HERBICIDAL MANAGEMENT OF CHINESE SPRANGLETOP [*Leptochloa chinensis*(L.) Nees.] IN DIRECT SEEDED RICE

By

GEETHU JACOB

(2011-11-127)

THESIS

submitted in partial fulfilment of the requirement for the degree

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KERALA, INDIA

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DECLARATION

I hereby declare that the thesis entitled **"HERBICIDAL MANAGEMENT OF CHINESE SPRANGLETOP [*Leptochloa chinensis* (L.) Nees.] IN DIRECT SEEDED RICE"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellanikkara **Geethu Jacob**

Date: 11-04-2014 **(2011-11-127)**

CERTIFICATE

Certified that the thesis entitled **"HERBICIDAL MANAGEMENT OF CHINESE SPRANGLETOP [*Leptochloa chinensis*(L.) Nees.] IN DIRECT SEEDED RICE"** is a record of research work done independently by **Ms. Geethu Jacob (2011-11-127)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to her.

Vellanikkara

Date: 11-04-2014

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CERTIFICATE

We, the undersigned members of the advisory committee of **Ms. Geethu Jacob (2011-11-127)** a candidate for the degree of **Master of Science in Agriculture**, with major field in Agronomy, agree that the thesis entitled **"HERBICIDAL MANAGEMENT OF CHINESE SPRANGLETOP [*Leptochloa chinensis* (L.) Nees.] IN DIRECT SEEDED RICE"** may be submitted by **Ms. Geethu Jacob (2011-11-127),** in partial fulfilment of the requirement for the degree.

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Geethu Jacob

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INTRODUCTION

1. INTRODUCTION

Rice is the most important cereal crop of the world, being the staple food of about one fifth's of the world's population. In India, rice is grown in about 42.5 M ha, with a production of 104.32 M t in 2011-12 (the highest recorded so far), contributing to 51 percent of total food grain production of the country. Transplanting is the major practice followed in rice cultivation, the other being direct seeding of sprouted seed in wetland. Direct seeding offers a good alternative stand establishment practice to the transplanting system since it reduces labour cost and gives yield similar to transplanting, making it more economical. Weeds are considered to be a major biotic constraint to rice production. Crop-weed competition reduces agricultural output by 48.9 percent in rice (Singh *et al*., 2003).

In the *Kole* lands of Kerala, where rice is grown during September-October to February-March and the land remains submerged during the rest of the year, Abraham and Thomas (1998) reported the existence of *Echinochloa stagnina* and *E. crusgalli* as the important grass weeds along with other dominant sedges like *Fimbristylis miliacea*, *Cyperus iria* and *C. difformis*. Along with these, Vidya *et al.* (2004) also reported the existence of broad leaf weeds such as *Ludwigia parviflora*, *Lindernia crustacea*, *Limnocharis flava* and *Monochoria vaginalis,* and the fern *Marsilea quadrifolia*. In addition to these, Sindhu (2008) added *Oryza rufipogon*, *Sphenoclea zeylanica*, *Eichhornia crassipes*, *Salvinia molesta*, *Nymphaea nouchali*, and *Ludwigia perennis* to the weed flora in lower *Kole* areas comprising Alappad and Manakody *Koles*.

A yield loss of 40 to 100 per cent is recorded in direct seeding (Choubey *et al.*, 2001) compared to transplanting were weed problems are less critical (Moorthy and Saha, 2002). Among the various weed control measures, use of herbicides is the most important practice for most crops as it is easier, time and labour saving, and economical compared to the traditional hand weeding methods (Rekha *et al*., 2003).

However, repeated use of herbicides is one of the main factors responsible for the shift in weed species population in rice ecosystems (Azmi *et al.*, 2005). One such example of weed shift is the heavy infestation of weedy rice in the rice fields of Kerala in recent times. Many farmers in Kerala have been forced to abandon their rice crop due to considerable increase in the intensity of the wild and weedy forms of different species of rice. Weedy rice infestation has also caused severe problems in direct seeded rice areas in South East Asia (Hussain *et al.*, 2008). Another typical example of weed shift is the emergence of *Leptochloa chinensis* as a problem weed in the rice fields of Kerala.

Leptochloa chinensis (L.) Nees. (Chinese sprangletop or Red sprangletop) is one of the most important invasive weeds in direct seeded rice fields (Chin, 2001). In a survey of weeds in rice agroecosystems of Kerala, Chinese sprangletop was reported as a new weed specific to the alkaline soils of Chittoor taluk (Vidya *et al.*, 2004). Though this weed is listed as an indicator plant for alkaline conditions, it is now seen spreading rapidly in acidic soils also. In Kerala, this weed was reported to be spreading fast. Now it is one of the most serious weed problems in all the three major rice bowls of Kerala, *viz*., Kuttanad, *Kole* and Palakkad (KAU, 2009).

Chinese sprangletop is a C_4 grass species native to tropical Asia. Although an annual species, it can be perennial under suitable conditions. It is a slender tufted grass growing up to a height of 1.2 m with smooth linear leaves and terminal loose panicles (Soerjani *et al.*, 1987). This weed has the ability of high seed production and can grow in both flooded and upland condition (Galinato *et al.*, 1999). It has the same outbreak level as *Echinochloa crusgalli* (L.) Beauv. and after it germinates, it grows profusely in water logged spots in rice fields because of very poor land levelling in farmer's fields (Abeysekera, 1999). It is reported that the continuous use of bispyribac sodium from 1998 onwards to control propanil resistant barnyard grass has resulted in a shift to dominance by Chinese sprangletop in wet land rice fields of Sri Lanka (Marambe, 2002).

Chemical weed control is probably the only feasible alternative in wet seeded rice because of the absence of rows for hand or rotary weeding (Moody, 1977). Flooding is reported to have a suppressive effect on the emergence and dry matter production of Chinese sprangletop (Chauhan and Johnson, 2008). Several selective pre emergence herbicides have been developed which are in use throughout the rice growing countries. However, in Kerala, only butachlor and thiobencarb are recommended for weed control in puddled rice. However, application of pre emergence herbicides poses difficulties of proper water management and probable phytotoxicity to rice seedlings. Post emergence herbicides would be a more practical option.

Many new molecules of herbicides having broad spectrum activity are now appearing in the market. A few new herbicides tested recently in Kerala Agricultural University (azimsulfuron, penoxsulam, fenoxaprop-p-ethyl, metamifop etc.) have shown promise for weed control in rice. Fenoxaprop-p-ethyl @ 0.5-1L/ha provided excellent control of Chinese sprangletop in both dry and flooded conditions in Malaysia (Kuah and Sallehuddin, 1988). Metamifop @ 90 to 200 g/ha as post emergence application gave effective control of annual grass weeds including *Leptochloa chinensis* in Korea (Kim *et al.,* 2003). Continuous use of bispyribac sodium, which is one of the most popular rice herbicides among farmers in Kerala, to control barnyard grass resulted in the dominance of Chinese sprangletop. It is reported to be least effective in controlling *Leptochloa chinensis* in Sri Lanka (Abeysekera and Wickrama, 2004). Pre-emergence application of butachlor was also effective in controlling red sprangletop (Kathiresan, 2004). Application of both Cyhalofop butyl emulsion and granules showed effective control of Chinese sprangletop in Japan (Sumiyoshi and Suzuki, 2006). Two handweedings and pyrazosulfuron ethyl at 0.015 kg/ha were effective in reducing the nutrient removal by the weed and increasing the nutrient uptake by rice in Ludhiana, Punjab (Aulakh and Mehra, 2008).

In view of the growing menace of *Leptochloa chinensis* in the rice fields of Kerala, it is important to develop a new herbicide strategy by making use of the new molecule herbicides or the pre and post emergence herbicides already in use for effective control. Therefore a research project was formulated with the following objectives:

- ❖ To evaluate the efficacy of new promising herbicides against *Leptochloa chinensis* in direct seeded rice
- ❖ To assess the crop-weed competition, including nutrient removal, by the weed

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Rice (*Oryza sativa* L.) is a major food crop in Asia and many other tropical and sub-tropical countries of the world. Weed management is a major factor contributing a considerable share to the cost of production and deciding the final yield. Especially in direct seeded rice (DSR), as the crop and weeds emerge simultaneously due to which the crop suffers competition even from early stages of growth which in turn reduces the grain yield (Choubey *et al.*, 2001). Success of direct seeded rice depends largely on effective weed management techniques (Pandey and Velasco, 2002). This change in method of rice establishment from traditional manual transplanting to direct seeding has occurred in many Asian countries in the last two decades and repeated use of herbicides is the main reason for the shift of weed species population in rice ecosystem (Benvenuti *et al.*, 2004). Weed competition is the major limitation for success of DSR (Rao *et al.*, 2007).

Weeds are one of the most important biological constraints in rice production. Moody (1983) reported that weed competition is greater in wet seeded rice than transplanted rice due to similarities in age and morphological characters of grass weeds and rice seedlings. Singh *et al.* (2002) reported 48.9% yield reduction in weedy check as compared to two hand weedings in transplanted rice. Among the various methods for weed control, chemical method is the best with regard to labour savings and high B: C ratio (Bahar and Singh, 2004). Mukherjee and Singh (2005) reported that effective control of weeds increased grain yield by 85%. Uncontrolled weeds decreased yield by 96% in dry DSR and 61% in wet DSR (Maity and Mukherjee, 2008). Though comparatively a new entrant, *Leptochloa chinensis* has developed into a troublesome weed in the major rice growing tracts of Kerala, and its effective herbicidal control is essential.

2.1 Biology and Ecology of *Leptochloa chinensis*

Red or Chinese sprangletop (*Leptochloa chinensis*), a C_4 grass species, is a native of Tropical Asia and is now widely distributed in South and Southeast Asia, Africa, and Australia. This is a slender tufted grass that grows to a height up to 1.2 m with smooth and linear leaves and terminal loose panicle (Soerjani *et al.*, 1987). Chinese sprangletop has the ability to grow in both flooded and upland conditions, which makes it a widespread and abundant weed in rice and many other crops (Galinato *et al.*, 1999). It is known to be invasive, which has been linked to its high seed production (Manidool, 1992; Chin, 2001). Although it is an annual species, it can be perennial when suitable growing conditions exist (Chauhan and Johnson, 2008).

The seed production potential (4000-90,000 per plant) as well as seed rain (number of seeds/m^2) was highest for *Leptochloa chinensis*. *Leptochloa chinensis* seeds showed no dormancy and exhibited germination even in anoxic conditions as evidenced by the fact that some seedlings did emerge in flooded conditions when water was no deeper than 6 cm (Williams *et al.,* 1994). It is a common weed in direct seeded rice fields (Chin, 2001) and Chinese sprangletop has recently been reported as a new weed in Italy with increasing frequencies in rice fields (Benvenuti *et al.,* 2004). It is reported to occur in 16 countries in dry seeded rice and in seven countries in wet seeded rice (Rao *et al*., 2007). Irrespective of soil moisture condition, seedlings of this weed emerged from a depth of up to 4 cm (Chauhan and Johnson, 2008).

The earlier Chinese sprangletop was seeded, the longer its growing period was, and *vice versa*. Seed burial and concomitant flooding induced an unusual germination: first coleoptile emergence and subsequently emergence of radical was observed (Benvenuti *et al.,* 2004). Germination experiments in field under natural conditions showed that germination of Chinese sprangletop seeds burgeoned from 4 to 30 days after rice seeding, the culminating period of germination was during 6-10 days after rice seeding and the rate of germination was 41.26%. Manual removal of this weed could increase the emergence percentage of the weed by 23.53%, but rainstorm could decrease the weed emergence due to deeper water in field (LiYao *et al.*, 2011).

2.2 Scenario of weed shift of *Leptochloa chinensis* in rice ecosystem

Changes in method of rice establishment from traditional manual transplanting to direct seeding have occurred in many Asian countries in the last two decades in response to rising production costs, especially for labour and water. The continuous use of Bispyribac-sodium to control Propanil-resistant barnyard grass [*Echinochloa crusgalli* (L.) Beauv.] has resulted in a shift to dominance by Chinese sprangletop in Sri Lanka (Marambe, 2002). Similarly, in Jiangsu and Zhejiang provinces in eastern China, the long-term use of Butachlor [chloracetanilide] and Molinate [thiocarbamate] in rice has led to an increases in population of Chinese sprangletop (Zhang, 2003). The widespread introduction of direct seeding and the repeated use of herbicides are the main factors responsible for the shift in weed species population in rice ecosystems (Azmi *et al.*, 2005). Chinese sprangletop was not a prevalent and dominant weed in rice fields of Malaysia when transplanting of rice was the usual establishment practice but it became widespread with the shift to direct seeding of rice (Azmi *et al.*, 2005). With change in method of crop establishment, the population of *L. chinensis* increased tremendously and became more dominant than *Echinochloa* spp. (Evelyn *et al.*, 2005). Further, in Thailand, herbicide use has led to the evolution of resistance to Clefoxydim, Fenoxaprop-p-ethyl and Quizalofop-p in Chinese sprangletop (Rao *et al.*, 2007).

In a survey of weeds in rice agroecosystems of Kerala, Chinese sprangletop was first identified as a new weed in alkaline soils of Chittoor taluk (Vidya *et al.*, 2004). Though this weed is listed as an indicator plant for alkaline conditions, it is now seen spreading rapidly in acidic soils also. In Kerala, this weed was reported in rice fields of Palakkad, Kole areas of Thrissur and in Kuttanad region too (KAU, 2009).

2.3 Weed spectrum in rice

Among different group of weeds, grass weeds are most influential in reducing grain yield followed by broad leaved weeds and sedges (De Datta *et al.,* 1968). In India, yield loss due to unchecked weed competition was reported to range from 43 to 83 percent (Pillai and Rao, 1974). Weed spectrum and intensity differ according to the method under which the rice is grown (Smith and Moody, 1979). About 350 species in more than 150 genera and 60 plant families have been reported as weeds of rice (Barret and Seaman, 1980). Smith (1981) reported Poaceae as the most important plant family accounting for more than 80 species of weeds in rice. Grasses are the dominant weeds in early stages of crop growth while sedges and broad leaved weeds dominate later in the season (Jiang, 1989). Direct seeded rice can be grown under both rainfed upland and irrigated or flooded conditions. The distribution of weeds in paddy fields is largely determined by environmental factors modified by competition from rice. Many weeds have wide range of environmental tolerance and broad geographical distribution (Kim and Park, 1996).

Moorthy and Dubey (1978) reported that about 90% of weeds in wet seeded rice were sedges. *Echinochloa colona, Eleusine indica, Cyperus iria* and *Fimbristylis littoralis* are the major weeds of rice (Ahmed, 1981). On a world wide scale, *Echinochloa crusgalli, Cyperus difformis*, *Cyperus iria*, *Eleusine indica*, *Fimbristylis littoralis*, *Ischaemum rugosum*, *Monochoria vaginalis* and *Sphenoclea zeylanica* are the important weeds associated with rice (Smith, 1983). According to Joy *et al.* (1991) weed flora in wet seeded rice in Kerala consisted of 22% grasses, 40% sedges, and 32% broad leaved weeds. At 55 days after sowing (DAS), weed flora consisted of 37% grasses, 33% sedges and 30% broad leaved weeds (Joy *et al.,* 1993). Mahajan *et al.* (2006) reported *Cyperus difformis* and *Cyperus iria* among sedges, *Echinochloa crusgalli* and *Echinochloa colona* among grasses and *Trianthema portulacastrum* and *Eclipta alba* among broad leaved weeds as major weeds of rice under direct sown system.

In direct wet sown fields of Pattambi (Kerala), Nair *et al.* (1974) reported the presence of *Echinochloa crusgalli, Cyperus* sp., *Fimbristylis miliacea and Monochoria vaginalis* as the major weeds. Moorthy and Manna (1982) reported that the weed flora in puddled rice composed of *Fimbristylis miliacea, Cyperus difformis* and *Scirpus supines*. At IRRI, the major weed species observed in wet seeded rice in the order of importance include *Paspalum distichum, Monochoria vaginalis, Sphenoclea zeylanica, Echinochloa glabrescens* and *Cyperus difformis* (Mabbayad and Moody, 1984). In south East Asia, Allard and Zoschke (1990) observed *Echinochloa* sp., *Leptochloa chinensis, Cyperus* sp., *Fimbristylis miliacea, Scirpus* sp., *Monochoria vaginalis* and *Ludwigia adscendens* as the major weeds infesting wet sown rice. Sreedevi and Thomas (1993) suggested that sedges and broad leaved weeds constituted the major part of weed flora in direct sown puddled rice in Kerala, with few grasses. Choubey *et al.* (2001) observed *Echinochloa colona, Commelina benghalensis, Cyperus iria* and *Cynotis axillaris* as major weeds in DSR.

Joseph (1986) reported a high population of *Scirpus supines* followed by *Cyperus difformis* and *Cyperus iria* in wet sown rice in Kerala. John and Sadanandan (1989) identified *Cyperus iria, Cyperus difformis, Fimbristylis miliacea, Monochoria vaginalis, Ludwigia parviflora, Sphenoclea zeylanica, Marselia quadrifolia* and *Lindernia* sp. as major weeds of puddled low land rice at Moncompu (Kerala). According to Mohankumar *et al.* (1996) *Schoenoplectus lateriflorus, Monochoria vaginalis* and *Ludwigia perennis* were the predominant weeds in direct sown puddled rice.

In DSR, the major grass weed species include *Echinochloa colona, Echinochloa crusgalli, Leptochloa chinensis, Dactyloctenium aegyptium* and *Digitaria bicornis*. *Echinochloa colona* requires less moisture than *Echinochloa crusgalli*, and therefore, the density of *Echinochloa colona* depends on moisture conditions in the field. The density of *Echinochloa colona, Leptochloa chinensis* and *Eleusine indica* were higher in wet seeded rice (WSR). Weed density of *Leptochloa chinensis* was lower with pre emergence application of herbicides followed by two hand weedings at 30 and 60 DAS in WSR (Singh *et al*., 2005c). Seed rain was highest for *Cyperus esculentus* and *Ammania auriculata* in sedges and broad leaved weeds, respectively (Dhawan, 2007). Hussain *et al.* (2008) and Singh and Singh (2010) reported *Cyperus difformis, Cyperus iria, Sphenoclea zeylanica, Echinochloa crusgalli, Echinochloa colona, Fimbristylis miliacea* and *Eclipta alba* as the dominant weed species in DSR. Tiwari *et al.* (2010) noticed *Echinochloa crusgalli, Echinochloa colona, Commelina benghalensis, Monochoria vaginalis and Ludwigia perennis* in DSR. Weed flora in DSR field comprised of *Echinochloa colona* and *Panicum repens* under grasses, *Cyperus difformis and Fimbristylis miliacea* under sedges, *Eclipta alba, Marselia quadrifolia, Ammania baccifera* and *Ludwigia parviflora* under broad leaved weeds (Balasubramanian *et al.,* 2010). According to Muthukrishnan *et al.* (2010) in Tamil Nadu, weeds of major concern in DSR include *Ischaemum rugosum, Leptochloa chinensis, Digitaria sanguinalis, Dactyloctenium aegyptium, Cyperus iria, Fimbristylis miliacea* and *Cyperus difformis.* The seed production potential (4000-90,000) as well as seed rain (Number of seeds/m^2) was highest for *Leptochloa chinensis*. Major sedges included *Cyperus difformis, Cyperus esculentus, Fimbristylis miliacea* and broad leaved weeds included *Eclipta alba, Ludwigia palustris, Lindernia* sp.*, Alternanthera sessilis* and *Ammania auriculata.*

2.4 Critical period of crop-weed competition in rice

Critical period of crop-weed competition (CPWC) is the time span during the crop growth when weeding results in greatest economic returns. . The two critical periods in transplanted rice are 4-6 weeks after transplanting, causing greater damage by reducing number of panicles and 12th week (early ripening stage), causing reduction in grain weight (Clements, 1970). Moody (1977) observed that the time and duration of CPWC depends on weed flora, growth characteristics of rice and weeds, cultural practices and environmental factors.

The crop-weed competition starts with nutrient depletion by weeds and leads to suppression of plant height in rice (Ramamoorthy *et al.,* 1974). Competition from weeds at various stages of crop for different growth factors induces severe stress on crops. According to Matsunaka (1983), higher competitive ability of weeds is due to their C_4 nature with higher photosynthetic ability compared to rice, which is C_3 in nature. Similar findings were also reported by Kim and Moody (1989).

Zimdahl (1980) noted first 20 days after emergence was the CPWC in rice. According to Ali and Sankaran (1984) CPWC is up to 60 DAS in upland rice but Varshney (1985) reported it is up to 40 DAS. In dry sown rice, weed free period up to 60 DAS is needed for good yields (Sankaran and De Datta, 1985). Due to initial growth advantage for transplanted rice, weeds are less detrimental than in DSR. According to Singh *et al.* (1987) competition of weeds in the first 15 DAS has no significant effect on grain yield of upland rice. In DSR, the first 30-40 DAS is considered to be CPWC (Tewari and Singh, 1991). On the other hand, weeds emerging between 15 DAS and 45 DAS will compete with crop causing yield reduction. Abraham and Thomas (1998) stated that CPWC is from 15 to 45 DAS and also, Singh *et al.,* 2008 depicted the same with CPWC is longer for DSR from 15-45 DAS.

2.5 Critical period of rice-*Leptochloa chinensis* competition

Competition between rice plant and the red sprangletop for the first 3 weeks after sowing (WAS) caused 3% of yield reduction, but when competition occurred only for the first 2 weeks, the yield obtained was similar to the weed-free condition. Conversely, when plots were weed-free only for the first 2 to 3 weeks, yield loss ranged from 17 to 19%. To obtain high yields, rice plant must be weed-free for the first 4 WAS. In direct-seeded rice the critical period for weed control of red sprangletop is between 2 and 4 WAS of the rice. In unweeded rice, *L. chinensis* inflicted 41% yield loss (Pane, 1998).

The rice plant height and tiller number were reduced by red sprangletop (Pane and Mansor, 1996). With direct-sown rice, increasing densities of *L. chinensis* from 0 to 30 plants/m² decreased rice yield from 6.45 to 1.37 t/ha and 0 to 26 plants of *L. chinensis* decreased yields from 7.59 to 2.82 t/ha. Economic threshold for hand weeding was 1.73-2.31 plants of *L. chinensis*/m² (SongHan *et al.,* 1996). Thus competition occurred between red sprangletop and rice from the middle stage of vegetative growth to the grain-filling stage (Pane and Mansor, 1996). The weed grew quicker than rice by about 1 leaf, and the weed was much bigger at the late than at the early stage and application of herbicide at the 3-leaf stage of rice plants was safe for rice and the percentage of *L. chinensis* control reached over 95% (Xing *et al.,* 2000).

2.6 Effect of weed competition on growth parameters and yield of crop

Nakayama (1978) observed reduction in plant dry matter of rice due to competition from weeds. A negative correlation between crop dry matter and weed dry weight was reported by Patel *et al.* (1985). Higher weed dry matter production was observed in unweeded plots during 15 to 30 days (Singh *et al.,* 1987). Moody (1988) observed an inverse relation between rice yield and weed dry matter. Crop dry matter production was higher in hand weeded / herbicide (pre emergent) applied plots (Palaikudy, 1989). Nyarko and De Datta (1991) observed that there was a reduction of one kilogram in dry matter production of rice for every kilogram of weeds produced. Infestation of *Echinochloa glabrescens* in rice reduced plant height by 12%, LAI by 55% and total dry weight by 79% (Velu, 1996). Reduction in crop dry matter due to weeds at various crop growth stages was also reported by Vandana and Reddy (1999).

Crops under severe competitive stress produced delayed heading and smaller panicles (Noda *et al.,* 1968). Shetty (1973) recorded a yield loss ranging from 10% to 70% due to weed competition. A yield reduction of 30% to 35% in direct seeded puddled rice was reported by Pillai and Rao (1974). A linear relationship between rice yield with duration of *Cyperus difformis* and a yield reduction of 64.4 kg/ha for each day of competition up to tillering in high fertile soils was reported by Swain *et al.* (1975). Kumar (1984), Suja and Abraham (1991) as well as Gibson *et al.* (1999) reported that severe infestation of weeds suppressed the plant height and reduced crop dry matter production. Jayasree (1987) reported the reduction of rice plant height due to competitive stress in unweeded check. Sreedevi *et al.* (2009) observed that unweeded control recorded lower plant height.

A reduction in number of panicles/m^2 to the extent of 32% in unweeded plots over hand weeding twice was noticed by Moorthy (1980). Gobrial (1981) reported that weed competition in rice lowered panicle number per unit area by 37%, filled grains per panicle by 13% and test weight by 4%. Kumar and Gill (1982) registered a reduction of 63% and 11% in effective tillers and test grain weight respectively in unweeded plot over herbicide treated plots. Weed competition considerably decreased panicle production in rice due to less tiller production (Biswas *et al.*, 1992).

