# INTEGRATED WEED MANAGEMENT IN LOWLAND RICE

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## DECLARATION

I hereby declare that this thesis entitled "**Integrated weed management in lowland rice**" is a bonafide record of research work done by me during the course of research and that 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.

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## CERTIFICATE

Certified that this thesis entitled "**Integrated weed management in lowland rice**" is a record of research work done independently by Ms. Seema V. (2002-11-04) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| % | – | Per cent |
| °C | – | Degree Celsius |
| °E | – | Degree East |
| °N | – | Degree North |
| @ | – | At the rate of |
| 2,4-D | – | 2,4-dichloro phenoxy acetic acid |
| ai | – | Active ingredient |
| BCR | – | Benefit-cost ratio |
| CD | – | Critical difference |
| cm | – | Centimetre |
| cv. | – | Cultivar |
| DAS | – | Days after sowing |
| DAT | – | Days after transplanting |
| EC | – | Emulsifiable concentrate |
| *et al.* | – | And others |
| Fig. | – | Figure |
| g | – | Gram |
| ha | – | Hectare |
| HW | – | Hand weeding |
| K | – | Potassium |
| $K_2O$ | – | Potash |
| kg | – | Kilogram |
| kg $ha^{-1}$ | – | Kilogram per hectare |
| $l^{-1}$ | – | Per litre |
| LAI | – | Leaf area index |
| m | – | Metre |
| N | – | Nitrogen |
| NS | – | Non significant |
| P | – | Phosphorus |
| $P_2O_5$ | – | Phosphate |
| Rs. $ha^{-1}$ | – | Rupees per hectare |
| spp. | – | Species |
| t $ha^{-1}$ | – | Tonnes per hectare |
| *viz.* | – | Namely |
| WDG | – | Water dispersible granule |
| WP | – | Wettable powder |

# INTRODUCTION

# 1. INTRODUCTION

Rice is the staple food crop in India and there is a need to increase its production to match the growing population. This increase in production must be sought through sustainable agricultural practices to ensure continuous food supply. Rice suffers from various constraints in production and one of them is the competition through weeds. The spread of the high yielding dwarf varieties have now aggravated the problem of weeds in rice culture. The weeds form a serious negative factor in crop production and they must be controlled at the right time to get the desired production.

Rice is infested by heterogenous type of weed flora, which is one of the serious limitations in their control. Weeds alone cause an yield loss of upto 42 per cent under transplanted rice culture (Bhattacharya *et al.*, 1998). Prevention of weed competition and provision of weed free environment at critical period of crop growth is necessary for successful rice production. In transplanted rice, the young rice plants have an advantage over germinating weeds and immediate flooding limits the establishment of many weeds, hence yield losses due to weed competition tend to be less than those in direct seeded rice.

Rice is not very competitive with weeds during the seedling stage. Crop competitiveness with weeds is particularly important to limit weed infestation after the initial weed control treatment. Crop and weed interactions largely involve the competition for light, water and nutrients. Weeds usually have higher growth rates and nutrient demands than rice. Besides this, weeds adversely affect the microclimate around the plant, harbour disease organisms and insects, increase the cost of production and lower the quantity and quality of produce.

Several weed management strategies are adopted for effective weed control in transplanted rice. Among this, manual weeding is the most common method adopted by farmers. But it is an expensive, labour intensive and time consuming method. Herbicides offer a better alternative to handweeding. The use of herbicide imparts selective and economic control of weeds right from the beginning, giving crop a quick establishment and competitiveness. Chemical weed control is becoming increasingly popular in developing countries because of the high wages for manual weeding and paucity of labourer during peak period of demand. Herbicides viz., butachlor, 2,4-D and pretilachlor are nowadays extensively used by farmers for weed control in rice crop. With the extensive use of herbicides, there are more chances of shift in weed flora towards more persistent perennials, build up of herbicide residues in soil and consumable products (Kathiresan, 2001).

Herbicidal control of perennial grasses *viz.*, *Echinochloa* spp. has not been found always feasible. Therefore when such weeds pose a serious problem in rice, a combination of herbicidal control and manual weeding is resorted to (Gupta and Lamba, 1978). A combination of practices helps to minimize the build up of a single noxious weed or a group of weeds. No single weed management strategy will solve all weed problems in rice (Hill *et al.*, 1994). So there is a need for an integrated weed management strategy that make use of herbicides and handweeding. Integrated weed management reduces losses due to weeds combined with environmental preservation and improved agricultural sustainability.

With this background the present investigation was undertaken with the following objectives.

1. To find out the most suitable weed management method to control the obnoxious weedflora in lowland rice.

2. To assess the extent of yield loss due to weeds in lowland rice.
3. To assess the efficiency and economic feasibility of different weed management strategies in lowland rice.
4. To study the residual effect of applied herbicides on succeeding crop.

# REVIEW OF LITERATURE

# 2. REVIEW OF LITERATURE

Weed management plays an important role in increasing the grain yield in rice. Under transplanted condition, weed competition is less than direct seeded condition. However, conditions, which favour rice, are also favourable for weeds with the result weeds compete with crop and reduce the yield. A weed control study encompasses different aspects *viz.*, weed spectrum in rice fields, crop weed competition, yield reduction due to weeds, different methods of weed control, nutrient uptake of weeds etc. An attempt has been made to review the available literature on these aspects.

## 2.1 WEED SPECIES INFESTING RICE

Rice fields are colonized by terrestrial, semi aquatic and aquatic plants depending on the type of rice culture and season (Moody and Drost, 1983). They can be classified as grasses, sedges and broad-leaved weeds.

A brief review of the weed species infesting transplanted rice (Table 1) suggest that among grassy weeds, *Echinochloa* spp. is the foremost, while *Cyperus* spp. and *Fimbrystylis miliaceae* among sedges, *Monochoria vaginalis* and *Marselia quadrifolia* accounts for the broad leaved group.

## 2.2 CROP-WEED COMPETITION

Competition begins when crop and weeds grow in close proximity to one another and the supply of an essential factor falls below their demands. Crop plants vary greatly in their ability to compete with associated weeds. The total effect of interference as reflected in the crop growth and yield, results from competition for nutrients, moisture and sunlight (Rao, 2000).

Table 1. Weed species infesting transplanted rice

| Location | Grasses | Sedges | Broadleaved weeds | Reference |
|---|---|---|---|---|
| International Rice Research Institute, Philippines | *Echinochloa crus-galli*, *E. glabrescens* | *Cyperus difformis* | *Monochoria vaginalis* | (IRRI, 1981) |
| Onattukara, Kerala | *Echinochloa colonum*<br>*Echinochloa crus-galli*<br>*Sacciolepis indica* | *Cyperus iria*<br>*Cyperus rotundus* | *Cleome viscosa*<br>*Monochoria vaginalis* | (Lakshmi, 1983) |
| Vellayani, Kerala | *Echinochloa crus-galli*<br>*Echinochloa colonum*<br>*Panicum repens*<br>*Brachiaria ramosa* | *Cyperus spp.*<br>*Fimbristylis miliaceae* | *Monochoria vaginalis*<br>*Ludwigia parviflora* | Maheswari (1987) |
| Pattambi, Kerala | *Echinochloa crus-galli*<br>*Brachiaria* spp. | *Fimbristylis miliaceae* | *Cleome* spp. | Nair and Sadanandan (1975) |
| IARI, New Delhi | *Echinochloa crus-galli*<br>*E. colonum*<br>*Leptochloa chinensis* | - | *Eclipta alba*<br>*Commelina benghalensis* | Chander and Pandey (1996) |

Table 1 Continued

| | | | | |
|---|---|---|---|---|
| Karnal, Haryana | *Echinochloa crus-galli*<br>*Echinochloa colonum*<br>*Echinochloa glabrescens* | *Cyperus iria* | *Eclipta alba* | Singh *et al.* (1997) |
| Haryana | *Echinochloa* spp.<br>*Paspalum disticum* | *Cyperus* spp. | *Eclipta alba* | Dhiman *et al.* (1998) |
| Bangalore, Karnataka | *Echinochloa crus-galli*<br>*E. colonum*<br>*Leptochloa chinensis* | *Cyperus difformis*<br>*Cyperus iria* | *Monochoria vaginalis*<br>*Ludwigia adsandens*<br>*Marsilea quadrifolia* | Janardhan and Muniappa (1994) |
| Madurai, Tamil Nadu | *Echinochloa colonum* | *Cyperus iria* | - | Avudaithai and Veerabadran (2000) |
| Onattukara, Kerala | *Brachiaria ramosa*<br>*Cynodon dactylon*<br>*Panicum* spp. | *Echinochloa* spp.<br>*Cyperus iria*<br>*C.rotundus,*<br>*C. difformis*<br>*Scirpus juncoides*<br>*Fimbristylis miliaceae* | *Ammania baccifera*<br>*Ludwigia parviflora*<br>*Marsilea quadrifolia*<br>*Cleome viscosa*<br>*Monochoria vaginalis*<br>*Leucas aspera* | Rajan (2000) |
| Hyderabad, Andhra Pradesh | *Echinochloa colonum*<br>*Phasphalum disticum* | *Cyperus iria*<br>*Cyperus difformis*<br>*Scirpus supinus* | *Ammania baccifera*<br>*Marsilea quadrifolia* | Reddy *et al.* (2000) |

Table 1 Continued

| | | | | |
|---|---|---|---|---|
| Coimbatore, Tamil Nadu | *Echinochloa colonum* *Leptochloa chinensis* | *Cyperus iria* *Cyperus difformis* | *Eclipta alba* *Marsilea quadrifolia* | Jayakumar and Ananadakrishnan (2001) |
| Kharagpur, West Bengal | *Echinochloa crus-galli* | *Cyperus rotundus* *Cyperus difformis* *Fimbristylis miliaceae* | *Marsilea quadrifolia* *Ludwigia perennis* | Singh (2001) |
| Rajendranagar, Hyderabad | *Echinochloa colona* *Panicum repens* *Paspalum disticum* | *Cyperus difformis* *Cyperus iria* *Scirpus supinus* *Fimbrstylis dichotoma* | *Caesulia axillaris* *Eclipta alba* *Ammania baccifera* *Marsilea minuta* | Rekha *et al.* (2002) |
| Palampur, Himachal Pradesh | *Echinochloa crus-galli* *Panicum dichotomiflorum* | *Cyperus difformis* *Cyperus iria* *Scirpus* sp. | *Commelina benghalensis* *Ammania baccifera* *Scirpus* sp. | Saini and Angiras (2002) |
| Jabalpur, Madhya Pradesh | *Echinochloa crus-galli* *Paspalum distichum* | *Cyperus iria* | *Ludwigia parviflora* *Commelina communis* | Sharma and Upadhyay (2002) |
| Coimbatore, Tamil Nadu | *Echinochloa crus-galli* *Leptochloa chinensis* | *Cyperus difformis* | *Eclipta alba* *Marsilea quadrifolia* | Anandakrishnan and Jayakumar (2003) |
| IARI Regional Station, Karnal | *Echinochloa colona* *Leptochloa pamica* | *Cyperus iria* *Fimbristylis miliaceae* | *Sphenochlea zeylanica* *Eclipta alba* | Chopra and Chopra, (2003) |

Table 1 Continued

| | | | | |
|---|---|---|---|---|
| Annamalainagar, Tamil Nadu | *Echinochloa colona*<br>*Leptochloa chinensis* | *Cyperus rotundus*<br>*Cyperus difformis* | *Eclipta alba*<br>*Marsilea quadrifolia*<br>*Sphenoclea zeylanica* | Kathirvelu and Vaiyapuri (2003) |
| Central Rice Research Institute, Cuttak | - | *Cyperus difformis*<br>*Fimbristylis miliaceae* | *Sphenochlea zeylanica*<br>*Ludwigia parviflora* | Saha *et al.* (2003) |
| Haryana | *Echinochloa crus-galli* | *Cyperus iria*<br>*Cyperus difformis*<br>*Fimbristylis tenera* | *Eclipta alba*<br>*Linderia* sp.<br>*Sphenochlea* sp. | Sharma *et al.* (2003) |

De Dutta *et al.* (1968) reported that grassy weeds were most influential in reducing grain yield, followed by broad-leaved species and then by sedges. Muzik (1970) reported that weed competition was most serious when crops were young and that a moderate infestation is sometimes as serious as a heavy infestation.

**2.2.1 Critical Period of Competition**

Knowledge of the susceptible period of crop life to weed infestation decides the weed management programme to be adopted. Critical period of weed competition is the period at which the occurrence of weed competition greatly affects the quantity as well as the quality of crop yield. If the crop is kept weed free during the early stages for a certain length of time, weeds that emerge and develop subsequently may not affect the yield. This intervening period is termed as " critical period" of weed competition (Hewson and Roberts, 1971).

Shetty and Gill (1974) and Bhan and Mishra (1993) reported that the most critical period of crop weed competition was between 4 and 6 weeks after transplanting. According to Varughese (1978) and Sukumari (1982), the critical period of crop-weed competition was between 21 and 40 days after transplanting. Ali and Sankaran (1984) reported that for higher yields in lowland rice, the crop should be kept free of weeds during the first 50 days in the monsoon and 60 days in summer.

Chang (1970) investigated the effect of weeds emerging at 15, 30, 45 and 60 days after transplanting reduced the grain yields by 69, 47, 28 and 11 per cent respectively in the first crop. In the second crop, weeds emerging at 10 and 20 days after transplanting reduced the yield by 52.5 and 13 per cent respectively whereas weeds, which emerged later, did not significantly affect crop yield.

Panchal and Sastry (1974) revealed that increase in the duration of weed free period was accompanied by linear increase in grain yield of rice from 5.2 to 5.74 t $ha^{-1}$. Singh *et al.* (1999) reported that mean grain yield was highest in the plot kept weed free upto 60 days after transplanting. Presence of weeds for the entire crop season reduced the grain yield by about 3.7 per cent (Bhowmick, 2002). According to Dhammu and Sandhu (2002), weedy condition upto first 40 days or more had significantly less rice yield than weed free. They also reported that infestation of *Cyperus iria* throughout the crop growth period caused 64 per cent reduction in rice yield

**2.2.2 Competition for Nutrients**

Shetty and Gill (1974) observed that crop-weed competition for the nutrient was maximum during early period of crop growth and competition for soil nitrogen was maximum during 6 to 8 weeks after transplanting. Weeds are better in nitrogen uptake while the crop was more efficient in absorbing phosphate and potash from the soil. Pillai *et al.* (1976) found out that the major loss due to weed competition was that of nitrogen, which is the most essential nutrient element in rice production. The extent of nitrogen loss from unweeded plot ranged from 11 kg $ha^{-1}$ in transplanted crop to 92 kg $ha^{-1}$ in direct sown upland rice. Chakraborty (1981) reported that competition for nutrients, especially nitrogen is the major factor responsible for yield reduction in rice.

Mani (1975) reported comparatively lower amount of nitrogen uptake by weeds in transplanted rice indicating that puddling operations prior to transplanting effectively checked weed growth. Ravindran (1976) reported that nitrogen uptake by weed was negatively correlated with nitrogen uptake by crop. Singh *et al.* (1999) reported that weed free condition resulted in lower uptake of nitrogen by weeds.

Weeds remove considerable quantity of nutrients from the soil and are found to be much more than the crop plants. Sankaran *et al.* (1974) showed that the uptake of nutrients by weeds in unweeded plot were nearly nine times higher than that from plots weeded manually or using herbicides. Varughese (1978) reported that the maximum uptake of nutrients by the crop was during 31-40 days after transplanting, and out of the total uptake 55.07 per cent N, 60.18 per cent $P_2O_5$, 64.57 per cent $K_2O$ was during the critical period of weed growth *i.e.* 21-40 days after transplanting.

Among the rice weeds, *Echinochloa* spp. are the most competitive weeds for nutrients (Sahai and Bhan, 1992). Srinivasan and Palaniappan (1994) found the nutrient removal was greatest under *Marsilea minuta* compared to *Echinochloa* spp. In transplanted rice, the nutrient depletion by weeds was estimated to be 10.9, 2.6 and 9.8 kg $ha^{-1}$ of N, $P_2O_5$ and $K_2O$ respectively (Bhan and Mishra, 1993). Madhu and Nanjappa (1997) reported that the rate of increase in the uptake of major nutrients by weeds was proportional to the drymatter production of weeds. Rajan (2000) reported that N, $P_2O_5$ and $K_2O$ uptake by weeds at harvest were 8.53, 4.18 and 9.26 kg $ha^{-1}$ in unweeded check.

Mani (1975) found that herbicide use brought about an appreciable decrease in nitrogen removal by weeds, thus improving the uptake of nitrogen by the crop. Ali and Sankaran (1984) observed increased nitrogen, phosphorus and potassium uptake by rice through weed control.Lakshmi (1983) reported that N and $K_2O$ uptake by the crop was higher than $P_2O_5$ uptake at all stages of growth. Varshney (1990) observed considerable saving of N, P and K through weed control methods in transplanted rice. Nandal and Singh (1993) reported an increase in the nutrient uptake of rice by weed control treatment.

Renjan (1999) reported that at 20 days after transplanting in unweeded check, weeds removed 7.25, 3.75 and 8.13 kg N, $P_2O_5$ and $K_2O$ $ha^{-1}$ respectively, which is nearly the same quantity of nutrients removal by rice crop in the same plot (6.18, 3.33, 8.52 kg N, $P_2O_5$ and $K_2O$ $ha^{-1}$ respectively). Similarly, he reported that in the same weedy check, at 40 days after transplanting, weeds removed 23.38, 10.86 and 17.29 kg N, $P_2O_5$ and $K_2O$ $ha^{-1}$ respectively which is the same quantity of nutrients removed by rice in the same plot (22.59, 9.19 and 24.23 kg N, $P_2O_5$ and weeds are as competitive as rice crop during the critical period of crop-weed competition of 20 to 45 days after transplanting.

### 2.2.3 Competition for Light and Space

According to Zimdahl (1980), competition for light in field crop may operate throughout the crop cycle except when plants are young. Modern rice varieties with their upright canopy allow more solar radiation to penetrate through their canopy and encourage increased weed biomass compared to traditional ones with their broad and droopy leaf architecture (Gogoi *et al.*, 2000).

Smith (1968) reported that barnyard grass shaded rice during the crop season and competition was purely for light when water was not limiting. Okafor and De Datta (1976) reported that increase in dry weight of purple nutsedge population increased competition for light and reduced the light transmission ratio.Gu and Zhao (1984) observed that *Echinochloa* spp. grows faster than rice, competing for light and nutrients and decreasing the crop yield. Srinivasan and Palaniappan (1994) reported the *Echinochloa* spp. is most competitive in reducing growth and yield of rice and the light transmission ratio was lowest under *Echinochloa* spp. when compared to other rice weeds.

### 2.2.4 Effect of Competition on Crop Growth and Yield

Weed competition reduces crop yield by competing for nutrients, light and moisture. Weed infestation has direct effect on different yield attributes, which ultimately leads to yield reduction.

Ali and Sankaran (1975) noticed that severe infestation of weeds suppressed the height of rice plants. Okafor and De Datta (1974) reported that weed competition reduces the number of tillers, number of panicles and leaf area index. Renjan (1999) reported a decrease in leaf area index due to weed competition in rice.

Ramamoorthy *et al.* (1974) observed that competition reduced the productive tillers. Narayanan *et al.* (1999) reported that the number of panicles $m^{-2}$ in hand weeded plot was significantly higher than unweeded check, which were 573 and 395 respectively. Weed competition in rice lowered the filled grains $panicle^{-1}$ by 13 per cent and test weight by 4 per cent (Ghobrial, 1981). Reduction in panicle length was reported by Mabbayad and Moody (1992) and Singh *et al.* (1999). Mahapatra *et al.* (2002) and Saini and Angiras (2002) reported a decrease in thousand-grain weight due to weed competition.

The grain yield was reduced by 10-q $ha^{-1}$ as the time of removal of weeds was extended from 6 – 8 weeks after transplanting (Shetty and Gill, 1974). Ravindran (1976) found that the yield reduction caused by weeds in transplanted rice was 26.7 per cent. Varughese (1978) reported a yield reduction of 25.47 per cent in transplanted rice due to presence of weeds. Moody (1980) reported that yield reduction due to uncontrolled weed growth ranged from 20 to 25 per cent for transplanted rice and 40 to 50 per cent for rice that is broadcasted in puddled soil.

Singh (1985) reported that in India, the extent of yield reduction in rice due to weeds alone was estimated to be around 15 to 20 per cent in transplanted rice, 30 to 35 per cent in direct seeded rice under puddled condition and over 50 to 60 per cent in upland rice. Yield loss due to unchecked weed competition varies from 16.0 to 86 per cent in transplanted rice (Aurora and De Datta, 1992). In transplanted rice, weeds cause reduction of 38 (Jena and Mishra, 1992) to 56 per cent of grain yield (Chaudhury *et al.*, 1995). According to Kumari and Rao (1993) and Reddy and Gautam (1993), competition stress of weeds exerted reduction in yield of transplanted rice by 50 per cent. Upadhyay and Gogoi (1993) reported that the loss of yield occurs from 25 to 30 per cent due to unchecked weed growth.

Dhiman and Nandal (1995) estimated a yield reduction of 23.71 per cent in transplanted rice. Weeds caused a reduction of 35 to 55 per cent of grain yield (Saikia and Purushothaman, 1996) under transplanted condition. Raju and Reddy (1995) reported that transplanted rice faces 39 per cent yield reduction due to uncontrolled weeds. Brar *et al.* (1997) reported that unchecked weed growth could reduce the crop yield to tune of 33 per cent. Bhattacharya *et al.* (1998) reported that weed infestation reduces yield of rice by 42 per cent under transplanted condition. Several studies conducted in India and abroad indicate that weed incidence in lowland situation accounts for a yield loss of 11-20 per cent in transplanted rice (Ghosh and Moorthy, 1998). The extent of weed intensity caused an yield loss of 72.6 per cent in direct seeded puddled rice (Kolhe and Tripathi, 1998). Nandal *et al.* (1999) showed that in transplanted rice, the average reduction in rice grain yield was 43.2 per cent due to weed infestation.

According to Renjan (1999), yield reduction due to weeds in transplanted rice is 44.4 per cent. Weeds reduced the yield of transplanted rice by 28.7 per cent when not controlled (Mahapatra *et al.*, 2002). Malik *et al.* (2002) reported that uncontrolled weeds caused 89.9 per cent reduction in grain yield of rice when compared with weed free condition. Reddy *et al.* (2002) reported that weeds cause heavy loss in the yield of rice crop ranging from 17 to 90 per cent. Kathirvelan and Vaiyapuri (2003) reported that grain yield losses amounted to 69.9 per cent due to uncontrolled weed growth. The loss in grain yield due to unchecked weed competition was 42 per cent and 39 per cent during 2000 and 2001 respectively (Saha *et al.*, 2003).

## 2.3 METHODS OF WEED CONTROL

### 2.3.1 Manual Weeding

Hand weeding continues to be most common method of weed management in any system of rice culture. Manual weeding methods are most effective in young weeds whereas older weeds especially perennials with underground structures are difficult to control (Moody, 1977). Effectiveness of hand weeding in weed management was evidenced in a number of trials (Muthukrishnan *et al.*, 1997; Raju and Reddy, 1986; Azad *et al.* 1990). Raju and Reddy (1986) reported that hand weeding reduced weed dry weight by 88 per cent. However the re-emergence of sedges could not be controlled by hand weeding (Verma *et al.*, 1987). Patel and Mehta (1989) indicated the highest reduction of dryweed biomass with soil solarisation and hand weeding.

The manual method of weed control is laborious, back breaking and time consuming (Mani and Gautam, 1973). For smallholdings, use of traditional methods of weed control continues to be the most economical method (Scolari and Young, 1975). Ravindran (1976) reported that hand weeding on the 20$^{th}$ and 40$^{th}$ day after transplanting although gave higher yields; the net profit was lower due to increased labour charge.

Chandrakar and Chandrawanshi (1985) reported that the hand weeded plots recorded the highest number of panicles per m$^2$, highest grain yield and the least dry weight of weeds. Singh (1985) reported that hand weeding provided fairly good control because weeds from both inter and intra rows are removed, but it was very laborious and expensive. The cost-benefit ratio showed a negative return to weeding mainly due to a very high cost of labour input. Patel and Mehta (1989) indicated the highest reduction of dry weed biomass with soil solarisation and hand weeding. Moody (1991) reported manual weeding as the most common method of weed control in rice in Asia. Manual weeding by hand or hand tools is very effective but require more time and labour. Hand weeding registered higher grain yield of rice in a number of experiments (Pandey *et al.*, 1997; Singh *et al.*, 1992; Singh *et al.*, 1994). Kathiresan and Surendran (1992) observed a higher weed control efficiency of 81.9 per cent by hand weeding twice.

Singh *et al.* (1992) recorded significantly lowest dry weight of weeds and highest weed control efficiency under hand weeding twice at 30 and 60 DAT. He also recorded maximum grain yield under hand weeding at 30 and 60 DAT. Khare and Jain (1995) found that hand weeding gave the lowest weed biomass and highest weed control efficiency (60 kg $ha^{-1}$ and 91.6 per cent respectively).

Balasubramanian (1996) pointed out that number of productive tillers in rice was enhanced by hand weeding twice. Pandey *et al.* (1997) reported that maximum grain yield and net profit of Rs.6704 $ha^{-1}$ was obtained from hand weeded plots. Maximum grain yield was recorded with hand weeding treatment but it was well comparable to anilofos 0.3 kg + one hand weeding. Higher weed control efficiency was also recorded with hand weeding twice (AICRP, 1997). Hand weeding was more effective and the most common tool to control weeds in transplanted rice (Muthukrishnan *et al.*, 1997). According to Rao (2000) manual weeding is effective against annuals and biennials but do not control perennials and is expensive in areas where labour is scarce.

Laxminarayan and Mishra (2001) observed that hand weeding at 15, 30 and 40 DAT resulted in higher crop drymatter compared to anilofos 0.04 kg ai $ha^{-1}$. Two hand weedings at 20 and 40 DAT were able to control almost all categories of weeds (Bhowmick, 2002). Hand weeding twice recorded the least weed count and highest weed control efficiency (69.9 and 70.1 per cent) during first and second season respectively (Gnanavel and Kathiresan, 2002). Rekha *et al.* (2002) reported that hand weeding twice at 20 and 40 DAT resulted in lower weed density and dry weight compared to herbicide treatment and unweeded control. Pal *et al.* (2002) reported that hand weeding twice, ethoxysulfuron + anilofos resulted in higher grain yield and less weed growth compared to other treatments. Singh *et al.* (2003c) reported that hand weeding at 30 and 50 DAT recorded significantly lower weed population and drymatter accumulation of weeds over weedycheck. Kathirvelan and Vaiyapuri (2003) reported that hand weeding (20 and 40 DAT) recorded higher grain yield and straw yield (5.81 and 7.26 t $ha^{-1}$). They also added that none of the herbicide treatment could produce comparable results with hand weeding 20 and 40 DAT.

### 2.3.2 Chemical Weed Control

Though hand weeding is the common practice of weed control in rice, due to increased cost of labour and inadequate availability at the optimum time, the situation has changed, necessitating the use of chemicals. The weed control efficiency of various chemicals has been studied extensively and many herbicides are now available for rice growers. Results with herbicides in rice have been inconsistent from site to site and from year to year at the same site. Various weed species, their intensities and soil, moisture and climatic conditions may account for inconsistent results. Despite some problems in making herbicides effective, it seems that herbicides will play major role in controlling weeds in rice culture.

Chemical weed control can be considered as a better alternative (Singh and Singh, 1993). Rajkhowa *et al.* (2001) reported that available N and K increase due to herbicides probably due to reduction in nutrient removal by weeds. Narwal *et al.* (2002) reported that all herbicidal treatments gave significantly higher yield and yield attributes than weedy check. Sharma *et al.* (2003) observed that all herbicidal treatments significantly reduced the density and dry weight of weeds over weedy check.

#### *2.3.2.1 Pre Emergent Herbicides*

The use of pre-emergent herbicides makes it possible to contain weed growth from the beginning of transplanting the crop and offer scope to the crop for better utilization of resources (Sharanappa *et al.*, 1994). Herbicides applied at 4 DAT suppressed weed population. Application of pre-emergence herbicide was found to be effective in controlling weeds in rice (Reddy *et al.*, 1998).

Rangiah *et al.* (1974) reported that machete (Butachlor) granules @ 2.5 kg ai $ha^{-1}$ applied four days after transplanting provided effective weed control. Rethinum and Sankaran (1974) reported that pre-emergence application of butachlor @ 2 kg ai $ha^{-1}$ gave the best and economic weed control under transplanted condition.

According to Singh and Sharma (1981) the effect of butachlor was superior over other herbicides tried. Bernasor and De Datta (1986) reported better weed control with butachlor when applied at 4 – 6 DAT or 2 – 6 leaf stage of *Echinochloa crus-galli*. Fajardo and Moody (1987) reported that annual grasses were controlled by application of butachlor.

Bajpai and Singh (1992) observed that application of butachlor @ 1.5 kg $ha^{-1}$ upto 10 DAS significantly reduced monocot weeds (5.3 plant $m^{-2}$ and contributed for significant reduction in weed dry weight (669 kg $ha^{-1}$) than weedy check. The dicot weeds were also controlled effectively with butachlor upto 8 DAS (14.1 plants $m^{-2}$) than weedy check (17.3 plants $m^{-2}$).

