TIME OF APPLICATION OF PRE-EMERGENCE HERBICIDES ON PHYTOTOXICITY AND WEED CONTROL IN SEMI-DRY RICE

By

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THESIS

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To my husband

DECLARATION

I hereby declare that this thesis entitled "**Time of application of pre-emergence herbicides on phytotoxicity and weed control in semi-dry rice**" is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"Time of application of pre-emergence herbicides on phytotoxicity and weed control in semi-dry rice"** is a record of research work done independently by **Smt.Susan Lee Thomas** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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Introduction

INTRODUCTION

Rice, the most important food crop, forms the staple food for more than half the human population. Every continent on earth produces rice except Antartica. It is the most diverse crop in the world and is grown from equator to latitudes of 53°N (China) and 35-40°S and from below mean sea level (Kuttanadu) to an elevation of 3000 m (Himalayas). About 2.8 billion people in Asia, where 90 per cent of the World's rice is grown and consumed derive 35 to 60 per cent of the calories from rice. In India rice is grown in almost all states, the eastern part being the traditional area. The production of rice in India during 1992-'93 was 72 million tonnes from 39.04 million hectares contributing 19 per cent of the world rice production (Venkataramani, 1994). By 2000 A.D. the global rice production should go upto 560 million tonnes in order to meet the growing human population (Swaminathan, 1989).

In Kerala rice occupies an area of 5.41 lakh hectares with an annual production of 10.86 lakh tonnes (FIB, 1994). The three main seasons of rice cultivation in Kerala are first crop (Virippu), second crop (Mundakan) and third crop (Puncha). During the *Virippu* season semi-dry system of rice culture occupies 87 per cent of the area under rice. This system of rice culture involves the growing of rice as dry seeded crop upto 3 to 6 leaf stage and thereafter bringing the field under submergence. The initial period of the crop (3 to 6 leaf stage) is completely rainfed with no standing water in the field and by about July, the field gets completely flooded.

The first one to two months of the crop experiences heavy weed infestation due to the favourable weather conditions like high temperature, humidity and ample moisture in the soil. This leads to yield reduction due to weed competition (Nair *et al.*, 1974). Yield loss as high as 50 per cent due to weed competition was reported in direct seeded rice under upland conditions (Pillai and Rao, 1974). Timely weed control has a bearing on realizing the yield potential of the variety cultivated. Though hand weeding is the commonly adopted practice for the control of weeds in rice, it is expensive, time consuming and cumbersome. Moreover, hand weeding becomes difficult due to morphological similarity of grassy weeds and the rice crop, especially during early growth stages (Sharma *et al.*, 1977). It is at this juncture that the use of pre-emergence herbicides for the control of weeds in semi-dry rice comes into picture. Herbicides can be effectively utilized for increasing the efficiency of other costly inputs and to obtain economic yields.

Previously butachlor and nitrofen were the two pre-emergence herbicides recommended in semi-dry rice. As nitrofen is not currently available in the market, butachlor is the only choice for the farmers. Continuous use of the same herbicide may lead to the development of resistant genotypes and also a shift in weed flora. Elsewhere in the country, in addition to the above two herbicides, pendimethalin, thiobencarb and oxyfluorfen are also recommended for upland and semi-dry rice.

Selectivity of herbicides is often marginal, due to simultaneous germination of rice and weed seeds and this leads to toxicity in rice seedlings. Presently the pre-emergent application of herbicides is recommended on the same day of seeding. But if there is a rainfall on the day of seeding farmers are reluctant to apply it for fear of toxicity to rice seedlings. Hence a study was undertaken with the following objectives:

1. To find out the optimum time of application of pre-emergence herbicides viz., butachlor, thiobencarb, pendimethalin and oxyfluorfen without toxicity to rice seedlings.

2. To find out how far the application of herbicides can be delayed after seeding.

Review of Literature

REVIEW OF LITERATURE

Rampant infestation of weeds in first crop season (virippu) is a serious problem in semi-dry rice due to favourable weather conditions like high temperature, humidity and continuous rainfall. Effective weed control is necessary to obtain high yields. Majority of the weeds competing with rice can be controlled chemically by the use of pre-emergence herbicides. Time of application of the herbicides is important in deciding the efficiency and selectivity of the herbicides. This review focuses on the effect of crop-weed competition on yield and the time of application and effectiveness of four important pre-emergence herbicides viz. Oxyfluorfen, butachlor, pendimethalin and thiobencarb in rice.

2.1 Weed spectrum in semi-dry rice

About 350 species in more than 150 genera and 60 plant families have been reported as weeds of rice (De Datta, 1977a and Barret and Seaman, 1980). Smith Jr. (1983) observed Poaceae (Gramineae) as the most common weed family with more than 80 species as weeds in rice. Cyperaceae rank next in abundance with more than 50 species (Holm *et al.*, 1977). The problems caused by weed species vary with temperature, latitude, altitude, rice culture, seeding method, water management, fertility level and weed control technology (Smith and Moody, 1979).

The main weeds present in upland paddy fields of West Bengal were *Echinochloa colona, Cyperus rotundus, C. iria* (Pande and Bhan, 1964). In the rice fields at Mannuthy, Nair *et al.* (1979) found *Cynodon dactylon, Cyperus iria, Cyperus difformis, Amaranthus viridis, Ageratum conyzoides, Eupatorium odoratum, Tridax procumbens* and *Phyllanthus niruri* as the widely prevelant weeds.

The important weeds in rice were *Cyperus rotundus, Cynodon dactylon,* *Phyllanthus niruri* (Devi and George, 1979). According to Ahmed (1981) the major weeds in rice were *Echinochloa colona, Eleusine indica, Cyperus iria* and *Fimbristy lis littoralis*. Moody and Drost (1983) observed a shift in weed flora from broad leaved weeds to grasses with second crop of rice after forest clearing. *Echinochloa crus-galli,* the major weed in rice has wider distribution from north to south while *E. colona* tends to grow along the equator. Other weeds associated with rice on a world-wide scale are *Cyperus difformis, C. rotundus, C. iria, Eleusine indica, Fimbristylis littoralis, Ischaemum rugosum, Monochoria vaginalis* and *Sphenochlea zeylanica* (Smith Jr., 1983).

Senthong (1984) observed *Fimbristylis miliaceae* and *Monochoria vaginalis* in direct-sown lowland rice. *Cyperus iria, Digitaria ciliaris, Phyllanthus niruri* were prominent in upland drilled rice (Trivedi *et al.*, 1986). Predominant weed species in rice under semi-dry system of rice culture were *Echinochloa crus-galli, E. colonum, Ischaemum rugosum, Cyperus* sp., *Marsilia quadrifolia* and *Eicchornia crassipes* (Sudhakara and Nair, 1986).

Cruz *et al.* (1986) noticed *Cyperus rotundus, Rottboellia cochinchinensis. Digitaria* sp., *Cynodon dactylon, Echinochloa colona, Eleusine indica* and *Dactyloctenium aegyptium* in upland rice. Drill sown upland paddy was reported to be infested by *Echinochloa colonum, Ageratum conyzoides, Cyperus iria, Panicum maximum, Echinochloa crus-galli* (Dayanand, 1987). Singh *et al.* (1987) recorded *Echinochloa colonum, Dactyloctenium aegyptium, Cyperus rotundus, C. iria* and *Trianthema monogyna* as the major weeds in upland rice. *Echinochloa colonum, Cynodon dactylon, Eleusine indica, Cyperus iria, Trianthema monogyna, Phyllanthus niruri, Commelina benghalensis, Physalis minima, Eclipta alba* and *Cleome viscosa* were found as weeds in upland rice (Singh *et al.*, 1988). In rainfed upland rice in Bihar, predominant weeds were *Ageratum conyzoides, Commelina benghalensis, Echinochloa crus-galli, Cynodon dactylon, Cyperus rotundus* and *Cyperus difformis* (Choudhary and Pradhan, 1988). In Bhuvaneswar, Patro and Nanda (1988) observed grasses like *Digitaria sanguinalis, Echinochloa colona, Eleusine indica, Eragrostis nutans, Cynodon dactylon*, sedges like *Cyperus rotundus, C. iria, Fimbristylis miliaceae* and broad leaved weeds like *Celosia argentia, Sida rhombifolia* in upland rice.

According to Moody,(1989) grassy weeds were predominant in upland rice and about 140 species were observed in South and South East Asian countries. Of these, *Dactyloctenium aegyptium, Digitaria* spp., *Echinochloa colona, Eleusine indica, Imperata cylindrica, Rottboellia cochinchinensis* were more important on a global basis. *Cyperus rotundus, Echinochloa colonum, Cleome viscosa* were the dominant weed species in semi-dry rice (Bhargavi and Reddy, 1990). Upland rice was observed to be infested with *Echinochloa colona, Cyperus rotundus, Digitaria sanguinalis, Aeschynomene indica, Celosia argentia* (Mishra and Roy, 1990). Ramamoorthy (1991) found that the main weeds in upland rice were *Echinochloa colonum, Cyperus rotundus* and *Eclipta alba*. These weeds were also reported by Pandey *et al.* (1991) in upland rice. Padhi *et al.* (1991) observed *Cyperus rotundus, Echinochloa colonum, Cynodon dactylon* and *Commelina benghalensis* in rainfed direct seeded rice. The major part of the weed flora of semi-dry rice was constituted by grasses and sedges. The grasses reported were *Isachne miliaceae, Saccolepis interrupta* and *Echinochloa colona*. Among sedges, *Cyperus iria* was the most predominant (Jayasree, 1987; Palaikudy, 1989; Suja, 1989).

2.2 Crop-weed competition in rice

Weeds stand in the way of realising full yield potential of any crop as they compete with the crop plants for the basic resources. Yield reduction due to weeds can vary from 15-20% in transplanted rice, 30-35% in wet seeded rice and over 50-60% in upland rice (Smith, 1968). The weeds compete with the crop for light, space and nutrients and they also adversely affect the microclimate around the plant, harbour disease causing organisms and pests, increase cost of production and lower the quantity and quality of the crop produce.

2.2.1 Critical period of crop-weed competition

During the cropping period there is a particular length of time during which the presence of weeds above a certain density will cause significant yield reduction which is known as the critical period of crop-weed competition. Weeds are to be controlled within this period. The precise time and duration of the critical period depends on factors such as weed flora, growth characteristics of the rice and weeds, cultural practices and environmental factors (Moody, 1977). In upland rice this period varies from two to six weeks after emergence (Ghosh and Singh, 1985; Sahai and Bhan, 1982; Singh and Singh, 1985).

Weed competition during the first 15 days after sowing had no significant effect on the grain yield of upland rice. Grain yield of rice significantly increased with the increase in duration of weed free period upto 45 DAS. Weeds emerging 45 DAS were lower in density and their growth was suppressed by the crop. Density of weeds emerging between 15 DAS and 30 DAS was high and compete with the crop resulting in substantial yield reduction. The period during 15 DAS and 45 DAS was found to be the most important for crop-weed competition (Singh *et al.*, 1987).

The critical period of crop weed competition in upland rice was reported to be about 40 DAS by Varshney (1985) whereas Ali and Sankaran (1984) reported a period upto 60 DAS.

Yield decreased with delay in weeding to a maximum loss when weeding was delayed upto 100 days. Weeding at 40 DAS significantly reduced grain yield and additional weedings did not improve yield significantly (Singh and Tandon, 1982). Weed free condition upto 60 days is essential for getting good yields in dry sown rice (Sankaran and De Datta, 1985).

2.2.2 Effect of weeds on growth and yield components

a) Growth

Several workers have studied the competitive ability of weeds by observing growth patterns of crop and weeds under cropped conditions. Crop growth rate was negative at all stages of growth of crop, if weeds were allowed to grow as in unweeded control. The negative trend in crop growth rate was caused by senescence of leaves and death of tillers, probably owing to competition from weeds for solar radiation and also due to allelopathic effect of weeds. Majority of weeds, ie., about 56% belong to C_4 type. Under semi-dry condition moisture stress occurs during early stage of crop and both C_4 and C_3 plants close their stomata partially. However, for the same amount of stomatal opening, uptake of Co_2 might be higher in C_4 weeds than in C_3 rice probably leading to higher growth rate in weeds (Bhargavi and Reddy, 1993).

Weeds significantly reduced plant height (Mukhopadhyay and Bag, 1967; Tasic *et al.*, 1980; TNAU, 1985; Patel *et al.*, 1986). Plant height was decreased due to competitive stress in unweeded plots (Noda *et al.* 1968; Sreedevi, 1979 and Jayasree, 1987).

b) Dry matter production

Chakraborthy (1973), Balaswamy and Kondap (1988), Varshney (1990) recorded reduction in dry matter production in rice due to weed competition. In rice nurseries, crop dry weight was negatively correlated with weed dry weight (Patel *et al.*, 1985). Jayasree (1987) also obtained negative correlation between the dry matter production of crop and weed at all stages of the crop with higher correlation at the initial stages, indicating the importance of weed free condition during the early stages of the crop. Singh *et al.* (1987) also observed higher rate of dry matter production of weeds in unweeded plots during 15 to 30 days. Weed dry matter at harvest was highest for unweeded check resulting in grain yield reduction (Purushothaman *et al.*, 1988). The crop dry matter was also lowest in weedy check with lowest grain yields (Choudhary and Pradhan, 1988; Singh *et al.*, 1988; Nair *et al.*, 1979).

c) Yield attributes

Yield attributing characters like number of panicles/m^2, spikelets/panicle, 1000 grain weight were lowest in the unweeded control and suitable weed control methods at College of Agriculture, Vellayani, significantly improved the yield attributes (Ravindran *et al.*, 1978). Reduction in productive tillers due to weed competition was reported by Sreedevi (1979), Ramamoorthy *et al.* (1974) and Patel *et al.* (1986). Weed control treatments significantly increased the number of panicles/m^2 and filled grains/panicle compared with unweeded control (Kumar and Gautam, 1986). The reduction in grain yield due to increase in duration of competition was associated with a decrease in number of panicles/m row length and grains/panicle and simultaneous increase in dry matter production of weeds (Singh *et al.*, 1987). Kaushik and Mani (1980) and Jayasree (1987) observed that weed control treatments improved grain filling and plumpness. Sudhakara and Nair (1986) also reported better tillering and higher panicle weight with effective weed control.

Negative correlations were observed between weed dry weight and crop dry weight, leaf area index, number of panicles/m row; number of fertile grains/panicle and grain yield (Singh and Dash, 1988). Yield attributes viz. number of panicles/m^2, weight of panicle and 1000 grain weight were lower in unweeded plots (Mishra *et al.*, 1989).

In semi-dry rice, growth and grain yield were affected by weed infestation through reduction in number of panicles, seed setting, test weight and length of panicle (Zhiyong and Shengxuan, 1990).

Yield attributes viz. panicles/hill, length of panicle and 1000 grain weight were lower in the case of unweeded check in transplanted rice (Varshney, 1990). In wet seeded rice unchecked weed growth resulted in reduction in number of panicles/m^2 and panicle weight leading to lower grain yield (Budhar *et al.*, 1991; Kulmi, 1991).

2.2.3 Yield reduction due to weed competition

Uncontrolled weed growth recorded low grain yield in semi-dry rice (Nair *et al.*, 1979). The extent of decline in the yield of rice due to weeds have been reported from 94 to 100 per cent (Mukhopadhyay *et al.*, 1972; De Datta, 1972). Weed competition and corresponding yield losses are greater in upland rice than in other systems of rice cultivation (Moody, 1982). Weeding only at 40 days significantly reduced grain yield and additional weeding did not improve yield significantly (Singh and Tandon, 1982).

Rice yield was inversely related to weed dry matter (Janiya and Moody, 1987). Regression studies by Singh and Dash (1988) showed that an increase in dry weight of weeds at the rate of 1 g/m^2 decreased the grain yield of rice by 0.0074 t/ha and N uptake by 0.084 kg N/ha. Herbicide treated plots recorded higher grain yields than untreated plots (Estorninos, 1988).

Bhan *et al.* (1985) reported 80 per cent yield reduction due to uncontrolled weed growth. According to Budhar *et al.* (1991) grain yield increased significantly due to weed control treatments over no-weeding. Ramiah and Muthukrishnan (1992) observed 11-30 per cent yield reduction in unweeded plots. Whereas Vaishya *et al.* (1992) reported an yield reduction of 68 per cent in upland direct seeded rice.

2.2.4 Nutrient uptake

Yield reduction due to weeds result mainly from competition for nutrients, especially during the early growth stages (Pande and Bhan 1966; Smith, 1968, Shetty and Gill, 1974). In uplands, where rice is grown the limited availability of nutrients and their high costs warrant their judicious use for obtaining greater efficiency (Ramamoorthy, 1991).

The demand for nutrients was in the order K > N > P by crop and weed (Varghese and Nair, 1986). When there was a competition between weeds and crop for nutrients, both crop and weeds could not utilize them to the fullest extent This pin points the need for keeping the field weed free to enable crops to absorb more nutrients from the soil (Balasamy and Kondap, 1988).

2.2.4.1 Nutrient drain by weeds

Sahai and Bhan (1982) reported significant negative relationship between nitrogen uptake by drill-seeded rice and weeds. Earlier studies by Shetty and Gill (1974), Sankaran and Mani (1975), Ravindran (1976) and Balu (1977) also revealed substantial quantities of nutrient removal by weeds.

Weeds in unweeded check removed 24 kg N, 7.9 kg P_2O_5 and 30.5 kg K_2O/ha Nutrient uptake by weeds in unweeded check indicated maximum N, P_2O_5 and K_2O uptake during 31 to 40 DAS (Varghese and Nair, 1986). Weed dry weight and N-uptake by weeds were positively correlated (Singh and Dash, 1988). Weeds removed 19.4-33.7 kg N/ha, 1.5-1.8 kg P/ha, 17.4-33.7 kg K from soil (Moorthy and Mithra, 1990). Weeds when allowed to compete with crop depleted 25.8, 3.65 and 21.3 kg N, P_2O_5 and K_2O/ha, respectively during kharif in upland rice (Ramamoorthy, 1991). According to Ghosh and Mittra (1991) increasing rates of N promoted weed growth and dry matter at harvest in upland rice.

2.2.4.2 Nutrient uptake by rice

Nitrogen uptake by rice tripled while P_2O_5 and K_2O uptake doubled in the absence of weeds (Swain, 1967). The uptake by the crop in the weedy check was 30.9 kg/ha as against 61 kg/ha in weed free plot indicating the adverse effect of weeds in reducing crop yields (Lakshmi *et al.*, 1987).

The nitrogen uptake by rice in the weed free condition was 108.7 kg/ha while that in the weedy check was 49.5 kg/ha (Lakshmi *et al.*, 1987).

According to Varghese and Nair (1986), the crop weed competition for N was upto 50 days in transplanted rice.

