and crop yield (Narayanan *et al*., 2001). The methods like spraying, sand mix, urea mix by which herbicides are applied needs to be streamlined. Time of application of herbicides varies greatly with method of sowing, water management, fertilizer management etc. In direct sown rice under sufficient moisture availability condition, pre-emergence herbicides are applied at one day after sowing or in dry condition one day after rain, while in transplanted rice it is 3-8 DAT. Delay in application of herbicide beyond the date of sowing decreases the phytotoxicity to the crop but increase resistance of germinating weeds. So the complexity of our rice farming system, soil and environmental conditions, as also the farmer's ignorance of the herbicide technology necessitates development of relative safe, economic and easily acceptable herbicides.

MICRO HERBICIDE

Use of low dose herbicide (micro herbicide) of sulfonylurea group is relatively new group of compound, which control grassy, non-grassy and sedges in cereals. In preliminary studies, it has been found that sulfonylurea herbicides are characterized by broad spectrum weed control at very low dose (2 to 25 g ha^{-1}), good selectivity and low acute and chronic animal toxicity. Further, an environmental advantage derives from their very low application rates, which markedly reduce the "Chemical load" in the environment resulting from herbicide usage. Sulfonylurea herbicides use as low as 2 g ha^{-1} as compared to other herbicides like butachlor and thiobencarb, which are applied at the rate of 1000-2000 g ha^{-1}. The potency of herbicides is unprecedented (Mukherjee and Singh, 2002). Also most of low doses herbicides are non toxic to animals (both vertebrate and invertebrate) and soil micro-organisms and the low octanol/water partition co-efficient of these herbicides and their degradation products indicate a low potential to accumulate in non-target organism. Aside from their reduced chemical input into the environment, all sulfonylurea herbicides degrade in soil by two concurrent mechanisms: abiotic hydrolysis and microbial degradation (Brown, 1990). Micro herbicidal approach of weed management is totally a new concept. Recently a number of low dose sulfonylurea herbicides like metsulfuron methyl (MSM), chlorimuron ethyl (CME) and MSM + CME (almix), sulfosulfuron etc., have been developed which control grassy and non-grassy weeds in cereals.

Discovery of sulfonylurea herbicides signaled a new era in the history of herbicide chemistry. Chemical weed control began in the mid 1940's with the substituted phenylureas, triazines, diphenylethers, glyphosate and others. These materials offered broad spectrum weed control with use rates generally ranging from 250-4000 g ha^{-1}, and allowed for selective weed control in crops, both pre and post-emergence. With the discovery of sulfonyluea herbicides the present low dose era of herbicide use has started, that is characterized by crop selective weed control at use rates of 2 - 100 g ha^{-1}. This provides a 50-100 a fold increase in herbicidal activity over preceding materials, with crop selective weed control achieved at very low doses. This group of herbicides has been commercialized for use in rice, wheat, barley, oats, soybeans, corn, and oilseed rape (canola), with specialized uses in flax, peanuts and pasture grasses. Sulfonylurea crop selectivity is in every case based on rapid metabolic inactivation of the herbicide by the tolerant crop. Numerous studies have shown that diverse tolerant crops rapidly metabolize the selective sulfonylurea while sensitive species metabolize the herbicide much more slowly. Pathway of which sulfonylurea herbicides are inactivated among these plants include aromatic hydroxylation followed by conjugation to glucose and urea bridge hydrolysis, the glucose conjugates and the bridge hydrolysis products of sulfonylurea are herbicidally inactive (Brown *et al.,* 1990). These herbicides are potent inhibitors of plant growth. Shoot and root growth is rapidly inhibited but further visual symptoms develop slowly with vein reddening, chlorosis and terminal bud death appearing over a period of 4-10 days after treatment. They act through blocking the biosynthesis of the branched amino acids valine, leucine and isoleucine by inhibiting acetolactate synthase (ALS). The inhibition leads to the rapid cessation of plants cell division and growth. Sulfonylureas degrade in soil through a combination of bridge hydrolysis and microbial degradation (Brown, 1990).