Pre-emergence application of butachlor at 1.5 kg ai $ha^{-1}$ has been reported to increase the rice grain yield (Goi and Kalita, 1992). Application of butachlor 5 per cent as (30 kg $ha^{-1}$) gave significantly higher grain yield over farmer's practice. Application of butachlor @ 1.5 kg $ha^{-1}$ reduced weed population and increased the grain yield of rice (Singh *et al.*, 1992; Patil, 1994). Maximum WCE was observed in the butachlor treatment @ 1 kg $ha^{-1}$ (Gogoi and Gogoi, 1993). Singh *et al.* (1995) observed WCE of 46.1 per cent due to application of butachlor @ 1.5 kg ai $ha^{-1}$ in rainfed lowland transplanted rice.

Butachlor 1 kg $ha^{-1}$ and Pretilachlor 0.75 kg $ha^{-1}$ were at par and resulted in significantly lower weed drymatter accumulation over weedy check at 25 DAT, while at 45 DAT, butachlor 1 kg $ha^{-1}$ resulted in lowest weed drymatter accumulation (AICRP, 2001). Butachlor at 1.0 kg $ha^{-1}$ applied 30 DAT, significantly reduced the weed infestation until 45 DAT and resulted in higher rice yield over the weedy control (Rajkhowa *et al.*, 2001). The highest additional net return (Rs.51.35 $ha^{-1}$) was obtained with application of butachlor 0.5 kg $ha^{-1}$ along with closer planting (Gogoi *et al.*, 2001).

Butachlor is a pre-emergence herbicide in paddy, which is recommended at the rate of 1.25 kg ai $ha^{-1}$ at 0 – 6 days after sowing (KAU, 2002). Flufenacet and butachlor have been reported to be effective on grasses (Rekha *et al.*, 2002).

However Arceo and Mercado (1981) and Diop and Moody (1989) reported that butachlor controlled weeds poorly and the crop stand reduction caused by butachlor resulted in weed growth. Yield reduction was observed upto 16 to 18 per cent due to application of butachlor 50 EC @ 1.25 kg ai $ha^{-1}$ as compared to pretilachlor @ 750 g ai $ha^{-1}$ (Mahapatra *et al.*, 2002). Butachlor at 1000 g $ha^{-1}$ was only moderately effective in minimizing weed competition (Moorthy, 2002).

Application of pretilachlor was found to be effective in controlling *Cyperus rotundus, Cyperus iria, Echinochloa crus-galli, Eclipta alba* and *Monochoria vaginalis* (Tewari *et al.*, 1986). Cruz (1990) reported pretilachlor as one of the promising herbicides for pre-emergence application in rice. Kurmi (1991) reported that pretilachlor @ 1 kg $ha^{-1}$ enhanced spikelet number; grains $panicle^{-1}$ and grain yield of rice. Prusty and Behara (1992) compared the effect of hand weeding and pretilachlor application and recorded higher yield in pretilachlor treated plot compared to two hand weeding treatment. Application of pretilachlor @ 1.0 kg $ha^{-1}$ resulted in the highest grain yield, followed by piperophos @ 1.25 kg $ha^{-1}$ (Kulmi, 1992). He also reported that pretilachlor recorded significantly higher leaf area index throughout the growth period compared with the control. Muthukrishnan *et al.* (1994) observed that application of pretilachlor at 0.5 kg ha$^{-1}$ controlled weed population, reduced weed dry weight and increased grain yield of rice.

Pre-emergence application of pretilachlor was effective on all weeds with maximum weed control efficiency in rice ecosystem (Balasubramanian, 1997). Angiras and Rana (1998) could control the weeds like *Echinochloa, Scirpus* and *Cyperus* spp. in puddled rice with application of pretilachlor @ 800 g ai ha$^{-1}$. Pretilachlor at 0.75 and 1.0 kg ha$^{-1}$ and oxadiargyl at all the doses provided effective control of *E.colona* and sedges. The grain yield of rice due to application of butachlor 1 kg ha$^{-1}$ or pretilachlor 0.75 kg ha-1 was at par, but significantly higher than weedy check (AICRP, 2001).

Pretilachlor at 6.75 kg ha$^{-1}$ applied 3 DAT significantly reduced weed infestation until 45 DAT and resulted in higher rice yield over the weedy control (Rajkhowa *et al.*, 2001). Narayanan *et al.* (2001) reported that the highest yield of 2.13 t ha$^{-1}$ was recorded with pretilachlor at 0.50 kg ha$^{-1}$. He also reported that weed control efficiency of pretilachlor at 0.50 kg ha$^{-1}$ and 1.0 kg ha$^{-1}$ was 71.6 per cent and 69.7 per cent respectively. Islam *et al.* (2001) reported that pretilachlor 437.5 g ai ha$^{-1}$ decreased weed population and weed dry weight resulting in higher grain yield and B: C ratios.

Application of pretilachlor caused greater reduction in weed drymatter than butachlor alone, butachlor + one hand weeding and two hand weedings (Mahajan *et al.*, 2003). Pretilachlor @ 0.75 kg ai ha$^{-1}$ applied as pre-emergence herbicide in rice field significantly lowered the density of all categories of weeds (Gnanasambandan and Kumaran, 2002). Application of pretilachlor 50 EC at 500 g ai ha$^{-1}$ 5 DAT significantly reduced weed density and weed drymatter at all the stages of growth and having weed control efficiency of 82 per cent (Mahapatra *et al.*, 2002).

Anilofos is one of the recent additions to the list of rice herbicides used in India. It has pre-emergence and early post emergence activity. In transplanted crop, it can be applied but 4 to 10 DAT at 0.4 kg ai $ha^{-1}$ (Thomas and Abraham, 1998).

Balaswamy and Kondap (1989) found that in transplanted rice, anilofos and fluchloralin + 2,4-DEE were equally effective in decreasing nutrient uptake by weeds and increasing N, P and K uptake by rice. According to Munegowda *et al.* (1990), anilofos at 0.6 kg $ha^{-1}$ applied at 4or 10 DAT gave excellent control of grassy weeds, including some broad leaved species at 30 and 60 DAT and there is no significant difference in grain yields obtained from anilofos at 0.4 kg and 0.6 kg $ha^{-1}$. But the higher rate proved to be more effective in controlling weeds.

Gill *et al.* (1991), compared anilofos at 0.5 kg $ha^{-1}$ and 0.3 kg $ha^{-1}$ and found that anilofos at 0.5 kg $ha^{-1}$ resulted in lowest weed dry weight and effective control of weeds *Echinochloa crus-galli* and *Ischaemum rugesum*. But the highest rice grain yield was from plots treated with anilofos at 0.3 kg $ha^{-1}$.

Joy *et al.* (1991) on rice cv. MO-6 found anilofos 0.6 kg $ha^{-1}$ as effective and more economic than hand weeding. Nandal and Singh (1994) reported that for transplanted rice, anilofos 0.45 kg $ha^{-1}$ and 0.60 kg $ha^{-1}$ applied 5 or 10 DAT were equally effective in suppressing weed growth and resulted in higher grain yield of rice. Khare and Jain (1995) ranked the performance of weed control chemicals in transplanted rice in descending order as anilofos > thiobencarb > butachlor.

Based on trials with 0.30 to 0.45 kg ai $ha^{-1}$ anilofos applied at 3 or 6 DAT on rice cv. IR50 at Karnataka, Kumar and Basavaraj (1996) concluded that anilofos applied at 6 DAT produced grain yield which was not significantly different from yield obtained from weed free plot. Jain *et al.* (1998) reported that in rice at 60 DAT, anilofos at a higher dose of 0.6 kg $ha^{-1}$ is superior to a lower dose of 0.4 kg $ha^{-1}$ as it resulted in greatest WCE of 91.54 per cent, maximum grain yield and lowest energy utilization by weeds. Both doses of anilofos resulted in higher energy utilization by rice.

In a study conducted to ascertain the influence of different pre-emergence herbicides on weed control and crop performance in transplanted rice, Balaswamy (1999) found out that anilofos gave a higher weed control efficiency of 84.32 per cent and effectively controlled sedges and grasses. Gogoi *et al.* (2000) found anilofos 0.4 kg $ha^{-1}$ and butachlor +2,4-D mixture (1.0 kg $ha^{-1}$) in 60:40 proportions to be equally effective in controlling weeds and increasing rice yields in transplanted rice.

Ravi *et al.* (2000) evaluated different doses of the herbicide (0.41, 0.45, 0.50, 0.55, 0.60 kg ai $ha^{-1}$) in controlling weeds in transplanted rice cv. ADT 36 at Pattukkottai, Tamil Nadu and concluded that the minimum weed population and maximum rice grain yield were noticed in plots treated with anilofos at 0.6 kg ai $ha^{-1}$ and the crop growth was comparable with weed free control. Application of anilofos 0.45 kg $ha^{-1}$ or butachlor 1.0 kg $ha^{-1}$ was on par and resulted in significantly higher grain yield over weedy check (AICRP, 2001). Narayanan *et al.* (2001) reported that anilofos at 0.40 kg ai $ha^{-1}$ increased grain yield to 2.3 per cent and 60.1 per cent over butachlor at 1.5 kg $ha^{-1}$ and weeded control respectively. Malik *et al.* (2002) reported that the highest grain yield of rice (4916 kg $ha^{-1}$) was recorded in weed free condition, which was almost similar to anilofos at 400 g $ha^{-1}$ at 7 DAS..

Anilofos @ 0.4 kg ai $ha^{-1}$ produced lowest grain yield followed by metsulfuron methyl @ 0.004 kg ai $ha^{-1}$. The poor performance of anilofos was also reported by Raju and Reddy (1986).

Avudaithai *et al.* (2002) reported that compared to herbicide mixtures, single anilofos application resulted in 8 per cent and 22 per cent reduction in nutrient uptake by crop during Rabi and summer seasons. They also reported that single application of anilofos resulted in 30 and 50 per cent higher N removal and 24 and 28 per cent higher K removal by weeds during Rabi and summer season. Madhavi and Reddy (2002) reported that application of anilofos at 0.4 kg $ha^{-1}$ 8 DAS was found to be toxic. Singh *et al.* (2003a) reported that anilofos alone @ 400 g $ha^{-1}$ at 3 DAT was not effective on sedges and *Caesulia axillaris*.

Narayanan *et al.* (1999) observed that metsulfuron methyl at 0.008 kg $ha^{-1}$ recorded lowest weed density and weed dry weight with a weed control efficiency of 94 per cent and also gave 61.8 per cent yield increase over unweeded control. He also recommended metsulfuron methyl 0.008 kg $ha^{-1}$ at 3 – 9 DAT followed by hand weeding once at 40 DAT, as an efficient weed control practice. Walia *et al.* (1999) found metsulfuron methyl 0.010 and 0.015 kg $ha^{-1}$ effective in controlling broad-leaved weeds.

Chander and Pandey (1996) reported that the scented rice cv. Pusa Basmati – 1, Chlorimuron ethyl 0.012 kg ai $ha^{-1}$ was most effective against broad leaved weeds, while Singh and Bhan (1998) found that chlorimuron ethyl 0.025 kg $ha^{-1}$ applied at 15 DAT significantly lowered the weed density and weed dry matter in transplanted rice and also resulted in higher grain yield. Rice yield from chlorimuron ethyl treated plots was comparable to plots hand weeded twice at 20 and 40 DAT (Mukherjee and Bhattacharya, 1999). Chlorimuron is more effective against broadleaved weeds and it is not likely to be accepted as sole herbicide due to its little effect on grass weeds (Balyan, *et al.*, 1994).

According to Singh *et al.* (1997) chlorimuron at 4g $ha^{-1}$ did not exhibit a significant increase on paddy yield because of relatively poor control of weeds.

Bhattacharya *et al.* (2002) reported that application of chlorimuron 4 g ai $ha^{-1}$ (classic 20 WP) at 1 DAT resulted in high reduction in weeds, and gave similar level of control with that of hand weeding twice (20 and 40 DAT). He also added that higher rate of classic as pre-emergence inhibited tiller formation in rice and failed to produce satisfactory yield.

*2.3.2.2 Post Emergent Herbicides*

The chlorophenoxy herbicide, 2,4-D (2,4-dichloro phenoxy acetic acid) has been available throughout most of the Asia for the past four or five decades. Many rice growers have been using it routinely for post emergence control of annual broad leaf weeds such as *Monochoria vaginalis, Sphenoclea zeylanica*, sedges such as *Cyperus difformis, C.iria and Fimbrystylis littoralis* (De Datta, 1981). Most dicolyledonous crops are sensitive to 2,4-D (Rao, 2000).

2,4-D formulations are either esters emulsified in oil (EE) or water-soluble salts such as sodium. Of these, 2,4-D sodium salt is the most widely used formulation in rice. Ester formulations (EE) are more toxic to weeds and less selective than salt formulation.

2,4-DEE is a pre-emergent herbicide and it can be applied at 4 – 5 DAT, which may kill certain grasses besides sedges and broad-leaved weeds. For broad-spectrum weed control, 2,4-D can be combined with other pre-emergence herbicides like anilofos, butachlor, pretilachlor etc. According to Thomas and Abraham (1998) from four-leaf stage upto just before the boot stage, rice is most tolerant to application of 2,4-D.

Mahadevaswamy and Nanjappa (1991) observed reduced weed weight (56.4 q $ha^{-1}$) compared to unweeded control (83.6 q $ha^{-1}$) due to application of 2,4-D @ 1 kg 25 DAS in rice variety Jaya. Ramiah and Muthukrishnan (1992) reported better weed control and enhanced tillering of rice through sequential application of pendimethalin followed by 2,4- D sodium salt, which resulted in higher grain yield. Brar *et al.* (1997) reported that application of 2,4-D at 0.8 kg $ha^{-1}$ alone or its tank mixed or sequential combination with anilofos @ 0.6 + 0.4 kg $ha^{-1}$ respectively was effective in controlling *Caesulia axillaris* in transplanted rice. 2,4-D is recommended at 1.0 kg ha$^{-1}$ at 20 DAS or transplanting (KAU, 2002). The performance of 2,4-DEE at 0.5 kg ha$^{-1}$ in controlling weeds resulted in lower yield attributes and grain yield of rice as compared to other treatments (Saini and Angiras, 2002).

De and Mukhopadhyay (1985) showed that pre-emergence application of 2,4-D EE at 1.0 kg ha$^{-1}$ showed highest weed control efficiency of 84.23 per cent at 45 DAT. Shahi (1985) reported effective control of *Echinochloa crus-galli*, *E. colonum*, *Cyperus* spp. and other weeds in rice by applying 2,4-D EE at 1 kg ha$^{-1}$ at 4 DAT. Comparing 2,4-D sodium salt at 0.80 kg ha$^{-1}$ and 2,4-DEE at 0.75 to 0.80 kg ha$^{-1}$, both applied at 7 DAT, both were effective in controlling weeds at 21 DAT, the most effective being 2,4-D sodium salt (Tripathy and Mishra, 2000).

The post emergence of 2, 4-D sodium salt was not satisfactory and recorded lower yield (Narayanan *et al.*, 2001). The performance of 2,4-DEE at 0.5 kg ha$^{-1}$ in controlling weeds resulted in lower yield attributes and grain yield of rice as compared to other treatments (Saini and Angiras, 2002). The lowest weed control efficiency was observed in the 2,4-D sodium salt at 0.8 kg ha$^{-1}$ treated plots (Anandakrishnan and Jayakumar, 2003).

Ethoxysulfuron at the rate of 30 g ha$^{-1}$ gave better control of *Scirpus supinus* (88 %), *Cyperus difformis* (100 %), *Cyperus. iria* (100 %) and *Rotala densiflora* (100%) (Reddy *et al.*, 2000). According to Singh (2001) ethoxysulfuron at the rate of 0.15 kg ha$^{-1}$ applied at 15 DAT was quite effective in controlling weeds and it recorded comparable grain yield to that of weed free treatment. Bhowmick and Ghosh (2002) reported that ethoxysulfuron 15 WSG at 0.02 kg/ha as post emergence effectively controlled most of the sedges and broad-leaved weeds and improved both grain and straw yield. Ethoxysulfuron 30 g/ha resulted in significantly lower population of broad leaved weeds and sedges and hence lower total weed dry weight and higher yield attributes and grain yield over other treatments at 15 DAT and 20 DAS (Saini and Angiras, 2002). Sharma *et al.* (2003) reported that ethoxysulfuron alone at 15 and 20 g $ha^{-1}$ applied 8DAT was inferior in increasing number of effective tillers and grain yield of rice but was better than weedy plots.

### *2.3.2.3 Combination of pre and post Emergent Herbicides*

Herbicide combination in the form of ready mix controlled more weed species and the effective control lasted longer than the single herbicide treatment (Ravichandran, 1993). Increased efficiency of weed control by mixed application of herbicide in transplanted rice has been reported by AICRP (1997). Anilofos + ethoxysulfuron at 390 g $ha^{-1}$ applied 8 DAT and butachlor at 1500 g $ha^{-1}$ applied 3 DAT provided the similar number of effective tillers and were found on par with weed free conditions (AICRP, 2001). The grain yield of rice increased significantly with increase in corresponding dose of anilofos + ethoxysulfuron from 260 to 390 g $ha^{-1}$. Bhowmick and Ghosh (2002) reported that ethoxysulfuron 0.02 kg $ha^{-1}$ when tank mixed with anilofos 30 EC at 0.375 kg $ha^{-1}$ and applied as post emergence had a wide efficiency spectrum with regard to management of all categories of dominant weeds as well as complex weed flora in summer rice and found as effective as hand weeding twice and superior to all other rice herbicides. Ethoxysulfuron + anilofos resulted in higher grain yield and less weed growth compared to other treatments (Pal *et al.*, 2002).

Narwal *et al.* (2002) reported that ready mixture of anilofos + ethoxysulfuron showed increase in paddy yield, maximum being at 390 g $ha^{-1}$ applied 8 DAT which was at par with butachlor and weed free conditions. Application of anilofos + ethoxysulfuron (0.25 + 0.010 kg ai $ha^{-1}$) at 10 DAS and butachlor + safener (1 kg ai $ha^{-1}$) at 3 DAS have recorded significantly higher grain and straw yield over weedy check. They were on par with hand weeding twice at 20 and 40 DAS (Nagappa *et al.*, 2002). Moorthy and Saha (2002) observed superior performance of anilofos + ethoxysulfuron in terms of crop safety and weed control efficiency in puddled seeded rice.

Anilofos + ethoxysulfuron at 312 + 12 g $ha^{-1}$ reduced the population of sedges, grasses and broad leaved weeds and weed dry weight and resulted in higher WCE of 86 per cent (Rekha *et al.*, 2003). They also added that grain yield was significantly higher than unweeded check and on par with hand weeding twice (20 and 40 DAT) and butachlor at 1500 g $ha^{-1}$. Saha *et al.* (2003) reported that anilofos + ethoxysulfuron at 312 + 12 g $ha^{-1}$ and butachlor + safener at 1000 g $ha^{-1}$ controlled weeds effectively and increased grain yield of rice comparable to hand weeded plot.

Butachlor 0.1 kg $ha^{-1}$ + 2,4-D 0.4 kg $ha^{-1}$ produced significantly less weed population at harvest in comparison to other herbicides except farmer's practice (AICRP, 2001). Mixed application of 1500 g butachlor + 400 g 2,4-D registered lowest weed density (27.5 $m^2$) and weed total drymatter at 60 DAT than the weedy control and this has increased grain yield by 23 per cent than weedy control (Singh *et al.*, 2002).

Pretilachlor (0.75 kg $ha^{-1}$) + 2,4-D (0.5 kg $ha^{-1}$) is found to be effective for weed control is transplanted rice but appeared to be inferior to weedfree condition with regard to grain yield (AICRP, 1997). Pretilachlor 0.75 kg $ha^{-1}$ + 2,4-D 0.4 kg $ha^{-1}$ recorded the least weed population at 25 DAP and highest grain yield (AICRP, 2001).

Gupta (1997) reported that in transplanted rice anilofos +2,4 – DEE (0.3 + 0.4 kg/ha) resulted in greatest reduction of weed biomass. Singh *et al.* (1999) reported that pre-emergence application of mixture of anilofos + 2,4-DEE (0.4 + 0.5 kg $ha^{-1}$) recorded lower weed dry weight and higher grain yield than their single application.

Application of herbicide mixtures at 4 DAT recorded higher nutrient uptake, leaf area index, productive tillers and grain yield compared to application at 8 DAT. Ready mix application of anilofos and 2,4-D resulted in 56 and 51 per cent reduction in N removal by weeds during Rabi and summer (Avudaithai *et al.*, 2002). Application of butachlor + safener 50 EC at 1.0 kg $ha^{-1}$ within 3 DAS remaining statistically at par with anilofos + 2, 4-DEE (24 + 32 EC) at 0.40 + 0.53 kg $ha^{-1}$ at 10 DAS reduced the accumulation of drymatter by weeds significantly and resulted in higher grain yield (Bindra *et al.*, 2002). These treatments were as good as hand weeding twice (20 and 40 DAS).

Hand weeding twice at 30 and 50 DAT, anilofos 0.4 kg $ha^{-1}$ pre-emergence to weeds + 2, 4-D EE (0.5 kg $ha^{-1}$) post emergence to weeds and anilofos + 2, 4- DEE (0.4 + 0.5 kg $ha^{-1}$) pre-emergence to weed followed by one hand weeding at 30 DAT were statistically at par to each other with regard to weed growth (Singh *et al.*, 2003d).

Nandal *et al.* (1999) found hand weeding twice at 20 and 40 DAT and anilofos + 2,4 DEE ready mix (0.4 + 0.53 kg $ha^{-1}$) to be equally good with respect to grain yield, yield attributers, reduction in weed population and dry weight. Singh *et al.* (2003a) reported that tank mix application of anilofos at 400 + 2,4 – D at 40 g $ha^{-1}$ was very effective in reducing density of grasses, sedges and non-grasses. Phogat and Pandey (1998) reported that at 35 DAT, anilofos + 2,4 - D resulted in maximum decrease in drymatter accumulation owing to better control of both monocot and dicot weeds.

Almix (metsulfuron methyl 10 % and Chlorimuron ethyl 10 %) 0.008 kg ai $ha^{-1}$ applied 4 DAT resulted in grain yield statistically similar to butachlor at 1.5 kg ai $ha^{-1}$ applied 4 DAT (Bhattacharya *et al.*, 1997). According to Phogat and Pandey (1998) metsulfuron and chlorimuron did not bring appreciable reduction in grassy weeds. Sharma and Pahuja (2001) reported that metsulfuron methyl at 0.004 kg ai $ha^{-1}$ and chloromuron ethyl at 0.015 kg ai $ha^{-1}$ were effective only against broad leaved weeds. Saha *et al.* (2003) reported that the herbicide almix at 4 g $ha^{-1}$ completely controlled the major weed *Cyperus difformis* but higher population of grasses and broadleaved weeds resulted in poor weed control in almix treated plots.

Almix alone @ 4 g ai $ha^{-1}$ proved to be inferior herbicide for producing the effective tillers and grain yield of rice and it could not provide good control of weeds (Singh *et al.*, 2003b).

## 2.4 INTEGRATED WEED MANAGEMENT (IWM)

Smith and Reynolds (1966) defined integrated weed management as a weed population management that used all suitable methods in a compatible manner to reduce weed population and to maintain them at levels below those causing economic injury. According to Baldwin and Santleman (1980), IWM aimed at maintaining the growth of weed populations at ecologically, agronomically and economically acceptable levels. According to Slife (1981) objective of IWM is to create conditions unfavourable to weeds while maintain suitable for crops or other beneficial vegetation. Integrated weed management thus emphasized the integration of control tactics in a holistic manner with all other practices that influenced the ecosystem and linked weed control to the broader picture of ecosystem management.

Currently the most promising single approach for weed management is the use of manual and mechanical methods in conjunction with herbicides, which is effective, economic and environmentally sound.

Reliance on a single method of weed control such as continuous use of the same or similar herbicides could create serious problem by perennial weeds. So the recent approach in weed control is the development of integrated method of weed control using limited quantities of low cost chemicals in combination with direct and indirect weed control techniques, which may be the most effective alternative from agronomic, economic and ecological point of view.

Pre-emergence application of anilofos at 0.4 kg $ha^{-1}$ supplemented with one hand weeding at 40 DAT resulted in significantly higher grain yield, net income and B:C ratio and N uptake. It also resulted in minimum weed density and weed dry weight among chemical treatments (Singh *et al.*, 1999).

Narayanan *et al.* (1999) concluded that pre-emergence application of metsulfuron methyl @ 0.008 kg ai $ha^{-1}$ at 3 – 9 DAT followed by one hand weeding at 40 DAT can be recommended as an efficient weed management practice for low land transplanted rice. Jayakumar and Anandakrishnan (2001) reported that application of anilofos + metsulfuron methyl (300 + 3 g $ha^{-1}$) or metsulfuron methyl alone at 6 g $ha^{-1}$ followed by one hand weeding at 40 DAT controlled weeds most effectively and brought out higher grain yield. According to Yogabalalekshmi (2001) the application of Almix 0.004 kg ai $ha^{-1}$ followed by one hand weeding 30 DAT gave excellent broad-spectrum control of grasses, sedges and broad-leaved weeds apart from highest grain and straw yields.

Narayanan *et al.* (2001) reported that pretilachlor @ 0.50 kg $ha^{-1}$+ hand weeding at 30 DAS can be recommended as an effective weed management practice. Pre-emergence application of pretilachlor + safenor at 0.45 kg $ha^{-1}$ followed by one hand weeding on 35 DAS effectively controlled the weeds in direct wet seeded rice (AICRP, 2001).

Bhowmick (2002) reported that pre-emergence application of 437.5 g $ha^{-1}$ pretilachlor supplemented with one hand weeding at 40 DAT proved more effective than the sole application of same herbicide. It gave results comparable to hand weeding twice in minimizing weeds and improving crop growth and yield. Pre-emergence application of pretilachlor + safener @ 0.3 kg $ha^{-1}$ on 8 DAS + hand weeding twice on 30 and 40 DAS registered increased yield attributes and yield besides higher weed control efficiency (Raju *et al.*, 2002).

Purushotham and Hosamani (1990) reported that good control of weeds by the use of butachlor alone / and coupled with additional hand weeding as compared to farmer's practice. Summer ploughing and pre-emergence application of butachlor @ 1.5 kg $ha^{-1}$ followed by one hand weeding 30 DAT controlled weeds effectively and registered higher grain yield (Arunachalam *et al.*, 1992). Application of butachlor @ 1.5 kg ai $ha^{-1}$ + hand weeding at 30 DAT as well as application of butachlor and benthiocarb each @ 1.5 kg ai $ha^{-1}$ alone controlled the weeds more efficiently as measured by drymatter production of weeds recorded at 30 and 60 DAT (Singh *et al.*, 1992). The number of panicles $m^{-2}$ in butachlor followed by hand weeding was on par with that of hand weeding twice at 30 and 50 DAS and significantly superior to all other treatments (Madhavi and Reddy, 2002).

# MATERIALS AND METHODS

# 3. MATERIALS AND METHODS

An investigation was carried out at the Cropping Systems Research Centre (CSRC), Karamana to find out the most suitable weed management method to control the obnoxious weed flora in rice and the residual effect of applied herbicides on the succeeding crop.

The experiment was conducted during the first crop season from 9th June to 15th October in the year 2003. The details of the materials used and methods adopted for the study are presented below:

## 3.1 EXPERIMENTAL SITE

The experiment was conducted at the Cropping Systems Research Centre, Karamana, Thiruvananthapuram of the Kerala Agricultural University. It is located at 8.5°N latitude and 76.9°E longitude and at an altitude of 29 m above mean sea level.

### 3.1.1 Soil

The soil of the experimental site was sandy loam with pH 5.3, low in cation exchange capacity, available N and medium in available P and K contents. Soil samples were collected from 30 cm depth and a composite sample was used for the determination of physico-chemical properties. The important physico-chemical properties studied are given in Table 2.

### 3.1.2 Weather Conditions

Data on weather conditions like temperature, rainfall and relative humidity were obtained from the meteorological observatory at College of Agriculture, Vellayani. The average values of climatic parameters for the cropping period are given in Appendix -1 and graphically represented in Fig. 1. Mean maximum and minimum temperature ranged from 29.9°C to 34.18°C and 23.21°C to 24.04°C respectively. The mean relative humidity ranged from 71.8 to 91.57 per cent. The total rainfall received during the cropping period was 453.80 mm.