2.3 Chemical weed control in semi-dry rice

2.3.1 Pre-emergence herbicides

Pre-emergence herbicides can be effectively used for weed control in semi-dry rice. Chemical control of weeds in direct sown rice assumes importance because of the scarcity of labour at peak periods of requirement along with its prohibitively high cost (Nair *et al.*, 1974; Subramanian and Ali, 1985). Pre-emergence herbicides used in the experiment were butachlor, thiobencarb, pendimethalin and oxyfluorfen.

2.3.1.1 Butachlor

Butachlor is a pre-emergence herbicide which is found to be effective against many annual grasses, sedges and some broad leaved weeds. Application of butachlor 2 kg a.i/ha was found to reduce weed growth in rice (Devi, 1979). Complete control of *Cyperus* spp. with butachlor was reported by Nair *et al.* (1974) and Moorthy and Manna (1984).

A pre-emergence application of butachlor followed by post emergence application with propanil or mechanical weeding may be effective in providing broad spectrum weed control and rice yields equal to those obtained from repeated hand weeding (Sharma *et al.*, 1977). Plant height, number of fertile tillers, panicle length, number of spikelets per panicle were observed to increase by application of butachlor (Pawan and Gill, 1981; Pradhan, 1989).

Pande (1982) observed selective control of barnyard grass with the application of butachlor at 1.25-1.87 kg a.i/ha sprayed at 3 to 8 DAS. Better control of sedges and annual broad leaved weeds was achieved with the application of butachlor before, rather than after sowing (Mercado and Cadag, 1983). Butachlor 1 kg a.i/ha 5-6 to days after transplanting (DAT) rice seedlings gave excellent control of weeds and markedly increased paddy yields (Pillai *et al.*, 1983). Butachlor 1.5 kg a.i/ha increased crop growth and yield components over weedy check (Singh and Singh 1985). Good weed control and higher grain yield with butachlor reported by Tasic *et al.* (1980) and Singh and Dash (1986). Rao and Rao (1990) found that application of butachlor 1.5 kg a.i/ha on 3 DAS was found to be useful in controlling *Echinochloa colonum* without any phytotoxic effect on rice seedlings. Emmanuel (1991) observed that butachlor did not inhibit rice seed germination. Weed population and dry matter production of weeds were found to be reduced with highest grain yield when butachlor was applied @ 1.5 kg a.i/ha followed by hand weeding 30 DAS (Gogoi and Kalite, 1990).

According to Arceo and Mercado (1981) application of butachlor 2 days before sowing exhibited the lowest phytotoxicity in rice with imporved weed control than when applied at 6 DAS. Mercado and Cadag (1983) was also of the opinion that better control of sedges and annual broad leaved weeds was achieved with the application of butachlor before rather than after sowing.

At IRRI an experiment in upland rice showed poor control of grasses with butachlor (IRRI, 1977). Bhol and Singh (1987) also reported poor control of grassy weeds with butachlor due to rapid decomposition by ultraviolet light under irrigated conditions and quick degradation by soil microbes decreased its effectiveness. Moody (1989) concluded that the erratic performance of butachlor was due to difference in weed population, soil properties and climatic conditions.

2.3.1.2 Thiobencarb

Thiobencarb applied pre-emergence showed little phytotoxicity to rice (Tosh *et al.*, 1981). Bhan *et al.* (1986) reported the population and dry weight of weeds to be lowest in direct sown rice when thiobencarb was applied as pre-emergence @ 1 to 2 kg a.i/ha. Application of thiobencarb at 1.0 to 1.5 kg a.i/ha sprayed 3 to 8 days after sowing gave selective control of barnyard grass (Pande, 1982). Singh and Singh (1985) reported that thiobencarb @ 1.6 kg a.i/ha was effective in minimising N-depletion by weeds and mamimising N-uptake by crop. The application of thiobencarb followed by propanil 2 kg a.i/ha 16 days after sowing gave high grain yield in direct seeded flooded rice (Ali, 1984). Thiobencarb at 1.13 kg a.i/ha recorded higher grain yield (Shivamadaiah *et al.*, 1987). Higher straw and grain yield was also obtained by Mishra *et al.* (1988) by the application of thiobencarb 1.4 kg a.i/ha. Thiobencarb 1.5 kg a.i/ha controlled weeds in upland rice and improved rice yields (Choudhary and Pradhan, 1988). Rice yields were higher when thiobencarb was applied at 1 and 1.5 kg (Dawood and Balasubramanian, 1988). Thiobencarb 1.5 kg a.i/ha increased the number of panicles/m^2 and grain yield of upland rice (Pradhan and Choudhary, 1989).

Selectivity for branyard grass *Echinochloa crusgalli* control in direct-sown rice was shown by thiobencarb. Exposure of weed and crop to thiobencarb had no impact on germination and did not markedly affect photosynthesis or respiration of rice seedlings. The inhibition of top growth with the application of thiobencarb was severe in case of *Echinochloa crus-galli* but temporary in the case of rice and it was due to the inhibition in cell elongation governed by auxin and protein synthesis (Ichizen, 1980). Thiobencarb at 1 kg a.i/ha followed by one hand weeding gave best control of *Echinochloa colona, Cyperus rotundus, Ludwigia* spp. and *Marsilia quadrifoliata*. Highest rice yields were also recorded by thiobencarb application in dry-sown rice (Kandasamy and Palaniappan, 1990). Application of thiobencarb at 1.87 and 2.50 kg a.i/ha was found effective in controlling *Echinochloa colona* without any phytotoxic effect on rice seedlings (Rao and Rao, 1990). Pre-emergence herbicide thiobencarb gave effective weed control against grasses and sedges and reduced labour cost in direct-sown rice under puddled condition (Budhar *et al.*, 1991). Highest rice leaf chlorophyll content at 50 days after sowing was obtained when thiobencarb was treated at 1.5 kg a.i/ha pre-emergence (Singh and Ram, 1991). Thiobencarb 1.5 kg a.i/ha pre-emergence supplemented with two hand weedings given at 20 and 40 days after sowing recorded the highest weed control efficiency and also provided the grain yield of crop comparable to the yield of weed free treatment (Vaishya *et al.*, 1992). Laboratory experiments showed that thiobencarb had no effect on rice germination (Mabbayad and Moody, 1992).

Post-emergence application of thiobencarb and 2,4-D was not effective for dry or wet seeded rice (Kandasamy and Palaniappan, 1990). This chemical was found to be phytotoxic pre or post-sowing (Om *et al.*, 1988). Crop stand reductions occurred with 1.5 kg a.i/ha thiobencarb applied at 0 or 3 days after sowing (Mabbayad and Moody, 1992).

2.3.1.3 Pendimethalin

Pre-emergence application of pendimethalin has been reported to control weeds effectively in upland rice (De Datta, 1977b; Singlachar and Chandrasekhar, 1977; Shelke *et al.*, 1986). Manipon *et al.*, (1981) reported a reduction in grass population after the application of pendimethalin in dry-seeded conditions. According to Gowda and Devi (1984) pre-emergence application of pendimethalin at 1.25-1.5 kg a.i/ha was effective against dicotyledonous weeds and its effect persisted upto harvest. Pendimethalin recorded highest grain yield when applied at 0.75 kg a.i/ha or 8 and 12 days after sowing in rainfed bunded summer rice (Ali and Sankaran, 1984). Similar results were reported by Verma *et al.*, 1987; Choudhary and Pradhan, 1988; Mishra and Roy, 1990.

Application of pendimethalin followed by one hand weeding on 25 to 30 DAS was found to achieve good control over weeds by reducing weed dry weight (Singh and Prakash, 1990; Pandey *et al.*, 1991). The highest nutrient uptake and yield in rice was recorded in the same combination (Ramamoorthy, 1991; Bhagat *et al.*, 1991). Ramiah and Muthukrishnan (1992) also recorded similar results in semi-dry rice at Madurai.

Application of pendimethalin immediately after sowing or after the receipt of rain resulted in rice injury, but when the application was delayed by 4 days after emergence or after rain, no crop injury was noticed (IRRI, 1979).

2.3.1.4 Oxyfluorfen

Pre-emergence application of oxyfluorfen was reported to control all types of weeds throughout the growth period of rice and give good grain yield (Gidnawar, 1981). Mukhopadhyay and Mandal (1982) observed that oxyfluorfen was effective against grasses, broadleaved weeds and sedges when applied at 4 DAT. Azad *et al.* (1990) found oxyfluorfen granules at 0.2 kg a.i/ha gave similar results when applied at 5 to 6 DAT.

In upland rice also application of oxyfluorfen was effective in controlling weeds from the germinating stage with the lowest dry weight of weeds, highest number of panicles/m^2 and grain yield (Ghosh and Singh, 1985). Similar effects with the application of oxyfluorfen 0.1 to 0.15 kg a.i/ha was noticed by Kumar and Gautam (1986); Mishra *et al.* (1988); Pradhan and Choudhary (1989).

In semi-dry rice also oxyfluorfen was reported to be effective against weeds (Porpavai and Ramiah, 1992).

Regarding the phytotoxicity of oxyfluorfen application on rice, though initial yellowing was noticed which was later recovered after about 2 to 3 weeks (Mukhopadhyay and Mandal, 1982). However no inhibitory effect on rice seed germination was noted by the application of oxyfluorfen (Yasin *et al.*, 1988; Emmanuel *et al.*, 1991).

Materials and Methods

MATERIALS AND METHODS

A field experiment was conducted during the first crop season (Virippu) of 1993 to find out the optimum time of application of different pre-emergence herbicides viz. oxyfluorfen, butachlor, pendimethalin and thiobencarb which give maximum weed control efficiency and crop selectivity in semi-dry rice. These four herbicides were also compared for their suitability and phytotoxicity on rice plants. The materials used and the methods followed are described in this chapter.

3.1 Site, climate and soil

The experiment was conducted at the Agricultural Research Station, Mannuthy under the Kerala Agricultural University, Vellanikkara, Thrissur. The station is located at 12° 32' N latitude, 74° 20' E longitude and at an altitude of 22.23 m above MSL. The region enjoys typical humid tropical climate.

The study was conducted during May to September, 1993. The details of meteorological observations recorded during the crop season are presented in (Fig. 1, Appendix I).

The texture of soil is sandy loam. The physical and chemical composition of soil in the field are given in Table 1.

The experimental field was under the cultivation of cucurbitaceous vegetables during the previous summer season.

3.2 Treatments

The treatments consisted of four different pre-emergence herbicides viz. oxyfluorfen, butachlor, pendimethalin and thiobencarb and four different times of

Fig.1.Meteorological data (Weekly average) for the crop period (May 20, 1993 to Sep. 10, 1993)

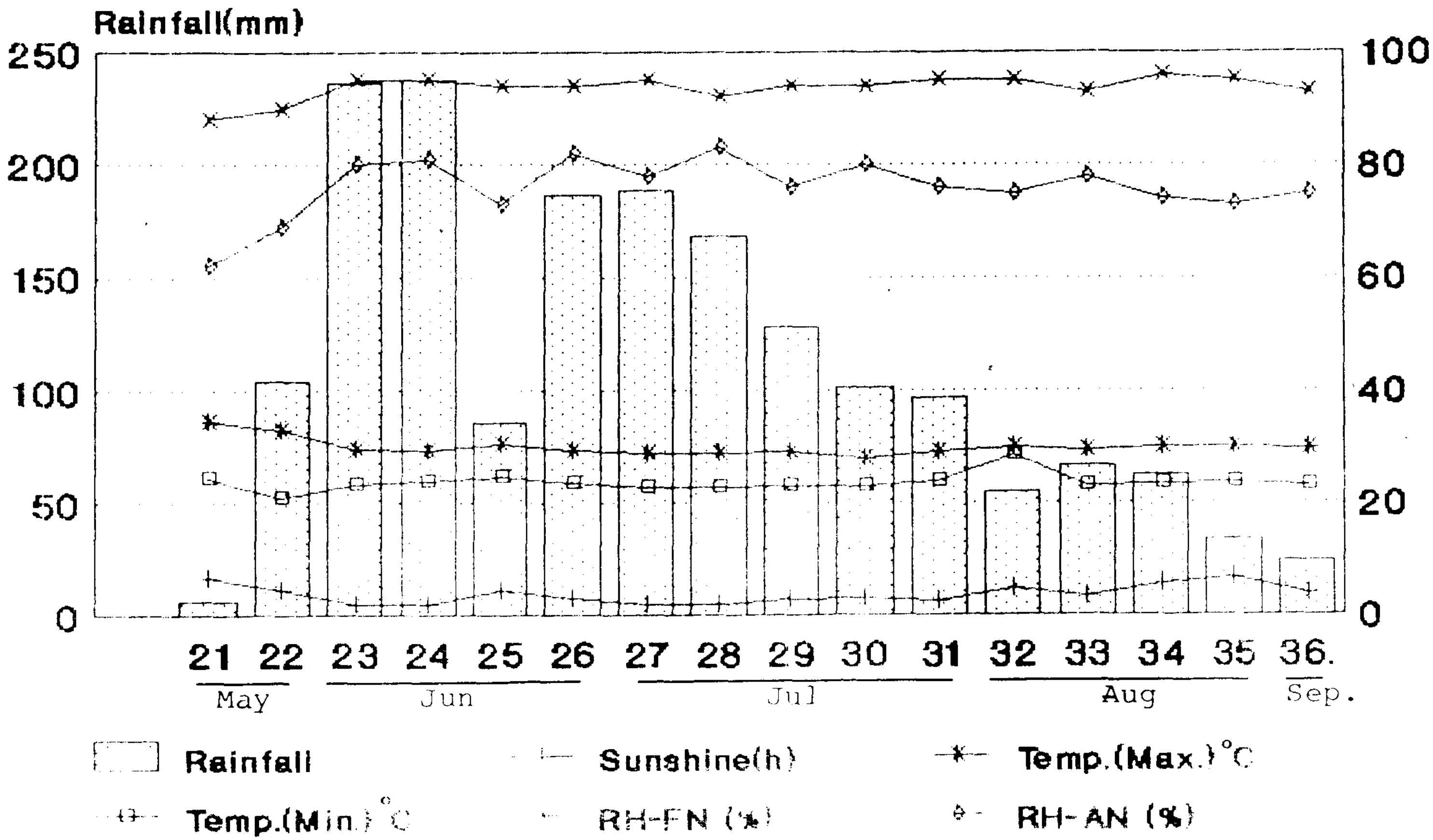


Table 1. Physico-chemical characteristics of the soil in the experimental field

Particulars	Value	Rating	Method employed
A. Mechanical composition			
Sand %	65.76		Robinson's International Pipette method (Piper, 1942)
Silt %	18.50		
Clay %	16.00		
Texture	Sandy loam		
B. Chemical composition	Value	Rating	
Total N (%)	0.129		Micro-kjeldahl method (Jackson, 1973)
Available P (kg ha^{-1})	29.82	High	Bray I extractant, chlorostannous reduced molybdophosphoric blue colour method (Jackson, 1973)
Available K (kg ha^{-1})	175.12	Medium	Neutral normal ammonium acetate extract, flame photometry (Jackson, 1973)
pH	5.12	Strongly acidic	1 : 2.5 soil-water suspension, using a pH meter (Jackson, 1973)

application of the above herbicides ie. zero, three, six and nine days after sowing (DAS). In addition an unweeded control and a hand weeded control (two hand weedings at 20 and 40 DAS) were also included for comparison.

Treatments	Subplot treatments	Main plot	Notation
1. Oxyfluorfen	0.1 kg a.i/ha	0 DAS	M_1T_1
2. ,,	,,	3 DAS	M_2T_1
3. ,,	,,	6 DAS	M_3T_1
4. ,,	,,	9 DAS	M_4T_1
5. Butachlor	1.25 kg a.i/ha	0 DAS	M_1T_2
6. ,,	,,	3 DAS	M_2T_2
7. ,,	,,	6 DAS	M_3T_2
8. ,,	,,	9 DAS	M_4T_2
9. Pendimethalin	1.25 kg a.i/ha	0 DAS	M_1T_3
10. ,,	,,	3 DAS	M_2T_3
11. ,,	,,	6 DAS	M_3T_3
12. ,,	,,	9 DAS	M_4T_3
13. Thiobencarb	1.5 kg a.i/ha	0 DAS	M_1T_4
14. ,,	,,	3 DAS	M_2T_4
15. ,,	,,	6 DAS	M_3T_4
16. ,,	,,	9 DAS	M_4T_4
17. Handweeded control			HW
18. Unweeded control			UWC

3.3 Design and layout (Fig. 2)

1. Design : Split plot design
2. Replications : 3
3. Gross plot size: 5.5 x 4.5 m^2 (1m strip along the 5.5m side for destructive sampling)
4. Border : 0.5 m on all sides
5. Net plot size : 3.5 x 3.5 m^2 = 12.25 m^2

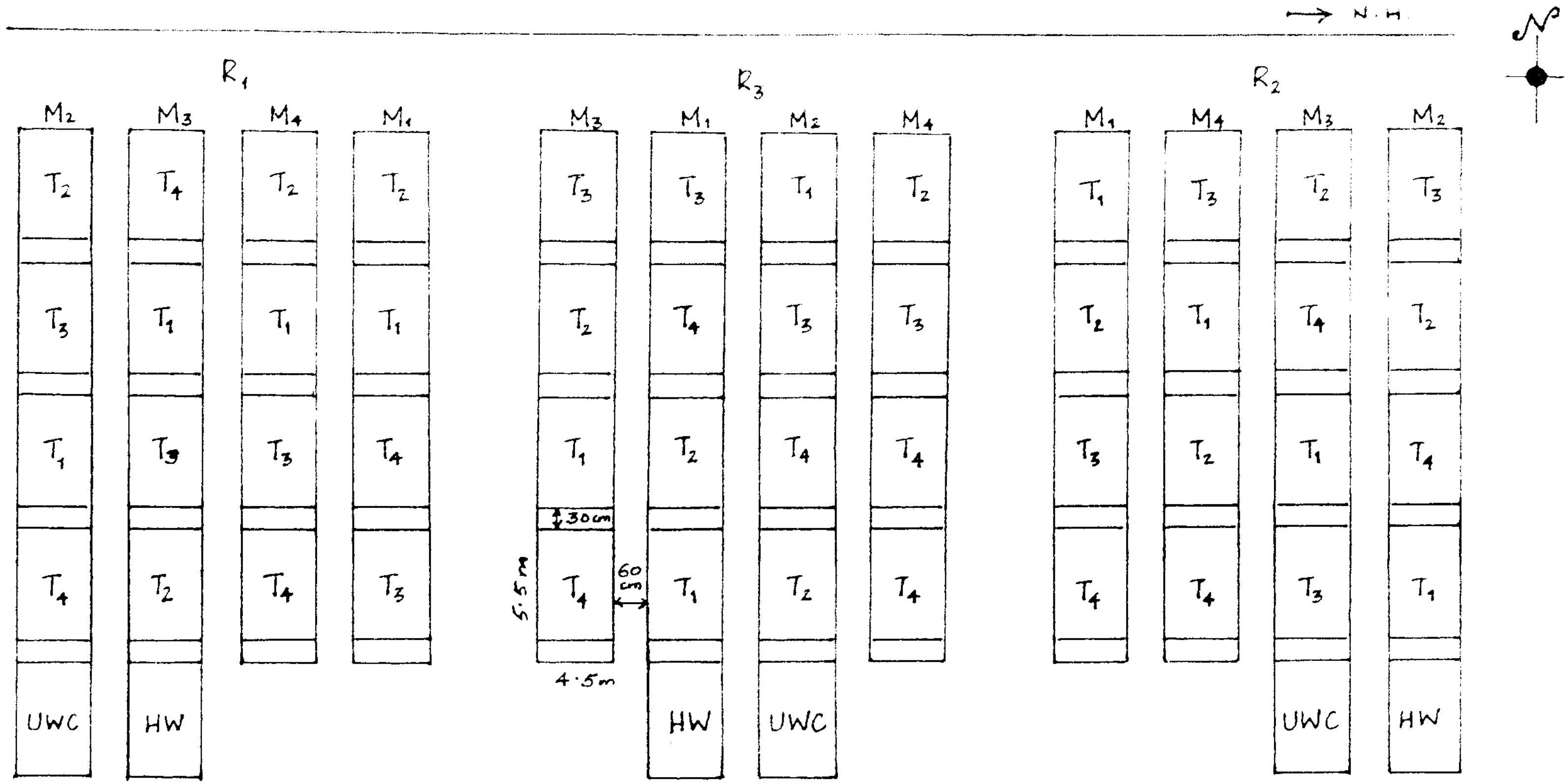
3.4 Herbicides

The details of herbicides used are given below and in Appendix-II.

