# EFFECTIVENESS AND CROP SELECTIVITY OF PRE-EMERGENCE HERBICIDES UNDER DIFFERENT METHODS OF APPLICATION IN PUDDLED RICE

By
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**THESIS**

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Dedicated to my Parents

## DECLARATION

I hereby declare that the thesis entitled "**Effectiveness and crop selectivity of pre-emergence herbicides under different methods of application in puddled 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 to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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Certified that the thesis entitled "**Effectiveness and crop selectivity of pre-emergence herbicides under different methods of application in puddled rice**" is a record of research work done independently by **Mr.P.D.Mohan Kumar** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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## CERTIFICATE

We, the undersigned members of the Advisory Committee of **Mr.P.D.Mohan Kumar**, a candidate for the degree of **Master of Science in Agriculture** with major in Agronomy, agree that this thesis entitled "**Effectiveness and crop selectivity of pre-emergence herbicides under different methods of application in puddled rice**" may be submitted by Mr.P.D.Mohan Kumar in partial fulfilment of the requirements for the degree.

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# Introduction

# INTRODUCTION

In Kerala, rice is cultivated in 5.41 lakh ha (FIB, 1994), of which more than 3 lakh hectares fall under Mundakan (second crop) and Puncha (summer) season. Majority of rice farmers in Kerala practise direct seeding of pre-germinated seeds onto puddled field called wet-seeding during these seasons (Joy *et al.*, 1991). Wet seeding is more advantageous than transplanting as it eleminates the use of seedlings, pulling, transporting and transplanting of seedlings. Hence this method holds promise as an alternative to transplanting in our state which experiences acute labour shortage during peak seasons and higher wage rates.

Weed competition is one of the major problems associated with puddled rice. Rice seedlings suffer from greater weed competition under puddled rice than when transplanted because of their similarities in age and morphology with that of grassy weeds. Hand weeding as a result is more difficult and costlier in puddled rice than in transplanted rice.

Chemical weed control is probably the only feasible alternative in wet-seeded rice because of the absence of rows for hand or rotary weeding (Moody and Cordova, 1985). Several selective pre-emergence herbicides have been developed and are in use throughout the rice growing countries. However in Kerala, only butachlor and thiobencarb are recommended for weed control in puddled rice. It has been observed that continuous use of the same herbicide can lead to a shift in weed flora resulting in the build-up of tolerant species, usually perennial hard-to-control types. Hence it is advisable to use different herbicides in rotation. But it is more

difficult to find out suitable pre-emergence herbicides for weed control in wet-seed rice than in transplanted rice, as the herbicides are applied at the time of emergence and seedling establishment stage of the crop which brings about a higher degree of phytotoxicity on rice seedlings. However results of experiments showed that a 30 per cent reduction in rice seedling stand will not affect the crop yield. Herbicide selectivity in wet-seeded rice can be improved by adjusting the time of application and by applying crop safeners (Mabbayad and Moody, 1985).

EC formulation of herbicides are usually applied by spraying. However in wet-seeded rice, spraying is not easy, due to the peculiar field condition, which impedes free movement. In such situation, granular herbicide formulations are preferred, because they are more selective to the crop, as granulation avoids direct contact between the herbicide and plant. But, for unit quantity of herbicide the cost is higher for granular formulation compared to EC formulation. However, as an alternative to spraying, sand mixed broadcast application of EC formulation of herbicides is reported to be feasible and effective in many places and it helps in reducing the cost too. In Kerala works on this aspect are meagre particularly in wet-seeded rice. Hence an experiment was conducted with the following objectives.

1) To identify alternate chemicals other than the usually recommended butachlor and thiobencarb for the control of weeds in direct sown puddled rice (wet-seeded rice).
2) To ascertain the feasibility of sand mixed broadcast application of EC formation of herbicides as an alternative to spraying in such situations.

# Review of Literature

# REVIEW OF LITERATURE

With respect to the intensity of weed problem, wet seeded rice comes in between upland rice and transplanted low land rice. Use of different herbicides in rotation is advocated for efficient and economic control of weeds and to avoid shift in weed flora. Several new pre-emergence herbicides are being used in rice elsewhere in the country in addition to the usually recommended butachlor and thiobencarb in Kerala. Moreover, in wet seeded rice the peculiar field condition restricts spraying of pre-emergence herbicides. As an alternative, sand mixed broadcasting of herbicides is suggested.

A brief review on the weed problems, pre-emergence herbicides and the different methods of application of herbicides in wet seeded rice is given below.

## 2.1 Weed spectrum

Ali *et al.* (1977) listed *Brachiaria platyphyllus, Echinochloa colona, E. crusgalli, Cyperus difformis, Fimbristylis miliacea, Marsilia quadrifoliata, Eclipta alba* and *Ammania baccifera* as the major weeds seen in direct seeded rice under puddled conditions at Coimbature. Moorthy and Dubey (1978) reported that weed infestation in puddled rice was modest and 90 per cent of the weeds were sedges at CRRI, Cuttack. Moorthy (1980) observed *Cyperus difformis, Scirpus mucronatus, Fimbristylis miliacea, Echinochloa colona, Sphenochlea zeylanica* and *Ludwigia parviflora* as the major weed species in direct sown rice on puddled soil at CRRI,

Cuttack. Kumar and Gill (1982) reported that barnyard grass (*Echinochloa crusgalli*) was the only major weed in puddled rice in Ludhiana. Moorthy and Manna (1982) reported that the weed flora in puddled rice composed of *Fimbristylis miliacea, Cyperus difformis* and *Scirpus supines*. The major weed species occurred in wet seeded rice at IRRI in order of importance were - *Paspalam distichum, Monochoria vaginalis, Sphenochlea zeylanica, Echinochloa glabrescens* and *Cyperus difformis* (Mabbayad and Moody, 1984). Senthong (1984) reported that *Cyperus procerus, Fimbristylis miliacea* and *Monochoria vaginalis* were the major weeds in low land direct seeded rice in Indonesia. In trials with puddled rice, *Cyperus difformis, Cyperus iria, Scirpus* sp., *Fimbristylis miliacea, Sphenochlea zeylanica* and *Marsilia quadrifoliata* were identified as the dominant weeds (Moorthy and Manna, 1985). *Echinochloa colona* and *E. crusgalli* constituted the major weed flora in puddled rice at IARI, New Delhi (Bhol and Singh, 1987). Pablico and Moody (1987) identified a total of twenty two species of weeds occurring in wet seeded rice in Philippines of which ten were grasses, and six were sedges. Major species were *Cyperus difformis, Echinochloa glabrescens, Fimbristylis miliacea* and *Ludwigia octovalis*. Yasin *et al.* (1988) reported that *Monochoria vaginalis, Marsilia crenata, Paspalam* sp. and *Cyperus iria* were the major weeds in direct sown rice at Maros. According to Hare *et al.* (1989) the major weed species found in wet seeded rice of Malaysia included *Echinochloa crusgalli, Leptochloa chinensis, Limnocharis flava, Sagittaria guyanensia* and *Sphenochlea zeylanica*. Allard and Zoschke (1990) reported *Echinochloa* sp., *Leptochloa chinensis, Cyperus* sp., *Fimbristylis miliacea, Scirpus* sp., *Monochoria vaginalis* and *Ludwigia odscendens* as the major weeds infesting wet sown rice in SE Asia. Vaishya *et al.* (1992) reported that the dominant weed flora in

puddled rice at Faizabad, UP consisted of *Echinochloa colona, E. crusgalli, Fimbristylis miliacea, Cyperus* sp., *Ammania baccifera, Eclipta alba, Alternanthera sessilis* and *Caeselia axillaris*.

Nair *et al.* (1974) reported *Echinochloa crusgalli, Cyperus* sp., *Fimbristylis miliacea, Monochoria vaginalis* as the predominant weeds in puddled rice at Pattambi. Joseph (1986) reported a high population of 56.8 *Scirpus supines* per square metre in wet sown rice, at 40 days after sowing in Kerala. He also recorded the presence of *Cyperus difformis* and *Cyperus iria*, as the major weeds in wet sown rice accounting for 43.4 per cent of the total weed population; *Cyperus difformis* and *Scirpus supines* together constituted 79 per cent of the total weed population along with broad leaved weeds like *Sphaeranthus indicus, Sphenochlea zeylanica, Ludwigia octovalvis, Nymphaea nouchali*.

John and Sadanandan (1989) reported the following weeds in puddled low land rice at Moncompu, Kerala - grasses - *Echinochloa colona* and *E. crusgalli*; sedges - *Cyperus iria, Cyperus difformis* and *Fimbristylis miliacea*; broad leaved weeds - *Monochoria vaginalis, Ludwigia parviflora, Sphenochlea zeylanica, Marsilia quadrifoliata* and *Lindernia* sp. According to Joy *et al.* (1991) the weed flora in wet seeded rice in Kerala, at 40 DAS, consisted of 22 per cent grasses, 40 per cent sedges and 32 per cent broad leaved weeds, and dominant weed species were *Echinochloa colona, E. crusgalli, Ischaemum rugosum, Cyperus difformis, C. iria, Fimbristylis miliacea, Ludwigia perennis, Marsilia quadrifoliata, Monochoria vaginalis* and *Sphenochlea zeylanica*. Joy *et al.* (1993) identified *Echinochloa colona, E. crusgalli, Tragus* sp., *Ischaemum rugosum, Cyperus iria, C. difformis, C. halapan,*

*Fimbristylis miliacea, Schoenoplectus corymbosus, Juncus* sp., *Monochoria vaginalis, Limnocharis flava, Ludwigia perennis, L. odscendens, Sphenochlea zeylanica* and *Marsilia quadrifoliata* as the important weed species in low land wet seeded rice culture in Kerala and at 55 DAS, the weed flora consisted of 37 per cent grasses, 33 per cent sedges and 30 per cent broad leaved weeds by weight. Sreedevi and Thomas (1993) reported that sedges and broad leaved weeds constituted the major part of the weed flora in direct sown puddled rice in Kerala, with few grasses. Among them, *Cyperus iria, C. difformis, C. haspen, Fimbristylis miliacea* and *Schoenoplectus lateriflorus* were the main sedges and *Ludwigia perennis. Sphenochlea zeylanica, Dapotrium junceum* and *Ammania baccifera* were the major broad leaved weeds.

From the foregoing review it is clear that the weedflora associated with wet seeded rice is a mix of grasses, sedges and broad leaved weeds in varying proportions with a dominance of *Cyperus difformis, C. iria, Fimbristylis miliacea, Sphenochlea zeylanica, Ludwigia* sp. and *Schoenoplectus lateriflorus*.

## 2.2 Effect of weed competition on growth of rice

### 2.2.1 Plant height

Sreedevi (1979) reported a reduction in plant height due to severe weed infestation in dry seeded rice. Kumar (1984) observed that the height of rice plants in the weedy check was more than that in the herbicide treated plots in the beginning, but subsequently this trend was reversed with plants in the weedy check having a short stature than those in the herbicide treated plots, throughout the cropping period in wet seeded rice. Reduction in plant height due to severe weed competition was reported by Palaikudy (1989) and Suja (1989) in dry seeded rice. Taller

plants were also reported in unweeded plots where the tall growing weeds induced the crop to grow taller (Jayasree, 1987; Priya, 1992).

### 2.2.2 Dry matter production

Chakraborthy (1973) reported a reduction in crop dry matter production due to weed competition. Kumar (1984) observed the weedy check as the least efficient in phytomass yield. Patel *et al.* (1985) observed a negative correlation between dry matter production of crop and weeds. Jayasree (1987) obtained the highest crop dry matter production in hand weeded check and herbicide treated plots and the lowest in the unweeded check. Suja (1989) mentioned that severe weed competition and high weed density affected the crop growth and reduced crop dry matter production. The dry matter production by crop was higher in plots where hand weeding or application of pre-emergence herbicides was repeated (Palaikudy, 1989). Priya (1992) reported that crop dry matter production was highest in the hand weeded plots and in weedy check it was only 23-58 per cent of the total dry matter accumulation in the hand weeded plots during different stages of growth.

## 2.3 Effect of weed competition on yield and yield attributes of rice

### 2.3.1 Grain yield

The loss in rice yield due to weeds ranged from 10-70 per cent (Mani *et al.*, 1968; Shetty, 1973). Pillai and Rao (1974) estimated an yield reduction of 30-35 per cent in direct seeded rice under puddled conditions. Moorthy and Dubey (1978) reported 42 per cent reduction in yield in unweeded plots as compared to a hand weeded one in direct sown puddled rice. Imperial (1980) obtained the lowest yield in an unweeded plot of direct seeded flooded rice. Sarkar and Moody (1981)

reported that yield losses due to uncontrolled weed growth ranged from 2.4 to 4.4 t/ha in rainfed wet seeded rice. Moorthy and Manna (1982) reported an yield reduction of about 21 per cent as caused by weeds dominated by sedges in direct seeded rice. According to Rao (1983) weeds caused 10-15 per cent yield reduction without causing any visible symptoms in rice. Yield losses due to uncontrolled weed growth were on an average 9 per cent greater in wet seeded rice than in transplanted rice, in trials conducted at IRRI, over the last 20 years (Moody, 1983). Moorthy and Manna (1985) reported yield reduction due to weed competition to the tune of 49.7 per cent and 31.7 per cent in consecutive years in puddle seeded rice. Patil *et al.* (1986) observed an yield reduction to the tune of 30.7 per cent by *Schoenoplectus corymbosus* in transplanted rice in Karnataka. A 15 per cent yield reduction was recorded by Vijayaraghavan *et al.* (1988) in direct seeded rice. In uncontrolled plots of wet seeded rice, yield loss was 74 per cent (Ho, 1985) and 54 per cent (Singh and Singh, 1992). Joy *et al.* (1991, 1993) reported that weeds caused an yield loss of about 29-60 per cent in wet seeded rice in Kerala.

### 2.3.2 Yield attributes

Kumar and Gill (1982) obtained a low count of effective tillers per unit area, lowest number of panicles and lowest number of spikelets per panicle in an unweeded plot as compared to that in a hand weeded plot. Drost and Moody (1982) and Kumar (1984) also reported that the lowest number of tillers were produced in unweeded check in direct sown puddled rice. According to Ho (1985) the yield reduction due to weed infestation in wet seeded rice was highly related to the decrease in panicles per unit area. Budhar *et al.* (1991) observed that panicle number per unit area did not differ significantly between treatments and unweeded check.

However, no significant difference was obtained in the case of thousand seed weight among treatments (Kumar and Gill, 1982; Ho, 1985).

The above review reveals that weed competition especially during the early growth stages affects the growth and yield of rice adversely.

## 2.4 Nutrient removal by weeds

Swain (1967) noted a significant negative correlation between nutrient uptake by crops and weeds. He also reported that barnyard grass (*Echinochloa crusgalli*) in rice fields could remove 60-80 per cent of nitrogen from soil. Mukhopadhyay (1972) reported that grasses accounted for 90-94 per cent of the total nitrogen removal by weeds. Severe infestation of *Echinochloa colona* removed 30.4-37.1 kg N/ha from soil, reducing the yield by 74.98 per cent. Shetty and Gill (1974) revealed that weeds were more efficient in nitrogen removal than the crop. Weeds have a large requirement for nutrients and their tissues have higher mineral nutrient content than crop plants (Alkamper 1976; Pons and Utomo, 1979). Crops plus weeds from an unweeded area absorbed about the same amount of nitrogen as the crop from a weed free plot (Moorthy and Dubey, 1979; Nanjappa and Krishnamoorthy, 1980). Nitrogen uptake study by Manna and Moorthy (1980) revealed that in unweeded treatments weeds depleted 26.3 kg N/ha while it was reduced considerably by weed control treatments. Nanjappa and Krishnamoorthy (1980) reported that weeds in weedy check removed 42.0 kg N/ha compared with only 10.5 kg/ha in weed free plot in direct sown upland rice. The highest nitrogen uptake by crop was in weed free plot (98.4 kg/ha) The reduction in N uptake by crop in unweeded plot was 45 per cent. Weeds grow faster than rice plants and thus absorb the available nutrients earlier resulting in deprivation of nutrients for the rice plants. Therefore

poor soil fertility often seriously limits crop production, because of the relatively greater weed growth at low levels of soil fertility which requires substantial proportion of nutrients available in the soil (Iruthayaraj, 1981; Ahmed and Moody, 1981). Kumar (1984) reported that the nitrogen removal by weeds in a weedy check was 19.87 and 32.50 kg/ha in consecutive years, in wet seeded rice. John and Sadanandan (1989) estimated the nitrogen removal in unweeded plots to the tune of 16.2 kg/ha as compared to 2.2 kg/ha in handweeded plots, in low land direct seeded rice in Kerala. Srivastava and Vaishya (1993) reported that unweeded checks removed the highest amount of nitrogen averaging 60.96 kg/ha in puddle seeded rice at Faizabad.

Verma and Mani (1970) reported that uncontrolled weed growth depleted soil phosphorus to the extent of 11.8 kg/ha. Nanjappa and Krishnamoorthy (1980) estimated a removal of 22.15 kg/ha $P_2O_5$ by weeds in weedy plots, whereas in weed free plot it was only 4.27 kg/ha in direct seeded upland rice. Kaushik and Mani (1980) reported that weeds removed 5.8 kg/ha $P_2O_5$ in direct sown rice. Kumar (1984) observed a removal of 4.26 and 4.54 kg/ha $P_2O_5$/ha by weeds in unweeded plots in wet seeded rice at IARI, New Dehi. Jayasree (1987) observed a nutrient removal of 8.71 kg/ha $P_2O_5$ in direct sown rice in Kerala. Palaikudy (1989) reported a phosphorus removal of 5.17 kg/ha by weeds in weedy check.

Nanjappa and Krishnamoorthy (1980) estimated a potassium removal of 56.04 kg/ha in unweeded control Kaushik and Mani (1980) reported that weeds removed 63.4 kg/ha $K_2O$ in direct sown rice. Kumar (1984) observed that weeds removed 32.48 kg/ha $K_2$ in weedy check. Jayasree (1987) obtained a $K_2$ removal of

103.31 kg/ha in direct sown rice. Palaikudy (1989) found that weeds removed 65.49 kg/ha $K_2O$ by weeds.

Regarding nutrient removal, the figures reported by various workers vary widely (7.3-62.1 kg/ha N, 0.8-20 kg/ha $P_2O_5$ and 27.5-64.8 kg/ha $K_2O$) for wet seeded rice depending on the nature of weed flora, soil and water management practices (Kakati and Mani, 1977; Moorthy and Dubey, 1979). Moody (1981) summarised these reports and suggested that weeds growing in association with wet seeded rice removed approximately 27.0, 6.6 and 44.8 kg/ha of N, $P_2O_5$ and $K_2O$ respectively.

## 2.5 Efficiency of pre-emergence herbicides in wet seeded rice

A major constraint to the wider application of wet seeding in puddled soil is weed competition. Many workers including De Datta and Bernasor (1973); Chang and De Datta (1974) and Subbiah and Morachan (1976) have reported the difficulty in hand weeding a wet seeded rice when it is broadcast, because of the absence of rows for hand or rotary weeding (Moody and Cordova, 1985). Unless drilled in rows to make hand weeding possible, weed control is limited to the use of selective herbicides (De Datta, 1980).

### 2.5.1 Weed control

Several pre-emergence herbicides are in use for weed control in rice. Richardson *et al.* (1976) reported that oxyflourfen had a very high level of activity and gave good control of several annual grasses and broad leaved weeds, as well as perennials like *Allium vincale*. Oxyflourfen gave good initial weed control without decreasing the rice seedling population in pre-germinated rice sown in soil prepared

under water (CIAT, 1979). In an experiment conducted at RARS Pattambi, oxyflourfen was found to be very effective in controlling weeds in direct sown puddled rice (Pillai *et al.*, 1980). Yasin *et al.* (1988) evaluated the performance of oxyflourfen in direct sown rice at Maros and found that at rates of 0.36 - 0.48 kg/ha, it controlled all major weeds, without being phytotoxic to rice. Jiang *et al.* (1989) reported that oxyflourfen @ 0.10 kg/ha gave 90-100 per cent control of *Echinochloa crusgalli, Rotala indica, Monochoria vaginalis, Cyperus iria* and *Leptochloa chinensis*.

From experiments conducted at IRRI, it was found that butachlor lacked activity against broad leaved weeds (IRRI, 1986). Butachlor gave pre-emergence control of annual grasses and broadleaved weeds in rice and regarding the spectrum of activity, it controlled rice weeds, such as *Echinochloa crusgalli, E. colona, Panicum spp, Fimbristylis miliacea*, perennial sedges such as *Cyperus rotundus* (Paul and Jacob, 1977; Pillai *et al.* 1977; Mohammed Ali *et al.*, 1977; Moorthy and Dubey, 1981). Sharma and Singh (1981) obtained good weed control, when butachlor was applied @ 1-2 kg/ha. Ali (1984) observed butachlor @ 1.0 kg/ha giving more selective control of *E. crusgalli* and *Cyperus difformis* when applied on 8th day after sowing. From weed control trials in direct sown rice under puddled conditions in Kerala, butachlor @ 1.0 kg/ha gave effecetive control of weeds comparable to weed free check (KAU, 1991).

De Datta and Bernasor (1971) observed that thiobencarb showed high degree of selectivity between rice and weed seedlings when applied six days after sowing. Pillai and Ghosh (1980) reported that thiobencarb @ 1.0 kg/ha could effectively control grasses in wet-seeded rice. An experiment conducted at Pattambi,

Kerala revealed that benthiocarb was the most efficient pre-emergence herbicide for controlling weeds in direct seeded puddled rice (KAU, 1984). Senthong (1984) reported that granular thiobencarb (10%) gave good control of *Cyperus procerus*, *Fimbristylis miliacea* and *Monochoria vaginalis* in direct sown low land rice. Ali (1984) obtained selecetive control of *Echinochloa crusgalli* and *Cyperus difformis* with 1 kg thiobencarb applied at 8 days after sowing. According to Moussavi *et al.* (1989) thiobencarb applied 3-5 days before sowing or post-emergence at two leaf stage of *E. crusgalli* was effective in puddled rice.