Table 2 Soil characteristics of the experimental site

| Sl.no. | Fractions | Content in soil | Method used |
|---|---|---|---|
| A. Mechanical composition | | | |
| 1. | Sand (%) | 72.0 | International pipette method (Piper, 1967) |
| 2. | Silt (%) | 7.1 | |
| 3. | Clay (%) | 20.0 | |
| 4. | Textural class | Sandy loam | |
| B. Chemical properties | | | |
| 1. | Available Nitrogen (Kg $ha^{-1}$) | 240 | Alkaline Permanganate method (Subbiah& Asija, 1956) |
| 2. | Available $P_2O_5$ (Kg $ha^{-1}$) | 26 | Bray colorimetric Method (Jackson, 1973) |
| 3. | Available $K_2O$ (Kg $ha^{-1}$) | 158 | Ammonium acetate method (Jackson, 1973) |
| 4. | Soil reaction (pH) | 5.2 | 1:2.5 soil solution ratio using pH meter with glass electrode (Jackson, 1973) |

## 3.2 MATERIALS

### 3.2.1 Seed Material

The rice variety selected for the experiment was 'Kanchana' (ptb-50) released from RARS, Pattambi, the progeny of a cross between IR-36 and Pavizham. Kanchana is a red kerneled variety, having duration of 110-120 days. It is reported to be resistant to the incidence of rice

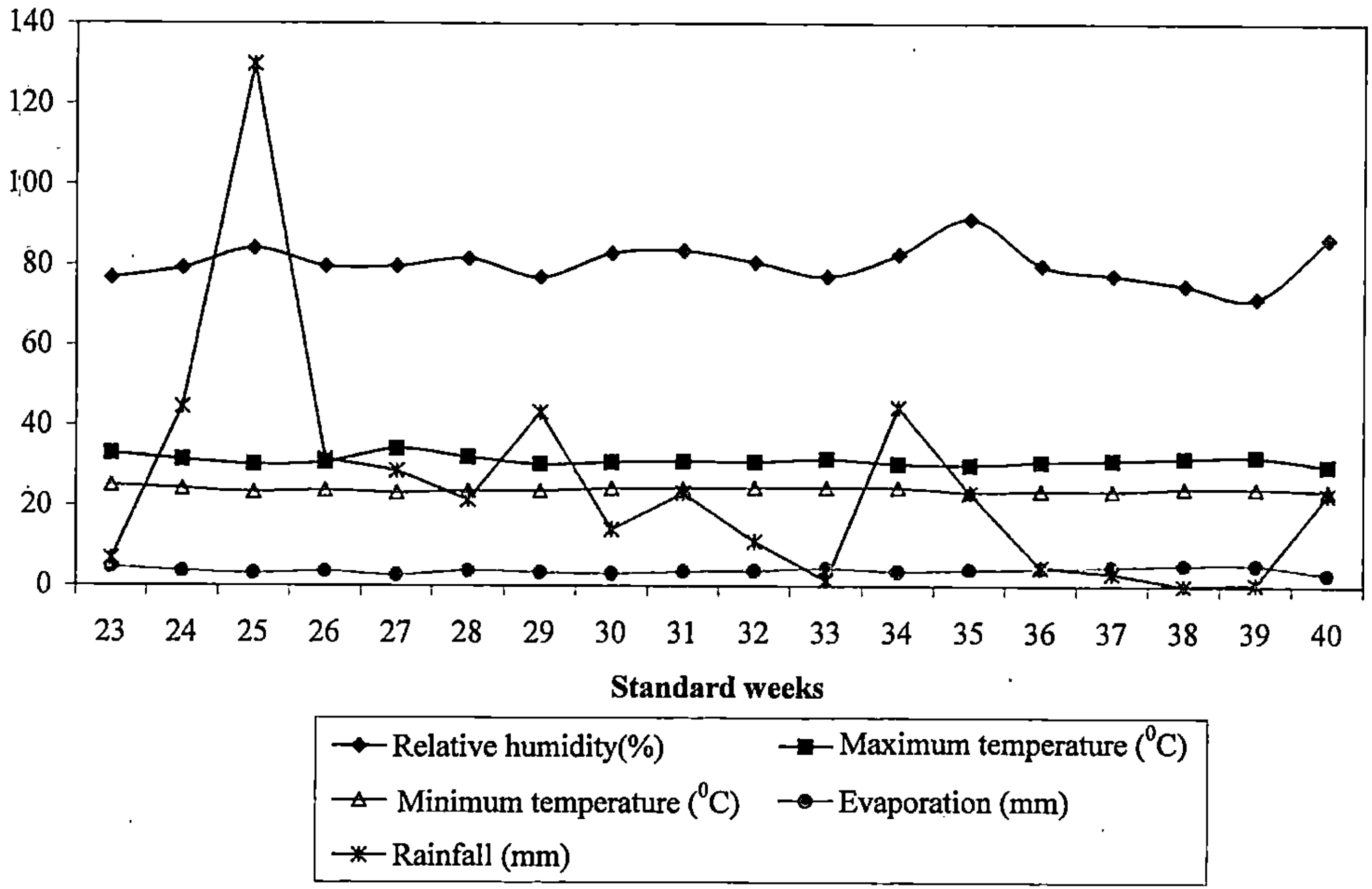


**Fig. 1 Weather parameters during the cropping period (June to October 2003)**

diseases such as sheath blight, blast, brown spot, tungro virus and to insects like stemborer and gall midge. The seeds are moderately dormant and have an yield potential of 5 t $ha^{-1}$.

### 3.2.2 Source of Seed Material

The seeds of Kanchana were obtained from CSRC, Karamana.

### 3.2.3 Manures and Fertilizers

Farmyard manure with an analytical value of 0.4, 0.3, 0.2 per cent N, $P_2O_5$, $K_2O$ respectively was used for the experiment. Urea (46 % N), mussoriephos (20 % $P_2O_5$) and muriate of potash (60 % $K_2O$) were used as source of nitrogen (N), phosphorus (P) and potassium (K) respectively.

### 3.2.4 Herbicides

The herbicides Butachlor, 2,4-D sodium salt, Anilofos, Almix, One shot, Pretilachlor, ethoxysulfuron were applied according to the treatments.

1. Butachlor: N- (butoxymethyl)-2-chloro-2, 6-diethyl-acetanilide
   Formulation: 50 per cent EC
   Trade name: Butachlor
   Produced by: Hoechst India Ltd.
   Price: Rs.240 $l^{-1}$

2. Anilofos: (5-4-chlorophenyl-N- isopropyl-carbianiloyl methyl)-0,0-dimethyl phosphorothioate
   Formulation: Anilofos 30 % EC
   Trade name: Aniloguard
   Produced by: Gharda chemicals Ltd.
   Price: Rs.50/250 ml

3. 2,4-D Sodiumsalt: Sodium salt of 2,4-dichlorophenoxy acetic acid
   Formulation: 2,4-D sodium salt 80 % WP

Trade name: Weed killer

Produced by: Akruthi Trexim Pvt. Ltd.

Price: Rs. 190 $kg^{-1}$

4. Metsulfuron methyl and chlorimuron ethyl

Formulation: Metsulfuron methyl 10 % + chlorimuron ethyl 10 %

Trade name: Almix 20 % WP

Produced by: Du Pont de Nemours and Company

Price: Rs. 160 / 8 g

5. Pretilachlor: 2-chloro-2, 6-diethyl-N- (2-propoxyethyl) acetanilide

Formulation: Pretilachlor 50% EC

Trade Name: Rifit

Produced by: Hindusthan Ciba-geigy Limited

Price: Rs.410 $l^{-1}$

6. Ethoxysulfuron: 3-(4,6-dimethoxypyrimedin-2-yl) 1-(ethoxy phenoxy sulfuronyl)-urea

Formulation: Ethoxysulfuron 15 % WDG

Trade Name: Sunrice

Produced by: Aventis Crop Science India Ltd.

Price: Rs.62/10 g

7. Anilofos + 2,4-D ethyl ester: (5-4-chlorophenyl-N- isopropyl-carbianiloyl methyl)-0,0-dimethyl phosphorothioate + Ethyl ester of 2,4-dichlorophenoxy acetic acid

Formulation: Anilofos 24 per cent + 2,4-DEE 32 % EC

Trade name: One shot

Produced by: Agro Evo

Price: Rs.450 $l^{-1}$

### 3.2.5 Cucumber Seeds

Cucumber seeds used for herbicide residue test were collected from the Instructional Farm, College of Agriculture, Vellayani.

## 3.3 METHODS

### 3.3.1 Design and Layout

The experiment was laid out in randomized block design (RBD) with twelve treatments replicated thrice. Altogether there were 36 treatment combinations. The layout plan of the experiment is given in Fig. 2. General view of the experimental field is given in Plate 1. The details of the layout are given below.

| | |
|---|---|
| Design | : Randomized Block Design (RBD) |
| Treatment | : 12 |
| Replications | : 3 |
| Gross plot size | : 5 x 4 m |
| Net plot size | : 4.4 x 3.6 m |
| Spacing | : 15 x 10 cm |
| Variety | : Kanchana |
| Season | : Kharif 2003 |

Two rows of plants were left on border on all the sides and the observations were taken from the net plot area.

### 3.3.2 Treatments

$T_1$- Butachlor (1.25 kg ai $ha^{-1}$) + 2, 4-D sodium salt (1.0 kg ai $ha^{-1}$)

$T_2$- Butachlor (1.25 kg ai $ha^{-1}$) + one hand weeding

$T_3$- Anilofos 24 per cent + 2,4-D ethyl ester (1.0 kg ai $ha^{-1}$)

$T_4$- Anilofos 24 per cent + 2,4-D ethyl ester (1.0 kg ai $ha^{-1}$) + one hand weeding

$T_5$- Pretilachlor (1.0 kg ai $ha^{-1}$) + one hand weeding

$T_6$- Pretilachlor (1.0 kg ai $ha^{-1}$) + 2,4-D sodium salt (1 kg ai $ha^{-1}$)

$T_7$- Anilofos (0.325 kg ai $ha^{-1}$) + ethoxysulfuron (0.012 kg $ha^{-1}$)

$T_8$- Anilofos (0.325 kg ai $ha^{-1}$) + ethoxysulfuron (0.012 kg $ha^{-1}$) + one hand weeding

$T_9$-Metsulfuron methyl and chlorimuron ethyl (0.004 kg $ha^{-1}$)

N

| | | | | | | |
|---|---|---|---|---|---|---|
| $R_3$ | $R_3T_2$ | $R_3T_8$ | $R_3T_{10}$ | $R_3T_4$ | $R_3T_1$ | $R_3T_6$ |
| | $R_3T_{11}$ | $R_3T_7$ | $R_3T_3$ | $R_3T_9$ | $R_3T_{12}$ | $R_3T_5$ |
| $R_2$ | $R_2T_4$ | $R_2T_2$ | $R_2T_7$ | $R_2T_1$ | $R_2T_{11}$ | $R_2T_5$ |
| | $R_2T_{12}$ | $R_2T_6$ | $R_2T_3$ | $R_2T_{10}$ | $R_2T_9$ | $R_3T_8$ |
| $R_1$ | $R_1T_3$ | $R_1T_{12}$ | $R_1T_6$ | $R_1T_{10}$ | $R_1T_9$ | $R_1T_{11}$ |
| | $R_1T_7$ | $R_1T_4$ | $R_1T_5$ | $R_1T_1$ | $R_1T_8$ | $R_1T_2$ |

**Fig. 2 Layout plan of the experimental field**

$T_{10}$-Metsulfuron methyl and chlorimuron ethyl (0.004 kg $ha^{-1}$) + one hand weeding

$T_{11}$-Two hand weeding

$T_{12}$- Unweeded control

**3.3.3 Cultural Practices**

All cultural practices except weed management were carried out as per Package of Practices Recommendations 'Crops' (KAU, 2002).

*3.3.3.1 Nursery*

Nursery was prepared and seeds were sown in the nursery at the rate of 80 kg $ha^{-1}$ on $10^{th}$ June 2003.

*3.3.3.2 Main Field Preparation*

The experimental area was well ploughed puddled, levelled and weeds and stubbles were removed. Three blocks with 12 plots each were laid out. The plots were separated with bunds of 30 cm in height and were properly levelled.

*3.3.3.3 Application of Manures and Fertilizers*

Farmyard manure was applied to all plots at the rate of 5 t $ha^{-1}$. Urea, mussoriephos and muriate of potash were applied to supply N, $P_2O_5$ and $K_2O$ at the rate of 70, 35 and 35 kg $ha^{-1}$ respectively (KAU, 2002).

Two-third dose of N, full dose of $P_2O_5$ and half dose of $K_2O$ were applied as basal dose. The remaining doses of N and $K_2O$ were applied at panicle initiation to all treatments.

*3.3.3.4 Transplanting*

Twenty five day old, healthy seedlings were gently uprooted from nursery, roots washed and transplanted in the main field at the rate of 2 seedlings $hill^{-1}$.


**Plate 1 General view of the experimental field**

*3.3.3.5 Weed Management*

Weeding as per treatments was done. At 20 DAT 2,4-D sodium salt was applied as postemergent to $T_1$ and $T_6$. One handweeding was given at 20 DAT to treatments $T_2$and $T_{11}$. At 40 DAT handweeding was given to $T_4$, $T_{11}$, $T_8$ and $T_{10}$. All other herbicides are applied as pre emergent.

*3.3.3.6 Plant Protection*

One spray of methyl parathion (0.05 per cent) was given against leaf folder with knapsack sprayer.

*3.3.3.7 Harvest*

The net plot area was harvested separately, threshed, winnowed and weight of grains and straw from individual plots were recorded.

## 3.4 OBSERVATIONS

### 3.4.1 Observation on Weeds

*3.4.1.1 Weed Flora*

Weeds from the experimental area during the experiment were identified and recorded.

*3.4.1.2 Absolute Density (Ad)*

Absolute weed density was recorded by placing 25 x 25 cm quadrate at random in four sites in each plot and calculating the average. The weeds were categorized into grasses, broadleaved weeds and sedges and the absolute density was recorded at 20, 40, 60$^{th}$ days after transplanting using the formula suggested by Philips (1959).

Ad = Total number of weeds of a given species $m^{-2}$

*3.4.1.3 Relative Density (Rd)*

Relative density (Rd) of grasses, broadleaved weeds and sedges were worked out separately at 20, 40, 60 DAT using the formula put forward by Philips (1959).

$$Rd = \frac{\text{Absolute density of a species}}{\text{Total absolute density of all species}} \times 100$$

*3.4.1.4 Absolute Frequency (Af)*

Absolute frequency was computed at 20, 40, 60 DAT according to the equation developed by Philips (1959). Absolute weed frequency of grasses, broadleaved weeds and sedges were recorded separately.

$$Af = \frac{\text{Number of quadrates in which a given species occurred}}{\text{Total number of quadrates used}} \times 100$$

*3.4.1.5 Relative Frequency (Rf)*

The computation of relative weed frequency was done 20, 40 and 60 DAT separately for grasses, broad-leaved weeds and sedges using the relationship developed by Philips (1959).

$$Rf = \frac{\text{Absolute frequency of a species}}{\text{Total of absolute frequencies of all species}} \times 100$$

*3.4.1.6 Summed Dominance Ratio (SDR)*

Summed Dominance Ratio (SDR) was worked out at 20, 40, 60 DAT according to the equation developed by Sen (1981). Summed dominance ratio of grasses, broadleaved weeds and sedges were worked out separately.

$$SDR = \frac{\text{Relative density + Relative frequency}}{2}$$

*3.4.1.7 Weed Drymatter*

Weed samples for taking dry weight were collected from the area left aside for taking destructive samples. Weeds coming inside the quadrate were pulled out carefully with roots intact, washed, dried under shade and then overdried at $80\pm5^0$C to a constant weight. The dry weight was expressed in g $m^{-2}$. Weed dry weight was recorded at 20, 40, 60 DATand at harvest

*3.4.1.8 Weed Control Efficiency (WCE)*

Weed control efficiency was calculated by adopting the formula suggested by Mani et al. (1973).

$$WCE = \frac{WDWC - WDWT}{WDWC} \times 100$$

Where,

WCE – weed control efficiency

WDWC – weed dry weight in unweeded (control) plot

WDWT – Weed dry weight in treated plot

**3.4.2 Observation on Crop**

***3.4.2.1 Crop Growth Characters***

***3.4.2.1.1 Height of the plant***

The height of the plant was recorded at 20, 40, 60 DAT and at harvest. Height of five randomly selected plants from the net plot area was measured from the base of the plant to the tip of the longest leaf or the tip of the longest earhead whichever was taller and the average was recorded in centimetres.

***3.4.2.1.2 Number of Tillers Hill$^{-1}$***

The number of tillers per hill was worked out from five randomly selected hills at 20, 40, 60 DAT and at harvest.

*3.4.2.1.3 Leaf Area Index (LAI)*

Leaf area index was determined at harvest. Five sample hills were selected and the maximum width (w) and length (l) of all the leaves of the middlemost tiller of each hill was measured and leaf area index was calculated according to the method developed by Gomez (1972). Leaf area of a single leaf was worked out using the relationship. Leaf area = k x l x N, where K is the adjustment factor which is 0.6 at harvest.

Leaf area $hill^{-1}$ = Total leaf area of middle most tiller × Total number of tillers

$$LAI = \frac{\text{Sum of leaf area / hill of 5 sample hills } (cm^2)}{\text{Area of land covered by that hills } (cm^2)} \times 100$$

*3.4.2.1.4 Drymatter Production*

From each plot five hills were uprooted at harvest. They were washed, dried in shade and later in a hot air oven till a constant weight is attained. Dry weights of the plants were found out and drymatter production was expressed in kg $ha^{-1}$.

*3.4.2.2 Yield Attributes*

*3.4.2.2.1 Number of Productive tillers $m^{-2}$*

At harvest, the number of productive tillers was obtained from five randomly selected hills in the net plot area and was expressed as number of productive tillers $m^{-2}$.

*3.4.2.2.2 Length of Panicle*

Ten panicles were taken randomly from the net plot area and average panicle length was measured and expressed in cm.

*3.4.2.2.3 Weight of Panicle*

Weight of panicle was obtained from ten randomly selected panicles and expressed in grams.

*3.4.2.2.4 Number of Spikelets per Panicle*

Number of spikelets per panicle was found out by counting the grains from ten randomly selected panicles in each plot.

*3.4.2.2.5 Number of Filled Grains per Panicle*

Number of filled grains per panicle was obtained by counting the number of filled grains from ten panicles randomly taken from each plot and taking the mean number of grains per panicle.

*3.4.2.2.6 Chaff Percentage*

Total number of spikelets per panicle and number of unfilled grains per panicle were obtained from ten randomly selected panicles and chaff percentage was worked out using the following relationship

$$\text{Chaff percentage} = \frac{\text{Number of unfilled grains per panicle}}{\text{Number of filled grains per panicle}} \times 100$$

*3.4.2.2.7 Thousand Grain Weight*

One thousand grains were counted from the cleaned and dried produce from the net plot area of each plot and the weight of the grains was recorded in grams.

*3.4.2.2.8 Grain Yield*

The net plot area was harvested individually, threshed, cleaned, dried and weight was recorded and expressed in kg $ha^{-1}$.

*3.4.2.2.9 Straw Yield*

The straw obtained from net plot area was dried in sun, weighed and expressed in kg $ha^{-1}$.

*3.4.2.2.10 Harvest Index (HI)*

Harvest index was worked out using the following formula suggested by Donald and Hanohlin (1976).

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

*3.4.2.2.11 Weed Index (WI)*

Weed index was calculated according to the equation suggested by Gill and Vijayakumar (1969).

$$WI = \frac{X - Y}{X} \times 100$$

X – yield from weed free plot or from the treatment, which recorded minimum number of weeds

Y – yield from the plot for which weed index is to be worked out

## 3.5 CHEMICAL ANALYSIS

*3.5.1 Soil Analysis*

Composite soil samples collected before the start of the experiment was analysed to determine the available N, available $P_2O_5$ and available $K_2O$. The physical composition and pH were also determined. After the harvest of the crop, soil samples were taken from each plot separately and analysed for available N, P, K.

*3.5.1.1 Physical Composition of Soil*

Percentage of coarse sand, fine sand, silt and clay were determined by International Pipette Method (Piper, 1967).

*3.5.1.2 Available Nitrogen*

Available nitrogen content of the soil was estimated by alkaline permanganate method (Subbiah and Asija, 1956).

*3.5.1.3 Available $P_2O_5$*

Available $P_2O_5$ content was determined by Dickman and Brays molybdenum blue method. Bray No.1 reagent was used for extraction (Jackson, 1973).

*3.5.1.4 Available $K_2O$*

Available $K_2O$ was determined using neutral normal ammonium acetate extract and estimated using EEL Flame Photometer (Jackson, 1973).

*3.5.1.5 Soil Reaction*

pH of the soil was estimated using 1:2.5 soil water suspension using Perkin Elmer pH meter (Jackson, 1973).

**3.5.2 Plant Analysis**

The weed samples uprooted 20, 40 and 60 DAT and the rice plants uprooted at harvest were analysed for total N, P and K. After harvest, the grains were analysed separately for total nitrogen content. The samples were dried in a electric hot air oven to constant weight, ground and passed through a 0.5 mm sieve. The required quantity of samples were weighed out accurately in an electronic balance, subjected to acid extraction and used for analysis.

*3.5.2.1 Total Nitrogen Content*

Total nitrogen content was estimated by modified microkjeldal method (Jackson, 1973).

*3.5.2.2 Total Phosphorus Content*

Total phosphorus content was found out using Vanadomolybdo phosphoric yellow colour method (Jackson, 1973).

*3.5.2.3 Total Potassium Content*

Total potassium content in plant was determined using EEL Flame Photometer (Jackson, 1973).

3.6 UPTAKE OF NUTRIENTS

The uptake of N, P and K weeds at 20, 40 and 60 DAT and by the crop at harvest were calculated as the product of content of these nutrients and the respective plant dry weight and expressed as kg $ha^{-1}$.

3.7 PROTEIN CONTENT OF RICE GRAINS

The protein content of grains was computed by multiplying the percentage nitrogen content of grains by 6.25 (Simpson *et al.*, 1965).

## 3.8 OBSERVATION ON RESIDUAL EFFECT OF HERBICIDES

Hundred cucumber seeds were sown in 1 $m^2$ area in each plot treated with herbicides and also in control plot.

### 3.8.1 Germination Percentage

Germination count was taken ten days after sowing and recorded.

### 3.8.2 Speed of Germination

The number of seedlings emerged was recorded daily until the final count day (10DAS). The speed of germination was calculated by adding the quotients of the daily count divided by the number of days for germination (Agarwal, 1980).

### 3.8.3 Seedling Vigour

Seedling vigour index (VI) was calculated by adopting the formula suggested by Abdul-Baki and Anderson (1973) and expressed as a number

VI = Germination percent x (Root length + Shoot length)

Ten seedlings were uprooted after ten days and the length of the shoots were measured from the collar region to the base of the terminal bud, the mean worked out and expressed in cm. The root length was measured from the collar region to the root tip. The average was worked out and expressed in cm

## 3.9 SHIFT IN WEEDFLORA IN NEXT RICE

Impact of different herbicides on shift in weed flora in next rice is to be observed.

## 3.10 ECONOMICS OF CULTIVATION

For analyzing the economics of cultivation, net income and benefit cost ratio were determined based on cost of cultivation and prevailing price of the crop produce.

### 3.10.1 Cost of Cultivation

Cost of cultivation was worked out for all treatments.

### 3.10.2 Net Income

Net income was computed using the formula,

Net income (Rs. $ha^{-1}$) = Gross income – Total expenditure

### 3.9.3 Benefit Cost Ratio (BCR)

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

## 3.11 STATISTICAL ANALYSIS

The data generated were subjected to analysis of variance (Panse and Sukhatme, 1967). The data, which do not satisfy the basic assumptions of ANOVA, were transformed using angular and square root transformation ($\sqrt{n+1}$) and the transformed values were used for analysis of variance. Whenever the result was significant the critical difference was worked out at 5 per cent probability.

# RESULTS

# 4. RESULTS

A field experiment was conducted at Cropping Systems Research Centre, Karamana, Thiruvananthapuram to evolve a suitable integrated weed management practice for lowland rice. The results of the experiment are presented in this chapter.

## 4.1 OBSERVATION ON WEEDS

Observation on weeds were gathered from the area set apart for that purpose. The data were statistically analysed after appropriate transformation.

### 4.1.1 Major Weedflora in Experimental Field

The different weed species observed in the experimental field were identified and categorized into grasses, sedges and broadleaved weeds.

*Echinochloa colona* (L.) Link, *Echinochloa crus-galli* (L.) Beauv. were the most important grassy weeds. Among sedges *Cyperus iria* L., *Cyperus difformis* L. and *Fimbrystylis miliaceae* (L.) Vahl. were the predominant ones. *Ludwigia parviflora* Roxb. and *Monochoria vaganalis* (Burm. F.) Kunth. and *Sphenocloea zeylanica* were the most problematic broadleaved weeds observed. Detailed list of all the weed species observed is given in Table 3.

Table 3 Weed species observed in the experimental site

| **Grasses** | **Broadleaves weeds** | **Sedges** |
|---|---|---|
| *Echinochloa colona* | *Ludwigia parviflora* | *Cyperus iria* |
| *Echinochloa crus-galli* | *Monochoria vaginalis* | *Cyperus difformis* |
| *Cynadon dactylon* | *Marsilea quadrifolia* | *Cyperus rotundus* |
| *Panicum repens* | *Sphenoclea zeylanica* | *Fimbrystylis miliaceae* |

### 4.1.2 Absolute Density

#### *4.1.2.1 Absolute Density of Grasses*

The results are presented in Table 4.

All the treated plots recorded less density of weeds. At 20 DAT, minimum weed density was detected in $T_6$ and $T_5$ which were on par. Among the treated plots excluding $T_{11}$, maximum density was detected in $T_9$ and $T_{10}$ which were on par. The weed population from $T_8$, $T_3$ and $T_7$ were found to be less than that of other treatments except $T_5$ and $T_6$. At 40 DAT, also all the treated plots were found to have less weed population. Here also, $T_6$ and $T_5$ were found to control maximum weeds followed by $T_4$ and $T_8$. The treatments $T_3$ and $T_7$ were on par and was found to control weeds better than $T_1$, $T_2$, $T_{10}$ and $T_{11}$. At 60 DAT also, all the treated plots were found to control weeds. Maximum control was obtained from $T_5$ and $T_6$ which were on par. $T_8$ was the next best treatment $T_7$, $T_3$, $T_1$ and $T_2$ were on par and was found to be better than $T_4$, $T_{10}$, $T_9$ and $T_{11}$. Here also, $T_9$ and $T_{10}$ were found to be on par. However at harvest stage, the response of treatments was not in the order, as they showed in the previous stages. Here $T_6$, $T_1$, $T_5$ and $T_2$ were on par and $T_6$, $T_1$ and $T_5$ were found to be better than the remaining treatments. $T_2$ was found to be more effective than $T_7$, $T_3$, $T_4$, $T_{10}$, $T_9$ and $T_{11}$ but on par with $T_5$ and $T_8$ while $T_8$ performed better than all treatments except $T_1$ and $T_6$.

#### *4.1.2.2 Absolute Density of Broadleaved Weeds*

The results are presented in Table 5.

At 20 DAT, all the treated plots registered lesser absolute density of broadleaved weeds. $T_7$ and $T_8$ were on par and were found to control weeds more than any other treatment. $T_1$ is found to be effective than all the remaining treatments except $T_7$ and $T_8$. At 40 DAT also, all the treated plots registered lesser population of broadleaved weeds,

Table 4. Effect of weed management practices on absolute density of grasses, number $m^{-2}$

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 7.02 (2.83) | 14.97 (4.00) | 25.83(5.08) | 22.37(4.83) |
| $T_2$ | 7.08 (2.84) | 15.08 (4.01) | 25.84(5.08) | 22.87(4.89) |
| $T_3$ | 6.57 (2.75) | 13.08(3.75) | 25.50(5.05) | 23.87(4.99) |
| $T_4$ | 6.91 (2.81) | 12.39(3.66) | 26.83(5.18) | 24.31(5.03) |
| $T_5$ | 5.24 (2.50) | 10.74(3.43) | 23.42(4.84) | 22.43(4.84) |
| $T_6$ | 5.24 (2.50) | 10.87(3.44) | 26.60(4.86) | 22.31(4.83) |
| $T_7$ | 6.71 (2.78) | 13.19(3.77) | 25.47(5.05) | 23.63(4.96) |
| $T_8$ | 6.33 (2.71) | 12.85(3.72) | 24.64(4.96) | 23.13(4.91) |
| $T_9$ | 8.90(3.15) | 16.37(4.17) | 28.21(5.31) | 25.70(5.17) |
| $T_{10}$ | 8.55(3.09) | 16.72(4.21) | 27.90(5.28) | 25.48(5.15) |
| $T_{11}$ | 41.70 (6.53) | 40.12(6.41) | 31.17(5.58) | 27.89(5.37) |
| $T_{12}$ | 51.10(7.22) | 92.13(9.65) | 146.77(12.16) | 144.84(12.08) |
| $F_{11,22}$ | 3212.33** | 91951.63** | 14824.11** | 6865.55** |
| SE | 0.028 | 0.006 | 0.017 | 0.025 |
| CD | 0.083 | 0.017 | 0.049 | 0.072 |

** Significant at 1 per cent level

Figures in parenthesis denote transformed values

Table 5. Effect of weed management practices on absolute density of broad leaved weeds, number $m^{-2}$

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 1.62(1.62) | 6.35(2.71) | 14.68(3.96) | 22.05(4.80) |
| $T_2$ | 1.91(1.71) | 7.32(2.89) | 16.71(4.21) | 23.75(4.97) |
| $T_3$ | 1.91(1.71) | 8.66(3.11) | 18.33(4.40) | 25.05(5.10) |
| $T_4$ | 1.82(1.68) | 7.15(2.85) | 17.49(4.30) | 24.58(5.06) |
| $T_5$ | 1.91(1.71) | 8.32(3.05) | 15.73(4.09) | 23.64(4.96) |
| $T_6$ | 1.88(1.70) | 7.92(2.99) | 14.90(3.99) | 22.17(4.81) |
| $T_7$ | 1.04(1.43) | 4.71(2.39) | 14.27(3.91) | 22.10(4.80) |
| $T_8$ | 1.01(1.42) | 4.60(2.37) | 13.93(3.86) | 21.74(4.77) |
| $T_9$ | 1.82(1.68) | 7.74(2.96) | 15.47(4.06) | 24.13(5.01) |
| $T_{10}$ | 1.77(1.67) | 7.62(2.93) | 15.26(4.03) | 24.09(5.01) |
| $T_{11}$ | 12.75(3.71) | 16.78(4.22) | 24.18(5.02) | 31.16(5.67) |
| $T_{12}$ | 22.41(4.84) | 27.46(5.33) | 34.43(5.95) | 43.30(6.66) |
| $F_{11,22}$ | 16408.04** | 7557.50** | 1669.51** | 366.10** |
| SE | 0.083 | 0.095 | 0.015 | 0.028 |
| CD | 0.024 | 0.028 | 0.043 | 0.082 |

** Significant at 1 per cent level

Figures in parenthesis denote transformed values

maximum control obtained from $T_7$ and $T_8$ which were on par and followed by $T_1$, $T_4$ and $T_2$ which were superior than remaining treatment. At 60 DAT, all the treatments were effective and maximum control being obtained from $T_8$ followed by $T_7$. $T_1$ was found to control weeds better than all treatments except $T_7$ and $T_8$. Among the other treated plots excluding $T_{11}$; $T_3$, $T_4$ and $T_2$ were found to be less effective. At harvest, differential response was obtained. $T_8$, $T_7$, $T_1$ and $T_6$ were on par and were found to be more effective than the remaining treatments. Among the other treatments excluding $T_{11}$; $T_3$ and $T_4$ were found to be less effective.