Name of herbicide	Name of commercial formulation	Name of manufacturer	Percentage of active ingredient
Oxyfluorfen	Goal	Indofil Chemicals	23.4 EC
Butachlor	Butachlor 50EC	Pest control Company	50.0 EC
Pendimethalin	Stomp	Cyanamid	30.0 EC
Thiobencarb	Saturn	Pesticides India ltd.	50.0 EC

3.5 Herbicide application

The herbicides, as per the treatments were sprayed uniformly on the soil surface with a knapsack sprayer fitted with a flat fan nozzle. Quantity of spray fluid used was 500 l/ha.



A. **MAIN PLOT TREATMENTS** -

TIME OF APPLICATION OF HERBICIDES

M1 - 0 DAYS AFTER SOWING (0 DAS)
M2 - 3 DAYS AFTER SOWING (3 DAS)
M3 - 6 DAYS AFTER SOWING (6 DAS)
M4 - 9 DAYS AFTER SOWING (9 DAS)
HW - HAND WEEDED CONTROL

B. **SUB PLOT TREATMENTS** -

HERBICIDES

T1 - OXYFLUORFEN 0.1 kg a.i./ha.
T2 - BUTACHLOR 1.25 kg a.i./ha.
T3 - PENDIMETHALIN 1.25 kg a.i./ha.
T4 - THIOBENCARB 1.5 kg a.i./ha.
UWC - UNWEEDED CONTROL

FIG. 2.

PLAN OF LAYOUT

3.6 Variety

Jyothi was the test variety used for the study. It has a duration of 110 to 125 days with red, long, bold grains. It is moderately tolerant to brown plant hopper and is specially suited for semi-dry rice.

3.7 Field culture

The crop was sown on 20th May 1993. The field was ploughed twice under dry conditions and brought to a fine tilth. All the weeds and stubbles were then removed from the field. Dry seeds were dibbled at a spacing of 20 cm x 15 cm after the basal application of fertilizers. All the cultural operations except weed control were done uniformly in all plots as per the package of practice recommendations (KAU, 1993). Herbicides were applied as per the treatments. The fields were flooded four weeks after sowing with the onset of monsoon. Infestation of rice bug was controlled by spraying metacid. The crop was harvested on September 10th 1993 when 80 per cent of the grain had matured.

Fertilizer used

The following fertilizers were used for the experiment.

Urea	: 46% N
Mussoriephos	: 20% P_2O_5
Muriate of Potash	: 60% K_2O
Fertilizer schedule	: 90, 45, 45 kg/ha N, P_2O_5 and K_2O respectively
Time of application	: Nitrogen was applied in three split doses. Fifty per cent N was applied as basal and 25 per cent each at active tillering and panicle initiation stage. Full dose of phosphorus was applied as basal. Potash was applied, half as basal and half at panicle initiation stage

3.8 Observations

3.8.1 Observations on weeds

The observations on weeds were taken from four locations in each plot from the sampling area using a 50 cm x 50 cm (0.25 m^2) iron quadrat. The following observations were recorded.

a) Weed count

The weed count from the sampling unit in each plot was observed species wise and recorded as number/m^2. The observations were taken at 15, 30, 45, 60 DAS and at harvest. The count of major weeds as well as total grass, sedge, broad-leaved weeds and the total weed population were recorded.

b) Dry matter production

The weeds from the sampling area in each plot were uprooted, first dried under shade and then in a hot air oven at 70°C and the weed dry weight was recorded in g/m^2 at 30 and 60 DAS.

c) Weed control efficiency

The weed control efficiency of different treatments were 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 (g/m^2)

Y = Dry matter production of weeds in the treatment (g/m^2)

3.8.2 Observations on crop

a) Phytotoxicity

The rice seedlings were observed for any phytotoxic symptoms like scorching, retarded growth etc. due to herbicide application. Toxicity rating was done using 0 to 9 scale (Rao, 1983).

b) Crop growth characters

i) Dry matter production

Three plants were collected from the sampling area, oven dried and the dry matter production was recorded in g/m^2. The observations were taken at 30, 60 DAS and at the time of harvest.

ii) Plant height

The plant height in cm was recorded at 30, 60 DAS and at the time of harvest. The height was measured from the bottom of the culm to the tip of the longest leaf or tip of the panicle whichever was the tallest.

iii) Number of tillers

The total number of tillers were counted from 0.25 m^2 using iron quadrat at 30, 60 DAS and at harvest and average expressed as number of tillers per m^2.

c) Yield attributes

i) Productive tillers

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

ii) Length of panicle

The length from the neck to the tip of five panicles were measured and the average length was given in cm.

iii) Number of filled grains per panicle

The total number of filled grains of all the sample panicles were seperately recorded and the average was worked out.

iv) Thousand grain weight

One thousand grains were counted from each treatment and the weight was expressed in grams.

d) Yield

i) Grain yield

The grains from each net plot were dried, cleaned, winnowed and the weight was recorded in quintals per hectare at 14 per cent moisture.

ii) Straw yield

The straw from each net plot was dried under sun and the weight recorded in quintals per hectare.

iii) Harvest index

$$HI = \frac{Yecon}{Ybiol}$$

where Yecon - Economic yield in q/ha

Ybiol - Biological yield in q/ha

e) Leaf area index at 60 DAS

Hills were selected at random from the row meant for destructive sampling after making sure that the hills were surrounded by living hills at each stage of observation. The number of tillers were counted from each selected hill. The length and maximum width of each of the leaves on the middle tiller was measured and the leaf area was computed using the length-width method. Leaf area = K x length x width where K is the adjustment factor. The value used for K was 0.75 (IRRI, 1972). The LAI was then derived by dividing leaf area by the corresponding land area.

f) Chlorophyll determination at 60 DAS

Chlorophyll content of the leaf at 60 DAS was determined after extraction in 80% acetone (Sestak *et al.* 1971). Transmittance read using spectronic 20 at wave length 663 nm and 645 nm. Total chlorophyll, was determined using the formula

$$\text{Chlorophyll (a+b)} = 8.02\ A_{663} + 20.2\ A_{645}$$

A_{663}, A_{645} = Absorbance at 663 nm and 645 nm respectively

3.9 Chemical analysis

The samples of weeds and crops were dried separately in a hot air oven, powdered well and analysed for N, P and K content.

The methods used for analysis were:

1. Nitrogen - Microkjeldahl method (Jackson, 1973)

2. Phosphorus - Vanadomolybdophophoric yellow colour method - Spectronic 20 (Jackson, 1973)

3. Potassium - Triple acid extract method, using flame photometer (Jackson, 1973).

The analysis of weed and crop samples taken at 30, 60 DAS and at harvest were done. At harvest the analysis of crop was done separately for grain and straw. The nitrogen, phosphorus and potassium removed by crop and weeds were calculated by multiplying the dry matter of the crop and weeds with the respective nutrient content and expressed in kg ha^{-1}.

3.10 Statistical analysis

The data recorded for different characters were compiled and tabulated in proper form and were subjected to analysis of variance (Panse and Sukhatma, 1978). Subsequently standard errors were worked out and wherever the 'F' tests were significant, appropriate critical differences (C.D) were calculated to test the significance of the treatment differences.

Analysis of variance for the data on weed population and weed dry matter production were carried out after transforming the data to $\sqrt{x+0.5}$ for those with zero values and to $\sqrt{x}$ for those without zero values.

3.11 Economics of weed control operations

The relative economics of different weed control operations were compared by calculating the additional cost for the operation over and above the unweeded control and working out the return per rupee invested on weed control.

Results & Discussion

RESULTS AND DISCUSSION

The results of the experiment conducted to find out the best time of application of four pre-emergence herbicide on phytotoxicity and weed control in semi-dry rice are presented and discussed in this chapter under the following heads:

4.1 Studies on weeds

4.1.1 Weed spectrum

4.1.2 Weed population

4.1.3 Dry matter production

4.1.4 Weed control efficiency

4.2 Studies on crop

4.2.1 Phytotoxicity

4.2.2 Growth characters

4.2.3 Yield attributes

4.2.4 Yield

4.3 Studies on nutrient uptake

4.3.1 Removal by weeds

4.3.2 Uptake by crop

4.4 Economics

4.1 Studies on weeds

4.1.1 Weed spectrum (Table 2)

Weeds appeared in the experimental field were mainly of upland nature since the field was under vegetable cultivation during the previous summer season. The main weed flora belonged to Poaceae family. The important among them were

Table 2. Weed flora of the experimental field

Scientific name	Common name	Family
A. Monocots		
(i) Grasses		
1 *Cynodon dactylon* (L.) Pers.	Bermuda grass, Stargrass Karuka (M)	Poaceae
2. *Dactyloctenium aegyptium* (L.) Beaur.	Crow's foot grass	Poaceae
3. *Digitaria sanguinalis* (L.) Scop.	Crab grass Kattamgula (M)	Poaceae
4. *Echinochloa colona*(L.) Link.	Jungle rice Kavada (M)	Poaceae
5. *Eleusine indica* (L.) Gaertn.	Fowl foot grass Kattuchama (M)	Poaceae
6. *Ischaemum rugosum* Salisb.	Padappanpullu (M)	Poaceae
7. *Panicum repens* L.	Torpedo grass Inchippullu (M)	Poaceae
(ii) Sedges		
1. *Cyperus iria* L.	Yellow nutsedge Manjakora (M)	Cyperaceae
2. *Cyperus rotundus* L.	Purple nutsedge, Nutgrass Muthanga (M)	Cyperaceae
(iii) Other monocots		
1. *Commelina benghalensis* L.	Hairy wandering jew Vazhapadatti (M)	Commelinaceae
B. Dicots		
1. *Cleome viscosa* L.	Kattukaduku (M)	Capparaceae
2. *Emilia sonchifolia*	Moyalcheviyan (M)	Compositeae
3. *Euphorbia hirta* L.	Garden spurge, Asthma weed	Euphorbiaceae
4. *Ludwigia parviflora* (Roxb.)	Neergrambu (M)	Onagraceae
5. *Phyllanthus niruri* Auct.	Kizharnelli (M)	Euphorbiaceae
6. *Trianthema portulacastrum*		Amaranthaceae

(M) - Malayalam name

Digitaria sanguinalis, Cynodon dactylon, Eleusine indica, Panicum repens and *Dactyloctenium aegyptium*. Cyperaceae family ranked next comprising of *Cyperus rotundus* and *Cyperus iria*. *Commelina benghalensis* recorded a higher number among other monoctos. The major broadleaved weeds were *Cleome viscosa, Ageratum conyzoides* and *Euphorbia hirta*.

Smith Jr. (1983) observed Poaceae as the most common weed family infesting rice and the observations of Nair *et al.* (1979), Sudhakara and Nair (1986) and Moody (1989) pointed out that grasses are the major weed problem in upland rice. The presence of *Digitaria* spp., *Cynodon dactylon* and *Eleusine indica* were earlier reported by Trivedi *et al.* (1986), Cruz *et al.* (1986), Choudhary and Pradhan (1988), Bhargavi and Reddy (1990) and Padhi *et al.* (1991).

The abundance of Cyperaceae family in rice fields had been noticed by Pande and Bhan (1964), Holm *et al.* (1977), Cruz *et al.* (1986), Singh *et al.* (1987), Choudhary and Pradhan (1988). The menace of *Cyperus rotundus* in upland rice was observed by Ramamoorthy (1991) and Padhi *et al.* (1991). The presence of *Cleome viscosa* in semi-dry rice was reported by Bhargavi and Reddy (1990) and that of *Ageratum conyzoides* by Choudhary and Pradhan (1988).

4.1.2 Weed population

4.1.2.1 Grasses

(a) *Digitaria sanguinalis* (L.) Scop (Table 3, 4)

Among the herbicides, pendimethalin was found to be more effective in controlling *Digitaria sanguinalis* at 15, 30 and 60 DAS. At 45 DAS, though the herbicides had no significant difference pendimethalin gave the lowest value for weed count, retaining the same trend.

Table 3. Effect of herbicides and time of application on the population of *Digitaria sanguinalis** (plants/m^2)

Treatments	Stages			
	15 DAS	30 DAS	45 DAS	60 DAS
M_1 (0 DAS)	2.41	2.56	2.86	3.42
M_2 (3 DAS)	2.83	2.95	2.53	4.15
M_3 (6 DAS)	2.27	3.20	2.40	3.53
M_4 (9 DAS)	3:49	4.43	3.10	5.82
SEm ±	0.28	0.11	0.36	0.13
CD (0.05)	NS	0.38	NS	0.45
T_1 (Oxyfluorfen)	2.23	3.78	3.18	3.40
T_2 (Butachlor)	4.07	3.45	2.82	6.34
T_3 (Pendimethalin)	1.70	2.45	2.43	1.67
T_4 (Thiobencarb)	3.02	3.47	2.47	5.51
H.W.	3.50	2.60	2.12	0.71
U.W.C.	4.10	6.80	8.03	11.80
SEm ±	0.24	0.14	0.32	0.09
CD (0.05)	0.70	0.41	NS	0.26

* transformed values $\sqrt{x+0.5}$ transformation

Stages of observation	Main plot	Subplot
15 DAS	NS	$\overline{T_3T_1}\ T_4T_2$
30 DAS	$\overline{M_1M_2}\ M_3M_4$	$T_3\overline{T_2}\ \overline{T_4T_1}$
45 DAS	NS	NS
60 DAS	$\overline{M_1M_3}\ M_2M_4$	$T_3T_1\ T_4T_2$

Table 4. Interaction effect of herbicides and time of application on the population of *Digitaria sanguinalis** at 60 DAS (plants/m^2)

Treatments	0 DAS	3 DAS	6 DAS	9 DAS	Mean
T_1 (Oxyfluorfen)	3.87	4.47	1.87	3.40	3.40
T_2 (Butachlor)	5.97	7.60	4.13	7.67	6.34
T_3 (Pendimethalin)	0.71	0.87	0.71	4.37	1.67
T_4 (Thiobencarb)	3.13	3.67	7.40	7.82	5.51
Mean	3.42	4.15	3.53	5.82	

SE of interaction of time of application and herbicides = 0.198
CD of above at 5 per cent level = 0.58

* Transformed data: $\sqrt{x+0.5}$ transformation

Hand weeded plots gave higher weed count than pendimethalin treated plots indicating the superiority of pendimethalin in controlling *Digitaria sanguinalis*. Unweeded control recorded the highest population of *Digitaria sanguinalis*. On perusal of the interaction effect of herbicides and time of application at 60 DAS, pendimethalin was superior to other herbicides when applied at 0, 3 and 6 DAS. At 6 DAS oxyfluorfen gave the lowest count of Digitaria, closely followed by pendimethalin.

From the results, among the four herbicides, pendimethalin was the best in reducing the population of *Digitaria sanguinalis* when applied upto 6 DAS. It is also observed that *Digitaria sanguinalis* is more sensitive to application of pendimethalin before 9 DAS. Similar results were obtained by Manipon *et al.* (1981) with pendimethalin in reducing grass population. The sensitiveness of *Digitaria sanguinalis* to oxyfluorfen has also been reported by Rao (1983).

(b) *Cynodon dactylon* (L.) Pers. (Table 5, 6)

Out of the four herbicides tested, oxyfluorfen recorded the lower number of *Cynodon dactylon* at 15, 30 and 45 DAS, whereas at 60 DAS pendimethalin recorded the lower value. However, handweeded plots gave the lower count while UWC recorded the higher number of *Cynodon dactylon*.

From the interaction effect of the herbicides with the time of application at 60 DAS, pendimethalin at 0 DAS gave the lower weed count and was comparable with butachlor application at 0 and 6 DAS and thiobencarb at 0 DAS.

The above results reveal that oxyfluorfen was effective for controlling *Cynodon dactylon* upto 45 DAS. However for prolonged control of *Cynodon dactylon* pendimethalin was better.

Table 5. Effect of herbicides and time of application on the population of *Cynodon dactyolon* (plants/m^2)

Treatments	Stages			
	15 DAS	30 DAS	45 DAS	60 DAS
M_1 (0 DAS)	19.88	17.00	41.34	24.94
M_2 (3 DAS)	17.29	12.34	36.90	39.46
M_3 (6 DAS)	24.85	10.50	28.50	43.95
M_4 (9 DAS)	14.38	12.00	46.08	57.42
SEm±	1.01	1.40	2.52	2.27
CD (0.05)	3.49	NS	NS	7.85
T_1 (Oxyfluorfen)	10.15	9.99	32.27	42.06
T_2 (Butachlor)	19.88	14.09	36.67	43.60
T_3 (Pendimethalin)	24.09	14.41	36.12	30.35
T_4 (Thiobencarb)	22.29	13.34	48.05	49.75
H.W.	22.00	5.00	4.80	4.00
U.W.C.	26.80	63.00	105.00	90.00
SEm±	1.00	1.79	2.39	1.47
CD (0.05)	2.92	5.23	6.97	4.29

Stages of observation	Main plot	Sub plot
15 DAS	$\overline{M_4 M_2}$ $M_1 M_3$	$T_1 T_2$ $T_4 T_3$
30 DAS	NS	$T_1 T_4$ $T_2 T_3$
45 DAS	NS	$\overline{T_1 T_3}$ $T_2 T_4$
60 DAS	$M_1 M_2$ $M_3 M_4$	$T_3 T_1$ $T_2 T_4$

Table 6. Interaction effect of herbicides and time of application on the population of *Cynodon dactylon* at 60 DAS (plants/m^2)

Treatments	0 DAS	3 DAS	6 DAS	9 DAS	Mean
T_1 (Oxyfluorfen)	29.00	30.30	54.30	54.67	42.06
T_2 (Butachlor)	22.47	30.60	27.00	94.33	43.60
T_3 (Pendimethalin)	21.60	38.30	29.53	32.00	30.35
T_4 (Thiobencarb)	26.67	58.67	65.00	48.67	49.75
Mean	24.94	39.46	43.95	57.42	

SE of interaction of time of application and herbicides = 2.29
CD of above at 5 per cent level = 6.69

The effectiveness of oxyflurofen against grasses was also reported earlier by Mukhopadhyay and Mandal (1982) and Sreedevi and Thomas (1993).