Whereas, activity and selectivity are some important properties for any new herbicide, safety and environmental compatibility are also critical to its acceptance by growers, governments and society. The sulfonylurea herbicides have chemical and toxicological properties, which set high standards in these areas. The commercialized sulfonylurea herbicides have very low acute and chronic toxicity to animal species (in part due to lack of the ALS target site in animals) and are not mutagenic. Their very low lipophilicity suggests that they will not accumulate in non-target organism and they are non-volatile, negating the possibility of off site movement by this mechanism (Brown, 1990). Depending on the plant species, dose and environmental conditions, a variety of secondary responses often develop. These include enhanced anthocynin formation, loss of nyctinasty, abscission, vein discoloration, terminal bud death, chlorosis and necrosis. These secondary effects are often slow to develop, with plant death sometimes not occurring until a week or more of the herbicide treatments. This micro herbicide are generally formulated as wettable powder or water dispersible granules and disperse easily in spray tanks and can be easily applied in normal spray volumes with conventional equipments. In addition, they are particularly compatible with low and ultra-low-spray volumes. There formulations can be easily tank mixed with a variety of commercial herbicides like 2,4-D, butachlor, anilofos etc. (Breyer and Martin, 1988).

Following few of recent micro herbicides and their combination used are as follow :

Metasulfuron methyl

Metsulfuron methyl belongs to sulfonylurea group herbicides. Peterson *et al.* (1990) revealed the efficacy of metsulfuron methyl at the rate of 4 g ha^{-1} against 38 important weeds of rice. Application of metsulfuron methyl can be made to paddy water or by direct foliar contact after weed emergence and is useful in many cultural situations, including fields of upland rice for the control of broad-leaved weeds. They also observed that this herbicide was environmentally safe and non-mutagenic and is required at high concentration before resulting in toxic effects on rat, rabbit, mice, various fish species and waterfowl.

Mukhopadhyay and Mallick (1991) reported that application of metsulfuron methyl at 2, 4 and 8 g ha^{-1} for post transplanting weed control in rice in standing water in *kharif* seasons in West Bengal has great promise. They observed no toxicity on rice plants on any occasion even at the highest rate. All the rate of metsulfuron methyl gave at par result with weed free check. Among the yield contributing characters, the number of effective tillers m^{-2} (445, 441 433) and number of filled grains $panicle^{-1}$ (68, 68, 67) showed significant increase i.e. 35 and 33 per cent in metsulfuron methyl treatment over the unweeded control (283 effective tillers and 45 filled grains $panicle^{-1}$). Metsulfuron methyl at all the rates recorded grain yield at par with butachlor 1.50 kg ha^{-1} and was 67 per cent higher grain yield over unweeded control. They also observed that metsulfuron methyl with its all rates effectively controlled weeds like *Echinochloa colona*, *Ludwigia parviflora*, *Sphenoclea zeylanica* and *Fimbristylis miliacea* within 10 days after application and kept the plots weed free until harvest. Application of metsulfuron methyl 4 g ha^{-1} in transplanted rice at 60 days stage control weeds like *Echinochloa colona, Echinochloa crusgalli* and *Cyperus* spp. 95, 65 and 25 per cent, respectively. The grain yield was recorded 7.10 t ha^{-1}, which was at par with butachlor 1.50 kg ha^{-1} (7.00 t ha^{-1}), anilofos 0.40 kg ha^{-1} (7.20 t ha^{-1}) and weed free (7.20 t ha^{-1}). Also metsulfuron methyl recorded significantly higher grain yield than control (weedy), which was 1.50 t ha^{-1} (AICRPWC, 1993). Observation at Coimbatore, also showed that metsulfuron methyl 3 g ha^{-1} gave better performance than the most commonly used rice herbicide butachlor. Metsulfuron methyl maintained minimum weed density upon critical period of crop-weed competition (50 DAT). This center also reported that low dose and high efficiency herbicide metsulfuron methyl recorded taller plants as compared to hand weeding and presently used conventional herbicides. Yield components, panicle per unit area and grain yield more in metsulfuron methyl compared to butachlor (AICRPWC, 1993). At Pantnagar, metsulfuron methyl controlled 90% *Echinochloa colona* and 20% *Cyperus rotundus.* Metsulfuron methyl 8 g ha^{-1} did not show any superiority over 4 g ha^{-1} with respect to weed control. Weed control efficiency of metsulfuron 4 and 8 g ha^{-1} on *Echinochloa* spp. was higher as compared to that of chlorimuron ethyl 6 g ha^{-1}. Uncontrolled weeds caused 77.52 per cent reduction in grain yield of rice as compared to weed free treatment (AICRPWC, 1994).