Mishra *et al.* (1988) reported that anilofos @ 0.3 and 0.4 kg/ha lacked adequate activity against broadleaved weeds in wet seeded rice. Nandal and Singh (1993) reported that anilofos applied @ 0.60 kg/ha at 5 days after sowing was found effective in controlling *Echinochloa colona* and *Cyperus iria* and thus reducing total dry matter accumulation to that of herbicide checks. They also observed that hand weeding remained at par with anilofos applied @ 0.45 kg/ha at 5 and 10 days after sowing and @ 0.6 kg/ha at 10 days after sowing.

Pendimethalin is another pre-emergence herbicide used in wet seeded rice. Singh and Singh (1977) reported the effectiveness of pendimethalin for controlling weeds in wet sown rice. Pendimethalin was found effective in controlling weeds in low land rice in Kerala (KAU, 1983).

Pretilachlor is a new herbicide recommended for pre-emergence application in rice. It's combination with a safener was found safe and effective for controlling weeds in wet seeded rice. Bhandhuflack and Hare (1985) reported the superiority of pretilachlor + safener (Sofit$^{(R)}$) in controlling weeds of wet sown rice in

Thailand. According to Ooi and Chang (1988) pretilachlor + safener (Sofit 300 EC(R)) applied @ 0.4-0.6 kg/ha provided excellent control of *Echinochloa crusgalli, Fimbristylis miliacea, Cyperus difformis, Monochoria vaginalis* and *Sphenochlea zeylanica* which were the major rice weeds. Hare *et al.* (1989) reported that pretilachlor safened with fenclorim (Sofit(R)) and applied @ 350-450 g/ha at 4 days after sowing provided 76-99 per cent control of grasses mainly *Echinochloa crusgalli* and *Leptochloa chinensis* and 29-68 per cent control of broad leaved weeds dominated by *Limnocharis flava, Sagittaria guyanensia* and *Sphenochlea zeylanica*. The same chemical when applied with 10-20 g cinsulfuron (Set off(R)) at 4 days after sowing gave 25-47 per cent control of grasses and 91-94 per cent control of broad leaved weeds in wet sown rice fields in Malayasia. The best overall control of 82, 96 and 94 per cent of grasses, broad leaved and sedge weeds respectively was given by Sofit Super at 350 + 10 g safener. Allard and Zoschke (1990) reported that pretilachlor-fenclorim at 3:1 (Sofit(R)) provided excellent control of the most important annual weed species in wet sown rice, including *Echinochloa* sp., *Leptochloa chinensis, Cyperus* sp., *Ludwigia odscendens, Fimbristylis miliacea, Scirpus* sp., and *Monochoria vaginalis*. Tomar (1991) obtained the best weed control and lowest weed dry matter production, when pretilachlor was used @ 1.25 kg/ha in transplanted rice Joy *et al.* (1993) found that among different herbicides tried oxadiazon and butachlor + PSE combinations alone effectively controlled weeds in direct sown rice in Kerala.

### 2.5.2 Crop selectivity

De Datta and Bernasor (1971) reported that thiobencarb showed a high degree of selectivity between rice and weed seedlings when applied 6 days after

sowing. Patro and Tosh (1971) reported that thiobencarb @ 2.0 kg/ha applied 6 days after sowing was safe to rice seedlings. Manna and Dubey (1972) observed that thiobencarb @ 1.5 kg/ha applied 12 days after sowing was compeletely safe to direct sown paddy. According to Mercado and Cadag (1983) phytotoxicity due to thiobencarb in wet seeded rice can be reduced by varying the time of application.

Oxyflourfen gave good initial weed control without decreasing rice seedling population in pre-germinated rice sown in puddled rice (CIAT, 1979). Pillai *et al.* (1980) reported that in direct seeded rice oxyflourfen granules @ 0.5 kg/ha applied six days after sowing caused some phytotoxicity on the rice leaves, but after a week the crop recovered. Granular formulations of oxyflourfen @ 0.10 kg/ha applied at 6 days after sowing was effective in direct sown rice, though it showed some toxicity. According to Biswas and Thakur (1983), in direct upland rice, oxyflourfen when applied six days after sowing was not toxic to the crop. Yasin *et al.* (1988) found that oxyflourfen controlled weeds in wet seeded rice @ 0.36-0.48 without being phytotoxic to rice seedlings.

Nair *et al.* (1974) reported that Machete(R) (Butachlor) @ 1.0 kg/ha was safe to young rice plants and caused mild leaf injury when the dose was increased to 1.5 kg/ha. Ahme and Moody (1979) observed that rice plant was moderately tolerant to butachlor when applied 12 days after emergence. Mabbayad and Moody (1983) reported that butachlor when applied 2 days after sowing caused significant reduction in rice seedlings. Ali (1984) observed that butachlor @ 1.0 kg/ha gave more selective control of weeds when applied at 8 days after sowing.

According to Mabbayad and Moody (1984) crop selectivity of butachlor and thiobencarb in wet seeded rice could be achieved by varying the time of application and for crop safety, the residual herbicides should be applied before seeding. Butachlor was found more effective and less phytotoxic when applied 3 days before sowing than when applied at 6 days after sowing (IRRI, 1986).

Patro and Tosh (1971) reported that thiobencarb @ 2.0 kg/ha applied at 6 days after sowing was safe to rice seedlings. De Datta and Bernasor (1971) also reported a high degree of selectivity by thiobencarb when applied 6 days after sowing. Manna *et al.* (1972) observed no phytotoxicity symptoms on direct sown paddy, following thiobencarb application at 10-12 days after sowing.

Nako (1977) found that shallow planting and high soil moisture after applying thiobencarb decreased establishment and inhibited growth of seedlings. Mercado and Cadag (1983) reported that phytotoxicity caused by thiobencarb in wet seeded rice can be reduced by varying time of application.

Ali (1984) observed that application of thiobencarb, butachlor and pendimethalin each @ 1.0 kg/ha applied at 8 days after sowing was more selective than when applied at 5 days after sowing, in puddled rice.

Ooi and Chang (1988) observed that Sofit 300 EC (pretilachlor + safener) @ 0.4-0.6 kg/ha was tolerated by rice varieties when applied at 1 day before sowing or 4 days after sowing. Allard and Zoschke (1990) found that pretilachlor + fenclorim at 3:1 (Sofit$^{(R)}$) was safe to wet sown rice. Joy *et al.* (1993) reported that pretilachlor @ 0.75 and 1.0 kg/ha were toxic to direct seeded low land rice in Kerala.

Joy *et al.* (1993) observed high toxicity to rice seedlings when anilofos was applied @ 0.4 and 0.6 kg/ha at 6 days after sowing. Sreedevi and Thomas (1993) reported that application of anilofos @ 0.3-0.45 kg/ha 8 days after sowing was found to be toxic and the toxicity was reduced when the spraying was delayed to 10 days after sowing and at 12 days after sowing the herbicide was completely safe.

Sandhu *et al.* (1988) found that herbicides like butachlor, thiobencarb, oxadiazon and pendimethalin were well tolerated by rice seedlings even at higher dose, when applied as sand mixed broadcast.

The above review indicate that application of some of the pre-emergence herbicides can lead to phytotoxicity and the crop selectivity can be improved considerably by varying the time of application, dose of herbicide, method of application or by adding a crop safener to the herbicide.

### 2.5.3 Growth and yield of rice

Ali *et al.* (1977) reported that butachlor @ 1.0 kg/ha resulted in better tillering and yield of rice comparable with weeded control. Sharma and Singh (1981) obtained good rice yields comparable with hand weeding, when butachlor was applied @ 1-2 kg/ha. Kumar and Gill (1982) obtained consistent higher yields (11-14.5 per cent higher than hand weeding) using piperophos + dimethametryn (Avirosan$^{(R)}$) @ 1.0 kg/ha in puddled rice in Ludhiana. According to Yasin *et al.* (1988) application of oxyflourfen @ 0.36-0.48 kg/ha resulted in grain yield which was on par with hand weeded plots. Mishra *et al.* (1988) obtained the best straw and grain yield of direct seeded rice when weed control was effected with application of thiobencarb @ 1.4 kg ai/ha.

Kumar and Gautam (1986) observed that thiobencarb application increased number of panicles/$m^2$, filled grains per panicle and gave higher yields compared to weedy control in puddled rice. From weed control trials in direct sown rice under puddled condition in Kerala, butachlor @ 1.0 kg/ha gave good grain yield comparable to weed free check and hand weeding twice (KAU, 1991). Hare *et al.* (1988) reported that pretilachlor safened with fenclorim (Sofit$^{(R)}$) applied at 4 days after sowing gave highest grain yield (195% of the unweeded control) in direct seeded rice. Allard and Zoschke (1990) observed positive effects on rice grain yields (890-2570 kg/ha above untreated controls) by Sofit along with its favourable herbicidal efficiency and they concluded that pretilachlor + fenclorim (Sofit$^{(R)}$) is very suitable for solving the major weed problems in wet sown rice in SE Asia. Joy *et al.* (1991) observed from field trials in Kerala that all pre-emergence herbicides, tridiphane @ 0.4-0.6 kg/ha, butachlor (Thunder$^{(R)}$ 50 EC) @ 1.0 kg/ha, butachlor (Searle$^{(R)}$ @ 1.0-1.5 kg/ha. and thiobencarb 10 g @ 1.5 kg/ha increased grain yields of wet seeded rice compared to unweeded control. In an experiment with transplanted paddy, pretilachlor @ 1.25 kg/ha resulted in a higher number of panicles and higher grain yield (Tomar, 1991). Rathore *et al.* (1992) obtained highest grain yield using butachlor/thiobencarb @ 1.5 kg/ha as pre-emergence in direct seeded flooded rice. Vaishya *et al.* (1992) reported that application of thiobencarb @ 1.5 kg/ha as pre-emergence followed by 2,4-D @ 0.5 kg/ha post-emergence recorded significantly higher yield compared to hand weeding twice. Sreedevi and Thomas (1993) found that anilofos applied alone or in combination with 2,4-DEE, at 12 days after sowing gave higher yields.

## 2.6 Comparative efficacy of spraying and sand mixed broadcasting of pre-emergence herbicides in rice

### 2.6.1 Weed control

Sathasivan *et al.* (1981) observed no marked difference in field performance between spray and sand mixed application of butachlor with regard to weed control in transplanted rice. In trials conducted under the All India Co-ordinated Research Project on Weed Control, it was found that sand mixed application of thiobencarb in transplanted rice one day after planting could effectively control the weeds (AICRPWC, 1986). Jayasree (1987) reported that spray application of thiobencarb was significantly superior in controlling weeds as compared to sand mixed broadcast in direct sown upland rice.

### 2.6.2 Crop selectivity

Sathasivan *et al.* (1981) found no significant difference between spray and sand mixed application of butachlor with regard to crop safety in transplanted rice. Kumar and Gill (1982) reported that molinate mixed with sand and applied as pre-emergence gave better performance in terms of crop selectivity than when applied as post-emergence spray. Moorthy and Manna (1982) tried to determine the efficacy of spray, broadcast sand mixed and broadcast granular application techniques in the case of thiobencarb and butachlor in puddle seeded rice. They observed that spray application of thiobencarb was superior to sand mixed application, while for butachlor, the sand mixed application of EC formulation was found to be on par with spray application. Sandhu *et al.* (1988) evaluated the efficacy and tolerance of herbicides in transplanted rice and found that all the herbicides were well tolerated

by cultivars even at twice the recommended dose when applied as sand mixed broadcast. Reddy and Bharghavi (1989) found that butachlor applied in water as spray was more effective than sand mixed application of the same.

### 2.6.3 Growth and yield of rice

Kahlon and Singh (1978) reported that liquid formulations of fluchloralin and butachlor gave very good results when applied as broadcast after mixing with sand or urea. According to Patel (1981) broadcast application of butachlor mixed with sand was an effective method of application of herbicide. Sathasivan *et al.* (1981) observed no marked difference in field performance between spray and sand mixed application of butachlor with regard to yield in transplanted paddy. Srinivasan (1989) observed that anilophos + 2,4-D ethyl ester when applied as sand mixed broadcast, provided higher grain yields than hand weeding in transplanted rice.

Jayasree (1987) reported that sand mixed application of thiobencarb was inferior to spraying in weed control efficiency and resulted in poor yield in direct sown upland rice.

The foregoing review shows that EC or EN formulations of herbicides can be applied in rice either as spray or as sand mixed broadcast.

## 2.7 Economics

Nair *et al.* (1974) observed that in direct seeded puddled rice, use of herbicides was more profitable than hand weeding. Manipon *et al.* (1983) reported that in wet seeded rice, application of butachlor or thiobencarb @ 4.0 kg/ha gave greater profits than hand weeding twice. Joy *et al.* (1991) observed from field trials

conducted in Kerala in wet seeded rice, that all pre-emergence herbicides viz. tridiphane, butachlor and thiobencarb resulted in an increase in gross returns compared to hand weeding twice. Joy *et al.* (1993) found PSE, 2,4-D and oxadiazon giving maximum gross returns and most economic in wet seeded rice in Kerala.

Jayasree (1987) reported a higher return per rupee invested in spray treatment compared to sand mixed broadcast application in dry sown rice. According to John and Sadanandan (1989) cost of weed control was reduced to about one third when fernoxone was mixed with urea and applied instead of spraying.

# Materials and Methods

# MATERIALS AND METHODS

A field study was conducted during the second crop season of 1992-93, to identify alternate chemicals other than the usually recommended butachlor and thiobencarb for the control of weeds in wet seeded rice and also to ascertain the feasibility of sand mixed broadcasting as an alternative to spraying. The materials used and methods followed are described below.

## 3.1 Site, climate and soil

The field experiment was conducted during the 2nd crop season at the Agricultural Research Station, Mannuthy of the Kerala Agricultural University, Vellanikkara, Thrissur. The station is located at 12° 32'N latitude and 74° 20'E longitude at an altitude of 22.5 m above MSL, and enjoys a typical tropical climate.

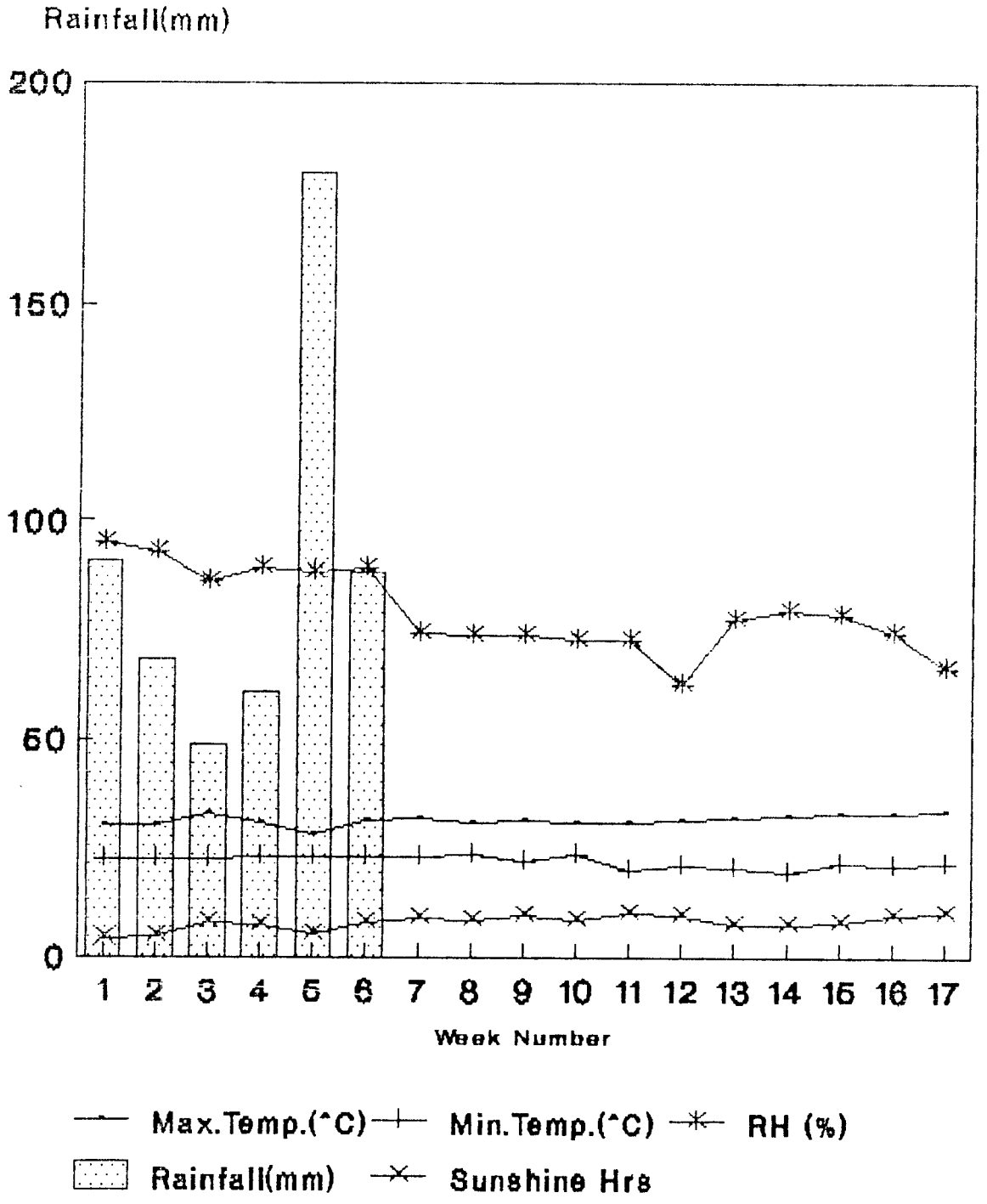
The details of meteorological observations taken during the period of experimentation are presented in Fig.1. The soil of the experimental field was sandy clay loam in texture. The physical and chemical characteristics of the soil are presented in Table 1.

The experimental area is a double cropped wet land and was under bulk crop of paddy during the previous season.

## 3.2 Treatments

The treatments included six pre-emergence herbicides viz., oxyflourfen, thiobencarb, butachlor, anilofos, pendimethalin and pretilachlor + safener, applied

Fig. 1 Weather parameters during the study period




From 22/10/92 to 11/02/93

Table 1. Physico-chemical nature of soil in the experimental field

| Particulars | Value | Method employed |
|---|---|---|
| A. Mechanical composition | | |
| Coarse sand (%) | 27.6 | Robinson's International Pipette Method (Piper, 1942) |
| Fine sand (%) | 24.2 | |
| Silt (%) | 22.2 | |
| Clay (%) | 26.0 | |
| Bulk density | 1.54 | Core Sampler Method (Piper, 1942) |
| B. Chemical composition | | |
| Organic carbon (%) | 0.67 | Walkley and Black Method (Soil Survey Staff, 1967) |
| Total N % | 0.17 | Kjeldahl Digestion and Distillation Method (Jackson, 1958) |
| Available P (kg/ha) | 87.00 | Bray I extractant, Ascorbic acid blue colour method (Watanabe and Olsen, 1965) |
| Available K (Kg/ha) | 218.4 | Neutral Normal Ammonium acetate extract Flame photometry (Jackson, 1958) |
| pH | 5.7 | 1:2.5 soil-water suspension using a pH meter (Jackson, 1958) |

either as spray or as sand mixed broadcast. There were 14 treatments in total as listed below.

| Treatments | Notation |
|---|---|
| 1. Oxyflourfen 0.1 kg ai/ha - spray | Os |
| 2. Oxyflourfen 0.1 kg ai/ha - sand mixed broadcast | $O_b$ |
| 3. Thiobencarb 1.0 kg ai/ha - spray | $T_s$ |
| 4. Thiobencarb 1.0 kg ai/ha - sand mixed broadcast | $T_b$ |
| 5. Butachlor 1.25 kg ai/ha - spray | $B_s$ |
| 6. Butachlor 1.25 kg ai/ha - sand mixed broadcast | $B_b$ |
| 7. Anilofos 0.4 kg ai/ha - spray | $A_s$ |
| 8. Anilofos 0.4 kg ai/ha - sand mixed broadcast | $A_b$ |
| 9. Pendimethalin 1.0 kg ai/ha - spray | $P_s$ |
| 10. Pendimethalin 1.0 kg ai/ha - sand mixed broadcasting | $P_b$ |
| 11. Pretilachlor + safener 0.4 kg ai/ha - spray (Pyramidine derivative) | $P+S_s$ |
| 12. Pretilachlor + safener 0.4 kg ai/ha - sand mixed broadcasting (Pyramidine derivative) | $P+S_b$ |
| 13. Hand weeding at 20 and 40 DAS | HW |
| 14. Unweeded control | UW |

## 3.3 Design and layout

1. Design : Randmoised Block Design
2. Replication : 3

Table 2. Pre-emergence herbicides used in the experiment

| Herbicide | Commercial formulation used | Manufacturer | Active ingredient (%) |
|---|---|---|---|
| 1. Oxyflourfen | Goal | Indofil | 23.5 |
| 2. Thiobencarb | Saturn | Pesticides India Ltd. | 50.0 |
| 3. Butachlor | Machete | Monsanto Chemicals of India Ltd., Bombay | 50.0 |
| 4. Anilofos | Aniloguard | Ghardha Chemicals | 30.0 |
| 5. Pendimethalin | Stomp | Indofil | 30.0 |
| 6. Pretilachlor + Safener | Sofit | Ceiba-Geigy India Ltd. | 33.0 |

3. Plot size

i) Gross plot size : 4 m x 4.5 m = 18 $m^2$

ii) Sampling area : One metre strip along the 4.5 m side inside the border area

iii) Net plot size : 2.6 m x 3.9 m = 10.14 $m^2$

The layout plan of the trial is given in Fig.2.