(c) Total grass population (Table 7, 8)

Among the herbicides, oxyfluorfen treated plots recorded the lower grass population at all stages. Though HW plot recorded the lower number of grasses in the initial stages, at 60 DAS, the number was more than that in herbicide treated plots. However, the UWC plot retained the higher number of grasses all through the stages.

The interaction effect of herbicides and time of application at 60 DAS revealed that thiobencarb gave the lowest grass population when applied at 6 DAS and was comparable with oxyfluorfen at 6 DAS. However pendimethalin was also comparable with it when applied at 3, 6 and 9 DAS. All the herbicides were more or less equal in controlling grassy weeds when applied at 3 DAS. All the herbicide treatments were superior to HW and UWC.

Oxyfluorfen gave lower values of weed population at all the four stages with 6 DAS recording the least weed count. This may be due to the fact that all the members of the Poaceae family including rice are more sensitive to oxyfluorfen during the time of emergence and hence lower weed number was noticed even when the chemical was applied at 9 DAS. The higher grass population at 60 DAS in handweeded plot might be due to the lack of weeding after 40 DAS.

4.1.2.2 Sedges (Table 9, 10)

The lower population of sedges was observed in plots treated with oxyfluorfen at all stages except at 45 DAS. At 45 DAS oxyfluorfen was comparable

Table 7. Effect of herbicides and time of application on the total grass weed population (plants/m^2)

Treatments	Stages			
	15 DAS	30 DAS	45 DAS	60 DAS
M_1 (0 DAS)	31.33	31.25	54.59	95.80
M_2 (3 DAS)	39.90	31.40	44.59	57.96
M_3 (4 DAS)	36.70	29.50	40.40	44.50
M_4 (9 DAS)	38.99	36.75	83.00	77.00
SEm ±	3.49	1.10	2.29	4.12
CD (0.05)	NS	3.81	7.92	14.26
T_1 (Oxyfluorfen)	35.25	27.84	35.42	57.00
T_2 (Butachlor)	35.25	35.50	59.58	76.33
T_3 (Pendimethalin)	35.34	33.34	66.67	93.67
T_4 (Thiobencarb)	41.10	32.25	61.00	73.33
H.W.	22.00	38.00	18.00	100.00
U.W.C.	50.00	109.00	131.00	140.00
SEm ±	3.27	1.04	1.98	3.39
CD (0.05)	NS	3.04	5.78	9.89

Stages of observation	Main plot	Sub plot
15 DAS	NS	NS
30 DAS	$\overline{M_3M_1\ M_2}M_4$	$T_1\overline{T_4\ \overline{T_3}}T_2$
45 DAS	$M_3M_2\ M_1M_4$	$T_1\overline{T_2\ \overline{T_4}}T_3$
60 DAS	$\overline{M_3M_2}\ M_4M_1$	$T_1\overline{T_4\ T_2}T_3$

Table 8. Interation effect of herbicides and time of application on the total grass weed population at 60 DAS (plants/m^2)

Treatments	0 DAS	3 DAS	6 DAS	9 DAS	Mean
T_1 (Oxyfluorfen)	76.00	60.00	34.00	58.00	57.00
T_2 (Butachlor)	116.60	62.60	58.00	73.00	76.33
T_3 (Pendimethalin)	183.00	62.60	57.00	72.00	93.67
T_4 (Thiobencarb)	112.67	46.66	29.00	105.00	73.33
Mean	95.80	57.96	44.50	77.00	

SE of interaction of time of application and herbicides = 6.78
CD of above at 5 per cent level 19.79

Table 9. Effect of herbicides and time of application on the population of sedges (plants/m^2)

Treatments	Sedges			
	15 DAS	30 DAS	45 DAS	60 DAS
M_1 (0 DAS)	47.40	57.90	54.25	23.25
M_2 (3 DAS)	40.50	42.80	45.25	12.83
M_3 (6 DAS)	36.80	29.40	32.00	10.00
M_4 (9 DAS)	35.30	54.67	52.25	10.34
SEm ±	0.56	1.85	0.76	0.32
CD (0.05)	1.95	6.40	2.63	1.10
T_1 (Oxyfluorfen)	33.40	39.33	44.00	11.33
T_2 (Butachlor)	43.00	48.83	45.80	13.33
T_3 (Pendimethalin)	46.80	57.20	53.90	16.92
T_4 (Thiobencarb)	36.80	39.50	40.00	14.83
H.W.	20.00	26.00	10.00	9.00
U.W.C.	45.00	65.00	59.00	40.00
SEm ±	1.20	1.83	1.98	0.89
CD (0.05)	3.50	5.34	5.78	2.59

<u>Stages of observation</u>	<u>Main plot</u>	<u>Sub plot</u>
15 DAS	$\overline{M_4M_3}\ M_2M_1$	$\overline{T_1T_4}\ T_2T_3$
30 DAS	$M_3M_2\ \overline{M_4M_1}$	$\overline{T_1T_4}\ T_2T_3$
45 DAS	$M_3M_2\ \overline{M_4M_1}$	$\overline{T_4T_1}\ T_2T_3$
60 DAS	$\overline{M_3M_4}\ M_2M_1$	$\overline{T_1T_2}\ T_4T_3$

Table 10. Interaction effect of herbicides and time of application on the population of sedges at 60 DAS (plants/m^2)

Treatments	0 DAS	3 DAS	6 DAS	9 DAS	Mean
T_1 (Oxyfluorfen)	16.00	10.00	15.30	4.00	11.33
T_2 (Butachlor)	15.00	12.00	14.67	11.67	13.33
T_3 (Pendimethalin)	28.00	18.00	4.00	17.67	16.92
T_4 (Thiobencarb)	34.00	11.33	6.00	8.00	14.83
Mean	23.25	12.83	9.99	10.34	

SE of interaction of time of application and herbicides = 1.78
CD of above at 5 per cent level = 5.19

with thiobencarb which recorded the lowest value for sedge population. At all stages pendimethalin was found to give the highest population of sedges.

Handweeded plots recorded lower weed population and was significantly superior to all the herbicides tested. Irrespective of the stages of observation, UWC gave the highest sedge population.

Though the interaction effect of herbicides and time of application was significant at 60 DAS, the population of sedges was found to be reduced considerably at 60 DAS. This is because after flowering most of the sedges have started drying up leading to a reduction in the weed count.

From the results, oxyfluorfen and thiobencarb are found equally effective in reducing the population of sedges in semi-dry rice. The effectiveness of thiobencarb against sedges in dry seeded rice was reported earlier by Budhar *et al.* (1991).

4.1.2.3 Broadleaved weeds (Table 11)

Significant difference between herbicides was noted only at 30 DAS. Pendimethalin recorded the lowest broadleaved weed count among herbicides and was comparable with thiobencarb. Hand weeded plots had the lowest number of broad leaved weeds. Unweeded control retained a large population of broad leaved weeds.

From the results a steady increase in the population of broad leaved weeds can be observed upto 45 DAS and thereafter a decline. This decline in the population of broad leaved weeds may be due to the smothering effect of the grasses making the broad leaved weeds less competitive. Similar results were also found by Singh *et al.* (1987) in upland rice where grassy weeds dominated over non-grassy

Table 11. Effect of herbicides and time of application on the population of broad leaved weeds (plants/m^2)

Treatments	Stages			
	15 DAS	30 DAS	45 DAS	60 DAS
M_1 (0 DAS)	2.42	24.75	31.50	3.10
M_2 (3 DAS)	1.57	19.74	18.33	2.71
M_3 (6 DAS)	1.75	10.34	13.58	2.47
M_4 (9 DAS)	1.42	20.25	12.75	2.52
SEm ±	1.54	1.11	2.60	0.54
CD (0.05)	NS	3.84	8.99	NS
T_1 (Oxyfluorfen)	1.24	26.17	20.00	2.83
T_2 (Butachlor)	1.96	18.67	19.25	1.67
T_3 (Pendimethalin)	1.30	14.92	18.58	2.81
T_4 (Thiobencarb)	2.64	15.34	18.34	3.50
H.W.	0.71	8.00	8.00	3.20
U.W.C.	1.58	76.00	80.00	8.30
SEm ±	1.53	0.81	1.70	2.07
CD (0.05)	NS	2.36	NS	NS

Stages of observation	Main plot	Sub plot
15 DAS	NS	NS
30 DAS	$M_3\overline{M_2\ M_4}M_1$	$\overline{T_3T_4}\ T_2T_1$
45 DAS	$\overline{M_4M_3\ M_2}M_1$	NS
60 DAS	NS	NS

weeds and sedges at 75 DAS. Effective control of broad leaved weeds by the application of pendimethalin at 1.25 - 1.5 kg a.i/ha was also reported by Gowda and Devi (1984).

4.1.2.4 Total weed population (Table 12, 13)

Observations at all stages revealed the superiority of oxyfluorfen in recording the lower weed population followed by pendimethalin at 15 DAS and thiobencarb at 30 and 45 DAS and butachlor at 60 DAS. Hand weeded plots recorded lower weed count only at 45 DAS and unweeded control retained the higher number of weed population at all stages.

The lower weed count in hand weeded plot at 45 DAS may be due to the weeding operations. The interaction effect of treatments on total weed population at 60 DAS showed that among the herbicides applied at 0 and 9 DAS oxyfluorfen recorded the lowe weed population. At 3 DAS and 9 DAS oxyfluorfen and pendimethalin were comparable. However at 6 DAS though thiobencarb recorded the lower total weed count when applied at 6 DAS it was similar to oxyfluorfen at 6 DAS. From the results at 60 DAS oxyfluorfen and pendimethalin were equally effective in controlling all types of weeds when applied at 9 DAS. This is because sedges which constituted a large proportion of total weed population got dried up after flowering by about 60 days. Pendimethalin is found to be less effective for the control of sedges and hence the total weed population at the earlier stages were higher in pendimethalin applied plots.

However, irrespective of the chemical a decreasing trend in the total weed population was observed when the application was delayed upto 6 days and then a marginal increase when applied at 9 DAS. This may be because by about 9 DAS the weed seedlings become slightly tolerant to the chemicals, while at 0 DAS

Table 12. Effect of herbicides and time of application on the total weed population (plants/m^2)

Treatments	Stages			
	15 DAS	30 DAS	40 DAS	60 DAS
M_1 (0 DAS)	85.25	114.16	140.33	168.75
M_2 (3 DAS)	75.58	94.34	108.16	84.50
M_3 (6 DAS)	77.00	72.41	86.00	62.99
M_4 (9 DAS)	76.33	73.40	147.99	87.50
SEm±	2.07	1.05	3.53	2.82
CD (0.05)	7.16	3.63	12.20	9.76
T_1 (Oxyfluorfen)	70.90	86.00	99.33	82.08
T_2 (Butachlor)	81.75	102.80	124.67	93.75
T_3 (Pendimethalin)	78.17	98.50	139.17	127.83
T_4 (Thiobencarb)	83.33	92.00	119.33	100.08
H.W.	86.00	132.00	36.00	110.00
U.W.C.	97.00	210.00	270.00	248.00
SEm±	1.63	1.84	3.62	3.03
CD (0.05)	4.76	5.36	10.57	8.85

<u>Stages of observation</u>	<u>Main plot</u>	<u>Sub plot</u>
15 DAS	$\overline{M_2M_4\ M_3}M_1$	$T_1\overline{T_3\ \overline{T_2}}\overline{T_4}$
30 DAS	$\overline{M_3M_4}\ M_2M_1$	$T_1T_4\ \overline{T_3T_2}$
45 DAS	$M_3M_2\ \overline{M_1M_4}$	$T_1\overline{T_4\ T_2}T_3$
60 DAS	$M_3\overline{M_2\ M_4}M_1$	$T_1\overline{T_2\ T_4}T_3$

Table 13. Effect of herbicides and time of application on the total weed population at 60 DAS (plants/m^2)

Treatments	0 DAS	3 DAS	6 DAS	9 DAS	Mean
T_1 (Oxyfluorfen)	127.33	89.67	49.33	62.00	82.08
T_2 (Butachlor)	130.67	77.00	79.33	88.00	93.75
T_3 (Pendimethalin)	265.00	79.33	84.00	83.00	127.83
T_4 (Thiobencarb)	152.00	92.00	39.33	117.00	100.08
Mean	168.75	84.50	62.99	87.50	

SE of interaction of time of application and herbicides = 60.7
CD of above at 5 per cent level = 17.6

the weeds are in the seed stage, and are less sensitive to the herbicides. This may be the reason for the highest weed population at 60 DAS when the chemicals were applied at 0 DAS. In general, the application of oxyfluorfen, pendimethalin and butachlor were better when applied at 3,6 and 9 DAS. But in the case of thiobencarb, more effectiveness in controlling all types of weeds was noticed when applied at 3 and 6 DAS. At 9 DAS the weed seedlings become more tolerant to thiobencarb.

4.1.3 Dry matter production of weeds (Table 14, 15)

Oxyfluorfen recorded the lowest dry matter production of weeds at 30 DAS and was similar to butachlor which in turn was comparable with thiobencarb. Pendimethalin recorded the highest dry matter production at 30 DAS. However, at 60 DAS, the lowest dry matter production was recorded by pendimethalin and was comparable with butachlor and oxyfluorfen.

Handweeded control was significantly superior to the herbicide treated plots with respect to weed dry matter production at both stages. The highest weed dry matter production was retained by unweeded control at all stages.

Interaction effect of treatments on the dry matter production of weeds at 60 DAS showed that there was a decreasing trend in DMP when pendimethalin application was delayed from 0 to 9 days with 9 DAS recording the lowest value. In the case of oxyfluorfen effectiveness of the chemical was more pronounced when applied at 3 and 6 DAS before and after which an increase was noticed in dry matter production.

From the above results, though pendimethalin recorded highest DMP at 30 DAS, the same chemical gave the lowest DMP at 60 DAS. This might be due to the reduction in the sedge population consequent to flowering and drying up by about 60 days.

Table 14. Effect of herbicides and time of application on the dry matter production of weeds (g/m^2)

Treatments	Stages 30 DAS	Stages 60 DAS
M_1 (0 DAS)	108.50	195.00
M_2 (3 DAS)	61.50	155.50
M_3 (6 DAS)	52.80	152.67
M_4 (9 DAS)	106.00	177.25
SEm ±	3.17	3.84
CD (0.05)	10.97	13.29
T_1 (Oxyflourfen)	68.00	155.75
T_2 (Butachlor)	75.50	150.00
T_3 (Pendimethalin)	102.33	148.67
T_4 (Thiobencarb)	83.00	226.00
H.W.	20.00	56.00
U.W.C.	318.00	344.00
SEm ±	4.09	2.46
CD (0.05)	11.94	7.18

<u>Stages of observation</u>	<u>Main plot</u>	<u>Sub plot</u>
30 DAS	$\overline{M_3M_2}\ M_4M_1$	$\overline{T_1T_2}\ T_4T_3$
60 DAS	$\overline{M_3M_2}\ M_4M_1$	$\overline{T_3T_2\ T_1}T_4$

Table 15. Interaction effect of herbicides and time of application of dry matter production by weeds at 60 DAS (kg ha^{-1})

Treatments	0 DAS	3 DAS	6 DAS	9 DAS	Mean
T_1 (Oxyfluorfen)	211.00	110.00	110.00	192.00	155.80
T_2 (Butachlor)	163.00	122.00	176.00	139.00	150.00
T_3 (Pendimethalin)	156.00	154.00	144.70	140.00	148.67
T_4 (Thiobencarb)	250.00	236.00	180.00	238.00	226.00
Mean	195.00	155.50	152.67	177.30	

SE of interaction of time of application and herbicides = 4.92
CD of above at 5 per cent level = 14.36

This is in confirmity with the findings of Ghosh and Singh (1985) wherein lower DMP was recorded with oxyfluorfen application. Singh and Prakash (1990) reported a reduction in weed dry matter production with pendimethalin application.

4.1.4 Weed control efficiency (Table 16, 17)

Among the herbicides, oxyfluorfen recorded the highest weed control efficiency at 30 DAS and was comparable with butachlor. At 60 DAS pendimethalin gave highest value followed by butachlor and oxyfluorfen. Thiobencarb recorded the lowest weed control efficiency at 60 DAS. At both the stages handweeded plot registered the highest weed control efficiency.

4.2 Studies on crop

4.2.1 Phytotoxicity

The phytotoxicity rating of the crop by 0-9 scale at 15 DAS revealed that phytotoxic symptoms appeared in rice only when oxyfluorfen was applied at 6 and 9 DAS. Initial yellowing noticed in the oxyfluorfen treated plots at 6 and 9 DAS recouped later in about 2-3 weeks.

From the results, phytotoxic symptoms developed by oxyfluorfen when applied at 6 and 9 DAS coincides with the time of emergence and seedling stage of rice indicating the possibility of complete recovery. Mukhopadhyay and Mandal (1982) also observed phytotoxic symptoms in rice with the application of oxyfluorfen. This was also confirmed by an experiment at Madurai in semi-dry rice where phytotoxic symptoms observed in the rice seedlings by the application of oxyfluorfen disappeared completely later (Porpavai and Ramiah, 1992).