Smith (1968) showed that yield reduction due to weeds range from 30 to 35% in wet seeded rice and more than 60% in upland rice. Density of *Echinochloa crusgalli,* at 20/m^2, competing from 7 to 14 days after emergence in low land rice reduced the yield up to 20%, and 40 plants/m^2 decreased yields up to 40% without any further reduction in yield with increase in weed density of 60, 80 and 100 plants/m^2 (Lubigan and Vega, 1971). The decline in rice yield due to weed competition ranged between 94 to 100% (Mukhopadhyay *et al.*, 1972). Grain yield of broadcasted upland rice was reduced by 41% due to competition from *Cyperus rotundus* (Okafor and De Datta, 1974). According to De Datta (1981) rice yield decreases by 45% in rainfed low land DSR and 67% in upland rice due to effect of weeds. The yield losses can range between 10 to 100% depending on the type of weed flora, their density and duration of competition. *Echinochloa* incidence for four weeks reduced rice yield by 40% in upland DSR (Mandal, 1990). Uncontrolled weed growth caused yield reduction of 73 to 86% (AICRP-WC, 1992). Unchecked weed competition causes yield losses to the tune of 50-65% (Subbaiah and Sreedevi, 2000). Uncontrolled weeds on an average caused 75.8, 70.6 and 62.6% reduction in grain yield when compared to weeded condition in DSR, wet seeded rice and transplanted rice, respectively (Singh *et al.*, 2005).

Singh and Tewari (2005) observed that a yield loss in direct seeded puddled rice was 40.2%. Weeds posed a major problem in dry seeded rice production due to the prevalence of congenial atmosphere and uncontrolled growth and reduced yield up to 30% (Singh *et al.*, 2005b). The extent of yield reduction due to weeds is 51-74% in rainfed lowland rice, 30-35% in direct seeded puddled rice and 15-20% in puddled transplanted rice (Sharma, 2007). Weedy situation throughout the crop growth caused yield reduction to the tune of 64-66% in wet seeded rice in comparison to season long weed free situation (Mukherjee *et al.*, 2008). Arunvenkatesh and Velayatham (2010) reported yield losses as high as 46% due to weeds in DSR.

2.7 Effect of *Leptochloa chinensis* on growth parameters and yield of rice

Height and tiller number of rice at 45 days after sowing were not affected by weed competition. However, the weight of 1000 filled grains was affected by competition, and panicle number/m² showed a significant correlation with red sprangletop density. Panicle number and number of grains/m² had a significant correlation with rice yield. Yield declined significantly when the rice plants competed with the red sprangletop at a density of 16 plants/m², and this effect was even greater as the weed population increased. More than 35% rice yield loss was recorded from the plots which had 40 red sprangletop plants/m², while the highest yield of 4.44 t/ha was harvested from the plot which was weed-free (control). These results suggested that competition occurred between red sprangletop and rice from the middle stage of vegetative growth to the grain-filling stage (Pane and Mansor, 1996).

2.8 Nutrient uptake by weeds and crops

Weeds are more severe competitors for nutrients than for water and have higher nutrient use efficiency than rice (Loomis, 1958). The demand for nutrients was in the order of K>N>P by crop and weed. Weeds removed 24.0 kg N, 7.5 kg P_2O_5 and 30.5 kg K_2O per hectare in unweeded check (Varughese, 1978). Weeds accumulate more nitrogen in direct sown rice than the crop, indicating severe competition for nitrogen (Singh and Sharma, 1984). Similar growth habits and efficient photosynthetic pathway (C_4) resulted in higher nutrient content and higher removal of nutrients by weeds than crops (Singh *et al.*, 1986). Weeds accumulate higher concentration of plant nutrients in their tissues than crops (Chungi and Ramteke, 1998).

The rate and time of nitrogen fertilization affected weed population and number of weed seeds produced (Dotzenko *et al.*, 1969). Weeds are found to be insensitive to low soil K and do not respond to added K (Buchanan and Hoveland, 1973). It is also reported that there is significant correlation between nutrient uptake by crops and weeds (Sahai and Bhan, 1982). According to Singh and Dash (1988), N uptake and weed dry weight are positively correlated. Yogabalalekshmi (2001) reported that higher N doses increased weed leaf area index with better absorption of applied N.

Weeds depleted 25.8 kg N, 3.65 kg P_2O_5 and 21.83 kg K_2O when they were allowed to compete with rice (Ramamoorthy, 1991). Depending upon the intensity of weed growth, the nutrient removal per hectare may go up to 86.5 kg N, 12.4 kg P and 134.5 kg K (Malik and Moorthy, 1996). Thirumurugan *et al.* (1998) reported that weeds in wet seeded rice removed significantly higher quantities of N, P and K due to higher population and weed dry matter. Weed infestation depleted 24.7 kg N, 5.8 kg P and 63.4 kg K/ha in one season (Sharma, 2007). Weeds in complete weedy situation removed 34.4 kg N, 7.4 kg P and 37.8 kg K/ha in transplanted rice and 50.9 kg N, 15.7 kg P and 63.7 kg K/ha in wet seeded rice (Mukherjee and Maity, 2011).

The combination of manual weeding and chemical weeding reduced the nutrient removal by weeds and maximum N, P and K removal by weeds was recorded in unweeded check (Choubey *et al.,* 1999). Reddy (2000) also reported decreased nutrient removal by weeds under high plant densities. Brar and Walia (2001) reported that higher plant density of 44 hills/m^2 in rice reduced weed count as well as weed dry matter accumulation than 33 hills/m^2. Weeds removed 2.3 kg N, 0.6 kg P, 3.3 kg K/ha under 44 hills/m^2 in comparison to 3.7 kg N, 1 kg P, 5.3 kg K/ha under 22 hills/m^2 and corresponding nutrient uptake by crop was 156 kg N, 38 kg P, 153 kg K and 132 kg N, 33 kg P, 133 kg k/ha, respectively.

2.9 Nutrient uptake by *Leptochloa chinensis*

Yield reduction of 14 to 44% is reported by various densities of *Leptochloa* in transplanted rice (Prusty *et al.*, 1993). Red sprangletop (*Leptochloa chinensis*) is an invasive alien weed in rice (Kathiresan, 2004). Frequent cultivation practices during off season reduced *Leptochloa* count as well as nutrient removal by it (2 kg N, 0.6 kg P and 2.9 kg K/ha) and increased crop nutrient uptake (155 kg N, 38 kg P and 150 kg K) compared to undisturbed land (Aulakh and Mehra, 2008). Similar results were also reported by Gnanavel and Kathiresan (2002) and Benvenuti *et al.* (2004).

The reduction in the concentration of nitrogen due to red sprangletop competition ranged from 0.03 to 0.13 g/plant which was 4.0-21 kg N/ha (Pane and Mansor, 1996). *Leptochloa* removed 16.5 kg N, 3.5 kg P and 25.8 kg K/ha under unweeded conditions (Reddy, 2000).

2.10 Effect of hand weeding on weed and crop growth

The practice of hand weeding continues to be effective and safe until economical herbicides are easily available to farmers (Singh and Rath, 2000). Higher weed control efficiency (WCE) of 93% was obtained in hand weeded control (Moorthy and Saha, 2002). Hand weeding twice at 20 DAS and 40 DAS significantly lowered weed density (Rekha *et al.*, 2002; Kathirvelan and Vaiyapuri, 2003). Suresh and Singh (2003) recorded maximum yield attributing factors like number of productive tillers, grains/panicle, and test weight under manual weeding. Although hand weeding is the most effective method of weed control, it is labour intensive and uneconomical (Saha *et al.*, 2005).

Hand weeding twice resulted in higher panicle number and grain yield (Suganthi *et al.*, 2005). Lakshmi *et al.* (2006) recorded highest crop growth parameters, yield attributes, grain (5.4 t/ha) and straw yield (5.7 t/ha) under hand weeded condition in dry sown rice. Sharma (2007) noted that two hand weedings, one at 10 to15 DAS and second at 25 to 50 DAS, were enough in upland rice. Two hand weedings ensure 100 percent control of weeds (Singh *et al.*, 2007). The highest WCE of 65.5 percent was recorded with two hand weedings at 30 and 45 DAS (Payman and Singh, 2008). According to Subhalakshmi and Venkataramana (2009) hand weeding at 20 and 40 DAT recorded the highest plant height, dry matter production, tillers/m^2, nutrient uptake by crop and the highest grain and straw yield.

2.11 Effect of herbicides

Metamifop is a new aryl oxy phenoxy propionate (AOPP) post emergence herbicide which shows an exclusive whole plant safety to rice with a high control efficacy to annual grass weeds, especially barnyard grass (*Echinochloa crusgalli*). Selectivity of Metamifop between rice and barnyard grass could be due to both differential foliar absorption rate and differential Acetyl Co-A carboxylase sensitivity (Kim *et al.*, 2003). **Cyhalofop butyl**, available as Clincher 10 EC, is an aryl oxy phenoxy propionate (AOPP) herbicide developed for post emergence control of grass weeds in dry as well as wet seeded rice. It is a phloem mobile, systemic herbicide that inhibits Acetyl Co-A carboxylase enzyme activity (Sharma *et al.*, 2004). **Fenoxaprop p-ethyl,** available as Rice star, is a new aryl oxy phenoxy propionate (AOPP) post emergence herbicide inhibiting Acetyl Co-A carboxylase enzyme and is effective against grass weeds in rice. **Penoxsulam** is a new post-emergence rice herbicide belonging to triazolopyrimidine sulfonamide family with ALS (AcetoLactate Synthase) inhibition as its mode of action and is used for the control of annual grasses, sedges and broad leaved weeds in rice culture (Jabusch and Tjeerdema, 2005). It is a systemic herbicide that is absorbed primarily via leaves and secondarily via roots. **Bispyribac sodium**, available as Nomineegold, is a pyrimidinyl carboxy herbicide, is broad spectrum in activity, effective to control many annual and perennial grasses, sedges and broad leaved weeds in rice fields (Yun *et al*., 2005). **Azimsulfuron** is a post emergence sulfonyl urea herbicide useful for controlling weeds in rice fields (Valle *et al.,* 2006).

Prakash *et al.* (1995), reported **Oxyfluorfen,** pre emergence herbicide at 0.1 kg/ha controlled the weeds to the greatest extent (73.3%). **Pyrazosulfuron-ethyl** is a soil active early post-emergence rice herbicide belonging to sulfonylurea family with ALS (AcetoLactate Synthase) inhibition as its mode of action and is used for the control of annual grasses, sedges and broad leaved weeds in rice culture (Hwang *et al*., 2003). **Butachlor,** the pre emergence herbicide comes under substituted acetamides. **Pretilachlor,** at 1.5 L/ha applied 1 to 3 days after sowing (DAS) is very effective in controlling the weeds when water is maintained at the level of 5 to 7 cm and with the application of pretilachlor alone, most of the sedges and the broad-leaved weeds are controlled and the biomass of grasses is reduced (Evelyn *et al.,* 2005).

1. Fenoxaprop p-ethyl

1.1 Effect of fenoxaprop p-ethyl on weeds

Smith (1988) also reported fenoxaprop p-ethyl as an effective alternative for control of graminaceous weeds in rice. Similar results were also reported by Khodayari *et al.* (1989). Snipes and Street (1987) evaluated ethyl ester of fenoxaprop p-ethyl and reported that it is an effective herbicide against barnyard grass at 0.17 and 0.2 kg/ha when applied up to 5-6 leaf stage of weed and fenoxaprop p-ethyl did not adversely affect the grain yield of rice. Saini and Angiras (2002) reported that fenoxaprop p-ethyl at 90 g/ha (20 DAS) significantly reduced the population of *Echinochloa crusgalli* and completely controlled *Panicum dichotomiflorum*. Weed dry weight reduced to 42.5 g/m^2 with application of fenoxaprop p-ethyl at 90 g/ha (15 DAT) compared to 224.2 g/m^2 in weedy check (Singh *et al.*, 2003). Singh *et al.* (2004) reported that application of fenoxaprop p-ethyl at 56.25 g/ha 10 DAT effectively controlled *Echinochloa colona*, *Echinochloa crusgalli, Leptochloa chinensis* and *Ischaemum rugosum*. Fenoxaprop p-ethyl at 60 g/ha was highly effective for controlling grasses in DSR (Dixit and Varshney, 2008). According to Kumar *et al.* (2010), fenoxaprop p-ethyl at 60 g/ha (20 DAT) followed by one hand weeding 30 DAT significantly reduced the total weed population and weed dry weight at all crop growth stages compared to weedy check. Use of surfactant with fenoxaprop p-ethyl at 120 g/ha slightly increased its efficacy.

According to Banga and Yadav (2004) fenoxaprop p-ethyl at 120 g/ha is superior to its lower dose (100 g/ha) and was on par with its higher dose (140 g/ha) in terms of weed density, but ineffective against *Rumex* sp. and *Coronopus didymus*. Tank mix of fenoxaprop p-ethyl + Chlorsulfuron @ 100 g + 20 g/ha provided 73 to 84% control of weeds (Yadav *et al.*, 2004). Fenoxaprop p-ethyl provided control of *Phalaris minor* in wheat (Dahiya *et al.*, 2005). Singh *et al.* (2005c) reported that fenoxaprop p-ethyl at 100 g/ha when applied with power activator (Puma super) caused quick killing and thereby less density of *Phalaris minor* compared to its application without surfactant at 60 days stage of observation. Fenoxaprop p-ethyl followed by metsulfuron efficiently controlled complex weed flora, reduced total dry matter accumulation by weeds in wheat and thereby its nutrient removal (Jat *et al.*, 2007). Weed control efficiency (WCE) of 95.5% was obtained with application of Fenoxaprop p-ethyl @ 60 g/ha followed by one HW and thereby lowest weed index (Kumar *et al.*, 2009).

According to Yadav *et al.* (2002), tank mixture of fenoxaprop p-ethyl and 2,4-D sodium salt could not provide effective weed control due to their antagonistic effect. Fenoxaprop p-ethyl at 50 g/ha could be used as post emergence spray for the control of grass weeds (Singh *et al.*, 2008). The weed density, frequency and abundance were highly affected by fenoxaprop- p- ethyl + ethoxy sulfuron at 45+10 g/ha (15 DAS) (Katiyar and Kolhe, 2006). Tank mix of fenoxaprop + ethoxysulfuron (50+18 g/ha) effectively controlled both grasses and broad leaved weeds when applied post emergence between 18 to 21 DAS in rice (Singh *et al.*, 2008). Metsulfuron, 2,4-D ester as well as 2,4-D sodium salt had antagonistic effect on the efficacy of fenoxaprop p-ethyl against *Phalaris minor* when applied as tank mixture but it did not affect the efficacy of above herbicides against broad leaved weeds in wheat (Yadav *et al.*, 2009). Mallick *et al.* (2009) observed a gradual decrease in grass weed density and dry weight by fenoxaprop p-ethyl (6.9% EC) application. Tiwari *et al.* (2010) noticed the highest WCE in rice on mixing fenoxaprop p-ethyl (0.06 kg/ha) with ethoxysulfuron (0.015 kg/ha). Application of fenoxaprop p-ethyl + Almix at 30 DAS recorded the lowest grass and broad leaved weed density, total weed dry weight and highest WCE in rice.

1.2 Effect of fenoxaprop p-ethyl on *Leptochloa chinensis*

In a direct seeded rice trial by Kuah and Sallehuddin (1988), 0.5-0.1 litre of fenoxaprop-p-ethyl/ha applied at 14-25 days after sowing provided excellent control of *Leptochloa chinensis* and *Echinochloa crusgalli* in both dry and flooded conditions but a supplementary application of 2,4-D was required to control broad leaved weeds and sedges. Control of Chinese sprangletop in direct sown rice fields of China was more than 90% after use of fenoxaprop-p-ethyl when applied on rice plants with more than 6 leaves (Yang *et al.*, 2004). Both fenoxaprop-p-ethyl resistant and susceptible Chinese sprangletop were found from same field on Saphan-Sung district of Bangkok, Thailand and the resistant Chinese sprangletop had higher level of ACCase. It was 10 times less sensitive to fenoxaprop (based on I_{50} value) than the susceptible sprangletop (Pronporm *et al.*, 2006). Combination of fenoxaprop-p-ethyl with ethoxysulfuron also proved better than lower doses of azimsulfuron 50DF in Chattisgarh plains of India under DSR (Singh *et al.*, 2010).

1.3 Effect of fenoxaprop p-ethyl on rice

Saini and Angiras (2002) recorded higher grain yield (3.3 t/ha) as well as yield attributing factors with application of fenoxaprop p-ethyl @ 90 g/ha (20 DAS). Fenoxaprop p-ethyl at 56.25 g/ha applied at 10 days stage produced grain yield of 6798 kg/ha which was at par with weed free treatment (Singh *et al.*, 2004a). Dahiya *et al.* (2005) observed that grain yield of rice with application of fenoxaprop p-ethyl @ 120 g/ha along with surfactant was 6% higher than application of fenoxaprop p-ethyl alone. Dixit and Varshney (2008) observed higher number of panicles/m^2 (236) and grains/panicle (71) under post emergence application of fenoxaprop p-ethyl. Higher grain and straw yield (4268 kg/ha and 5583 kg/ha) was obtained with application of fenoxaprop p-ethyl followed by one hand weeding which was on par with mechanical hoeing (Kumar *et al.*, 2009).

Singh *et al.* (2003a) also observed similar results due to better management practices and reduction in crop-weed competition, arising from reduction in weed population and dry weight. Banga and Yadav (2004) reported length and number of spike, number of grains/spike, 1000 grain weight and grain yield similar to weed free condition on application of fenoxaprop p-ethyl + sulfosulfuron @ 116.7g + 23.3 g/ha. Application of fenoxaprop p-ethyl at 100 g/ha with or without power activator produced wheat yield on par with weed free check (Singh *et al.*, 2005c). Sreedevi *et al.* (2009) recorded higher mean plant height with application of fenoxaprop p-ethyl. Kumar *et al.* (2010) recorded higher panicles/m^2 (228) with lesser weed dry weight (15.3 g/m^2) and higher yield (4.3 t/ha; next to weed free plot) with application of fenoxaprop p-ethyl @ 60 g/ha followed by one hand weeding. Fenoxaprop p-ethyl (0.06 kg/ha) mixed with ethoxysulfuron (0.015 kg/ha) produced higher grain yield (Tiwari *et al.*, 2010).

2. Cyhalofop-butyl

2.1 Effect of cyhalofop butyl on weeds

Singh *et al.* (1997) reported that cyhalofop butyl was superior to pre emergence application of butachlor and anilofos in minimizing weed population and dry matter accumulation. Cyhalofop butyl @ 90 g/ha at 20 DAS was superior to butachlor in decreasing dry weight of *Echinochloa crusgalli.* Post emergence application of cyhalofop butyl @ 80 g/ha was found effective in controlling *Echinochloa colona* (Choubey *et al.,* 2001). Cyhalofop butyl @ 90 g/ha + 0.3% surfactant controlled weeds in transplanted rice and reduced total dry matter of *Echinochloa* sp. (Saini *et al.*, 2001). Sequential application of cyhalofop butyl @ 90g/ha followed by 2,4-D @ 1 kg/ha decreased dry weight of major weeds with a weed control efficiency (WCE) of 89.6% as compared to tank mix application of the same due to antagonistic effect (Angiras and Attri, 2002). Nut grass, ammania were also controlled by cyhalofop butyl at 75 g a.i./ha (Zhang *et al.*, 2001).

Saini (2003a) reported cyhalofop butyl @ 100g/ha as post emergence application was effective against most of the annual grasses in wet seeded rice. Scott (2003) found cyhalofop butyl to be a very effective herbicide against barnyard grass and observed that it was safer when tank mixed with 2,4-D amine. Sharma *et al.* (2004) reported that cyhalofop butyl @ 90 g/ha is optimum for controlling *Echinochloa* in rice nursery. Application of cyhalofop butyl @ 120 g/ha at 15 DAS followed by 2,4-D at 1 kg/ha at 20 DAS recorded lower total weed dry weight and higher WCE (Saini, 2005). According to Singh *et al.* (2008) cyhalofop butyl @ 120 g/ha could be used as post emergence spray for the control of grassy weeds. Cyhalofop butyl at 15 DAS followed by one hand weeding at 45 DAS reduced weed density, which was on par with hand weeding twice (20 & 45 DAS) (Sangeetha *et al.*, 2009). Post emergence application of cyhalofop butyl alone was ineffective in controlling broad leaved weeds (Saini *et al.*, 2001, Kiran and Subramanyan, 2010).

2.2 Effect of cyhalofop butyl on *Leptochloa chinensis*

Cyhalofop butyl 100% EC recorded excellent weed control, resulting in the lowest population and dry weight of *L. chinensis*, and in addition, did not have any adverse effect on grain yield (Abeysekhara and Wickrama, 2004). With 5 Chinese sprangletop seeds/m^2 in a directly sown rice field, 51.2% of the rice yield was lost, and with the application of a mixture of cyhalofop-butyl at 75 g a.i./ha and bensulfuron at 225-300 g/ha at 3 leaf stage of rice, 95% of Leptochloa was controlled (Zhang *et al.,* 2001). Cyhalofop butyl 100% EC applied at 7-10 DAS showed 90-94% control over Leptochloa (Abeysekhara and Wickrama, 2004).

2.3 Effect of cyhalofop butyl on rice

Cyhalofop butyl @ 90 g/ha resulted in more number of panicles and higher grain yield of rice (4.5 t/ha) (Angiras and Attri, 2002). Saini (2003a) reported that application of cyhalofop butyl at 10, 15 and 20 DAS resulted in higher paddy yield. Cyhalofop butyl applied to rice plants did not show any visual phytotoxicity symptoms (Abeysekhara and Wickrama, 2004). Saini (2005) reported that cyhalofop butyl at 120 g/ha (15 DAS) followed by 2,4-D at 1 kg/ha (20 DAS) and 2,4-D at 15 DAS followed by cyhalofop butyl at 20 DAS were on par with each other and recorded higher number of panicles/m^2, panicle length, grains/panicle and 1000 grain weight. Sangeetha *et al.* (2009) reported application of cyhalofop butyl (15 DAS) + 1 HW (45 DAS) produced more panicles/m^2, filled grains/panicle and yield which were on par with HW twice.

3. Metamifop

3.1 Effect of metamifop on weeds and *Leptochloa chinensis*

Kim *et al.* (2003) reported that metamifop was a new aryl oxyphenoxy propionate (AOPP) herbicide developed by Dongbu Hannong Chemical Co Ltd. (Korea Republic). Like other AOPPs, metamifop provided excellent control over a

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wide range of annual grass weeds. In directly-sown rice cultivation, metamifop applied post emergence at 90-200 g a.i./ha gave excellent control of major grass weeds including *Echinochloa* spp., *Leptochloa chinensis*, *Digitaria* spp. and *Eleusine indica*. Metamifop recorded favourable toxicological, ecotoxicological and environmental profiles.

4. Azimsulfuron

4.1 Effect of azimsulfuron on weeds

In transplanted rice, efficacy of azimsulfuron against sedges has been found excellent but not as good against broad leaved weeds (Yadav *et al.*, 2007). However Yadav *et al.*, (2008a) reported excellent control of broad leaved weeds and sedges (90-100%) with application of azimsulfuron alone or admixed with metsulfuron. Azimsulfuron at all doses (10, 15, 22.5, 25, 30 g/ha) lowered the density of broad leaved weeds to a graeter extent when applied at 15 DAT than application at 25 DAT. It also provided excellent control of sedges and there was 82% control of grass weeds, 93-99% control of broad leaved weeds, and 100% control of sedges when applied at 30 g/ha, 15 DAT (Yadav *et al.*, 2008a). For sedges including *Cyperus rotundus* and broad leaved weeds, post emergence application of azimsulfuron @ 25 to 30 g/ha was effective in DSR (Singh *et al.*, 2008).

Sangeetha *et al.* (2010) reported that there was absolute control of *Echinochloa* and no regeneration of dried *Echinochloa* seedlings with application of azimsulfuron 21 DAT @ 35 and 40 g/ha. Sakthivel and Balasubramanian (2010) reported broad spectrum control of weeds with application of azimsulfuron 50DF @ 30 g/ha at 30 and 60 DAT. Azimsulfuron provided excellent control of sedges even at 10 g/ha and also controlled grasses and broad leaved weeds at 30 g/ha (Yadav *et al.*, 2010). Post emergence application of azimsulfuron suppressed the late emerged weeds effectively (Murali *et al.*, 2010).

Shirakura *et al.* (1995) reported poor efficacy of azimsulfuron against grass weeds but excellent control of sedges, particularly *Cyperus rotundus.* It was effective in controlling perennial weeds at very low application rate but higher concentrations were needed to control annual weeds. Singh *et al.* (2009) noticed that azimsulfuron at lower doses (25 and 27.5g /ha) was not effective against grasses and there was no advantage of tank mix application of azimsulfuron with metsulfuron methyl over azimsulfuron alone for control of sedges and broad leaved weeds. But azimsulfuron was very effective in controlling sedges and broad leaved weeds in DSR.

Jayadeva *et al.* (2009) reported that application of azimsulfuron @ 35 g/ha + 0.2% surfactant significantly reduced the density and dry weight of grasses, sedges and broad leaved weeds at 45 DAT. Similar results were also reported by Saini (2003b). According to Singh *et al.* (2010) azimsulfuron applied as tank mix with Almix proved superior to application of Almix alone in reducing total weed density and dry weight and they provided 90-95% control of broad leaved weeds and sedges. However, tank mixing with Almix did not produce any complimentary effect over azimsulfuron alone.

4.2 Effect of azimsulfuron on *Leptochloa chinensis*

Tank mix sequential application of bispyribac sodium with azimsulfuron at 25 g/ha each provided excellent control on all weeds except the aerobic grassy weeds like *Leptochloa chinensis, Eragrostis sp., Eleusine sp., and Dactyloectinium aegyptium* (Yadav *et al.,* 2010).