#### *4.1.2.3 Absolute Density of Sedges*

The results are presented in Table 6.

At 20 DAT, all the treatments were found to control the weeds. Maximum control being obtained from $T_7$ and $T_8$. Among the treatments excluding $T_{11}$; $T_9$ and $T_1$ were the least effective and they were on par. At 40 DAT, all the treated plots registered less number of weeds than $T_{11}$ and $T_{12}$. Maximum control is obtained from $T_8$ followed by $T_4$ and $T_7$ which were on par. $T_2$, $T_{10}$, $T_5$, $T_9$ and $T_3$ were on par and less effective. At 60 DAT, all the treatments were found to control the weeds, maximum control being obtained from $T_4$ and $T_6$ which were on par. $T_1$ and $T_5$ were found to be better than the remaining treatments. At this stage, $T_7$ and $T_9$ were found to be on par with $T_{11}$ while $T_{10}$ was on par with $T_7$ and $T_9$. Among the treatments $T_7$, $T_9$ and $T_{10}$ were less effective. At harvest stage also, treated plots registered less number of weeds. Maximum control is obtained from $T_4$ followed by $T_3$, $T_8$ and $T_7$. The treatments $T_6$, $T_9$, $T_1$ and $T_{10}$ were found to be on par and was found to control weeds better than $T_2$, $T_5$ and $T_{11}$. $T_2$ and $T_5$ were found to be least effective and they faired worse than $T_{11}$.

Table 6. Effect of weed management practices on absolute density of sedges, number $m^{-2}$

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 1.70(1.64) | 6.13(2.67) | 25.37(5.13) | 9.13(3.18) |
| $T_2$ | 1.86(1.69) | 6.77(2.79) | 26.18(5.21) | 13.25(3.78) |
| $T_3$ | 1.82(1.68) | 6.34(2.71) | 25.97(5.19) | 7.13(2.85) |
| $T_4$ | 1.69(1.64) | 5.32(2.51) | 24.18(5.02) | 5.89(2.62) |
| $T_5$ | 1.73(1.65) | 6.57(2.75) | 25.37(5.13) | 11.74(3.57) |
| $T_6$ | 1.67(1.63) | 6.23(2.69) | 24.65(5.06) | 9.49(3.24) |
| $T_7$ | 1.08(1.44) | 5.37(2.52) | 27.59(5.35) | 8.15(3.24) |
| $T_8$ | 1.04(1.43) | 4.90(2.43) | 26.72(5.26) | 7.68(3.02) |
| $T_9$ | 3.31(2.07) | 6.52(2.74) | 27.48(5.34) | 9.49(2.94) |
| $T_{10}$ | 3.22(2.06) | 6.55(2.75) | 27.27(5.32) | 9.12(3.24) |
| $T_{11}$ | 13.21(3.77) | 17.18(4.26) | 28.02(5.39) | 11.07(3.18) |
| $T_{12}$ | 17.43(4.29) | 26.97(5.29) | 36.38(6.11) | 14.64(3.47) |
| $F_{11,22}$ | 5701.47** | 986.45** | 236.38** | 246.10** |
| SE | 0.012 | 0.027 | 0.018 | 0.024 |
| CD | 0.036 | 0.080 | 0.054 | 0.072 |

** Significant at 1 per cent level

Figures in parenthesis denote transformed values

*4.1.2.4 Total Absolute Density*

The results are presented in Table 7.

At 20 DAT, all the treatments were found to be effective in controlling weeds. $T_6$, $T_7$ and $T_8$ were found to be on par and $T_7$ and $T_8$ found to control maximum than the remaining treatments except $T_6$. At 40 DAT, all the treatments were effective and maximum control being obtained from $T_7$ and $T_8$ which were on par, followed by $T_4$ and $T_6$ which were also on par. The treatments $T_4$ and $T_6$ were found to be better than the remaining treatments. Among the treatments excluding $T_{11}$, $T_9$ and $T_{10}$ were least effective. At 60 DAT, maximum control is obtained from $T_6$ followed by $T_5$ and $T_8$ which were on par. $T_1$ and $T_7$ were on par and found to perform better than the remaining treatments excluding $T_6$, $T_5$ and $T_8$. Among the treatments, $T_9$ and $T_{10}$ are the least effective. However, they controlled the weeds better than $T_{11}$. At harvest, $T_8$, $T_1$, $T_7$ and $T_6$ were on par and $T_8$ was found to control the weeds better than the remaining treatment. All treatments found to control weeds better than hand weeding twice ($T_{11}$). Among the treatments $T_2$ and $T_9$ were least effective. $T_1$, $T_7$, $T_6$ and $T_4$ were on par and controlled the weeds better than the remaining treatments.

**4.1.3 Relative Density**

Relative density of grasses, broadleaved weeds and sedges are recorded at 20, 40, 60 DAT and at harvest.

***4.1.3.1 Relative Density of Grasses***

The results are presented in Table 8.

Relative density of grasses was influenced by different weed management practices. Among the chemical treatments, $T_5$ recorded lowest relative density of grasses at 20 DAT which was on par with $T_6$. $T_7$ recorded the highest relative density of grasses followed by $T_8$.

Table 7. Effect of weed management practices on total absolute density, number $m^{-2}$

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 10.34(3.37) | 27.45(5.33) | 67.55(8.28) | 53.55(7.39) |
| $T_2$ | 10.85(3.44) | 29.18(5.49) | 68.74(8.35) | 59.88(7.80) |
| $T_3$ | 10.30(3.36) | 28.08(5.39) | 69.81(8.40) | 56.07(7.55) |
| $T_4$ | 10.41(3.38) | 24.85(5.08) | 68.50(8.34) | 54.58(7.45) |
| $T_5$ | 8.89(3.14) | 25.63(5.16) | 64.52(8.09) | 57.91(7.68) |
| $T_6$ | 8.79(3.13) | 25.02(5.10) | 63.15(8.01) | 58.97(7.41) |
| $T_7$ | 8.82(3.13) | 22.95(4.89) | 67.27(8.26) | 53.87(7.41) |
| $T_8$ | 8.38(3.06) | 22.36(4.83) | 65.28(8.14) | 52.85(7.34) |
| $T_9$ | 13.77(3.84) | 30.59(5.62) | 71.17(8.49) | 59.33(7.77) |
| $T_{10}$ | 13.80(3.85) | 30.89(5.65) | 70.45(8.45) | 58.49(7.71) |
| $T_{11}$ | 67.67(8.29) | 74.08(8.67) | 83.37(9.18) | 70.13(8.43) |
| $T_{12}$ | 90.94(9.59) | 146.55(12.15) | 217.58(14.78) | 202.78(14.28) |
| $F_{11,22}$ | 7759.99** | 39172.22** | 14208.02** | 6325.71** |
| SE | 0.025 | 0.011 | 0.016 | 0.024 |
| CD | 0.073 | 0.032 | 0.046 | 0.071 |

** Significant at 1 per cent level

Figures in parenthesis denote transformed values

Table 8. Effect of weed management practices on relative density of grasses

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 67.87 | 54.53 | 38.23 | 41.77 |
| $T_2$ | 65.23 | 51.69 | 37.59 | 38.20 |
| $T_3$ | 63.77 | 46.57 | 36.53 | 42.60 |
| $T_4$ | 66.34 | 49.85 | 39.16 | 44.54 |
| $T_5$ | 58.97 | 41.90 | 36.30 | 38.75 |
| $T_6$ | 59.56 | 43.43 | 37.38 | 40.88 |
| $T_7$ | 76.05 | 57.49 | 37.86 | 43.86 |
| $T_8$ | 75.47 | 57.48 | 37.73 | 43.76 |
| $T_9$ | 64.62 | 53.51 | 39.80 | 43.33 |
| $T_{10}$ | 61.94 | 54.13 | 39.61 | 43.56 |
| $T_{11}$ | 61.62 | 54.16 | 37.39 | 40.04 |
| $T_{12}$ | 56.19 | 62.86 | 67.45 | 71.42 |
| $F_{33,72}$ | | | | 332.86** |
| SE | | | | 0.336 |
| CD | | | | 0.951 |

** Significant at 1 per cent level

At 40 DAT, $T_5$ recorded lowest relative density of grasses followed by $T_6$. Among the other treatments, $T_3$ was found to be better than others followed by $T_4$. All other treatments recorded higher relative density of grasses. At 60 DAT, $T_5$ recorded lowest relative density of grasses which was on par with $T_3$. $T_{11}$, $T_2$, $T_6$, $T_7$, $T_8$ and $T_1$ were found to be on par with each other. At 60 DAT, $T_2$ recorded lowest relative density of grasses followed by $T_5$. $T_1$, $T_6$ and $T_{11}$ were found to be on par with each other.

### *4.1.3.2 Relative Density of Broadleaved Weeds*

The results are presented in Table 9.

At 20 DAT, $T_7$ recorded lowest relative density of broad leaved weeds which was on par with $T_8$. Among the other treatments, $T_{10}$ recorded lowest which was on par with $T_9$. $T_2$ and $T_4$ were found to be on par. At 40 DAT, $T_5$ recorded highest relative density of broad leaved weeds and $T_7$ recorded lowest relative density of broad leaved weeds which was on par with $T_8$. At this stage $T_1$ is found to be on par with $T_{11}$ and recorded lower relative density of broad leaved weeds than the other treatments. At 60 DAT also $T_7$ recorded lowest relative density of broad leaved weeds which was on par with $T_1$, $T_9$ and $T_{10}$. Among the other treatments, $T_6$ recorded lowest relative density followed by $T_2$. At harvest, $T_2$ recorded lowest relative density among the chemical treatments. Among the other treatments, $T_9$, $T_8$, $T_7$, $T_6$, $T_5$ and $T_{11}$ were found to be on par.

### *4.1.3.3 Relative Density of Sedges*

The results are presented in Table 10.

At 20 DAT, $T_7$ recorded lowest relative density of sedges which was on par with $T_8$. $T_9$ recorded highest relative density of sedges and was on par with $T_{10}$. At 40 DAT, $T_5$ recorded highest value and was on par with $T_6$. Except at 20 DAT, at all other stages, unweeded control

Table 9. Effect of weed management practices on relative density of broad leaved weeds

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 15.66 | 23.12 | 21.73 | 41.17 |
| $T_2$ | 17.60 | 25.10 | 24.31 | 39.66 |
| $T_3$ | 18.58 | 30.84 | 26.26 | 44.67 |
| $T_4$ | 17.45 | 28.76 | 25.53 | 45.05 |
| $T_5$ | 21.53 | 32.45 | 24.39 | 40.82 |
| $T_6$ | 21.39 | 31.67 | 23.59 | 41.07 |
| $T_7$ | 11.75 | 20.52 | 21.21 | 41.01 |
| $T_8$ | 12.08 | 20.59 | 21.33 | 40.80 |
| $T_9$ | 13.21 | 25.28 | 21.74 | 40.67 |
| $T_{10}$ | 12.79 | 24.65 | 21.66 | 41.19 |
| $T_{11}$ | 18.85 | 22.65 | 29.00 | 44.44 |
| $T_{12}$ | 24.64 | 18.73 | 15.82 | 21.35 |
| $F_{33,72}$ | | | | 297.18** |
| SE | | | | 0.235 |
| CD | | | | 0.665 |

** Significant at 1 per cent level

Table 10. Effect of weed management practices on relative density of sedges

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 16.46 | 22.35 | 37.56 | 17.05 |
| $T_2$ | 17.17 | 23.21 | 38.09 | 22.22 |
| $T_3$ | 17.64 | 22.59 | 37.21 | 12.73 |
| $T_4$ | 16.26 | 21.40 | 35.30 | 10.80 |
| $T_5$ | 19.50 | 25.65 | 39.31 | 20.27 |
| $T_6$ | 19.04 | 24.90 | 39.03 | 17.59 |
| $T_7$ | 12.20 | 23.60 | 41.01 | 15.12 |
| $T_8$ | 12.44 | 21.93 | 40.93 | 14.53 |
| $T_9$ | 24.01 | 21.30 | 38.62 | 16.00 |
| $T_{10}$ | 23.38 | 21.21 | 38.71 | 15.61 |
| $T_{11}$ | 19.53 | 23.60 | 33.60 | 15.80 |
| $T_{12}$ | 19.17 | 18.40 | 16.72 | 7.22 |
| $F_{33,72}$ | | | | 119.09** |
| SE | | | | 0.345 |
| CD | | | | 0.977 |

** Significant at 1 per cent level

recorded lowest relative density of sedges. Among the other treatments $T_{10}$ recorded lowest relative density of sedges which was on par with T9, $T_4$ and $T_8$. At 60 DAT, $T_7$ recorded highest relative density of sedges which was on par with $T_8$. At 60 DAT, $T_7$ recorded highest relative density of sedges which was on par with $T_8$. At harvest, $T_2$ registered highest followed by $T_5$. $T_4$ recorded lowest followed by $T_3$.

### 4.1.4 Absolute Frequency

Absolute frequency of grasses, broadleaved weeds and sedges were recorded at 20, 40, 60 DAT and at harvest.

#### *4.1.4.1 Absolute Frequency of Grasses*

The results are presented in Table 11. There is no significant difference between the absolute frequency of different treatments.

#### *4.1.4.2 Absolute Frequency of Broadleaved Weeds*

The results are presented in Table 12. No significant difference between the treatments.

#### *4.1.4.3 Absolute Frequency of Sedges*

The results are presented in Table 13.

At 20 DAT, $T_4$ and $T_6$ recorded lowest absolute frequency which were on par with $T_8$. All other treatments recorded highest absolute frequency. At all other stages, there is no significant difference between the treatments.

#### *4.1.4.4 Total Absolute Weed Frequency*

The results are presented in Table 14. At 20 DAT, $T_4$ recorded lowest total absolute weed frequency which was on par with $T_1$, $T_2$, $T_6$ and $T_8$. Unweeded control recorded highest total absolute frequency which was on par with all other treatments excluding $T_1$, $T_2$, $T_4$, $T_6$ and $T_8$. At 40 DAT and at harvest, there is no significant difference between

Table 11. Effect of weed management practices on absolute frequency of grasses

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 82.16(64.98) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $T_2$ | 97.00(80.00) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $T_3$ | 97.00(80.00) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $T_4$ | 97.00(80.00) | 97.00(80.00) | 97.00(80.00) | 100.00(90.00) |
| $T_5$ | 97.00(80.00) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $T_6$ | 88.32(69.99) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $T_7$ | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $T_8$ | 97.00(80.00) | 97.00(80.00) | 97.00(80.00) | 100.00(90.00) |
| $T_9$ | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $T_{10}$ | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $T_{11}$ | 97.00(80.00) | 88.32(69.99) | 100.00(90.00) | 100.00(90.00) |
| $T_{12}$ | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $F_{11,22}$ | $0.94^{ns}$ | $1.75^{ns}$ | $0.896^{ns}$ | |
| SE | 8.23 | 7.93 | 4.18 | |
| CD | - | - | - | |

Figures in parenthesis denote transformed values
ns – not significant

Table 12. Effect of weed management practices on absolute frequency of broad leaved weeds

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 82.16(64.99) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $T_2$ | 75.04(60.00) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $T_3$ | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $T_4$ | 75.02(59.99) | 97.00(80.00) | 100.00(90.00) | 100.00(90.00) |
| $T_5$ | 97.00(80.00) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $T_6$ | 82.16(64.99) | 97.00(80.00) | 100.00(90.00) | 100.00(90.00) |
| $T_7$ | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $T_8$ | 88.32(69.99) | 93.32(75.00) | 100.00(90.00) | 100.00(90.00) |
| $T_9$ | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $T_{10}$ | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $T_{11}$ | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $T_{12}$ | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $F_{11,22}$ | $1.402^{ns}$ | $0.811^{ns}$ | | |
| SE | 11.15 | 6.02 | | |
| CD | - | - | | |

Figures in parenthesis denote transformed values
ns : not significant

Table 13. Effect of weed management practices on absolute frequency of sedges

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $T_2$ | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $T_3$ | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $T_4$ | 82.16(64.69) | 97.00(80.00) | 97.00(80.00) | 100.00(90.00) |
| $T_5$ | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $T_6$ | 82.16(64.99) | 93.32(74.99) | 97.00(80.00) | 100.00(90.00) |
| $T_7$ | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $T_8$ | 97.00(80.00) | 97.00(80.00) | 97.00(80.00) | 100.00(90.00) |
| $T_9$ | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $T_{10}$ | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $T_{11}$ | 100.00(90.00) | 82.16(64.99) | 100.00(90.00) | 100.00(90.00) |
| $T_{12}$ | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) | 100.00(90.00) |
| $F_{11,22}$ | 2.84* | 1.50$^{ns}$ | 0.818$^{ns}$ | |
| SE | 5.792 | 6.746 | 5.004 | |
| CD | 16.991 | - | - | |

* Significant at 5 per cent level, ns : not significant

Figures in parenthesis denote transformed values

Table 14. Effect of weed management practices on total absolute weed frequency

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 248.32 (15.79) | 300.00 (17.35) | 300.00 (17.35) | 300.00 (17.35) |
| $T_2$ | 256.50 (16.05) | 300.00 (17.35) | 300.00 (17.35) | 300.00 (17.35) |
| $T_3$ | 291.55 (17.10) | 300.00 (17.35) | 300.00 (17.35) | 300.00 (17.35) |
| $T_4$ | 230.54 (15.22) | 274.00 (16.60) | 281.21 (16.86) | 300.00 (17.35) |
| $T_5$ | 283.21 (16.86) | 300.00 (17.35) | 300.00 (17.35) | 300.00 (17.35) |
| $T_6$ | 232.32 (15.27) | 275.8 1(16.58) | 291.55 (17.10) | 300.00 (17.35) |
| $T_7$ | 300.00 (17.35) | 300.00 (17.35) | 300.00 (17.35) | 300.00 (17.35) |
| $T_8$ | 265.73 (16.33) | 274.62 (16.60) | 283.21 (16.86) | 300.00 (17.35) |
| $T_9$ | 300.00 (17.35) | 300.00 (17.35) | 300.00 (17.35) | 300.00 (17.35) |
| $T_{10}$ | 300.00 (17.35) | 300.00 (17.35) | 300.00 (17.35) | 300.00 (17.35) |
| $T_{11}$ | 291.55 (17.10) | 257.41 (16.08) | 300.00 (17.35) | 300.00 (17.35) |
| $T_{12}$ | 300.00 (17.35) | 300.00 (17.35) | 300.00 (17.35) | 300.00 (17.35) |
| $F_{11,22}$ | 2.37* | $1.98^{ns}$ | 2.59* | |
| SE | 0.537 | 0.324 | 0.121 | |
| CD | 1.575 | - | 0.354 | |

*Significant at 5 per cent level, ns: not significant

Figures in parenthesis denote transformed values

the treatments. At 60 DAT, $T_4$ and $T_8$ recorded lowest which was on par with $T_6$ and unweeded control recorded highest value which was similar to all other treatments excluding $T_4$, $T_8$ and $T_6$.

### 4.1.5 Relative Frequency

Relative frequency of grasses, sedges and broadleaved weeds were recorded at 20, 40 and 60 DAT and at harvest.

#### *4.1.5.1 Relative Frequency of Grasses*

The results are presented in Table 15. No significant difference between the treatments.

#### *4.1.5.2 Relative Frequency of Broadleaved Weeds*

The results are presented in Table 16. There is no significant difference between the treatments.

#### *4.1.5.3 Relative Frequency of Sedges*

The results are presented in Table 17. There is no significant difference between the treatments.

### 4.1.6 Summed Dominance Ratio (SDR)

Summed dominance ratio of grasses, broadleaved weeds and sedges are recorded at 20, 40, 60 DAT and at harvest.

#### *4.1.6.1 Summed Dominance Ratio of Grasses*

The results are presented in Table 18.

At 20 DAT, $T_8$ recorded highest SDR and was on par with $T_2$, $T_4$, $T_5$ and $T_7$. The lowest SDR was recorded by unweeded control. In all other stages, unweeded control recorded the highest SDR of grasses. At 40 DAT, $T_5$ recorded the lowest SDR followed by $T_3$. $T_3$ was found to be on par with $T_4$ and $T_6$.. Among the other treatments, $T_2$ was found be on par with $T_{11}$, $T_9$, $T_{10}$, $T_1$. At 60 DAT, $T_5$ recorded lowest SDR of grasses

Table 15. Effect of weed management practices on relative frequency of grasses

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 29.44 | 33.33 | 33.33 | 33.33 |
| $T_2$ | 36.87 | 33.33 | 33.33 | 33.33 |
| $T_3$ | 31.31 | 33.33 | 33.33 | 33.33 |
| $T_4$ | 40.21 | 33.23 | 32.32 | 33.33 |
| $T_5$ | 32.32 | 33.33 | 33.33 | 33.33 |
| $T_6$ | 36.40 | 37.03 | 34.34 | 33.33 |
| $T_7$ | 33.33 | 33.33 | 33.33 | 33.33 |
| $T_8$ | 34.34 | 33.33 | 32.32 | 33.33 |
| $T_9$ | 33.33 | 33.33 | 33.33 | 33.33 |
| $T_{10}$ | 33.33 | 33.33 | 33.33 | 33.33 |
| $T_{11}$ | 31.31 | 32.22 | 33.33 | 33.33 |
| $T_{12}$ | 33.33 | 33.33 | 33.33 | 33.33 |
| $F_{33,72}$ | | | | $0.80^{ns}$ |
| SE | | | | 1.694 |
| CD | | | | - |

ns: not significant

Table 16. Effect of weed management practices on relative frequency of broad leaved weeds

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 29.44 | 33.33 | 33.33 | 33.33 |
| $T_2$ | 23.23 | 33.33 | 33.33 | 33.33 |
| $T_3$ | 34.34 | 33.33 | 33.33 | 33.33 |
| $T_4$ | 20.04 | 33.33 | 35.35 | 33.33 |
| $T_5$ | 32.32 | 33.53 | 33.33 | 33.33 |
| $T_6$ | 31.56 | 33.33 | 34.34 | 33.33 |
| $T_7$ | 33.33 | 33.33 | 33.33 | 33.33 |
| $T_8$ | 31.31 | 29.90 | 35.35 | 33.33 |
| $T_9$ | 33.33 | 33.33 | 33.33 | 33.33 |
| $T_{10}$ | 33.33 | 33.33 | 33.33 | 33.33 |
| $T_{11}$ | 34.34 | 39.26 | 33.33 | 33.33 |
| $T_{12}$ | 33.33 | 33.33 | 33.33 | 33.33 |
| $F_{33,72}$ | | | | $0.819^{ns}$ |
| SE | | | | 2.15 |
| CD | | | | - |

ns: not significant

Table 17. Effect of weed management practices on relative frequency of sedges

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 41.11 | 33.33 | 33.33 | 33.33 |
| $T_2$ | 39.90 | 33.33 | 33.33 | 33.33 |
| $T_3$ | 34.34 | 33.33 | 33.33 | 33.33 |
| $T_4$ | 31.74 | 33.23 | 32.32 | 33.33 |
| $T_5$ | 35.35 | 33.33 | 33.33 | 33.33 |
| $T_6$ | 32.03 | 29.63 | 31.31 | 33.33 |
| $T_7$ | 33.33 | 33.33 | 33.33 | 33.33 |
| $T_8$ | 34.34 | 33.53 | 32.32 | 33.33 |
| $T_9$ | 33.33 | 33.33 | 33.33 | 33.33 |
| $T_{10}$ | 33.33 | 33.33 | 33.33 | 33.33 |
| $T_{11}$ | 34.34 | 28.52 | 33.33 | 33.33 |
| $T_{12}$ | 33.33 | 33.33 | 33.33 | 33.33 |
| $F_{33,72}$ | | | | $0.739^{ns}$ |
| SE | | | | 1.849 |
| CD | | | | - |

ns: not significant

Table 18. Effect of weed management practices on summed dominance ratio of grasses

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 48.65 | 43.93 | 35.76 | 37.55 |
| $T_2$ | 51.04 | 42.51 | 35.46 | 35.76 |
| $T_3$ | 48.00 | 39.95 | 34.93 | 37.96 |
| $T_4$ | 53.26 | 41.54 | 35.74 | 38.93 |
| $T_5$ | 50.19 | 37.61 | 34.81 | 36.04 |
| $T_6$ | 47.98 | 40.23 | 35.85 | 37.10 |
| $T_7$ | 54.69 | 45.41 | 35.59 | 38.59 |
| $T_8$ | 54.90 | 45.51 | 35.02 | 38.54 |
| $T_9$ | 48.97 | 43.42 | 36.56 | 38.34 |
| $T_{10}$ | 47.64 | 43.73 | 36.47 | 34.44 |
| $T_{11}$ | 46.46 | 43.19 | 35.36 | 36.68 |
| $T_{12}$ | 44.88 | 48.09 | 50.39 | 52.37 |
| $F_{11,22}$ | 3.94** | 10.96** | 51.95** | 524.85** |
| SE | 1.608 | 0.854 | 0.593 | 0.191 |
| CD | 4.716 | 2.505 | 1.751 | 0.560 |

** Significant at 1 per cent level

and was on par with all other treatments except unweeded control. At harvest, $T_2$ recorded the lowest SDR and was on par with $T_5$.

### *4.1.6.2 Summed Dominance Ratio of Broadleaved Weeds*

The results are presented in Table 19.

At 20 DAT, unweeded control recorded the highest SDR and was on par with $T_2$, $T_3$, $T_5$, $T_6$ and $T_{11}$. The lowest SDR was recorded by $T_8$ which was on par with $T_1$, $T_4$, $T_7$, $T_9$ and $T_{10}$. Except at 20 DAT, unweeded control recorded the lowest SDR of broadleaved weeds at all other stages. At 40 DAT, highest SDR registered by $T_5$ and was on par with $T_6$, $T_3$, $T_4$ and $T_{11}$. At 60 DAT, $T_{11}$ recorded highest SDR and was on par with $T_3$ and $T_4$. At harvest $T_4$ recorded highest SDR and was on par with $T_3$ and $T_{11}$.

### *4.1.6.3 Summed Dominance Ratio of Sedges*

The results are presented in Table 20.

At 20 DAT, $T_1$ recorded highest SDR and was on par with $T_9$, $T_2$, $T_{10}$, $T_5$, $T_{11}$ and unweeded control. $T_7$ recorded lowest SDR and was on par with $T_8$, $T_3$, $T_4$, $T_6$ and $T_{12}$. At 40 DAT, there is no significant difference between the treatments. At 60 DAT, unweeded control recorded lowest SDR. $T_7$ recorded highest SDR and was on par with $T_5$, $T_8$, $T_9$ and $T_{10}$. At harvest $T_2$ recorded highest SDR and was on par with $T_5$ and $T_1$. Unweeded control recorded lowest SDR and was on par with $T_{11}$ and $T_4$.

## 4.1.7 Dry Weight of Weeds

Dry weight was recorded at 20, 40, 60 and at harvest.

### *4.1.7.1 Dry Weight of Grasses*

The results are presented in Table 21.