Table 16. Effect of herbicides and time of application on the weed control efficiency (%)

Treatments	Stages	
	30 DAS	60 DAS
M_1 (0 DAS)	67.99	43.28
M_2 (3 DAS)	81.44	54.53
M_3 (6 DAS)	81.63	55.53
M_4 (9 DAS)	66.65	48.43
SEm ±	0.99	1.16
CD (0.05)	3.43	4.00
T_1 (Oxyfluorfen)	78.77	54.68
T_2 (Butachlor)	77.06	56.33
T_3 (Pendimethalin)	68.08	56.53
T_4 (Thiobencarb)	73.80	34.23
H.W.	93.70	83.70
SEm ±	0.91	0.73
CD (0.05)	3.15	2.53

<u>Sedges of observation</u>	<u>Main plot</u>	<u>Sub plot</u>
30 DAS	$\overline{M_3M_2}$ $\overline{M_1M_4}$	$\overline{T_1T_2}$ T_4T_3
60 DAS	$\overline{M_3M_2}$ M_4M_1	$\overline{T_3T_2\ T_1}T_4$

Table 17. Interaction effect of herbicides and time of application on weed control efficiency at 60 DAS (%)

Treatments	0 DAS	3 DAS	6 DAS	9 DAS	Mean
T_1 (Oxyfluorfen)	38.60	52.57	54.60	27.33	54.68
T_2 (Butachlor)	67.97	64.47	54.33	31.37	56.33
T_3 (Pendimethalin)	67.97	48.80	57.93	47.40	56.53
T_4 (Thiobencarb)	44.17	59.50	59.29	30.80	34.23
Mean	43.28	54.53	55.53	48.43	

SE of interaction of time of application and herbicides = 1.46
CD of above at 5 per cent level = 4.26

4.2.2 Growth characters

(a) Plant population/m row length (Table 18)

At both the stages of observation, i.e., 30 and 60 DAS, no significant difference was noticed between the herbicides on the plant population/m row length. However, handweeded plots gave higher number of plants/m row length.

(b) Plant height

There was no significant difference between herbicides in the case of plant height at any of the stages of observation. However, plants in the handweeded plots gave higher values for plant height while UWC gave the lowest value.

(c) Number of tillers/m^2 (Table 18)

At 30 and 60 DAS pendimethalin treated plots gave the highest number of tillers/m^2 and were similar to oxyfluorfen. At both the stages of observation, though handweeded plots recorded the lower number of tillers/m^2 than pendimethalin it was comparable with pendimethalin. Irrespective of the stages of observation, unweeded control registered the lowest number of tillers/m^2.

Interaction effect of time of application and herbicides was not significant at 60 DAS.

(d) Leaf area index (Table 19)

Herbicides showed no significant difference with respect to leaf area index of crop at 60 DAS.

The panicle initiation stage of the crop coincides with 60 DAS and before the initiation of panicle, few of the tillers may die and decay, reducing the total leaf area index.

Table 18. Effect of herbicides and time of application on plant population/m row length and number of tillers/m^2

Treatments	Plant population/m row length		No. of tillers/m^2	
	30 DAS	Harvest	30 DAS	60 DAS
M_1 (0 DAS)	5.42	5.92	107.50	293.67
M_2 (3 DAS)	6.00	6.25	97.50	247.33
M_3 (6 DAS)	6.00	6.50	110.00	307.00
M_4 (9 DAS)	5.58	5.30	90.00	225.50
SEm ±	0.37	0.28	5.25	12.33
CD (0.05)	NS	NS	NS	42.66
T_1 (Oxyfluorfen)	6.00	6.08	102.50	283.60
T_2 (Butachlor)	5.92	6.17	90.00	241.50
T_3 (Pendimethalin)	5.58	6.08	115.00	309.30
T_4 (Thiobencarb)	5.82	5.67	97.50	239.17
H.W.	7.00	7.00	120.00	306.00
U.W.C.	5.00	2.00	60.00	236.00
SEm ±	0.27	0.19	5.10	12.50
CD (0.05)	NS	NS	14.89	36.50

Observations	Main plot	Sub plot
Plant population/m row length 30 DAS	NS	NS
Plant population/m row length at harvest	NS	NS
No. of tillers/m^2 30 DAS	NS	$\overline{T_3 \overline{T_1} \; T_4} T_2$
No. of tillers/m^2 60 DAS	$\overline{M_3 M_1}$ $\overline{M_2 M_4}$	$\overline{T_3 T_1}$ $\overline{T_2 T_4}$

Table 19. Effect of herbicides and time of application on the leaf area index and chlorophyll content of rice at 60 DAS

Treatments	LAI	Chlorophyll content
M_1 (0 DAS)	3.19	2.19
M_2 (3 DAS)	2.91	2.29
M_3 (6 DAS)	2.49	2.21
M_4 (9 DAS)	2.43	2.26
SEm±	0.38	0.09
CD (0.05)	NS	NS
T_1 (Oxyfluorfen)	2.41	2.19
T_2 (Butachlor)	3.19	2.30
T_3 (Pendimethalin)	3.04	2.11
T_4 (Thiobencarb)	2.35	2.34
H.W.	2.40	1.66
U.W.C.	2.10	1.03
SEm±	0.27	0.15
CD (0.05)	NS	NS

Observations	Main plot	Sub plot
LAI	NS	NS
Chlorophyll content	NS	NS

(e) Chlorophyll content (Table 19)

No significant difference was noticed between herbicides on the content of chlorophyll (a+b) at 60 DAS. Pendimethalin gave the highest value for chlorophyll (a+b). Chlorophyll (a+b) content given by pendimethalin was significantly superior to hand weeding. The interaction effect of herbicides and time of application on the content of chlorophyll at 60 DAS was not significant.

From the above results, pendimethalin treated plots gave higher chlorophyll content than handweeded plots indicating the tonic effect of pendimethalin in improving the chlorophyll content in rice.

(f) Dry matter production (Table 20, 21)

At 30 and 60 DAS pendimethalin gave the highest dry matter production of rice while at harvest, oxyfluorfen recorded the highest dry matter production and was comparable with pendimethalin. Handweeded plots had similar dry matter production as that of pendimethalin treated plots, whereas unweeded control registered the lowest dry matter production at 60 DAS and at harvest.

Interaction effect of time of application and herbicides showed that application of pendimethalin at 0, 3 and 9 DAS were comparable and were similar to that of thiobencarb application at 0 DAS. This may be because at 6 DAS, the application of pendimethalin would have affected the emergence of the crop and thereby further accumulation of dry matter.

4.2.3 Yield attributes

(a) Plant height at harvest (Table 23)

There was no significant difference between herbicides in the case of

Table 20. Effect of herbicides and time of application on the dry matter production by rice (g/m^2)

Treatments	Stages		
	30 DAS	60 DAS	Harvest
M_1 (0 DAS)	30.17	208.25	306.67
M_2 (3 DAS)	30.67	197.08	251.92
M_3 (6 DAS)	41.58	177.67	232.92
M_4 (9 DAS)	45.25	201.75	266.58
SEm ±	2.08	8.39	9.58
CD (0.05)	7.19	NS	33.15
T_1 (Oxyfluorfen)	23.25	185.42	315.33
T_2 (Butachlor)	44.17	176.92	244.67
T_3 (Pendimethalin)	50.25	234.67	286.25
T_4 (Thiobencarb)	30.00	187.75	211.83
H.W.	40.00	230.00	270.00
U.W.C.	45.00	118.00	170.00
SEm ±	1.49	8.55	11.67
CD (0.05)	5.16	24.97	34.08

Stages of observation	Main plot	Sub plot
30 DAS	$\overline{M_4M_3}\ \overline{M_2M_1}$	$T_3T_2\ T_4T_1$
60 DAS	NS	$T_3\overline{T_4\ T_2}T_1$
Harvest	$M_1\overline{M_4\ \overline{M_2}}M_3$	$\overline{T_1T_3}\ \overline{T_2T_4}$

Table 21. Interaction effect of herbicides and time of application on the dry matter production by rice at 60 DAS (g/m^2)

Treatments	0 DAS	3 DAS	6 DAS	9 DAS	Mean
T_1 (Oxyfluorfen)	195.00	190.00	193.33	163.33	185.42
T_2 (Butachlor)	156.33	213.33	134.67	203.33	176.92
T_3 (Pendimethalin)	263.33	235.00	192.67	247.67	234.67
T_4 (Thiobencarb)	218.33	150.00	190.00	192.67	187.75
Mean	208.25	197.08	177.67	201.75	

SE of interaction of time of application and herbicides = 17.09
CD of above at 5 per cent level = 49.90

plant height at harvest. However plants in the handweeded plots gave higher values of plant height while unweeded control gave the lowest value.

(b) Productive tillers/m^2 (Table 22, 23)

Results revealed the superiority of pendimethalin over other herbicides. The number of productive tillers/m^2 produced by pendimethalin treated plots were comparable with handweeded plots. Unweeded control had the lowest number of productive tillers/m^2.

Interaction effect of time of application and herbicides revealed that pendimethalin applied at 0, 3, 6 and 9 DAS was comparable with oxyfluorfen applied at 0 and 3 DAS and butachlor at 3 DAS. The highest number of productive tillers/m^2 was obtained from plots treated with pendimethalin at 3 DAS.

From the results higher values for productive tillers were observed when pendimethalin was applied at 3 and 9 DAS and lower values at 0 and 6 DAS. This may be because at 0 DAS or spraying on the same day of sowing, crop and weed are in the seed stage which are less sensitive to the herbicide application. Further the herbicides applied at this stage will be accumulated, in the seed coat which will be shed during emergence, precluding the further translocation of herbicides in the weeds (Rao, 1983). This ultimately reduce the effectiveness of the chemical on the weeds and thereby the competitive advantage of the crop over the weeds leading to a reduction in the number of productive tillers. At 6 DAS, crop is in the emergence stage and is most sensitive to any herbicide in turn affecting further growth and tiller production.

(b) Length of panicle (Table 22, 24)

Pendimethalin and oxyfluorfen treated plots recorded similar panicle

Table 22. Effect of herbicides and time of application on plant height, number of effective tillers/m^2, length of panicle, grains/panicle, 1000 grain weight

Treatments	Plant height at harvest (cm)	No. of effective tillers/m^2	Length of panicle (cm)	Grains/ panicle	1000 grain weight (gm)
M_1 (0 DAS)	87.13	190.08	17.64	56.08	28.69
M_2 (3 DAS)	81.90	213.77	19.58	55.75	28.01
M_3 (6 DAS)	78.05	180.10	18.92	56.18	27.85
M_4 (9 DAS)	75.77	164.00	18.27	60.00	29.03
SEm ±	1.28	5.89	0.38	3.61	0.52
CD (0.05)	4.42	20.38	1.31	NS	NS
T_1 (Oxyfluorfen)	78.34	177.52	19.28	61.50	28.79
T_2 (Butachlor)	82.37	167.25	17.47	57.60	27.33
T_3 (Pendimethalin)	82.23	219.17	19.72	53.00	29.00
T_4 (Thiobencarb)	79.91	184.02	17.94	55.92	28.48
H.W.	99.10	210.00	19.00	59.00	27.80
U.W.C.	69.40	106.00	17.00	35.00	26.10
SEm ±	1.76	8.25	0.28	2.98	0.38
CD (0.05)	NS	24.09	0.82	NS	1.10

Observations	Main plot	Sub plot
Plant height at harvest (cm)	$M_1 M_2\ M_3 M_4$	NS
No. of effective tillers/m^2	$M_2 M_1\ M_3 M_4$	$T_3\overline{T_4\ T_1 T_2}$
Length of panicle (cm)	$M_2 M_3\ M_4 M_1$	$\overline{T_3 T_1}\ \overline{T_4 T_2}$
Grains/panicle	NS	NS
1000 grain weight	NS	$T_3 T_1\ T_4 T_2$

Table 23. Interaction effect of herbicides and time of application on the number of productive tillers/m^2

Treatments	0 DAS	3 DAS	6 DAS	9 DAS	Mean
T_1 (Oxyfluorfen)	225.00	208.00	126.10	151.00	177.53
T_2 (Butachlor)	153.00	218.00	151.00	147.00	167.30
T_3 (Pendimethalin)	196.00	241.00	217.33	222.00	219.10
T_4 (Thiobencarb)	186.00	188.10	226.00	136.00	184.03
Mean	190.08	213.77	180.10	164.00	

SE of interaction of time of application and herbicides = 16.49
CD of above at 5 per cent level = 48.15

Table 24. Interaction effect of herbicides and time of application on the length of panicle (cm)

Treatments	0 DAS	3 DAS	6 DAS	9 DAS	Mean
T_1 (Oxyfluorfen)	19.80	19.93	19.13	18.30	19.30
T_2 (Butachlor)	13.40	19.80	18.20	18.50	17.50
T_3 (Pendimethalin)	20.50	20.40	19.53	18.40	19.70
T_4 (Thiobencarb)	16.90	18.20	18.80	17.90	17.94
Mean	17.64	19.60	18.92	18.30	

SE of interaction of time of application and herbicides 0.57
CD of above at 5 per cent level 1.65

Table 25. Interaction effect of herbicides and time of application on the number of filled grains/panicle

Treatments	0 DAS	3 DAS	6 DAS	9 DAS	Mean
T_1 (Oxyfluorfen)	79.33	47.33	56.67	62.67	61.49
T_2 (Butachlor)	54.33	60.67	51.67	63.67	57.59
T_3 (Pendimethalin)	36.67	53.33	60.33	61.67	53.00
T_4 (Thiobencarb)	54.00	61.67	56.00	52.00	55.92
Mean	56.10	55.80	56.16	60.00	

SE of interaction of time of application and herbicides 5.97
CD of above at 5 per cent level 17.43

lengths and were comparable with that of handweeded plots. All the herbicides were significantly superior to unweeded control.

Interaction effect of time of application and herbicides revealed that pendimethalin applied at 0, 3 and 6 DAS were similar with oxyfluorfen at 0, 3 and 6 DAS. The above combination gave better results with productive tillers also.

(c) Grains/panicle (Table 22, 25)

There was no significant difference between herbicides in the number of grains/panicle. However oxyfluorfen and pendimethalin applied plots were comparable with handweeded plots. All the herbicides were superior than unweeded control.

Interaction effect of time of application and herbicide was significant. Oxyfluorfen at 0 DAS recorded the highest number of grains/panicle and was comparable with oxyfluorfen and butachlor applied at 9 DAS. Oxyfluorfen being a contact herbicide with pre-emergence and early post-emergence action, will affect the crop especially at and around the emergence stage. The slight set back occurred during the time of phytotoxicity and its recovery will be reflected on the later stages of growth of the crop.

(d) Thousand grain weight (Table 22, 27)

Among the four herbicides tested, pendimethalin and oxyfluorfen were similar and recorded the higher thousand grain weight than handweeded plots though they were comparable. Unweeded control had the lowest thousand grain weight compared to the herbicides tested.

Table 26. Interaction effect of herbicides and time of application on thousand grain weight (gm)

Treatments	0 DAS	3 DAS	6 DAS	9 DAS	Mean
T_1 (Oxyfluorfen)	29.70	27.50	29.40	28.57	28.49
T_2 (Butachlor)	27.96	27.50	25.20	28.50	27.32
T_3 (Pendimethalin)	27.87	29.00	28.80	30.33	29.00
T_4 (Thiobencarb)	29.20	28.10	27.97	28.73	28.47
Mean	28.68	28.03	27.84	29.03	

SE of interaction of time of application and herbicides = 0.75
CD of above at 5 per cent level 2.20

There was significant interaction between time of application and herbicides with respect to thousand grain weight. Pendimethalin at 9 DAS gave the highest test weight and was similar to its application at 3 and 6 DAS. It was also comparable with oxyfluorfen applied at 0, 6 and 9 DAS.

4.2.4 Yield

(a) Grain yield (Table 27, 28 and Fig. 3, 4)

Among the herbicides tested, pendimethalin gave the highest grain yield and was comparable with oxyfluorfen and handweeded control. Unweeded control recorded the lowest grain yield.

Interaction effect of time of application and herbicides revealed that pendimethalin gave the highest grain yield at 3 DAS and was comparable with its application at 0 and 6 DAS. The application of oxyfluorfen at 3 and 9 DAS was also similar to the application of pendimethalin at 3 DAS.

The more number of productive tillers recorded in pendimethalin applied plots at 3 DAS might have contributed to the increase in grain yield. The same combination also gave higher values for dry matter production and test weight of grains.

Thus the higher dry matter production in pendimethalin applied plots at 3 DAS, test weight of grain together with highest number of productive tillers might have contributed to the highest grain yield in the above combination. Though not significant, the same combination recorded the highest straw yield indicating the better translocation of photosynthates leading to more grain yield in the above combination.

Table 27. Effect of herbicides and time of application on grain yield t ha^{-1} straw yield t ha^{-1} and harvest index

Treatments	Grain yield	Straw yield	Harvest index
M_1 (0 DAS)	2.02	2.43	0.46
M_2 (3 DAS)	1.97	2.51	0.43
M_3 (6 DAS)	1.82	2.20	0.48
M_4 (9 DAS)	1.78	2.02	0.44
SEm ±	0.07	0.13	0.02
CD (0.05)	NS	NS	NS
T_1 (Oxyfluorfen)	2.03	2.39	0.45
T_2 (Butachlor)	1.71	2.03	0.48
T_3 (Pendimethalin)	2.13	2.49	0.46
T_4 (Thiobencarb)	1.67	2.25	0.42
H.W.	2.20	3.60	0.38
U.W.C.	0.38	0.73	0.34
SEm ±	0.07	0.11	0.011
CD (0.05)	0.20	0.32	0.03

Observations	Main plot	Sub plot
Grain yield	NS	$\overline{T_3T_1}\ \overline{T_2T_4}$
Straw yield	NS	$\overline{T_3T_1\ T_4}\overline{T_2}$
Harvest index	NS	$\overline{T_2T_3}\ T_1T_4$

Table 28. Interaction effect of herbicides and time of application on the grain yield (t ha^{-1})

Treatments	0 DAS	3 DAS	6 DAS	9 DAS	Mean
T_1 (Oxyfluorfen)	1.90	2.20	1.70	2.30	2.03
T_2 (Butachlor)	2.03	1.60	1.87	1.35	1.71
T_3 (Pendimethalin)	2.13	2.32	2.23	1.83	2.13
T_4 (Thiobencarb)	2.00	1.75	1.49	1.45	1.67
Mean	2.02	1.97	1.82	1.73	

SE of interaction of time of application and herbicides = 0.145
CD of above at 5 per cent level = 0.420