3.3.1 Herbicides

The details of herbicides used in the experiment are presented in Table 2.

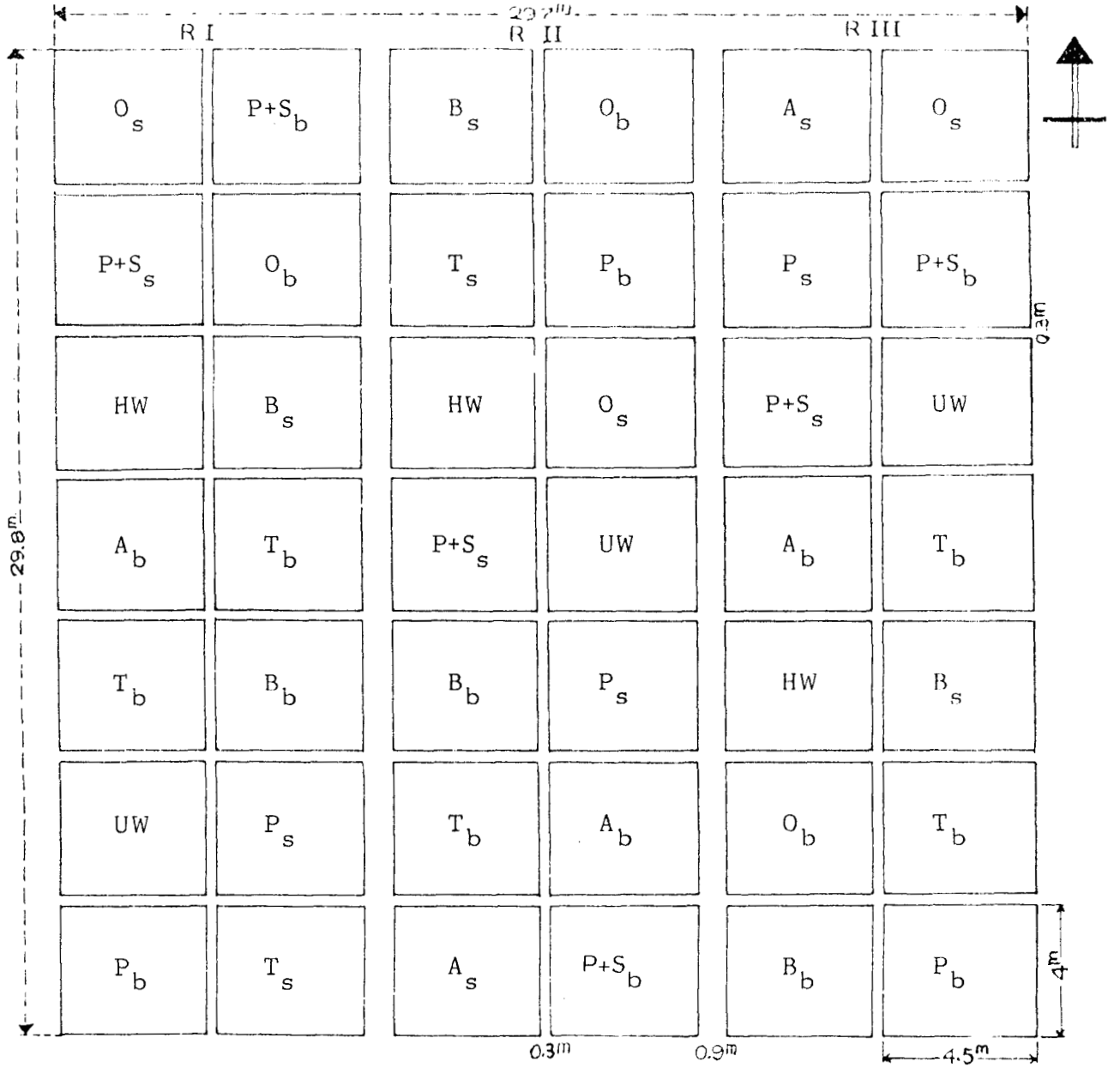
3.3.2 Herbicide application

The herbicides were applied at 6 DAS. Spraying was done with a knap-sack sprayer, fitted with a flat fan nozzle. Quantity of spray fluid used was 500 l/ha. For sand mixing, the herbicide was thoroughly mixed with washed sand @ 40 kg/ha and broadcast uniformly.

## 3.4 Variety

Rice variety Jyothi a hybrid derivative of Ptb 10 x TN-1 was used for the study. It has a duration of 110 to 125 days, with red kernel, long and bold grains. The variety possesses moderate tolerance to brown plant hopper and blast and is susceptible to sheath blight (KAU, 1993). The seeds were procured from Regional Agricultural Research Station, Pattambi.

# Fig. 2 Plan of layout




$O_s$ - Oxyflourfen spray
$O_b$ - Oxyflourfen sand mixed braodcast
$T_s$ - Thiobencarb spray
$T_b$ - Thiobencarb sand mixed broadcast
$B_s$ - Butachlor spray
$B_b$ - Butachlor sand mixed broadcast
$A_s$ - Anilofos spray
$A_b$ - Anilofos sand mixed broadcast
$P_s$ - Pendimethalin spray
$P_b$ - Pendimethalin sand mixed broadcast
$P+S_s$ - Pretilachlor + safener spray
$P+S_b$ - Pretilachlor + safener sand mixed broadcast
HW - Hand weeding twice
UW - Unweeded control

## 3.5 Field culture

The seeds taken @ 100 kg/ha were soaked in water for 24 hrs and kept for germination in a gunny bag after draining out the water. The field was ploughed, and puddled and levelled with a wooden plank and pre-germinated seeds were sown by broadcasting on 19-10-1992. All the cultural operations except weed control were followed as per the package of practices recommendations (KAU, 1989). The crop was affected by leaf roller at the maximum tillering stage and was controlled by spraying phosphamidon @ 250 ml/ha. Rice bug attack at the milk stage of the crop was controlled by spraying methyl parathion @ 500 ml/ha. Weed control was effected as per the treatments. The crop was harvested on 4-2-1993.

## 3.6 Observation

### 3.6.1 Observations on weeds

The observations on weeds were taken using a 0.25 $m^2$ quadrat.

(a) Weed count

Species wise weed count was taken from four random places in each plot using a quadrat of 0.25 $m^2$ at 15, 30, 45, 60 DAS and at harvest and recorded as number/$m^2$.

(b) Dry matter production

All the weeds enclosed by the 0.25 $m^2$ quadrat placed at one random place in the sampling area of each plot were uprooted, dried in a hot air oven and the dry weight recorded in g/$m^2$ at 30 and 60 DAS and at harvest.

(c) Weed control efficiency

The weed control efficiency of the different treatments was calculated using the formula

$$\text{Weed control efficiency (\%)} = \frac{(X - Y)}{X} \times 100$$

where, X = Dry matter production of weeds in the unweeded check

Y = Dry matter production of weeds in the corresponding treatment

3.6.2 Observations on the crop

(a) Phytotoxicity

The rice seedlings were observed for any phytotoxic symptoms like scorching, retarded growth etc. due to herbicide application. The visual phytotoxicity symptoms were scored on a 0-9 scale.

(b) Crop growth characteristics

(i) Dry matter production

Crop samples were also taken from an area of 0.25 $m^2$ from where weed samples were collected, oven dried to constant weight and the dry matter production was recorded in $g/m^2$. The sampling was done at 30 and 60 DAS and at harvest.

(ii) Height

The height of 10 plants was recorded at 30 and 60 DAS and at the time of harvest. The height was measured from soil surface to the tip of the longest leaf or to the tip of the earhead.

(iii) Number of tillers

Total number of tillers of ten plants were counted at 30 and 60 DAS and at harvest and the average was expressed as number of tillers per plant.

(c) Yield attributes

(i) Productive tillers

The number of productive tillers of ten plants were counted and the average expressed as number of productive tillers per plant.

(ii) Length of panicle

The length of ten panicles, taken randomly from each plot was measured from the neck to the tip of the panicle and the average length recorded in cm.

(iii) Number of grains per panicle

The total number of filled grains present in ten panicles from each plot was counted and the average recorded.

(iv) Thousand seed weight

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

(d) Yield

(i) Grain yield

The grain harvested from each net plot was dried to 14 per cent moisture, cleaned, winnowed, weighed and expressed as kg/ha.

(ii) Straw yield

The straw from each net plot was dried uniformly, weighed and expressed as kg/ha.

(e) Weed index

Weed index values for different treatments were calculated using the equation given by Gill and Vijayakumar (1969).

$$\text{Weed index} = \frac{(X - Y)}{X} \times 100$$

where, X = Yield obtained from the hand weeded plot

Y = Yield obtained from the treatment

## 3.7 Chemical analysis

The weed and crop samples collected at 30 and 60 DAS and at harvest were dried separately in a hot air oven to constant weight, powdered well in a willey mill and representative samples were analysed for nitrogen, phosphorus and potassium content.

The methods used for analysis were,

| | | |
|---|---|---|
| 1. Nitrogen | : | Nessler's Reagent Method (A.O.A.C., 1960) using Spectronic-20 spectrometer |
| 2. Phosphorus | : | Vandomolybdo phosphoric yellow colour method Spectronic 20 spectrometer (Jackson, 1958) |
| 3. Potassium | : | Triacid extract using flam photometer (Jackson, 1958) |

# Results and Discussion

# RESULTS AND DISCUSSION

The results of the experiment to find out the effectiveness and crop selectivity of pre-emergence herbicides under different methods of application in puddled rice are presented and discussed in this chapter. The data on different observations were subjected to analysis of variance and the results are discussed under the following heads.

4.1 Studies on weeds

4.1.1 Weed spectrum

4.1.2 Weed population

4.1.3 Weed drymatter production

4.1.4 Weed control efficiency

4.1.5 Nutrient removal by weeds

4.2 Studies on crop

4.2.1 Phytotoxicity

4.2.2 Growth characteristics

4.2.3 Yield and yield attributes

4.2.4 Weed index

4.2. Nutrient uptake

4.3 Economics of weed control operations

## 4.1 Studies on weeds

### 4.1.1 Weed spectrum

Sedges and broadleaved weeds constituted the major part of the weed flora with a few grasses, at all stages of crop growth. Among the sedges, *Schoenoplectus lateriflorus* had a widespread occurrence while *Cyperus difformis* and *Fimbristylis miliacea* were present in lesser numbers. In the early stages broadleaved weeds like *Monochoria vaginalis, Ludwigia perennis, Nymphaea nouchali, Marsilia quadrifoliata, Sphenochlea zeylanica* and the algae *Chara* sp. were present along with the different sedges listed.

The weeds emerged along with rice seedlings and wherever herbicide related toxicity and subsequent stand reduction were noticed, they completely dominated the field, suppressing rice seedlings. The broadleaved weeds seen in the early stages were of aquatic type and they thrived well under the near submerged condition in the field. As water level came down, there was a marked shift in the weed flora. More hardier type of weeds like *Sphaeranthus indicus, Ammania baccifera, Echinocloa colona* and *Ludwigia parviflora* were seen towards the later stages of crop growth. In the unweeded control and wherever plant stand was uniform, no single weed species was found dominating, rather it was a mix of all the species listed at varying proportions.

At 45 DAS, weed flora consisted of sedges like *Cyperus difformis, Cyperus iria, Schoenoplectus lateriflorus, Fimbristylis miliacea* and broadleaved weeds like *Monochoria vaginalis, Sphenochlea zeylanica, Sphaeranthus indicus, Ludwigia perennis, Nymphaea nouchali, Marsilia quadrifoliata* and algae *Chara* sp.

4.1.2 Weed population

4.1.2.1 Broadleaved weeds

At 15 DAS, in general, lesser number of broadleaved weeds were observed in all the herbicide treated plots compared to hand weeding twice and unweeded control, though the effect was not significant (Table 3). This might be due to the effect of herbicides applied at 6 DAS. Among the different herbicide treatments butachlor spray, oxyflourfen spray, pendimethalin spray and pretilachlor + safener sand mixed broadcast registered lower number of broadleaved weeds at this stage.

At 30 DAS, there was an increase in the number of broadleaved weeds in almost all the treatments compared to that at 15 DAS. Among the different herbicide treatments, lowest number of broadleaved weeds was recorded by butachlor sand-mixed broadcast. This was similar to all other treatments except thiobencarb sand mixed broadcast, anilofos spray, anilofos sand mixed broadcast and unweeded control. The results indicated that all the herbicides except anilofos were effective in reducing the population of broadleaved weeds upto 30 DAS, inrrespective of the method of application. This is in agreement with Mishra *et al.* (1988) who observed that anilofos lacked adequate activity against broadleaved weeds in direct seeded rice, when applied @ 0.3 and 0.4 kg/ha.

At 45 DAS, the treatment hand weeding twice at 20 and 40 DAS was free of broadleaved weeds due to the handweeding given at 40 DAS.

At 60 DAS also, handweeding twice recorded the lowest number of broadleaved weeds. Treatments, pendimethalin spray and pretilachlor + safener

Table 3. Effect of different treatments on the population of broadleaved weeds (plants/$m^2$)

| Treat-ments | 15 DAS | | 30 DAS | | 45 DAS | | 60 DAS | | Harvest | |
|---|---|---|---|---|---|---|---|---|---|---|
| | T | O | T | O | T | O | T | O | T | O |
| $O_s$ | 2.28 | 5.33 | 5.79 | 36.66 | 5.68 | 34.00 | 6.96 | 48.00 | 4.45 | 19.00 |
| $O_b$ | 4.17 | 19.66 | 5.81 | 35.00 | 5.27 | 28.67 | 6.82 | 53.00 | 5.83 | 35.67 |
| $T_s$ | 4.11 | 17.66 | 7.86 | 63.00 | 8.05 | 64.00 | 6.63 | 43.67 | 3.53 | 14.67 |
| $T_b$ | 3.61 | 12.33 | 9.54 | 91.33 | 6.80 | 46.33 | 8.03 | 63.67 | 4.44 | 19.00 |
| $B_s$ | 2.08 | 3.66 | 2.93 | 64.66 | 5.22 | 26.33 | 5.85 | 34.00 | 3.45 | 11.67 |
| $B_b$ | 3.37 | 11.33 | 5.72 | 36.00 | 5.99 | 35.33 | 6.25 | 39.33 | 5.11 | 26.33 |
| $A_s$ | 3.99 | 19.00 | 9.35 | 88.33 | 8.04 | 71.33 | 9.76 | 96.00 | 5.21 | 26.33 |
| $A_b$ | 4.25 | 20.00 | 10.07 | 103.70 | 7.37 | 54.00 | 8.41 | 70.00 | 4.01 | 16.33 |
| $P_s$ | 2.19 | 4.00 | 6.10 | 39.00 | 5.10 | 26.67 | 4.39 | 18.67 | 5.71 | 38.00 |
| $P_b$ | 3.86 | 17.00 | 6.29 | 48.00 | 5.45 | 31.33 | 6.38 | 46.67 | 5.01 | 26.33 |
| $P + S_s$ | 3.65 | 17.33 | 6.41 | 47.33 | 6.21 | 44.00 | 4.96 | 25.67 | 4.69 | 26.33 |
| $P + S_b$ | 2.39 | 5.33 | 8.54 | 73.30 | 5.21 | 26.67 | 6.10 | 40.67 | 3.65 | 12.33 |
| HW | 5.80 | 37.33 | 6.92 | 48.0 | 1.00 | 0 | 2.30 | 7.67 | 4.00 | 17.00 |
| UW | 5.07 | 27.00 | 9.27 | 89.33 | 7.39 | 53.00 | 7.48 | 56.00 | 5.12 | 29.00 |
| SEm± | 0.804 | | 1.050 | | 0.908 | | 1.010 | | 1.029 | |
| CD (0.05) | NS | | 3.058 | | 2.639 | | 2.937 | | NS | |

T - Transformed value ($\sqrt{x + 1}$)  O - Original value

spray were found on par with handweeding twice as well as with their application as sand mixed broadcast. The treatments oxyflourfen spray, oxyflourfen sand mixed broadcast, thiobencarb spray, butachlor spray and its sand mixed broadcast were found as effective as the above treatments.

At harvest, in general, a reduction in the population of broadleaved weeds was noticed irrespective of treatments, when compared to that at 60 DAS. The reduction might be due to the completion of life cycle and drying up of some of the broadleaved aquatics like *Monochoria vaginalis, Marsilia quadrifoliata* etc. consequent to the recession of flood water. Moreover, no significant difference could be observed between treatments.

The above results indicate that besides butachlor and thiobencarb, other pre-emergence herbicides such as pretilachlor + safener, oxyflourfen and pendimethalin were effective in reducing the broadleaved weed population in wet seeded rice, when applied as sand mixed broadcast or as spray.

The effectiveness of pretilachlor + safener, oxyflourfen and pendimethalin in reducing the broadleaved weeds in wet seeded rice was reported by Ooi and Chang (1988), Jiang *et al.* (1989) and Singh and Singh (1987).

a) *Monochoria vaginalis*

The data on the population of *Monochoria vaginalis,* the major broadleaved weed, at various stages of the crop growth under different weed control treatments are presented in Table 4.

At 15 DAS all the treatments recorded the presence of *Monochoria*

*vaginalis* but there was no significant difference between the treatments. However at 15 DAS, butachlor spray effected 89 per cent reduction in the population of this weed compared to hand weeding twice which recorded the highest number. At 30 DAS, pendimethalin spray registered 85 per cent reduction compared to unweeded control.

At 45 DAS, *Monochoria vaginalis* was absent in hand weeded plot as the treatment was given at 40 DAS. However, pretilachlor + safener spray and butachlor sand mix broadcast were comparable with hand weeding twice. All the other herbicide treatments except thiobencarb sand mixed broadcast, anilofos spray and sand mixed broadcast were similar to pretilachlor + safener spray.

At 60 DAS also the lowest number of *Monochoria vaginalis* was observed in handweeded plots. The herbicide treatments pretilachlor + safener spray, pendimethalin spray, oxyflourfen sand mixed broadcast, butachlor spray and sand mixed broadcast, were as effective as handweeding twice in reducing the population of *Monochloria vaginalis*.

After 60 DAS, the weed *Monochoria vaginalis* present in all the plots got dried up and at the time of harvest of the crop, none of them could be observed in the plot.

The above result shows that under wet seeded condition, the population of the broadleaved weed *Monochoria vaginalis* in the early stages of rice crop could be reduced to a great extent by pre-emergence application of any one of the herbicides - butachlor, thiobencarb, pretilachlor + safener, oxyflourfen or pendimethalin. The application can be either as spray or as sand mixed broadcast.

Table 4. Effect of different treatments on the population of *Monochoria vaginalis* (plants/m²)

| Treat-ments | 15 DAS | | 30 DAS | | 45 DAS | | 60 DAS | |
|---|---|---|---|---|---|---|---|---|
| | T | O | T | O | T | O | T | O |
| $O_s$ | 2.28 | 5.33 | 3.16 | 10.00 | 3.80 | 12.33 | 4.97 | 25.67 |
| $O_b$ | 3.79 | 15.00 | 3.51 | 12.67 | 3.03 | 10.00 | 4.12 | 20.33 |
| $T_s$ | 3.80 | 14.67 | 2.82 | 9.00 | 3.29 | 12.67 | 4.36 | 20.33 |
| $T_b$ | 4.01 | 15.67 | 5.24 | 27.67 | 4.66 | 23.00 | 6.53 | 43.67 |
| $B_s$ | 1.93 | 3.00 | 3.56 | 13.00 | 3.60 | 12.67 | 4.37 | 20.33 |
| $B_b$ | 3.37 | 11.33 | 3.21 | 10.00 | 2.77 | 7.67 | 3.99 | 16.67 |
| $A_s$ | 4.22 | 19.33 | 5.859 | 35.33 | 4.26 | 17.33 | 6.86 | 47.33 |
| $A_b$ | 3.93 | 16.33 | 4.65 | 22.00 | 5.09 | 25.33 | 6.76 | 45.67 |
| $P_s$ | 2.24 | 4.33 | 2.48 | 6.67 | 3.04 | 10.33 | 2.27 | 6.00 |
| $P_b$ | 2.83 | 8.00 | 3.94 | 19.00 | 3.76 | 16.00 | 5.26 | 33.00 |
| $P+S_s$ | 3.54 | 16.33 | 4.10 | 18.67 | 2.37 | 4.67 | 3.16 | 10.33 |
| $P+S_b$ | 2.27 | 4.67 | 4.39 | 19.33 | 3.75 | 14.00 | 5.24 | 31.00 |
| HW | 5.05 | 26.33 | 3.90 | 15.00 | 1.00 | 0 | 2.16 | 4.67 |
| UW | 3.99 | 15.67 | 6.48 | 42.00 | 4.56 | 21.67 | 5.25 | 32.67 |
| SEm± | 0.657 | | 0.921 | | 0.648 | | 0.882 | |
| CD (0.05) | NS | | NS | | 1.884 | | 2.564 | |

T - Transformed value $\sqrt{x+1}$ O - original value

The efficiency of thiobencarb, pretilachlor + safener, oxyflourfen in controlling *Monochoria* was also reported by Senthong (1984), Ooi and Chang (1988), Jiang *et al.* (1989), respectively.