4.3 Effect of azimsulfuron on crops

Yadav *et al.* (2008a) noticed a yield of 6242 kg/ha with application of 30 g/ha azimsulfuron along with 2 g/ha metsulfuron at 25 DAT. Weight of grains/panicle was higher with post emergence application of azimsulfuron @ 25 and 30 g/ha (Walia *et al.*, 2008). Singh *et al.* (2009) reported that azimsulfuron @ 30 g/ha + metsulfuron @ 2 g/ha produced higher grain (5.54 t/ha) and straw yield (8.5 t/ha). They also observed some yellowing of rice leaf when azimsulfuron was applied but plants recovered in 15-20 days. Sakthivel *et al.* (2009) noted slight yellowing of rice at initial stage, with higher dose of azimsulfuron 50 DF which disappeared by 10 days after application.

Walia *et al.* (2009) reported that pre emergence application of pendimethalin @ 0.75 kg/ha with post emergence application of azimsulfuron @ 25 g/ha produced 42% higher yield. Singh *et al.* (2010) obtained the highest grain and straw yield with application of azimsulfuron @ 25 g/ha alone or tank mixed with Almix. Application of azimsulfuron 50 DF @ 30 g/ha resulted in increased yield components and yield of rice (Sakthivel and Balasubramanian, 2010).

5. Penoxsulam

5.1 Effect of penoxsulam on weeds

Yadav *et al.* (2008b) observed that post emergence application of penoxsulam was better than its pre emergence application. Penoxsulam application @ 25 g/ha as pre emergence (3 DAT) and @ 20-22.5 g/ha (10-12 DAT) is needed for satisfactory weed control in transplanted rice to get better yield without any residual toxicity. Weed density under penoxsulam @ 22.5 g/ha (10-12 DAT) was at par with weed free treatment and there was 85-88% control of grass weeds and 75-83% control of broad leaved weeds and sedges. According to Singh *et al.* (2009) penoxsulam was effective against *Echinochloa colona, E.crusgalli, Cyperus difformis, Alternanthera sessilis.* It was also observed that penoxsulam @ 20 g/ha applied as pre emergence (3 DAT) was more effective in reducing weed density as well as crop-weed competition compared to early post emergence (10 DAT). Penoxsulam @ 40 g/ha was a broad spectrum herbicide that controlled *Echinochloa* sp. and major broad leaved weeds and sedges.

Pal and Banerjee (2007) observed that penoxsulam @ 22.5 g/ha (8-12 DAT) provided control of broad leaved weeds like *Monochoria vaginalis, Ludwigia parviflora, Cyperus difformis* with high WCE. Singh *et al.* (2007) reported that penoxsulam application @ 25 g/ha (1-5 DAT) provided significant reduction in density of grasses and broad leaved weeds and was superior to butachlor @ 1.5 kg/ha (1-3 DAT). They obtained a WCE of 86.7% due to its greater phytotoxic effect on all types of weeds, particularly on sedges. Application of penoxsulam @ 22.5 g/ha (10 DAT) significantly controlled *Eriocaulon* sp. (Mishra *et al.,* 2007). According to Damalas *et al.* (2008), the most effective herbicide for control of *Echinochloa* was penoxsulam, and the order of herbicide efficacy averaged over *Echinochloa* populations was penoxsulam > clefoxydim > bispyribac sodium > cyhalofop > propanil. They also reported that morphological variation was consistently associated with differences in sensitivity of *Echinochloa* sp. to various herbicides used for weed control in rice.

5.2 Effect of penoxsulam on *Leptochloa chinensis*

Penoxsulam+benthiocarb followed by bentazon/MCPA showed better broad spectrum weed control especially on *Echinochloa crusgalli* and *Leptochloa chinensis* (Juraimi *et al.*, 2010). Sole application of penoxsulam at 15 g a.i. /ha only lowered 21% of Leptochloa population whereas sequential application of penoxsulam with any pre emergence herbicide like pendimethalin could control red sprangletop up to 80% (Khaliq *et al.*, 2011).

5.3 Effect of penoxsulam on crops

Pal and Banerjee (2007) obtained high grain yield (3.53 t/ha) comparable with hand weeding (3.74 t/ha), lowest weed index of 5.6% resulting in 87% increase in yield over unweeded control, with application of penoxsulam @ 22.5 g/ha (8-12 DAT). Singh *et al.* (2007) reported that application of penoxsulam @

25 g/ha (1-5 DAT) and @ 22.5 g/ha (8-12 DAT) gave higher number of panicles/m^2 and thereby higher yield. According to Mishra *et al.* (2007) early post emergent application (10 DAT) was better than pre emergent (5 DAT) application of penoxsulam in increasing the grain yield. The highest grain yield of 4.8 t/ha was obtained with application of penoxsulam @ 22.5 g and 25 g/ha with higher number of panicles/unit area due to less weed competition (Singh *et al.*, 2009).

6. Bispyribac sodium

6.1 Effect of bispyribac sodium on weeds

Yadav *et al.* (2007) reported that bispyribac sodium was very effective against mixed flora of weeds in wet seeded rice. Walia *et al.* (2008) found that *Echinochloa colona* and *Cyperus* sp. were very effectively controlled by post emergent application of bispyribac sodium. According to Yadav *et al.* (2009) bispyribac sodium @ 25 g/ha applied at 15-25 DAT was a suitable herbicide for complex weed flora in transplanted rice. Pre emergent application of pendimethalin (0.75 kg/ha) followed by bispyribac sodium (20 g/ha) recorded less weed dry weight (0.17 t/ha) (Walia *et al.*, 2008). Application of bispyribac sodium @ 30-60 g/ha (15 DAT) and @ 25-60 g/ha (25 DAT) effectively controlled grass weeds and density of sedges and was at par with weed free check (Yadav *et al.*, 2009). According to Kiran *et al.* (2010) sequential application of oxadiargyl @ 75 g/ha and bispyribac sodium @ 30 g/ha recorded lowest weed density and dry weight with maximum WCE (88%) which was on par with hand weeding twice (89%). These results were confirmed by Kiran and Subramanyan (2010).

Veeraputhiran and Balasubramanian (2010) recorded significant reduction in total weed dry weight and highest WCE of 98% with application of bispyribac sodium. Bispyribac sodium applied @ 15 or 25 DAT was found effective against grass weeds but control of broad leaved weeds and sedges was more when applied at 15 DAT (Yadav *et al.*, 2010). Mehta *et al.* (2010) got maximum weed control efficiency of bispyribac sodium when applied @ 30 g/ha particularly against *Echinochloa crusgalli.* Application of bispyribac sodium @ 25 g/ha at 20 DAT registered lower weed density and higher WCE (ARWR, 2011).

6.2 Effect of bispyribac sodium on *Leptochloa chinensis*

Acetolactate synthase (ALS) was the main target of herbicides and bispyribac-sodium prevented biosynthesis of branched-chain amino acids by inhibition of ALS but its activity was high in red sprangletop and it was recommended that 10% bispyribac-sodium SC applied with thiobencarb or fenoxaprop-p-ethyl, especially controlled *L. chinensis* (Wang *et al.,* 2000). Bispyribac sodium 10% SC was the least effective against *L. chinensis*; the other herbicides showed moderate control efficacy (40-60%) (Abeysekhara and Wickrama, 2004). Application techniques of bispyribac sodium for controlling weeds were studied in direct seeded rice fields in Zhejiang, China, in 1998-99 and the results showed bispyribac sodium was very effective on Gramineae [Poaceae], sedge and broadleaved weeds including *Echinochloa crusgalli*, *Paspalum distichum*, and *Alternanthera philoxeroides*, but not on *Leptochloa chinensis*. The highest Leptochloa was observed with bispyribac sodium applied alone (Abeysekhara and Wickrama, 2004).

6.3 Effect of bispyribac sodium on crops

Walia *et al*. (2008) obtained more tillers/m^2 (310), grain weight/panicle (21.7 g), and a yield of 5016 kg/ha with pre emergence application of pendimethalin followed by bispyribac sodium @ 20 g/ha. Walia *et al*. (2008) recorded highest grain yield of 4684 kg/ha with post emergent application of bispyribac sodium (30 g/ha) at 30 DAS. Yadav *et al*. (2009) reported 41% increase in grain yield with application of bispyribac sodium @ 25 g/ha at 15-25 DAT. Bispyribac sodium 10% SC @ 30 g/ha gave higher grain yield (Rao *et al.,* 2009). Walia *et al*. (2009) recorded pre emergence application of pendimethalin @ 0.75 kg/ha with post emergence application of bispyribac sodium @ 25 g / ha (25 - 30

DAS) produced 61.7% higher yield. Application of bispyribac sodium @ 25 g/ha on 20 DAT registered higher grain yield (ARWR, 2011).

7. Pyrazosulfuron ethyl

7.1 Effect of pyrazosulfuron ethyl on weeds

Pyrazosulfuron ethyl @ 30 g a.i./ha was shown best in reducing weed population and weed dry matter specially sedges with an efficiency of 90.86% and recorded higher grain yield (Hwang *et al.*, 1996). Cross resistance to this herbicide by *Lindernia sp*. were reported by Uchino *et al.*, 2000. Pyrazosulfuron + molinate at 1000 g/ha recorded significant control of weeds with weed control efficiency of 58-73.5% (Sanjoy, 2005). Lowest weed population and weed density was also reported by Gowda *et al.* (2009) by using this herbicide which was on par with handweeding. Pyrazosulfuron resistant *Cyperus sp*. was also reported (Galon *et al.*, 2008).

7.2 Effect of pyrazosulfuron ethyl on *Leptochloa chinensis*

Pyrazosulfuron at the rate of 10 and 15 g a.i./ha controlled *Leptochloa chinensis* (Moorthy and Saha, 2002). Pyrazosulfuron ethyl at 20 and 25 g/ha significantly reduced the density and total dry weight of *C. iria, S. zeylanica, Echinochloa colona* and *Leptochloa chinensis* when applied 3-10 DAT (Chopra and Chopra, 2005). Pyrazosulfuron ethyl granules were found to be as effective as cyhalofop butyl in controlling Leptochloa (Sumiyoshi and Suzuki, 2006).

7.3 Effect of pyrazosulfuron ethyl on crop

Pyrazosulfuron ethyl reduced rice growth, especially root growth **(**Usui and Iibin, 1996**).** The plants would recover completely from phytotxic symptoms within 25 days after application (Hwang *et al.*, 1996). Application enhanced the grain yield and almost all the yield attributes of rice and significantly lowered total weed dry weight (Saini, 2003b). Gowda *et al.* (2009) also observed that higher nutrient uptake was seen in rice, i.e. 97, 52, 79 kg/ha of N, P, K respectively. Minimum weed seed counts were recorded with the application of pyrazosulfuron ethyl in soil depths 0-5 and 5-10 cm and high yield was gained **(**Soni *et al.,* 2012).

8. Pretilachlor

8.1 Effect of pretilachlor on weeds

It provided excellent control of *Echinochloa sp., L. chinensis, Cyperus spp., Fimbristylis miliacea, Scirpus spp., Monochoria vaginalis and Ludwigia sp.* (Allard and Zoschke, 1990). The major weeds like *C. rotundus, E. colona, L. chinensis, Marsilea quadrifolia, Eclipta alba and Sphenoclea zeylanica* were controlled effectively by the application of 2,4-D and Pretilachlor at the rate of 300 g/ha each, which recorded least weed densities 6-4 weeds/m^2 (Kathirvelan and Vaiyapuri, 2003).

8.2 Effect of pretilachlor on *Leptochloa chinensis*

Pretilachlor (with or without safener), though it provided good control of aerobic grassy weeds like Leptochloa, was lowest in terms of grain yield due to poor control of major weeds (Yadav *et al*., 2011)

8.3 Effect of pretilachlor on crop

Pretilachlor 50 EC @ 0.75 kg a.i.ha^{-1} at 3-5 days after transplanting registered significantly lowest weed density, and weed dry weight at 60 DAT over other herbicidal treatments, leading to highest weed control efficiency of 79.73 and 90.23% and lowest weed index values of 3.95 and 14.52 and highest herbicidal efficiency indices 1.82 and 2.21, higher number of panicles m^{-2} (381 and 278), panicle weight (3.70 and 3.80 g), grain (4.96 and 4.23 t ha^{-1}) and straw yield (6.61 and 5.81 t ha^{-1}) in 2007 and 2008, respectively (Prakash *et al*., 1995). The application of pretilachlor at 1.5 and 3.0 kg/ha resulted in severe crop phytotoxicity (Suganthi *et al.*, 2005).

9. Butachlor

9.1 Effect of butachlor on weeds

Butachlor at 1000 g/ha gave excellent control (81-96%) of weed species *E. crus-galli*, *E. colona* and *Leptochloa chinensis* (Gopinath and Pandey, 2006).

9.1 Effect of butachlor *on Leptochloa chinensis*

Tank mix of propanil 36 EC + butachlor 60 EC was effective in controlling *Leptochloa* and sedges (Garcia *et al.*, 2004). Submergence periods of two and three weeks after the application of butachlor at 1.5 kg/ha gave 46.7 and 48.1% increase in grain yield of rice over one week submergence as reported by Aulakh and Mehra (2006).

9.1 Effect of butachlor on crop

The germinating rice seeds were most sensitive to butachlor, with phytotoxicity decreasing with time before or after germination and sowing (Zhang and Tang, 1991). Rice, barnyard grass (*Echinochloa crusgalli*) and Monochoria (*Monochoria vaginalis*) seedlings contained relatively high levels of non-protein thiols, while glutathione S-transferase (GST) activity was found to be highest in rice and lowest in Monochoria. It was suggested that the difference in GST activity among these species might be related to their sensitivity to butachlor (Wenfu, 1995). It was found that butachlor application reduced the quality of tillering. The higher the application dosage was, the less the tillering number. Moreover, the tillering number of rice before the seedling recovery was less than that after the seedling recovery (Han *et al.*, 2007).

10. Oxyfluorfen

10.1 Effect of oxyfluorfen on weeds

Oxyfluorfen at 0.1 to 0.3 kg/ha gave appreciable control of *Chenopodium album, Trianthema monogyna* and *Phalaris minor* but poor control of *Cyperus rotundus* (Chauhan and Ramakrishnan, 1981). Oxyfluorfen at 0.1 kg/ha gave 90-100% control of *Echinochloa crusgalli, Lindernia sp., Rotala indica, Monochoria vaginalis, Leptochloa chinensis,* and *Cyperus iria* (Jiang, 1989).

10.2 Effect of oxyfluorfen on *Leptochloa chinensis*

Oxyfluorfen at 0.1 kg/ha gave 90-100% control of red sprangletop (Jiang, 1989). *Leptochloa chinensis* and *Echinochloa crusgalli* was effectively controlled by 0.25 kg/ha oxyfluorfen + hand weeding at 40 days after transplanting (Prakash *et al.,* 1995).

10.3 Effect of oxyfluorfen on crops

Kumar and Gautam (1986) reported that Oxyfluorfen at 0.15 kg/ha was efficient in direct seeded puddled rice. Oxyfluorfen at 100 g/ha caused lower plant height than 150 g/ha and application of this herbicide at 150-200 g/ha would effectively control grasses, sedges and broad leaved weeds (Abraham *et al.,* 2010).

2.12 Effect of weed management practices on economics of rice production

Saini *et al.* (2001) reported B:C ratio of 2.01 with application of cyhalofop butyl @ 90 g/ha at 15 DAT. Hand weeding, due to higher labour cost reduced the net return and there by B:C ratio (Mukherjee and Singh, 2005). Application of butachlor (938 g/ha) at 3 DAT recorded the maximum benefit cost ratio indicating high economic returns (Patra *et al.,* 2006). Hussain *et al.* (2008) obtained the highest net benefit by application of bispyribac sodium followed by fenoxaprop p-ethyl. The highest gross and net return was recorded by pre emergence application of pretilachlor @ 0.45 kg/ha (3 DAS) followed by azimsulfuron 50 DF @ 35 g/ha (20 DAS) followed by one hand weeding (45 DAS) (Murali *et al.,* 2010). Post emergence application of bispyribac sodium @ 25 g/ha registered the highest net profit of Rs. 42,452/ha and B:C ratio of 2.89 (Veeraputhiran and Balasubramanian, 2010). Application of post emergence herbicide bispyribac sodium @ 25g/ha at 20 DAT registered higher net profit of Rs. 42,452/ha and B:C ratio of 2.89 (ARWR, 2011). According to Kiran *et al.* (2010) sequential application of oxadiargyl (75g/ha) and bispyribac sodium (30g/ha) recorded highest grain yield of 6758 kg/ha, highest net returns (Rs. 58,407) and B:C ratio (3.06). Similar results were reported by Kiran and Subramanyam (2010). The highest net returns (Rs. 21019/ha) and benefit:cost ratio (2.15) were recorded with pyrazosulfuron ethyl @ 30 g a.i./ha (Thimmegowda *et al.*, 2010). The net returns and benefit:cost ratio were quite lower (Rs. 10,940/ha and 1.77) with two hand weedings at 20 and 45 DAS (Gowda *et al.*, 2009). Pretilachlor at 1.25 kg 3 DAT resulted in grain yields and gross returns equal to those of the weed-free control. Pretilachlor at 0.75 and anilofos 6.4 kg a.i./ha were also effective and proved more economic than hand weeding (Joy *et al.*, 1992).

2.13 Herbicide toxicity to rice

There was no phytotoxicity for **fenoxaprop p-ethyl** from 45-90 g/ha at different stages of application (Singh *et al.,* 2003). Katiyar and Kolhe (2006) observed no phytotoxic effect on rice due to various rates of fenoxaprop p-ethyl+ ethoxysulfuron. Mallick *et al.* (2009) recorded no phytotoxicity on rice with application of fenoxaprop p-ethyl 6.9% EC up to the dose of 60.38 g/ha. But slight stunting in growth was observed at double dose (7 days after application) which recovered within two weeks time. **Cyhalofop butyl** applied to rice plants did not show any visual phytotoxicity symptoms (Abeysekhara, 1999). There is no phytotoxicity for **Azimsulfuron** on rice at 15 and 30 days after spray and there was no residual toxicity on succeeding crop of wheat (Yadav *et al.,* 2008a). Singh *et al.* (2010) reported phytotoxicity symptoms like yellowing and stunted growth of rice cultivar 'Rajshree' at higher doses of Azimsulfuron (27.5 and 30 g/ha). Yadav *et al.* (2010) also observed there was no phytotoxicity for Azimsulfuron on rice and no residual toxicity on succeeding wheat. Yadav *et al.* (2008b) observed there was no phytotoxicity for **Penoxsulam** on rice and succeeding wheat. Yadav *et al.* (2009) noted that there was no phytotoxicity for bispyribac sodium on rice and no residual toxicity for succeeding crop of wheat. Abeysekhara and Wickrama (2004) and Rao *et al.* (2009) also reported that **bispyribac sodium** was a safe herbicide to rice and to rice fallow crops. **Metamifop** showed a robust safety to rice (Kim *et al.,* 2003) and application of metamifop 10 EC at 100 g a.i. / ha at 2-3 leaf stage was found to be better in controlling grass weeds in direct seeded rice (Nithya *et al.*, 2011). Phytotoxic symptoms like reducing rice growth, especially root growth, was greater at a low temperature (20/11°C) than at a high temperature (30/22°C) for **Pyrazosulfuron-ethyl (**Usui and Iibin, 1996**). Pretilachlor** + safener 500 g/ha applied at 7 DAT caused phytotoxicity symptoms in rice with leaves having pale yellow and burning tip appearance (Rao *et al.*, 2007). Even though some phytotoxicity effect like yellowing and drying of leaves was noticed in rice seedlings immediately after application of **Oxyfluorfen**, the seedlings recovered within 15 days after application (Abraham *et al.*, 2010).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The field trial on "Herbicidal management of Chinese sprangletop [*Leptochloa chinensis*(L.) Nees.] in direct seeded rice" was conducted from November 2012 to March 2013 in a farmer's field at Alappad-Pullu in the *Kole* lands of Thrissur district. The details of materials used and methods adopted are presented in this chapter.

3.1 General details

Location

Alappad-Pullu *Kole* is located in Chazhur panchayat of Thrissur district at $75^0 58'$ latitude and $76^0 11'$ longitude and 1m below MSL.

Climate and weather conditions

The experimental site experiences typical humid tropical climate. The mean monthly average of important meteorological parameters observed during the experimental period are presented in Appendix I.

Soil characters

Kole lands are clay loam in texture and acidic in reaction and come under the soil order Inceptisol. The physico-chemical characteristics of the soil of the experimental field are presented in Table 1.

Table 1. Physico-chemical characteristics of soil

Particular	Value	Method used
A) Particle size analysis		
Sand (%)	20.5	International Pipette Method (Piper, 1966)
Silt (%)	22.3	
Clay (%)	57.2	
B) Chemical composition		
Organic C (%)	1.4	Walkley and Black method (Jackson, 1958)
Available N (kg/ha)	890	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P_2O_5 (kg/ha)	24	Bray-1 Extractant Ascorbic acid reductant method (Watnabe and Olsen, 1965)
Available K_2O (kg/ha)	281	Neutral Normal Ammonium Acetate extractant flame photometry (Jackson, 1958)
pH	5.2	1:2.5 soil water ratio Beckman glass electrode (Jackson,1958)

Variety

The rice variety Jyothi (PTB 39), a red kernelled, short duration variety of 115-120 days duration was used for the research programme. The variety is suitable for direct seeding and transplanting during both first (Virippu) and second (Mundakan) crop seasons. It is tolerant to BPH and rice blast disease, moderately susceptible to sheath blight and capable of yielding over 8 Mg/ha under favourable situations and gives moderate yields even under adverse conditions.

Season of cultivation

The crop period was from 15th November 2012 to 10th March 2013 (Mundakan season). The crop duration was 115 days.

Cropping history of the experimental site

Pullu *Kole* is a single cropped land, where rice is grown from September-October to February-March. The land remains submerged during the rest of the year.

3.2 Experimental details

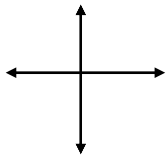
Treatments

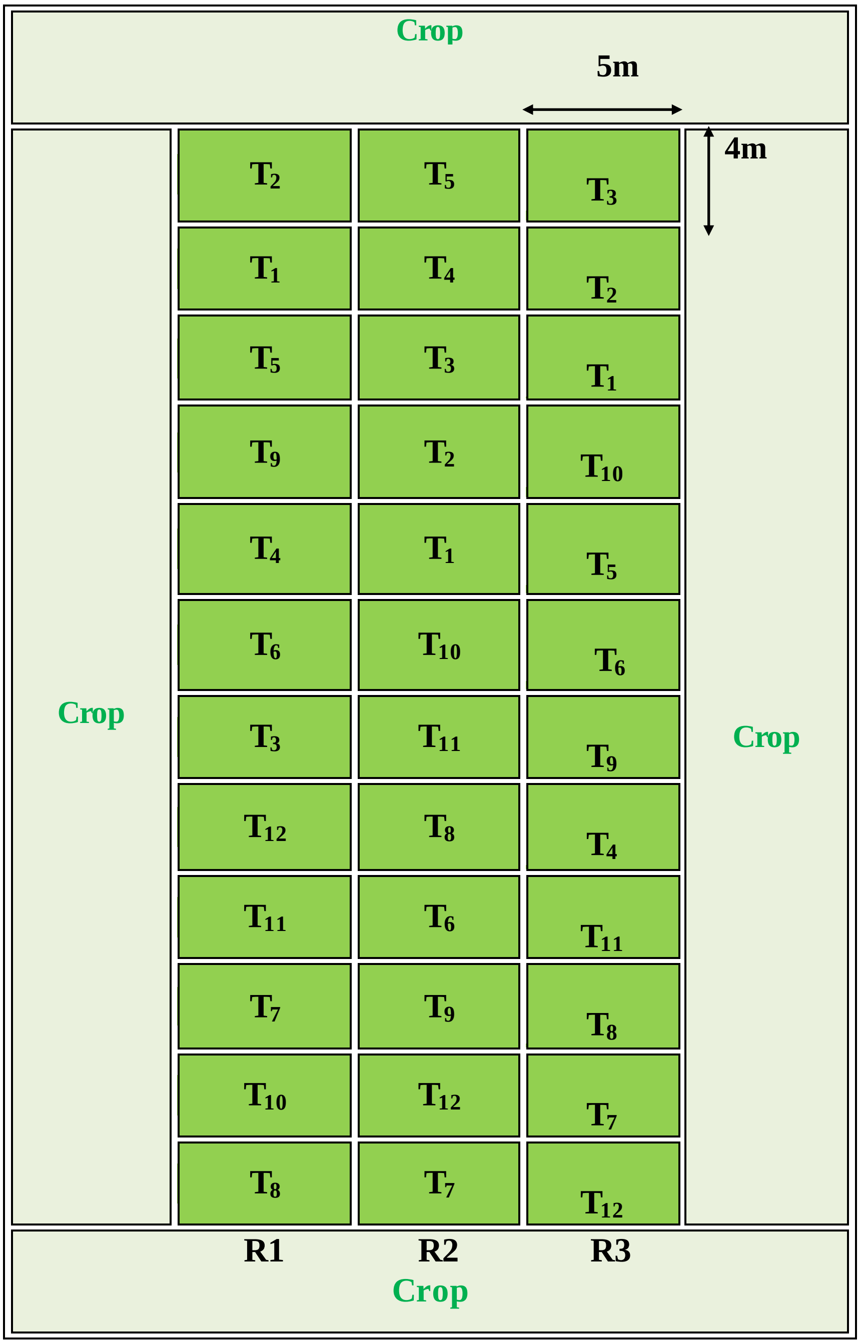
The experiment was conducted in a farmer's field during the second crop (Mundakan) season of 2012-2013. The experiment was laid out in randomized block design (RBD) with 12 treatments replicated thrice (Fig.1). The treatments including the details of the herbicides applied are presented in Table 2 :-

Table 2. Treatments

No.	Herbicide	Trade Name	Formulation	Dosage (g *a.i.*/ha)	Time of Application (DAS#)
1	Cyhalofop-butyl	Clincher	10 EC**	80	20
2	Metamifop	Metamifop^	10 EC	100	20
3	Fenoxaprop-p-ethyl	Rice star	6.7% w/w	60	20
4	Azimsulfuron	Segment	50 DF****	35	20
5	Penoxsulam	Granite*	21.7% w/w	25	20
6	Bispyribac sodium	Nominee gold	10 SC***	30	20
7	Pyrazosulfuron-ethyl	Saathi	10 WP****	30	8
8	Butachlor	Machete	50 EC	1250	6
9	Pretilachlor	Rifit	50EC	500	6
10	Oxyfluorfen	OxyGold	23.5 EC	150	3
11	Hand weeding	-	-	-	20 & 40
12	Unweeded control	-	-	-	

^ Trade name not given *Trade name proposed #Days after sowing
**EC- Emulsifiable concentrate ***DF- Dry flowable ****WP- Wettable powder
***SC- Soluble concentrate





Treatments

T1	Cyhalofop-butyl
T2	Metamifop
T3	Fenoxaprop-p-ethyl
T4	Azimsulfuron
T5	Penoxsulam
T6	Bispyribac sodium
T7	Pyrazosulfuron-ethyl
T8	Butachlor
T9	Pretilachlor
T10	Oxyfluorfen
T11	Hand weeding
T12	Unweeded control

Fig.1 Layout of the experiment

3.3 Field operations

The details of various field operations from land preparation to threshing are given below.