Fig 3. Grain yield and dry matter production of weed at 60 DAS

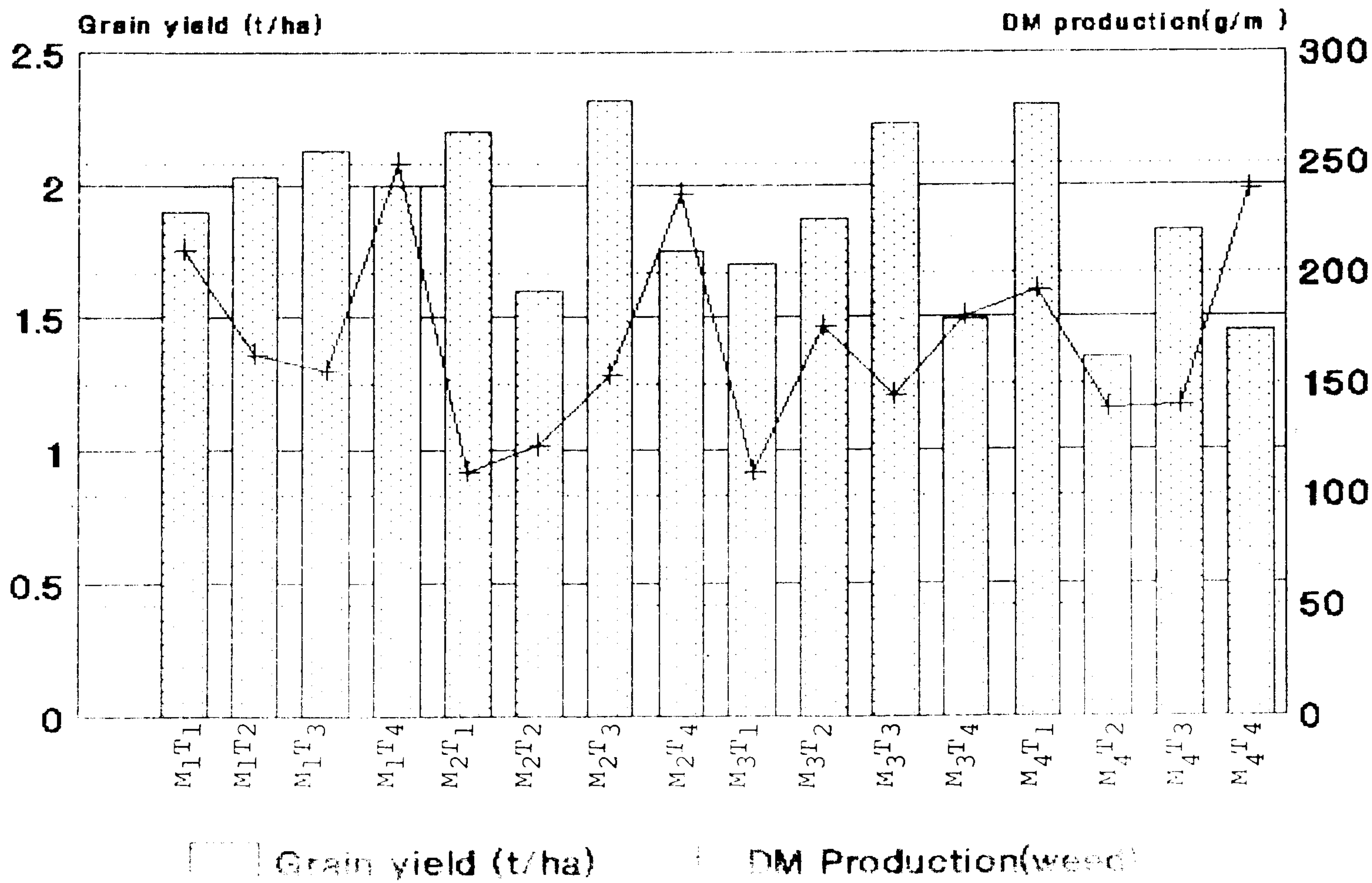
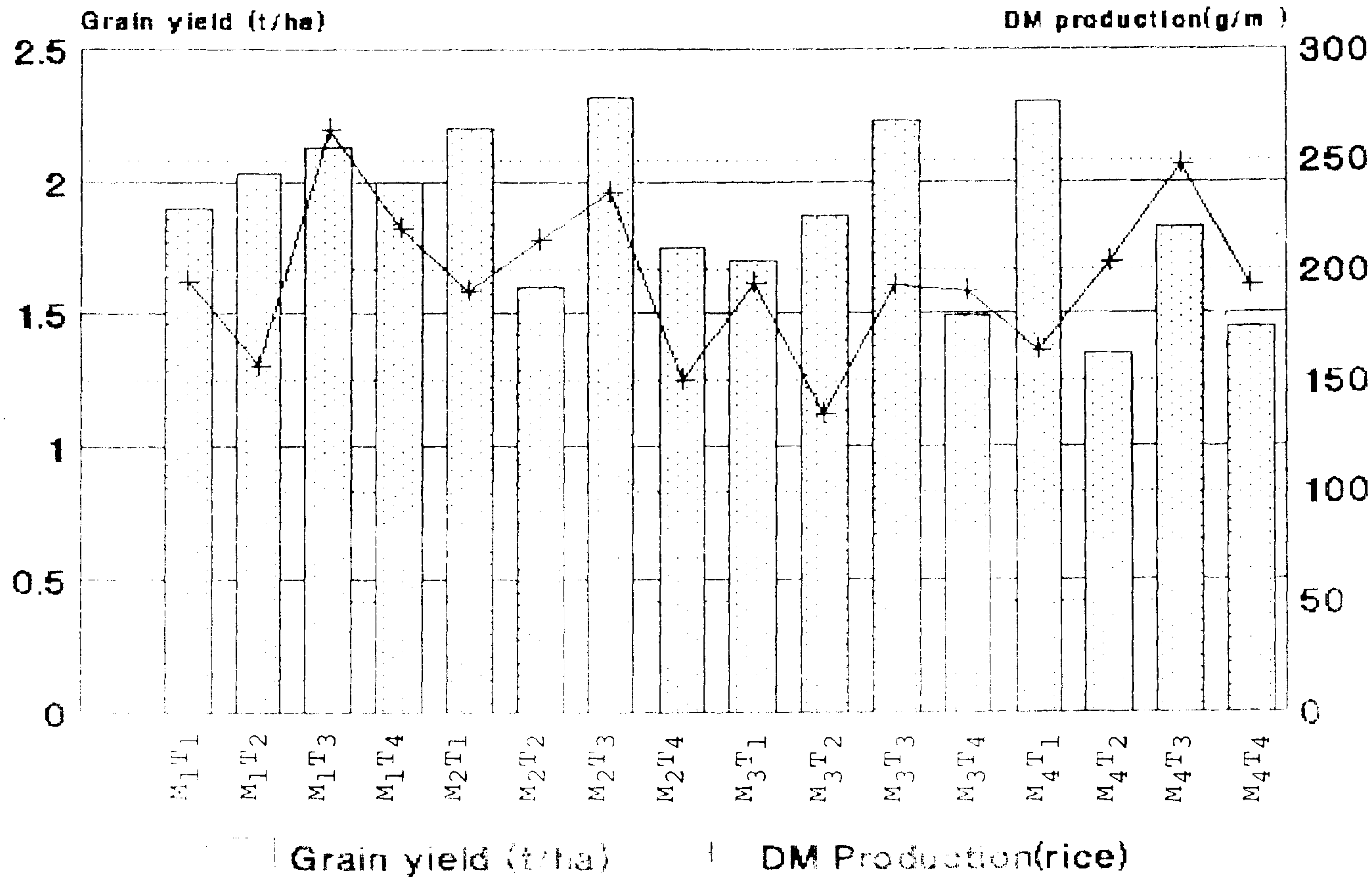


Fig 4. Grain yield and dry matter production of rice at 60 DAS



This is in confirmity with the findings of Ali and Sankaran (1984), Verma *et al.* (1987), Choudhary and Pradhan (1989) and Mishra *et al.* (1990) wherein higher grain yields were recorded in rice with the application of pendimethalin.

(b) Straw yield (Table 27)

Pendimethalin recorded the highest straw yield among herbicides and was comparable with oxyfluorfen. Handweeded plots were superior to herbicide treated plots. Unweeded control had the lowest straw yield.

Interaction effect of time of application and herbicide was not significant in the case of straw yield. However pendimethalin applied at 3 DAS registered the highest value for straw yield. The highest number of productive tillers in the same combination might have contributed to higher straw yield.

(c) Harvest index (Table 27)

Pendimethalin and butachlor were comparable with respect to harvest index. The above two herbicides were significantly superior to handweeding. Unweeded control recorded the lowest harvest index.

From the results, though the harvest index values for pendimethalin and butachlor were similar, grain yields were more in pendimethalin applied plots indicating the better conversion of biological yield into economic yield. However, interaction between herbicides and time of application was not significant. This reveals that the time of application of herbicides had no effect on the process of conversion of biological yield into economic yield.

4.3 Studies on nutrient uptake

4.3.1 Removal by weeds

(a) Nitrogen (Table 29, 30 and Appendix-III)

Among the herbicides, thiobencarb recorded the lowest value for N removal at 30 DAS and was comparable with oxyfluorfen and butachlor. On the other hand at 60 DAS, oxyfluorfen gave the lowest N removal by weeds followed by pendimethalin and butachlor which were similar. However at both the stages, the least N removal was registered by handweeded control and the highest by unweeded control.

Interaction between herbicides and time of application showed that the lowest value of N removal was recorded at 60 DAS by oxyfluorfen applied at 6 DAS and was on par with its application at 3 and 9 DAS. This was comparable with the application of pendimethalin at 0, 6 and 9 DAS.

The above results reveal that oxyfluorfen, being a contact herbicide, will control weeds more effectively when applied at the emerging stage rather than at the seed stage reducing the N removal. But with respect to the application of pendimethalin, weeds were more affected when the chemical was applied at 3 DAS leading to a reduction in N removal.

(b) Phosphorus (Table 32 and Appendix-IV)

Significant difference in phosphorus removal by weeds at 30 DAS was noticed between herbicides where in the lowest value of phosphorus removal was recorded by thiobencarb. Handweeded plots registered lowest P removal and unweeded control removed the highest quantity of phosphorus. The lack of significance in phosphorus removal at 60 DAS, may be because phosphorus is mostly needed for

Table 29. Effect of herbicides and time of application on the removal of nitrogen by weeds (kg ha^{-1})

Treatments	Stages	
	30 DAS	60 DAS
M_1 (0 DAS)	12.36	17.80
M_2 (3 DAS)	7.68	20.71
M_3 (6 DAS)	5.61	12.57
M_4 (9 DAS)	12.54	15.38
SEm±	0.53	0.66
CD (0.05)	1.83	2.28
T_1 (Oxyfluorfen)	8.97	12.40
T_2 (Butachlor)	8.79	14.91
T_3 (Pendimethalin)	11.87	14.03
T_4 (Thiobencarb)	8.57	25.12
H.W.	1.60	3.92
U.W.C.	40.10	33.70
SEm±	0.49	1.09
CD (0.05)	1.43	3.18

Stages of observation	Main plot	Sub plot
30 DAS	M_3M_2 $\overline{M_1M_4}$	$\overline{T_4T_2\ \ T_1T_3}$
60 DAS	M_3M_4 M_1M_2	$\overline{T_1T_3\ \ T_2}T_4$

Table 30. Interaction effect of herbicides and time of application on the removal of nitrogen by weeds at 60 DAS (kg ha^{-1})

Treatments	0 DAS	3 DAS	6 DAS	9 DAS	Mean
T_1 (Oxyfluorfen)	16.17	12.30	8.50	12.60	12.40
T_2 (Butachlor)	19.83	13.73	14.07	12.00	14.90
T_3 (Pendimethalin)	11.27	22.73	10.13	11.97	14.03
T_4 (Thiobencarb)	23.93	34.07	17.53	24.93	25.12
Mean	17.80	20.70	12.56	15.36	

SE of interaction of time of application and herbicides = 2.20
CD of above at 5 per cent level = 6.42

Table 31. Effect of herbicides and time of application on the removal of phosphorus by weeds (kg ha^{-1})

Treatments	Stages	
	30 DAS	60 DAS
M_1 (0 DAS)	4.50	3.63
M_2 (3 DAS)	1.63	2.38
M_3 (6 DAS)	1.62	2.89
M_4 (9 DAS)	3.48	2.28
SEm ±	0.16	0.67
CD (0.05)	0.55	NS
T_1 (Oxyfluorfen)	2.52	2.68
T_2 (Butachlor)	2.76	2.54
T_3 (Pendimethalin)	3.48	3.00
T_4 (Thiobencarb)	2.47	2.96
H.W.	0.76	1.68
U.W.C.	11.40	12.20
SEm ±	0.22	0.29
CD (0.05)	0.64	NS

Stages of observation	Main plot	Sub plot
30 DAS	$\overline{M_3M_2}$ M_4M_1	$\overline{T_4T_1}$ T_2T_3
60 DAS	NS	NS

the root formation and establishment and is needed more in the initial stages of growth of any plant especially grain crops (Tisdale and Nelson, 1975).

(c) Potassium (Table 32, 33 and Appendix-V)

At 30 DAS, though butachlor recorded the lowest potassium drain, it was comparable with oxyfluorfen which in turn was on par with pendimethalin. However, at 60 DAS pendimethalin registered the lowest potassium removal and was similar to the removal by oxyfluorfen. At both the stages, handweeded plot gave the lowest value for potassium removal while the unweeded control the highest.

Irrespective of the stage of observation, potassium removal was higher compared to the removal of other nutrients. Varghese and Nair (1986) also reported more of potassium removal compared to nitrogen and phosphorus in rice as well as in weeds associated with rice. Substantial quantities of nutrient removal by weeds was reported by Shetty and Gill (1974), Sankaran and Mani (1975), Ravindran (1976) and Balu (1977).

4.3.2 Nutrient uptake by rice

(a) Nitrogen (Table 34, 35 and Appendix-VI)

Chemical analysis of the utilization of nitrogen by the crop revealed that at 30 DAS butachlor gave the highest value for N uptake and was comparable with pendimethalin.

On the other hand at 60 DAS, pendimethalin gave the highest value for N uptake. At harvest oxyfluorfen and pendimethalin were similar. Unweeded plots recorded lower values for nitrogen uptake when compared with the herbicide treated plots.

Fig 5. Uptake of major nutrients by rice at 60 DAS and grain yield

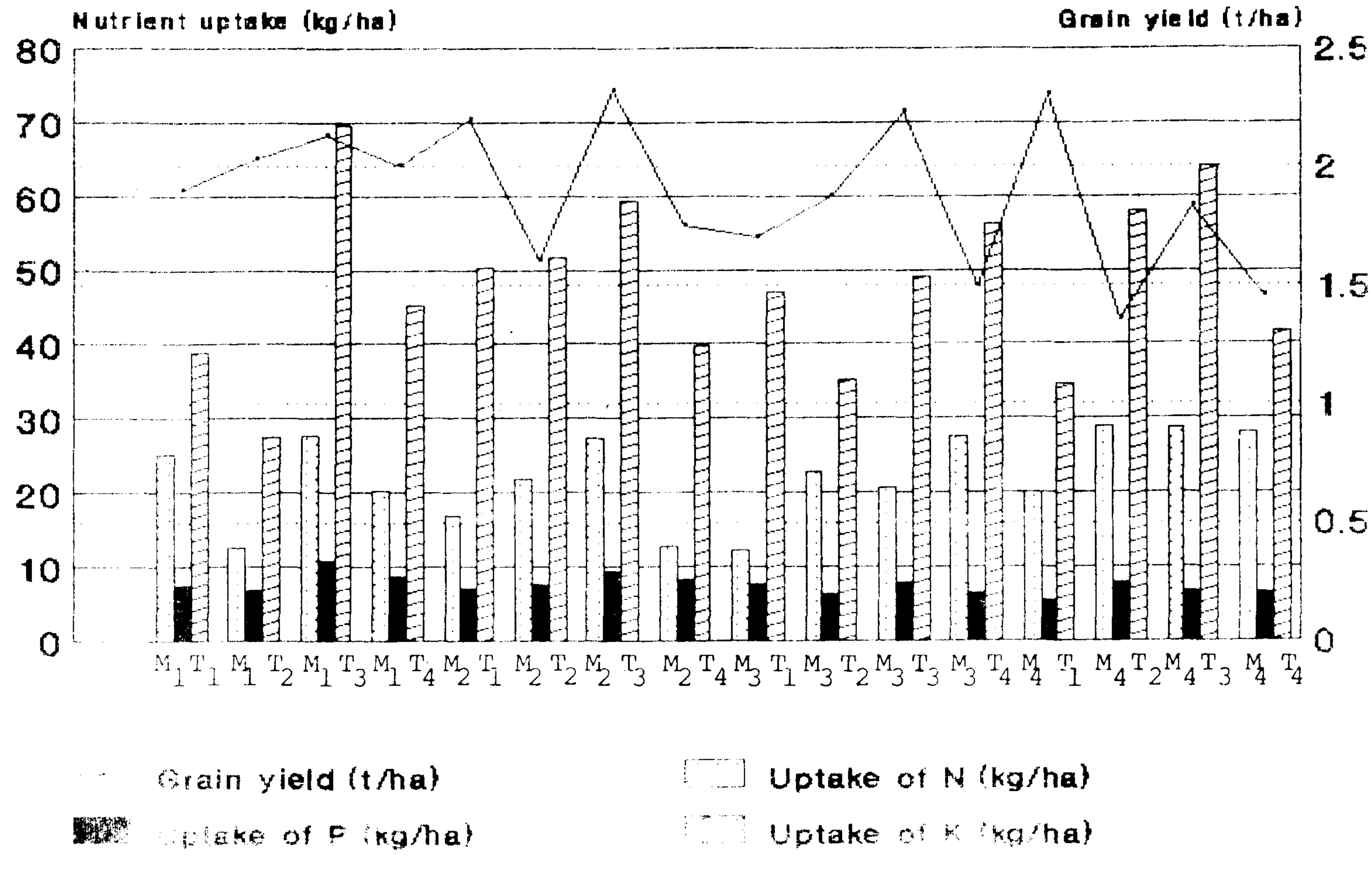


Table 32. Effect of herbicides and time of application on the removal of potassium by weeds (kg ha^{-1})

Treatments	Stages	
	30 DAS	60 DAS
M_1 (0 DAS)	30.90	30.50
M_2 (3 DAS)	21.45	26.83
M_3 (6 DAS)	16.78	32.01
M_4 (9 DAS)	29.50	37.03
SEm ±	1.25	1.49
CD (0.05)	4.33	5.16
T_1 (Oxyfluorfen)	20.80	23.99
T_2 (Butachlor)	19.60	35.61
T_3 (Pendimethalin)	23.06	23.97
T_4 (Thiobencarb)	25.40	42.85
H.W.	5.00	14.20
U.W.C.	81.00	14.60
SEm ±	1.06	1.16
CD (0.05)	3.09	3.39

Stages of observation	Main plot	Sub plot
30 DAS	$M_3M_2\ \overline{M_4M_1}$	$\overline{T_2T_1}\ T_3T_4$
60 DAS	$\overline{M_2M_1}\ M_3M_4$	$\overline{T_3T_1}\ T_2T_4$

Table 33. Interaction effect of herbicides and time of application on the removal of potassium by weeds at 60 DAS (kg ha^{-1})

Treatments	0 DAS	3 DAS	6 DAS	9 DAS	Mean
T_1 (Oxyfluorfen)	15.63	19.23	27.77	33.33	23.99
T_2 (Butachlor)	37.47	15.10	47.43	42.43	35.61
T_3 (Pendimethalin)	20.97	29.77	20.93	24.20	23.97
T_4 (Thiobencarb)	48.10	43.23	31.90	48.20	42.85
Mean	30.50	26.83	32.00	37.04	

SE of interaction of time of application and herbicides = 2.33
CD of above at 5 per cent level 6.80

Table 34. Effect of herbicides and time of application on the uptake of nitrogen by rice (kg ha^{-1})

Treatments	Stages		
	30 DAS	60 DAS	Harvest
M_1 (0 DAS)	3.80	21.43	41.44
M_2 (3 DAS)	3.87	19.67	35.92
M_3 (6 DAS)	4.04	21.08	35.59
M_4 (9 DAS)	5.15	26.46	36.78
SEm $\pm$	0.46	1.46	4.25
CD (0.05)	NS	NS	10.41
T_1 (Oxyfluorfen)	2.66	18.87	45.64
T_2 (Butachlor)	5.65	21.54	35.12
T_3 (Pendimethalin)	5.43	26.07	39.49
T_4 (Thiobencarb)	3.12	22.15	29.48
H.W.	3.24	25.76	26.50
U.W.C.	2.30	13.22	11.90
SEm $\pm$	0.31	1.47	3.33
CD (0.05)	0.91	4.29	6.87

Stages of observation	Main plot	Sub plot
30 DAS	NS	$\overline{T_2 T_3}\ \overline{T_4 T_1}$
60 DAS	NS	$T_3 T_4\ T_2 T_1$
Harvest	NS	$T_1 T_3\ T_2 T_4$

Table 35. Interaction effect of herbicides and time of application on the uptake of nitrogen by rice at 60 DAS (kg ha^{-1})

Treatments	0 DAS	3 DAS	6 DAS	9 DAS	Mean
T_1 (Oxyfluorfen)	25.23	16.83	12.27	20.13	18.87
T_2 (Butachlor)	12.57	21.77	22.87	28.97	21.54
T_3 (Pendimethalin)	27.70	27.30	20.67	28.60	26.07
T_4 (Thiobencarb)	20.20	12.77	27.50	28.13	22.15
Mean	21.42	19.67	21.08	26.46	

SE of interaction of time of application and herbicides - 2.95
CD of above at 5 per cent level 8.61

Interaction effect of herbicides and time of application at 60 DAS revealed higher values of N uptake with pendimethalin application. Irrespective of the time of application, pendimethalin applied plots recorded comparable values, with it application at 6 DAS recording the lowest N uptake. The same combinations i.e., pendimethalin at 0, 3 and 9 DAS gave higher values for yield, number of productive tillers and dry matter production of rice substantiating the above trend in N uptake.