4.1.2.2 Monocot weeds

Total number of monocot weeds under different stages are presented in Table 5.

At 15 DAS, the plots sprayed with pendimethalin recorded the highest number of moncots, followed by its sandmixed broadcast and anilofos sand mixed broadcast. Stand reduction of rice seedlings resulted from phytotoxicity of applied herbicides favoured the spread of weeds mainly *Schoenoplectus lateriflorus* and *Cyperus* sp. in these plots from the early stages of the crop. However, butachlor applied both as spray and as sand mixed broadcast could bring down the population of monocot weeds to 30.4 per cent and 36.4 per cent respectively compared to the unweeded control. All other treatments except pendimethalin spray, pendimethalin sand mixed broadcast and anilofos sand mixed broadcast were similar to butachlor spray and sand mixed broadcast.

At 30 DAS, hand weeding twice recorded the lowest number of monocots. The notable reduction in the population of monocot weeds in hand weeded plot at 30 DAS compared to that at 15 DAS was due to the weeding given at 20 DAS. Among the herbicides, pretilachlor spray and its sand mixed broadcast, oxyflourfen spray and thiobencarb spray were on par with hand weeding twice. No significant difference was observed between spray and sand mixed broadcast in the case of oxyflourfen and thiobencarb.

Table 5. Effect of different treatments on the population of monocot weeds (plants/$m^2$)

| Treat-ments | 15 DAS | | 30 DAS | | 45 DAS | | 60 DAS | | Harvest | |
|---|---|---|---|---|---|---|---|---|---|---|
| | T | O | T | O | T | O | T | O | T | O |
| $O_s$ | 6.27 | 45.33 | 4.47 | 25.00 | 6.82 | 53.00 | 6.94 | 50.67 | 6.80 | 47.67 |
| $O_b$ | 6.59 | 60.33 | 7.01 | 50.00 | 8.27 | 70.33 | 8.21 | 66.67 | 7.52 | 56.67 |
| $T_s$ | 3.91 | 20.00 | 3.96 | 19.66 | 5.06 | 26.33 | 6.63 | 43.00 | 6.43 | 42.00 |
| $T_b$ | 3.27 | 6.00 | 5.14 | 28.60 | 5.85 | 36.67 | 8.17 | 67.00 | 5.61 | 32.00 |
| $B_s$ | 2.45 | 7.00 | 2.20 | 5.33 | 2.85 | 5.00 | 4.45 | 20.67 | 4.01 | 18.00 |
| $B_b$ | 2.94 | 11.33 | 3.31 | 13.00 | 4.31 | 21.00 | 5.19 | 26.00 | 5.04 | 24.67 |
| $A_s$ | 3.59 | 25.33 | 7.29 | 56.00 | 11.03 | 117.00 | 13.37 | 189.00 | 11.18 | 127.67 |
| $A_b$ | 12.61 | 162.33 | 7.00 | 52.66 | 8.36 | 78.00 | 9.07 | 86.33 | 8.64 | 83.33 |
| $P_s$ | 14.99 | 224.33 | 12.81 | 169.00 | 16.82 | 293.30 | 17.97 | 323.00 | 17.20 | 299.00 |
| $P_b$ | 12.99 | 187.33 | 10.85 | 131.66 | 16.33 | 169.67 | 14.00 | 210.00 | 13.42 | 185.67 |
| $P+S_s$ | 5.04 | 42.00 | 4.18 | 22.00 | 6.08 | 51.67 | 6.16 | 42.00 | 5.03 | 25.00 |
| $P+S_b$ | 5.04 | 32.66 | 3.98 | 20.00 | 4.89 | 28.00 | 4.50 | 22.67 | 4.36 | 19.00 |
| HW | 8.29 | 99.33 | 1.82 | 3.66 | 1.00 | 00.00 | 1.00 | 00.00 | 2.32 | 5.33 |
| UW | 8.07 | 110.00 | 11.10 | 126.33 | 9.69 | 97.33 | 11.61 | 137.67 | 9.37 | 95.00 |
| SEm± | 2.213 | | 0.997 | | 1.284 | | 1.17 | | 1.22 | |
| CD (0.05) | 6.17 | | 2.898 | | 3.731 | | 3.398 | | 3.558 | |

T - Transformed value $\sqrt{x+1}$ O - original value

Observations at 45 and 60 DAS showed hand weeding twice as free of monocot weeds; pendimethalin sprayed plots recording the highest weed population. Butachlor spray and its sand mixed broadcast were on par with hand weeded plots at this stage. Both the methods of application of pretilachlor + safener and thiobencarb were comparable with butachlor spray, which recorded the lowest number among herbicides.

At 60 DAS, butachlor spray recorded the lowest number of monocots followed by pretilachlor + safener sand mixed broadcast. Oxyflourfen spray, thiobencarb spray, butachlor sand mixed broadcast and pretilachlor + safener spray yielded similar results. At this stage, in addition to the widespread *Schoenoplectus lateriflorus* other sedges like *Cyperus iria, C. difformis* and *Fimbristylis miliacea* were also noticed, though in lesser number.

At the time of harvest also, all the treatments recorded the presence of monocot weeds consisted mainly of *Schoenoplectus lateriflorus*. The lowest number was present in hand weeded plot. Thiobencarb sand mixed broadcast, butachlor spray and its sand mixed broadcast, pretilachlor + safener spray and its sand mixed broadcast were also found to give similar results, as that of hand weeding twice. Among herbicides, butachlor spray recorded the lowest count for monocots, followed by pretilachlor + safener sand mixed broadcast.

The data on monocot weeds at different stages showed no significant difference between treatments with respect to their method of application.

The above results indicate the critical nature of competition posed by

sedges and grasses to wet seeded rice. Regarding their control, instead of hand weeding, any pre-emergence herbicide such as oxyflourfen, pretilachlor + safener, butachlor or thiobencarb can be applied either as spray or as sand mixed broadcast. The relatively lower number of monocot weeds in unweeded control plots, can be attributed to the uniform plant stand, which effectively smothered weed growth.

a) *Schoenoplectus lateriflorus*

Effect of different treatments on the population of *Schoenoplectus lateriflorus* at different stages of crop growth is presented in Table 6.

The above weed reached at an identifiable stage only about three weeks after sowing and hence recorded from 30 DAS only. Hand weeded plots registered the lowest number of this species at all stages of crop growth. The maximum number of this species was found in pendimethalin sprayed plots, which was significantly higher than that in the unweeded control at all stages of observation.

At 30 DAS, among herbicides, butachlor spray recorded the lowest population of *Schoenoplectus lateriflorus*. Oxyflourfen spray, thiobencarb spray, butachlor sand mixed broadcast, anilofos spray, pretilachlor + safener spray and its sand mixed broadcast were as effective as butachlor spray and were on par with hand weeded plot. Treatments did not differ significantly regarding the method of application of herbicides.

At 45 DAS, hand weeded plot was free of *Schoenoplectus lateriflorus* due to the handweedings given at 20 and 40 DAS. Among herbicides, butachlor spray retained its superiority. Apart from butachlor spray, the treatments thiobencarb spray and its sand mixed broadcast, butachlor sand mixed broadcast and pretilachlor

Table 6. Effect of different treatments on the population of *Schoenoplectus lateriflorus* (plants/$m^2$)

| Treat-ments | 30 DAS | | 45DAS | | 60 DAS | | Harvest | |
|---|---|---|---|---|---|---|---|---|
| | T | O | T | O | T | O | T | O |
| $O_s$ | 4.71 | 28.33 | 6.78 | 52.33 | 6.54 | 45.33 | 6.80 | 47.67 |
| $O_b$ | 7.01 | 50.00 | 8.11 | 67.00 | 7.66 | 59.67 | 7.12 | 52.00 |
| $T_s$ | 3.87 | 18.33 | 4.84 | 24.33 | 6.32 | 40.33 | 6.23 | 46.00 |
| $T_b$ | 5.11 | 28.33 | 6.00 | 37.00 | 7.82 | 62.67 | 5.37 | 30.00 |
| $B_s$ | 2.20 | 5.33 | 2.85 | 8.33 | 3.96 | 17.67 | 3.81 | 16.33 |
| $B_b$ | 3.31 | 13.00 | 4.31 | 21.00 | 4.93 | 24.67 | 4.00 | 17.67 |
| $A_s$ | 4.92 | 34.33 | 9.37 | 103.67 | 13.39 | 190.67 | 10.64 | 115.00 |
| $A_b$ | 6.68 | 48.67 | 8.14 | 74.33 | 8.51 | 79.67 | 8.56 | 81.67 |
| $A_s$ | 12.65 | 165.67 | 16.35 | 274.00 | 18.10 | 329.33 | 17.16 | 297.67 |
| $P_b$ | 10.93 | 133.00 | 13.03 | 196.30 | 13.82 | 209.00 | 13.33 | 183.33 |
| $P+S_s$ | 4.19 | 18.33 | 8.75 | 135.67 | 5.21 | 36.00 | 4.20 | 19.67 |
| $P+S_b$ | 3.82 | 18.00 | 4.87 | 27.67 | 4.15 | 20.00 | 4.07 | 16.00 |
| HW | 1.82 | 3.67 | 1.00 | 0 | 2.98 | 9.67 | 2.10 | 4.00 |
| UW | 9.84 | 104.67 | 8.71 | 78.33 | 11.08 | 128.00 | 9.28 | 92.67 |
| SEm± | 1.31 | | 1.82 | | 1.25 | | 1.25 | |
| CD (0.05) | 3.82 | | 5.30 | | 3.63 | | 3.62 | |

T - Transformed value $\sqrt{x + 1}$ O - Original value

+ safener sand mixed broadcast were on par with hand weeding twice. Other treatments, which were found as effective as butachlor spray included oxyflourfen spray and its sand mixed broadcast and anilofos sand mixed broadcast.

AT 60 DAS, handweeded plot recorded the lowest count of *Schoenoplectus lateriflorus* followed by butachlor spray. Oxyflourfen spray, thiobencarb spray, butachlor sand mixed broadcast, pretilachlor + safener spray and its sand mixed broadcast were also found on par with hand weeding twice.

Handweeding twice recorded the lowest number of *Schoenoplectus lateriflorus* at the time of harvest also. Among herbicides, pretilachlor + safener spray and its sand mixed broadcast, butachlor spray and its sand mixed broadcast and thiobencarb sand mixed broadcast were found as effective as handweeding twice. Both anilofos and pendimethalin, irrespective of the method of application, recorded higher number of *Schoenoplectus lateriflorus*. The reduction in crop stand due to the phytotoxic effect of these herbicides might have contributed to the dominance of *Schoenoplectus lateriflorus*. The ineffectiveness of pendimethalin in controlling sedges consisted mainly of *Scirpus* sp. in wet seded rice has been reported by Manipon *et al.* (1983). Similar result was observed by Thomas (1994) in dry seeded rice.

The result indicates the possibility of herbicide use for controlling *Schoenoplectus lateriflorus* in wet seeded rice. Any of the pre-emergence herbicides, such as oxyflourfen, pretilachlor + safener, butachlor or thiobencarb can be effectively used either as spray or as sand mixed broadcast.

4.1.2.3 Total weed count

Data on the total weed population at different stages of crop growth under different treatments are given in Table 7.

The hand weeded plots recorded the lowest number of weeds at all stages except at 15 DAS. In the initial stages, i.e., upto 15 DAS, the herbicide treated plots showed a lower number of weeds. Treatments anilofos sand mixed broadcast, pendimethalin spray and its sand mixed broadcast registered a higher number of weeds than unweeded control and hand weeding twice. This is probably due to the reduction in crop stand caused by herbicide toxicity and the resultant spurt in weed growth especially that of sedges as more space was available. Among herbicides, butachlor spray recorded the lowest weed population. All other herbicide treatments barring anilofos sand mixed broadcast, pendimethalin spray and its sand mixed broadcast were on par with butachlor spray.

At 30 DAS, hand weeding twice recorded the lowest weed count as a result of the weeding given at 20 DAS. Treatments, oxyflourfen spray and its sand mixed broadcast, thiobencarb spray, butachlor spray and its sand mixed broadcast, pretilachlor spray and its sand mixed broadcast were found as effective as handweeding twice in reducing the total weed population.

At 45 DAS, hand weeded plot was free of weeds, as a result of the weeding given at 40 DAS. Butachlor spray registered the lowest weed population, among herbicides. All other herbicides barring anilofos and pendimethalin applied either as spray or as sand mixed broadcast, were found on par with butachlor spray.

Table 7. Effect of different treatments on total weed count (plant/m²)

| Treat-ment | 15 DAS | | 30 DAS | | 45 DAS | | 60 DAS | | Harvest | |
|---|---|---|---|---|---|---|---|---|---|---|
| | T | O | T | O | T | O | T | O | T | O |
| $O_s$ | 5.97 | 48.00 | 7.45 | 61.66 | 8.83 | 87.00 | 9.47 | 92.00 | 8.02 | 66.60 |
| $O_b$ | 8.51 | 82.66 | 8.89 | 81.66 | 9.80 | 99.00 | 10.81 | 118.33 | 9.59 | 92.33 |
| $T_s$ | 5.74 | 37.66 | 9.02 | 82.66 | 9.50 | 90.30 | 9.99 | 101.33 | 9.09 | 83.00 |
| $T_b$ | 4.83 | 22.30 | 10.88 | 118.66 | 8.96 | 83.00 | 11.49 | 132.33 | 7.12 | 51.00 |
| $B_s$ | 3.26 | 10.60 | 8.25 | 70.00 | 5.94 | 34.66 | 7.29 | 54.67 | 5.11 | 29.66 |
| $B_b$ | 4.46 | 22.66 | 7.31 | 55.33 | 7.43 | 56.33 | 7.99 | 64.67 | 7.12 | 51.00 |
| $A_s$ | 5.61 | 68.00 | 11.86 | 144.33 | 13.16 | 188.33 | 16.73 | 291.33 | 12.31 | 154.00 |
| $A_b$ | 13.31 | 182.33 | 12.35 | 156.00 | 11.21 | 132.00 | 12.48 | 157.00 | 9.69 | 99.67 |
| $P_s$ | 15.12 | 228.30 | 14.32 | 208.00 | 17.33 | 310.00 | 18.76 | 353.67 | 18.16 | 337.00 |
| $P_b$ | 13.89 | 205.67 | 13.21 | 179.66 | 13.79 | 201.00 | 15.99 | 264.00 | 14.28 | 212.00 |
| $P+S_s$ | 6.12 | 59.33 | 7.68 | 69.33 | 8.79 | 95.66 | 7.99 | 69.67 | 6.85 | 51.33 |
| $P+S_b$ | 5.77 | 38.00 | 9.60 | 93.33 | 7.36 | 54.66 | 7.68 | 63.33 | 5.54 | 31.33 |
| HW | 10.91 | 136.00 | 7.17 | 51.66 | 1.00 | 0 | 5.29 | 29.00 | 4.44 | 22.33 |
| UW | 10.65 | 137.00 | 14.67 | 215.66 | 11.17 | 130.66 | 13.80 | 193.67 | 10.83 | 124.00 |
| SEm± | 2.04 | | 1.02 | | 1.35 | | 2.67 | | 1.22 | |
| CD | 5.94 | | 2.96 | | 3.93 | | 7.76 | | 3.54 | |

T - Transformed value $\sqrt{x} + 1$ O - original value

Pendimethalin spray recorded a significantly higher number of weeds compared to unweeded control, the reason for which is discussed earlier.

At 60 DAS, all treatments including hand weeding twice showed a general increase in the number of total weed population. This can be attributed to the emergence of new weed species. However, lowest weed population was recorded by hand weeding twice. Among other treatments, only anilofos spray, pendimethalin spray and pendimethalin sand mixed broadcast and unweeded control were found inferior to hand weeding. All other herbicide treatments were found as effective as hand weeding twice.

At the time of harvest, a slight decline in weed population was observed compared to that at 60 DAS. This can be attributed to the natural drying up of some of the weeds, especially aquatics such as *Monochoria vaginalis, Sphenochlea zeylanica, Marsilia quadrifoliata* etc. Hand weeding twice registered the lowest count and treatments thiobencarb spray, butachlor spray and its sand mixed broadcast, pretilachlor + safener spray and its sand mixed broadcast were found on par with hand weeding twice. Among herbicides, butachlor spray recorded the lowest weed count and other treatments which were found as effective as butachlor spray included oxyflourfen spray, butachlor sand mixed broadcast, pretilachlor + safener spray its sand mixed broadcast. Pendimethalin spray and its sand mixed broadcast showed significantly higher number of weeds compared to unweeded control.

The above results indicate the effectiveness of pre-emergence herbicides, viz. pretilachlor + safener, oxyflourfen and butachlor, in controlling weeds during the initial stages of crop growth. The effectiveness of the herbicides in controlling weeds lasted only upto 30 DAS, as evidenced by the general increase in weed count

after 30 DAS. However, the herbicides like butachlor, pretilachlor + safener, thiobencarb and oxyflourfen were found effective in controlling the weeds, for a reasonably longer period of crop growth. As no significant difference could be noticed between the two methods of application, sand mixed broadcast of herbicides which is easier and cheaper can be considered as a viable substitute for spraying in wet seeded rice.

4.1.3 Weed dry matter production

Table 8 and Fig. 3 show the data on dry matter production by weeds under different treatments during different stages of crop growth.

At 30 DAS, hand weeding twice recorded the lowest weed dry matter production. All treatments except oxyflourfen sand mixed broadcast, butachlor sand mixed broadcast, pendimethalin spray and its sand mixed broadcast recorded a weed dry matter production similar to that in hand weeding twice. Among herbicide treatments thiobencarb spray showed the lowest weed dry matter production and other treatments which were equally effective as thiobencarb spray included oxyflourfen spray, butachlor spray and its sand mixed broadcast, anilofos spray and its sand mixed broadcast and pretilachlor + safener spray and its sand mixed broadcast. Highest weed dry matter production was recorded by pendimethalin sand mixed broadcast followed by unweeded check.

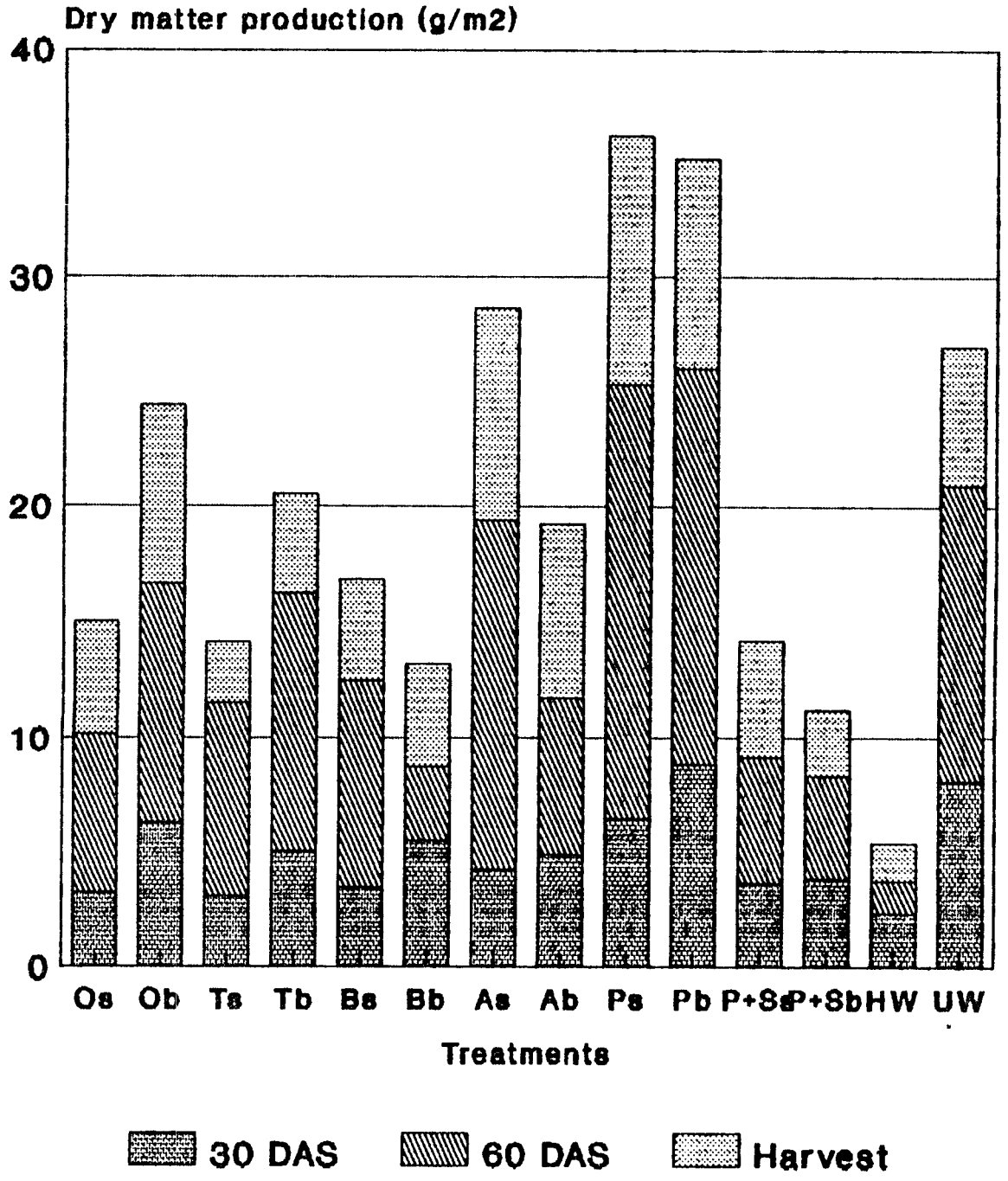
At 60 DAS also the hand weeded plot recorded the lowest weed dry matter production. The treatments pretilachlor + safener spray and its sand mixed broadcast and butachlor sand mixed broadcast were on par with hand weeding twice. Butachlor and its sand mixed broadcast recorded the lowest weed dry matter

Table 8. Effect of different treatments on weed drymatter production g/m²

| Treat-ments | 30 DAS | | 60 DAS | | Harvest | |
|---|---|---|---|---|---|---|
| | T | O | T | O | T | O |
| $O_s$ | 3.23 | 10.80 | 6.95 | 65.87 | 4.73 | 31.87 |
| $O_b$ | 6.33 | 41.47 | 10.21 | 114.67 | 7.84 | 88.93 |
| $T_s$ | 3.07 | 9.60 | 8.38 | 73.60 | 2.58 | 10.67 |
| $T_b$ | 5.06 | 33.33 | 11.08 | 168.67 | 4.41 | 41.73 |
| $B_s$ | 3.45 | 12.27 | 8.99 | 81.07 | 4.32 | 23.87 |
| $B_b$ | 5.52 | 30.93 | 3.24 | 13.20 | 4.31 | 25.33 |
| $A_s$ | 4.27 | 17.60 | 15.12 | 243.07 | 9.29 | 92.40 |
| $A_b$ | 4.87 | 23.73 | 6.84 | 63.73 | 7.56 | 83.87 |
| $P_s$ | 6.49 | 47.47 | 18.80 | 370.40 | 10.89 | 127.07 |
| $P_b$ | 8.88 | 78.53 | 17.20 | 435.60 | 9.15 | 116.00 |
| $P+S_s$ | 3.70 | 18.27 | 5.45 | 31.20 | 4.95 | 54.67 |
| $P+S_b$ | 3.83 | 14.00 | 4.52 | 24.00 | 2.88 | 14.40 |
| HW | 2.30 | 5.47 | 1.50 | 1.38 | 1.63 | 1.87 |
| UW | 8.11 | 65.47 | 12.89 | 168.00 | 6.03 | 48.13 |
| SEm± | 1.05 | | 1.82 | | 2.13 | |
| CD (0.05) | 3.038 | | 5.29 | | NS | |

T - Transformed value $\sqrt{x} + 1$ O - original value

Fig. 3 Effect of various treatments on weed dry matter production



production among herbicides. Oxyflourfen spray, thiobencarb spray, pretilachlor safener spray and its sand mixed broadcast and anilofos sand mixed broadcase were on par with butachlor sand mixed broadcast. Pendimethalin spray recorded a significantly higher weed dry matter production than unweeded control, which is probably due to the presence of a higher weed population especially that of sedges (Table 5).