Land preparation, sowing and fertilizer application

The area was ploughed, puddled and levelled. The plot size adopted was $20m^2$. Plots of size 5m x 4m were formed by taking bunds of 25 cm width and height. After levelling, fertilizers to supply NPK @ 90:35:45 kg/ha were applied. Urea, factamphos and muriate of potash were used for supplying the nutrients. Full dose of P was applied basally. N and K were applied in three equal splits at land preparation, maximum tillering and panicle initiation stages. After basal fertilizer application, the seeds were broadcasted at the rate of 250 g/plot (125 kg/ha). In hand weeded treatment, hand weeding was done at 20 and 40 DAS. Herbicides were sprayed at 3, 6, 8 and 20 DAS (as per treatments) using knapsack sprayer of 13L capacity at the recommended doses (Table 2).

Visual phytotoxicity rating of crop and weeds were done on seventh and fifteenth day after spraying. Symptoms of injury were graded from 0 – 5 using the toxicity scale as per Thomas and Abraham (2008) given below:-

Table 3. Scale for rating herbicide phytotoxicity in crop and weeds

Rating	Effect on weeds	Effect on crop
0	None	No injury
1	Slight control	Slight injury
2	Moderate control	Moderate injury
3	Good control	Severe injury
4	Very good control	Very severe injury
5	Complete control	Complete destruction

Plant protection

Timely plant protection measures were taken up as per package of practices (POP) of KAU (KAU, 2011). As a preventive measure, egg cards (Trichocards) were placed against stem borer as well as leaf folder at fortnightly intervals from one week after sowing to booting stage.

Harvesting

The crop was harvested on 10th of March 2013 after the grains were fully matured. Threshing was done manually and the produce was cleaned, dried and weighed and the yield was expressed in kg/ha.

3.4 Observations recorded

3.4.1 Biometric observations on crop

Plant height

Height of ten plants was measured in cm from ground level to the tip of the longest leaf at 30 DAS, 60 DAS and at harvest.

Tiller production

The number of tillers in one square metre area of each experimental plot at 30 DAS and 60 DAS was counted and recorded using quadrat of 0.5m x 0.5m (0.25m^2).

Number of panicles

The number of panicles in one square metre area of each plot was counted and recorded using a 0.25m^2 quadrat.

Number of filled grains per panicle

Grains collected from ten randomly selected panicles were separated into filled grains and chaff. The average number of filled grains for a single panicle was then worked out.

Thousand grain weight

One thousand grains were counted from the produce of each plot and their weight was recorded in grams.

Grain and straw yield

The crop was harvested from each plot area, threshed, winnowed and weight of grain and straw was recorded separately and expressed in kg/ha.

3.4.2 Biometric observations on weeds

Weed identification and weed count

Species wise weed count was taken using a 50cm x 50cm (0.25 m^2) quadrat. The quadrat was placed randomly in each plot and all the weed species inside were counted at 30 DAS, 60 DAS and at harvest, and were recorded in number/m^2.

Dry weight of weeds

The weeds uprooted from the quadrat were cleaned, air dried and then oven dried at 80 ± 5^0C and dry weight were recorded in g/m^2 at 30 DAS, 60 DAS and at harvest. Similarly, dry weight of weeds at these stages was also recorded in the hand weeded plot.

Weed Control Efficiency (WCE)

WCE was calculated as per formula of Gupta (2010)

$$\text{WCE} = \frac{{}^{*}\text{WDMP in control plot} - \text{WDMP in treatment plot}}{\text{WDMP in control plot}} \times 100$$

*Weed Dry Matter Production

Weed index (WI)

WI was calculated as per the formula of Gupta (2010)

$$\text{WI} = \frac{\text{Yield in hand weeded plot} - \text{Yield in treatment plot}}{\text{Yield in hand weeded plot}} \times 100$$

3.4.3 Chemical analysis

Soil analysis

Primary nutrients *viz.*, available N, available P and available K were estimated in soil samples collected by the standard sampling procedure. Soil samples thus collected after land preparation were also used for analyzing the status of organic carbon and pH using the standard procedures listed in Table 1.

Plant analysis

The N, P and K contents of weeds (at 30 DAS, 60 DAS and harvest) and rice (at harvest) were analyzed by standard procedures (Jackson, 1958). Total N content of plant samples was determined by Microkjeldhal digestion and distillation method. Plant sample was digested in a diacid mixture and the P content was determined by Vanadomolydophosphoric yellow colorimetric method. Intensity of color was read using Spectronic 20 spectrophotometer at 470 nm. Potassium content in the diacid digest was estimated by making up the volume and directly reading in a flame photometer. The nutrient removal by weeds (at 30 DAS, 60 DAS and harvest) and rice (at harvest) was calculated as the product of nutrient content and the plant dry weight and expressed in kg/ha.

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3.5 Economics of weed control

The prevailing labour charge in the locality, costs of inputs and extra treatment costs were taken together and gross expenditure was computed and expressed in rupees per hectare. The value of paddy and straw at current local market prices were taken as total receipts for computing gross return and expressed in rupees per hectare. Benefit/ cost ratio was worked out by dividing the gross return with total expenditure per hectare.

3.6 Data analysis

The data were subjected to analysis of variance using the statistical package 'MSTAT-C' (Freed, 1986). Data on weed count and biomass, which showed wide variation, were subjected to square root transformation $\sqrt{(x+0.5)}$ to make the analysis of variance valid (Gomez and Gomez, 1984). Multiple comparisons among treatment means, where the F test was significant (at 5% level) were done with Duncan's Multiple Range Test (DMRT).

RESULTS

Leptochloa chinensis infestation in the field before layout of experiment (previous season)

Experiment field after layout

Plate 1. Experiment field

4. RESULTS

The experiment on "Herbicidal management of Chinese sprangletop [*Leptochloa chinensis*(L.) Nees.] in direct seeded rice" was conducted during the second crop season (*Mundakan*) of 2011-'12 in the *Kole* lands of Thrissur district. The data from the observations after statistical analysis are presented in this chapter.

1. Studies on weeds

Observations on the weed spectrum, species wise weed count, weed dry weight, and nutrient uptake by weeds, with special reference to *Leptochloa chinensis* are given below.

1.1. Weed spectrum

The experiment was laid out in a site where high infestation of *Leptochloa chinensis* was reported every year. Species wise count of weeds was taken at 30 DAS, 60 DAS and at harvest. The details of the weeds present in the field are given in Table 4.

Table 4. Important weeds in the field

Sl.no.	Common name	Scientific name	Family
1	Chinese or red sprangletop	*Leptochloa chinensis*	Poaceae
2	Barnyard grass	*Echinochloa crusgalli*	Poaceae
3	Hippo grass	*Echinochloa stagnina*	Poaceae
4	Rice flat sedge	*Cyperus iria*	Cyperaceae
5	Small flower umbrella plant	*Cyperus difformis*	Cyperaceae
6	Hoorah grass	*Fimbristylis miliacea*	Cyperaceae
7	Water primrose	*Ludwigia parviflora*	Onagraceae
8	Hard slitwort	*Lindernia crustacea*	Scrophulariaceae
9	Sessile joy weed	*Alternanthera sessilis*	Amaranthaceae

The grass weeds comprised of *Leptochloa chinensis, Echinochloa crusgalli*, and *Echinochloa stagnina*. The main broad leaved weeds were *Ludwigia parviflora* and *Lindernia crustacea*. The sedges present were *Fimbristylis miliacea, Cyperus iria* and *Cyperus difformis*. Effect of treatments on the count of individual species at 30 DAS, 60 DAS and harvest stages are given in Table 5 and effect on weeds grouped as grasses, sedges and broad leaf weeds are presented in Table 6.

Leptochloa chinensis
Chinese or red sprangletop

Echinochloa crusgalli
Barnyard grass

Echinochloa stagnina
Hippo grass

Cyperus iria
Rice flat sedge

Cyperus difformis
Small flower umberella plant

Plate 2. Important weeds in the field

Fimbristylis miliacea
Hoorah grass

Ludwigia parviflora
Water primrose

Lindernia crustacea
Hard slitwort

Alternanthera sessilis
Sessile joy weed

Plate 3. Important weeds in the field

Table 5. Count of important weeds at 30 DAS, 60 DAS and harvest (no./m^2)

Treatment	*Leptochloa chinensis*			*Echinochloa* spp.			*Cyperus* spp.			*Fimbristylis miliacea*			*Ludwigia parviflora*			*Lindernia crustacea*		
	***30**	***60**	***H**	**30**	**60**	**H**	**30**	**60**	**H**	**30**	**60**	**H**	**30**	**60**	**H**	**30**	**60**	**H**
Butachlor	*0.71^{g} (0)	5.06^{g} (25.7)	4.16^{f} (17.3)	3.69^{b} (13.7)	6.53^{b} (42.7)	5.97^{b} (35.7)	2.73^{g} (7.0)	2.26^{gh} (4.67)	1.56^{g} (2.0)	2.94^{f} (8.7)	2.16^{f} (4.7)	2.36^{d} (5.7)	2.15^{d} (4.7)	2.8^{c} (7.7)	2.30^{f} (5.3)	0.71^{d} (0)	0.71^{e} (0)	0.71^{h} (0)
Oxyfluorfen	0.71^{g} (0)	5.77^{f} (33.3)	4.0^{f} (16.0)	2.3^{d} (5.33)	5.06^{d} (25.7)	3.99^{d} (16.0)	2.54^{g} (6.0)	3.39^{e} (11.0)	2.40^{f} (5.3)	2.3^{c} (5.0)	2.89^{de} (8.3)	0.71^{e} (0)	0.71^{e} (0)	2.9^{c} (8.3)	3.0^{e} (9.0)	0.71^{d} (0)	0.71^{e} (0)	2.1^{f} (4.3)
Pretilachlor	0.71^{g} (0)	4.65^{h} (21.7)	2.89^{g} (8.3)	0.71^{f} (0)	2.76^{g} (7.7)	2.94^{f} (8.7)	0.71^{h} (0)	2.86^{f} (7.7)	1.46^{g} (1.7)	0.71^{i} (0)	2.15^{f} (4.7)	0.71^{e} (0)	2.1^{d} (4.3)	3.9^{b} (15.0)	3.31^{d} (11.0)	2.6^{a} (6.7)	4.72^{c} (22.3)	4.65^{b} (21.7)
Pyrazosulfuron ethyl	0.71^{g} (0)	6.11^{e} (37.3)	5.06^{e} (25.7)	0.71^{f} (0)	6.70^{c} (44.7)	5.77^{b} (33.3)	4.2^{e} (17.3)	2.40^{gh} (5.3)	1.34^{g} (1.3)	1.63^{h} (2.7)	3.0^{d} (9.0)	0.71^{e} (0)	1.82^{d} (3.3)	2.15^{d} (4.7)	2.23^{f} (5.0)	0.71^{d} (0)	0.71^{e} (0)	0.71^{h} (0)
Azimsulfuron	3.65^{c} (13.3)	7.98^{d} (63.7)	6.11^{d} (37.3)	2.64^{cd} (7.0)	7.21^{b} (52.0)	4.51^{c} (20.3)	3.53^{f} (12.0)	2.47^{g} (5.7)	0.71^{h} (0)	4.54^{d} (20.7)	2.71^{e} (7.3)	0.71^{e} (0)	4.03^{b} (16.3)	2.2^{d} (5.0)	2.16^{f} (4.7)	0.71^{d} (0)	0.71^{e} (0)	3.7^{e} (13.7)
Bispyribac sodium	4.69^{a} (22.0)	10.33^{a} (106)	7.53^{a} (56.7)	2.94^{c} (8.7)	2.77^{g} (7.7)	2.82^{f} (8.0)	4.70^{d} (21.7)	3.80^{d} (14.0)	2.86^{d} (7.7)	3.82^{e} (14.7)	0.71^{h} (0)	0.71^{e} (0)	0.71^{e} (0)	0.71^{e} (0)	0.71^{g} (0)	0.71^{d} (0)	2.16^{d} (4.7)	2.16^{f} (4.7)
Cyhalofop butyl	2.36^{e} (5.7)	2.82^{i} (8.0)	2.16^{h} (4.7)	0.71^{f} (0)	3.90^{f} (15.0)	2.77^{f} (7.7)	6.04^{c} (36.0)	5.82^{c} (33.3)	5.31^{c} (27.7)	5.32^{c} (28.3)	5.92^{b} (35.0)	4.0^{b} (16.0)	4.10^{b} (16.7)	3.8^{b} (14.3)	3.64^{c} (13.3)	1.82^{b} (3.3)	4.54^{c} (20.7)	3.95^{d} (15.7)
Fenoxaprop-p-ethyl	0.71^{g} (0)	0.71^{j} (0)	1.38^{i} (2)	0.71^{f} (0)	0.71^{h} (0)	1.38^{h} (2.0)	6.44^{b} (41.0)	7.34^{ab} (53.3)	6.54^{b} (42.3)	5.20^{c} (27.0)	1.91^{g} (3.7)	3.60^{c} (13.0)	3.82^{b} (14.7)	5.51^{a} (30.3)	3.7^{c} (13.7)	1.71^{b} (3.0)	5.10^{b} (25.7)	4.4^{c} (19.3)
Metamifop	2.99^{d} (9.0)	8.48^{c} (72.0)	6.73^{b} (45.3)	2.77^{c} (7.7)	4.20^{e} (17.7)	3.37^{e} (11.3)	6.67^{b} (44.0)	7.24^{b} (52.0)	41.0^{d} (16.3)	6.11^{b} (37.3)	4.8^{c} (22.7)	4.16^{b} (17.3)	3.8^{b} (14.3)	5.2^{a} (27.0)	4.2^{b} (17.7)	0.71^{d} (0)	0.71^{e} (0)	0.71^{h} (0)
Penoxsulam	3.69^{c} (13.7)	7.98^{d} (63.7)	6.43^{c} (45.3)	3.69^{ab} (13.7)	2.83^{g} (8.0)	2.10^{g} (4.3)	3.34^{f} (10.7)	2.11^{h} (4.0)	0.71^{h} (0)	2.15^{g} (4.7)	2.94^{d} (8.7)	0.71^{e} (0)	3.0^{c} (9.0)	3.8^{b} (14.3)	3.5^{cd} (12.0)	0.71^{d} (0)	0.71^{e} (0)	0.71^{h} (0)
Handweeded control	1.22^{f} (1)	0.71^{j} (0)	0.71 (0)	1.22^{e} (1)	0.71^{h} (0)	0.71^{i} (0)	0.71^{h} (0)	1.22^{i} (1)	0.71^{h} (0)	2.77^{f} (7.7)	0.71^{h} (0)	0.71^{e} (0)	1.4^{e} (2.0)	0.71^{e} (0)	0.71^{g} (0)	1.10^{c} (1.3)	0.71^{e} (0)	1.82^{g} (3.3)
Unweeded control	4.20^{b} (17.7)	9.75^{b} (95.0)	6.81^{b} (46.3)	4.04^{a} (16.3)	8.20^{a} (67.0)	6.78^{a} (46.0)	7.15^{a} (50.7)	7.63^{a} (57.7)	7.17a (51.0)	8.02^{a} (64.3)	8.6^{a} (74.0)	6.81^{a} (46.3)	4.7^{a} (22.0)	5.44^{a} (30.0)	5.9^{a} (34.3)	3.0^{a} (9.3)	6.05^{a} (36.7)	6.03^{a} (36.3)
SEm+_	0.87	0.98	1.14	0.89	1.04	0.71	1.32	1.22	0.98	0.91	0.79	1.21	1.14	1.06	0.99	0.98	0.90	0.79
CD (P=0.05)	1.69	1.79	2.06	1.69	1.91	1.29	2.42	2.21	1.82	1.66	1.45	2.57	2.08	1.94	1.81	2.08	1.92	1.50

*__30__-30DAS **60**-60 DAS **H**- harvest

*$\sqrt{x+0.5}$ transformed values, Original values in parentheses. In a column, figures followed by same alphabet do not differ significantly at 5% level in DMRT.

Table 6. Effect of herbicidal treatments on total weed count (no./m^2)

Treatment	30 DAS			60 DAS			Harvest		
	G	S	B	G	S	B	G	S	B
Butachlor	*3.80[f] (14)	4.06[h] (16)	3.81[e] (14)	9.62[e] (92)	3.14[h] (9.4)	2.92[f] (8)	7.31[e] (53)	2.92[e] (8)	2.12[i] (4)
Oxyfluorfen	2.55[g] (6)	3.39[i] (11)	5.34[b] (28)	7.52[h] (56)	4.53[e] (20)	2.92[f] (8)	5.70[g] (32)	2.34[f] (5)	4.06[f] (16)
Pretilachlor	0.71[i] (0)	0.71[k] (0)	4.95[c] (24)	5.34[i] (28)	3.54[g] (12)	6.67[c] (44)	4.18[h] (17)	1.60[g] (2)	6.04[d] (36)
Pyrazosulfuron ethyl	0.71[i] (0)	4.52[g] (20)	2.92[f] (8)	10.22[c] (104)	3.81[f] (14)	2.12[g] (4)	7.78[c] (60)	1.22[gh] (1)	2.92[h] (8)
Azimsulfuron	4.53[d] (20)	5.70[f] (32)	4.53[d] (20)	10.79[b] (116)	3.54[g] (12)	2.92[f] (8)	7.78[c] (60)	0.71[i] (0)	4.53[e] (20)
Bispyribac sodium	5.61[b] (31)	6.07[e] (36)	0.71[h] (0)	10.12[d] (102)	4.53[e] (20)	2.12[g] (4)	8.09[b] (65)	2.92[e] (8)	2.12[i] (4)
Cyhalofop butyl	2.55[g] (6)	8.03[d] (64)	5.34[b] (28)	4.95[j] (24)	8.28[c] (68)	5.96[d] (36)	3.54[i] (12)	6.67[c] (44)	8.03[b] (64)
Fenoxaprop-p-ethyl	0.71[i] (0)	8.27[c] (68)	4.95[c] (24)	0.71[k] (0)	7.52[d] (56)	7.97[b] (63)	2.12[h] (4)	7.45[b] (55)	6.67[c] (44)
Metamifop	4.06[e] (16)	9.08[b] (82)	5.34[b] (28)	9.41[f] (88)	9.41[b] (88)	6.04[d] (36)	7.52[d] (56)	5.79[d] (33)	4.53[e] (20)
Penoxsulam	5.28[c] (24)	3.99[h] (15)	3.81[e] (14)	8.51[g] (72)	3.54[g] (12)	3.80[e] (14)	7.11[f] (50)	0.71[i] (0)	3.54[g] (12)
Handweeded control	1.58[h] (2)	2.74[j] (7)	1.87[g] (3)	0.71[k] (0)	1.22[i] (1)	0.71[h] (0)	0.71[j] (0)	0.71[i] (0)	1.87[j] (3)
Unweeded control	6.04[a] (36)	10.7[a] (115)	6.36[a] (40)	12.66[a] (161)	11.44[a] (130)	8.75[a] (76)	9.61[a] (92)	9.87[a] (97)	9.19[a] (84)
SEm+_	2.67	3.03	2.29	2.39	1.73	1.71	1.94	1.77	1.83
CD (P=0.05)	5.67	6.33	4.78	5.02	3.63	3.57	4.07	3.87	3.82

G – Grasses, S – Sedges, B – Broad leaf weeds

*√x+0.5 transformed values, Original values in parentheses. In a column, figures followed by same alphabet do not differ significantly at 5% level in DMRT.

The weed count was highest at 60 DAS. The counts at 30 DAS as well as at harvest were less than the count at 60 DAS. Therefore, the analysis and interpretation on the distribution of weed flora was made based on the count at 60 DAS.

The relative density of major weeds in the field is presented in Table 7. Out of the total 10 species of weeds present in the field, grass weeds accounted for 45% of the population, sedges for 36%, and broad leaf weeds for 19%. Among grasses, *Echinochloa* spp. which included *Echinochloa crusgalli* and *Echinochloa stagnina,* comprised 17%, and *Leptochloa chinensis* accounted for 28%. Among dicots only *Ludwigia parviflora* was the serious weed (12%), and among sedges, *Fimbristylis miliacea* (14%), *Cyperus iria* and *Cyperus difformis* (21%) were the important ones.

Table 7. Relative density (%) of major weeds in the field

Major weed	30 DAS	60 DAS	Harvest	Relative density
Leptochloa chinensis	10.9	35.0	30.6	28
Echinochloa spp.	9.7	19.0	19.4	17
Cyperus spp.	32.7	16.5	15.5	21
Fimbristylis miliacea	29.1	11.8	9.9	14
Ludwigia parviflora	14.2	10.4	12.6	12
Lindernia crustacea	3.1	7.3	12.0	8

1.2 Weed density

Effect of the treatments on the population of different weeds is presented in Table 5. Fenoxaprop-p-ethyl was the most effective herbicide against *Leptochloa chinensis* and resulted in 100% control of the weed at 30 and 60 DAS. This was followed by cyhalofop butyl and pretilachlor. The pre emergence herbicides pretilachlor, butachlor and oxyfluorfen were effective in controlling the germination and establishment of *Leptochloa chinensis* in the early stages of crop, as indicated by the data at 30 DAS. There was subsequent germination resulting in higher count of *Leptochloa* at 60 DAS and harvest stages of crop. Metamifop and azimsulfuron were not very effective against this weed.

Against *Echinochloa* spp., treatments fenoxaprop-p-ethyl and bispyribac sodium gave good control at all three stages. Other post emergence herbicides *viz*., cyhalofop butyl, metamifop and penoxsulam resulted in reasonably good control of *Echinochloa* compared to unweeded control. Among pre emergence herbicide treatments, pretilachlor gave best result followed by oxyfluorfen and butachlor. Pyrazosulfuron ethyl could not give good control at later stages of crop, even though it resulted in 100% control at 30 DAS.

All the pre emergence herbicide caused reduction in the population of *Fimbristylis miliacea*. Among the post emergence herbicides, bispyribac sodium was the best treatment followed by penoxsulam and azimsulfuron whereas cyhalofop butyl, fenoxaprop-p-ethyl as well as metamifop were not effective against *Fimbristylis miliacea*. Almost similar result was observed in *Cyperus* spp. also.

Against *Ludwigia parviflora*,, the most important broad leaf weed observed in the field, all the pre emergence herbicides showed very good control. Among these, best was pyrazosulfuron ethyl, followed by oxyfluorfen and butachlor. Among post emergence herbicide treatments, bispyribac sodium was the best, resulting in 100% control of this weed at all three stages of observation. However, the herbicides cyhalofop butyl and fenoxaprop-p-ethyl were not at all effective against this weed and resulted in a *Ludwigia parviflora* population almost similar to unweeded control. Penoxsulam, metamifop and azimsulfuron reduced the population of this weed considerably when compared to unweeded control.

In all plots including unweeded control, the population of *Lindernia crustacea* at 30 DAS was very low and population increased with the advancement of the stage of the crop. In the plots treated with pyrazosulfuron ethyl, butachlor, penoxsulam, metamifop, bispyribac sodium, and azimsulfuron, the population of *Lindernia* was nil or very low throughout the crop period, whereas in cyhalofop butyl, fenoxaprop-p-ethyl and pretilachlor treated plots, *Lindernia* population was higher.

1.3. Weed dry weight

The data on dry weight of weeds at 30 DAS, 60 DAS and at harvest are presented in Table 8. The treatments unweeded control and handweeded control recorded the highest and lowest weed dry weight respectively at all three observations.