Singh (1994) while working with metsulfuron methyl in transplanted rice during 1990-1991 and 1991-1992 reported that metsulfuron methyl 4 and 8 g ha^{-1} controlled *Echinochloa crusgalli, Echinochloa colona* and *Cyperus* spp. by 40, 60, 20 and 20, 60, 20 per cent, respectively. Metsulfuron methyl 4 and 8 g ha^{-1} gave 5.90 and 6.02 t ha^{-1} grain yield, which was at par with butachlor 1.50 kg ha^{-1} and weed free (6.14 t ha^{-1}). Also metsulfuron methyl 4 and 8 g ha^{-1} gave significantly higher grain yield than unweeded control (2.22 t ha^{-1}). Studies at Hisar, revealed that metsulfuron methyl provided 47-57 per cent control of barnyard grass in 1990 and 27 to 45 per cent in 1991. The dry weight of weeds was significantly lower in treated plots. The mean paddy yield following the application of metasulfuron methyl 8 g ha^{-1} was 5364 kg ha^{-1} as compared to 6255 kg ha^{-1} in plots treated with anilofos 0.40 kg ha^{-1} (Singh *et al*., 1999). Mukherjee and Bhattacharya (1999) observed with increase dose of metsulfuron methyl from 4 to 8 g ha^{-1} significantly reduced weed population and weed dry weight and had helped to enhance number of effective tiller m^{-2}, number of filled grains $panicle^{-1}$ and ultimately grain yield ha^{-1}. Walia *et al*. (1999) had observed that application of metsulfuron methyl 10 and 15 g $ha^{-1}$was very effective against all broad-leaved weed population and check the dry weight. This lead to higher number of effective tillers and helps to increase grain yield from 25.31 to 41.52 q ha^{-1}.

Four field experiments were conducted during 1998-99 and 1999-2000 at two locations in Goias, Brazil to evaluate the selectivity of different herbicides at different growth stage of rice. The rice cultivars tested were Primavera, Marvilha and Canastra and the herbicide treatments were metsulfuron methyl 2.40 g ha^{-1} at 10 and 20 days after emergence (DAE); 2, 4-DEE (335, 502 and 670 g ha^{-1}) at 10,20 and 30 DAE; fenoxa prop-p-ethyl (fenoxyprop-p) 41.40 g ha^{-1} at 10, 20, and 30 DAE and clefoxydin (120 g ha^{-1}) at 10,20 and 30 DAE. The results showed that the selectivity of the herbicides depends on the cultivars and rice growth stage at the time of application. Metsulfuron methyl at 20 DAE and fenoxa prop-p-ethyl and clefoxydin at 30 DAE are recommended for cultivar Primavera. For Marvilha, metsulfuron methyl applied at any growth stage (Cobucci and Portela, 2001). Bhattacharya *et al*. (2002) reported metsulfuron methyl 8 g ha^{-1} controlled the weeds effectively at the early stage but it failed to maintain its effectiveness at the later stage. It was due to its rapid degradation.