At harvest stage, no significant difference was observed between treatments. However, thiobencarb spray registered a 57 per cent reduction in weed dry matter production compared to unweeded control, followed by 52 per cent in pretilachlor + safener sand mixed broadcast.

The results indicated that during the initial stages of crop growth i.e., upto 30 DAS, the herbicides pretilachlor + safener, thiobencarb, oxyflourfen, butachlor and anilofos were effective in reducing the weed dry matter production. The rise in dry matter production of weeds at 60 DAS, is probably due to the subsequent germination of weeds, especially broadleaved type, as evidenced by the data given in Table 3.

At the time of harvest, a slight reduction in the dry matter production of weeds was observed in all the plots, which can be attributed to the drying up of some of the weeds, especially the broadleaved aquatics.

### 4.1.4 Weed control efficiency

Weed control efficiency of different treatments presented in Table 9 showed that hand weeding twice was the most efficient. Among the different herbicides, thiobencarb spray recorded the highest weed control efficiency followed by oxyflourfen spray and butachlor spray. All the treatments except pendimethalin sand

Table 9. Weed control efficiency (%) of different treatments

| Treatment | WCE (%) |
|---|---|
| $O_s$ | 83.50 |
| $O_b$ | 36.66 |
| $T_s$ | 85.34 |
| $T_b$ | 49.09 |
| $B_s$ | 81.26 |
| $B_b$ | 52.76 |
| $A_s$ | 73.17 |
| $A_b$ | 63.75 |
| $P_s$ | 27.49 |
| $P_b$ | -19.95 |
| $P + S_s$ | 72.09 |
| $P + S_b$ | 78.62 |
| HW | 91.65 |

mixed broadcast recorded positive values, indicating the effectiveness of herbicides during the early stages of crop growth. In general, spray application of herbicides resulted in a higher weed control efficiency, compared to their sand mixed broadcast application. But this effect was nullified by the higher phytotoxicity of herbicides except pretilachlor + safener, when they were applied as spray, than as sand mixed broadcast application (Table 13) and hence not reflected on the grain yield. Among the herbicides pendimethalin recorded the lowest weed control efficiency. Moorthy (1980) also obtained the lowest weed control efficiency (13%) with pendimethalin in wet-seeded rice.

4.1.5 Nutrient removal by weeds

a) Nitrogen

Nitrogen removal by weeds at different stages of crop growth under different treatments are presented in Table 10 and the nitrogen content is presented in Appendix II.

At all stages of crop growth hand weeding twice recorded the lowest value for nitrogen removal by weeds. This is probably due to the low weed dry matter production as a result of weeding operations given at 20 and 40 DAS.

At 30 DAS, oxyflourfen spray, butachlor spray, thiobencarb spray, pretilachlor + safener spray and sand mixed broadcast, anilofos spray and sand mixed broadcast were on par with handweeding twice. This can be attributed to the comparatively lower weed dry matter production at this stage, consequent to the application of the above herbicides. Pendimethalin sand mixed broadcast recorded the highest nitrogen removal by weeds followed by its spray application, and unweeded control. This can be attributed to the lesser efficiency of this herbicide in reducing

Table 10. Effect of different treatments on nitrogen removal by weeds (kg/ha)

| Treatments | 30 DAS | | 60 DAS | | Harvest | |
|---|---|---|---|---|---|---|
| | T | O | T | O | T | O |
| Os | 1.59 | 1.64 | 3.39 | 13.50 | 1.50 | 1.44 |
| Ob | 2.58 | 5.81 | 3.94 | 15.67 | 1.47 | 1.59 |
| Ts | 1.80 | 2.50 | 3.44 | 11.56 | 2.17 | 1.25 |
| Tb | 2.38 | 5.73 | 5.49 | 31.15 | 1.80 | 3.53 |
| Bs | 1.72 | 2.12 | 4.74 | 21.70 | 2.02 | 3.83 |
| Bb | 1.99 | 3.08 | 1.73 | 2.46 | 1.85 | 2.96 |
| As | 2.06 | 3.30 | 5.72 | 32.56 | 3.37 | 11.27 |
| Ab | 1.91 | 2.79 | 3.67 | 16.03 | 2.69 | 8.04 |
| Ps | 3.08 | 9.43 | 6.52 | 41.93 | 4.11 | 16.93 |
| Pb | 3.85 | 13.89 | 6.38 | 40.46 | 3.74 | 16.78 |
| P + Ss | 1.84 | 2.99 | 2.32 | 5.52 | 1.24 | 0.64 |
| P + Sb | 1.94 | 2.78 | 1.95 | 3.34 | 1.45 | 1.51 |
| HW | 1.31 | 0.77 | 1.38 | 1.67 | 1.18 | 0.71 |
| UW | 3.62 | 12.14 | 5.08 | 24.80 | 2.33 | 5.30 |
| Em± | 0.338 | | 0.632 | | 0.595 | |
| CD (0.05) | 0.982 | | 1.837 | | 1.73 | |

T - Transformed value ($\sqrt{x} + 1$  O - Original value

the weed dry matter production (Table 8). There was no significant difference between the methods of application of the herbicides tested except for oxyflourfen, where sand mixed broadcast recorded significantly higher nitrogen removal by weeds than its spray.

At 60 DAS, hand weeding twice recorded the lowest quantity of nitrogen removal by weeds. Among the herbicide treatments butachlor sand mixed broadcast, pretilachlor + safener sand mixed broadcast as well as its spray were on par with hand weeded control. The highest quantity of nitrogen removed by weeds was observed in pendimethalin spray. Pendimethalin sand mixed broadcast, thiobencarb sand mixed broadcast, butachlor spray and anilofos spray were found on par with pendimethalin spray. In general, sand mixed broadcast of all the herbicides except thiobencarb resulted in a lower nitrogen removal by weeds compared to their spray application. Moreover the effect was significant in the case of butachlor.

At harvest stage, a decrease in the quantity of nitrogen removed by weeds was noticed in all treatments compared to that at 60 DAS. This is probably due to the reduction in weed dry matter accumulation towards later stages of crop growth, as a result of drying up of broadleaved aquatic weeds. Handweeding twice recorded the lowest nitrogen removal followed by pretilachlor + safener spray and its sand mixed broadcast application. All treatments except anilofos spray, pendimethalin spray and its sand mixed broadcast were on par with hand weeding twice. At this stage also sand mixed broadcast of herbicides showed a lesser nitrogen removal by weeds, except in pretilachlor + safener treated plots, though the difference was not significant.

The above results also indicate that sand mixed application of herbicides is equally effective as their spray in wet seeded rice.

Phosphorus

At all stages of crop growth, hand weeding twice recorded the lowest quantities of phosphorus removal by weeds (Table 11 and phosphorus content in Appendix III).

At 30 DAS, all herbicide treatments except pendimethalin applied both as spray and sand mixed broadcast, oxyflourfen sand mixed broadcast, and unweeded control were found equally effective as hand weeding twice in reducing the phosphorus removal by weeds. This trend exhibited by herbicide treated plots can be less attributed to the lower weed drymatter production consequent to the application of herbicides at 6 days after sowing, in either way. The highest phosphorus removal was recorded by pendimethalin sand mixed broadcast. No significant difference could be observed between the methods of application of herbicides.

At 60 days also, hand weeding twice recorded the lowest value, followed by butachlor sand mixed broadcast. Other treatments comparable with hand weeding twice were pretilachlor + safener sand mixed broadcast, and its spray, spray application of oxyflourfen and thiobencarb, sand mixed broadcast of butachlor and anilofos. Anilofos sand mixed broadcast was found superior to its spray application, in reducing the phosphorus removal by weeds.

At harvest stage, no significant difference was observed between treatments, the lowest being hand weeding twice, followed by pretilachlor + safener.

Table 11. Effect of different treatments on phosphorus removal by weeds (kg/ha)

| Treatments | 30 DAS | | 60 DAS | | Harvest | |
|---|---|---|---|---|---|---|
| | T | O | T | O | T | O |
| Os | 1.18 | 0.41 | 1.67 | 2.01 | 1.39 | 1.05 |
| Ob | 1.65 | 1.79 | 2.11 | 3.71 | 1.65 | 2.55 |
| Ts | 1.18 | 0.39 | 1.68 | 1.87 | 1.33 | 0.88 |
| Tb | 1.49 | 1.34 | 2.30 | 4.91 | 1.34 | 1.04 |
| Bs | 1.22 | 0.51 | 2.07 | 3.29 | 1.30 | 0.73 |
| Bb | 1.50 | 1.27 | 1.18 | 0.41 | 1.35 | 0.94 |
| As | 1.37 | 0.89 | 3.07 | 9.30 | 1.99 | 3.12 |
| Ab | 1.45 | 1.13 | 1.60 | 1.73 | 1.65 | 1.95 |
| Ps | 1.84 | 2.62 | 3.32 | 10.28 | 2.23 | 4.17 |
| Pb | 2.07 | 3.31 | 3.58 | 12.73 | 1.98 | 3.44 |
| P + Ss | 1.26 | 0.64 | 1.37 | 1.04 | 1.04 | 0.07 |
| P + Sb | 1.25 | 0.56 | 1.22 | 0.51 | 1.12 | 0.29 |
| HW | 1.09 | 0.20 | 1.14 | 0.31 | 1.09 | 0.20 |
| UW | 1.96 | 2.85 | 2.22 | 4.05 | 1.39 | 1.05 |
| Em± | 0.154 | | 0.326 | | 0.272 | |
| CD (0.05) | 0.446 | | 0.947 | | NS | |

T - Transformed value ($\sqrt{x}$ + 1) O - Original value

Moreover, at this stage, a decrease in the actual quantity of phosphorus removal by weeds was observed in all treatments which probably may be due to the reduction in weed dry matter production.

Potassium

At all stages, hand weeding twice recorded the lowest potassium removal by weeds (Table 12 and potassium content in Appendix IV).

At 30 DAS, hand weeding twice registered the lowest potassium removal, followed by thiobencarb spray. All other herbicide treatments except pendimethalin spray and its sand mixed broadcast application were on par with thiobencarb spray. No significant difference could be observed between the two methods of application in any of the herbicides. The highest potassium removal by weeds was observed in pendimethalin sand mixed broadcast, which was on par with unweeded control and pendimethalin spray. This is probably due to the higher weed dry matter production contributed mainly by sedges, in pendimethanlin applied plots, due to its lower efficiency in controlling sedges.

At 60 DAS, an increase in the potassium removal by weeds was observed in all treatments except hand weeding twice compared to that at 30 DAS. The increased weed dry matter accumulation by 60 DAS, can be cited as the probable reason for this. Hand weeding twice recorded the lowest potassium removal by weeds at 60 DAS as the weed dry matter production was reduced as a result of the weeding operation done on 40 days after sowing. Butachlor sand mixed broadcast, pretilachlor + safener sand mixed broadcast, as well as spray, anilofos sand mixed application were equally effective. Highest potassium removal by weeds at this stage

Table 12. Effect of different treatments on potassium removal by weeds (kg/ha)

| Treatments | 30 DAS | | 60 DAS | | Harvest | |
|---|---|---|---|---|---|---|
| | T | O | T | O | T | O |
| Os | 1.87 | 2.81 | 4.21 | 23.39 | 3.13 | 11.92 |
| Ob | 3.20 | 9.85 | 4.83 | 25.72 | 3.28 | 20.21 |
| Ts | 1.86 | 2.77 | 3.78 | 13.88 | 3.07 | 10.85 |
| Tb | 2.66 | 7.47 | 5.33 | 31.79 | 3.45 | 22.95 |
| Bs | 2.02 | 3.58 | 4.61 | 20.38 | 2.48 | 6.44 |
| Bb | 2.77 | 6.82 | 1.83 | 2.89 | 2.96 | 10.68 |
| As | 2.41 | 4.95 | 5.48 | 32.87 | 5.82 | 36.62 |
| Ab | 2.61 | 6.05 | 2.46 | 6.30 | 4.92 | 30.97 |
| Ps | 3.78 | 15.36 | 9.25 | 88.96 | 7.70 | 62.28 |
| Pb | 4.82 | 22.36 | 8.34 | 71.51 | 6.36 | 53.87 |
| P + Ss | 2.14 | 4.66 | 2.58 | 7.62 | 1.59 | 2.24 |
| P + Sb | 2.24 | 4.18 | 2.18 | 4.63 | 2.01 | 5.04 |
| HW | 1.42 | 1.13 | 1.62 | 1.83 | 1.53 | 1.50 |
| UW | 3.78 | 13.41 | 6.74 | 44.60 | 3.55 | 15.11 |
| SEm± | 0.477 | | 0.847 | | 1.12 | |
| CD (0.05) | 1.387 | | 2.46 | | 3.26 | |

T - Transformed value ($\sqrt{x} + 1$) O - Original value

was recorded by pendimethalin spray, followed by its sand mixed broadcast. Unweeded control was also on par with these treatments. Significant difference in potassium removal was noticed between butachlor sand mixed broadcast and its spray, with the former recording a lower value. Anilofos also gave a similar trend.

At harvest, potassium removal by weeds showed a decreasing trend, irrespective of the treatments, compared to that at 60 DAS. The reduction in weed dry matter production as a result of drying up of many of the broadleaved aquatics, towards the later stage provides explanation to this. Hand weeding twice recorded the lowest potassium removal by weeds. All other treatments except anilofos and pendimethalin applied both as spray and sand mixed broadcast, were on par with hand weeding twice. However, no significant difference could be observed between the two methods of application of herbicides.

The general trend in nutrient removal by weeds is a lesser removal during the early stages, reaching the maximum by 60 days and declining towards the later stages. The quantity of nutrients removed by weeds was directly related to their dry matter production. The lower nutrient removal during the early stages can be attributed to the lesser weed dry matter production. About 60 DAS, the weeds attained their peak growth and resulted in the highest nutrient removal. The decrease in nutrient removal by weeds towards later stages is probably due to the decrease in weed dry matter production as a result of drying up of broadleaved aquatics. The nutrient removal by weeds was lowest in hand weeded plots at all stages, and highest in pendimethalin treated plots. The probable reason for which is the same as discussed above.

Among the different herbicides tried, pretilachlor + safener spray and its sand mixed broacast resulted in lower nutrient removal and higher grain yield. The formulation containing pretilachlor + safener was effective in controlling weeds especially during the early stages and was well tolerated by rice seedlings. The higher grain yield in plots where weeds were controlled without affecting rice plants can be attributed to the lower nutrient removal by weeds, as the weed dry matter production and nutrient removal are positively dependent. This indicates that herbicides with better weed control efficiency and lesser phytotoxic effect on rice seedlings result in lesser nutrient removal by weeds and thereby producing higher grain yield.

There was no significant difference between the two methods of application viz., spraying and sand mixed broacast, regarding nutrient removal by weeds, which again showed the comparable efficacy of sand mixed broadcast application with spraying.

## 4.2 Studies on crops

### 4.2.1 Phytotoxicity

#### 4.2.1.1 Rice plant population/m²

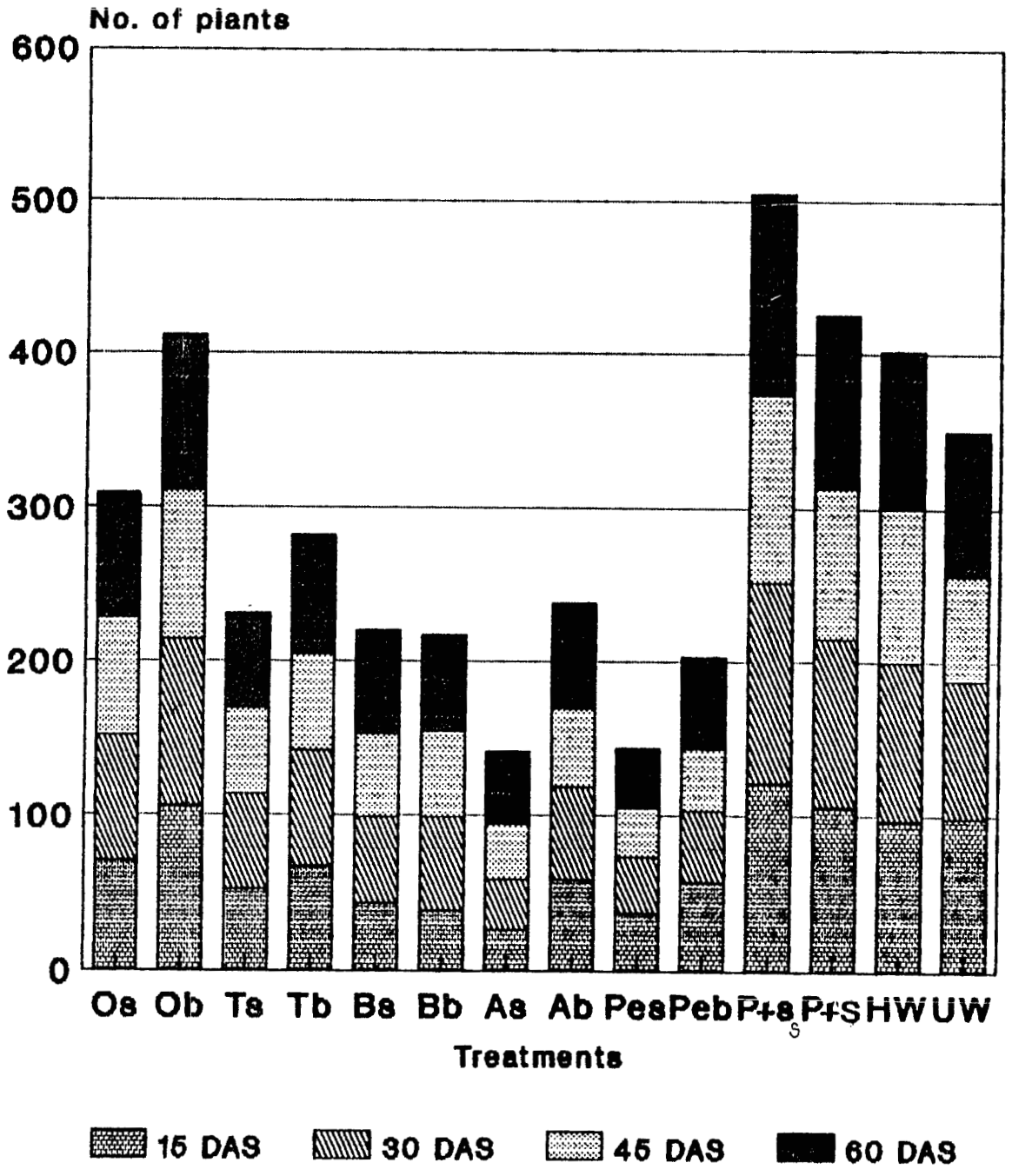
Effect of different treatments on rice population (Table 13, Fig. 4) showed that sand mixed broadcast application of most of the herbicides resulted in a better crop stand compared to their spray application.