At 30 DAS, weed dry weight was generally lower compared to 60 DAS and harvest. The treatments metamifop, oxyfluorfen, penoxsulam, and bispyribac sodium resulted in weed dry weight of more than a hundred kilograms per hectare whereas the other treatments *viz*, cyhalofop, pretilachlor, azimsulfuron, butachlor, fenoxaprop-p-ethyl, and pyrazosulfuron showed lesser weed dry weight.

At 60 DAS, the weed dry weight was higher than at 30 DAS. The weed dry weight increased to the tune of six times in unweeded control, which recorded a weed dry weight accumulation of 1074.6 kg/ha, and the lowest weed dry weight of 362.35 kg/ha was noticed in fenoxaprop-p-ethyl treated plots followed by the treatment cyhalofop butyl with 436.53 kg/ha. The treatments butachlor, metamifop, oxyfluorfen, bispyribac sodium, azimsulfuron, pyrazosulfuron ethyl, pretilachlor and penoxsulam had weed dry weight ranging between 448.5 and 993.37 kg/ha.

At the time of harvest also, weed dry weight was the lowest at 16.22 kg/ha in hand weeded plots followed by 340.12 kg/ha in the treatment fenoxaprop-p-ethyl. The treatments cyhalofop butyl and pyrazosulfuron ethyl were the next best treatments with a lower weed dry weight of 406 and 478 kg/ha respectively. There was an increase in weed dry weight (1104.0 kg/ha) in unweeded plot. However, in most of the herbicide treatments, weed dry weight was less at harvest stage than at 60 DAS.

Table 8. Effect of herbicidal treatments on weed dry weight (kg/ha) at 30 DAS, 60 DAS and at harvest

Treatment	30 DAS	60 DAS	At harvest
Butachlor-50 EC	60.10^{i}	993.37^{b}	764.50^{d}
Oxyfluorfen-23.5 EC	136.99^{c}	809.60^{d}	704.00^{e}
Pretilachlor-50 EC	88.00^{g}	578.76^{h}	527.13^{h}
Pyrazosulfuron-ethyl-10 WP	25.33^{k}	595.46^{g}	478.00^{i}
Azimsulfuron-50 DF	78.40^{h}	637.80^{f}	792.50^{c}
Bispyribac sodium-10 SC	110.00^{e}	652.86^{e}	614.00^{g}
Cyhalofop-butyl-10 EC	94.26^{f}	436.53^{j}	406.00^{j}
Fenoxaprop-p-ethyl-6.9 EC	29.30^{j}	362.35^{k}	340.12^{k}
Metamifop-10 EC	144.00^{b}	903.37^{c}	880.70^{b}
Penoxsulam-24 SC	115.80^{d}	448.50^{i}	685.40^{f}
Handweeded control	20.17^{l}	4.80^{l}	16.22^{l}
Unweeded control	169.50^{a}	1074.60^{a}	1104.00^{a}
SEm+_	1.14	2.73	1.7
CD (P=0.05)	2.37	5.87	3.72

In a column, means followed by common letters do not differ significantly at 5% level by DMRT.

1.4. Nutrient removal by weeds

At 30 DAS, highest N removal of 4.93 kg/ha was observed in unweeded control (Table 9). The treatments pyrazosulfuron ethyl, fenoxaprop-p-ethyl, butachlor and azimsulfuron registered lower values of removal ranging between 0.477 and 1.65 kg/ha. In handweeded control, N removal of 0.277 kg/ha was seen. By 60 DAS, N removal increased fivefold to 29 kg/ha in unweeded control and a lowest removal of 7.59 kg/ha was recorded in the plot treated with fenoxaprop-p-ethyl. N removal by weeds was 0.120 kg/ha in handweeded control as weed dry weight was lowest in this treatment. At harvest, highest removal of 24.58 kg/ha was observed in unweeded control, which was lower compared to the removal at 60 DAS. At harvest stage, handweeded treatment recorded the least N removal with 0.187 kg/ha. Among the herbicide treatments, lowest removal of 5.587 kg/ha was noticed in fenoxaprop-p-ethyl followed by the treatments pyrazosulfuron ethyl and cyhalofop butyl with 7.59 and 7.74 kg/ha respectively.

At 30 DAS, higher P removal by weeds (Table 10) was noticed in unweeded control with 0.790 kg/ha followed by the treatment metamifop (0.620 kg/ha). By 60 DAS, the treatments metamifop and unweeded control registered an increased removal of 2.68 and 2.53 kg/ha respectively whereas there was very low removal of nutrients by weeds in handweeded plot (0.010 kg/ha), followed by lowest removal registered in the treatment fenoxaprop-p-ethyl (0.277 kg/ha). The removal increased from 2.53 kg/ha at 60 DAS to 3.0 kg/ha in unweeded control at harvest. The treatments penoxsulam as well as fenoxaprop-p-ethyl recorded lower P removal of 0.39 and 0.45 kg/ha respectively and the lowest P removal was observed in handweeded plot (0.008 kg/ha).

The trend was similar in the case of K removal (Table 11) at 30 DAS, with highest removal of 6.177 kg/ha in unweeded control which was statistically superior to others. The treatments metamifop and oxyfluorfen recorded next higher removals of 4.82 and 4.07 kg/ha. K removal at 60 DAS was highest in unweeded control (37.25 kg/ha) and the lowest removal was in the treatment handweeded control (0.158 kg/ha) followed by fenoxaprop-p-ethyl (13.68 kg/ha). At harvest stage the unweeded control had the highest removal of 35.29 kg/ha and lowest was in the treatment fenoxaprop-p-ethyl (9.37 kg/ha). The hand weeded plot at harvest registered the lowest K removal of 0.328 kg/ha only.

Table 9. Effect of herbicidal treatments on N removal (kg/ha) by weeds at 30 DAS, 60 DAS and at harvest

Treatment	N (kg/ha)		
	30 DAS	60 DAS	At harvest
Butachlor-50 EC	0.920[i]	14.180[d]	9.787[f]
Oxyfluorfen-23.5 EC	2.283[e]	12.820[e]	9.740[f]
Pretilachlor-50 EC	1.717[g]	10.727[f]	8.963[g]
Pyrazosulfuron-ethyl-10 WP	0.477[k]	10.900[f]	7.743[h]
Azimsulfuron-50 DF	1.650[h]	13.247[e]	14.847[c]
Bispyribac sodium-10 SC	2.983[c]	15.953[c]	11.770[e]
Cyhalofop-butyl-10 EC	1.993[f]	8.687[g]	7.593[h]
Fenoxaprop-p-ethyl-6.9 EC	0.557[j]	7.590[h]	5.587[i]
Metamifop-10 EC	3.533[b]	24.067[b]	18.930[b]
Penoxsulam-24 SC	2.430[d]	9.193[g]	12.817[d]
Handweeded control	0.277[l]	0.120[i]	0.187[j]
Unweeded control	4.933[a]	28.870[a]	24.583[a]
SEm+_	0.02	0.31	0.22
CD (P=0.05)	0.05	0.65	0.45

In a column, means followed by common letters do not differ significantly at 5% level by DMRT.

Table 10. Effect of herbicidal treatments on P removal (kg/ha) by weeds at 30 DAS, 60 DAS and at harvest

Treatment	P (kg/ha)		
	30 DAS	60 DAS	At harvest
Butachlor-50 EC	0.197[g]	1.637[d]	1.047[d]
Oxyfluorfen-23.5 EC	0.367[de]	0.833[g]	0.930[e]
Pretilachlor-50 EC	0.280[f]	1.107[f]	0.760[f]
Pyrazosulfuron-ethyl-10 WP	0.083[h]	2.033[c]	1.207[c]
Azimsulfuron-50 DF	0.253[f]	0.857[g]	1.040[d]
Bispyribac sodium-10 SC	0.417[cd]	1.053[f]	0.880[e]
Cyhalofop-butyl-10 EC	0.350[e]	1.223[e]	1.097[d]
Fenoxaprop-p-ethyl-6.9 EC	0.153[g]	0.507[h]	0.453[g]
Metamifop-10 EC	0.620[b]	2.683[a]	2.343[b]
Penoxsulam-24 SC	0.423[c]	0.277[i]	0.393[g]
Handweeded control	0.093[h]	0.010[j]	0.008[h]
Unweeded control	0.790[a]	2.530[b]	3.003[a]
SEm+_	0.02	0.04	0.03
CD (P=0.05)	0.05	0.09	0.07

In a column, means followed by common letters do not differ significantly at 5% level by DMRT.

Table 11. Effect of herbicidal treatments on K removal (kg/ha) by weeds at 30 DAS, 60 DAS and at harvest

Treatment	K (kg/ha)		
	30 DAS	60 DAS	At harvest
Butachlor-50 EC	1.467[g]	26.167[b]	18.043[d]
Oxyfluorfen-23.5 EC	4.070[c]	26.907[b]	18.633[d]
Pretilachlor-50 EC	2.317[f]	19.970[e]	14.513[g]
Pyrazosulfuron-ethyl-10 WP	0.700[hi]	21.753[d]	15.950[f]
Azimsulfuron-50 DF	2.640[e]	23.473[c]	27.107[c]
Bispyribac sodium-10 SC	3.163[d]	14.143[fg]	12.693[h]
Cyhalofop-butyl-10 EC	2.593[e]	14.873[f]	12.503[h]
Fenoxaprop-p-ethyl-6.9 EC	0.913[h]	13.683[g]	9.377[i]
Metamifop-10 EC	4.820[b]	37.617[a]	30.990[b]
Penoxsulam-24 SC	2.160[f]	14.413[fg]	17.410[e]
Handweeded control	0.547[i]	0.158[h]	0.328[j]
Unweeded control	6.177[a]	37.250[a]	35.290[a]
SEm+_	0.11	0.52	0.29
CD (P=0.05)	0.23	1.09	0.61

In a column, means followed by common letters do not differ significantly at 5% level by DMRT.

1.5 Dry weight of *Leptochloa chinensis*

The dry weight of *Leptochloa chinensis* (Table12) was seen increasing from 30 DAS to harvest in most of the treatments. At 30 DAS, the highest dry weight of Chinese sprangletop was registered in unweeded control treatment (58 kg/ha). The treatments pyrazosulfuron ethyl, fenoxaprop-p-ethyl, oxyfluorfen, pretilachlor and butachlor were free of *Leptochloa chinensis*, as was also the handweeded control.

At 60 DAS, 574.2 kg/ha was highest dry weight recorded in the treatment unweeded control followed by bispyribac sodium, with 417.6 kg/ha. *Leptochloa chinensis* was absent in fenoxaprop-p-ethyl and in handweeded treatments.

At harvest, the dry weight of *Leptochloa chinensis* increased to 614 kg/ha in unweeded control followed by bispyribac sodium sprayed plot (527.7 kg/ha). Among the herbicides used, lowest dry weight was in fenoxaprop-p-ethyl with 10.2 kg/ha followed by cyhalofop butyl (48 kg/ha). Handweeded control was devoid of *Leptochloa chinensis*.

Table 12. Effect of herbicidal treatments on dry matter production (kg/ha) of *Leptochloa chinensis* at 30 DAS, 60 DAS and at harvest

Treatment	30 DAS	60 DAS	At harvest
Butachlor-50 EC	0	139.20[h]	186.40[h]
Oxyfluorfen-23.5 EC	0	185.60[f]	192.22[g]
Pretilachlor-50 EC	0	116.10[i]	96.00[i]
Pyrazosulfuron-ethyl-10 WP	0	173.03[g]	288.00[f]
Azimsulfuron-50 DF	23.30[c]	368.20[d]	336.0[e]
Bispyribac sodium-10 SC	34.80[b]	417.60[b]	527.70[b]
Cyhalofop-butyl-10 EC	11.60[d]	23.30[j]	48.00[j]
Fenoxaprop-p-ethyl-6.9 EC	0	0	10.20[k]
Metamifop-10 EC	23.40[c]	200.80[e]	432.50[d]
Penoxsulam-24 SC	23.80[c]	371.40[c]	477.40[c]
Handweeded control	0	0	0
Unweeded control	58.00[a]	574.23[a]	614.00[a]
SEm+_	1.51	1.50	1.64
CD (P=0.05)	3.36	3.17	3.44

In a column, means followed by common letters do not differ significantly at 5% level by DMRT.

1.6 Nutrient removal by *Leptochloa chinensis*

The Tables 13, 14, 15 respectively show the N, P, and K nutrient removal by *Leptochloa chinensis*. The lower weed dry weight and therefore nutrient removal of *Leptochloa chinensis* was very low at 30 DAS compared to 60 DAS and at harvest. At 30 DAS, N removal was high for unweeded control treatment (1.340 kg/ha) followed by bispyribac sodium (0.717 kg/ha). The P removal (Table 14) was high (0.143 kg/ha) in unweeded control followed by the treatments bispyribac sodium, azimsulfuron, metamifop and penoxsulam, the figures ranging from 0.05 to 0.07 kg/ha. The K removal (Table15) was highest in unweeded control (0.163 kg/ha) followed by bispyribac sodium sprayed plot (0.06 kg/ha), azimsulfuron (0.06 kg/ha), metamifop (0.05 kg/ha), penoxsulam (0.047 kg/ha) and cyhalofop butyl (0.02 kg/ha).

At 60 DAS, highest N removal of 11.83 kg/ha was seen in unweeded control followed by bispyribac sodium treated plot (9.323 kg/ha). The lowest N removal was in the plots treated with fenoxaprop-p-ethyl followed by cyhalofop butyl (0.297 kg/ha), pretilachlor (1.527 kg/ha) and butachlor (1.767 kg/ha). P removal was highest in unweeded control (1.717 kg/ha). The K removal showed highest value in unweeded control (12.84 kg/ha).

At harvest, highest N removal was in unweeded control (11.53 kg/ha) followed by bispyribac sodium treated plot with 9.077 kg/ha and penoxsulam with 8.163 kg/ha. Among the herbicide treatment, lowest removal was in fenoxaprop-p-ethyl (0.103 kg/ha) followed by cyhalofop butyl treatment (0.517 kg/ha). The P removal was highest in the treatment bispyribac sodium (1.780 kg/ha) and lowest removal was recorded by fenoxaprop-p-ethyl with 0.021 kg/ha. K removal was highest in unweeded control (12.48 kg/ha) followed by bispyribac sodium treatment (6.577 kg/ha). Low removal of K was seen in the plot sprayed with fenoxaprop-p-ethyl (0.216 kg/ha).

Table 13. Effect of herbicidal treatments on N removal (kg/ha) by *Leptochloa chinensis* at 30 DAS, 60 DAS and at harvest

Treatment	N (kg/ha)		
	30 DAS	60 DAS	At harvest
Butachlor-50 EC	0	1.767[g]	1.923[g]
Oxyfluorfen-23.5 EC	0	3.507[e]	3.253[f]
Pretilachlor-50 EC	0	1.527[g]	1.033[h]
Pyrazosulfuron-ethyl-10 WP	0	3.217[ef]	3.267[f]
Azimsulfuron-50 DF	0.513[d]	6.247[d]	5.667[e]
Bispyribac sodium-10 SC	0.717[b]	9.323[b]	9.077[b]
Cyhalofop-butyl-10 EC	0.180[e]	0.297[h]	0.517[i]
Fenoxaprop-p-ethyl-6.9 EC	0	0	0.103[j]
Metamifop-10 EC	0.610[c]	2.563[f]	6.517[d]
Penoxsulam-24 SC	0.523[d]	7.093[c]	8.163[c]
Handweeded control	0	0	0
Unweeded control	1.340[a]	11.830[a]	11.153[a]
SEm+_	0.04	0.38	0.10
CD (P=0.05)	0.08	0.79	0.20

In a column, means followed by common letters do not differ significantly at 5% level by DMRT.

Table 14. Effect of herbicidal treatments on P removal (kg/ha) by *Leptochloa chinensis* at 30 DAS, 60 DAS and at harvest

Treatment	P (kg/ha)		
	30 DAS	60 DAS	At harvest
Butachlor-50 EC	0	0.387[g]	0.487[f]
Oxyfluorfen-23.5 EC	0	0.727[d]	0.673[e]
Pretilachlor-50 EC	0	0.323[h]	0.243[g]
Pyrazosulfuron-ethyl-10 WP	0	0.600[e]	0.703[e]
Azimsulfuron-50 DF	0.070[b]	0.877[c]	1.127[c]
Bispyribac sodium-10 SC	0.070[b]	1.550[b]	1.780[a]
Cyhalofop-butyl-10 EC	0.020[c]	0.057[i]	0.117[h]
Fenoxaprop-p-ethyl-6.9 EC	0	0	0.021[i]
Metamifop-10 EC	0.057[b]	0.500[f]	0.993[d]
Penoxsulam-24 SC	0.050[b]	0.757[d]	1.033[d]
Handweeded control	0	0	0
Unweeded control	0.143[a]	1.717[a]	1.693[b]
SEm+_	0.02	0.02	0.02
CD (P=0.05)	0.05	0.05	0.05

In a column, means followed by common letters do not differ significantly at 5% level by DMRT.

Table 15. Effect of herbicidal treatments on K removal (kg/ha) by *Leptochloa chinensis* at 30 DAS, 60 DAS and at harvest

Treatment	K (kg/ha)		
	30 DAS	60 DAS	At harvest
Butachlor-50 EC	0	2.287[h]	2.443[f]
Oxyfluorfen-23.5 EC	0	5.023[d]	4.623[d]
Pretilachlor-50 EC	0	2.870[g]	2.043[f]
Pyrazosulfuron-ethyl-10 WP	0	3.620[f]	5.950[c]
Azimsulfuron-50 DF	0.060[b]	5.783[c]	6.057[c]
Bispyribac sodium-10 SC	0.060[b]	7.280[b]	6.577[b]
Cyhalofop-butyl-10 EC	0.027[b]	0.443[i]	0.780[g]
Fenoxaprop-p-ethyl-6.9 EC	0	0	0.216[h]
Metamifop-10 EC	0.050[b]	5.113[d]	4.483[d]
Penoxsulam-24 SC	0.047[b]	4.123[e]	3.867[e]
Handweeded control	0	0	0
Unweeded control	0.163[a]	12.843[a]	12.483[a]
SEm+_	0.02	0.16	0.22
CD (P=0.05)	0.05	0.33	0.47

In a column, means followed by common letters do not differ significantly at 5% level by DMRT.

1.7 Weed control efficiency (WCE)

The Table 16 shows the effect of WCE of different treatments. At 30 DAS, handweeded control showed 88.11% WCE followed by pyrazosulfuron with 85.06%. The least WCE was with metamifop at 15.05%. At 60 DAS handweeded control showed 100% control of weeds followed by fenoxaprop-p-ethyl (60.7%), and the lowest values were in metamifop (7.56%) and butachlor (6.83%). At harvest, the highest WCE was in the handweeded plot with 97% followed by fenoxaprop-p-ethyl with 69.19%. The lowest WCE was recorded in metamifop with 11.17%.

Table 16. Weed control efficiency (WCE) of treatments with regard to weeds at 30DAS, 60DAS and at harvest

Treatment	WCE %		
	30 DAS	60 DAS	At harvest
Butachlor-50 EC	64.54^{d}	6.83^{k}	30.75^{i}
Oxyfluorfen-23.5 EC	19.20^{j}	24.66^{i}	36.23^{h}
Pretilachlor-50 EC	48.10^{f}	46.14^{e}	52.25^{e}
Pyrazosulfuron-ethyl-10 WP	85.06^{b}	44.59^{f}	56.70^{d}
Azimsulfuron-50 DF	53.76^{e}	40.65^{g}	28.21^{j}
Bispyribac sodium-10 SC	35.11^{h}	39.25^{h}	44.38^{f}
Cyhalofop-butyl-10 EC	44.41^{g}	59.38^{c}	63.23^{c}
Fenoxaprop-p-ethyl-6.9 EC	82.72^{c}	60.70^{b}	69.19^{b}
Metamifop-10 EC	15.05^{k}	7.56^{j}	11.17^{k}
Penoxsulam-24 SC	31.70^{i}	58.26^{d}	37.92^{g}
Handweeded control	88.11^{a}	100.00^{a}	97.00^{a}
Unweeded control	-	-	-
SEm+_	0.68	0.25	0.15
CD (P=0.05)	1.43	0.53	0.31

In a column, means followed by common letters do not differ significantly at 5% level by DMRT.

1.8 Weed control efficiency for *Leptochloa chinensis*

At 30 DAS, 60 DAS and harvest (Table17) the fenoxaprop-p-ethyl treatment was on par with handweeded control with 98 to 100% control of Chinese sprangletop. At 30 DAS, cyhalofop butyl showed 80% WCE followed by metamifop (60.1%) and azimsulfuron with 59.81%. The least WCE was with bispyribac sodium with 40.2%. At 60 DAS again handweeded control and fenoxaprop-p-ethyl showed 100% control of *Leptochloa chinensis* followed by cyhalofop butyl (96%), but the least efficiency was with bispyribac sodium (27.3%) followed by penoxsulam (35.37%). At harvest, the highest WCE was for handweeding (100%) followed by fenoxaprop-p-ethyl (98.33%) and cyhalofop butyl with 92.20%. The lowest WCE was recorded with bispyribac sodium with 14.05%.

Table 17. Weed control efficiency of treatments with regard to *Leptochloa chinensis* at 30DAS, 60DAS and at harvest

Treatment	WCE %		
	30 DAS	60 DAS	At harvest
Butachlor-50 EC	100	76.00[c]	69.64[d]
Oxyfluorfen-23.5 EC	100	67.70[e]	68.70[de]
Pretilachlor-50 EC	100	79.80[b]	84.40[c]
Pyrazosulfuron-ethyl-10 WP	100	69.90[d]	53.10[e]
Azimsulfuron-50 DF	59.81[b]	36.00[g]	45.30[f]
Bispyribac sodium-10 SC	40.20[d]	27.30[i]	14.05[i]
Cyhalofop-butyl-10 EC	80.00[a]	96.00[a]	92.20[b]
Fenoxaprop-p-ethyl-6.9 EC	100.00	100.00	98.33[a]
Metamifop-10 EC	60.10[b]	65.03[f]	29.60[g]
Penoxsulam-24 SC	59.00[c]	35.32[h]	22.25[h]
Handweeded control	100	100	100
Unweeded control	-	-	-
SEm+_	1.21	0.55	0.13
CD (P=0.05)	2.79	1.17	0.27

In a column, means followed by common letters do not differ significantly at 5% level by DMRT.

1.9 Weed index

Weed index (Table18) was highest in unweeded control (56%) followed by metamifop (46%). Lowest weed index was in fenoxaprop-p-ethyl (20%) followed by cyhalofop butyl (25%).

Table 18. Effect of herbicidal treatments on weed index

Treatment	WI %
Butachlor-50 EC	37[d]
Oxyfluorfen-23.5 EC	34[de]
Pretilachlor-50 EC	43[bc]
Pyrazosulfuron-ethyl-10 WP	29[ef]
Azimsulfuron-50 DF	35[d]
Bispyribac sodium-10 SC	38[cd]
Cyhalofop-butyl-10 EC	25[fg]
Fenoxaprop-p-ethyl-6.9 EC	20[g]
Metamifop-10 EC	46[b]
Penoxsulam-24 SC	33[de]
Handweeded control	-
Unweeded control	56[a]
SEm+_	0.02
CD (P=0.05)	0.05

In a column, means followed by common letters do not differ significantly at 5% level by DMRT.

2. Studies on crop growth and yield parameters

The results of the observations taken in rice are given below.

2.1 Plant height

Data regarding the effect of various treatments on height of rice plants at 30 DAS, 60 DAS and at harvest are given in Table 19. At 30 DAS, significantly tallest plants were recorded in unweeded control (35.59 cm). At 60 DAS there was no significant difference in height between the treatments butachlor, oxyfluorfen, pretilachlor, bispyribac sodium and handweeded control. The crop height at harvest was ranging from 90.5 cm for azimsulfuron, fenoxaprop-p-ethyl and metamifop to the lowest height in the treatment penoxsulam (83.62 cm).

Table 19. Effect of herbicidal treatments on plant height (cm)

Treatment	30 DAS	60 DAS	At harvest
Butachlor-50 EC	24.81^{d}	73.30^{a}	89.49^{ab}
Oxyfluorfen-23.5 EC	27.27^{c}	74.50^{a}	88.63^{ab}
Pretilachlor-50 EC	32.23^{b}	72.75^{ab}	86.51^{bcd}
Pyrazosulfuron-ethyl-10 WP	28.31^{c}	69.93^{bcd}	86.65^{bc}
Azimsulfuron-50 DF	31.49^{b}	67.53^{de}	90.50^{a}
Bispyribac sodium-10 SC	32.12^{b}	73.20^{a}	85.07^{cd}
Cyhalofop-butyl-10 EC	31.93^{b}	65.97^{e}	89.17^{ab}
Fenoxaprop-p-ethyl-6.9 EC	31.37^{b}	69.13^{cde}	90.47^{a}
Metamifop-10 EC	31.44^{b}	72.90^{ab}	90.49^{a}
Penoxsulam-24 SC	31.64^{b}	67.47^{de}	83.62^{d}
Handweeded control	32.33^{b}	72.29^{abc}	86.97^{bc}
Unweeded control	35.59^{a}	69.43^{cd}	85.20^{cd}
SEm+_	1.07	1.42	1.30
CD (P=0.05)	2.23	2.94	2.68

In a column, means followed by common letters do not differ significantly at 5% level by DMRT.

2.2 Number of tillers

The data pertaining to tiller count (Table 20) indicates that at 30 DAS, the highest number of tillers was in handweeded treatment which was significantly higher than all other treatments at all stages of observation, followed by fenoxaprop-p-ethyl and cyhalofop butyl. At 60 DAS highest tiller count was recorded in handweeded control followed by fenoxaprop-p-ethyl and lowest in unweeded control followed by the treatments pyrazosulfuron ethyl, metamifop and pretilachlor.