The comparatively lower uptake of N with the application of pendimethalin at 6 DAS may be due to the coincidence of the application of the chemical with the emergence of rice seedlings, affecting further establishment and development of rice plants leading to a reduction in the N uptake.

(b) Phosphorus (Table 36 and Appendix-VII)

Uptake of phosphorus at 30 DAS revealed the superiority of pendimethalin over other herbicides. At 60 DAS there was no significant difference between herbicides. However at harvest, oxyfluorfen and pendimethalin were similar with pendimethalin giving the highest value.

Pendimethalin was significantly superior than handweeding at 30 DAS but at 60 DAS handweeding was significantly superior to pendimethalin in the case of phosphorus uptake. However, at harvest, handweeding was similar to pendimethalin and oxyfluorfen application.

Interaction effect of herbicides and time of application was significant at 60 DAS. Pendimethalin application at 0 and 3 DAS gave the highest P uptake and was comparable with thiobencarb at 0 DAS. From the results, the uptake of P also followed the same trend as that of N. Pendimethalin and oxyfluorfen gave comparable values indicating the superiority of the above chemicals in checking weeds ultimately leading to higher phosphorus uptake by rice plants.

Table 36. Effect of herbicides and time of application on the uptake of phosphorus by rice (kg ha^{-1})

Treatments	Stages		
	30 DAS	60 DAS	Harvest
M_1 (0 DAS)	1.33	5.95	11.15
M_2 (3 DAS)	1.39	5.33	13.39
M_3 (6 DAS)	1.89	4.69	11.07
M_4 (9 DAS)	1.95	3.35	11.89
SEm±	0.08	0.73	1.48
CD (0.05)	0.28	NS	NS
T_1 (Oxyfluorfen)	1.09	4.88	13.38
T_2 (Butachlor)	1.76	4.74	10.33
T_3 (Pendimethalin)	2.34	5.14	13.81
T_4 (Thiobencarb)	1.08	4.56	9.99
H.W.	2.16	8.30	6.88
U.W.C.	1.60	3.80	5.60
SEm±	0.08	4.56	0.76
CD (0.05)	0.23	NS	1.57

Stages of observation	Main plot	Sub plot
30 DAS	$\overline{M_4M_3}$ $\overline{M_2M_1}$	T_3T_2 $\overline{T_4T_1}$
60 DAS	NS	NS
Harvest	NS	$\overline{T_3T_1}$ $\overline{T_2T_4}$

(c) Potassium (Table 37, 38 and Appendix-VIII)

At 30 and 60 DAS pendimethalin was superior to all other herbicides whereas at harvest oxyfluorfen was superior to the rest of the herbicides tested. Handweeding was superior to pendimethalin only at 60 DAS, while unweeded control recorded lower potassium uptake at 60 DAS and at harvest.

Interaction effect of herbicides and time of application was significant at 60 DAS. Pendimethalin at 0 DAS gave the highest potassium uptake and was comparable with pendimethalin at 3 and 9 DAS. The same trend was noticed with dry matter production of rice, productive tiller number and also grain yield indicating the effective utilization of the nutrient absorbed.

However, in general, the nutrient uptake by rice irrespective of the stages of observation, were lower. This might be due to the excessive uptake of nutrients by the weeds consequent to the severe weed infestation and competition. Though high intensity rains were received frequently, proper and continuous flooding could not be achieved after about 3 to 4 leaf stage of the crop due to the slightly elevated nature of the cropped field. This attributed to excessive weed growth and nutrient removal.

4.4 **Economics** (Table 39 and Appendix-IX)

The highest total returns was obtained from handweeded plot. Pendimethalin applied at 3 DAS had the next highest total returns followed by oxyfluorfen application at 9 DAS. The lowest total returns was recorded by the unweeded control

With regard to the return per rupee invested, pendimethalin at 3 DAS

Table 37. Effect of herbicides and time of application on the uptake of potassium by rice (kg ha^{-1})

Treatments	Stages		
	30 DAS	60 DAS	Harvest
M_1 (0 DAS)	9.19	45.32	55.53
M_2 (3 DAS)	9.60	50.26	43.06
M_3 (6 DAS)	12.62	46.90	51.72
M_4 (9 DAS)	14.13	49.56	41.46
SEm ±	0.71	1.95	3.35
CD (0.05)	2.46	NS	8.21
T_1 (Oxyfluorfen)	6.85	42.75	56.88
T_2 (Butachlor)	13.88	43.08	47.14
T_3 (Pendimethalin)	15.52	60.53	49.40
T_4 (Thiobencarb)	9.29	45.68	38.34
H.W.	13.80	77.00	42.44
U.W.C.	13.50	38.40	32.12
SEm ±	0.48	1.92	3.42
CD (0.05)	1.40	5.61	7.05

Stages of observation	Main plot	Sub plot
30 DAS	$\overline{M_4M_3}$ $\overline{M_2M_1}$	T_3T_2 T_4T_1
60 DAS	NS	$\overline{T_3T_4\ T_2T_1}$
Harvest	$\overline{M_1M_3}$ $\overline{M_2M_4}$	$T_1\overline{T_3\ T_2}T_4$

Table 38. Interaction effect of herbicides and time of application on the uptake of potassium by rice at 60 DAS (kg ha^{-1})

Treatments	0 DAS	3 DAS	6 DAS	9 DAS	Mean
T_1 (Oxyfluorfen)	39.00	50.37	47.03	34.60	42.75
T_2 (Butachlor)	27.57	51.60	35.23	57.93	43.08
T_3 (Pendimethalin)	69.53	59.40	49.10	64.00	60.53
T_4 (Thiobencarb)	45.17	39.60	56.23	41.70	45.67
Mean	45.32	50.30	46.89	49.56	

SE of interaction of time of application and herbicides = 3.85
CD of above at 5 per cent level = 11.24

and oxyfluorfen at 9 DAS gave the highest values. Handweeding had a lower value for return per rupee invested because of the high cost of labour involved in hand weeding operation. However unweeded control gave the lowest return.

Table 39. Economics of different treatments

Treatments	Cost of weed control operation Rs./ha	Total cost of cultivation Rs./ha	Return from grain yield Rs./ha	Return from straw yield Rs./ha	Total returns Rs./ha	Return/rupee invested (Rs.)	Expenditure for chemical weed control as % of hand weeding
M_1T_1	885	7969.4	6650	2008	8658	1.08	32.7
M_1T_2	484	7568.4	7105	1736	8841	1.17	17.9
M_1T_3	945	8029.4	7455	1872	9327	1.16	35.0
M_1T_4	1100	8184.4	7000	2152	9152	1.12	40.7
M_2T_1	885	7969.4	7700	2152	9852	1.24	32.7
M_2T_2	484	7568.4	5600	1576	7176	0.94	17.9
M_2T_3	945	8029.4	8120	2248	10368	1.29	35.0
M_2T_4	1100	8184.4	6125	2064	8189	1.00	40.7
M_3T_1	885	7969.4	5950	1576	7526	0.94	32.7
M_3T_2	484	7568.4	6545	1728	8273	1.09	17.9
M_3T_3	945	8029.4	7805	2096	9901	1.23	35.0
M_3T_4	1100	8184.4	5215	1640	6855	0.84	40.7
M_4T_1	885	7969.4	8050	1896	9946	1.25	32.7
M_4T_2	484	7568.4	4725	1456	6181	0.82	17.9
M_4T_3	945	8029.4	6405	1768	8173	1.01	35.0
M_4T_4	1100	8184.4	5075	1344	6419	0.78	40.7
H.W.	2700	9784.4	7700	2880	10580	1.08	100.0
U.W.C.	-	7084.4	1330	584	1914	0.27	-

Cost of cultivation excluding cost for weed control Rs.7084/-
Price of paddy Rs.3.50/quintal
Price of straw Rs.80/quintal
Cost of Oxyfluorfen - Rs.900/l
Cost of Butachlor - Rs.182/l
Cost of Pendimethalin - Rs.275/l
Cost of Thiobencarb - Rs.245/l
Handweeding - 2 handweeding; 90 W; Rs.30/Women
Spraying - 3 men Rs.40/man

Summary

SUMMARY

A field experiment was conducted at the Agricultural Research Station, Mannuthy during the first crop season (Virippu) to find out the best time of application of pre-emergence herbicide on phytotoxicty and weed control in semi-dry rice. The experiment was laid out in split plot design with three replications. Treatments included in the experiment were pre-emergence application of herbicides such as pendimethalin, thiobencarb, butachlor and oxyfluorfen at 0, 3, 6 and 9 days after sowing with handweeded and unweeded plots as the two controls. The important findings of the experiment are given below.

The weed spectrum of the experimental field comprised mainly of grasses and sedges. Broadleaved weeds were also present in the field. Among the grasses, *Digitaria sanguinalis* and *Cynodon dactylon* were the most predominant species. *Cyperus rotundus* and *Cyperus iria* were the sedges present in the field. The major broadleaved weeds were *Cleome viscosa* and *Ageratum conyzoides.*

The population of *Digitaria sanguinalis* reduced when pendimethalin was applied upto 6 DAS. Oxyfluorfen was effective in controlling *Cynodon dactylon* upto 45 DAS but, for its prolonged control pendimethalin was better. The total grass population was lowest for plots treated with oxyfluorfen at 6 DAS. Handweeding was significantly superior to herbicides in lowering the population of sedges and broadleaved weeds. Among the herbicides tested oxyfluorfen reduced sedge population and was comparable with thiobencarb. Number of broadleaved weeds was lower in pendimethalin treated plots throughout the crop period. At 60 DAS, though thiobencarb applied at 6 DAS recorded the lowest total weed population it was comparable with oxyfluorfen applied at 6 DAS.

Dry matter production by weeds was lowest in handweeded plots at 30 and 60 DAS with oxyfluorfen recording the lowest value among herbicides.

Handweeded plots recorded the highest weed control efficiency at 30 and 60 DAS. Among the herbicides, oxyfluorfen recorded the highest weed control efficiency at 30 DAS while pendimethalin gave the highest value at 60 DAS.

Phytotoxic symptoms were developed in rice seedlings with the application of oxyfluorfen at 6 and 9 DAS only and was later recovered by about two weeks.

No significant difference was observed between herbicides in the case of plant height as well as plant population/m row length. At 30 and 60 DAS pendimethalin treated plots gave the highest number of tillers/m^2 and were similar to oxyfluorfen and handweeding. Butachlor at 3 DAS, pendimethalin at 0 DAS and handweeding were comparable with respect to leaf area index.

Pendimethalin treated plots gave higher chlorophyll content than handweeded plots.

At 30 and 60 DAS pendimethalin gave the highest dry matter production in rice while at harvest, oxyfluorfen recorded the highest dry matter production and was comparable with pendimethalin. Interaction effect of time of application and herbicides on dry matter production of rice showed that application of pendimethalin at 0, 3 and 9 DAS were comparable and were similar to that of thiobencarb application at 0 DAS.

The highest number of productive tillers/m^2 was obtained from plots treated with pendimethalin at 3 DAS and was comparable with its application at 0, 6 and 9 DAS. Pendimethalin and oxyfluorfven treated plots recorded similar panicle length and was comparable with handweeded plots. Unweeded control recorded lowest length of panicle than all other herbicides.

Oxyfluorfen at 0 DAS recorded the highest number of grains/panicle and was comparable with oxyfluorfen and butachlor applied at 9 DAS. With regard to test weight of grains, pendimethalin at 9 DAS gave the highest value and was similar to its application at 3 and 6 DAS. It was also comparable with oxyfluorfen applied at 0, 6 and 9 DAS.

Pendimethalin at 3 DAS gave the highest grain yield and was comparable with its application at 0 and 6 DAS. In the case of straw yield and harvest index also pendimethalin gave the highest value.

Among the herbicides, oxyfluorfen at 6 DAS gave the lowest value for nitrogen removal and was similar to its application at 3 and 9 DAS. With respect to phosphorus removal by weeds at the initial stage, thiobencarb gave the lowest value and was comparable with oxyfluorfen. However, lower values for potassium removal was noticed in oxyfluorfen and pendimethalin treated plots at 30 and 60 DAS. However, weeds in the handweeded control removed the lowest quantity of nitrogen, phosphorus and potassium.

Pendimethalin was better compared to other herbicides with respect to the uptake of major nutrients by rice.

Among the herbicides tested, pendimethalin at 3 DAS and oxyfluorfen at 9 DAS recorded higher values for both total returns and return per rupee invested. Though handweeded plots recorded the highest total returns, the return per rupee invested was lower due to the high cost of labour involved in weeding operation.

Plate 1. View of the plots showing the different treatments at 90 DAS

a) Oxyfluorfen at 0.1 kg a.i/ha at 0 DAS

b) Oxyfluorfen 0.1 kg a.i/ha at 3 DAS


R1 M1 T1
Oxy 0·1 kg/ha
0 DAS


R2 M2 T1
Oxy 0·1 kg/ha
3 DAS

Plate 2. View of the plots showing the different treatments at 90 DAS

c) Oxyfluorfen at 0.1 kg a.i/ha at 9 DAS

d) Pendimethalin at 1.25 kg a.i/ha at 6 DAS


M4 T1
Oxy 0·1 kg/ha
9 DAS


R1 M3 T3
Pendi 1·25 kg/

Plate 3. View of the plots showing the different treatments at 90 DAS

e) Butachlor at 1.25 kg a.i/ha at 3 DAS


R2 M2 T2
But 1·25 kg/ha
3 DAS

Plate 4. View of the plots showing the different treatments at 90 DAS

f) Handweeded control

g) Unweeded control


R3
HW


UWC

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*Originals not seen

Appendices

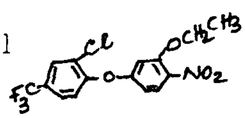
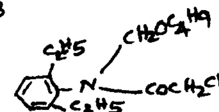
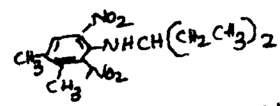
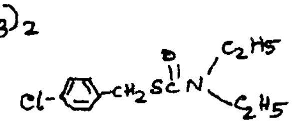
APPENDIX-I

Meteorological data (weekly average) for the experimental period
(20-5-1993 to 10-9-1993)

Standard weed No.	Month and date	Temperature °C		Total rainfall (mm)	Bright sunshine hours	Relative humidity (%)	
		Maximum	Minimum			FN	AN
21	May 21-27	34.5	24.4	6.0	6.6	88	62
22	May 28 - Jun 3	32.8	20.8	103.8	4.3	90	69
23	Jun 4-10	29.6	23.3	236.6	1.8	95	80
24	Jun 11-17	29.2	23.8	237.9	1.9	95	81
25	Jun 18-24	30.4	24.5	85.5	4.4	94	73
26	Jun 25 - Jul 1	29.2	23.6	186.4	2.9	94	82
27	Jul 2-8	28.6	22.7	188.9	2.0	95	78
28	Jul 9-15	28.7	22.6	167.8	1.8	92	83
29	Jul 16-22	28.9	22.9	128.1	2.8	94	76
30	Jul 23-29	28.0	23.1	101.0	2.9	94	80
31	Jul 30 - Aug 5	29.1	23.7	96.4	3.6	95	76
32	Aug 6-12	29.9	28.5	54.9	4.6	95	75
33	Aug 13-19	29.2	23.1	66.3	3.3	93	78
34	Aug 20-26	29.8	23.2	61.9	5.6	96	74
35	Aug 27 - Sep 2	29.8	23.5	33.6	6.5	95	73
36	Sep 3-9	29.4	23.0	23.7	3.9	93	75

APPENDIX-II

Details of herbicides used in the trial

Sl. No.	Particulars	Oxyfluorfen	Butachlor	Pendimethalin	Thiobencarb
1	2	3	4	5	6
1	Chemical name	2-chloro-1-(3-ethoxy-4 nitrophenoxy-4 trifluormethyl benzene	(N-(butoxymethyl) -2-chloro-N-chloro-N-2,6 diethyl phenyl) acetamide	N-(1-ethylpropyl)-3,4-dimethyl-2,6 dinitrobenzenamine	S(4-chlorophenyl) methyl diethyl carbamothioate
2	Structural formula				
3	Herbicide family	Diphenyl	Amides	Dinitroanilines	Thiocarbamates
4	Manufacturer	Indofil chemicals	Pest control company	Cyanamid	Pesticides India Ltd., Udaipur, Rajasthan
5	Trade name	Goal 23,5 EC	Butachlor 50 EC	Stomp 30 EC	Saturn 50 EC
6	Formulation	EC 23.5	EC 50	EC 30	EC 50
7	Physical	Melting point: 84-85°C	Boiling point: 156°C at 0.5 mm Hg.	Melting point: 56-57°C	Boiling point: 126 to 129°C at 0.008 mm Hg.
		Physical state of colour: Orange crystline solid at room temperature	Physical state: Slightly sweet aromatic amber liquid	Physical state: Orange yellow crystals	Physical state: Light yellow on brownish yellow liquid
		Vapour pressure: $2x10^{-16}$ mm		Vapour pressure: 40 μpa (25°C)	
		Solubility: (i) less than 0.1 ppm in water at 25°C			

Contd.