At 15 DAS, pretilachlor + safener spray, recorded the highest number of rice plants followed by oxyflourfen sandmixed broadcast and pretilachlor + safener

Table 13. Effect of different treatments on rice plant population/$m^2$

| Treatments | 15 DAS | 30 DAS | 45 DAS | 60 DAS |
|---|---|---|---|---|
| $O_s$ | 70.67 | 80.67 | 76.67 | 31.33 |
| $O_b$ | 107.33 | 107.00 | 97.67 | 99.33 |
| $T_s$ | 52.00 | 62.33 | 55.00 | 61.33 |
| $T_b$ | 66.67 | 75.33 | 62.33 | 77.67 |
| $B_s$ | 43.00 | 56.00 | 53.67 | 67.00 |
| $B_b$ | 38.33 | 61.00 | 55.33 | 62.00 |
| $A_s$ | 26.00 | 32.67 | 35.67 | 47.00 |
| $A_b$ | 58.33 | 60.00 | 50.67 | 68.33 |
| $P_s$ | 36.67 | 36.00 | 33.00 | 38.33 |
| $P_b$ | 56.33 | 46.67 | 40.33 | 59.33 |
| $P+S_s$ | 121.33 | 130.00 | 122.33 | 131.67 |
| $P+S_b$ | 106.33 | 108.33 | 99.33 | 112.00 |
| HW | 97.00 | 102.33 | 101.00 | 101.67 |
| UW | 98.67 | 89.67 | 68.67 | 92.33 |
| SEm± | 9.05 | 10.28 | 9.118 | 12.09 |
| CD (0.05) | 26.31 | 29.88 | 26.32 | 35.15 |

Fig. 4 **Effect of treatments on the number of rice plants /sq.m.**



sand mixed broadcast. The treatment hand weeding twice was on par with pretilachlor + safener spray. All other herbicide treatments recorded significantly lower plant population at this stage which can be attributed to their phytotoxic effect. Hand weeded and unweeded plots maintained a uniform plant population.

At 30 DAS also, pretilachlor + safener spray recorded the highest plant population. Pretilachlor + safener sand mixed broadcast, hand weeding twice and oxyflourfen sand mixed broadcast were on par with pretilachlor + sefener spray. Oxyflourfen spray and thiobencarb sand mixed broadcast were found similar to hand weeding twice. Herbicide treatments did not differ significantly, regarding their method of application.

At 45 and 60 DAS also, pretilachlor + safener spray maintained its superiority in respect of this parameter. Oxyflourfen sand mixed broadcast, pretilachlor + safener sand mixed broadcast and handweeding twice were found equally effective as pretilachlor + safener spray in maintaining the rice plant population.

The above results indicate that among the herbicides tested, pretilachlor + safener is the safest, pre-emergence herbicide for weed control in wet seeded rice. The higher number of rice plants in the above treatment might be due to the lesser phytotoxic effect of this herbicide, achieved through the safener added in it. The results also showed that in most of the herbicides, sand mixed broadcast resulted in a slightly higher plant population compared to their spray application, eventhough the effect was not significant. This can be attributed to the lesser phytotoxic effect of herbicides on rice seedlings when applied as sand mixed broadcast, than as spray.

4.2.2 Growth characteristics

4.2.2.1 Plant height

The data presented in Table 14 showed that plant height was not affected by different treatments except at 60 DAS. Earlier reports by Rathinam and Sankaran (1974) and Barman and Mehta (1985) stated that plant height was relatively unaffected by weed control treatments.

However at all stages in the case of most of the herbicides, the sand mixed broadcast recorded taller plants than spray. This is probably due to the lesser phytotoxic effect of herbicides when applied as sandmixed broadcast compared to spray. This trend was not observed in pretilachlor + safener applied plots at any stages of observation. This might be due to the lesser phytotoxicity on rice plants as a result of the action of safener added to the herbicide.

At 60 DAS, oxyflourfen spray produced the tallest plants. Eventhough, oxyflourfen caused toxicity, the seedlings recovered and made use of the relatively weed free condition and resulted in taller plants. oxyflourfen sand mixed broadcast, butachlor sand mixed broadcast, anilofos sand mixed broadcast, pretilachlor + safener spray and hand weeding twice were on par with oxyflourfen spray. Sand mixed broadcast of butachlor and anilofos produced significantly taller plants, than their spray, which again showed the superiority of sand mixed broadcast over spray.

4.2.2.2 Tiller production/plant

At 30 DAS, anilofos sand mixed broadcast recorded the highest number of tillers (Table 15). All other treatments except oxyflourfen spray, butachlor spray and its sand mixed broadcast and pendimethalin spray were on par with anilofos

Table 14. Effect of different treatments on the height of rice plants (cm)

| Treatments | 30 DAS | 60 DAS | Harvest |
|---|---|---|---|
| $O_s$ | 41.67 | 60.63 | 69.80 |
| $O_b$ | 45.67 | 55.27 | 63.53 |
| $T_s$ | 41.00 | 50.30 | 60.13 |
| $T_b$ | 42.60 | 52.80 | 63.13 |
| $B_s$ | 38.07 | 51.60 | 61.40 |
| $B_b$ | 41.67 | 58.83 | 65.47 |
| $A_s$ | 43.47 | 49.73 | 57.87 |
| $A_b$ | 43.47 | 60.17 | 67.87 |
| $P_s$ | 42.13 | 52.27 | 61.20 |
| $P_b$ | 41.53 | 51.27 | 61.93 |
| $P+S_s$ | 44.13 | 57.00 | 65.40 |
| $P+S_b$ | 43.33 | 54.27 | 62.80 |
| HW | 44.47 | 57.60 | 65.93 |
| UW | 43.33 | 52.93 | 61.87 |
| SEm± | 1.776 | 1.958 | 2.23 |
| CD (0.05) | NS | 5.698 | NS |

sand mixed broadcast. However, no significant difference was observed between the two methods of application viz., spraying and sand mixed broadcast, in any of the herbicides tested.

At 60 DAS, oxyflourfen spray was having the highest number of tillers followed by anilofos spray and anilofos sand mixed broadcast.

At harvest stage also, oxyflourfen spray recorded the highest number of tillers per plant. All other treatments except anilofos spray, were found to possess significantly lower number of tillers compared to oxyfluorfen spray.

The higher number of tillers observed in anilofos treated plots and oxyflourfen sprayed plots might be due to the increased space availability to individual rice plants, consequent to the phytotoxicity and stand loss. The relatively good weed control effected by these herbicides because of their broadspectrum nature enabled the plants to make use of the resources for effective tillering. However, this effect was not noticed in the case of pendimethalin treated plots, which also recorded a lower plant population as a result of toxicity. This is probably due to the heavy weed infestation, especially of *Schoenoplectus lateriflorus*. Unlike oxyflourfen and anilofos, pendimethalin is more suited for the control of grasses, which enabled an increase in the sedge population such as *Schoenoplectus lateriflorus* in these plots. The lower number of tillers per plant recorded by other treatments compared to that in anilofos treated plots, either as spray or as sand mixed broadcast, might be due to the reasonable crop stand, as a result of absence or lesser phytotoxic effect.

Table 15. Effect of different treatments on the number of tillers/plant

| Treatments | 30 DAS | 60 DAS | Harvest |
|---|---|---|---|
| $O_s$ | 3.23 | 7.30 | 9.40 |
| $O_b$ | 4.47 | 4.37 | 4.13 |
| $T_s$ | 4.27 | 4.87 | 5.50 |
| $T_b$ | 4.20 | 5.20 | 4.73 |
| $B_s$ | 3.07 | 4.93 | 5.53 |
| $B_b$ | 3.07 | 4.37 | 4.87 |
| $A_s$ | 4.87 | 6.50 | 8.33 |
| $A_b$ | 5.07 | 5.80 | 7.07 |
| $P_s$ | 3.13 | 4.33 | 5.00 |
| $P_b$ | 4.40 | 4.67 | 4.80 |
| $P+S_s$ | 4.40 | 4.67 | 4.33 |
| $P+S_b$ | 3.80 | 4.13 | 4.27 |
| HW | 4.73 | 5.20 | 5.40 |
| UW | 3.93 | 4.03 | 4.60 |
| SEm± | 0.50 | 0.55 | 0.608 |
| CD (0.050 | 1.45 | 1.60 | 1.76 |

4.2.2.3 Dry matter production

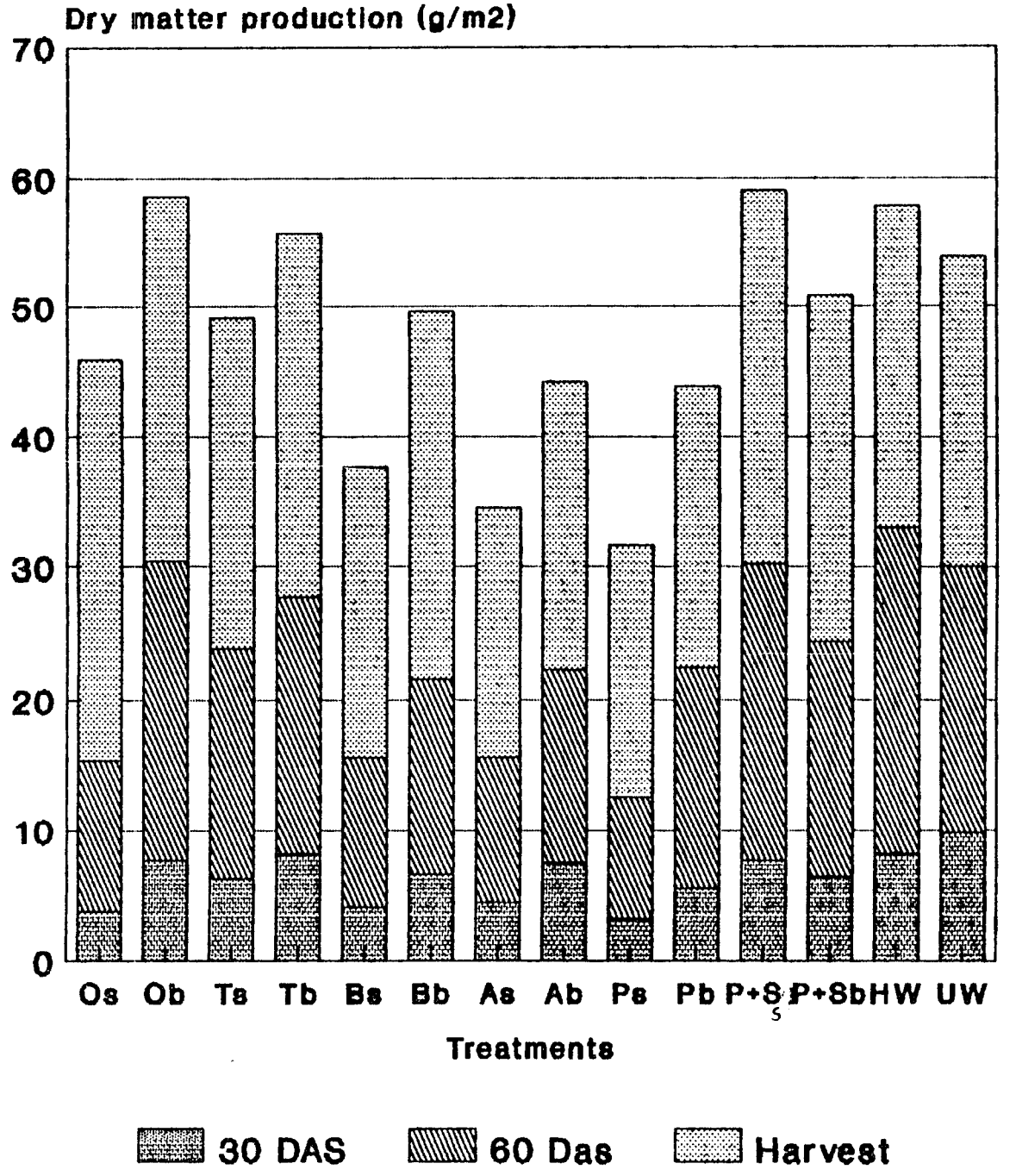
In general, at all stages of observation, sand mixed broadcast recorded higher or similar crop dry matter production, compared to spray (Table 16 and Fig.5). This is probably due to the comparable weed control efficiency and lesser phytotoxicity as a result of sand mixed broadcast of herbicides than their spray application. With the exception of pretilachlor + safener, all the herbicides produced toxicity symptoms at varying intensities. The recovery from phytotoxicity by rice seedlings was also not uniform. Between methods, sand mixed broadcast was found to be more safer than spray, in respect of phytotoxicity to rice seedlings.

At 30 DAS, all the herbicide treatments recorded a lower crop dry matter production compared to unweeded control. However, treatments oxyflourfen sand mixed broadcast hand weeding twice, thiobencarb sand mixed broadcast, pretilachlor + safener applied both as spray and sand mixed broadcast were on par with unweeded control. Among herbicides, sand mixed broadcast of oxyflourfen recorded the highest dry matter production. Butachlor sand mixed broadcast, and anilofos sand mixed broadcast were on par with oxyflourfen sand mixed broadcast. The significantly lower dry matter production in other herbicide treatments, mostly in sprayed plots, and in pendimethalin applied plots, both as spray and sand mixed broadcast, is probably due to the phytotoxic effect of the herbicides on rice seedlings and consequent stand loss. Sand mixed broadcast of oxyflourfen, thiobencarb and pendimethalin produced significantly higher dry matter than their spray, which revealed the superiority of sand mixed broadcast over spray.

Table 16. Effect of different treatments on the drymatter production by crop (g/m²)

| Treat-ments | 30 DAS | | 60 DAS | | Harvest | |
|---|---|---|---|---|---|---|
| | T | O | T | O | T | O |
| $O_s$ | 3.81 | 14.80 | 11.600 | 297.87 | 30.440 | 939.60 |
| $O_b$ | 7.72 | 59.67 | 22.687 | 518.00 | 28.211 | 802.40 |
| $T_s$ | 6.24 | 39.73 | 17.659 | 321.07 | 25.203 | 668.53 |
| $T_b$ | 8.13 | 67.84 | 19.598 | 427.07 | 28.047 | 795.60 |
| $B_s$ | 4.00 | 16.40 | 11.645 | 140.13 | 21.999 | 498.27 |
| $B_b$ | 6.51 | 43.33 | 15.103 | 241.73 | 28.015 | 825.470 |
| $A_s$ | 4.40 | 20.67 | 11.268 | 128.53 | 18.927 | 365.60 |
| $A_b$ | 7.53 | 47.20 | 14.713 | 222.00 | 21.881 | 499.407 |
| $P_s$ | 3.23 | 10.47 | 9.317 | 103.33 | 19.182 | 375.47 |
| $P_b$ | 5.48 | 32.18 | 16.987 | 298.27 | 21.336 | 469.07 |
| $P+S_s$ | 7.59 | 58.67 | 22.723 | 518.40 | 28.738 | 833.30 |
| $P+S_b$ | 6.35 | 40.93 | 18.028 | 340.53 | 26.489 | 706.93 |
| HW | 8.18 | 67.87 | 24.865 | 620.93 | 24.787 | 615.33 |
| UW | 9.74 | 95.07 | 20.346 | 414.13 | 23.835 | 576.13 |
| SEm± | 0.66 | | 2.23 | | 2.318 | |
| CD (0.05) | 1.906 | | 6.463 | | 6.739 | |

Fig. 5 Effect of different treatments on the dry matter production by crop (g/sq. m)



At 60 DAS, handweeding twice recorded the highest drymatter production. Pretilachlor + safener spray, oxyflourfen sand mixed broadcast, and thiobencarb sand mixed broadcast were similar to hand weeding twice. The weed free condition provided by the two hand weedings given at 20 and 40 DAS might have helped for a greater crop drymatter accumulation in handweeded plots. Pretilachlor + safener recorded the highest dry matter production among herbicide treatments. In addition to the above treatments, pretilachlor sand mixed broadcast, oxyflourfen spray, thiobencarb spray and pendimethalin sand mixed broadcast were also on par with pretilachlor + safener spray. The comparable crop drymatter production in herbicide treated plots with hand weeding twice at 60 DAS might be due to the recovery of rice seedlings from the phytotoxic effect. Pendimethalin spray and sand mixed broadcast, and spray application of anilofos and butachlor produced significantly lower drymatter, probably due to the slow recovery from herbicide toxicity. By about 60 days, plants in oxyflourfen treated plots recovered from toxicity and started to produce new tillers. The deleterious effect of anilofos in wet seeded rice when applied as spray at 6 DAS was reported by Joy *et al.* (1993). Increased phytotoxicity in wetseeded rice due to the application of anilofos before 10 DAS was also reported by Sreedevi and Thomas (1993).

At harvest stage, oxyflourfen spray recorded the highest drymatter production. Treatments pretilachlor + safener spray, oxyflourfen sand mixed broadcast, thiobencarb sand mixed broadcast, butachlor sand mixed broadcast, pretilachlor + safener sand mixed broadcast, and hand weeding twice were found on par with oxyflourfen spray. The increased drymatter production in these plots can be attributed to the higher tiller production combined with a decline in weed population during

later stages. The marked increase in drymatter production by the crop towards the later stages is a direct consequence of the weed control efficiency of herbicides applied either as spray or as sand mixed broacast. Wherever the crop suffered phytotoxicity and resulted in stand loss, weed infestation was more and recorded a lower drymatter production. Patel *et al.* (1985) reported that crop drymatter was negatively correlated with weed dry weight.

The results indicate that among the herbicides tried, pendimethalin and anilofos recorded lower drymatter production compared to other herbicides, as a result of their higher phytotoxic effect and the resultant reduction in crop stand. Further, the data revealed that sand mixed broadcast is better than spray for higher crop drymatter production, which is probably due to a reduction in phytotoxic effect of herbicides on rice seedlings. Earlier report by Sandhu *et al.* (1988) also indicated the high crop tolerance to herbicides when applied as sand mixed broadcast. However in the case of pretilachlor + safener, its application either as spray or as sand mixed broadcast did not have any significant effect on crop drymatter production at any stage which showed the effectiveness of the safener added to the herbicide.

A correlation study between crop and weed dry matter production at different stages of crop growth showed that there was significant negative correlation between the two parameters at 60 DAS when the weed drymatter production was maximum (Table 17).

Table 17. Correlation between crop and weed drymatter production at different stages

| Stages | Correlation coefficient |
|---|---|
| 30 DAS | 0.1821 |
| 60 DAS | -0.4249* |
| Harvest | 0.2904 |

4.2.3 Yield and yield attributes

4.2.3.1 Productive tillers

The data presented in Table 18 showed that oxyflourfen spray recorded the highest number of productive tillers per plant. Anilofos spray and its sand mixed broadcast were on par with oxyflourfen spray. All other treatments recorded a significantly lesser number of productive tillers per plant, compared to oxyflourfen spray. The higher number of productive tillers per plant recorded by oxyflourfen spray, anilofos spray, and its sand mixed broadcast can be attributed to the higher number of total tillers per plant as evident from Table 15, the reason for which is discussed thereunder.

4.2.3.2 Panicle length

Panicle length of rice was not affected by different treatments (Table 18). This showed that none of the pre-emergence herbicides tested eighter as spray or as sand mixed broadcast had any adverse effect on the length of panicle. Among different treatments, pendimethalin spray, recorded the longest and oxyflourfen spray, the shortest.

4.2.3.3 Number of filled grains per panicle

The data presented in Table 18 showed that the effect of different treatments on the number of grains per panicle was not significant. Pendimethalin spray recorded the highest number and hand weeding twice the lowest. This again showed that the pre-emergence herbicides tested had no adverse effect on the number of grains per panicle.

4.2.3.4 Thousand seed weight

The data presented in Table 18 revealed that none of the herbicides tested could bring about any significant effect on thousand seed weight. However all treatments except anilofos spray recorded a slightly higher thousand seed weight compared to unweeded control.

The data on yield attributes clearly showed that none of the pre-emergence herbicide tested had any adverse effect on any of the yield attributing characters, even though they could not bring about any significant positive influence except on the number of productive tillers per plant. Though oxyflourfen spray, anilofos spray and its sand mixed broadcast resulted in a higher number of productive tillers per plant, it was not reflected on the grain yield. This is probably because of the reduction in total plant population due to the phytotoxic effect of the herbicides, in spite of the increased tiller number per plant.