Table 20. Effect of herbicidal treatments on tiller count (no./m^2)

Treatment	30 DAS	60 DAS
Butachlor-50 EC	234.0^{e}	465.6^{ef}
Oxyfluorfen-23.5 EC	264.0^{d}	510.7^{de}
Pretilachlor-50 EC	233.6^{e}	398.5^{g}
Pyrazosulfuron-ethyl-10 WP	227.4^{e}	429.0^{fg}
Azimsulfuron-50 DF	264.0^{d}	483.2^{e}
Bispyribac sodium-10 SC	286.0^{bcd}	530.5^{bcd}
Cyhalofop-butyl-10 EC	300.6^{bc}	567.3^{bc}
Fenoxaprop-p-ethyl-6.9 EC	308.0^{b}	583.0^{b}
Metamifop-10 EC	182.7^{f}	398.5^{g}
Penoxsulam-24 SC	278.3^{cd}	516.2^{cde}
Handweeded control	333.0^{a}	592.0^{a}
Unweeded control	182.6^{f}	337.7^{h}
SEm+_	0.11	0.22
CD (P=0.05)	0.23	0.47

In a column, means followed by common letters do not differ significantly at 5% level by DMRT.

2.3. Yield attributes

2.3.1. Number of panicles

The effect of various treatments on yield attributes is given in Table 21. The highest number of panicles per square meter was recorded in hand weeded treatment (461.3/m^2) and lowest was noticed in unweeded control (272.0/m^2) and the values were significantly different from other treatments. The treatments fenoxaprop p-ethyl, cyhalofop butyl, pyrazosulfuron ethyl and bispyribac sodium were the best treatments with respect to panicles/m^2 and were statistically superior to other herbicide treatments.

Table 21. Effect of herbicidal treatments on yield attributes

Treatment	Panicles (No./m^2)	Grains/panicle (No.)	1000 grain weight (g)	Fertility (%)
Butachlor-50 EC	368.0^{bcd}	85.53^{de}	27.57^{b}	81.43^{ab}
Oxyfluorfen-23.5 EC	306.7^{de}	89.33^{cde}	27.00^{f}	76.53^{ef}
Pretilachlor-50 EC	324.0^{de}	92.15^{cde}	27.33^{d}	76.30^{ef}
Pyrazosulfuron-ethyl-10 WP	374.7^{bcd}	95.40^{cd}	27.27^{e}	80.45^{abc}
Azimsulfuron-50 DF	341.3^{cde}	99.20^{bc}	27.87^{a}	73.13^{g}
Bispyribac sodium-10 SC	372.0^{bcd}	108.50^{ab}	27.33^{d}	79.53^{bcd}
Cyhalofop-butyl-10 EC	409.3^{bc}	109.40^{ab}	27.67^{a}	82.40^{ab}
Fenoxaprop-p-ethyl-6.9 EC	441.37^{ab}	112.50^{a}	27.57^{b}	83.33^{a}
Metamifop-10 EC	341.0^{cde}	91.30^{cde}	26.87^{g}	73.80^{fg}
Penoxsulam-24 SC	340.0^{cde}	72.13^{f}	27.17^{f}	76.07^{ef}
Handweeded control	461.3^{a}	111.8^{a}	27.43^{c}	78.43^{cde}
Unweeded control	272.0^{e}	81.20^{ef}	27.33^{d}	77.43^{de}
SEm+_	0.15	4.84	0.44	1.33
CD (P=0.05)	0.31	10.04	0.92	2.76

In a column, means followed by common letters do not differ significantly at 5% level by DMRT.

2.3.2 Grains per panicle and test weight of rice

The number of grains per panicle ranged from 72.13 to 112.50. Highest number of grains/panicle of 112 was recorded in hand weeded control and fenoxaprop-p-ethyl treatments which were on par. The panicles in unweeded control plot registered 81.2 grains/panicle. The significant differences between treatments for 1000 grain weight (test weight) of grains were very less. The test weight was in the range of 26.87 to 27.87g and fertility percentage ranged from 73.13 in azimsulfuron to 83.33 in fenoxaprop-p-ethyl treatment.

2.3.3 Grain and straw yield

Grain and straw yields as influenced by the treatments are given in Table 22. The highest grain yield of 6.46 t/ha was recorded in hand weeded plot which was followed by fenoxaprop-p-ethyl (5.88 t/ha) and cyhalofop butyl (5.46 t/ha). The lowest yield of 4.07 t/ha was obtained in unweeded control. In the case of straw, the highest yield were obtained in hand weeded control (5.87 t/ha) followed by fenoxaprop-p-ethyl and cyhalofop butyl (5.74 t/ha) which were on par. The lowest straw yield was recorded in azimsulfuron with 4.92 t/ha.

Table 22. Effect of herbicidal treatments on grain and straw yield (t/ha)

Treatment	Grain yield	Straw yield	Harvest index
Butachlor-50 EC	4.74^{h}	5.19^{de}	0.47
Oxyfluorfen-23.5 EC	4.76^{g}	4.99^{e}	0.48
Pretilachlor-50 EC	4.53^{j}	5.20^{de}	0.46
Pyrazosulfuron-ethyl-10 WP	4.67^{i}	5.63^{bc}	0.45
Azimsulfuron-50 DF	4.83^{f}	4.92^{f}	0.48
Bispyribac sodium-10 SC	5.02^{d}	5.25^{d}	0.48
Cyhalofop-butyl-10 EC	5.46^{c}	5.74^{b}	0.49
Fenoxaprop-p-ethyl-6.9 EC	5.88^{b}	5.74^{b}	0.50
Metamifop-10 EC	4.48^{k}	5.37^{c}	0.45
Penoxsulam-24 SC	4.93^{e}	5.64^{bc}	0.45
Handweeded control	6.46^{a}	5.87^{a}	0.52
Unweeded control	4.07^{l}	5.37^{c}	0.42
SEm+_	0.13	0.34	-
CD (P=0.05)	0.26	0.70	-

In a column, means followed by common letters do not differ significantly at 5% level by DMRT.

3. Nutrient uptake by rice

The data on nutrient uptake by rice (Table 23) at harvest revealed that highest N, P and K uptake was in hand weeded treatment with 66.78 kg/ha, 10.34 kg/ha,14.23 kg/ha and 43.07 kg/ha, 8.37 kg/ha, 74.79 kg/ha N, P, K by grain and straw respectively. Fenoxaprop-p-ethyl followed by cyhalofop butyl treated plots recorded the second highest N, P, K uptake by both grain and straw. The treatments that showed lowest N, P, K values were metamifop, penoxsulam, and azimsulfuron, followed by unweeded control.

Table 23. Effect of herbicidal treatments on nutrients uptake (kg/ha) by grain and straw at harvest

Treatment	Grain (kg/ha)			Straw (kg/ha)		
	N	P	K	N	P	K
Butachlor-50 EC	33.62^{de}	6.48^{de}	8.79^{c}	26.47^{g}	5.76^{g}	46.52^{f}
Oxyfluorfen-23.5 EC	34.44^{d}	6.71^{d}	7.62^{de}	28.44^{f}	5.69^{g}	40.11^{h}
Pretilachlor-50 EC	28.97^{fg}	6.50^{de}	7.91^{cd}	28.60^{f}	5.92^{f}	39.15^{i}
Pyrazosulfuron-ethyl-10 WP	41.66^{cd}	8.26^{c}	11.86^{b}	30.13^{e}	6.51^{de}	41.85^{g}
Azimsulfuron-50 DF	25.58^{h}	6.08^{ef}	5.31^{fg}	24.44^{i}	5.42^{h}	33.46^{l}
Bispyribac sodium-10 SC	43.68^{c}	9.37^{b}	13.56^{ab}	34.65^{d}	6.79^{d}	54.25^{d}
Cyhalofop-butyl-10 EC	43.46^{c}	9.50^{b}	11.99^{b}	38.46^{b}	7.54^{b}	65.09^{c}
Fenoxaprop-p-ethyl-6.9 EC	47.65^{b}	9.88^{ab}	14.12^{a}	35.50^{c}	7.34^{c}	66.02^{b}
Metamifop-10 EC	22.11^{i}	5.84^{f}	5.83^{f}	26.31^{g}	5.98^{f}	38.66^{j}
Penoxsulam-24 SC	27.95^{gh}	6.61^{de}	7.64^{de}	24.90^{h}	6.24^{e}	47.75^{e}
Handweeded control	66.78^{a}	10.34^{a}	14.23^{a}	43.07^{a}	8.37^{a}	74.79^{a}
Unweeded control	31.14^{ef}	4.66^{g}	7.41^{e}	24.95^{h}	3.77^{i}	36.35^{k}
SEm+_	1.36	0.35	0.75	1.40	0.44	2.11
CD (P=0.05)	2.82	0.72	1.56	4.06	1.27	6.09

In a column, means followed by common letters do not differ significantly at 5% level by DMRT.

4. Phytotoxicity rating

Phytotoxicity scoring of both weeds as well as crop was done at seven and fifteen days after spraying (Table 24 and Table 25 respectively). Injury symptoms were graded from 0-5 using toxicity scale as per Abraham and Thomas (2007). Among various herbicides applied, butachlor, pretilachlor, oxyfluorfen and pyrazosulfuron ethyl showed phytotoxicity on rice at seven days after spraying. The rating given was '1' indicating the phytotoxicity on crop. Whitening of leaf tips and scorched appearance of leaves of crop as a whole were noted. However, the crop recovered within two weeks after spraying and no phytotoxic symptoms were seen on crop. Inhibited crop elongation and stunted growth were the symptoms seen in pyrazosulfuron ethyl on the crop.

As expected, all herbicides showed phytotoxic effect on weeds with scoring ranging from 2 to 4 indicating moderate control to very good control. Fenoxaprop-p-ethyl caused phytotoxic symptoms on weeds in the form of purple blotches on leaves. Leaf scorching and drying up of weeds were also observed. Of the various herbicides, fenoxaprop p-ethyl showed very good control of *Leptochloa chinensis*.

Table 24. Phytotoxicity rating at seven days after spraying herbicides

Treatment	Score on crop	Score on weeds
Butachlor-50 EC	1	4
Oxyfluorfen-23.5 EC	1	4
Pretilachlor-50 EC	1	3
Pyrazosulfuron-ethyl-10 WP	1	3
Azimsulfuron-50 DF	0	2
Bispyribac sodium-10 SC	0	4
Cyhalofop-butyl-10 EC	0	3
Fenoxaprop-p-ethyl-6.9 EC	0	3
Metamifop-10 EC	0	2
Penoxsulam-24 SC	0	3

Butachlor

Oxyfluorfen

Pretilachlor

Pyrazosulfuron ethyl

Plate 4. Phytotoxicity symptoms on rice

Table 25. Phytotoxicity rating at fifteen days after spraying herbicides

Treatment	Score on crop	Score on weeds
Butachlor-50 EC	1	3
Oxyfluorfen-23.5 EC	0	3
Pretilachlor-50 EC	0	2
Pyrazosulfuron-ethyl-10 WP	1	3
Azimsulfuron-50 DF	0	2
Bispyribac sodium-10 SC	0	3
Cyhalofop-butyl-10 EC	0	3
Fenoxaprop-p-ethyl-6.9 EC	0	3
Metamifop-10 EC	0	1
Penoxsulam-24 SC	0	2

5. Economics of cultivation

Table 26 shows the economics of weed control expressed in terms of rupees per hectare. Among different treatments, maximum B:C ratio of 2.1 was obtained in fenoxaprop-p-ethyl followed by handweeded control and cyhalofop butyl which were on par with a value of 1.9. Fenoxaprop-p-ethyl produced highest net profit of Rs.67046 /ha and the unweeded control had the least B:C ratio of 1.3 due to the reason of low profit (Rs.42071/ha) with respect to the total cost of cultivation (Rs.30519/ha). In terms of weed management, many herbicidal treatments were inferior to hand weeding twice, as the net return was lower especially for the treatments pretilachlor (Rs. 44979/ha), pyrazosulfuron ethyl (Rs. 46671/ha) and metamifop (Rs. 42798/ha).

Table 26. Economics of weed control (Rs./ha)

Treatment	Additional cost for WM*	Total income	Net returns	B:C ratio
Butachlor-50 EC	1625	80580	48436	1.6
Oxyfluorfen-23.5 EC	1275	80920	49126	1.6
Pretilachlor-50 EC	1512	77010	44979	1.5
Pyrazosulfuron-ethyl-10 WP	2200	79390	46671	1.5
Azimsulfuron-50 DF	3462	82110	48129	1.6
Bispyribac sodium-10 SC	3500	85340	51321	1.7
Cyhalofop-butyl-10 EC	3200	92820	59101	1.9
Fenoxaprop-p-ethyl-6.9 EC	2394	99960	67046	2.1
Metamifop-10 EC	2860	76160	42798	1.4
Penoxsulam-24 SC	2843	83810	50447	1.6
Handweeded control	20250	109820	59051	1.9
Unweeded control	-	72590	42071	1.3

Total cost of cultivation excluding *(WM) weed management is Rs.30,519 per ha.

DISCUSSION

5. DISCUSSION

A field experiment was conducted at Alappad- Pullu *Kole* lands of Thrissur to study herbicidal management of Chinese sprangletop [*Leptochloa chinensis*(L.) Nees.] in direct seeded rice. Herbicide use has become an indispensible practice in rice, considering the occurrence of the wide spectrum and large population of weeds, shortage and high cost of labour for manual weeding and the availability of cheap chemical herbicides for selective weed control. However, continuous use of herbicides and increasing adoption of the direct seeding system has led to a shift in the weed flora in rice ecosystems. *Leptochloa chinensis* is one such weed which has emerged as a problem weed in the *Kole* lands of Thrissur. Many new molecule herbicides reported to be effective against *Leptochloa chinensis* in direct seeded rice have been evaluated in the present experiment. The results obtained from the experiment, reported in the previous chapter, are discussed below with supporting literature.

5.1 Weed flora

A critical analysis of relative proportion of grasses, sedges and broad leaf weeds in the weed population in unweeded control (Fig. 2, 3 and 4) revealed that during the crop growth period, the population of grasses was higher at 60 DAS and at harvest out of which *Leptochloa* constituted about 50-60%. The higher proportion of grasses compared to sedges and broad leaved weeds in rice in *Kole* lands was also reported by Joy *et al.* (1993) and Sindhu (2008). Sedges like *Fimbristylis miliacea*, *Cyperus difformis* and *Cyperus iria* were present, among which the population of *Fimbristylis miliacea* was higher than that of *Cyperus* spp. The population of broad leaved weeds was very low, and in general, in the experimental site grasses dominated. John and Sadanandan (1989), Hussain *et al.* (2008) and Singh and Singh (2010) also reported the major weeds as *Echinochloa crusgalli*, *Leptochloa chinensis*, *Cyperus iria*, *Fimbristylis miliacea*, *Ludwigia parviflora*, *Lindernia crustacea* and *Monochoria vaginalis* in wet seeded rice. The rice plants completely covered the land area by about 45 days and

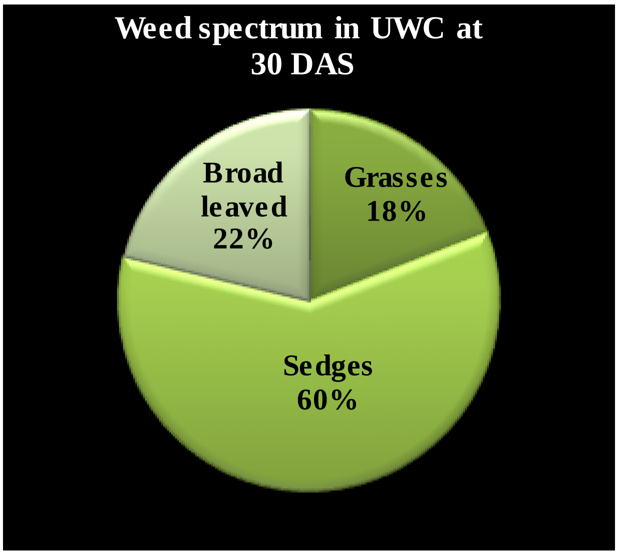

Fig.2

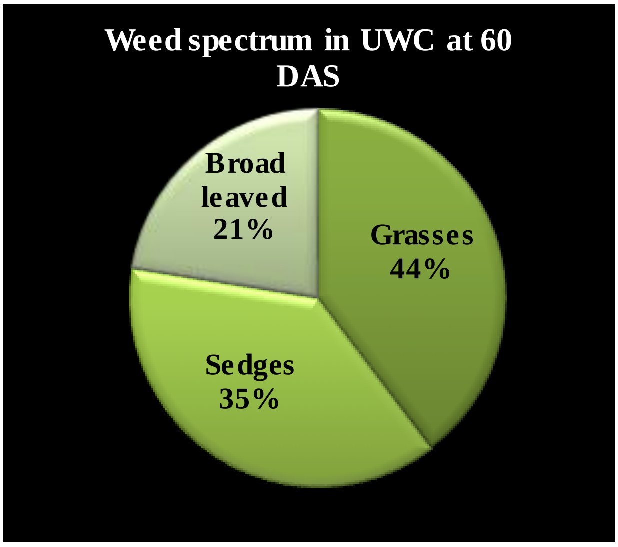

Fig.3

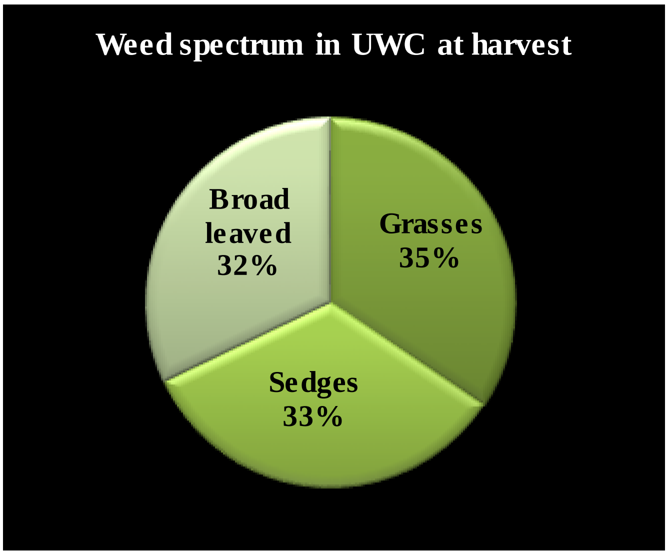

Fig.4

further weed growth was low. Only *Lindernia crustacea*, a minor weed, was present even in the hand weeded plot at harvest, most probably because it can survive under a low level of light intensity.

5.2 Effects of herbicides on population of weeds including *Leptochloa chinensis* at different stages

Observations taken at three stages of growth revealed that only a few species of grasses, sedges and broad leaf weeds were persistent in the *Kole* lands of Alappad-Pullu. All grasses, sedges and broad leaf weeds persisted till harvest, and dry weight (Table 8) was highest in the unweeded plot. Hand weeding, as expected, resulted in lowest weed count and weed dry weight.

At 30 DAS the population of *Leptochloa chinensis* and dry weight were low compared to that at 60 DAS and harvest in all treatments (Fig. 5, 6 and 7) on the basis of data on weed count (Table 5.), indicating subsequent germination of this weed probably due to well managed water level in the plots. Juraimi *et al*. (2010) reported that at all water regime treatments, seed population of *Leptochloa* was lowest. Subsequent emergence of *Leptochloa* could be related to delay in letting in water into the *Kole* fields. Fig. 5 also shows that the *Leptochloa* was absent in the treatments handweeded control, fenoxaprop-p-ethyl, pyrazosulfuron ethyl, oxyfluorfen, pretilachlor and butachlor which showed effectiveness at 30 DAS. The treatments metamifop and azimsulfuron were not effective in controlling *Leptochloa*. The effectiveness of the pre emergence herbicides pyrazosulfuron ethyl, oxyfluorfen, pretilachlor and butachlor on controlling red sprangletop is therefore questionable.

The effectiveness of fenoxaprop-p-ethy and cyhalofop butyl in controlling *Leptochloa* was maintained at 60 DAS, while bispyribac sodium, metamifop, azimsulfuron and penoxsulam failed to control the weed. Fenoxaprop-p-ethyl, however, controlled only grasses, and so high weed count was recorded in this treatment due to high infestation of broad leaf weeds and sedges. The effectiveness of fenoxaprop-p-

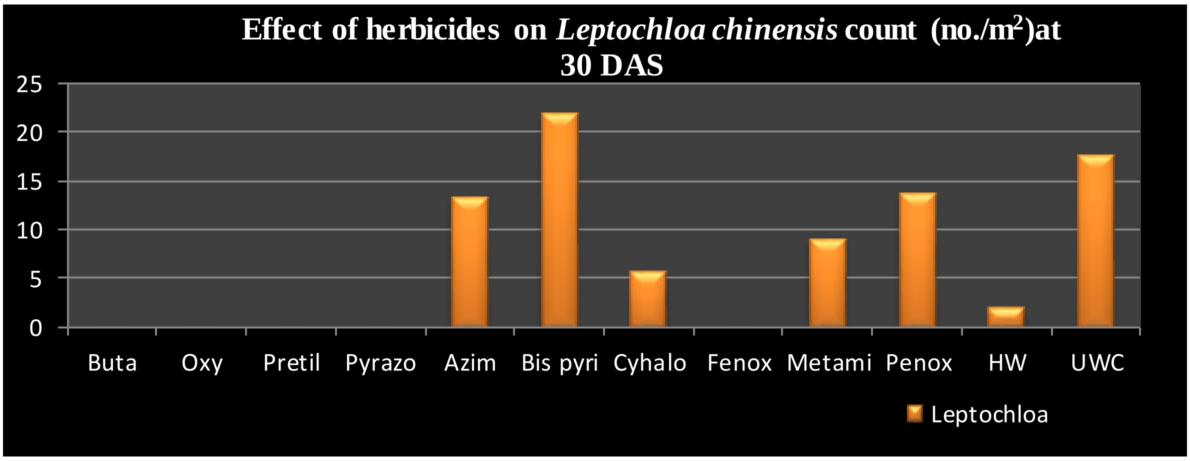

Fig.5

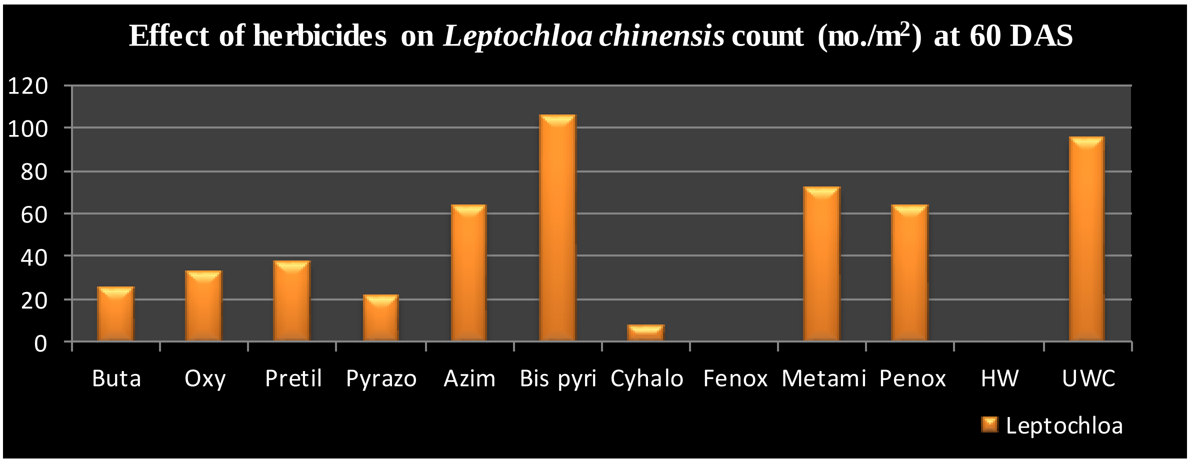

Fig.6

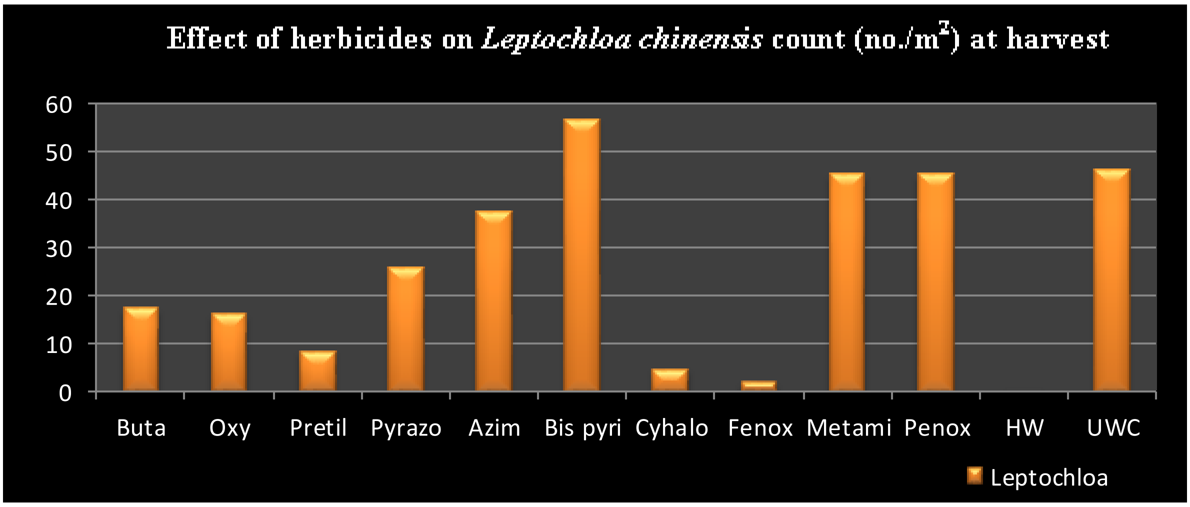

Fig.7

ethyl against only grasses and failure to control broad leaf weeds was reported by Khodayari *et al.* (1989). Similar was the case with cyhalofop butyl.