Table 19. Effect of weed management practices on summed dominance ratio of broad leaved weeds

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 22.55 | 28.23 | 27.53 | 37.26 |
| $T_2$ | 27.07 | 29.21 | 28.82 | 36.49 |
| $T_3$ | 26.46 | 32.08 | 29.79 | 39.00 |
| $T_4$ | 22.74 | 31.14 | 30.44 | 39.18 |
| $T_5$ | 26.92 | 32.88 | 28.86 | 37.07 |
| $T_6$ | 26.48 | 32.49 | 28.96 | 37.20 |
| $T_7$ | 22.54 | 26.92 | 27.27 | 37.17 |
| $T_8$ | 21.69 | 27.46 | 28.34 | 37.23 |
| $T_9$ | 23.27 | 29.30 | 27.53 | 37.00 |
| $T_{10}$ | 23.06 | 28.98 | 25.49 | 37.26 |
| $T_{11}$ | 26.59 | 30.95 | 31.16 | 38.88 |
| $T_{12}$ | 28.98 | 26.03 | 24.57 | 27.34 |
| $F_{11,22}$ | 6.57** | 8.65** | 8.71** | 265.94** |
| SE | 0.950 | 0.770 | 0.646 | 0.189 |
| CD | 2.787 | 2.260 | 1.894 | 0.556 |

** Significant at 1 per cent level

Table 20. Effect of weed management practices on summed dominance ratio of sedges

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 28.78 | 27.84 | 35.45 | 25.19 |
| $T_2$ | 28.53 | 28.27 | 35.71 | 27.77 |
| $T_3$ | 25.99 | 27.96 | 35.27 | 23.03 |
| $T_4$ | 24.00 | 27.31 | 33.81 | 22.01 |
| $T_5$ | 27.42 | 29.49 | 36.32 | 26.80 |
| $T_6$ | 25.34 | 27.26 | 35.17 | 24.02 |
| $T_7$ | 22.77 | 28.47 | 37.17 | 24.23 |
| $T_8$ | 23.39 | 27.73 | 36.62 | 24.03 |
| $T_9$ | 28.67 | 27.31 | 35.97 | 24.67 |
| $T_{10}$ | 28.35 | 27.27 | 36.02 | 24.47 |
| $T_{11}$ | 26.93 | 26.06 | 33.46 | 22.16 |
| $T_{12}$ | 26.25 | 25.86 | 25.03 | 20.27 |
| $F_{11,22}$ | 2.52* | 1.12 $^{ns}$ | 23.11** | 5.239** |
| SE | 1.340 | 0.931 | 0.668 | 0.896 |
| CD | 3.931 | - | 1.962 | 2.630 |

*Significant at 5 per cent level, ** Significant at 1 per cent level

Table 21. Effect of weed management practices on dry weight of grasses,g $m^{-2}$

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 0.93(0.27) | 0.23(0.88) | 0.41(1.19) | 0.33(1.15) |
| $T_2$ | 0.93(0.27) | 0.23(0.88) | 0.42(1.19) | 0.34(1.16) |
| $T_3$ | 0.93(0.26) | 0.24(0.87) | 0.39(1.18) | 0.34(1.16) |
| $T_4$ | 0.93(0.26) | 0.24(0.87) | 0.39(1.18) | 0.35(1.16) |
| $T_5$ | 0.95(0.23) | 0.25(0.87) | 0.36(1.16) | 0.34(1.16) |
| $T_6$ | 0.95(0.23) | 0.25(0.87) | 0.35(1.16) | 0.33(1.15) |
| $T_7$ | 0.94(0.25) | 0.24(0.87) | 0.38(1.18) | 0.35(1.16) |
| $T_8$ | 0.94(0.31) | 0.24(0.87) | 0.37(1.17) | 0.34(1.16) |
| $T_9$ | 0.91(0.31) | 0.17(0.91) | 0.40(1.18) | 0.36(1.17) |
| $T_{10}$ | 0.91(0.31) | 0.17(0.91) | 0.39(1.18) | 0.36(1.17) |
| $T_{11}$ | 1.21(1.49) | 0.78(1.33) | 0.93(1.39) | 0.81(1.35) |
| $T_{12}$ | 1.31(1.52) | 2.59(1.89) | 3.09(2.02) | 3.01(2.00) |
| $F_{33,72}$ | | | | 4017.10** |
| SE | | | | 0.002 |
| CD | | | | 0.006 |

** Significant at 1 per cent level

Figures in parenthesis denote transformed values

At all stages, dry weight of grasses was significantly low in all chemically treated plots in comparison to hand weeding twice. At 20 DAT, least dry weight was observed in pretilachlor (1.0kg ai $ha^{-1}$) + one handweeding at 20 DAT ($T_5$) which was on par with pretilachlor (1.0kg ai $ha^{-1}$) + 2,4-D (1.0 kg ai $ha^{-1}$) ($T_6$) and anilofos (0.325 kg ai $ha^{-1}$) + ethoxysulfuron (0.012 kg $ha^{-1}$) + one handweeding at 40 DAT ($T_8$). At 40 DAT, maximum dry weight among chemical treatments was recorded by Metsulfuron methyl and chlorimuron ethyl (0.004 kg $ha^{-1}$) ($T_9$) and Metsulfuron methyl and chlorimuron ethyl (0.004 kg $ha^{-1}$) + one hand weeding ($T_{10}$). There was no significant difference in dry weight of grasses among the other treatments. During 60 DAT, maximum dry weight recorded from Butachlor (1.25 kg ai $ha^{-1}$) + 2, 4-D sodium salt (1.0 kg ai $ha^{-1}$) ($T_1$). At harvest also, Metsulfuron methyl and chlorimuron ethyl (0:004 kg $ha^{-1}$) ($T_9$) was having maximum dry weight among chemically treated plots which was on par with Metsulfuron methyl and chlorimuron ethyl (0.004 kg $ha^{-1}$) + one hand weeding ($T_{10}$). There was no significant difference between the other treatments.

#### *4.1.7.2 Dry Weight of Broadleaved Weeds*

The results are presented in Table 22.

At all stages, all the chemically treated plots recorded lesser dry weight than hand weeding twice ($T_{11}$). At 20 DAT, anilofos (0.325 kg ai $ha^{-1}$) + ethoxysulfuron (0.012 kg $ha^{-1}$) ($T_7$) and anilofos (0.325 kg ai $ha^{-1}$) + ethoxysulfuron (0.012 kg $ha^{-1}$) + one hand weeding ($T_8$) were found to have minimum dry weight followed by butachlor (1.25 kg ai $ha^{-1}$) + 2, 4-D sodium salt (1.0 kg ai $ha^{-1}$) ($T_1$). At 40 DAT, among chemically treated plots pretilachlor (1.0 kg ai $ha^{-1}$) + one hand weeding ($T_5$) was found to have minimum dry weight. At 60 DAT, minimum dry weight was registered by anilofos (0.325 kg ai $ha^{-1}$) + ethoxysulfuron (0.012 kg $ha^{-1}$) + one hand weeding ($T_8$) which was on par with anilofos (0.325 kg ai $ha^{-1}$) + ethoxysulfuron (0.012 kg $ha^{-1}$) ($T_7$). At harvest, minimum dry

Table 22. Effect of weed management practices on dry weight of broad leaved weeds, g $m^{-2}$

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 0.98(0.15) | 0.94(0.25) | 0.49(0.72) | 0.21(0.89) |
| $T_2$ | 0.95(0.22) | 0.92(0.28) | 0.34(0.81) | 0.03(0.99) |
| $T_3$ | 0.95(0.22) | 0.92(0.28) | 0.31(0.83) | 0.04(0.98) |
| $T_4$ | 0.95(0.21) | 0.92(0.28) | 0.32(0.83) | 0.92(0.99) |
| $T_5$ | 0.95(0.21) | 0.99(0.10) | 0.35(0.81) | 0.03(0.98) |
| $T_6$ | 0.96(0.20) | 0.92(0.29) | 0.48(0.72) | 0.12(0.91) |
| $T_7$ | 0.98(0.12) | 0.94(0.25) | 0.49(0.71) | 0.18(0.91) |
| $T_8$ | 0.99(0.11) | 0.94(0.23) | 0.51(0.70) | 0.19(0.90) |
| $T_9$ | 0.96(0.19) | 0.91(0.29) | 0.48(0.72) | 0.03(0.99) |
| $T_{10}$ | 0.97(0.18) | 0.92(0.29) | 0.48(0.72) | 0.03(0.98) |
| $T_{11}$ | 0.79(0.46) | 0.60(0.63) | 0.12(1.06) | 0.20(1.09) |
| $T_{12}$ | 0.70(0.55) | 0.40(0.78) | 0.81(1.35) | 0.96(1.40) |
| $F_{33,72}$ | | | | 229.14** |
| SE | | | | 0.004 |
| CD | | | | 0.010 |

** Significant at 1 per cent level

Figures in parenthesis denote transformed values

weight was recorded by butachlor (1.25 kg ai ha$^{-1}$) + 2, 4-D sodium salt (1.0 kg ai ha$^{-1}$) ($T_1$) which was on par with snilofos (0.325 kg ai ha$^{-1}$) + ethoxysulfuron (0.012 kg ha$^{-1}$) + one hand weeding ($T_8$).

#### *4.1.7.3 Dry Weight of Sedges*

The results are presented in Table 23.

All chemical treatments registered less dry weight of sedges than handweeding twice ($T_{11}$) at all stages. At 20 DAT, maximum dry weight was recorded by metsulfuron methyl and chlorimuron ethyl (0.004 kg ha$^{-1}$) ($T_9$) and metsulfuron methyl and chlorimuron ethyl (0.004 kg ha$^{-1}$) + one hand weeding ($T_{10}$). At 40 DAT, there was not much difference in dry weight. At 60 DAT and at harvest, same trend was observed.

#### *4.1.7.4 Total Weed Dry Weight*

The results are presented in Table 24.

At 20 DAT, anilofos (0.325 kg ai ha$^{-1}$) + ethoxysulfuron (0.012 kg ha$^{-1}$) + one hand weeding ($T_8$) and anilofos (0.325 kg ai ha$^{-1}$) + ethoxysulfuron (0.012 kg ha$^{-1}$) ($T_7$) were on par and found to have least dry weight. At all stages, hand weeding twice recorded highest dry weight of weeds. At 40 DAT, lowest dry weight registered by pretilachlor (1.0 kg ai ha$^{-1}$) + one hand weeding ($T_5$). At 60 DAT, pretilachlor (1.0 kg ai ha$^{-1}$) + 2,4-D sodium salt (1 kg ai ha$^{-1}$) ($T_6$) and Anilofos (0.325 kg ai ha$^{-1}$) + ethoxysulfuron (0.012 kg ha$^{-1}$) + one hand weeding ($T_8$) have values lesser than that of remaining treatments. At harvest stage, all the chemically treated plots recorded lesser dry weight than hand weeding twice ($T_{11}$).

### 4.1.8 Weed Control Efficiency

Weed control efficiency of grasses, broadleaved weeds and sedges are recorded at 20, 40, 60 and DAT and at harvest.

Table 23. Effect of weed management practices on dry weight of sedges, g $m^{-2}$

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 0.87(0.36) | 0.51(0.70) | 0.48(1.21) | 0.35(1.16) |
| $T_2$ | 0.87(0.36) | 0.49(0.71) | 0.48(1.22) | 0.39(1.18) |
| $T_3$ | 0.87(0.36) | 0.50(0.70) | 0.48(1.22) | 0.35(1.16) |
| $T_4$ | 0.88(0.35) | 0.51(0.70) | 0.47(1.21) | 0.35(1.16) |
| $T_5$ | 0.87(0.36) | 0.50(0.71) | 0.48(1.1.22) | 0.39(1.18) |
| $T_6$ | 0.88(0.35) | 0.51(0.70) | 0.48(1.21) | 0.37(1.17) |
| $T_7$ | 0.88(0.35) | 0.51(0.70) | 0.49(1.22) | 0.35(1.16) |
| $T_8$ | 0.88(0.35) | 0.52(0.70) | 0.48(1.22) | 0.35(1.16) |
| $T_9$ | 0.83(0.41) | 0.49(0.72) | 0.49(1.22) | 0.36(1.17) |
| $T_{10}$ | 0.85(0.39) | 0.49(0.71) | 0.49(1.22) | 0.36(1.17) |
| $T_{11}$ | 0.47(0.73) | 0.68(1.29) | 0.59(1.26) | 0.52(1.23) |
| $T_{12}$ | 0.18(0.91) | 0.96(1.40) | 1.22(1.49) | 0.83(1.35) |
| $F_{33,72}$ | | | | 2829.88** |
| SE | | | | 0.002 |
| CD | | | | 0.005 |

** Significant at 1 per cent level

Figures in parenthesis denote transformed values

Table 24. Effect of weed management practices on total weed dry weight, g $m^{-2}$

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 0.45(0.74) | 0.34(1.16) | 1.46(1.57) | 1.45(1.56) |
| $T_2$ | 0.41(0.77) | 0.36(1.17) | 1.51(1.59) | 1.54(1.59) |
| $T_3$ | 0.42(0.76) | 0.33(1.15) | 1.51(1.58) | 1.51(1.58) |
| $T_4$ | 0.43(0.76) | 0.32(1.15) | 1.50(1.58) | 1.52(1.59) |
| $T_5$ | 0.44(0.75) | 0.30(1.14) | 1.48(1.57) | 1.53(1.59) |
| $T_6$ | 0.45(0.74) | 0.34(1.16) | 1.43(1.56) | 1.46(1.57) |
| $T_7$ | 0.47(0.73) | 0.33(1.15) | 1.45(1.57) | 1.47(1.57) |
| $T_8$ | 0.48(0.72) | 0.32(1.15) | 1.43(1.56) | 1.45(1.57) |
| $T_9$ | 0.38(0.79) | 0.41(1.19) | 1.46(1.57) | 1.53(1.59) |
| $T_{10}$ | 0.40(0.77) | 0.40(1.18) | 1.46(1.57) | 1.53(1.59) |
| $T_{11}$ | 1.53(1.59) | 1.75(1.66) | 2.01(1.73) | 1.93(1.71) |
| $T_{12}$ | 1.72(1.65) | 3.16(2.04) | 3.84(2.20) | 3.72(2.17) |
| $F_{33,72}$ | | | | 2694.32** |
| SE | | | | 0.002 |
| CD | | | | 0.006 |

** Significant at 1 per cent level

Figures in parenthesis denote transformed values

### 4.1.8.1 *Weed Control Efficiency of Grasses*

The results are presented in Table 25.

All treated plots registered better value than hand weeding twice ($T_{11}$). At 20 DAT and 40 DAT, pretilachlor (1.0 kg ai $ha^{-1}$) + 2,4-D sodium salt (1 kg ai $ha^{-1}$) ($T_6$) and pretilachlor (1.0 kg ai $ha^{-1}$) + one hand weeding ($T_5$) have better weed control efficiency than the remaining treatments which were on par. At all stages, handweeding twice ($T_{11}$) recorded lowest weed control efficiency. At 60 DAT, pretilachlor (1.0 kg ai $ha^{-1}$) + 2,4-D sodium salt (1 kg ai $ha^{-1}$) ($T_6$) and pretilachlor (1.0 kg ai $ha^{-1}$) + one hand weeding ($T_5$) were on par and had better weed control efficiency than the remaining treatments.

### 4.1.8.2 *Weed Control Efficiency of Broadleaved Weeds*

The results are presented in Table 26.

At 20 DAT, the treatments anilofos (0.325 kg ai $ha^{-1}$) + ethoxysulfuron (0.012 kg $ha^{-1}$) ($T_7$) and anilofos (0.325 kg ai $ha^{-1}$) + ethoxysulfuron (0.012 kg $ha^{-1}$) + one handweeding ($T_8$) recorded significantly higher weed control efficiency than the remaining treatments. At all stages, hand weeding twice recorded least weed control efficiency. But at 40 DAT, pretilachlor (1.0 kg ai $ha^{-1}$) + one hand weeding ($T_5$) was found to have the highest weed control efficiency followed by anilofos (0.325 kg ai $ha^{-1}$) + ethoxysulfuron (0.012 kg $ha^{-1}$) + one handweeding ($T_8$) and anilofos (0.325 kg ai $ha^{-1}$) + ethoxysulfuron (0.012 kg $ha^{-1}$) + ($T_7$) which were on par. At 60 DAT, maximum weed control efficiency was recorded by anilofos (0.325 kg ai $ha^{-1}$) + ethoxysulfuron (0.012 kg $ha^{-1}$) + one handweeding ($T_8$) followed by anilofos (0.325 kg ai $ha^{-1}$) + ethoxysulfuron (0.012 kg $ha^{-1}$) ($T_7$) which was on par with butachlor (1.25 kg ai $ha^{-1}$) + 2, 4-D sodium salt (1.0 kg ai $ha^{-1}$ ($T_1$) and superior to remaining treatments. At harvest, butachlor (1.25 kg ai $ha^{-1}$) + 2, 4-D sodium salt (1.0 kg ai $ha^{-1}$ ($T_1$).

Table 25. Effect of weed management practices on weed control efficiency of grasses, %

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 94.36 | 90.43 | 85.30 | 85.83 |
| $T_2$ | 94.31 | 90.35 | 85.26 | 85.71 |
| $T_3$ | 94.56 | 90.49 | 85.65 | 85.70 |
| $T_4$ | 94.51 | 90.56 | 85.61 | 85.66 |
| $T_5$ | 94.83 | 90.61 | 86.11 | 85.79 |
| $T_6$ | 94.92 | 90.65 | 86.19 | 85.90 |
| $T_7$ | 94.66 | 90.47 | 85.73 | 85.59 |
| $T_8$ | 94.72 | 90.52 | 85.98 | 85.71 |
| $T_9$ | 93.87 | 89.56 | 85.55 | 85.40 |
| $T_{10}$ | 93.98 | 89.66 | 85.57 | 85.43 |
| $T_{11}$ | 74.34 | 72.55 | 76.66 | 78.01 |
| $T_{12}$ | - | - | - | - |
| $F_{11,22}$ | 614.309** | 2661.33** | 5239.33** | 11496** |
| SE | 0.205 | 0.079 | 0.028 | 0.016 |
| CD | 0.606 | 0.233 | 0.082 | 0.048 |

** Significant at 1 per cent level

Table 26. Effect of weed management practices on weed control efficiency of broad leaved weeds, %

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 60.32 | 69.85 | 76.49 | 69.09 |
| $T_2$ | 52.77 | 67.95 | 70.61 | 61.50 |
| $T_3$ | 52.96 | 67.78 | 69.52 | 62.30 |
| $T_4$ | 53.72 | 68.06 | 69.77 | 61.15 |
| $T_5$ | 53.62 | 78.80 | 71.05 | 61.62 |
| $T_6$ | 54.76 | 67.34 | 76.31 | 68.02 |
| $T_7$ | 62.39 | 70.47 | 76.70 | 67.90 |
| $T_8$ | 63.24 | 71.14 | 77.24 | 68.69 |
| $T_9$ | 55.98 | 67.00 | 76.22 | 61.51 |
| $T_{10}$ | 57.58 | 67.51 | 76.34 | 61.84 |
| $T_{11}$ | 18.82 | 27.90 | 48.40 | 50.70 |
| $T_{12}$ | - | - | - | - |
| $F_{11,22}$ | 579.77** | 1607.71** | 7233.18** | 182.46** |
| SE | 0.304 | 0.193 | 0.059 | 0.231 |
| CD | 0.896 | 0.570 | 0.175 | 0.684 |

** Significant at 1 per cent level

#### *4.1.8.3 Weed Control Efficiency of Sedges*

The results are presented in Table 27

At all stages, handweeding twice ($T_{11}$) recorded lowest weed control efficiency. At 20 DAT all other treatments except handweeding twice ($T_{11}$) were having same weed control efficiency. At 40 DAT, anilofos (0.325 kg ai $ha^{-1}$) + ethoxysulfuron (0.012 kg $ha^{-1}$) + one hand weeding ($T_8$) registered maximum weed control efficiency than the remaining treatments. At 60 DAT, anilofos 24 per cent + 2,4-D ethyl ester (1.0 kg ai $ha^{-1}$) + one hand weeding ($T_4$) was found to have better weed control efficiency than all the remaining treatments except pretilachlor (1.0 kg ai $ha^{-1}$) + 2,4-D sodium salt (1 kg ai $ha^{-1}$) ($T_6$). At harvest, all treatments registered higher weed control efficiency than handweeding twice ($T_{11}$).

#### *4.1.8.4 Total Weed Control Efficiency*

The results are presented in Table 28.

At all stages, handweeding twice ($T_{11}$) recorded least total weed control efficiency. Total weed control efficiency was highest for anilofos (0.325 kg ai $ha^{-1}$) + ethoxysulfuron (0.012 kg $ha^{-1}$) ($T_7$) and Anilofos (0.325 kg ai $ha^{-1}$) + ethoxysulfuron (0.012 kg $ha^{-1}$) + one hand weeding ($T_8$) which were on par at 20 DAT. Total weed control efficiency of pretilachlor (1.0 kg ai $ha^{-1}$) + 2,4-D sodium salt (1 kg ai $ha^{-1}$) ($T_6$) was on par with butachlor (1.25 kg ai $ha^{-1}$) + 2, 4-D sodium salt (1.0 kg ai $ha^{-1}$) ($T_1$) but greater than the remaining treatments.

At 40 DAT, maximum total weed control efficiency was registered by pretilachlor (1.0 kg ai $ha^{-1}$) + one hand weeding ($T_5$) which was on par with anilofos 24 per cent + 2,4-D ethyl ester (1.0 kg ai $ha^{-1}$) + one hand weeding ($T_4$) but superior to remaining treatments. At 60 DAT, pretilachlor (1.0 kg ai $ha^{-1}$) + 2,4-D sodium salt (1 kg ai $ha^{-1}$) ($T_6$) was found to be on par with anilofos (0.325 kg ai $ha^{-1}$) + ethoxysulfuron

Table 27. Effect of weed management practices on weed control efficiency of sedges, %

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 71.89 | 80.07 | 47.08 | 35.09 |
| $T_2$ | 71.37 | 79.58 | 46.88 | 33.19 |
| $T_3$ | 71.49 | 79.96 | 46.84 | 35.33 |
| $T_4$ | 71.99 | 80.26 | 47.29 | 35.55 |
| $T_5$ | 71.74 | 79.68 | 47.00 | 33.21 |
| $T_6$ | 71.99 | 80.09 | 47.17 | 34.50 |
| $T_7$ | 72.20 | 80.17 | 46.50 | 35.43 |
| $T_8$ | 72.07 | 80.31 | 46.96 | 35.53 |
| $T_9$ | 68.05 | 79.30 | 46.39 | 34.66 |
| $T_{10}$ | 69.50 | 79.50 | 46.52 | 34.93 |
| $T_{11}$ | 33.57 | 21.79 | 41.30 | 24.23 |
| $T_{12}$ | - | - | - | - |
| $F_{11,22}$ | 1792.11** | 13985.18** | 548.44** | 1589.32** |
| SE | 0.159 | 0.091 | 0.042 | 0.052 |
| CD | 0.469 | 0.267 | 0.124 | 0.152 |

** Significant at 1 per cent level

Table 28. Effect of weed management practices on total weed control efficiency,%

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 87.57 | 86.82 | 76.58 | 75.31 |
| $T_2$ | 86.90 | 86.65 | 75.65 | 73.64 |
| $T_3$ | 87.13 | 87.06 | 75.77 | 74.09 |
| $T_4$ | 87.28 | 87.18 | 75.85 | 73.91 |
| $T_5$ | 87.42 | 87.45 | 76.30 | 73.71 |
| $T_6$ | 87.66 | 86.93 | 77.13 | 75.07 |
| $T_7$ | 88.07 | 87.01 | 76.74 | 74.98 |
| $T_8$ | 88.16 | 87.11 | 77.10 | 75.19 |
| $T_9$ | 86.23 | 85.96 | 76.57 | 73.66 |
| $T_{10}$ | 86.70 | 86.12 | 76.63 | 73.75 |
| $T_{11}$ | 13.03 | 58.44 | 65.77 | 65.22 |
| $T_{12}$ | - | - | - | - |
| $F_{11,22}$ | 66189.00** | 3666.59** | 4686.29** | 2198.36** |
| SE | 0.056 | 0.094 | 0.030 | 0.038 |
| CD | 0.165 | 0.278 | 0.089 | 0.111 |

** Significant at 1 per cent level

(0.012 kg $ha^{-1}$) + one hand weeding ($T_8$) and recorded maximum weed control efficiency. At harvest, maximum weed control efficiency was recorded by butachlor (1.25 kg ai $ha^{-1}$) + 2, 4-D sodium salt (1.0 kg ai $ha^{-1}$) ($T_1$) which was on par with anilofos (0.325 kg ai $ha^{-1}$) + ethoxysulfuron (0.012 kg $ha^{-1}$) + one hand weeding ($T_8$) but superior to remaining treatments.

### 4.1.9 Weed Index

The results are presented in Table 29. No significant difference between the treatments.

## 4.2 CROP GROWTH CHARACTERS

Observations on crop growth characters like plant height, tiller number per hill, leaf area index and crop dry matter production where collected from randomly selected hills from the net plot area.

### 4.2.1 Plant Height

The plant height (cm) was recorded at 20, 40, 60 DAT and at harvest. The results are presented in Table 30.

On all the growth stages, the weed management practices significantly influenced plant height. At 20 DAT, two hand weeding ($T_{11}$) was on par with butachlor (1.25 kg ai $ha^{-1}$) + one hand weeding ($T_2$). Maximum plant height was observed for plants treated with pretilachlor (1.0 kg ai $ha^{-1}$) + 2,4-D sodium salt (1 kg ai $ha^{-1}$) ($T_6$), which was on par with $T_5$, $T_4$, and $T_3$. No significant difference in plant height was observed for butachlor (1.25 kg ai $ha^{-1}$) + 2, 4-D sodium salt (1.0 kg ai $ha^{-1}$) ($T_1$) and btachlor (1.25 kg ai $ha^{-1}$) + one hand weeding ($T_2$) but plant height recorded by these treatments were significantly lower than that of remaining treatments excluding $T_{11}$ and unweeded control ($T_{12}$).

When the plant height was recorded at 40 DAT, two handweeding gave similar result as that of unweeded control. At this stage also

Table 29. Effect of weed management practices on weed index

| Treatments | Weed index |
|---|---|
| $T_1$ | 7.47(1.24) |
| $T_2$ | 14.23 (1.38) |
| $T_3$ | 7.47 (1.24) |
| $T_4$ | 9.23 (1.28) |
| $T_5$ | 11.38 (1.33) |
| $T_6$ | 7.47 (1.24) |
| $T_7$ | 14.23 (1.38) |
| $T_8$ | 2.94 (1.00) |
| $T_9$ | 11.64 (1.34) |
| $T_{10}$ | 7.65 (1.25) |
| $T_{11}$ | 11.68 (1.34) |
| $T_{12}$ | 32.99(1.63) |
| $F_{11,22}$ | $1.92^{ns}$ |
| SE | 0.105 |
| CD | - |

** Significant at 1 per cent level

Figures in parenthesis denote transformed values

Table 30. Effect of weed management practices on plant height, cm

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 40.53 | 70.27 | 88.27 | 90.40 |
| $T_2$ | 40.11 | 70.76 | 86.48 | 89.24 |
| $T_3$ | 41.37 | 71.48 | 87.37 | 90.31 |
| $T_4$ | 41.57 | 71.84 | 87.43 | 90.44 |
| $T_5$ | 41.80 | 70.86 | 87.43 | 89.95 |
| $T_6$ | 42.03 | 71.03 | 87.28 | 90.11 |
| $T_7$ | 41.15 | 71.53 | 86.45 | 90.49 |
| $T_8$ | 41.01 | 71.06 | 87.20 | 89.78 |
| $T_9$ | 41.14 | 70.66 | 86.67 | 89.52 |
| $T_{10}$ | 41.20 | 71.24 | 87.33 | 89.09 |
| $T_{11}$ | 39.56 | 69.86 | 86.46 | 88.67 |
| $T_{12}$ | 37.68 | 69.52 | 85.80 | 87.23 |
| $F_{33,72}$ | | | | 3.56** |
| SE | | | | 0.269 |
| CD | | | | 0.762 |

** Significant at 1 per cent level

increased plant height was seen in all treated plots with no difference between butachlor (1.25 kg ai $ha^{-1}$) + 2, 4-D sodium salt (1.0 kg ai $ha^{-1}$) ($T_1$) and handweeding twice ($T_{11}$). At 60 DAT, again differential response in plant height was observed for all the treatments. Here, maximum height was registered by butachlor (1.25 kg ai $ha^{-1}$) + 2, 4-D sodium salt (1.0 kg ai $ha^{-1}$) ($T_1$) followed by anilofos 24 per cent + 2,4-D ethyl ester (1.0 kg ai $ha^{-1}$) + one hand weeding ($T_4$) and pretilachlor (1.0 kg ai $ha^{-1}$) + one hand weeding ($T_5$). While butachlor (1.25 kg ai $ha^{-1}$) + one hand weeding ($T_2$), handweeding twice ($T_{11}$) and anilofos (0.325 kg ai $ha^{-1}$) + ethoxysulfuron (0.012 kg $ha^{-1}$) ($T_7$) are on par with unweeded control ($T_{12}$) At harvest stage, there was no significant difference among the treatments.

### 4.2.2 Number of Tillers per Hill

Number of tillers per hill was recorded at 20, 40, 60 DAT and at harvest. The results are presented in Table 31.

At 20 DAT, anilofos (0.325 kg ai $ha^{-1}$) + ethoxysulfuron (0.012 kg $ha^{-1}$) + one hand weeding ($T_8$) recorded better tiller number than all other treatments. However all the treatments faired better than two handweeding ($T_{11}$) and unweeded control ($T_{12}$). At 40 DAT, anilofos (0.325 kg ai $ha^{-1}$) + ethoxysulfuron (0.012 kg $ha^{-1}$) + one hand weeding ($T_8$) was on par with all treatments except two handweeding ($T_{11}$) and unweeded control ($T_{12}$). This was not the trend at 60 DAT where the plots treated with pretilachlor (1.0 kg ai $ha^{-1}$) + 2,4-D sodium salt (1 kg ai $ha^{-1}$) ($T_6$) produced more tiller number than all the treatments except $T_7$, $T_5$ and $T_4$. At harvest stage, pretilachlor (1.0 kg ai $ha^{-1}$) + 2,4-D sodium salt (1 kg ai $ha^{-1}$) ($T_6$), anilofos (0.325 kg ai $ha^{-1}$) + ethoxysulfuron (0.012 kg $ha^{-1}$) ($T_7$) and anilofos (0.325 kg ai $ha^{-1}$) + ethoxysulfuron (0.012 kg $ha^{-1}$) + one hand weeding ($T_8$) were on par but tiller number was higher in plots treated with anilofos (0.325 kg ai $ha^{-1}$) + ethoxysulfuron (0.012 kg $ha^{-1}$) ($T_7$).