Chlorimuron ethyl

It belongs to sulfonylurea group of herbicides. Chlorimuron ethyl applied 6, 12 and 24 g ha^{-1} for weed control in transplanted rice at Sriniketan, West Bengal resulted 3.92, 3.83 and 3.24 t ha^{-1} grain yields, respectively which were at par with butachlor 1500 g ha^{-1}(3.90 t ha^{-1}) and weed free check (3.64 t ha^{-1}). The yield contributing characters like number of effective tillers m^{-2} and number of filled grains $panicle^{-1}$ did not differ with weed free treatment. Chlorimuron ethyl even at the lowest dose i.e. 6 g ha^{-1} killed all categories of weeds within 10 days after its application and kept the plots weed free throughout the growth period of rice crop (Mukhopadhyay and Mallick, 1991).

Singh (1994) reported that chlorimuron ethyl 6 and 12 g ha^{-1} were effective against *Echinochloa* spp. and *Cyperus rotundus.* Chlorimuron ethyl at both these rates controlled 70 and 90 per cent of *Echinochloa colona* and *Echinochloa crusgalli*, respectively. Grain yield at these rate were 5.86 and 6.95 t ha^{-1}, respectively. An experiment conducted at IARI, New Delhi, revealed that application of chlorimuron ethyl 12 g ha^{-1} transplanted rice lowered down the weed population and their dry weight, and resulted in significant increase in yield attributes and yield of rice compared with weedy check. They also indicated that butachlor 1kg ha^{-1}, anilofos 0.50 kg ha^{-1} and chlorimuron ethyl 12 g ha^{-1} were almost identical in their weed control efficiency, but chlorimuron ethyl was found more effective against broad-leaved weeds (Chandra and Pandey, 2001). Studies conducted by Singh and Bhan (1998) at Jabalpur in *kharif* to assess the efficacy of metsulfuron methyl 3-5 g, chlorimuron ethyl 15-25 g and tribenuron methyl 10-30 g ha^{-1} applied 15 DAT, and compared with pretilachlor 750-1000 g and butachlor 1500 g ha^{-1} applied 3 DAT for weed control in rice cv. Kranti. Weed density and dry matter were lowest in the chlorimuron ethyl 25 g ha^{-1} and it produced highest grain yield and the petilachlor and butachlor treatment produced next highest yields. Mukherjee and Singh (2004 b) during there study at Varanasi reported that chlorimuron ethyl 20 g ha^{-1} significantly reduced the weed population particularly *Echinochloa colona, Echinochloa crusgalli*, *Leptochloa chinensis*, *Eclipta alba* and *Commelina benghalensis* and their dry weight. This will help to increase nitrogen use efficiency of crop.

Combination of sulfonylurea herbicides

From research findings in the recent years, it was observed that combination of different sulfonylurea herbicides with other standard herbicides even at lower dose proved more effective against a broad spectrum of weeds in transplanted rice. Mukhopadhyay and Mallick (1991) observed that metsulfuron methyl + chlorimuron ethyl 2 + 6 and 4 + 4 g ha^{-1} resulted rice grain yield of 3.74, 3.67 t ha^{-1}, which was at par with butachlor 1.50 kg ha^{-1} (3.00 t ha^{-1}) and weed free (3.64 t ha^{-1}). Combinations of these herbicides at both the rates resulted significantly higher yield (62 %) than the unweeded control (2.27 t ha^{-1}). Application of metsulfuron methyl + chlorimuron ethyl 4 + 4 and 3 + 3 g ha^{-1} provided 7.10 and 7.00 t ha^{-1} rice grain yields in transplanted rice. Both the combinations were at par with butachlor 1.50 kg ha^{-1} (7.00 t ha^{-1}), anilofos 0.40 kg ha^{-1} (7.20 t ha^{-1}) (AICRPWC, 1993). Singh (1994) reported that metsulfuron methyl + chorimuron ethyl 2 + 2, 4 + 4 and 6 + 6 g ha^{-1} yielded grain yields of 6.21, 6.80 and 7.00 t ha^{-1}, which were almost similar to butachlor 1.50 kg ha^{-1} (6.91 t ha^{-1}), anilofos 0.40 kg ha^{-1} (6.40 t ha^{-1}) and weed free treatment (7.00 t ha^{-1}). Singh and Bhan (1998) reported that combine application of metsulfuron methyl + chlorimuron ethyl (4+12 g ha^{-1}) showed best performance in reducing total weed population (95.32%) and total dry matter production. This treatment thus showed highest weed control efficiency (95.18%).