At harvest too, fenoxaprop-p-ethyl recorded its superiority in controlling *Leptochloa*, followed by cyhalofop butyl and pretilachlor. Allard and Zoschke (1990) reported that pretilachlor at 750 g/ha were effective against *Leptochloa* in wet sown condition. At harvest, it was seen that grass weeds were best controlled by hand weeding, followed by the treatments fenoxaprop-p-ethyl and cyhalofop butyl. Grasses, sedges and broad leaf weeds were highest in unweeded control. The herbicides penoxsulam, azimsulfuron, pretilachlor and pyrazosulfuron ethyl were effective in controlling sedges, while the treatments butachlor, pyrazosulfuron ethyl and bispyribac sodium which were on par with handweeded control in the control of broad leaf weeds.

Comparing the different herbicidal treatments (Fig. 8), fenoxaprop-p-ethyl was most effective in controlling weeds, including *Leptochloa*, at all stages of observations (Table 12) since *Leptochloa* was absent at 30 and 60 DAS and recorded lowest count at harvest. Singh *et al.* (2004) also reported the effectiveness of fenoxaprop-p-ethyl against *Leptochloa*. Cyhalofop butyl was the next best herbicide in controlling weeds as is evident from the weed occurrence and weed dry weight (Table 12). Saini (2003a) noticed reduction in population of annual grasses by the application of cyhalofop butyl in wet seeded rice, especially that of red sprangletop. Cyhalofop butyl was also effective in controlling *Leptochloa chinensis*, as per recorded weed dry weight of 11.6, 23.3 and 48 kg/ha at 30 DAS, 60 DAS and at harvest of the weed. The emergence of *Leptochloa chinenesis* as a problem weed in *Kole* lands is considered to be an effect of widespread application of bispyribac sodium, which ranked next only to the unweeded control in the population of the weed.

Weed dry weight (Table 8) recorded a trend similar to the weed count. Chinese sprangletop was absent in the treatment fenoxaprop-p-ethyl, and cyhalofop butyl recorded a weed dry weight of 11.6 kg/ha. Weed dry weight production of 60 to 144 kg/ha was recorded in all other herbicidal treatments, due to contributions by sedges and broad leaf weeds. At 60 DAS, among the herbicide treatments, bispyribac sodium

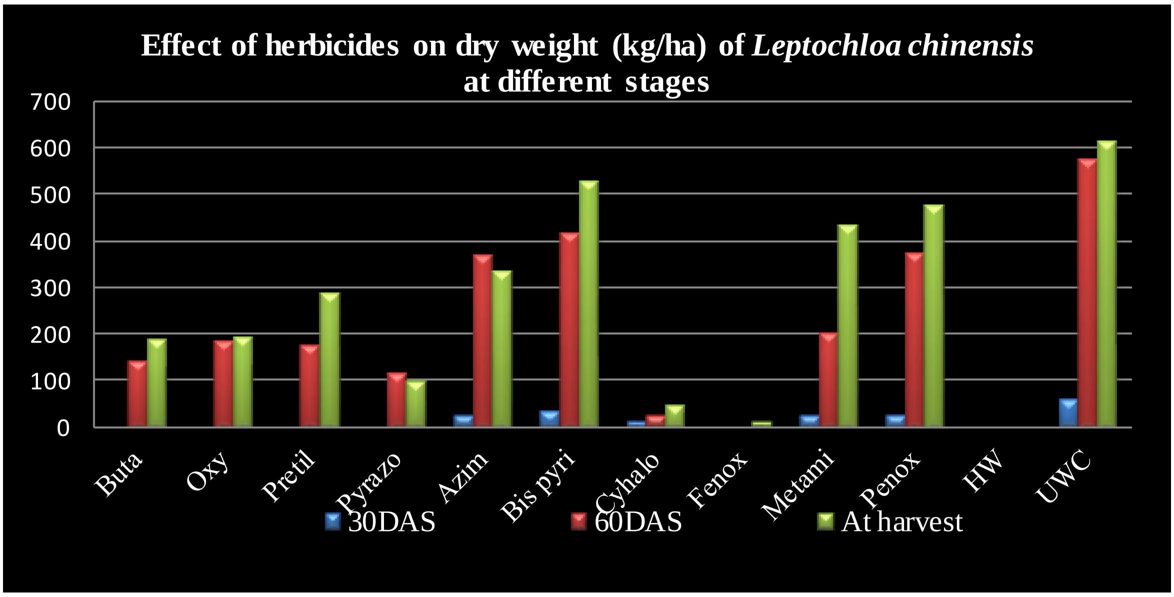
Effect of herbicides on dry weight (kg/ha) of *Leptochloa chinensis* at different stages
700
600
500
400
300
200
100
0
Buta
Oxy
Pretil
Pyrazo
Azim
Bis pyri
Cyhalo
Fenox
Metami
Penox
HW
UWC
30DAS
60DAS
At harvest

Fig.8

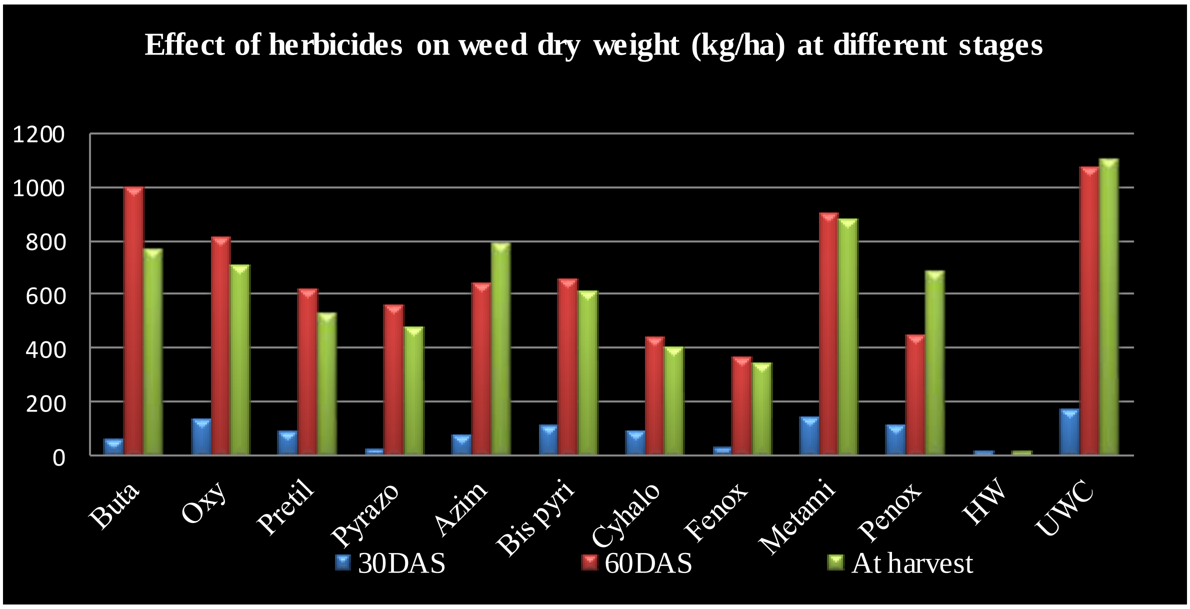
Effect of herbicides on weed dry weight (kg/ha) at different stages
1200
1000
800
600
400
200
0
Buta
Oxy
Pretil
Pyrazo
Azim
Bis pyri
Cyhalo
Fenox
Metami
Penox
HW
UWC
30DAS
60DAS
At harvest

Fig.9

registered the highest dry weight production of *Leptochloa* (417.6 kg/ha), and the lowest production was in the treatment cyhalofop butyl (23.3 kg/ha). Total weed dry weight production was lowest in fenoxaprop-p-ethyl (422.35 kg/ha), followed by cyhalofop butyl (436.53 kg/ha). At harvest too, the trend was similar with the bispyribac sodium treated plot showing highest *Leptochloa* production (527.7 kg/ha) and fenoxaprop-p-ethyl showing the least (10.2 kg/ha), followed by cyhalofop butyl (48 kg/ha). Hand weeding resulted in lowest total weed and *Leptochloa* dry matter production. Rekha *et al.* (2002) have also reported a lower weed dry matter production in handweeded control.

Table 6 shows that weeds, especially sedges and broad leaf weeds were present in all treatments except in pretilachlor, where sedges were not recorded, and in bispyribac sodium, where broad leaf weeds were absent. Azimsulfuron and penoxsulam, though broad spectrum herbicides, were found less effective in the present study compared to bispyribac sodium in controlling broad leaf weeds. Metamifop was seen to be least effective against sedges, and also less effective against grasses and broad leaf weeds. While the unweeded control recorded the highest count of sedges and broad leaf weeds, among the herbicides, metamifop was least effective against sedges, while broad leaf weeds were highest in the treatment cyhalofop butyl. Fenoxaprop-p-ethyl was seen to be the most effective herbicide to control grasses, and was on par with the handweeding treatment.

Fig. 9 shows the effect of herbicides on weed dry weight. It was observed that weed dry weight production (Table 8) was generally lower at 30 DAS compared to 60 DAS and harvest. At 30 DAS the treatments cyhalofop, pretilachlor, azimsulfuron, butachlor, fenoxaprop-p-ethyl, and pyrazosulfuron showed less weed dry matter production. At 60 DAS, the weed dry weight increased to the tune of six times in unweeded control and the lowest dry weight was noticed in fenoxaprop-p-ethyl treated plots followed by the treatment cyhalofop butyl. The handweeded treatment showed very low accumulation of weed dry weight. At the time of harvest also, weed dry weight production was the lowest in hand weeded plots followed by the treatment fenoxaprop-p-ethyl. The treatments cyhalofop butyl and pyrazosulfuron ethyl were the next best treatments with a lower weed dry weight. However, in most of the herbicide treatments, weed dry weight was less at harvest stage than at 60 DAS.

5.3 Effect of herbicides on nutrient uptake by weeds and *Leptochloa chinensis*

Nutrient uptake by weeds is a function of weed dry matter production and nutrient content. In general, the demand for nutrients was in the order of K>N>P by rice crop and weeds. Highest N, P and K uptake (Tables 9, 10 and 11) was noticed in unweeded control irrespective of stage of crop growth due to high weed dry weight production. Similar results were also reported by Choubey *et al.* (1999) and Thirumurugan *et al.* (1998).

The trend of nutrient uptake followed that of weed dry weight closely. N uptake (Table 9) was least in treatment fenoxaprop-p-ethyl, due to low weed dry weight. Cyhalofop butyl also recorded low N uptake values. Ineffective control of weeds by metamifop was reflected in high N uptake values for this treatment.

In the case of P uptake (Table 10) by weeds, the treatment fenoxaprop-p-ethyl again registered lowest values. The pre emergent herbicides pretilachlor, oxyfluorfen, and butachlor also resulted in low P uptake values. Here again, due to better weed growth, metamifop treated plot registered high P uptake values. As in the case of N and P, K uptake (Table 11) was lowest in the fenoxaprop-p-ethyl treatment, and high in the metamifop treatment.

N uptake by *Leptochloa chinensis* (Table 13) followed the trend of dry weight production by the weed. After unweeded control, highest uptake was by the treatment bispyribac sodium, while uptake in the treatment fenoxaprop-p-ethyl was lowest. A similar uptake pattern was seen in the case of uptake of P (Table 14) and K (Table 15).

5.4. Herbicidal effects on rice

5.4.1. Phytotoxicity scoring

Phytotoxicity scoring (Table 24 and Table 25) done at seven and fifteen days after spraying of herbicides showed that among various herbicides applied, pyrazosulfuron ethyl, butachlor, pretilachlor and oxyfluorfen caused phytotoxicity on rice at seven days after spraying. Whitening of leaf tips and scorched appearance on leaves of crop as a whole was noted. However, the crop recovered within two weeks after spraying. Pyrazosulfuron ethyl inhibited crop elongation, and thinning of crop was noticed.

5.4.2. Plant growth parameters

Among the various treatments, at 30 DAS the greatest height (Table 19) was recorded in unweeded control (35.59 cm) which was significantly higher than all other treatments which may be due to the severe weed competition at early growth phase leading to increase in height at the expense of tillering. At 60 DAS there was no significant difference in height between the treatments butachlor, oxyfluorfen, pretilachlor, bispyribac sodium and handweeded control. The reduction in height especially in pyrazosulfuron ethyl treated plots could be due to the action of this herbicide on plant physiological activities *i.e.*, by inhibiting cell elongation. Fujita (1996) reported that application of pyrazosulfuron ethyl leads to reduction in plant height of rice. However, as plant growth advanced, there were no significant differences between the various herbicidal treatments showing that adverse effect if any, was short lived and the plants regained its growth rate. The crop height at harvest was ranging from 90.5 cm for azimsulfuron, fenoxaprop-p-ethyl and metamifop to 83.62 cm in the treatment penoxsulam.

At 30 DAS, 60 DAS and harvest hand weeding registered the highest number of tillers/m^2 (Table 20). Similar results were also reported by Lakshmi *et al.* (2006). Tiller count was significantly lower in the unweeded control compared to hand weeded control due to severe competition from weeds. Hand weeding twice was statistically superior to all other treatments.

5.4.3. Yield and yield attributes

The highest number of panicles/m^2, filled grains per panicle as well as yield of grain and straw was registered in the hand weeded treatment (Table 21). Several authors like Suganthi *et al*. (2005) and Subhalakshmi and Venkataramana (2009) reported an increase in yield and yield attributes due to hand weeding. A reduction in number of panicles/m^2 to the extent of 59 per cent in unweeded control over hand weeding was also noticed. Similar results were also reported by Moorthy (1980). Weed competition also lowered filled grains per panicle by 72 per cent in weedy check compared to hand weeding and was also reported by Gobrial (1981). Number of panicles/m^2 and grains per panicle followed exactly the same trend as that of grain yield. The test weight of grain did not differ significantly between treatments probably because it is a varietal character decided by genetic makeup of the plant. The fertility percentage ranged from 73.13 to 83.33.

The highest grain yield (Table 22) of 6.46 t/ha was recorded in hand weeded control plot, where highest WCE was also recorded (Fig. 10). Moorthy and Saha (2002) reported a WCE of 93 percent in hand weeded control and thereby higher grain yield. The next best treatments for grain yield were fenoxaprop-p-ethyl (5.88 t/ha) and cyhalofop butyl (5.46 t/ha) and lowest yield was obtained in unweeded control. High grain yield in the treatments hand weeding and fenoxaprop-p-ethyl can be attributed to higher number of grains per panicle and higher percentage of filled grain per panicle. In the case of straw, the highest yield was obtained in hand weeded control (5.87 t/ha) followed by fenoxaprop-p-ethyl and cyhalofop butyl (5.74 t/ha) which were on par. The lowest straw yield was recorded in azimsulfuron with 4.92 t/ha.

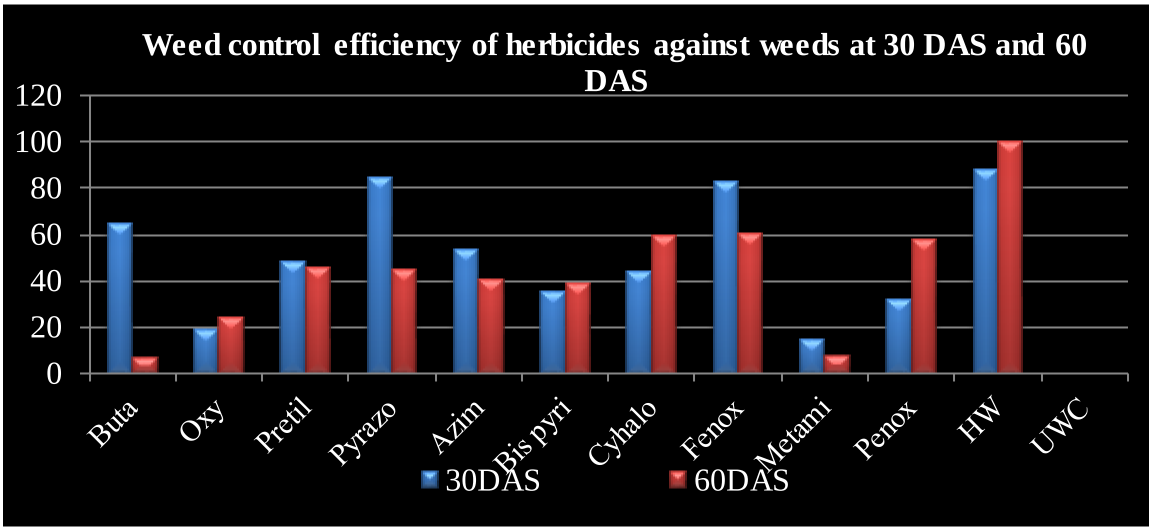
Weed control efficiency of herbicides against weeds at 30 DAS and 60 DAS
120
100
80
60
40
20
0
Buta
Oxy
Pretil
Pyrazo
Azim
Bis pyri
Cyhalo
Fenox
Metami
Penox
HW
UWC
30DAS
60DAS

Fig.10

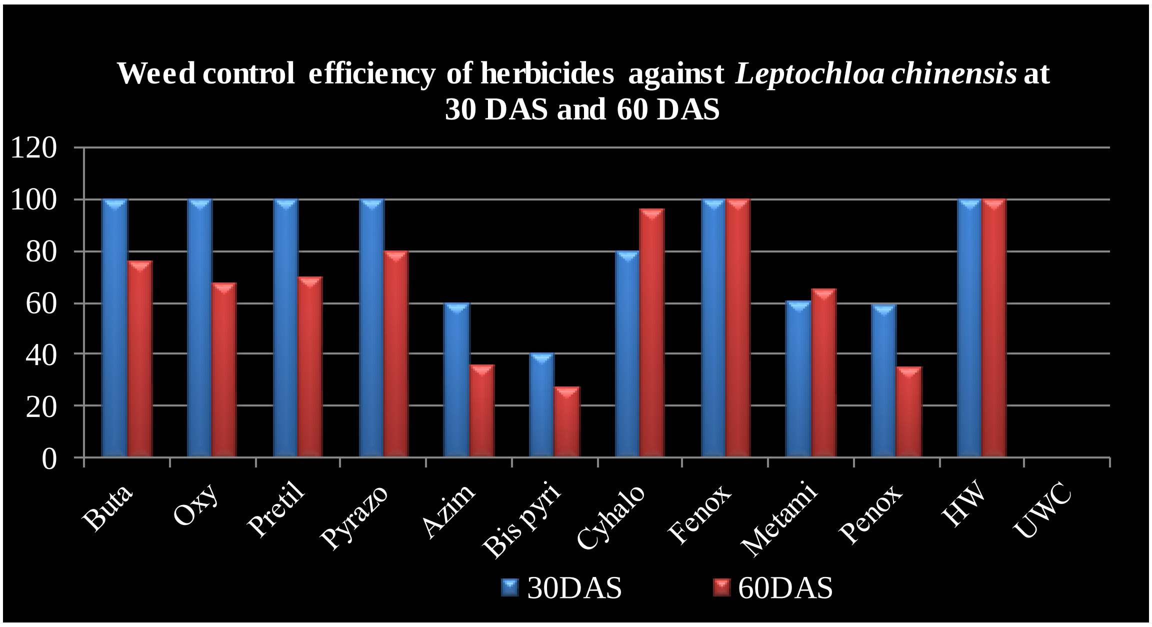
Weed control efficiency of herbicides against *Leptochloa chinensis* at 30 DAS and 60 DAS
120
100
80
60
40
20
0
Buta
Oxy
Pretil
Pyrazo
Azim
Bis pyri
Cyhalo
Fenox
Metami
Penox
HW
UWC
30DAS
60DAS

Fig.11

5.4.4. Efficacy of herbicidal treatments in controlling *Leptochloa chinensis* and other weeds

Fig. 10 shows the effect of WCE of different treatments on weeds at 30 and 60 DAS (Table 16). Following the common trend, after hand weeding, fenoxaprop-p-ethyl recorded the highest weed control efficiency followed by cyhalofop butyl. The lowest value was recorded by metamifop. The adverse effect of metamifop on rice was evident from the high weed index of 0.46. Conversely, fenoxaprop-p-ethyl recorded lowest weed index of 0.20 (Table 18).

Fig. 11 shows the effect of WCE of different treatments on *Leptochloa chinensis* at 30 and 60 DAS. At 30 DAS, 60 DAS and harvest (Table 17), the fenoxaprop-p-ethyl treatment was on par with handweeded control with 98 to 100% control of Chinese sprangletop followed by cyhalofop butyl, but the least efficiency was in bispyribac sodium.

5.4.5. Nutrient uptake by rice at harvest

The uptake of N, P and K by rice is a function of straw yield, grain yield and its nutrient content (Table 23). The N, P and K uptake was the highest in hand weeded control. The favourable growth conditions due to high WCE in hand weeded treatment resulted in better uptake of nutrients, a finding similar to that of Subhalakshmi and Venkataramana (2009). Fenoxaprop-p-ethyl treated plots recorded the second highest N, P, K uptake in both grain and straw. The treatment that showed lowest N, P, K values was metamifop followed by unweeded control.

5.5 Economics of cultivation

The major advantage in going for herbicidal control of weeds is reduction in the cost of cultivation. Working out the economics of cultivation while using different herbicides is important so that a final recommendation considering cost involved as well as net returns can be formulated. An analysis of the economics of rice cultivation shows that for high returns (Rs. 67046/ha) and B:C ratio (2.1), fenoxaprop-p-ethyl spraying is

Effect of herbicides on dry matter production (kg/ha) of *Leptochloa chinensis* (60 DAS) & grain yield (kg/ha)

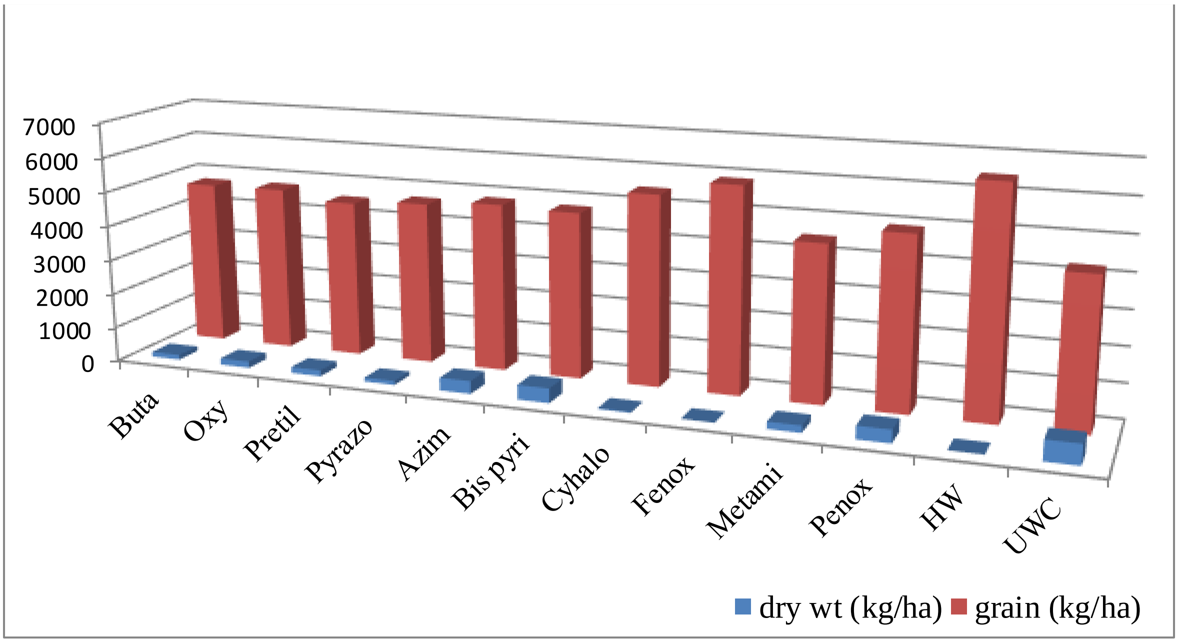

Fig.12

the best (Table 26). The performance of metamifop was inferior compared to fenoxaprop p-ethyl, (though both are graminicides) with respect to grain yield, net profit and B:C ratio. However, fenoxaprop p-ethyl was comparable to cyhalofop butyl statistically with regard to grain yield. The same trend was seen in net profit and B:C ratio also, though fenoxaprop p-ethyl gave higher net profit of Rs.67046/ha compared to Rs. 59101/ha for cyhalofop butyl. In terms of WCE also, the same trend was observed. The corresponding value for metamifop was Rs.42798/ha. The three new broad spectrum herbicides used in the study (bispyribac sodium, penoxsulam, azimsulfuron), though they resulted in low cost of cultivation, could not give high net profit or B:C ratio. The low WCE might have resulted in lower yield and resultant reduction in net profit.