Table 31. Effect of weed management practices on number of tillers per hill

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 2.60 | 8.18 | 9.98 | 9.13 |
| $T_2$ | 2.56 | 8.12 | 9.86 | 9.05 |
| $T_3$ | 2.62 | 8.14 | 9.88 | 9.24 |
| $T_4$ | 2.62 | 8.19 | 9.99 | 9.22 |
| $T_5$ | 2.64 | 8.18 | 10.04 | 9.13 |
| $T_6$ | 2.63 | 8.19 | 10.11 | 9.32 |
| $T_7$ | 2.67 | 8.15 | 10.07 | 9.38 |
| $T_8$ | 2.74 | 8.14 | 9.88 | 9.36 |
| $T_9$ | 2.61 | 8.10 | 9.94 | 9.05 |
| $T_{10}$ | 2.60 | 8.14 | 9.80 | 9.13 |
| $T_{11}$ | 2.16 | 8.03 | 9.86 | 8.98 |
| $T_{12}$ | 1.91 | 7.11 | 8.87 | 7.46 |
| $F_{33,72}$ | | | | 11.12** |
| SE | | | | 0.046 |
| CD | | | | 0.129 |

** Significant at 1 per cent level

### 4.2.3 Leaf Area Index

Leaf area index was recorded at panicle initiation stage and the results are presented in Table 32.

All the treated plants registered better LAI than unweeded control. $T_2$ was on par with $T_3$, while plots treated with T8 recorded higher LAI than plots received $T_9$, $T_1$, $T_5$, $T_3$, $T_2$ and unweeded control.

### 4.2.4 Dry Matter Production

The results are presented in Table 32. Dry matter production was recorded at harvest. All treated plots recorded significantly high dry matter production. $T_6$, $T_1$ and $T_4$ were on par but $T_6$ and $T_1$ treated plots recorded higher dry matter production than remaining plots.

### 4.2.5 Number of Productive Tillers $m^{-2}$

The results are presented in Table 33. Number of productive tillers was significantly high in all treated plots. $T_8$, $T_6$, $T_7$, $T_1$, $T_4$, $T_3$ and $T_{10}$ were on par but $T_8$ recorded significantly better than $T_5$, $T_2$, $T_9$, $T_{11}$ and unweeded control. $T_1$, $T_4$, $T_3$, $T_{10}$, $T_5$, $T_2$ and $T_9$ were on par with two handweeding.

### 4.2.6 Length of Panicle

The results are presented in Table 33.

Panicle length was measured and expressed in cm. All treatments recorded significantly high panicle length than unweeded control. However $T_1$ recorded higher value of panicle length and was on par with all other treatments.

### 4.2.7 Weight of Panicle

The results are presented in Table 34. Weight of panicle was significantly high in T4 and T8 compared to all treatments except T3, T1

Table 32. Effect of weed management practices on dry matter production (kg ha$^{-1}$) and leaf area index

| Treatments | Leaf area index | Dry matter production, kg ha$^{-1}$ |
|---|---|---|
| $T_1$ | 4.67 | 9355.20 |
| $T_2$ | 4.58 | 8989.17 |
| $T_3$ | 4.65 | 9261.93 |
| $T_4$ | 4.71 | 9333.10 |
| $T_5$ | 4.67 | 9223.67 |
| $T_6$ | 4.72 | 9359.50 |
| $T_7$ | 4.74 | 9070.17 |
| $T_8$ | 4.77 | 9208.83 |
| $T_9$ | 4.69 | 8993.17 |
| $T_{10}$ | 4.71 | 9020.43 |
| $T_{11}$ | 4.73 | 8957.60 |
| $T_{12}$ | 3.20 | 6632.33 |
| $F_{11,22}$ | 276.72** | 622.85** |
| SE | 0.026 | 29.86 |
| CD | 0.077 | 87.60 |

** Significant at 1 per cent level

Table 33. Effect of weed management practices on number of productive tillers $m^{-2}$, length of panicle, cm

| Treatments | Number of productive tillers $m^{-2}$ | Length of panicle, cm |
|---|---|---|
| $T_1$ | 545.38 | 21.35 |
| $T_2$ | 542.70 | 21.28 |
| $T_3$ | 544.71 | 21.34 |
| $T_4$ | 545.38 | 21.34 |
| $T_5$ | 542.70 | 21.21 |
| $T_6$ | 550.74 | 21.27 |
| $T_7$ | 549.40 | 21.34 |
| $T_8$ | 551.41 | 21.13 |
| $T_9$ | 542.03 | 21.20 |
| $T_{10}$ | 544.04 | 21.17 |
| $T_{11}$ | 537.34 | 21.14 |
| $T_{12}$ | 448.90 | 20.34 |
| $F_{11,22}$ | 111.90** | 2.50* |
| SE | 0.04 | 0.174 |
| CD | 0.12 | 0.512 |

** Significant at 1 per cent level

Table 34. Effect of weed management practices on weight of panicle (g) and number of spikelets / panicle

| Treatments | Weight of panicle, g | Number of spikelets / panicle |
|---|---|---|
| $T_1$ | 2.61 | 106.17 |
| $T_2$ | 2.59 | 105.24 |
| $T_3$ | 2.62 | 105.96 |
| $T_4$ | 2.64 | 106.09 |
| $T_5$ | 2.57 | 105.29 |
| $T_6$ | 2.61 | 106.17 |
| $T_7$ | 2.58 | 106.30 |
| $T_8$ | 2.63 | 106.38 |
| $T_9$ | 2.53 | 104.02 |
| $T_{10}$ | 2.57 | 104.10 |
| $T_{11}$ | 2.50 | 104.70 |
| $T_{12}$ | 2.31 | 93.38 |
| $F_{11,22}$ | 31.42** | 345.69** |
| SE | 0.016 | 0.193 |
| CD | 0.047 | 0.567 |

** Significant at 1 per cent level

and T6. However, weight of panicle was significantly high in all treated plots.

#### 4.2.8 Number of Spikelets per Panicle

The results are presented in Table 34. Significant increase was observed in all treated plots. $T_8$, $T_7$, $T_1$, $T_4$ and $T_3$ were on par but produced higher number of spikelets than all other treatments.

#### 4.2.9 Number of Filled Grains per Panicle

The results are presented in Table 35. Number of filled grains per panicle was significantly high in all treated plots including handweeding twice ($T_{11}$). Maximum number of filled grains per panicle was recorded from $T_1$, which was on par with $T_8$. Number of filled grains produced by $T_3$, $T_5$, $T_{10}$ and $T_9$ were significantly lower than that recorded from all the other treatments excluding handweeding twice ($T_{11}$) and unweeded control.

#### 4.2.10 Chaff Percentage

The results are presented in Table 35. Chaff percentage was significantly high in handweeding twice ($T_{11}$) and unweeded control ($T_{12}$). There was no significant difference among $T_1$, $T_4$, $T_6$, $T_8$, $T_{10}$, $T_9$ and $T_3$. However, $T_1$, $T_4$ and $T_6$ registered significantly low chaff percentage than $T_5$, $T_7$, $T_2$, $T_{11}$ and $T_{12}$.

#### 4.2.11 Thousand Grain Weight

The results are presented in Table 36. Thousand-grain weight was significantly high in all treated plots. Thousand-grain weights recorded from treated plots were on par and significantly higher than that recorded from $T_{11}$ and $T_{12}$. Lowest thousand-grain weight was recorded from $T_{12}$.

#### 4.2.12 Grain Yield

The results are presented in Table 37. The grain yield was considerably less from unweeded control. It was not significantly

Table 35. Effect of weed management practices on number of filled grains / panicle and chaff percentage, %

| Treatments | Number of filled grains / panicle | Chaff percentage,% |
|---|---|---|
| $T_1$ | 86.06 | 18.94 |
| $T_2$ | 84.35 | 19.84 |
| $T_3$ | 85.14 | 19.65 |
| $T_4$ | 85.96 | 18.98 |
| $T_5$ | 84.15 | 19.79 |
| $T_6$ | 86.00 | 18.99 |
| $T_7$ | 85.23 | 19.82 |
| $T_8$ | 86.12 | 19.04 |
| $T_9$ | 83.80 | 19.33 |
| $T_{10}$ | 83.99 | 19.32 |
| $T_{11}$ | 82.60 | 21.12 |
| $T_{12}$ | 71.58 | 23.34 |
| $F_{11,22}$ | 177.70** | 20.29** |
| SE | 0.299 | 0.279 |
| CD | 0.877 | 0.818 |

** Significant at 1 per cent level

Table 36. Effect of weed management practices on thousand grain weight,g

| Treatments | Thousand grain weight, g |
|---|---|
| $T_1$ | 22.60 |
| $T_2$ | 22.61 |
| $T_3$ | 22.71 |
| $T_4$ | 22.66 |
| $T_5$ | 22.65 |
| $T_6$ | 22.67 |
| $T_7$ | 22.72 |
| $T_8$ | 22.70 |
| $T_9$ | 22.64 |
| $T_{10}$ | 22.62 |
| $T_{11}$ | 21.54 |
| $T_{12}$ | 20.93 |
| $F_{11,22}$ | 34.78** |
| SE | 0.097 |
| CD | 0.284 |

** Significant at 1 per cent level

Table 37. Effect of weed management practices on grain yield (kg ha$^{-1}$), straw yield (kg ha$^{-1}$) and harvest index

| Treatments | Grain yield (kg ha$^{-1}$) | Straw yield (kg ha$^{-1}$) | Harvest index |
|---|---|---|---|
| $T_1$ | 3261 | 4536 | 0.42 |
| $T_2$ | 3051 | 4265 | 0.42 |
| $T_3$ | 3261 | 4748 | 0.41 |
| $T_4$ | 3366 | 5070 | 0.40 |
| $T_5$ | 3156 | 4576 | 0.41 |
| $T_6$ | 3261 | 4747 | 0.41 |
| $T_7$ | 3051 | 4576 | 0.40 |
| $T_8$ | 3577 | 5222 | 0.40 |
| $T_9$ | 3022 | 4262 | 0.42 |
| $T_{10}$ | 3261 | 4630 | 0.41 |
| $T_{11}$ | 3111 | 4726 | 0.40 |
| $T_{12}$ | 2328 | 3647 | 0.39 |
| $F_{11,22}$ | 3.28** | 2.66** | 0.88 $^{ns}$ |
| SE | 165.73 | 248.26 | 0.011 |
| CD | 486.11 | 728.17 | - |

** Significant at 1 per cent level

different between all the treatments except butachlor (1.25 kg ai $ha^{-1}$) + one hand weeding ($T_2$), and unweeded control ($T_{12}$). Anilofos (0.325 kg ai $ha^{-1}$) + ethoxysulfuron (0.012 kg $ha^{-1}$) + one hand weeding ($T_8$) recorded maximum grain yield compared to all other treatments.

### 4.2.13 Straw Yield

The results are presented in Table 37. Much difference in straw yield was observed among treatments except for better straw yield in T8 and $T_4$ in comparison with $T_{12}$, which was on par with $T_2$ and $T_9$.

### 4.2.14 Harvest Index

The results are presented in Table 37. Treatments did not influence the harvest index.

## 4.3 CHEMICAL ANALYSIS

### 4.3.1 Plant Analysis

#### *4.3.1.1 Total Nitrogen*

The results are presented in Table 38. Total nitrogen content in plant from all treated plots were significantly higher than that estimated from unweeded control. However, total nitrogen estimated from $T_8$ was found to be higher than that from $T_2$, $T_5$, $T_3$ and $T_{11}$, which are on with $T_1$, $T_4$, $T_7$, $T_9$ and $T_{10}$. Total nitrogen in plants treated with $T_6$ was also higher than that estimated from $T_3$ and $T_{11}$.

#### *4.3.1.2 Total Phosphorus*

The results are presented in Table 38. Total P estimated from all treated plots were significantly higher than that estimated from unweeded control. No significant difference in total P was found among $T_4$, $T_8$, $T_6$ and $T_1$, $T_7$, $T_{10}$, $T_3$ and $T_9$ but $T_4$, $T_8$ and $T_6$ were significantly higher than that of $T_2$, $T_5$ and $T_{11}$, which were on par with each other.

Table 38. Effect of weed management practices on total N, P, K of plant, %

| Treatments | N | P | K |
|---|---|---|---|
| $T_1$ | 1.35 | 0.72 | 1.22 |
| $T_2$ | 1.33 | 0.69 | 1.16 |
| $T_3$ | 1.32 | 0.71 | 1.22 |
| $T_4$ | 1.35 | 0.73 | 1.21 |
| $T_5$ | 1.33 | 0.68 | 1.16 |
| $T_6$ | 1.36 | 0.73 | 1.25 |
| $T_7$ | 1.35 | 0.72 | 1.27 |
| $T_8$ | 1.37 | 0.73 | 1.26 |
| $T_9$ | 1.35 | 0.71 | 1.22 |
| $T_{10}$ | 1.35 | 0.72 | 1.25 |
| $T_{11}$ | 1.32 | 0.67 | 1.20 |
| $T_{12}$ | 1.28 | 0.63 | 1.19 |
| $F_{11,22}$ | 4.003** | 7.85** | $1.971^{ns}$ |
| SE | 0.012 | 0.011 | 0.027 |
| CD | 0.034 | 0.032 | |

** Significant at 1 per cent level

ns: not significant

*4.3.1.3 Total Potassium*

The results are presented in Table 38. No significant difference in total K.

*4.3.1.4 Uptake of Nitrogen by Crop*

The results are presented in Table 39. Uptake of N was significantly higher in all treated plots. $T_{11}$ was found to be on par with $T_2$ but uptake of N by plants from $T_{11}$ was significantly lesser than remaining plots. No significant difference in N uptake was observed in $T_8$, $T_4$, $T_6$ and $T_1$, but significantly higher in comparison to other treatments.

*4.3.1.5 Uptake of Phosphorus by Crop*

The results are presented in Table 39. All treated plots recorded higher P uptake. In this case also, $T_2$ and $T_1$ were on par and uptake of P by plants from $T_{11}$ was significantly lower than that from remaining plots. Phosphorus uptake of plants from T6 treated plots were on par with t4, T1, $T_8$, $T_3$ and $T_{10}$ but significantly higher than that from remaining plots. A better P uptake was seen in $T_4$, $T_1$ and $T_8$ than $T_7$, $T_9$, $T_5$, $T_{11}$ and $T_{12}$.

*4.3.1.6 Uptake of Potassium by crop*

The results are presented in Table 39. All treated plots recorded higher K uptake. Potassium uptake of plants treated with $T_6$, $T_8$, $T_7$, $T_3$, $T_1$, $T_4$ and $T_{10}$ were on par but K uptake of plants treated with $T_6$, $T_8$ and $T_7$ were higher than that from $T_9$, $T_{11}$, $T_5$ and $T_2$, which were on par.

**4.3.2 Nutrient Uptake by Weeds**

Recorded at 20, 40, 60 DAT and at harvest.

*4.3.2.1 Nitrogen Uptake of Weeds (kg $ha^{-1}$)*

The results are presented in Table 40. N uptake was significantly high in hand weeded plots than chemically treated plots. No significant difference in N uptake was observed among $T_8$, $T_7$, $T_1$, $T_6$ and $T_4$ but $T_7$

Table 39.Effect of weed management practices on uptake of N, P and K by plant, kg ha$^{-1}$

| Treatments | N | P | K |
|---|---|---|---|
| $T_1$ | 125.86 | 67.35 | 113.81 |
| $T_2$ | 119.83 | 62.32 | 103.97 |
| $T_3$ | 122.70 | 65.75 | 113.93 |
| $T_4$ | 126.73 | 67.82 | 113.25 |
| $T_5$ | 122.65 | 62.72 | 106.68 |
| $T_6$ | 126.49 | 68.01 | 116.98 |
| $T_7$ | 122.26 | 65.29 | 115.18 |
| $T_8$ | 126.81 | 67.22 | 116.34 |
| $T_9$ | 121.66 | 64.14 | 109.40 |
| $T_{10}$ | 122.04 | 65.55 | 112.76 |
| $T_{11}$ | 117.77 | 60.01 | 107.35 |
| $T_{12}$ | 85.37 | 41.47 | 78.57 |
| $F_{11,22}$ | 114.73** | 69.99** | 26.81** |
| SE | 1.052 | 0.867 | 2.013 |
| CD | 3.088 | 2.540 | 5.904 |

** Significant at 1 per cent level

Table 40. Effect of weed management practices on nitrogen uptake of weeds, kg ha$^{-1}$

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 0.85 | 2.53 | 5.74 | 5.97 |
| $T_2$ | 0.96 | 2.56 | 6.16 | 6.56 |
| $T_3$ | 0.90 | 2.53 | 5.99 | 6.39 |
| $T_4$ | 0.87 | 2.47 | 6.09 | 6.40 |
| $T_5$ | 0.91 | 2.34 | 5.87 | 6.53 |
| $T_6$ | 0.85 | 2.45 | 5.67 | 6.02 |
| $T_7$ | 0.83 | 2.06 | 5.58 | 5.95 |
| $T_8$ | 0.81 | 1.90 | 5.33 | 5.68 |
| $T_9$ | 1.01 | 2.69 | 6.32 | 6.75 |
| $T_{10}$ | 0.97 | 2.67 | 6.17 | 6.62 |
| $T_{11}$ | 6.78 | 6.86 | 11.23 | 11.15 |
| $T_{12}$ | 7.85 | 20.74 | 37.00 | 37.21 |
| $F_{11,22}$ | 10320.80** | 3368.32** | 5069.70** | 10436.60** |
| SE | 0.024 | 0.092 | 0.126 | 0.087 |
| CD | 0.072 | 0.269 | 0.369 | 0.256 |

** Significant at 1 per cent level

and $T_8$ were found to have least N uptake than the remaining treatments.. $T_1$, T6 and $T_4$ were on par with $T_3$, $T_5$ and $T_2$, $T_{10}$ and $T_9$ were also on par. However uptake of N in $T_9$ was higher than that of all other except $T_{10}$ and $T_2$.

At 40 DAT, minimum uptake by $T_7$ and $T_8$ which were on par followed by $T_5$ which was on par with remaining treatments except $T_9$, $T_{10}$ and $T_{11}$. Here also hand weeding twice ($T_{11}$) registered higher uptake. At 60 DAT, in all the treated plots, uptake was significantly lower than that of hand weeding twice ($T_{11}$). Here uptake registered by $T_7$ and $T_8$ were significantly lower than that of all other treatments except $T_6$ which was on par with $T_7$ and $T_8$. Among the chemically treated plots, $T_9$ found to have a higher uptake value in comparison to $T_5$, $T_1$, $T_6$, $T_7$ and $T_8$. At harvest stage, $T_7$ and $T_8$ were found to have least N uptake in comparison with all the other treatments except $T_1$. All the chemically treated plots registered lesser N uptake than $T_{11}$. $T_1$ and $T_6$ were found to have lesser uptake than remaining treatments.

#### *4.3.2.2. Phosphors Uptake by Weeds (kg ha$^{-1}$)*

The results are presented in Table 41.

At 20 DAT, P uptake was more or less similar in all chemically treated plots and significantly lower than that of $T_{11}$. The same trend was seen at 40 DAT but at 60 DAT and at harvest, P uptake from $T_6$ and $T_8$ was significantly lower than that of $T_2$, $T_4$ and $T_5$.

#### *4.3.2.3 Potassium Uptake by Weeds (kg ha$^{-1}$)*

The results are presented in Table 42.

At 20 DAT, chemically treated plots registered less uptake than hand weeding twice. $T_1$, $T_6$, $T_7$ and $T_8$ were on par and K uptake from $T_7$ and $T_8$ was significantly lower than the remaining treatments. Maximum K uptake among chemically treated plots was observed in $T_9$ which was

Table 41.Effect of weed management practices on phosphorus uptake of weeds, kg ha$^{-1}$

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 0.47 | 0.97 | 2.05 | 2.42 |
| $T_2$ | 0.51 | 1.01 | 2.15 | 2.62 |
| $T_3$ | 0.49 | 0.95 | 2.02 | 2.46 |
| $T_4$ | 0.48 | 0.91 | 2.11 | 2.37 |
| $T_5$ | 0.48 | 0.92 | 2.16 | 2.61 |
| $T_6$ | 0.47 | 0.94 | 1.96 | 2.30 |
| $T_7$ | 0.45 | 0.93 | 2.09 | 2.44 |
| $T_8$ | 0.44 | 0.90 | 1.97 | 2.20 |
| $T_9$ | 0.53 | 0.97 | 2.00 | 2.49 |
| $T_{10}$ | 0.51 | 0.95 | 2.06 | 2.44 |
| $T_{11}$ | 3.40 | 3.09 | 3.17 | 3.44 |
| $T_{12}$ | 4.14 | 9.06 | 1055 | 9.95 |
| $F_{11,22}$ | 2604.89** | 1902.00** | 2703.69** | 1158.06** |
| SE | 0.008 | 0.018 | 0.054 | 0.063 |
| CD | 0.02 | 0.159 | 0.138 | 0.186 |

** Significant at 1 per cent level

Table 42. Effect of weed management practices on potassium uptake of weeds, kg ha$^{-1}$

| Treatments | 20 DAT | 40 DAT | 60 DAT | Harvest |
|---|---|---|---|---|
| $T_1$ | 1.07 | 2.78 | 5.45 | 6.78 |
| $T_2$ | 1.14 | 2.85 | 5.74 | 7.29 |
| $T_3$ | 1.12 | 2.81 | 5.59 | 7.11 |
| $T_4$ | 1.09 | 2.77 | 5.50 | 7.12 |
| $T_5$ | 1.08 | 2.71 | 5.51 | 7.25 |
| $T_6$ | 1.05 | 2.77 | 5.24 | 6.84 |
| $T_7$ | 1.03 | 2.79 | 5.37 | 6.83 |
| $T_8$ | 1.01 | 2.71 | 5.18 | 6.71 |
| $T_9$ | 1.20 | 3.03 | 5.42 | 7.27 |
| $T_{10}$ | 1.15 | 2.98 | 5.25 | 7.21 |
| $T_{11}$ | 7.62 | 8.38 | 7.91 | 9.71 |
| $T_{12}$ | 8.85 | 21.73 | 35.47 | 22.86 |
| $F_{11,22}$ | 21112.50** | 1147.96** | 21167.58** | 4779.93** |
| SE | 0.019 | 0.164 | 0.059 | 0.047 |
| CD | 0.056 | 0.480 | 0.174 | 0.139 |

** Significant at 1 per cent level

on par with $T_{10}$ and $T_2$. At 40 DAT, all the chemically treated plots were on par and registered lesser uptake than $T_{11}$. At 60 DAT, also chemically treated plots registered lower K uptake than $T_{11}$. K uptake from $T_6$, $T_8$ and $T_{10}$ were on par. K uptake in $T_8$ is significantly lower than that of remaining plots while $T_6$ was on par with $T_7$ but registered lesser K uptake than remaining treatments.

## 4.4 NUTRIENT CONTENT OF THE SOIL AFTER THE EXPERIMENT

NPK content of the soil after the experiment is presented in Table 43.

### 4.4.1 Soil Nitrogen Content

Soil nitrogen content was significantly higher in all treated plots. Soil nitrogen content in plots treated with $T_6$, $T_8$ and $T_4$ were on par but $T_6$ was better than the examining treatments, while $T_8$ and $T_4$ were on par with $T_1$.

$T_7$ and $T_3$ were on par and gave better soil nitrogen content than remaining treatments.

### 4.4.2 Soil Phosphorus Content

All treated plots recorded significantly higher soil P content. Soil phosphorus content in plots treated with $T_8$, $T_4$, $T_6$, $T_7$, $T_1$ and $T_3$ were on par but $T_8$ gave a better soil P content than $T_2$, $T_5$, $T_9$, $T_{10}$ and $T_{11}$ while $T_4$ and $T_6$ were better in soil P content than $T_9$, $T_{10}$ and $T_{11}$ which were on par.

### 4.4.3 Soil Potassium Content

Soil potassium content was significantly higher in all treated plots. $T_8$, $T_1$, $T_6$, $T_4$ and $T_7$ were on par but soil K content from plots treated with $T_8$ was significantly higher than that estimated from remaining

Table 43. Effect of weed management practices on NPK content of soil after the experiment, kg $ha^{-1}$

| Treatments | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|
| $T_1$ | 237.68 | 25.00 | 125.47 |
| $T_2$ | 232.54 | 24.66 | 122.73 |
| $T_3$ | 236.13 | 24.98 | 122.22 |
| $T_4$ | 237.95 | 25.67 | 125.35 |
| $T_5$ | 233.51 | 24.62 | 122.12 |
| $T_6$ | 238.90 | 25.52 | 125.46 |
| $T_7$ | 236.54 | 25.08 | 124.61 |
| $T_8$ | 238.53 | 25.94 | 126.22 |
| $T_9$ | 233.05 | 24.10 | 124.05 |
| $T_{10}$ | 233.95 | 24.10 | 124.07 |
| $T_{11}$ | 220.12 | 23.30 | 118.70 |
| $T_{12}$ | 215.84 | 21.50 | 112.53 |
| $F_{11,22}$ | 381.17** | 11.104** | 43.20** |
| SE | 0.377 | 0.363 | 0.584 |
| CD | 1.105 | 1.064 | 1.712 |

** Significant at 1 per cent level

treatments. $T_1$, $T_6$, $T_4$ and $T_7$ also gave better soil K content than $T_2$, $T_3$ and $T_5$, which were on par.

## 4.5 PROTEIN CONTENT OF RICE GRAINS

The results are presented in Table 44.

Protein content of rice grains estimated from all treated plots were significantly higher than that of $T_{11}$ and $T_{12}$. Protein content of rice grains from plots treated with $T_1$, $T_8$, $T_6$, $T_4$ and $T_2$ were on par but from $T_1$ and $T_2$ were significantly higher than that estimated from remaining treatments. The lowest value was estimated from $T_{12}$ followed by $T_{11}$.

## 4.6 RESIDUAL EFFECT OF HERBICIDES

Residual effect of herbicides on succeeding crop was assessed by recording the germination percentage, speed of germination and seedling vigour of cucumber seeds sown in herbicide treated plots after the harvest of rice crop.

### 4.6.1 Germination Percentage

The results are presented in Table 45.

The germination percentage of cucumber seeds was not significantly influenced by the residual effect of herbicides.

### 4.6.2 Speed of Germination

The results are presented in Table 45.

The speed of germination was not significantly influenced by residual effect of herbicides.

### 4.6.3 Seedling Vigour

The results are presented in Table 45.

Table 44. Effect of weed management practices on protein content of rice grains, %

| Treatments | Protein content,% |
|---|---|
| $T_1$ | 3.89 |
| $T_2$ | 3.85 |
| $T_3$ | 3.82 |
| $T_4$ | 3.87 |
| $T_5$ | 3.85 |
| $T_6$ | 3.87 |
| $T_7$ | 3.83 |
| $T_8$ | 3.88 |
| $T_9$ | 3.81 |
| $T_{10}$ | 3.84 |
| $T_{11}$ | 3.76 |
| $T_{12}$ | 3.68 |
| $F_{11,22}$ | 16.578** |
| SE | 0.015 |
| CD | 0.043 |

** Significant at 1 per cent level

Table 45. Residual effect of herbicides on germination per cent, speed of germination and seedling vigour of cucumber

| Herbicide | Germination, % | Speed of germination | Seedling vigour, VI |
|---|---|---|---|
| 1 | 80.33 | 16.07 | 1793.35 |
| 2 | 80.67 | 15.67 | 1800.45 |
| 3 | 80.00 | 15.67 | 1787.73 |
| 4 | 79.67 | 15.43 | 1780.73 |
| 5 | 79.00 | 15.47 | 1764.86 |
| 6 | 80.33 | 15.97 | 1793.77 |
| 7 | 80.00 | 15.77 | 1787.16 |
| 8 | 80.33 | 16.10 | 1792.51 |
| $F_{11,22}$ | $0.047^{ns}$ | $0.265^{ns}$ | $0.042^{ns}$ |
| SE | 2.395 | 0.499 | 53.197 |
| CD | - | - | - |

ns: not significant

Residual effect of herbicides did not significantly influenced the seedling vigour of cucumber seeds.

## 4.7 SHIFT IN WEED FLORA IN NEXT RICE

The study was conducted only during the Kharif season. This was not studied.

## 4.8 ECONOMIC ANALYSIS

The gross returns, net returns and B : C ratios were calculated.

### 4.8.1 Cost of Cultivation

The results presented in Table 46.

Hand weeding twice registered highest cost of cultivation. All the herbicide treatments and treatments involving herbicide + hand weeding registered lower cost of cultivation than hand weeding twice.

### 4.8.2 Gross Returns

The results are presented in Table 47.

All the treated plots registered higher gross returns than unweeded control. Among the other treatments gross returns from $T_8$ was significantly higher than that obtained from $T_7$, $T_2$ and $T_9$.

### 4.8.3 Net Returns

The results are presented in Table 47.

Net returns from $T_5$, $T_2$ and $T_{11}$ were on par with unweeded control. While net returns from $T_8$ was significantly higher than that from $T_{12}$. All the remaining treatments gave a better net return than unweeded control ($T_{12}$).