Mukherjee and Singh (2003) observed that combine application of metsulfuron methyl + chlorimuron ethyl (4 + 4 g ha^{-1}) controlled the weeds effectively throughout the growth and registered higher weed control efficiency value compared with chlorimuron ethyl 6 g ha^{-1} and metsulfuron methyl 8 g ha^{-1} alone. Thery further revealed application of almix (metsulfuron methyl + chlorimuron ethyl) 10 g ha^{-1} was ineffective to check the weed population and provide inferior to other herbicidal treatments in reducing the dry weight of weeds. With every increase dose from 10 to 20 g ha^{-1} brought about significant reduction in dry weight of weed.

Herbicide mixtures

It has been observed that individual herbicides like metsulfuron methyl, chlorimuron ethyl, butachlor, anilofos, 2, 4-DEE, which are effective on certain weed species fail to control other weed species. Hence, to have a broad spectrum of weed control in single application, herbicide mixtures (both concocted and tank) were tried and found to be effective. The simultaneous application of more than one herbicides in a mixture is increasingly becoming a standard practice in modern weed control strategies, particularly in absence of effective broad spectrum herbicides to control highly diverse weed populations. A grassy herbicide in combination with broad-leaved weeds killer would take care of both types or grass killer in combination with herbicide that control both sedges and broad-leaved weeds will give a wider spectrum of weed control.

Moody (1981) as well as Auroro and De Datta (1992) while reviewing the weed management rice, opined that herbicide combination usually provided wider control spectrum and /or better or more lasting control than when components of the combination are applied alone. They also reported that when herbicide used in combination, the rates are usually lower than when herbicides are used alone. Application of almix (metsulfuron methyl + chlorimuron ethyl) 6 and 8 g ha^{-1} yielded rice grain yields of 7012 and 7102 kg ha^{-1}, respectively, which was significantly higher than weedy check, which yielded 1815 kg ha^{-1}. The grain yield of rice due to almix and its tank mixed applications with anilofos (6 + 200, 6 + 300 and 8 + 200 g ha^{-1}) did not differ significantly (AICRPWC, 1995). Study conducted during *kharif* seasons of 1996 at Sriniketan, West Bengal indicated that almix 16 g ha^{-1} when combined with 2,4-DEE at different doses (100, 200 and 300 g ha^{-1}) resulted increase in grain yield and suppressed all kinds of weed categories.

Phytotoxicity

Phytotoxicity refers to injurious effect of herbicide on plant, which is assessed by visual scoring. In general, herbicides are non-phytotoxic to crop because of their selectivity, but there are reports of initial injury to rice in case of some new herbicides depending upon the dosage, time of application. Further, when herbicide mixtures are used crop damage is likely to occur if the component of mixtures is incompatible. Aurora and De Datta (1992) while reviewing weed management in rice, stated that effective treatments are those that provide 80 per cent weed control and not more than 30 per cent initial injury to rice, from which rice should eventually recover, and yields higher than unweeded plots. Mukherjee and Bhattacharya (1999) found that application of metsulfuron methyl + chlorimuron ethyl (4 + 4 g ha^{-1}) controlled the weed effectively throughout the growth and registered higher weed control efficiency value compared with chlorimuron ethyl 6 g ha^{-1}, but failed to evoke their response on grain yield, which could be attributed to their phytotoxicity towards the crop which ultimately inhibited the formation of effective tillers.