Handweeding resulted in highest grain and straw yields, but the B:C ratio was not highest because of the high labour cost. Still a high B:C ratio of 1.9 was obtained, and if labour availability was not a problem, handweeding would be one of the best options for weed control. In the current context of labour shortage, herbicidal use is the practical alternative. However, in the present study, all the herbicides tried gave only a partial control of weed flora, that is, of grasses or sedges or broad leaf weeds and so yield obtained was less than that in handweeded control. Combinations of herbicides to control a broad spectrum of weeds could give higher yield and B:C ratio.

Hence the study brings out the superiority of fenoxaprop-p-ethyl in controlling *Leptochloa chinensis*. Fig. 12 shows that *Leptochloa* dry matter production was negatively correlated with grain yield. Cyhalofop butyl was also seen to be an effective herbicide for this purpose. However, these herbicides were ineffective in controlling broad leaf weeds and sedges. Control of broad leaf weeds like *Ludwigia parviflora* and sedges like *Cyperus sp.* and *Fimbristylis miliacea* was effectively done by bispyribac sodium and pyrazosulfuron ethyl. These two herbicides, though ineffective in controlling *Leptochloa*, still produced reasonable grain and straw yields. Grain yields produced on application of the herbicides oxyfluorfen, pretilachlor, butachlor, penoxsulam, azimsulfuron and metamifop were significantly lower. The results indicate that while for the specific control of *Leptochloa chinensis*, the best herbicide would be fenoxaprop-p-ethyl @ 60 g a.i./ha, followed by cyhalofop butyl @ 80 g a.i./ha, both applied at 20 DAS. In areas where *Leptochloa* is not a severe problem, bispyribac sodium @ 30 g a.i./ha applied at 20 DAS is still the herbicide for controlling grasses, sedges and broad leaf weeds, while producing high grain and straw yields at the same time.

SUMMARY

6. SUMMARY

Herbicidal weed control is widely adapted in rice cultivation since use of chemical herbicides is easier, time and labour saving and economical compared to the traditional hand weeding methods. But the increasingly adopted direct seeding system and repeated use of herbicides are the main factors responsible for the shift in weed species populations in rice ecosystem. It is reported that the continuous use of bispyribac sodium from 1998 onwards to control barnyard grass has resulted in a shift to dominance by Chinese sprangletop in wetland rice fields. Thus the main objectives of the study were to evaluate the efficacy of new promising herbicides against *Leptochloa chinensis* in direct seeded rice and to assess the crop - weed competiton, including nutrient removal, by the weed.

A field experiment was conducted in Alappad-Pullu *Kole* lands of Thrissur district from November 2012 to March 2013, using the rice variety, Jyothi. The soil of the *Kole* lands is clayey in texture with pH 5.2 and belongs to the soil order Inceptisol. The plot size was 20 m^2 (5m x 4m). The treatments included application of both pre and post emergence herbicides. Pre emergence herbicides included oxyfluorfen, pretilachlor and butachlor. Cyhalofop butyl, fenoxaprop-p-ethyl, bispyribac sodium, metamifop, azimsulfuron and penoxsulam were the post emergence herbicides applied and pyrazosulfuron ethyl was also sprayed as an early post emergence herbicide. Hand weeded and unweeded controls were also included for effective comparison. Hand weedings were done at 20 and 40 days after sowing (DAS). Oxyfluorfen was sprayed at 3 DAS and butachlor and pretilachlor were sprayed at 6 DAS. The early post emergence treatment pyrazosulfuron ethyl was sprayed at 8 DAS. The post emergence herbicides cyhalofop butyl, fenoxaprop-p-ethyl, bispyribac sodium, metamifop, azimsulfuron and penoxsulam were sprayed at 20 DAS. Visual phytotoxicity rating of crop and weeds were done on the seventh and fifteenth day after spraying. Observations were recorded at 30 DAS, 60 DAS and at

harvest. The crop was harvested during the second week of March after the grains were fully matured. After manual threshing, cleaning and drying, yields were expressed in kg/ha.

Observations recorded were species wise weed count including *Leptochloa chinensis* count, dry weight of *Leptochloa chinensis* and total weeds, and N, P and K uptake by *Leptochloa chinensis* and total weeds (at 30 DAS, 60 DAS and at harvest) and by rice (at harvest). Rice plant height, numbers of tillers, yield attributes like number of panicles, filled grains per panicle, test weight of grains and chaff percentage were recorded. Grain as well as straw yield were recorded and expressed in kg/ha. Weed index, weed control efficiency and economics of cultivation were also calculated. The present investigation came out with the following findings.

Major weed species found in experimental plot were grasses which comprised of *Leptochloa chinensis, Echinochloa colona,* and *Echinochloa crusgalli. Ludwigia perennis, Lindernia crustacea,* and *Alternanthera sp*. were the broad leaved weeds and *Fimbristylis miliacea, Cyperus iria* and *Cyperus difformis* were the sedges present. At all stages of growth of rice, proportion of grasses especially *Leptochloa chinensis* were higher than that of sedges and broad leaved weeds. Among sedges, the population of *Fimbristylis miliacea* was higher than that of *Cyperus* sp. Among broad leaved weeds population of *Lindernia crustacea* was more than *Ludwigia perennis*. At harvest, *Lindernia* was the only weed present in hand weeded plot, though its dry weight accumulation was very low due to low count.

When observations on *Leptochloa* population was taken at 30 DAS, it was seen to be absent in the treatments fenoxaprop-p-ethyl, handweeded control, pyrazosulfuron ethyl, oxyfluorfen, pretilachlor and butachlor. At 60 DAS the population increased, and so the dry weight also increased as compared to 30 DAS. At 60 DAS, unweeded control showed the highest *Leptochloa chinensis* count followed by the treatments bispyribac sodium, metamifop, azimsulfuron and penoxsulam. However, *Leptochloa chinensis* was again absent in fenoxaprop-p-ethyl treatment and handweeded treatment. The *Leptochloa* count was very low for the cyhalofop butyl treatment at 60 DAS too. At harvest, *Leptochloa* count was lowest in the treatment fenoxaprop-p-ethyl, followed by cyhalofop butyl treated plots.

Observations on total weed population was taken at 30 DAS, 60 DAS and harvest showed that weeds, especially sedges and broad leaved weeds were present in all treatments except pretilachlor where sedges were not recorded and bispyribac sodium treatment where broad leaved weeds were absent. Fenoxaprop-p-ethyl controlled only grasses and hence the high weed count was contributed by broad leaved weeds and sedges. Azimsulfuron and penoxsulam, though broad spectrum herbicides, were found less effective in the present study compared to bispyribac sodium in the control of sedges and broad leaved weed population. Grass weeds were higher in the treatment azimsulfuron than in bispyribac sodium. Fenoxaprop-p-ethyl was on par with handweeded control. The count of sedges in the treatment metamifop was second to the unweeded control. The count of broad leaved weeds was higher in cyhalofop butyl treated plot, followed by unweeded control.

By 60 DAS, total weed dry weight increased six fold in unweeded control which recorded a weed dry weight accumulation of 1074.6 kg/ha, and the lowest dry weight of 422.35 kg/ha was noticed in fenoxaprop-p-ethyl treated plots followed by the treatment cyhalofop butyl, with 436.53 kg/ha while handweeded control showed lowest dry weight of weeds. At harvest, total weed dry weight was the lowest at 16.22 kg/ha in hand weeded plots, followed by 340.12 kg/ha in the treatment fenoxaprop-p-ethyl. With respect to *Leptochloa* dry weight at 30 DAS, 60 DAS and harvest, fenoxaprop-p-ethyl treatment registered lower dry weight followed by cyhalofop butyl. The highest weed dry weights were recorded in unweeded control followed by bispyribac sodium.

N, P and K uptake by *Leptochloa chinensis* was highest in the unweeded control, followed by bispyribac sodium due to higher dry weight of the weed. Lowest uptake was in the handweeded plot, followed by fenoxaprop-p-ethyl. When total weed uptake of N, P and K were considered, the unweeded control recorded highest values followed by metamifop. Lowest values were for handweeding and the treatment fenoxaprop-p-ethyl.

The phytotoxicity scoring done seven and fifteen days after spraying of herbicides showed that among various herbicides applied, pyrazosulfuron ethyl, butachlor, pretilachlor and oxyfluorfen caused phytotoxicity on rice at seven days after spraying. Whitening of leaf tips and scorching appearance on leaves of crop as a whole was noted. However, the crop recovered within two weeks after spraying. Pyrazosulfuron ethyl inhibited crop elongation and thinning of crop was seen.

Among the various treatments, the tallest plants with 36 cm height at 30 DAS were recorded in unweeded control. However, there was a slight reduction in the height of rice in plots treated with oxyfluorfen, butachlor and pyrazosulfuron-ethyl, compared to hand weeded control, though visual phytotoxicity symptoms were expressed. However, as the plant growth advanced, there were no significant differences between the various herbicidal treatments at 60 DAS with respect to plant height. The crop height at harvest was ranging from 90.5 cm for azimsulfuron, metamifop and fenoxaprop-p-ethyl to 83.62 cm in the treatment penoxsulam. At 30 DAS, 60 DAS and harvest hand weeding registered the highest tillers/m^2 followed by fenoxaprop-p-ethyl.

The highest number of panicles/m^2, filled grains per panicle as well as yield of grain and straw were registered in hand weeding. The performance was statistically superior to all others in the case of panicles/m^2. The test weight of grain did not differ significantly between treatments. The fertility percentage ranged from 83.33 to 73.13. The highest grain yield of 6.46 t/ha was recorded in hand weeded control plot, where highest WCE was also recorded. The next best treatments for grain yield were fenoxaprop-p-ethyl (5.88 t/ha) and cyhalofop buty (5.46 t/ha) and lowest yield of 4.07 t/ha was obtained in unweeded control. In the case of straw, the highest yield was obtained in handweeded control (5.87 t/ha) and lowest in azimsulfuron with 4.92 t/ha. The highest nutrient uptake of N, P and K was observed in hand weeded control. Fenoxaprop - p- ethyl treated plots recorded the second highest N, P, K uptake in both grain and straw. The treatments that showed lowest N, P, K values were metamifop followed by unweeded control.

At 30 DAS, 60 DAS and harvest the fenoxaprop-p-ethyl treatment was on par with handweeded control with 98-100% control over Chinese sprangletop. At 30 DAS and 60 DAS cyhalofop butyl showed WCEs of 80% and 92% over Chinese sprangletop, and the least WCE was in bispyribac sodium at 30 DAS, 60 DAS and at harvest. Similarly, at 30 DAS, WCE for the total weeds in handweeded control was highest, followed by pyrazosulfuron ethyl and the least WCE was for metamifop. At 60 DAS again handweeded control showed 100% control of weeds followed by fenoxaprop-p-ethyl but the least was in butachlor and metamifop. At harvest, the highest WCE was with handweeding (97%) followed by fenoxaprop-p-ethyl and the lowest WCE was recorded by metamifop. Among different treatments, highest B:C ratio of 2.1 was obtained in fenoxaprop-p-ethyl, followed by handweeded control and cyhalofop butyl which were on par with a value of 1.9.

Conclusion

In rice field, weed spectrum at 60 DAS was dominated by grasses (44%) of which *Leptochloa* accounted for 26% which was more than 60%. Pre emergence herbicides were effective in controlling *Leptochloa* initially, but subsequent germination was recorded at later stages. Post emergence herbicides fenoxaprop-p-ethyl (60 g a.i. /ha) and cyhalofop butyl (80g a.i./ha) sprayed at 20 DAS were effective in controlling *Leptochloa*. However the post emergence herbicide bispyribac sodium (30 g a.i./ha) sprayed at 20 DAS was not at all effective against *Leptochloa*. For high grain yield, net returns as well as high B:C ratio, the post emergent herbicide fenoxaprop p ethyl @ 60 g a.i. /ha or cyhalofop butyl @ 80 g a.i./ha can be recommended in *Leptochloa* infested fields. Whenever *Leptochloa* is not a problem weed bispyribac sodium @ 30 g a.i./ha can be recommended as it controls grasses, sedges and dicots.

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7. REFERENCES

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APPENDICES

Appendix – 1 **Monthly weather data during the crop period**

Month	Temperature (^{0}C)		RH (%)		Rainfall (mm)	Rainy days	Mean evaporation (mm)	Mean sunshine hours
	Max.	Min.	Morning	Evening				
November	32.5	22.7	85	53	46.7	3	3.4	7.5
December	33.0	23.2	73	43	19.8	2	5.1	8.1
January	34.1	22.3	70	34	0.0	0	4.9	8.7
February	34.7	23.3	76	37	84.4	2	5.1	8.6
March	35.4	24.4	82	46	14.6	2	4.9	7.1

Appendix – 2 **Details of cost of cultivation**

Sl.No.	Particular	Men (Rs.500/day)	Women (Rs.200/day)	Amount (Rs./ha)
	Field operation			
1	Land preparation	20	-	10000.00
2	Sowing + basal fertilizer application	1	-	500.00
3	Hand weeding (twice)	5	8	4100.00
4	Fertilizer top dressing	1	-	500.00
5	Irrigation	1	-	500.00
6	Harvesting (mechanized) @ Rs. 1600/hr	-	4 hr	6000.00
	Total cost			**21600.00**

Appendix – 3 **Details of cost of inputs**

Sl.No.	Particular	Quantity /ha	Amount (Rs./ha)
	Input		
1	Urea @ Rs.5.7/kg Factom phos @ Rs.14.8/kg MOP @ Rs.11.8/kg	120kg 175kg 75kg	684.00 2590.00 885.00
2	Seed @ Rs.20/kg	125kg	2500.00
3	PP chemicals	-	100.00
4	Trichocards (Rs. 60/card)	36 Nos.	2160.00
	Total cost		**8919.00**
	TOTAL		**30519.00**

Appendix- 4 **Details of cost of herbicides**

Slno	Herbicides	Trade name	Manufacturer	Quantity /ha	*Amount (Rs./ha)
1	Butachlor	Machete	Sinochem India	2.5 litre	1625.00
2	Oxyfluorfen	Oxy Gold	Indofil chemicals	638.3 ml	1275.00
3	Pretilachlor	Rifit	Syngenta Ltd.	1 litre	1512.00
4	Pyrazosulfuron-ethyl	Saathi	UPL	300 g	2200.00
5	Azimsulfuron	Segment	Dupont Ltd.	70 g	3462.50
6	Bispyribac- sodium	Nominee gold	PI industries	300 ml	3500.00
7	Cyhalofop-butyl	Clincher	Dow Agroscience	800 ml	3200.00
8	Fenoxaprop-p-ethyl	Rice star	Bayer Ltd.	870 ml	2394.50
9	Metamifop	Metamifop	LTC Ltd	1 litre	2860.00
10	Penoxsulam	Granite	Dow Agroscience	115.2ml	2843.50

*Herbicide application charge of Rs 1000/ha is added to each herbicide cost

Appendix- 5 **Nutrient contents of weeds at 30 DAS (%)**

Treatment	N	P	K
Butachlor	1.53	0.33	2.44
Oxyfluorfen	1.67	0.27	2.97
Pretilachlor	1.95	0.32	2.63
Pyrazosulfuron-ethyl	1.88	0.33	2.75
Azimsulfuron	2.11	0.32	3.37
Bispyribac- sodium	2.71	0.38	2.88
Cyhalofop-butyl	2.11	0.37	2.75
Fenoxaprop-p-ethyl	1.90	0.52	3.12
Metamifop	2.45	0.43	3.35
Penoxsulam	2.10	0.36	1.86
Handweeded control	1.36	0.47	2.70
Unweeded control	2.91	0.47	3.64

Appendix- 6 **Nutrient contents of weeds at 60 DAS (%)**

Treatment	N	P	K
Butachlor	1.42	0.16	2.61
Oxyfluorfen	1.58	0.10	3.32
Pretilachlor	1.85	0.19	3.45
Pyrazosulfuron-ethyl	1.83	0.34	3.65
Azimsulfuron	2.08	0.13	3.68
Bispyribac- sodium	2.44	0.16	2.17
Cyhalofop-butyl	1.99	0.28	3.41
Fenoxaprop-p-ethyl	1.80	0.12	3.24
Metamifop	2.42	0.27	3.79
Penoxsulam	2.05	0.06	3.21
Handweeded control	2.50	0.21	3.30
Unweeded control	2.69	0.23	3.47

Appendix- 7 **Nutrient contents of weeds at harvest (%)**

Treatment	N	P	K
Butachlor	1.28	0.14	2.36
Oxyfluorfen	1.38	0.13	2.65
Pretilachlor	1.70	0.14	2.75
Pyrazosulfuron ethyl	1.62	0.25	3.34
Azimsulfuron	1.87	0.13	3.42
Bispyribac sodium	1.92	0.14	2.07
Cyhalofop butyl	1.87	0.27	3.08
Fenoxaprop-p-ethyl	1.64	0.13	2.76
Metamifop	1.93	0.24	3.16
Penoxsulam	1.87	0.06	2.54
Unweeded control	2.23	0.27	3.20

Appendix-8 **Dry matter production (kg/ha) and nutrient removal (kg/ha) of weeds in handweeded control at different stages**

	Dry matter production (kg/ha)	N %	N(kg/ha)	P %	P(kg/ha)	K %	K(kg/ha)
20 DAS	8.2	1.22	0.10	0.44	0.03	2.40	0.19
40 DAS	1.8	1.32	0.02	0.45	0.01	2.51	0.04

Appendix - 9 **Nutrient contents (%) of *Leptochloa chinensis* at 30 DAS**

Treatment	N	P	K
Azimsulfuron	2.19	0.21	0.20
Bispyribac sodium	2.31	0.25	0.28
Cyhalofop butyl	1.57	0.18	0.23
Metamifop	2.61	0.24	0.21
Penoxsulam	2.06	0.19	0.17
Unweeded control	2.22	0.30	0.26

Appendix – 10 **Nutrient contents (%) of *Leptochloa chinensis* at 60 DAS**

Treatment	N	P	K
Butachlor	1.27	0.28	1.64
Oxyfluorfen	1.89	0.39	2.71
Pretilachlor	1.31	0.28	2.47
Pyrazosulfuron ethyl	1.28	0.25	2.55
Azimsulfuron	1.70	0.24	1.57
Bispyribac sodium	2.06	0.30	2.24
Cyhalofop butyl	1.28	0.25	1.90
Metamifop	2.23	0.37	1.74
Penoxsulam	1.91	0.20	1.11
Unweeded control	1.86	0.35	2.09

Appendix – 11 **Nutrient contents (%) of *Leptochloa chinensis* at harvest**

Treatment	N	P	K
Butachlor	1.03	0.26	1.31
Oxyfluorfen	1.69	0.35	2.41
Pretilachlor	1.07	0.26	2.13
Pyrazosulfuron ethyl	1.13	0.24	2.07
Azimsulfuron	1.51	0.23	1.04
Bispyribac sodium	1.82	0.28	2.03
Cyhalofop butyl	1.08	0.25	1.63
Metamifop	1.72	0.34	1.25
Penoxsulam	1.71	0.22	0.81
Unweeded control	1.69	0.34	1.80

Appendix – 12 **Nutrient contents (%) of grain at harvest**

Treatment	N	P	K
Butachlor	0.71	0.14	0.19
Oxyfluorfen	0.72	0.14	0.16
Pretilachlor	0.64	0.15	0.17
Pyrazosulfuron ethyl	0.76	0.15	0.22
Azimsulfuron	0.53	0.13	0.11
Bispyribac sodium	0.87	0.19	0.27
Cyhalofop butyl	0.93	0.20	0.26
Fenoxaprop-p-ethyl	0.81	0.17	0.24
Metamifop	0.49	0.13	0.13
Penoxsulam	0.57	0.13	0.16
Handweeded control	1.03	0.16	0.22
Unweeded control	0.73	0.11	0.17

Appendix – 13 **Nutrient contents (%) of straw at harvest**

Treatment	N	P	K
Butachlor	0.51	0.11	0.90
Oxyfluorfen	0.57	0.11	0.80
Pretilachlor	0.55	0.12	0.75
Pyrazosulfuron ethyl	0.53	0.12	0.74
Azimsulfuron	0.50	0.11	0.68
Bispyribac sodium	0.66	0.13	1.03
Cyhalofop butyl	0.67	0.13	1.13
Fenoxaprop-p-ethyl	0.62	0.13	1.15
Metamifop	0.49	0.11	0.72
Penoxsulam	0.44	0.11	0.85
Handweeded control	0.73	0.14	1.27
Unweeded control	0.46	0.07	0.68

HERBICIDAL MANAGEMENT OF CHINESE SPRANGLETOP [*Leptochloa chinensis*(L.) Nees.] IN DIRECT SEEDED RICE

By

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ABSTRACT OF THE THESIS

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8. ABSTRACT

Leptochloa chinensis (L.) Nees. (Chinese sprangletop or Red sprangletop) is one of the most important invasive weeds in direct seeded rice fields. It is a C_4 grass species, native to tropical Asia. Although an annual species, it can be perennial under suitable conditions. It is a slender tufted grass growing to a height of 1.2m with smooth linear leaves and terminal loose panicles. In a survey of weeds in rice agroecosystems of Kerala, Chinese sprangletop was first identified as a weed predominant in the alkaline soils of Chittoor taluk. Though this weed was listed as an indicator plant for alkaline conditions (Vidya *et al.*, 2004), it is now seen spreading rapidly in acidic soils also. In Kerala, under the National Invasive Weed Surveillance Programme (2008-11), this weed was reported in rice fields of Palakkad, Kole areas of Thrissur and in Kuttanad region too. This weed has the ability of high seed production and can grow in both flooded and upland conditions. It is reported that the continuous use of bispyribac sodium, a herbicide used for the control of broad spectrum of weeds, has resulted in a shift to the dominance by Chinese sprangletop in wet land rice fields.

With this background, the experiment ‘Herbicidal management of Chinese sprangletop [*Leptochloa chinensis*(L.) Nees.] in direct seeded rice’ was conducted in a farmer’s field in the *kole* lands at Pullu in Thrissur district during the period November 2012 - March 2013. Randomized block design was adopted with three replication and twelve treatments and with a plot size of 20 m^2. The variety used was Jyothi (PTB 39) which is of 115 days duration. The treatments included application of both pre emergence and post emergence herbicides. The pre emergence herbicides selected were oxyfluorfen sprayed at 3 days after sowing (DAS) and butachlor and pretilachlor both sprayed at 6 DAS. Pyrazosulfuron-ethyl, an early post emergence herbicide, was sprayed at 8 DAS. The herbicides cyhalofop butyl, fenoxaprop-p-ethyl, metamifop, penoxsulam, bispyribac sodium and azimsulfuron, are post emergence in action and were sprayed at 20 DAS. Hand weeded (handweeding at 20 and 40 DAS) and unweeded controls were also included for comparison with the herbicide treatments.

Observations on the weed spectrum, species wise weed count, weed dry matter production, and nutrient uptake by weeds as well as on the rice crop, with special reference to *Leptochloa chinensis* were taken at 30 DAS, 60 DAS and at harvest using a quadrat of 0.5m x 0.5m size. Major weed species found in experimental plot were grasses which comprised of *Leptochloa chinensis, Echinochloa colona,* and *Echinochloa crusgalli. Ludwigia perennis, Lindernia crustacea,* and *Alternanthera sp.* were the broad leaved weeds and *Fimbristylis miliacea, Cyperus iria* and *Cyperus difformis* were the sedges present. Visual phytotoxicity scoring of both weeds as well as crop was done at seven and fifteen days after spraying. As expected, all herbicides showed phytotoxic effect on weeds with scoring ranging from 2 to 4 indicating moderate control to very good control. Fenoxaprop-p-ethyl resulted in the phytotoxic symptoms on weeds in the form of purple blotches on leaves. The dry matter production of *Leptochloa chinensis* was seen increasing from 30 DAS to harvest in most of the treatments. Comparing the different herbicidal treatments, fenoxaprop-p-ethyl was most effective in controlling grass weeds including *Leptochloa* at all stages of observation, followed by cyhalofop butyl which was the next best herbicide as evident from the lower weed occurrence and production of dry matter as well as higher weed control efficiency. The highest grain yield of 6.46 t/ha was recorded in hand weeded control plot followed by fenoxaprop-p-ethyl (5.88 t/ha), and lowest yield was obtained in unweeded control. Highest B:C ratio of 2.1 was recorded by fenoxaprop-p-ethyl. Grain yields produced on application of all the other herbicides were significantly lower than that in handweeding and fenoxaprop-p-ethyl.

Thus the study brings out the superiority of fenoxaprop-p-ethyl in controlling *Leptochloa chinensis.* Cyhalofop butyl was also seen to be an effective herbicide for this purpose. However, these herbicides were ineffective in controlling broad leaf weeds and sedges. The treatment bispyribac sodium controlled broad leaf weeds like *Ludwigia parviflora* and sedges like *Cyperus spp.* and *Fimbristylis miliacea.* Although bispyribac sodium was ineffective in controlling *Leptochloa*, it still produced reasonable grain and straw yields. The results indicate that for the specific control of *Leptochloa chinensis*, the best herbicide would be fenoxaprop-p-ethyl 60 g a.i./ha or cyhalofop butyl 80 g a.i./ha, both applied at 20 DAS and in areas where *Leptochloa* is not a severe problem, bispyribac sodium 30 g a.i./ha at 20 DAS can be recommended for controlling grasses, sedges and broad leaf weeds.

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