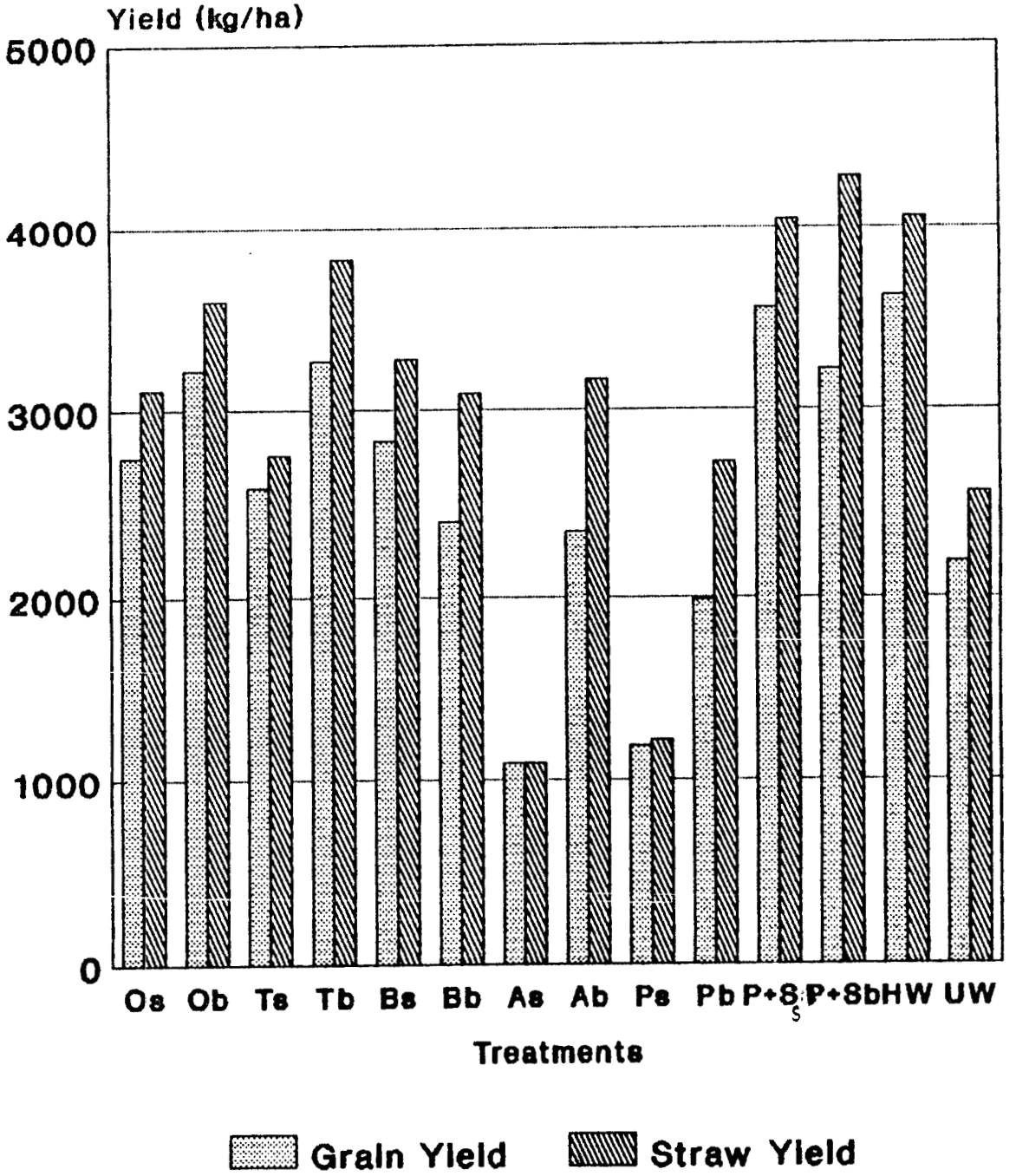
4.2.3.5 Grain yield

The data presented in Table 19, Fig. 6 showed that the highest grain yield was recorded by hand weeding twice (3619 kg/ha). All other treatments except

Table 18. Effect of different treatments on yield attributes

| Treatments | Productive tillers/ plant | Panicle length (cm) | No. of filled grains/panicle | Thousand seed weight (g) |
|---|---|---|---|---|
| $O_s$ | 7.57 | 16.83 | 73.80 | 27.93 |
| $O_b$ | 3.56 | 17.87 | 63.27 | 26.10 |
| $T_s$ | 4.57 | 18.07 | 73.27 | 29.03 |
| $T_b$ | 4.90 | 17.80 | 67.73 | 27.53 |
| $B_s$ | 5.10 | 18.57 | 73.80 | 25.53 |
| $B_b$ | 4.37 | 17.97 | 69.07 | 26.60 |
| $A_s$ | 7.17 | 18.13 | 70.60 | 23.20 |
| $A_b$ | 6.20 | 18.67 | 69.60 | 25.80 |
| $P_s$ | 3.73 | 18.13 | 64.07 | 25.63 |
| $P_b$ | 4.37 | 18.77 | 78.20 | 27.13 |
| $P + S_s$ | 3.97 | 18.00 | 65.20 | 28.60 |
| $P + S_b$ | 3.87 | 17.87 | 61.80 | 27.90 |
| HW | 4.83 | 17.53 | 58.73 | 27.43 |
| UW | 3.93 | 18.47 | 66.44 | 24.77 |
| SEm+ | 0.7 | 0.561 | 5.78 | 1.391 |
| CD (0.05) | 2.04 | NS | NS | NS |

Fig. 6 **Effect of different treatments on grain and straw yield (kg/ha)**



anilofos spray, spray and sand mixed application of pendimethalin and unweeded control were on par with hand weeding twice. The highest grain yield recorded by hand weeding twice might be due to the higher weed control efficiency (Table 9) and the uniform crop stand. Other treatments namely pretilachlor + safener spray, thiobencarb sand mixed broadcast, pretilachlor + safener sand mixed broadcast, oxyflourfen sand mixed broadcast, butachlor spray, thiobencarb spray, butachlor sand mixed broadcast and anilofos sand mixed broadcast recorded yields on par with hand weeding twice. This is probably due to the higher weed control efficiency or lesser phytotoxic effect of the applied herbicides or a combination of both under wet seeded condition. However, anilofos spray, pendimethalin spray and its sand mixed broadcast recorded significantly lower grain yield, compared to hand weeded control, and were found similar to unweeded control. The severe weed competition from weeds, mainly, *Schoenoplectus lateriflorus* in these plots (Table 6) combined with a low plant population (Table 13) as a result of herbicide toxicity might have resulted in a decreased yield, even lower than that recorded by unweeded control. Similar grain yield reduction was reported by Joy *et al.* (1993), when anilofos and pretilachlor were used in wet seeded rice. Sreedevi and Thomas (1993) also reported a reduction in grain yield due to phytotoxicity from anilofos, when applied alone or in combination with 2,4-D EE at 8 DAS in wet seeded rice. Moorthy (1980) and Manipon *et al.* (1983) also reported that pendimethalin produced lower grain yield due to poor weed control and its phytotoxic effect on crop.

Among herbicides tested, pretilachlor + safener spray produced the highest grain yield followed by the sand mixed application of thiobencarb. The safener added to pretilachlor might have protected the rice seedlings with simultaneous herbicidal control over the weeds, especially during the early stages of crop

growth. The use of pretilachlor without safener was found to have phytotoxic effect in dry seeded rice (AICRP WC unpublished, 1991-93). The herbicide treatments with the exception of anilofos spray, pendimethalin spray and its sand mixed broadcast brought about a yield increase in the range of 7.24 to 62.48 per cent over unweeded control (158.5 to 1367.63 kg/ha).

The results also showed that most of the plots which received herbicides as sand mixed broadcast recorded a slightly higher grain yield, compared to spray, eventhough the difference was not statistically significant. This might be due to the lesser phytotoxic effect of herbicides when applied as sand mixed broadcast, compared to spraying as evident from the data presented in Table 13. This indicates that under wet seeded condition, EC/EN formulations of herbicides can be effectively applied by mixing with sand instead of spray. By doing this, the direct contact between herbicides and germinating seed can be minimised. This is in conformity with the earlier findings of Kahlon and Singh (1978) and Srinivasan (1989).

4.2.3.6 Straw yield

Among the treatments, pretilachlor + safener sand mixed broadcast recorded the highest straw yield followed by hand weeding twice and pretilachlor + safener spray (Table 19). The comparable effect of pretilachlor + safener treatments to hand weeding is probably due to the absence of phytotoxic effect and efficient weed control brought about by the herbicide. However, the treatment, pretilachlor + safener sand mixed broadcast was on par with other treatments except thiobencarb spray, anilofos spray, pendimenthalin spray and unweeded control. The lower straw yield in anilofos spray and pendimethalin spray might be due to the lesser drymatter accumulation consequent to higher phytotoxicity and weed competition.

Table 19. Effect of different treatments on grain yield, straw yield and weed

| Treatments | Grain yield kg/ha | Straw yield kg/ha | Weed Index (%) |
|---|---|---|---|
| $O_s$ | 2746.03 | 3111.11 | 21.68 |
| $O_b$ | 3222.23 | 3600.63 | 9.63 |
| $T_s$ | 2587.31 | 2758.73 | 28.78 |
| $T_b$ | 3269.84 | 3833.33 | 8.85 |
| $B_s$ | 2841.27 | 3274.60 | 20.59 |
| $B_b$ | 2396.83 | 3090.81 | 32.77 |
| $A_s$ | 1095.24 | 1098.28 | 69.87 |
| $A_b$ | 2347.29 | 3169.21 | 27.54 |
| $P_s$ | 1190.48 | 1225.40 | 67.55 |
| $P_b$ | 1984.13 | 2715.87 | 43.69 |
| $P + S_s$ | 3556.43 | 4041.27 | 1.12 |
| $O + S_b$ | 3222.22 | 4276.19 | 11.67 |
| HW | 3619.04 | 4055.55 | 1.00 |
| UW | 2188.80 | 2558.25 | 39.82 |
| SEm± | 490.95 | 433.77 | |
| CD (0.05) | 1427.28 | 1261.04 | |

The data also showed that all herbicides except butachlor resulted in a slightly higher straw yield, when applied as sand mixed broadcast compared to spraying. Moreover, the effect was significant in the case of anilofos. This again shows the comparable efficacy of sand mixed broadcast of herbicides to spraying in wet seeded rice.

4.2.4 Weed Index

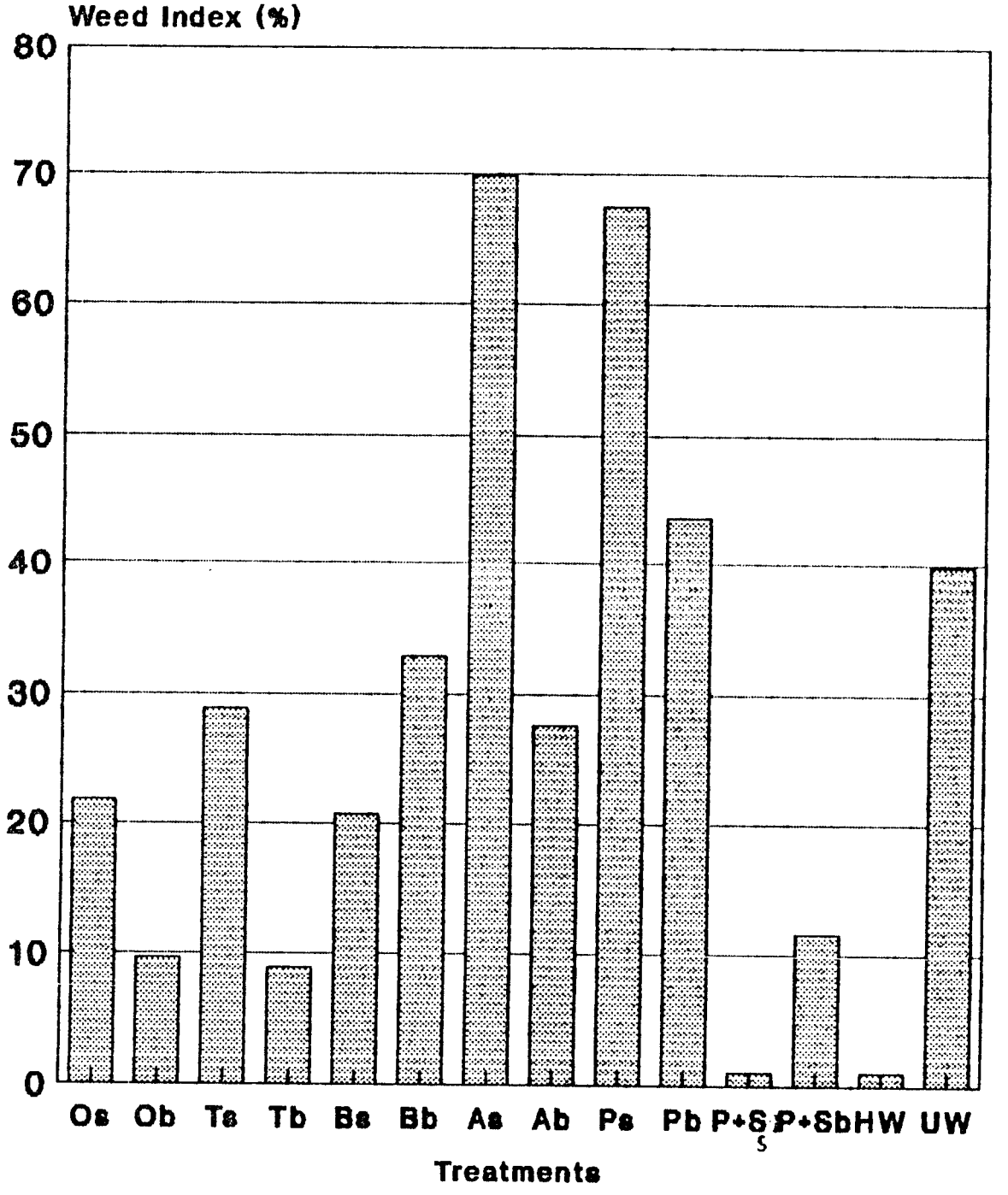
The weed index values for different treatments were calculated and presented in Table 19 and Fig. 7. The lowest weed index was recorded by pretilachlor + safener spray, followed by the sand mixed broadcast application of thiobencarb, oxyflourfen and pretilachlor + safener. The treatments anilofos spray, pendimethalin spray and its sand mixed broadcast recorded higher weed index values, even higher than that of unweeded control. This is probably due to the stand loss brought about by the phytotoxic effect of herbicides and the resultant yield reduction. In general, all herbicides, except pretilachlor + safener and butachlor resulted in lower weed indices when they were applied as sand mixed broadcast than as spray. This can be attributed to the lesser phytotoxic effect of the herbicides due to their lesser contact with the emerging rice seedlings when applied as sand mixed broadcast. This underscores the feasibility of sand mixed application of EC formulation of pre-emergence herbicides in rice under wet seeded condition.

4.2.5 Nutrient uptake

a) Nitrogen

Nitrogen uptake by crop at different stages are presented in Table 20 and the nitrogen content as percentage in Appendix V.

Fig. 7 **Effect of different treatments on Weed Index**



At 30 DAS thiobencarb sand mixed broadcast recorded the highest nitrogen uptake. In general sand mixed broadcast of all herbicides showed a higher nitrogen uptake compared to their spraying and there was significant difference between the two methods in the case of oxyflourfen, thiobencarb, butachlor and anilofos.

Oxyflourfen sand mixed broadcast, anilofos sand mixed broadcast, pretilachlor spray and its sand mixed broadcast and hand weeding twice were on par with thiobencarb sand mixed broadcast. The lowest nitrogen uptake was recorded by pendimethalin spray which was heavily infested with weeds especially sedges.

At 60 DAS, handweeding twice recorded the highest nitrogen uptake, followed by oxyflourfen sand mixed broadcast. Thiobencarb sand mixed broadcast, pretilachlor + safener broadcast and spray, oxyflourfen spray were also on par with hand weeding twice. The lowest nitrogen uptake by rice was observed in pendimethalin spray. At this stage also , in general the sand mixed broadcast of herbicides showed a higher nitrogen uptake than their spray application though the difference was not significant.

At harvest, pretilachlor + safener recorded the highest nitrogen uptake. Pretilachlor + safener sand mixed broadcast, oxyflourfen sand mixed broadcast, oxyflourfen spray thiobencarb spray and hand weeding twice were found equally effective. In most of the herbicides, sand mixed application recorded a higher nitrogen uptake compared to the respective spray application and the effect was significant in the case of anilofos.

Table 20. Effect of different treatments on nitrogen uptake by crop (kg/ha)

| Treatments | 30 DAS | | 60 DAS | Harvest |
|---|---|---|---|---|
| | T | O | | |
| $O_s$ | 2.38 | 5.79 | 62.75 | 93.48 |
| $O_b$ | 4.34 | 18.86 | 86.76 | 96.52 |
| $T_s$ | 3.14 | 10.29 | 52.98 | 74.45 |
| $T_b$ | 5.20 | 26.42 | 84.91 | 81.28 |
| $B_s$ | 2.30 | 5.45 | 27.04 | 63.29 |
| $B_b$ | 3.85 | 15.04 | 41.36 | 65.41 |
| $A_s$ | 2.66 | 7.25 | 25.95 | 24.78 |
| $A_b$ | 3.84 | 15.01 | 36.83 | 63.05 |
| $P_s$ | 1.69 | 2.86 | 17.84 | 33.79 |
| $P_b$ | 3.04 | 9.62 | 57.00 | 55.31 |
| $P + S_s$ | 4.74 | 22.65 | 80.04 | 104.94 |
| $P + S_b$ | 4.59 | 22.02 | 84.25 | 101.34 |
| HW | 4.60 | 21.49 | 105.03 | 88.79 |
| UW | 5.09 | 26.06 | 59.62 | 52.05 |
| SEm± | 0.34 | | 15.136 | 10.89 |
| CD (0.05) | 0.99 | | 44.00 | 31.65 |

T - Trfansformed value ($\sqrt{x}$)  O - Original value

b) Phosphorus

At 30 DAS, among herbicides, thiobencarb sand mixed broadcast recorded the highest phosphorus uptake, while pendimethalin spray recorded the lowest. For all the herbicides, sand mixed broadcast resulted in a higher phosphorus uptake than spray, but significant difference could be observed only in the case of oxyflourfen, thiobencarb and pendimethalin (Table 21 and Appendix VI).

At 60 DAS, hand weeding twice recorded the highest phosphorus uptake. Among herbicides, thiobencarb sand mixed broadcast, spray and sand mixed application of pretilachlor + safener, and oxyflourfen sand mixed broadcast, gave similar results. Irrespective of the herbicides, no significant difference was observed between the two methods of application.

At harvest, there was no significant difference between treatments in respect of phosphorus uptake by crop.

In general, at all growth stages of rice, phosphorus uptake was higher in plots where herbicides were applied as sand mixed broadcast compared to their spray.

c) Potassium

Potassium uptake by crop at different stages under different treatments is presented in Table 22 and the K-content in Appendix VII.

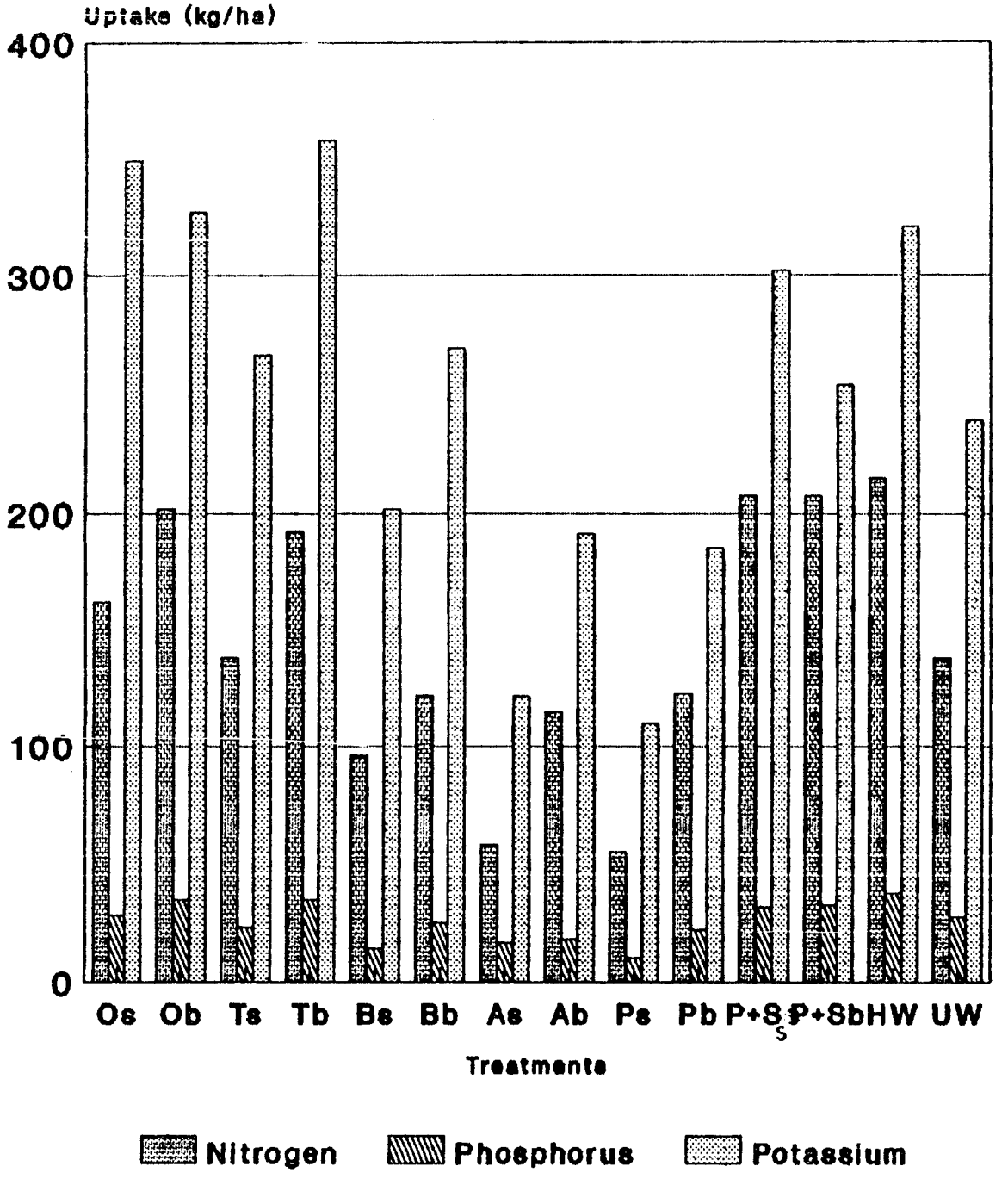
Among the herbicides, at 30 DAS, highest potassium uptake was observed in oxyflourfen sand mixed broadcast. Handweeding twice and pretilachlor + safener spray were found to give similar results. Pendimethalin spray recorded the

Table 21. Effect of different treatments on phosphorus uptake by crop (kg/ha)

| Treatments | 30 DAS | | 60 DAS | Harvest |
|---|---|---|---|---|
| | T | O | | |
| $O_s$ | 0.79 | 0.62 | 9.73 | 18.22 |
| $O_b$ | 1.68 | 2.89 | 14.74 | 17.34 |
| $T_s$ | 1.01 | 1.17 | 10.25 | 12.16 |
| $T_b$ | 1.68 | 2.94 | 16.37 | 16.04 |
| $B_s$ | 0.79 | 0.65 | 4.95 | 8.67 |
| $B_b$ | 1.18 | 1.40 | 7.88 | 15.73 |
| $A_s$ | 0.95 | 0.97 | 5.02 | 10.98 |
| $A_b$ | 1.38 | 2.04 | 6.45 | 9.56 |
| $P_s$ | 0.65 | 0.42 | 3.17 | 7.12 |
| $P_b$ | 1.21 | 1.58 | 9.52 | 10.94 |
| $P + S_s$ | 1.53 | 2.45 | 14.86 | 14.85 |
| $P + S_b$ | 1.57 | 2.64 | 13.61 | 16.39 |
| HW | 1.78 | 3.80 | 20.76 | 13.03 |
| UW | 2.10 | 4.46 | 14.26 | 8.90 |
| SEm $\pm$ | 0.186 | | 3.075 | |
| CD (0.05) | 0.54 | | 8.94 | NS |

T - Transformed value $\sqrt{x}$ O - Original value

Fig. 8 Effect of different treatments on nutrient uptake by rice (kg/ha)



lowest potassium uptake. In the case of oxyflourafen butachlor and anilofos, sand mixed broadcast registered a significantly higher potassium uptake than spray.