1	2	3	4	5	6
		Soluble in most organic solvents	Solubility: water - 23 ppm at 24°C Soluble in ether, acetone, benzene, alcohol, ethyl acetate and hexane at room temperature	Solubility: water 0.3 mg/l (20°C) Soluble in benzene, toluene, chloroform slightly soluble in petroleum ether and alcohol	Solubility: at 20°C Water - 30 ppm Readily soluble in acetone, ethyl alcohol and xylene
8	Molecular formula	$C_{15}H_{11}Cl\ F_3NO_4$	$C_{17}H_{26}Cl\ NO_2$	$C_{13}H_{19}N_3O_4$	$C_{12}H_{16}Cl\ NOS$
9	Molecular	361.72	311.9	281.31	257.8
10	Mode of action	Oxyfluorfen kills weed seedling through contact action and membrane disruption. Since light is required for herbicide activity DPE phytotoxicity is related to the process of photo-synthesis and inhibition of both electron transport and ATP synthesis.	Selective herbicide inhibits early seedling growth especially root growth. probably associated with an interfer-ence with cell division, cause cell enlargement. Inhibit nucleic acid and protein synthesis.	Selective herbicide, inhibit root and shoot growth and development. Roots which develop have swelling and thickening appear-ance and are devoid of secondary roots.	Selective herbicide, absorbed by the foliage and roots. Interferes with protein synthesis and inhibits photosynthesis.
11	Method of appli-cation	A single pre-emergence applicat-ion is recommended immediately after seeding before the emergence of crop and weeds. When used as post-emergence application, goal must be combined with paraquat, diuron MSMA or other suitable post-emergence herbi-cides	Pre-emergence soil surface treatment, application in water with trans-planted rice and as a post-emergence application in combination with propanil	Pre-emergence application	Pre-emergence to early post-emergence appli-cation in rice

Contd.

1	2	3	4	5	6
12	Average persist- ance at recomm- ended rates	Goal can remain active for a long period of time	6 to 10 weeks, varies with soil type and climatic conditions	Persistant in the soil for a few weeds	2 to 3 weeks under aerobic conditions and 6 to 8 months under anaerobic conditions

Source: WSSA (1993) Herbicide Hand Book of the Weed Science Society of America (5th Ed.) Weed Science Society of America, Illinois, pp.515

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APPENDIX-III

Nitrogen content of weeds at different stages (%)

Treatments	Stages	
	30 DAS	60 DAS
M_1T_1	1.31	0.77
M_1T_2	1.03	1.21
M_1T_3	1.45	0.98
M_1T_4	0.93	0.95
M_2T_1	1.21	1.12
M_2T_2	1.11	1.12
M_2T_3	1.35	1.26
M_2T_4	1.40	1.45
M_3T_1	1.25	0.79
M_3T_2	0.74	0.80
M_3T_3	0.79	0.70
M_3T_4	1.40	0.97
M_4T_1	1.35	0.65
M_4T_2	1.59	0.86
M_4T_3	1.17	0.86
M_4T_4	0.72	1.07
H.W.	0.80	0.70
U.W.C.	1.26	0.98

APPENDIX-IV

Phosphorus content of weeds at different stages (%)

Treatments	Stages	
	30 DAS	60 DAS
M_1T_1	0.50	0.26
M_1T_2	0.47	0.30
M_1T_3	0.35	0.35
M_1T_4	0.45	0.22
M_2T_1	0.25	0.23
M_2T_2	0.26	0.27
M_2T_3	0.30	0.22
M_2T_4	0.26	0.22
M_3T_1	0.21	0.25
M_3T_2	0.32	0.26
M_3T_3	0.27	0.31
M_3T_4	0.29	0.22
M_4T_1	0.39	0.24
M_4T_2	0.34	0.34
M_4T_3	0.34	0.38
M_4T_4	0.28	0.21
H.W.	0.38	0.30
U.W.C.	0.36	0.36

APPENDIX-V

Potassium content of weeds at different stages (%)

Treatments	Stages	
	30 DAS	60 DAS
M_1T_1	3.23	0.75
M_1T_2	2.63	2.33
M_1T_3	3.00	1.72
M_1T_4	3.23	1.70
M_2T_1	3.60	1.80
M_2T_2	2.70	1.27
M_2T_3	3.50	1.97
M_2T_4	3.57	1.87
M_3T_1	2.50	2.53
M_3T_2	3.00	2.70
M_3T_3	3.20	1.23
M_3T_4	2.73	1.80
M_4T_1	2.73	1.77
M_4T_2	2.33	3.07
M_4T_3	3.00	1.77
M_4T_4	2.87	2.03
H.W.	3.50	2.30
U.W.C.	2.20	1.10

APPENDIX-VI

Nitrogen content in rice at different stages (%)

Treatments	30 DAS	60 DAS	Harvest	
			Straw	Grain
M_1T_1	1.07	1.31	0.79	0.97
M_1T_2	1.26	0.69	0.92	0.77
M_1T_3	0.79	0.92	0.80	0.86
M_1T_4	1.21	0.91	0.65	0.83
M_2T_1	0.84	0.89	0.73	0.92
M_2T_2	1.35	0.86	0.73	0.93
M_2T_3	1.49	1.17	0.65	0.86
M_2T_4	0.84	1.03	0.83	0.91
M_3T_1	1.40	0.69	0.77	0.86
M_3T_2	1.03	1.45	0.78	0.86
M_3T_3	0.84	1.12	0.77	0.91
M_3T_4	0.89	1.26	0.78	0.84
M_4T_1	1.43	1.01	0.97	0.56
M_4T_2	1.45	1.25	0.97	0.83
M_4T_3	0.87	1.21	0.77	0.77
M_4T_4	0.84	1.21	0.77	0.59
H.W.	1.40	1.12	0.98	0.98
U.W.C.	0.56	1.12	0.70	0.80

APPENDIX-VII

Phosphorus content in rice at different stages (%)

Treatments	30 DAS	60 DAS	Harvest	
			Grain	Straw
M_1T_1	0.46	0.38	0.16	0.17
M_1T_2	0.39	0.45	0.25	0.13
M_1T_3	0.45	0.41	0.26	0.24
M_1T_4	0.46	0.41	0.32	0.29
M_2T_1	0.49	0.37	0.32	0.30
M_2T_2	0.49	0.37	0.22	0.24
M_2T_3	0.47	0.41	0.21	0.27
M_2T_4	0.35	0.46	0.32	0.19
M_3T_1	0.45	0.39	0.27	0.17
M_3T_2	0.35	0.47	0.28	0.25
M_3T_3	0.48	0.40	0.26	0.28
M_3T_4	0.51	0.35	0.22	0.27
M_4T_1	0.47	0.35	0.26	0.27
M_4T_2	0.40	0.38	0.28	0.27
M_4T_3	0.44	0.31	0.26	0.31
M_4T_4	0.45	0.31	0.28	0.25
H.W.	0.54	0.36	0.11	0.36
U.W.C.	0.36	0.33	0.11	0.21

APPENDIX-VIII

Potassium content in rice at different stages (%)

atments	30 DAS	60 DAS	Harvest	
			Grain	Straw
M_1T_1	2.77	2.33	0.17	1.73
M_1T_2	3.22	1.60	0.20	2.10
M_1T_3	3.13	2.67	0.27	1.72
M_1T_4	3.03	2.10	0.22	1.63
M_2T_1	3.10	2.67	0.18	2.00
M_2T_2	2.87	2.40	0.22	1.67
M_2T_3	3.37	2.53	0.17	1.46
M_2T_4	3.13	2.60	0.22	1.67
M_3T_1	3.00	2.73	0.23	1.53
M_3T_2	3.17	2.57	0.23	2.47
M_3T_3	2:80	2.67	0.12	1.90
M_3T_4	3.20	2.60	0.20	2.10
M_4T_1	3.00	2.17	0.15	1.53
M_4T_2	3.23	2.86	0.18	1.08
M_4T_3	3.17	2.60	0.20	1.97
M_4T_4	3.00	2.47	0.15	1.57
H.W.	3.45	3.85	0.25	0.60
U.W.C.	3.00	3.25	0.10	1.20

APPENDIX-IX

Cost of cultivation excluding cost for weed control (Rs./ha)

Particulars	Cost of	Labour wages			Total
		Tractor	Men	Women	
1. Land preparation (Tractor 12 hrs + 8 M + 3 W)	--	1707.50	320	90	2117.50
2. Seed (80 kg)	520	--	-	-	520.00
Dibbling (25 W)	--	--	-	750	750.00
3. Fertilizer					
Urea (198 kg/ha)	554.40	--	-	-	554.40
Mussoriphos (225 kg/ha)	405.00	--	-	-	405.00
M.O.P. (75 kg/ha)	352.50	--	-	-	352.50
Application (3 M)	--	--	120	-	120.00
4. Plant protection					
Metacid (500 ml)	195.00	--	-	-	195.00
Spraying (2 M)	--	--	80	-	80.00
5. Water management (5 M)	--	--	200	-	200.00
6. Harvest operations					
Harvesting (22 W)	--	--	-	660	660.00
Threshing (20 W)	--	--	-	600	600.00
Cleaning and drying (2 M + 15 W)	--	--	80	450	530.00
Total	2026.90	1707.50	800	2550	7084.40

Seeds	Insectices	Fertilizers	Labour charges
Paddy seeds Rs.6.50/kg	Metacid (500 ml)	Urea Rs.2.80/kg	Man @ Rs.40/day
		Mussoriphos 1.8 kg/ha	Woman @ Rs.30/day
		MOP Rs.4.70/kg	Tractor @ Rs.140/hr

APPENDIX-X

ABSTRACT OF ANOVA

Source	df	Mean squares							
		Digitaria sanguinalis count				*Cynodon dactylon* count			
		15 DAS	30 DAS	45 DAS	60 DAS	15 DAS	30 DAS	45 DAS	60 DAS
Replication	2	0.40	0.42	0.40	0.112	5.97	29.52	101.37	19.88
Main plot	3	3.67	7.83*	1.03	14.70**	237.21**	94.75	651.39	2151.74*
Error (a)	6	0.99	0.15	1.53	0.22	12.32	23.52	75.96	61.86
Subplot	3	12.69**	3.97*	1.45	53.45**	462.96**	49.14	555.58**	787.02**
Interaction	9	1.20	2.51*	2.46	8.38**	145.56**	104.69*	1041.31**	973.57**
Error (b)	24	0.70	0.25	1.23	0.12	12.00	38.4	68.43	15.78

* Significant at 5 per cent

** Significant at 1 per cent level

APPENDIX-XI
ABSTRACT OF ANOVA

Source	df	Mean squares							
		Sedges (plants/m²)				Grass (plants/m²)			
		15 DAS	30 DAS	45 DAS	60 DAS	15 DAS	30 DAS	45 DAS	60 DAS
Replication	2	47.58	2.15	25.19	19.39	89.77	52.08	30.27	30.33
Main plot	3	348.24**	2015.74**	1214.69**	465.29**	177.74	116.79*	4433.00**	13295.67**
Error (a)	6	3.81	41.12	6.94	1.26	146.16	14.61	63.27	203.33
Subplot	3	436.24**	878.74**	410.74**	66.85**	101.13	126.52**	2299.39**	2707.89**
Interaction	9	451.95**	648.93**	719.24**	144.29**	98.09	236.84**	1519.94**	1789.52**
Error (b)	24	17.42	40.15	46.97	9.46	128.06	13.09	47.08	137.94

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

APPENDIX-XII
ABSTRACT OF ANOVA

Source	df	Mean squares							
		Broad leaved weeds (plants/m²)				Total weed population (plants/m²)			
		15 DAS	30 DAS	45 DAS	60 DAS	15 DAS	30 DAS	45 DAS	60 DAS
Replication	2	29.19	2.65	69.27	0.22	48.27	31.02	343.94	181.31
Main plot	3	20.70	602.22**	900.36**	0.98	244.03*	3557.50**	9967.64**	25954.19**
Error (a)	6	28.33	17.20	81.29	3.61	31.88	13.35	149.41	95.98
Subplot	3	49.36	225.06**	6.69	6.98	366.14**	654.00**	3260.53**	4525.02**
Interaction	9	22.86	164.79**	255.27**	8.93	675.34**	1151.79**	3231.19**	3782.28**
Error (b)	24	28.02	7.92	34.88	5.69	51.73	40.74	157.49	110.42

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

APPENDIX-XIII
ABSTRACT OF ANOVA

Source	df	Mean squares			
		Weed dry matter production (g/m²)		Weed control efficiency	
		30 DAS	60 DAS	30 DAS	60 DAS
Replication	2	67.52	793.94	17.55	34.58
Main plot	3	10196.08**	2081.08*	812.13**	391.91**
Error (a)	6	120.69	845.74	11.75	16.15
Subplot	3	2610.08**	8156.83**	265.53**	1410.89**
Interaction	9	1596.31**	2653.13**	125.17**	245.46**
Error (b)	24	201.15	876.71	9.92	6.42

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

APPENDIX-XIV
ABSTRACT OF ANOVA

Source	df	Mean squares							
		Plant population/ row length 30 DAS	No. of tillers/ m²		Leaf area index at 60 DAS	Chlorophyll content at 60 DAS	Dry matter production g/m²		
			30 DAS	60 DAS			30 DAS	60 DAS	Harvest
Replication	2	2.65	56.25	2986.94	1.07	0.667*	8.39	793.94	6994.02*
Main plot	3	1.24	1025.00	17650.31*	1.74	0.02	703.39**	2081.08	11752.85**
Error (a)	6	1.62	331.25	1823.49	1.69	0.11	52.04	845.74	1101.85
Subplot	3	0.58	1325.00	13909.81**	2.43	0.13	1859.83**	8156.83**	24896.91**
Interaction	9	1.29	275.00	2533.81	2.74*	0.26	487.11**	2653.13*	6508.74**
Error (b)	24	0.85	312.50	1876.91	0.89	0.28	26.77	876.71	1634.54

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

APPENDIX-XV

ABSTRACT OF ANOVA

Source	df	Mean squares				
		Plant height at harvest (cm)	No. of effective tillers/m²	Length of panicle (cm)	Grains/ panicle	1000 grain weight (gm)
Replication	2	277.83**	2413.67*	5.01	312.06	4.11
Main plot	3	296.75**	5210.28**	8.39*	48.39	3.74
Error (a)	6	19.65	417.53	1.73	156.54	[illegible].23
Subplot	3	45.27	6094.36**	13.73**	151.06	6.69*
Interaction	9	75.71	3291.53**	7.29**	345.00*	3.15
Error (b)	24	37.22	815.94	0.97	106.89	1.69

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX-XVI

ABSTRACT OF ANOVA

Source	df	Mean squares		
		Grain yield	Straw yield	Harvest index
Replication	2	0.006	0.25	0.003
Main plot	3	0.18	0.59	0.003
Error (a)	6	0.06	0.21	0.003
Subplot	3	0.61*	0.48*	0.005*
Interaction	9	0.22	0.22	0.002
Error (b)	24	0.06	0.16	0.001

* Significant at 5 per cent level

APPENDIX-XVII
ABSTRACT OF ANOVA

Source	df	Mean squares					
		Nitrogen		Phosphorus		Potassium	
		30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS
Replication	2	1.75	0.85	0.192	81.61	6.56	25.74
Main plot	3	143.45**	144.35**	24.49**	4.54	542.93**	214.12*
Error (a)	6	3.42	5.28	0.29	5.45	18.79	26.57
Subplot	3	28.97**	398.66**	2.62*	0.59	429.57**	1035.14**
Interaction	9	27.56**	53.84**	1.96**	1.13	116.84**	272.71**
Error (b)	24	2.92	14.33	0.57	1.03	13.711	16.25

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

APPENDIXE-XVIII
ABSTRACT OF ANNOVA

Source	df	Mean square								
		Nitrogen			Phosphorus			Potassium		
		30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest
Replication	2	2.84	0.98	41.47	0.025	249.42	194.89	1.24	54.20	33.55
Main plot	3	4.77	105.64	106.70	1.263*	14.87	7.28	68.11**	63.75	484.61**
Error (a)	6	2.55	25.49	16.23	0.073	6.47	8.15	5.99	45.56	13.19
Sub plot	3	28.60**	105.96*	272.92**	3.52**	0.72	21.25**	192.79**	856.07**	673.49**
Interaction	9	8.46**	101.84**	74.36**	1.15**	3.81	8.08	54.95**	359.29**	297.45**
Error (b)	24	1.19	26.03	5.21	0.08	2.39	4.02	2.81	44.38	14.51

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

TIME OF APPLICATION OF PRE-EMERGENCE HERBICIDES ON PHYTOTOXICITY AND WEED CONTROL IN SEMI-DRY RICE

By

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ABSTRACT OF A THESIS

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ABSTRACT

A field experiment entitled 'Time of application of pre-emergence herbicides on phytotoxicity and weed control in semi-dry rice' was conducted during first crop season (Virippu) of 1993 i.e., from May to September at Agricultural Research Station, Mannuthy under the Kerala Agricultural University, Vellanikkara, Thrissur. The objective of the trial was to find out the best time of application of pre-emergence herbicides on phytotoxicity and weed control in semi-dry rice. The experiment was laid out in split plot design with three replications. Treatments included in the trial were pre-emergence application of herbicides such as pendimethalin, thiobencarb, butachlor and oxyfluorfen at 0, 3, 6 and 9 days after sowing with handweeded and unweeded plots as the controls.

The dominant weeds found in the experimental field were *Digitaria sanguinalis* and *Cynodon dactylon* among grasses, *Cyperus rotundus* and *Cyperus iria* among sedges and *Cleome viscosa* and *Ageratum conyzoides* among broadleaved weeds.

The population of grasses was reduced by the application of oxyfluorfen at 6 DAS and pendimethalin upto 6 DAS. Handweeding was significantly superior than the herbicides in lowering the number of sedges and broadleaved weeds. At 30 DAS the highest weed control efficiency was recorded by oxyfluorfen. Though phytotoxic symptoms were developed in rice seedlings where oxyfluorfen was applied at 6 and 9 DAS, it later recovered by about two weeks.

Pendimethalin and oxyfluorfen treated plots gave the highest number of tillers/m^2. Chlorophyll content of leaves and dry matter production of rice were

more in pendimethalin treated plots. Yield attributing characters and yield were higher in plots treated with pendimethalin at 3 DAS. Total returns and return per rupee invested were higher in the case of pendimethalin at 3 DAS and oxyfluorfen at 9 DAS.