Table 46. Cost of cultivation of different weed management practices, Rs ha$^{-1}$

| Treatments | Cost of cultivation (Rs ha$^{-1}$) |
|---|---|
| $T_1$ | 23937 |
| $T_2$ | 29200 |
| $T_3$ | 23900 |
| $T_4$ | 27400 |
| $T_5$ | 27020 |
| $T_6$ | 27257 |
| $T_7$ | 23390 |
| $T_8$ | 26890 |
| $T_9$ | 23180 |
| $T_{10}$ | 26680 |
| $T_{11}$ | 30100 |
| $T_{12}$ | 23100 |

Data not analysed

Table 47. Effect of weed management practices on gross return (Rs ha$^{-1}$), net return (Rs ha$^{-1}$) and BCR

| Treatments | Gross return (Rs ha$^{-1}$) | Net return (Rs ha$^{-1}$) | BCR |
|---|---|---|---|
| $T_1$ | 33536 | 9598 | 1.40 |
| $T_2$ | 31416 | 4216 | 1.15 |
| $T_3$ | 33839 | 9939 | 1.41 |
| $T_4$ | 35046 | 7646 | 1.28 |
| $T_5$ | 32827 | 5807 | 1.22 |
| $T_6$ | 33957 | 6699 | 1.25 |
| $T_7$ | 32037 | 8646 | 1.37 |
| $T_8$ | 37276 | 10385 | 1.39 |
| $T_9$ | 31194 | 8014 | 1.34 |
| $T_{10}$ | 33724 | 7044 | 1.26 |
| $T_{11}$ | 32785 | 2685 | 1.09 |
| $T_{12}$ | 24758 | 1658 | 1.03 |
| $F_{11,22}$ | 3.611** | 3.196** | 4.796** |
| SE | 1574.76 | 1574.74 | 0.058 |
| CD | 4618.91 | 4618.85 | 0.169 |

** Significant at 1 per cent level

### 4.8.4 B : C Ratio

The results are presented in Table 47.

B : C ratio from $T_2$ and $T_{11}$ was on par with unweeded control ($T_{12}$). There was no significant difference in B : C ratio from $T_3$, $T_1$, $T_8$, $T_7$, $T_9$, $T_4$, $T_{10}$ and $T_6$ but B : C ratio from $T_3$ and $T_1$ was significantly higher than that from $T_5$, $T_2$, $T_{11}$ and $T_2$.

# DISCUSSION

# 5. DISCUSSION

An experiment was conducted in the CSRC, Karamana during virippu season (June to October) 2003 to study the effectiveness of different weed management practices on growth and yield of rice. The results obtained in the investigation are discussed below.

## 5.1 OBSERVATION ON WEEDS

### 5.1.1 Weed Species

Observations on weed species revealed that grasses, broadleaved weeds and sedges competed with rice plants. The most important grass weeds identified were *Echinochloa colonum* (L.) Link. and *Echinochloa crus-galli* (L.) P. Beauv. Among the sedges, *Cyperus iria* L., *Cyperus difformis* L. and *Fimbrystylis miliaceae* (L.) Vahl., *Monochoria vaginalis* (Burm.F.) Kunth., *Ludwigia parviflora* (L.) Roxb., *Sphenochloa zeylanica* and *Marsilea quadrifolia* were the prominent broadleaved weeds. Mahapatra *et al.* (2002) observed *Echinochloa crus-galli, Echinochloa colonum, Cyperus iria, Cyperus difformis, Ludwigia parviflora, Monochoria vaginalis* and *Marsilea quadrifolia* as the dominant weeds in transplanted rice.

### 5.1.2 Effect of Treatments on Weed Growth

The influence of treatments on weed growth was analysed based on vegetation analysis parameters. Absolute density (Ad), relative density (Rd), absolute frequency (Af), relative frequency (Rf), summed dominance ratio (SDR), weed control efficiency (WCE) and weed dry weight were the different parameters used for determining the effect of treatments on weed growth.

#### *5.1.2.1 Effect of Weed Management Practices on Weed Growth*

The weed management practices adopted influenced the weed growth of all type of weeds and resulted in significant reduction in weed population. All herbicidal treatments significantly reduced the density and dry weight of weed over weedy control. Sharma *et al.* (2003) also reported similar results.

Different herbicides reduced the total absolute density of all weeds compared to unweeded check at all periods of observation. Pre-emergence application of anilofos + ethoxysulfuron followed by hand weeding at 40 days after transplanting recorded the lowest total absolute density at all stages except at 60 DAT. The ability of anilofos + ethoxysulfuron in controlling weeds effectively was reported by Saha *et al.* (2003). Pre-emergence application of pretilachlor followed by post emergence application of 2,4-D recorded the lowest absolute density of grasses at 20 DAT and at harvest; at 40 and 60 DAT, pretilachlor + one hand weeding recorded lowest absolute density and is on par with pretilachlor + 2,4-D.

The weed control efficiency of all the herbicide treatments were superior to hand weeding twice and unweeded control (Fig 3a to 3d). At 20 DAT, Butachlor + 2,4-D recorded highest WCE of 69.33 and hand weeding twice recorded lowest WCE of 21.15 per cent. At all stages, hand weeding twice recorded lowest WCE when compared to herbicides alone or herbicide + hand weeding. This indicates that it was not sufficient to suppress the weed population till the harvest of the crop. Also the soil disturbance caused by the manual weeding operation might have favoured the growth of dormant weed seeds, which were below the soil surface. This is in agreement with the findings of Gupta *et al.* (1975) and Rajan (2000).

The results of the experiment have indicated that the dry matter accumulation by weeds could be substantially reduced by herbicide treatments. All the herbicidal treatments recorded significantly lower dry matter compared to hand weeding twice and unweeded control. The lowest dry matter of weeds was recorded by anilofos + ethoxysulfuron followed by one hand weeding which was on par with anilofos +

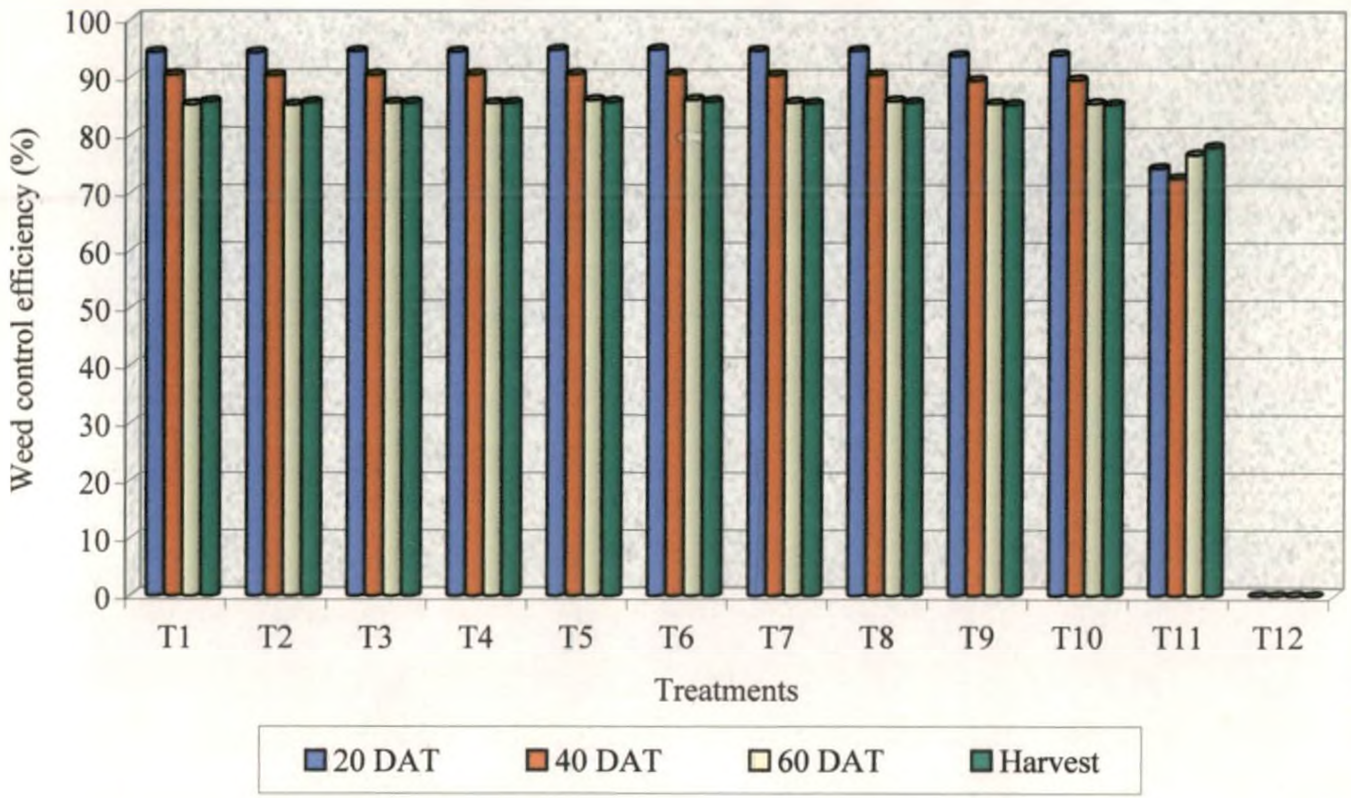


**Fig. 3a Effect of weed management practices on weed control efficiency of grasses (%)**

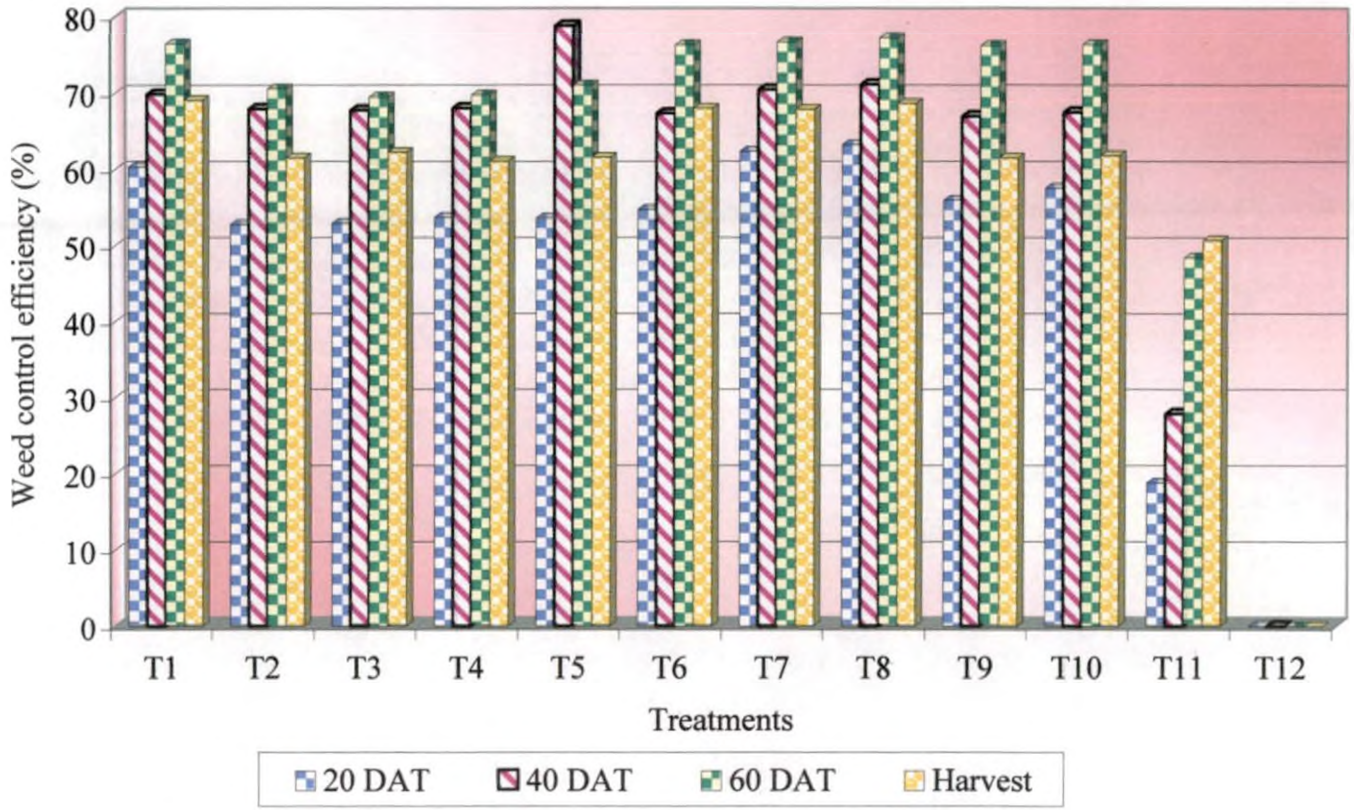


**Fig. 3b Effect of weed management practices on weed control efficiency of broadleaved weeds (%)**

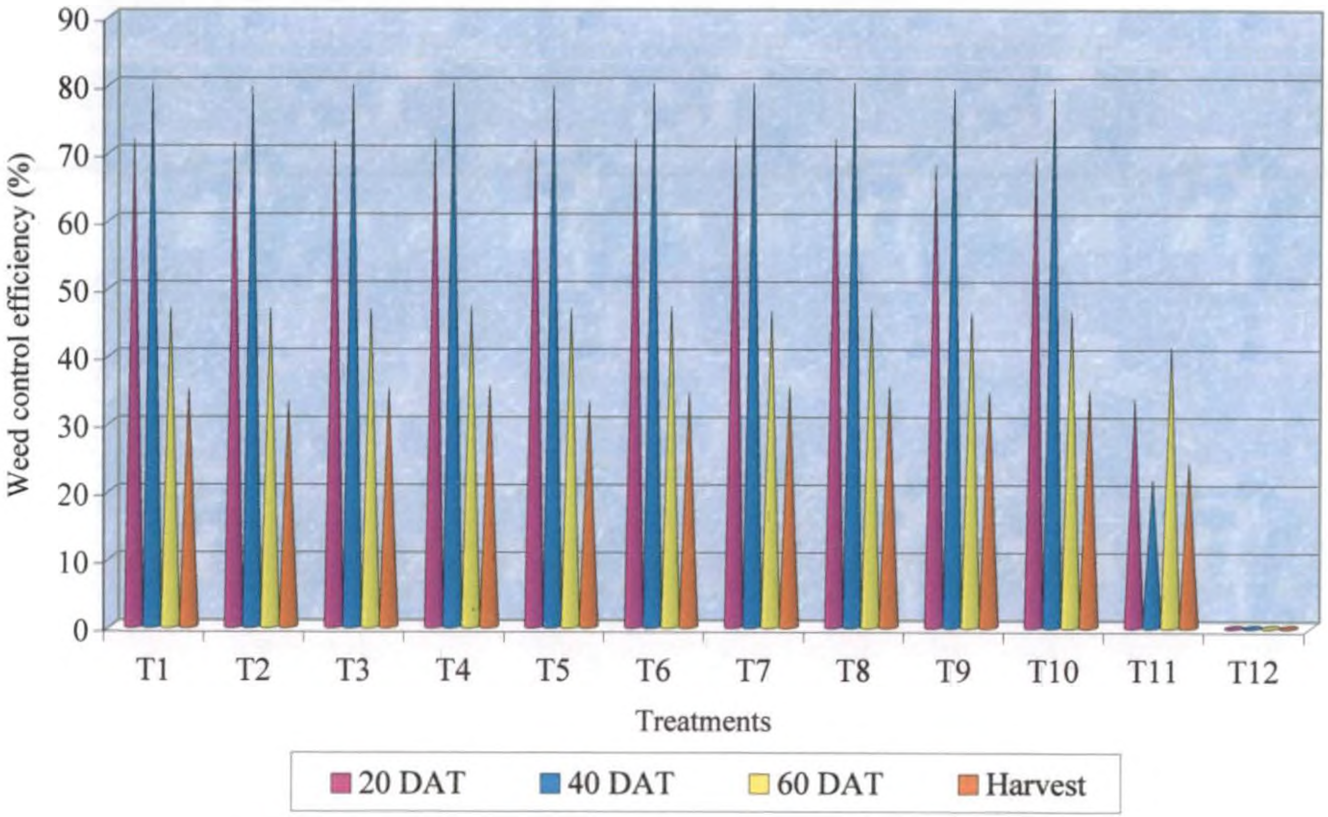


**Fig. 3c Effect of weed management practices on weed control efficiency of sedges (%)**

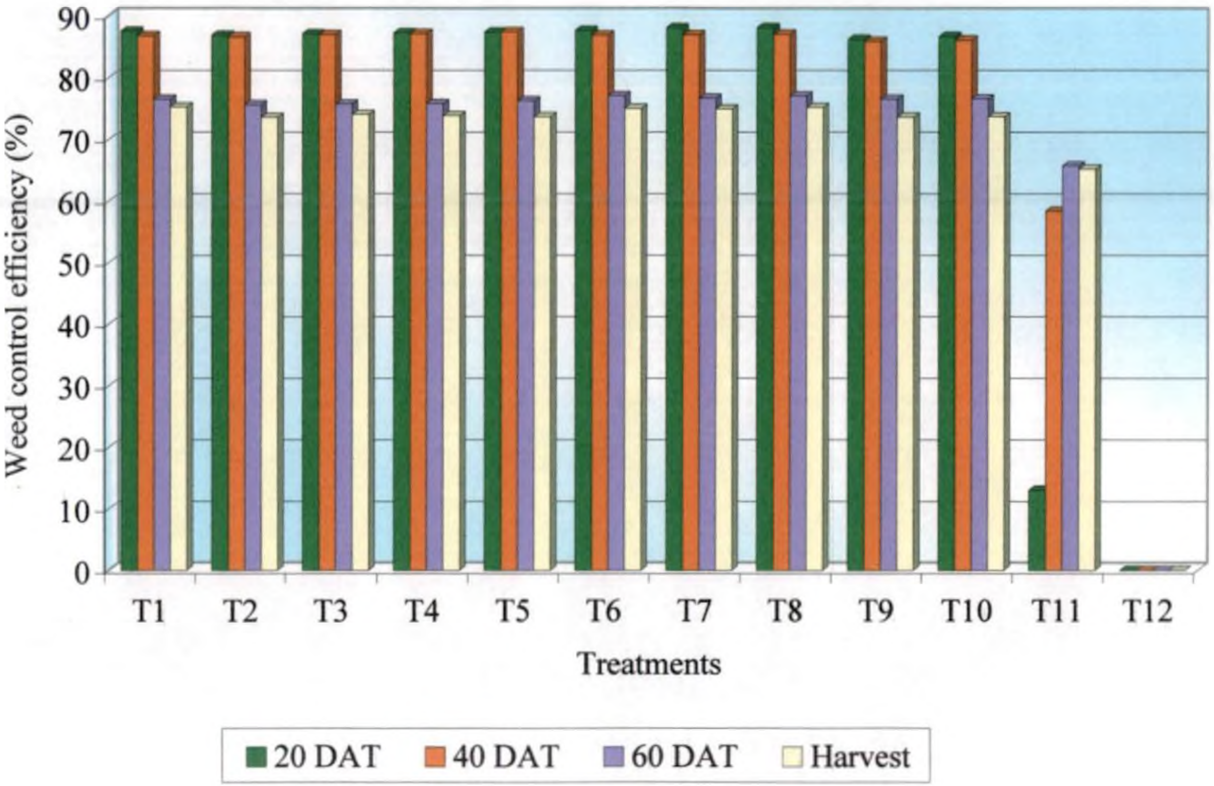


**Fig. 3d Effect of weed management practices on total weed control efficiency (%)**

Ethoxysulfuron alone. Rekha *et al.* (2002) also reported similar results (Fig 4a to 4d).

#### *5.1.2.2 Effect of Weed Management Practices on Nutrient Uptake by Weeds*

Weed management practices had significant influence on nutrient uptake by weeds. Pre-emergent application of anilofos + ethoxysulfuron followed by one hand weeding resulted in lower NPK uptake compared to all other treatments. Pre-emergence application of metsulfuron methyl and chlorimuron ethyl resulted in higher NPK uptake compared to other herbicidal treatments. This is because of the higher dry weight of weeds in that plot compared to other herbicide treatments and it couldn't provide effective control of weeds. This result is in corroborative with the findings of Singh *et al.* (2003c).

## 5.2 OBSERVATIONS ON CROP

### 5.2.1 Effect of Weed Management Practices on Crop Growth Characters

Plant height was significantly influenced by different weed management practices (Fig. 5). At 20 DAT, pre-emergence application of pretilachlor followed by 2,4-D at 20 DAT, resulted in higher plant height which was on par with application of pretilachlor + HW, application of anilophos + 2,4-DEE followed by one hand weeding and anilofos + 2,4-DEE. At 40 DAT, readimix application of anilofos + 2,4-DEE recorded highest plant height, but at 60 DAT, butachlor + 2,4-D recorded highest plant height and at harvest anilofos + ethoxy sulfuron recorded highest plant height when compared to all other treatments.

In general, all the weed management practices recorded better plant height than unweeded control, which recorded the lowest plant height. This was due to controlled weed growth in all weed management treatments, resulting in reduced competition while in unweeded control