At 60 DAS, hand weeding twice recorded the highest potassium uptake. Sand mixed broadcast application of oxyflourfen, pretilachlor + safener and thiobencarb were comparable with hand weeding twice. Sand mixed broadcast of all herbicides showed a higher potassium uptake than their spray application though the effect was not significant. Pendimethalin treated plots recorded lower values for potassium uptake, at this stage also.

The above results showed that in general, sand mixed broadcast application of all herbicides, except pretilachlor + safener resulted in higher nutrient uptake by rice compared to spraying (Fig. 8). Among the herbicides tested, pendimethalin recorded the lowest nutrient uptake by rice probably due to the higher phytotoxic effect and the consequent heavy weed infestation, of especially of sedges.

## 4.3 Economics of weed control operations

The details of economics of weed control operations (Table 23) showed that the total returns was highest in hand weeding twice (Rs.15911.04/ha) followed by pretilachlor + safener spray (Rs.15680.53/ha). The highest return per rupee invested on weed control was obtained from pretilchlor + safener applied as sand mixed broadcast (Rs.9.15) followed by pretilachlor + safener as spray (Rs.8.98) and thiobencarb sand mixed broadcast (Rs.8.28).

The highest total returns from hand weeding twice was marked by a lower returns per rupee invested (Rs.2.30) because of the high cost of labour involved. Thus the treatments oxyflourfen sand mixed broadcast, thiobencarb sand

Table 22. Effect of different treatments on the potassium uptake by crop (kg/ha

| Treatments | 30 DAS | | 60 DAS | Harvest |
|---|---|---|---|---|
| | T | O | | |
| $O_s$ | 1.86 | 3.51 | 70.13 | 275.42 |
| $O_b$ | 4.32 | 19.47 | 110.26 | 197.20 |
| $T_s$ | 2.93 | 8.86 | 65.45 | 192.31 |
| $T_b$ | 3.95 | 15.98 | 89.58 | 251.85 |
| $B_s$ | 1.86 | 3.57 | 33.90 | 164.65 |
| $B_b$ | 3.10 | 9.87 | 51.93 | 207.27 |
| $A_s$ | 2.20 | 5.18 | 25.89 | 90.03 |
| $A_b$ | 4.07 | 16.70 | 42.74 | 132.12 |
| $P_s$ | 1.60 | 2.56 | 22.20 | 84.85 |
| $P_b$ | 2.67 | 7.66 | 61.90 | 115.88 |
| $P - S_s$ | 4.16 | 17.56 | 75.37 | 208.99 |
| $P - S_b$ | 3.19 | 10.46 | 93.55 | 150.19 |
| HW | 4.19 | 17.76 | 131.65 | 171.32 |
| UW | 4.96 | 24.69 | 77.18 | 138.12 |
| SEm± | 0.414 | | 17.27 | |
| CD (0.05) | 1.20 | | 50.21 | NS |

T - Transformed value $\sqrt{x}$ O - Original value

mixed broadcast, pretilachlor + safener sand mixed broadcast and its spray which gave higher values for both total returns and return per rupee invested stood out clearly above hand weeding twice. Between the two methods of application sand mixed broadcasting of the most of the herbicides recorded a higher return per rupee invested, compared to their spray application.

A comparison between the returns per rupee invested and the expenditure on herbicidal control as percentage of hand weeding in variably points out the feasibility of chemical control in wet-sown rice.

The treatments thiobencarb sand mixed broadcast while accounting for 21.48 per cent of the cost of handweeding yielded a return of Rs.8.26 and pretilachlor + safener sand mixed broadcast costing 24.65 per cent gave Rs.9.15 per rupee invested compared to Rs.2.30 realised from hand weeding twice.

Table 23. Economics of different treatments

| Treatments | Cost of weed control operation (Rs./ha) | Gross return (Rs./ha) | Additional return from weed control | Return per rupee invested on weed control | Expenditure for chemical weed control as percentage of HW |
|---|---|---|---|---|---|
| $O_s$ | 731.88 | 12180.00 | 2472.61 | 3.38 | 27.11 |
| $O_b$ | 611.88 | 14158.31 | 4450.92 | 7.27 | 22.66 |
| $T_s$ | 700.00 | 11262.83 | 1555.44 | 2.22 | 25.92 |
| $T_b$ | 580.00 | 14511.10 | 4803.71 | 8.28 | 21.48 |
| $B_s$ | 650.00 | 12564.13 | 2856.74 | 4.39 | 24.10 |
| $B_b$ | 530.00 | 10861.56 | 1154.17 | 2.18 | 19.63 |
| $A_s$ | 479.00 | 4771.94 | -4935.45 | - | 17.74 |
| $A_b$ | 359.00 | 10750.89 | 1043.50 | 2.91 | 13.30 |
| $P_s$ | 1366.55 | 5147.00 | -4560.39 | - | 49.50 |
| $P_b$ | 1246.55 | 9117.15 | -590.24 | - | 46.17 |
| $P + S_s$ | 665.50 | 15680.53 | 5973.14 | 8.98 | 24.65 |
| $P + S_b$ | 545.50 | 14698.81 | 4991.42 | 9.15 | 20.20 |
| HW | 2700.00 | 15911.04 | 6203.65 | 2.30 | 100.00 |
| UW | | 9707.39 | | | |

Cost of
Oxyflourfen Rs.1250/l
Thiobencarb Rs. 245/l
Butachlor Rs. 180/l
Anilofos Rs. 210/l
Pendimethalin Rs. 378/l
Pretilachlor + safener Rs. 350/l (Provisional)

Hand weeding - 2 hand weedings - 90 W @ Rs.30/woman
Spraying - 5 Men/ha @ Rs.40/man
Broadcasting - 2 Men/ha @ Rs.40/man
Price of paddy Rs.350/q
Price of straw Rs. 80/q

# Summary

## SUMMARY

A field experiment was conducted at the Agricultural Research Station, Mannuthy under the Kerala Agricultural University, during the second crop season of 1992-93 to understand the effectiveness and crop selectivity of pre-emergence herbicides under different methods of application in wet sown rice. The experiment was laid out in randomised block design, with three replications. Treatments consisted of six pre-emergence herbicides viz. oxyflourfen, thiobencarb, butachlor, anilofos, pendimethalin and pretilachlor + safener applied at six days after sowing as spray and as sand mixed broadcast. The treatments were compared with the controls, viz. hand weeding twice and unweeded control. The important findings from the experiment are summarised below.

Sedges and broadleaved weeds dominated the weedflora. Among the sedges, *Schoenoplectus lateriflorus, Cyperus iria, C. difformis* and *Fimbristylis miliacea* were present in large numbers. During the early stages of crop growth, succulent aquatics, like *Monochoria vaginalis, Sphenochlea zeylanica, Nymphaea nouchali, Marsilia quadrifoliata* were the prominent ones, which later gave way to hardier types like *Sphaeranthus indicus, Ammania baccifera* with the recession of flood water.

The broadleaved weeds were effectively controlled by pretilachlor + safener, oxyflourfen and pendimethalin, besides butachlor and thiobencarb. The herbicides followed the same trend in controlling the prominent broadleaved weed *Monochoria vaginalis*, especially during the early stages. Butachlor application resulted in the best control of sedges followed by pretilachlor + safener, oxyflourfen

and thiobencarb. These herbicides resulted in lesser total weed population during the critical stages of crop growth. Pendimethalin and anilofos lacked adequate activity against sedges especially to *Schoenoplectus lateriflorus*.

Dry matter production of weeds was considerably reduced by butachlor and pretilachlor + safener especially during the early stages of crop growth. Other herbicides viz. thiobencarb and oxyflourfen also gave comparable results.

Sand mixed broadcast application of herbicides was found as effective as spray in reducing the weed population and dry matter production indicating that this method of application can be recommended in wet sown rice.

The highest weed control efficiency was observed in hand weeded plots and herbicides oxyflourfen spray, thiobencarb spray, butachlor spray, anilofos and pretilachlor + safener also recorded higher weed control efficiency at 30 DAS.

All the herbicides barring pretilachlor + safener produced phytotoxic symptoms. In general, sand mixed broadcast application of herbicides was lesser toxic than their spray application. The reduction in plant population led to an increased weed growth and resulted in poor crop dry matter production. A significant negative correlation between crop and weed dry matter production was found to exist at 60 DAS. Hand weeding twice, and the herbicides oxyflourfen, pretilachlor + safener and butachlor applied as spray and sand mixed broadcast, produced significantly higher crop dry matter. Plant height was found to be affected by different treatments only at 60 DAS. Sand mixed broadcasting of most of the herbicides produced slightly higher plants than spraying.

Oxyflourfen spray produced the highest number of productive tillers per plant and anilofos was on par with it. Panicle length, number of grains per panicle and the weight of thousand grains were not affected by different treatments. Hand weeding twice produced the highest grain yield followed by pretilachlor + safener spray. Sand mixed broadcast application of all herbicides except pretilachlor + safener spray, recorded a slightly higher grain yield. Pretilachlor + safener applied as sand mixed broadcast produced the highest straw yield. The lowest weed index was registered by pretilachlor + safener spray.

Nutrient uptake by crop and weed was negatively related. The N, P and K removal by weeds were lower in hand weeding twice, pretilachlor + safener, butachlor and thiobencarb which recorded a higher uptake of the same nutrients by crop.

Hand weeding twice recorded the highest gross returns. However, the treatment pretilachlor + safener applied as sand mixed broadcast recorded a higher return per rupee invested, followed by pretilachlor + safener spray and thiobencarb sand mixed broadcast.

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* Originals not seen

# Appendices

APPENDIX-I

Mean weekly weather parameters during the study period

| Week No. | Maximum temperature | Minimum temperature | RH | Rainfall (mm) | Sunshine hours |
|---|---|---|---|---|---|
| 42 | 30.5 | 22.7 | 95 | 90.6 | 4.3 |
| 43 | 30.7 | 22.8 | 93 | 68.2 | 4.6 |
| 44 | 33.0 | 22.7 | 86 | 48.8 | 7.6 |
| 45 | 31.0 | 22.9 | 89 | 60.6 | 7.4 |
| 46 | 28.6 | 23.4 | 88 | 179.3 | 5.0 |
| 47 | 31.5 | 23.2 | 89 | 88.0 | 7.7 |
| 48 | 32.1 | 23.2 | 74 | - | 8.7 |
| 49 | 31.1 | 23.6 | 73 | - | 8.3 |
| 50 | 31.4 | 22.2 | 73 | - | 9.3 |
| 51 | 30.8 | 23.6 | 72 | - | 8.3 |
| 52 | 30.9 | 20.1 | 72 | - | 9.8 |
| 1 | 31.5 | 20.9 | 62 | - | 9.3 |
| 2 | 32.3 | 20.6 | 77 | - | 7.4 |
| 3 | 32.9 | 19.4 | 79 | - | 7.1 |
| 4 | 33.2 | 21.6 | 78 | - | 7.7 |
| 5 | 33.4 | 21.3 | 74 | - | 9.7 |
| 6 | 33.9 | 21.6 | 66 | - | 9.8 |

APPENDIX-II

Nitrogen content of weeds at different stages (%)

| Treatments | Stages | | |
|---|---|---|---|
| | 30 DAS | 60 DAS | Harvest |
| $O_s$ | 0.82 | 1.75 | 0.49 |
| $O_b$ | 1.42 | 1.45 | 0.31 |
| $T_s$ | 2.49 | 1.54 | 1.27 |
| $T_b$ | 1.53 | 1.70 | 0.85 |
| $B_s$ | 1.70 | 2.39 | 1.49 |
| $B_b$ | 1.27 | 1.91 | 1.22 |
| $A_s$ | 1.89 | 1.52 | 1.29 |
| $A_b$ | 1.49 | 2.21 | 1.01 |
| $P_s$ | 2.20 | 1.40 | 1.37 |
| $P_b$ | 1.89 | 1.42 | 1.45 |
| $P + S_s$ | 1.49 | 1.39 | 1.17 |
| $P + S_b$ | 1.32 | 1.38 | 1.05 |
| HW | 1.67 | 1.30 | 0.82 |
| UW | 1.91 | 1.56 | 1.11 |

APPENDIX-III

Phosphorus content of weeds at different stages (%)

| Treatments | Stages | | |
|---|---|---|---|
| | 30 DAS | 60 DAS | Harvest |
| $O_s$ | 0.39 | 0.31 | 0.35 |
| $O_b$ | 0.43 | 0.33 | 0.39 |
| $T_s$ | 0.44 | 0.28 | 0.24 |
| $T_b$ | 0.43 | 0.30 | 0.25 |
| $B_s$ | 0.43 | 0.42 | 0.18 |
| $B_b$ | 0.42 | 0.36 | 0.35 |
| $A_s$ | 0.52 | 0.36 | 0.34 |
| $A_b$ | 0.48 | 0.29 | 0.29 |
| $P_s$ | 0.54 | 0.32 | 0.34 |
| $P_b$ | 0.42 | 0.38 | 0.30 |
| $P + S_s$ | 0.40 | 0.21 | 0.22 |
| $P + S_b$ | 0.40 | 0.21 | 0.19 |
| HW | 0.38 | 0.21 | 0.18 |
| UW | 0.44 | 0.24 | 0.27 |

APPENDIX-IV

Potassium content of weeds at different stages (%)

| Treatments | Stages | | |
|---|---|---|---|
| | 30 DAS | 60 DAS | Harvest |
| $O_s$ | 2.53 | 3.33 | 4.15 |
| $O_b$ | 2.40 | 2.07 | 3.30 |
| $T_s$ | 2.70 | 1.93 | 3.63 |
| $T_b$ | 2.33 | 1.90 | 4.25 |
| $B_s$ | 2.71 | 2.63 | 4.45 |
| $B_b$ | 2.38 | 2.25 | 4.10 |
| $A_s$ | 2.74 | 2.83 | 3.73 |
| $A_b$ | 2.57 | 2.10 | 3.42 |
| $P_s$ | 3.11 | 2.40 | 4.13 |
| $P_b$ | 2.88 | 2.32 | 4.65 |
| $P + S_s$ | 2.52 | 1.70 | 4.10 |
| $P + S_b$ | 2.89 | 1.73 | 3.60 |
| HW | 2.20 | 2.21 | 2.95 |
| UW | 2.05 | 2.70 | 3.10 |

APPENDIX-V

Nitrogen content of rice at different stages (%)

| Treatments | Stages | | | |
|---|---|---|---|---|
| | 30 DAS | 60 DAS | Harvest | |
| | | | Straw | Grain |
| $O_s$ | 3.83 | 2.21 | 0.41 | 1.97 |
| $O_b$ | 2.93 | 1.67 | 0.48 | 1.90 |
| $T_s$ | 3.24 | 1.67 | 0.52 | 1.77 |
| $T_b$ | 3.97 | 2.27 | 0.30 | 1.92 |
| $B_s$ | 3.40 | 2.16 | 0.28 | 1.72 |
| $B_b$ | 3.32 | 1.74 | 0.25 | 1.88 |
| $A_s$ | 3.61 | 1.67 | 0.25 | 1.60 |
| $A_b$ | 3.48 | 1.89 | 0.51 | 1.76 |
| $P_s$ | 3.05 | 1.93 | 0.41 | 1.48 |
| $P_b$ | 3.63 | 1.93 | 0.50 | 1.61 |
| $P + S_s$ | 3.72 | 1.87 | 0.43 | 1.93 |
| $P + S_b$ | 4.28 | 1.86 | 0.55 | 2.08 |
| HW | 2.87 | 1.70 | 0.25 | 2.07 |
| UW | 2.78 | 1.42 | 0.27 | 1.53 |

APPENDIX-VI

Phosphorus content of rice at different stages (%)

| Treatments | Stages | | | |
|---|---|---|---|---|
| | 30 DAS | 60 DAS | Harvest | |
| | | | Straw | Grain |
| $O_S$ | 0.43 | 0.33 | 0.14 | 0.25 |
| $O_b$ | 0.39 | 0.29 | 0.13 | 0.29 |
| $T_S$ | 0.44 | 0.33 | 0.11 | 0.29 |
| $T_b$ | 0.42 | 0.36 | 0.13 | 0.22 |
| $B_S$ | 0.40 | 0.35 | 0.23 | 0.28 |
| $B_b$ | 0.34 | 0.35 | 0.11 | 0.31 |
| $A_S$ | 0.47 | 0.36 | 0.30 | 0.26 |
| $A_b$ | 0.43 | 0.30 | 0.08 | 0.25 |
| $P_S$ | 0.45 | 0.34 | 0.15 | 0.22 |
| $P_b$ | 0.49 | 0.31 | 0.06 | 0.26 |
| $P + S_S$ | 0.45 | 0.35 | 0.09 | 0.26 |
| $P + S_b$ | 0.49 | 0.31 | 0.13 | 0.30 |
| HW | 0.48 | 0.34 | 0.09 | 0.27 |
| UW | 0.47 | 0.33 | 0.04 | 0.22 |

APPENDIX-VII

Potassium content of rice at different stages (%)

| Treatments | Stages | | | |
|---|---|---|---|---|
| | 30 DAS | 60 DAS | Harvest | |
| | | | Straw | Grain |
| $O_s$ | 2.25 | 2.32 | 2.75 | 0.73 |
| $O_b$ | 2.52 | 2.12 | 2.14 | 0.85 |
| $T_s$ | 2.33 | 1.96 | 2.85 | 0.80 |
| $T_b$ | 2.53 | 2.28 | 3.00 | 0.45 |
| $B_s$ | 2.16 | 2.43 | 2.96 | 0.80 |
| $B_b$ | 2.26 | 2.13 | 3.08 | 1.13 |
| $A_s$ | 2.51 | 1.86 | 2.59 | 0.70 |
| $A_b$ | 2.95 | 1.98 | 2.17 | 0.78 |
| $P_s$ | 2.49 | 2.12 | 2.09 | 0.60 |
| $P_b$ | 2.36 | 2.06 | 2.23 | 0.68 |
| $P + S_s$ | 2.93 | 1.98 | 2.30 | 0.57 |
| $P + S_b$ | 2.44 | 1.95 | 1.90 | 0.58 |
| HW | 2.64 | 2.11 | 2.60 | 0.73 |
| UW | 2.63 | 1.87 | 2.12 | 0.62 |

## ABSTRACT

A field experiment was conducted at the Agricultural Research Station, Mannuthy under the Kerala Agricultural University during the second crop season of 1992-93 to find out the effectiveness and crop selectivity of pre-emergence herbicides under different methods of application in puddled rice. Twelve treatments were compared with two controls (hand weeded and unweeded). The experiment was laid out in Randomised Block Design with three replications.

Sedges and broadleaved weeds dominated the weed flora. Among the sedges, *Schoenoplectus lateriflorus, Cyperus iria, C. difformis* and *Fimbristylis miliacea* were the prominent species, and the broadleaved weeds included *Monochoria vaginalis, Marsilia quadrifoliata, Sphenochlea zeylanica* and *Nymphaea nouchali*.

The broadleaved weeds were effectively controlled by pretilachlor + safener, oxyflourfen and pendimethalin, besides butachlor and thiobencarb. All the herbicides except pendimethalin and anilofos gave good control of sedges. Oxyflourfen spray showed the highest weed control efficiency among the herbicides tested.

Sand mixed broadcasting of herbicides was found to be lesser toxic than spray in all the herbicides except pretilachlor + safener, where the safener present protected the crop completely from phytotoxicity.

Crop growth characteristics were highly influenced by the herbicide and method of application. Pretilachlor + safener, oxyflourfen and thiobencarb were found superior. Yield attributes were relatively unaffected by the different treatments.

Pretilachlor + safener spray recorded the highest yield, among herbicides. Sand mixed broadcasting of all other herbicides produced a slightly higher grain yield compared to spray.

Nutrient uptake by crop was directly related to the dry matter accumulation. The lowest weed index value was registered by pretilachlor + safener spray. Pretilachlor + safener spray recorded the highest total returns and its sand mixed broadcast realised the highest return per rupee invested on weed control.