Economics

The practical utility of any weed control measure can be best judged based on its economic feasibility besides its efficient weed control. Although effectiveness of manual weeding in controlling weeds and there by enhancing yields is unquestionable. However, increased cost of labour wages coupled with non-availability of labour during peak period of field operations, the manual weeding has become uneconomical to the farmers in most of rice growing areas. Mukherjee and Singh (2004a) reported that a ready mix application of almix + 2,4-DEE (15 + 500 g ha^{-1}) applied at 8 DAT gave increased weed control efficiency. This combination enhances productive tillers and the numbers of filled grains, which lead to higher grain yield and gave highest net income and benefit : cost ratio of 3.97. So the weed control in rice through microherbicidal approach is quite cost effective as well as beneficial tool for weed management as per farmer and human welfare concern.

CONCLUSION

From the above review, it can be summarized that weed flora in rice is dynamic and varies with location to location and condition to condition. Weed effectively compete with the crop upto 40-45 DAT and reduce grain yields ranging from 10 to 83 per cent. Chemical weed control is getting popularity, particularly in areas where labour is scarce and costly. Also in the areas where labour is available economical because of the fact sometime situation in monsoon season is such that rainfall continues more than seven day, and labour is unable to work in the field, which results more weed growth. Some of the micro herbicides either alone or their combinations at lower dose have been proved economically viable alternative to hand weeding in management of weeds in transplanted rice. Therefore, efforts are needed seriously to achieve a broad spectrum, and season long (i.e. at least up to the critical period of 40 – 45 DAT) weed control with reasonably low cost for practical utility.

REFERANCES

AICRPWC. (1993). All India Coordinated Research Programme on Weed Control (ICAR). Annual Report. Tamil Nadu Agricultural University, Coimbatore, India. p. 62.

AICRPWC. (1994). All India Coordinated Research Programme on Weed Control (ICAR). Annual Report. G.B.P.U.A.T., Pantnagar, India. pp. 5-9.

AICRPWC. (1995). All India Coordinated Research Programme on Weed Control (ICAR). Annual Report. National Research Centre for Weed Science, Adhartal, Jabalpur, India. pp. 82-91.

Aurora, M. B. and De Datta, S.K. (1992). Weed management in rice. *Weed Abstr.* **41 (11) :** 495 – 508.

Bhattacharya, S.P., Sarkar, S. and Behra, P. (2002). Weed management through sulfonylurea herbicides and its effect on yield in transplanted rice. *Environment and Ecology* **20 (2) :** 426 – 428.

Breyer, A.M. and Martin, T.D. (1988). A review of the activity, fate and mode of action of sulfonylurea herbicides. *Pesticides Sci.* **22 (2) :** 193 – 219.

Brown, A.M. (1990). Mode of action, crop selectivity and soil relations of the sulfonylurea herbicides. *Pesticides Sci*. **29** (3) : 263-282.

Brown, H.M., Lichtner, F.T., Hutchison, J.M. and Saladini, J.A. 1990. The impact of sulfonylurea herbicides in cereals crops. In Proc: Br. Crop Prot. Conf. Weeds Brighton, U.K. **1**: 20-23.

Chandra, S. and Pandey, J. (2001). Effect of rice culture, nitrogen and weed control on nitrogen composition between scented rice and weeds. *Indian J. Agron.* **46 (1) :** 68-74.

Chopra, N.K. and Chopra, N. (2003). Effect of doses and stage of application of pyrazolsulfuron ethyl on weeds in transplanted rice. *Indian J. Weed Sci*. **35 (1&2) :** 27-29.

Cobucci, T. and Portela, C. (2001). Herbicides selectivity sprayed at different upland rice growth stage. *Plant Daninha* **19 (3) :** 359-366.

Datta, S.K. and Khushi, G.S. (2002). Improving rice to meet food and nutritional weeds biotechnological approaches. *J. Crop Production* **6 (1&2) :** 229 – 247.

GOI. (2003). Agricultural situation in India, Directorate of Economics and Statistics, Department of Agriculture and Co-operation, Ministry of Agricultural Government of India, Krishi Bhawan, New Delhi LVI **10** : 633-635.