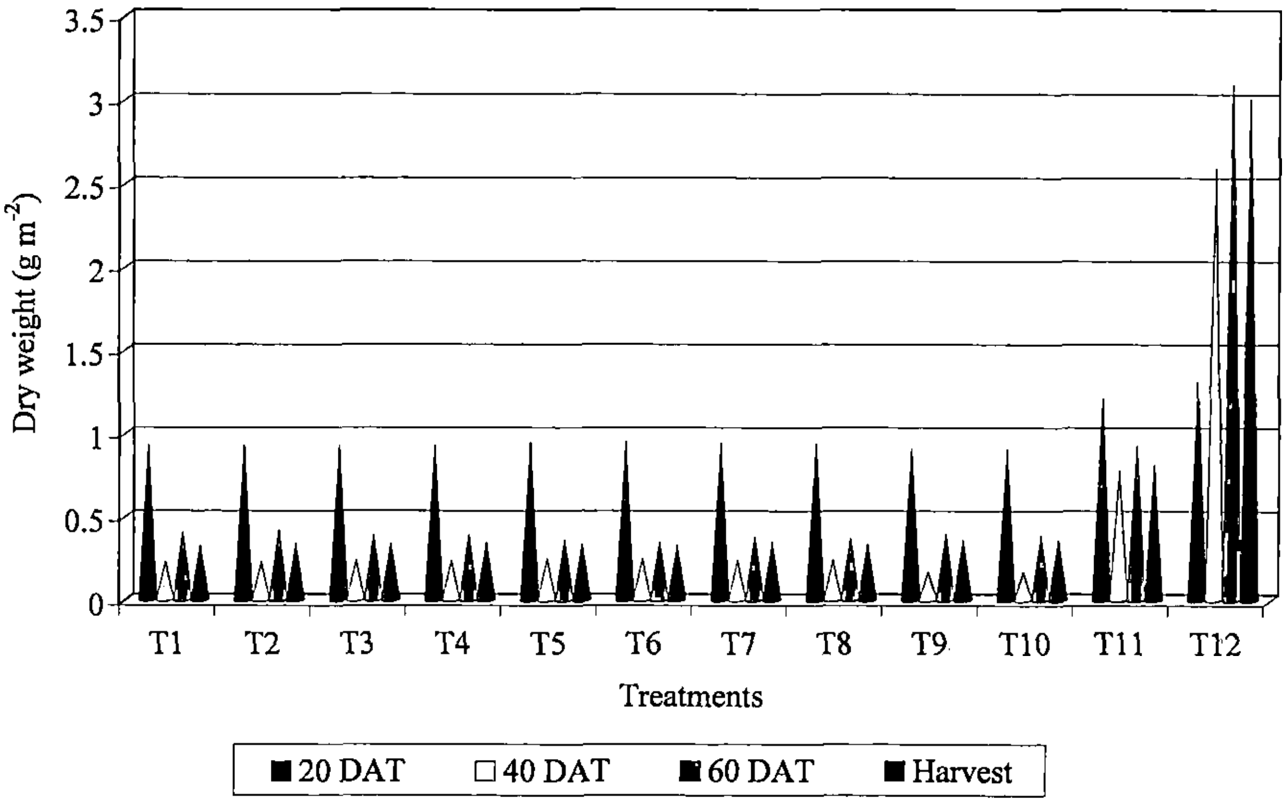


**Fig. 4a Effect of weed management practices on dry weight of grasses (g $m^{-2}$)**

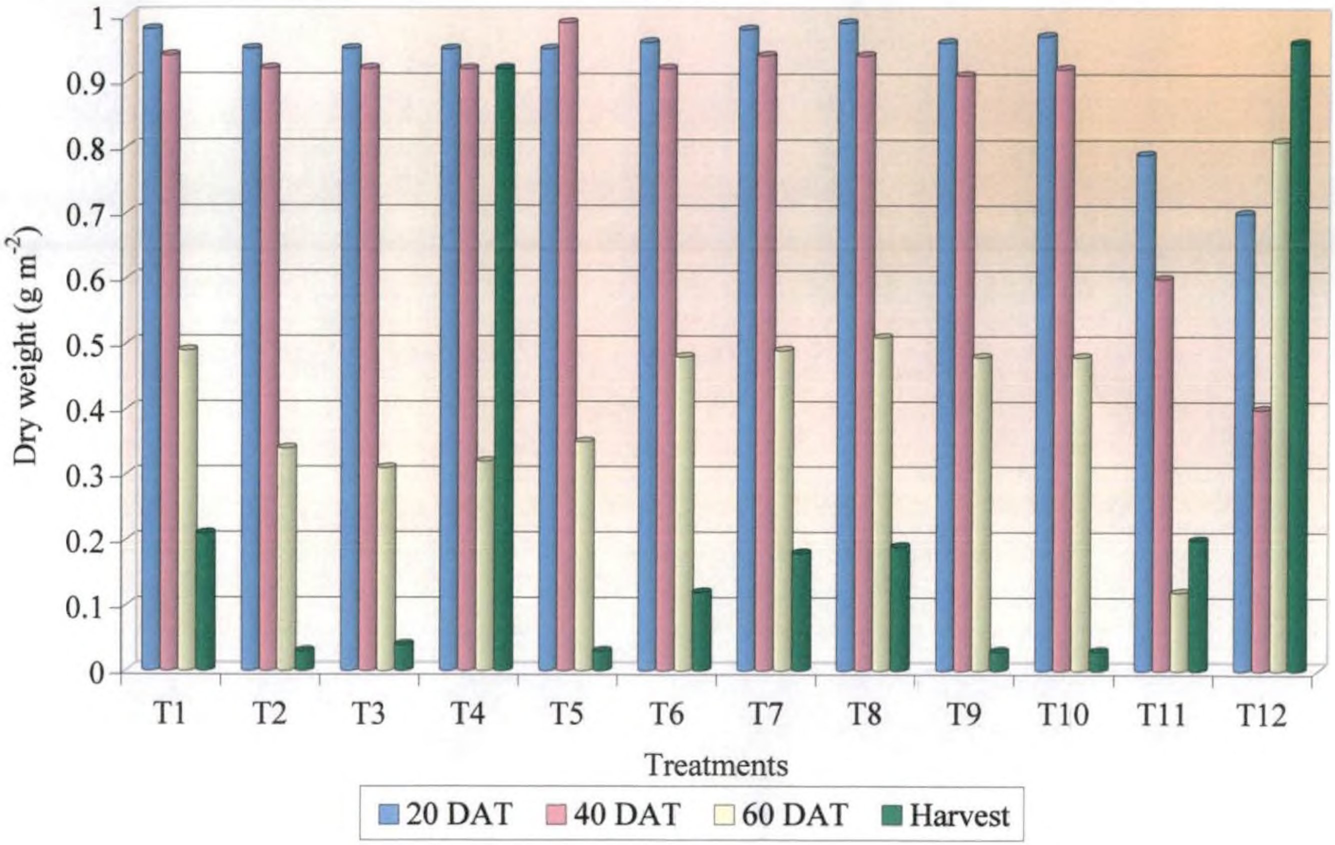


**Fig. 4b Effect of weed management practices on dry weight of broad leaved weeds (g $m^{-2}$)**

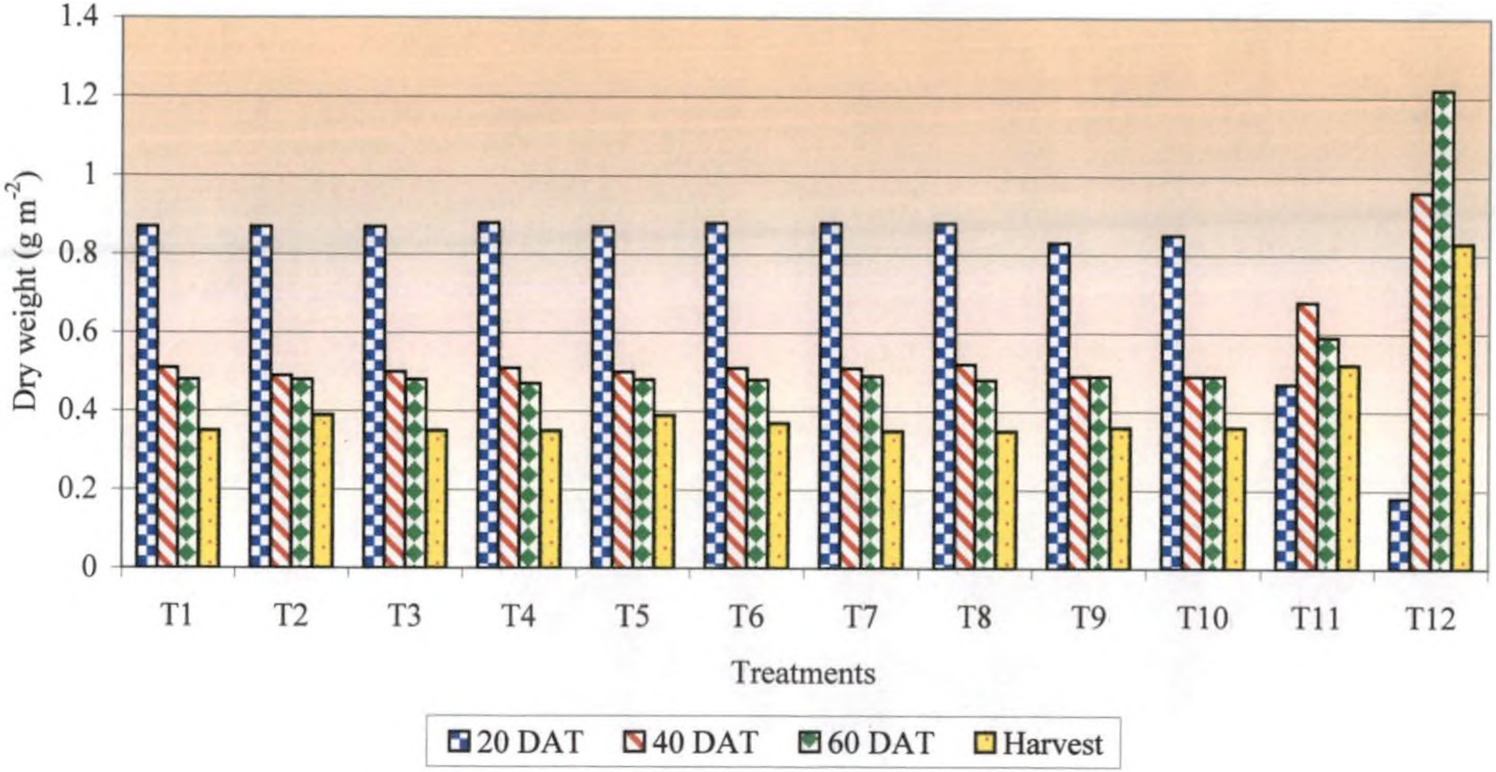


**Fig. 4c Effect of weed management practices on dry weight of sedges (g m-2)**

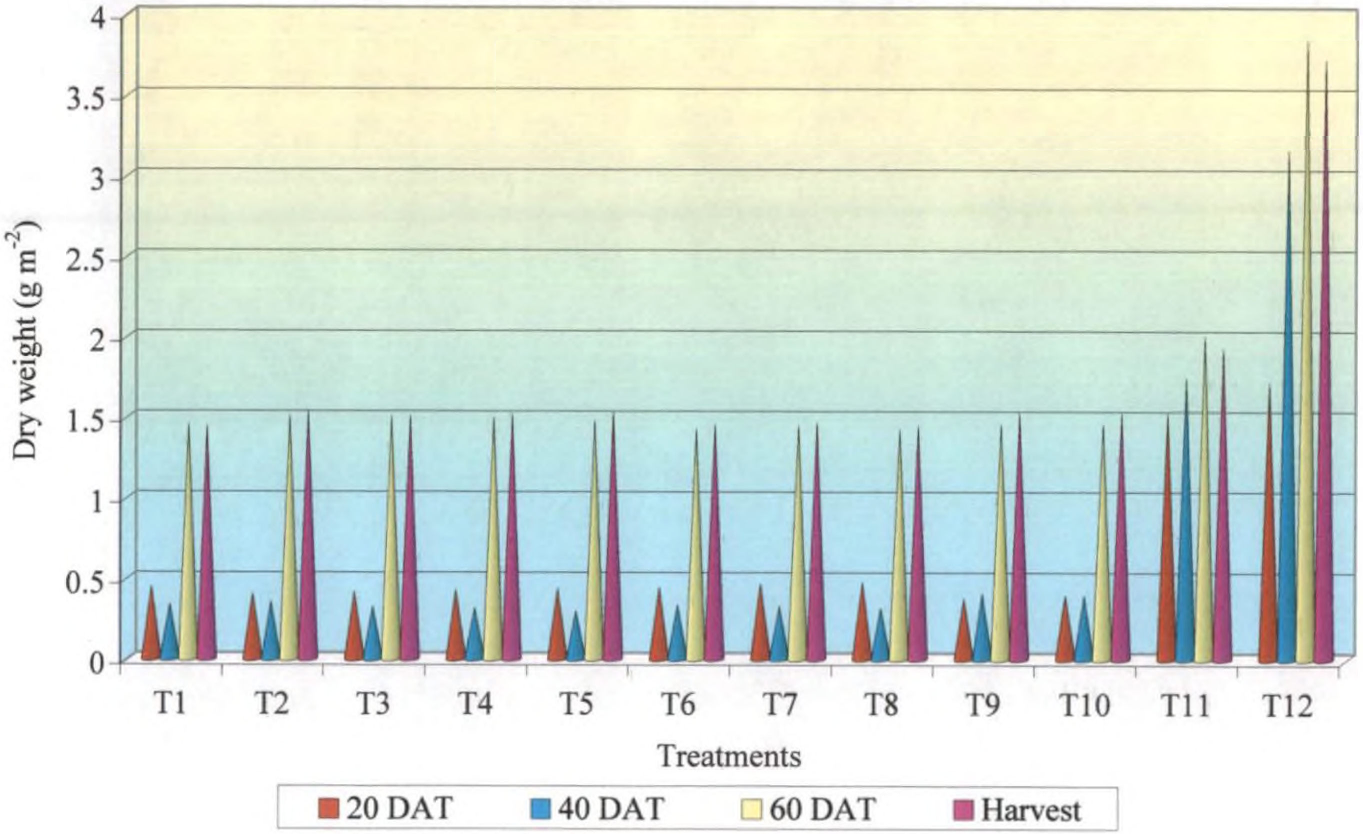


**Fig. 4d Effect of weed management practices on total weed dry weight ($g\ m^{-2}$)**

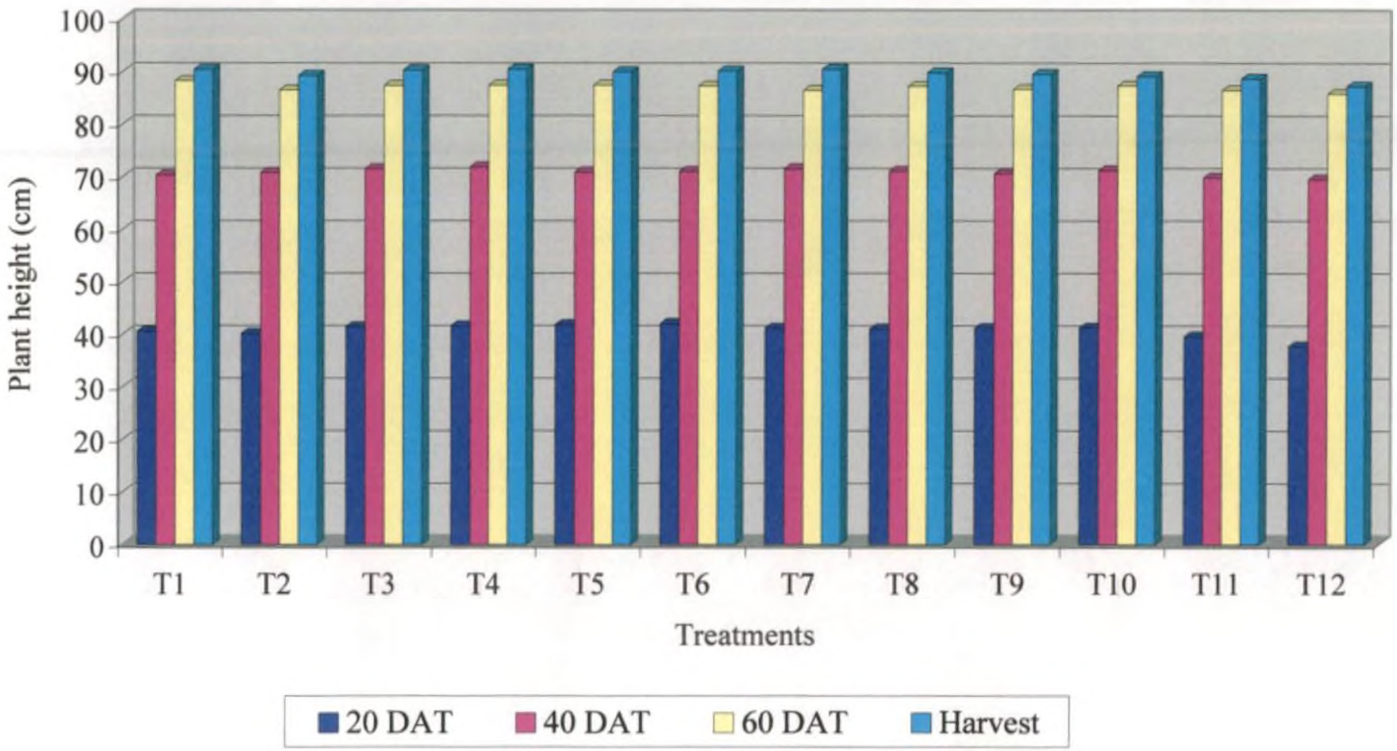


**Fig. 5 Effect of weed management practices on plant height (cm)**

weed competition might have reduced the plant height. Similar trend was noticed in almost all weed management studies throughout India.

The number of tillers $hill^{-1}$, dry matter production and LAI were also significantly influenced by weed management treatments. Balasubramanian (1996) noticed reduction in plant height and dry matter production due to weed infestation.

Leaf area index was highest in pre-emergent application of anilofos + ethoxysulfuron followed by HW at 40 DAT. LAI is an important measure of potential photosynthetic area and thus of the growth capability (Potter and Jones, 1997). The unweeded control recorded the lowest LAI, which may be attributed to the severe competition between the crop and weeds. Renjan (1999) and Nair (2001) reported a decrease in leaf area index due to weed competition. Pre-emergent application of anilofos + ethoxysulfuron followed by one hand weeding resulted in significantly higher tiller number at 20 DAT when compared to all other treatments. At 40 DAT, anilofos + 2,4-DEE and pretilachlor + 2,4-D recorded highest tiller number which were on par with all other treatments except hand weeding twice and unweeded control.

Unweeded control recorded the lowest tiller number at all stages of crop growth. From the data it was obvious that in weedy check, the weeds competed for nutrients and space with rice crop, which inhibited the tiller prduction of rice. At 20 DAT, anilofos + ethoxysulfuron followed by hand weeding recorded significantly higher tiller number which is followed by anilofos + ethoxysulfuron alone.

At 40 DAT, anilofos + 2,4-DEE + HW and pretilachlor + 2,4-D produced higher tiller number, at 60 DAT also pretilachlor + 2,4-D produced higher tiller number. This is due to effective control of weeds in the plots, which reduced the competition. Rajan (2000) reported similar results where pretilachlor + 2,4-D recorded maximum number of tillers.

But at harvest, anilofos + ethoxysulfuron treated plots produced higher tiller number and was on par with plots treated with pretilachlor + 2,4-D and anilofos + ethoxysulfuron + one HW. Compared to herbicide treatments values for growth attributes were lower in plots handweeded twice ($T_{11}$). This could be because manual weeding allowed unchecked weed growth upto 20 DAT (time of first manual weeding), thus causing considerable depletion of resources during the early crop growth. Gupta and Lamba (1978) observed that by manual weeding, weeds are removed after they have put forth considerable competition to crop and rarely at ideal time whereas herbicides provided the benefit of timely weed control.

All treated plots recorded significantly high dry matter production of crop. Plots treated with pretilachlor + 2,4-D and butachlor + 2,4-D recorded higher dry matter production of crop and was on par with anilofos + 2,4-DEE followed by one hand weeding. This might be due to the effective control of weeds by pre and post emergent application of suitable herbicides.

### 5.2.2 Effect of Weed Management Practices on Yield Attributing Characters and Yield

Various weed management practices adopted, significantly influenced the yield attributes and yield. Weed competition severely reduced the availability of moisture, nutrients and sunlight to rice crop resulting in lowest value in weedy check .($T_{12}$). All the herbicide treatments and herbicide + one hand weeding has given significantly higher yield attributes and yield than weedy check. Narwal *et al.* (2002) also reported similar results. This revealed that these practices were effective in reducing the weed competition with the crop and reduced the ill effects of weeds considerably. The number of productive tillers was enhanced by different weed management practices. Pre-emergent application of anilofos + ethoxysulfuron followed by handweeding at 40

DAT resulted in higher number of productive tillers. Number of productive tillers was less in unweeded check due to competition. Ramamoorthy *et al.* (1974) observed that competition reduced the number of productive tillers in rice crop. Reduction in panicle length was also observed due to weed competition. Mabbayad and Moody (1992) and Singh *et al.* (1999) also obtained similar results.

Grain and straw yield were significantly influenced by weed management practices (Fig. 6). The weedy check resulted in an yield loss of 35.7 per cent. The plots treated with anilofos + ethoxy sulfuron followed by hand weeding once recorded the highest grain and straw yield. This might be due to the higher number of productive tillers, 1000-grain weight and number of filled grains panicle$^{-1}$, which ultimately resulted in higher grain yield. This finding is in corroborative with Pal *et al.* (2002).

**5.2.3 Effect of Weed Management Practices on Nutrient Uptake by Crop**

All the weed management practices significantly influenced the nutrient uptake by the crop. Pre-emergence application of anilofos + ethoxysulfuron followed by one hand weeding recorded highest N uptake by the crop. It was on par with butachlor + 2,4-D, pretilachlor + 2,4-D and preemergent application of anilofos + 2,4-DEE. Arvdaithai *et al.* (2002) obtained higher nutrient uptake, leaf area index, productive tillers and grain yield when herbicide mixtures are applied at 4 DAT compared to application at 8 DAT. Pre-emergence application of pretilachlor followed by post emergence application of 2,4-D resulted in highest P and K uptake by crop. This was due to effective control of weeds by these herbicides, which resulted in lower weed dry weight, and lower uptake of nutrients by weeds. Hence the competition by weeds might be lower in this treatment. Thereby the uptake of P and K by crop was more in this treatment. Effectiveness of pretilachor + 2,4-D was reported by AICRP on weed control during 1997 and 2001. All the weed management practices results

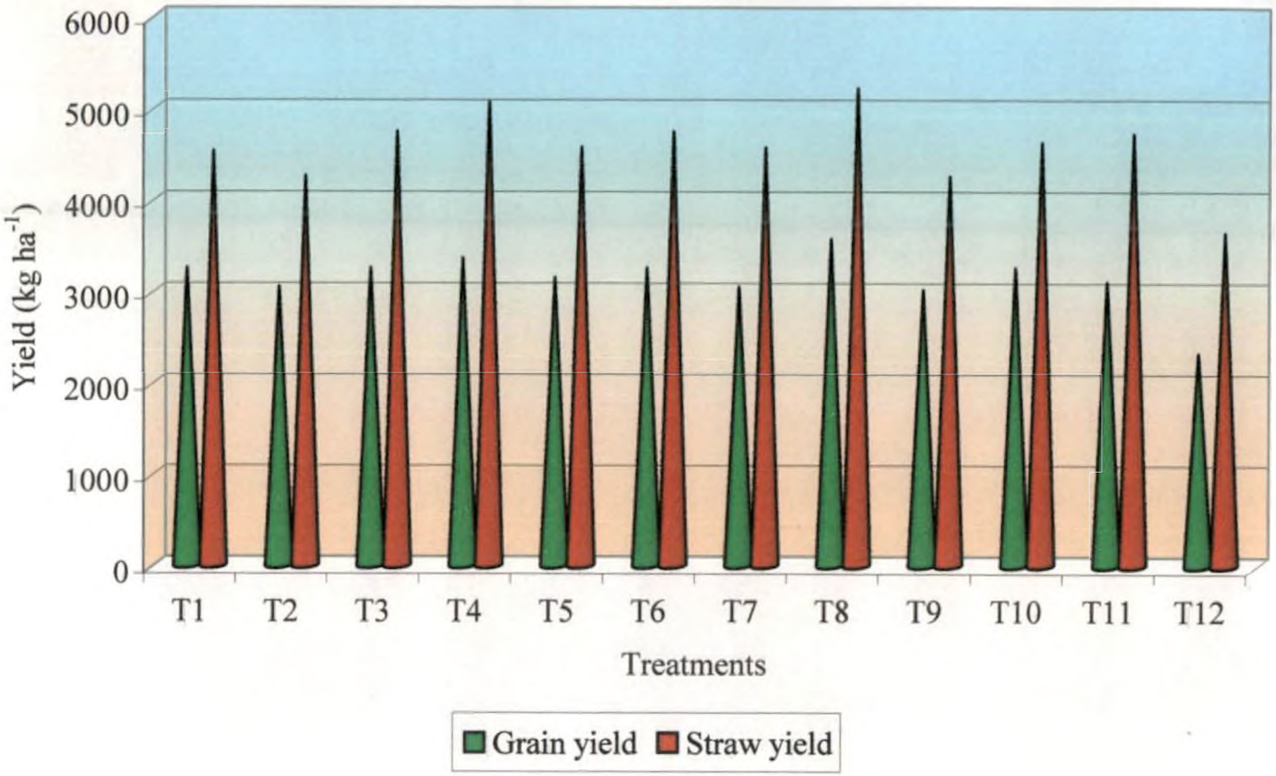


**Fig. 6 Effect of weed management practices on grain yield and straw yield (kg ha$^{-1}$)**

in an increase in the nutrient uptake by rice. This is similar to the findings of Nandal and Singh (1993).

## 5.3 NUTRIENT STATUS AFTER THE EXPERIMENT

The weed management practices had significant influence on the soil nutrient status. Nitrogen content was highest in plots treated with pretilachlor + 2,4-D which was on par with pre-emergent application of anilofos + ethoxy sulfuron followed by one hand weeding. This is due to less nitrogen removal by weeds in these treatments. Lowest NPK content of soil was recorded by unweeded control due to higher uptake of NPK by weeds. Highest P and K content of soil after experiment was recorded by anilofos + ethoxysulfuron followed by one hand weeding. This is due to less uptake of P and K by weeds in this treatment. Available NPK content in the soil increases due to herbicides due to the reduction in nutrient removal by weeds. This finding is in line with the work of Rajkhowa *et al.* (2001).

## 5.4 HERBICIDE PERSISTENCE IN SOIL

The results of the present study indicated that there was no residual toxicity of herbicides after the cropping season. So it is safe to go for even crops, which are noted, susceptible to these herbicides as the succeeding crop.

## 5.5 ECONOMICS OF WEED MANAGEMENT

Net returns and B: C ratio were appreciably influenced by the weed management practices. Pre-emergent application of anilofos + ethoxysulfuron followed by one hand weeding resulted in highest, gross and net return. Pre-emergent application of anilofos + 2,4-DEE resulted in highest B: C ratio of 1.41 followed by butachlor + 2,4-D with 1.40. Handweeding twice at 20 DAT and 40 DAT although gave good yield but net profit was less due to high labour charges. Hence looking in to the economics, pre and postemergent application of anilofos + ethoxysulfuron, anilofos + 2,4-DEE and butachlor + 2,4-D is very effective in weed management. The effective use of the above mentioned herbicide is economical in successful rice cultivation.

# SUMMARY

# 6. SUMMARY

The present study entitled "Integrated weed management in lowland rice" was carried out CSRC, Karamana during the virippu season of 2003. The main objectives of the experiment were to evolve a suitable integrated weed management strategy for lowland rice and to assess the efficiency and economic feasibility of different weed management strategies in lowland rice.

The experiment was laid out in randomised block design having three replications with twelve treatments. The different treatments consist of different herbicides alone and in combination with hand weeding, hand weeding twice and unweeded check. Butachlor, 2,4-D, anilofos + 2,4-DEE, metsulfuron methyl and chlorimuron ethyl, pretilachlor, anilofos and ethoxysulfuron were the herbicides used in the experiment. The residual effect of herbicides on the soil was also assessed based on the germination percentage, speed of germination and seedling vigour of cucumber seeds sown in herbicide treated plots and in control plots after the harvest of the crop.

The important results of the experiment are summarized below:

1. The most commonly observed weeds in the experimental site were *Echinochloa colona* (L.) Link., *Echinochloa crus-galli* (L.) P. Beauv and *Cynodon dactylon* Pers. among grasses, *Monochoria vaginalis* (Burm. F.) Kunth., *Mansilea quadrifolia* L., *Ludwigia parviflora* Roxb. among broadleaved weeds and *Cyperus difformis* L., *Cyperus iria* L. *Fimbrystylis miliaceae* (L.) Vahl. among sedges.
2. The unweeded check ($T_{12}$) recorded the highest weed growth throughout the crop period.

3. Pre-emergence application of anilofos + ethoxysulfuron followed by handweeding 40 days after transplanting recorded the lowest total absolute density at all stages except at 60 DAT.

4. The weed control efficiency of all the herbicide treatments were superior to hand weeding twice and unweeded control.

5. The lowest dry matter of weeds was recorded by anilofos + ethoxysulfuron followed by one handweeding which was on par with anilofos + ethoxysulfuron alone.

6. At all growth stages of rice, hand weeding twice recorded lowest weed control efficiency when, compared to herbicides alone or with hand weeding..

7. At 20 DAT, WCE of grasses recorded by pretilachlor + 2,4-D, pretilachlor + hand weeding, pre-emergent application of anilofos + ethoxysulfuron followed by hand weeding at 40 DAT, anilofos + ethoxysulfuron, readymix application of anilofos + 2,4-DEE and readymix application of anilofos + 2,4-DEE followed by hand weeding at 40 DAT were on par while pretilachlor + 2,4-D and pretilachlor + hand weeding have better weed controlled efficiency than the remaining treatments which were on par.

8. At 20 DAT, WCE of broadleaved weeds recorded by anilofos + ethoxysulfuorn and anilofos + ethoxysulfuron followed by handweeding at 40 DAT were significantly higher than the remaining treatments while at 40 DAT, pretilachlor + hand weeding found to have the highest weed control efficiency followed by pre-emergent application of anilofos + ethoxysulfuron followed by one hand weeding at 40 DAT and anilofos + ethoxysulfuron alone which were on par.

9. At 20 DAT, weed control efficiency of sedges recorded by pre-emergent application of anilofos + ethoxysulfuron alone, pre-

emergent application of anilofos + ethoxysulfuron followed by hand weeding at 40 DAT, ready mix application of anilofos + 2,4-DEE followed by hand weeding, pretilachlor + 2,4-D, butachlor + 2,4-D, pretilachlor + hand weeding at 20 DAT, ready mix application of anilofos + 2,4-DEE and butachlor + hand weeding at 20 DAT were having more or less same value.

10. At 40 DAT, maximum total weed control efficiency was registered by pretilachlor + hand weeding at 20 DAT which was on par with ready mix application of anilofos + 2,4-DEE followed by hand weeding at 40 DAT but superior to remaining treatments.

11. At 20 DAT, pre-emergent application of anilofos + ethoxysulfuron followed by hand weeding at 40 DAT and pre-emergent application of anilofos + ethoxysulfuron alone were on par and found to have least total weed dry weight.

12. At all growth stages of rice, hand weeding twice recorded highest total weed dry weight when compared to all other treatments.

13. At 40 DAT, lowest total weed dry weight was registered by pretilachlor + hand weeding at 20 DAT which was on par with ready mix application of anilofos + 2,4-DEE alone, ready mix application of anilofos + 2,4-DEE followed by hand weeding at 40 DAT, pre-emergent application of anilofos + ethoxysulfuron and pre-emergent application of anilofos + ethoxysulfuorn + hand weeding at 40 DAT.

14. At all stages, dry weight of grasses was significantly low in all chemically treated plots in comparison to hand weeding twice.

15. At 20 DAT, least dry weight of grasses was recorded by pretilachlor + hand weeding at 20 DAT which was on par with pretilachlor + 2,4-D and tank mix application of anilofos + ethoxysulfuron followerd by hand weeding at 40 DAT.

16. At 20 DAT, pre-emergent application of anilofos + ethoxysulfuron and anilofos + ethoxysulfuron followed by hand weeding at 40 DAT were found to have minimum dry weight of broadleaved weeds followed by butachlor + 2,4-D, while at 40 DAT, pretilachlor followed by hand weeding was found to have minimum dry weight of broadleaved weeds followed by tank mix application of anilofos + ethoxysulfuron followed by hand weeding at 40 DAT, pre-emergent application of anilofos + ethoxysulfuron alone and butachlor + 2,4-D.

17. All the herbicide treatments and herbicide + hand weeding gave significantly higher yield and yield attributes than weedy check.

18. The plots treated with anilofos + ethoxysulfuron followed by hand weeding recorded highest grain yield which was on par with ready mix application of anilofos + 2,4-DEE followed by hand weeding, anilofos + 2,4-DEE alone. In the case of straw yield also the same trend was noticed. The weedy check resulted in an yield loss of 35.7 per cent.

19. All the weed management practices resulted in an increase in the nutrient uptake of rice.

20. Pre-emergence application of anilofos + ethoxysulfuron followed by hand weeding resulted in lower NPK removal by weeds compared to all other treatments.

21. The results of the present study indicated that there was no residual toxicity of herbicides after the cropping season.

22. Pre-emergence application of anilofos + ethoxysulfuron followed by hand weeding at 40 DAT resulted in highest gross and net return.

**Future line of work**

From the result of the present study pre-emergence application of anilofos + ethoxysulfuorn followed by hand weeding at 40 DAT is found to be a remunerative method for weed control. The changes in weed flora over a period of time and in subsequent crops need detailed investigation. The study was carried out only during the kharif season at a single location. The effect of different treatments on weed control efficiency in rabi and summer season must be investigated, in detail to know about the change in weed flora over a period of time. A detailed study on shift in weed flora in the subsequent crop grown as a component in the cropping system prevailing in different locations of the state is also needed.

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# INTEGRATED WEED MANAGEMENT IN LOWLAND RICE

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# ABSTRACT

A field experiment was conducted at Cropping Systems Research Centre (CSRC), Karamana, Thiruvananthapuram to evolve a suitable integrated weed management practice for lowland rice. The study was conducted during the viruppu season of 2003.

The field experiment was laid out in randomised block design having three replication with twelve treatments. The treatments include different herbicides in combinations, herbicides + hand weeding, hand weeding twice and unweeded control. Butachlor, 2,4-D, pretilachlor, anilofos + 2,4-DEE, anilofos, ethoxysulfuron, metsulfuron methyl and chlorimuron ethyl were the different herbicides used in the experiment. The rice variety used for the experiment was Kanchana.

The results of the study revealed that grasses, broadleaved weeds and sedges competed with the rice crop. Different weed management practices significantly influenced the intensity and distribution of weeds.

The lowest dry matter of weeds was recorded by anilofos + ethoxysulfuron followed by one hand weeding which was on par with anilofos + ethoxysulfuorn alone.

All the weed management treatments resulted in improved yield attributes and higher grain yield compared to weedy check. The plots treated with anilofos + ethoxysulfuron followed by hand weeding at 40 DAT recorded the highest grain yield. This treatment resulted in enhanced plant height, number of productive tillers $hill^{-1}$, LAI and nutrient uptake of rice. The yield attributes and grain yield were significantly increased by this treatment. The total weed population, weed dry matter production and nutrient removal by weeds were also reduced and weed control efficiency was increased by this treatment. Unweeded control recorded the lowest

grain yield. No herbicide used in this experiment resulted in residual toxicity after the cropping season.

Manual weeding is expensive, laborious and time consuming. Labour non-availability at peak crop season for weeding also poses great threat. Readymix application of anilofos + 2,4-DEE ($T_3$) resulted in highest B:C ratio of 1.41 and butachlor + 2,4-D ($T_1$) with 1.40. Pre-emergence application of anilofos + ethoxysulfuron followed by one hand weeding at 40 DAT ($T_8$) was the most remunerative treatment.

# APPENDIX

## APPENDIX – I

**Weather parameters during the cropping period (June – October 2003)**

| Standard week | Relative humidity (%) | Temperature (°C) | | Evaporation | Rainfall, mm |
|---|---|---|---|---|---|
| | | Maximum | Minimum | | |
| 23 | 76.78 | 33.02 | 25.04 | 4.63 | 6.80 |
| 24 | 79.28 | 31.40 | 24.25 | 3.64 | 44.60 |
| 25 | 84.14 | 30.22 | 23.38 | 3.10 | 129.80 |
| 26 | 79.71 | 30.78 | 23.83 | 3.60 | 31.60 |
| 27 | 79.71 | 34.18 | 23.21 | 2.71 | 28.70 |
| 28 | 81.57 | 32.04 | 23.70 | 3.76 | 21.40 |
| 29 | 77.00 | 30.34 | 23.68 | 3.34 | 43.20 |
| 30 | 82.93 | 30.80 | 24.34 | 3.01 | 14.10 |
| 31 | 83.57 | 31.00 | 24.30 | 3.56 | 23.10 |
| 32 | 80.64 | 30.91 | 24.48 | 3.77 | 11.00 |
| 33 | 77.14 | 31.57 | 24.43 | 4.37 | 1.40 |
| 34 | 82.71 | 30.42 | 24.50 | 3.57 | 44.50 |
| 35 | 91.57 | 30.12 | 23.35 | 4.00 | 23.10 |
| 36 | 80.00 | 30.90 | 23.70 | 4.24 | 4.60 |
| 37 | 77.50 | 31.30 | 23.60 | 4.70 | 3.10 |
| 38 | 75.00 | 31.80 | 24.30 | 5.16 | 0 |
| 39 | 71.80 | 32.20 | 24.30 | 5.27 | 0 |
| 40 | 86.60 | 29.90 | 23.80 | 2.97 | 22.80 |