Madhu, M. and Nanjappa, H.V. (1997). Nutrient uptake by crop and weeds as influenced by weed control treatments in puddled rice. *Crop Res.* **13 (1) :** 1-6.

Moody, K. (1981). Weed fertilizer interactions in rice. Int. Rice Res. Notes **10** (1) : 81-80.

Moody, K. (1990). Yield losses due to weeds in rice in the Philippines. Int. Rice Res. Newsl. **18 (1) :** 11.

Mukherjee, D. (2002). Food security coping with nutritional challenge ahead. *Agric. Today* **8** : 30-32.

Mukherjee, D. (2004). Influence of stresses on crop efficiency. *Kisan world* **31 (10) :** 40.

Mukherjee, D. and Singh, R.P. (2002). Hebicide bating on low dose option. *Agric. Today* **12** : 44-45.

Mukherjee, D. and Singh, R.P. (2003). Proc. Biennial conference of Indian society of Weed Sci. held at Pant Nagar from 12-14, March. p 11.

Mukherjee, D. and Singh, R.P. (2004a). Efficacy of low doses herbicide on divergent weed flora in transplanted rice. *Oryza* ***41*** **(1&2) :** 20-23.

Mukherjee, D. and Singh, R.P. (2004b). Efficacy of certain low doses herbicides in medium land transplanted rice. *Indian J. Weed Sci.* ***36*** **(1&2):** 47-49.

Mukherjee, D. and Singh, R.P. (2005). Proc. Biennial conference of Indian society of Weed Sci. held at Punjab from 6-9, April. pp 12-13.

Mukherjee, P.K. and Bhattacharya, S.P. (1999). Comparative study of bio efficacy between new generation micro herbicides and traditional voluminous herbicides on transplanted rice culture. *Ann. Agric. Res.* **20 (4) :** 509-511.

Mukhopadhyay, S.K. and Mallick, R.P. (1991). Metsulfuron, chlorimuron and tribenuron – low dose high efficacy herbicides for weed control in transplanted rice. In Proc: 13th Asian Pacific Weed Sci. Soc. No. **1:** 157-163.

Narayanan, A., Poonguzhalan, R., Mohan, P. and Hanif, A.M. (2001). Chemical weed management in transplanted rice in karaikal region of Pondicherry Union Teritory. *Madras Agric. J.* **87 (10-12) :** 691-692.

Peterson, L.W., Reed, W.T. and Yamuguchi, T. (1990). Sulfuron methyl, metsulfuron methyl and their combinations for weed control in rice. In Proc: Pest management in rice (Conf. Held by the Soc. of Chemical Industry), London, U.K. pp. 358 – 367.

Singh, G. (1994). Bio efficacy of sulfonylurea herbicides in transplanated rice. *Pestology* **18 (10) :** 44-45.

Singh, G., Singh, R.K., Singh, V.P., Nayak, R. and Singh, R.S. (1999). Weed management in transplanted rice under rainfed lowland situation. *Indian J. Agron.* **44 (4) :** 725-732.

Singh, O.P. and Bhan, V.M. (1986). Effect of time of weeding on crop and associated weeds in transplanted rice. Abstr. Annual Conf. Indian Soc. Weed Sci., March 20-21, Agricultural Experiment Station, Jaipur, India. p. 29.

Singh, R.P. , Mukherjee, D., Singh, R.K. and Sinha, A.K. (2003). Bioefficacy of herbicides in late sown wheat. *Indian J. of Agronomy* **48 (3) :** 196-198.

Singh, S. and Bhan, V.M. (1998). Performance of sulfonylurea herbicides on weed control in transplanted rice. *Ann. of Plant Protection Sci.* **6 (1) :** 81-91.

Walia, U.S., Brar, L.S and Dhaliwal, B.K. (1999). Studies on the control of *Casulia axillaries* Roxb. in transplanted rice (*Oryza sativa* L.). *Indian J. Weed Sci.* **31 (3 & 4) :** 158-160.

Received : September, 2005; Accepted : March, 2006