COMBINED APPLICATION OF GRANULAR PREPARATIONS OF PRE-EMERGENT HERBICIDES AND FERTILIZERS IN RICE

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DECLARATION

I hereby declare that the thesis entitled **"Combined application of granular preparations of pre-emergent herbicides and fertilizers in rice"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara
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CERTIFICATE

Certified that the thesis entitled **"Combined application of granular preparations of pre-emergent herbicides and fertilizers in rice"** is a record of the research work done independently by **Miss. Bindu N. K.** 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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BINDU N. K.

In loving memory of my Father

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Introduction

INTRODUCTION

Among various pests, weeds cause the highest annual loss of 35 per cent equivalent to Rs. 1980 crores to Indian food production (Ahuja and Yaduraju, 1994). The intensive cultivation has created a number of complex and dynamic weed problems. The yield reduction due to weeds in rice is in the tune of 40 to 50 per cent (Singh and Singh, 1993). Rice cultivation is highly labourious and weed control operations constitute the bulk of cultivation cost. Conventional handweeding is time consuming and costly. Moreover, the availability of labourers is rather difficult now a days. Chemical weed control offers the most practical means of reducing weed competition, crop losses and labour costs.

Use of pre-emergence herbicides has been widely accepted. The recommended basal application of fertilizers before planting of rice often becomes impracticable under farmers' condition due to several reasons and it usually coincides with the time of pre-emergent herbicide application. If done in a single operation, considerable time, energy and cost of weed control can be saved. However, studies are to be conducted on synergistic and antagonistic interaction between the chemicals which can affect both the herbicide and fertilizer use efficiency, plant growth and yield.

Butachlor, anilofos and oxyflourfen are the recommended pre-emergence herbicides for rice weed control. Spray application of these herbicides as usually recommended requires the service of skilled labourers. Sometimes the spraying can become less efficient due to drift problems. Spraying is a costly operation and warrants the need of sprayers which a small farmer can hardly afford. Hence granular herbicide formulations are preferred, due to their easiness of uniform application, less phytotoxicity, longer residual action and low application cost. However granular formulations are costly and not easily available when compared to EC formulations. An alternative method to this would be the application of EC formulations coated on sand which may prove equal or more effective for weed control, with less cost. Hence an experiment was conducted with the following objectives.

1. To study the relative efficiency of granular preparations of herbicides over EC formulations.

2. To test the compatability and efficiency of herbicide - fertilizer mixtures in terms of phytotoxicity, weed control, yield and cost involved.

Review of Literature

REVIEW OF LITERATURE

The severity of weed infestation, non-availability of labour during peak season, increasing cost of labour etc. has led to the popularisation of chemical weed control in rice. Use of pre-emergence herbicides are preferred over the post-emergence ones due to obvious reasons. Application of the basal dose of fertilizers in wet land rice culture, usually coincides with the time of pre-emergent application of herbicides. If these two operations are combined, considerable time, energy and cost of weed control can be saved. Researches done on the weed problems in rice, pre-emergence herbicides and its combined application with fertilizers etc. are reviewed.

2.1. Weed spectrum in rice

Rice is found to be infested with a wide variety of weeds, the composition of which is defined by the method of cultivation adopted and the agro-climatic conditions.

Mohankumar and Alexander (1989) reported Sphenoclea zeylanica Gaertn., Marsilea mimuta (L.), Ludwigia octovalis (Jacq.) Raven, Echinochloa colonum (L.) Link, Echinochloa crusgalli (L.) Beauv., Monochoria vaginalis (Burm.4) Pers., Brachiaria mutica (Forsk.) Stapf. and Cyperus iria (L.) as the prominent weeds in rice fields at Pattambi, Kerala. _Echinochloa colonum_ (L.) Link., _E. crusgalli_ (L.) Beauv., _Ischaemum rugosum_ Salisb., _Cyperus iria_ (L.), _Cyperus difformis_ (L.), _Fimbristylis miliacea_ (L.) Vahl., _Limnophila perennis_ and _Marselia quadrifolia_ Linn. were predominant in wet land rice fields at Moncompu, Kerala (Joy _et al_., 1991). They further reported that at 55 days after transplanting 22 per cent of the weeds were grasses, 44 per cent sedges and 34 per cent broadleaved (Joy _et al_., 1992). George _et al_. (1993) recorded _Cyperus iria_ (L.), _Scirpus_ sp., _Fimbristylis miliacea_ (L.) Vahl., _Echinochloa_ sp. and _Monochoria vaginalis_ (Burm. 4) Pers. as the predominant weeds in the rice fields in the hilly tracts of Kerala, Wynad. The important weeds in the semi-dry rice fields at Mannuthy consisted of _Digitaria sanguinalis_ (L.) Scop., _Cynodon dactylon_ (L.) Pers., _Eleusine indica_ (L.) Gaertn., _Panicum repens_ (L.) and _Dactyloctenium aegyptium_ (L.) Beauv. (Thomas, 1994). John and Sadanandan (1995) reported that _Echinochloa colonum_ (L.) Link., _Echinochloa crusgalli_ (L.) Beauv. among grasses _Cyperus difformis_ (L.), _Fimbristylis miliaceae_ (L.) Vahl. among sedges and _Monochoria vaginalis_ (Burm. 4) Pers., _Ludwigia parviflora_ Roxb., _Sphenoclea zeylanica_ Gaertn. and _Marsilia quadrifolia_ Linn. among broadleaved weeds dominated the field in wet land rice culture at Moncompu. Kurian (1995) reported that _Isachne_ miliacea Roth., Saccolepis interrupta (Willd) Stapf., Echinochloa colonum (L.) Link., Fimbristylis miliacea (L.) Vahl., Cyperus iria (L). and Monochoria vaginalis Pres. were the predominant weeds in Mannuthy, Kerala. Schoenoplectus lateriflorus Gmel., Cyperus difformis (L.) and Fimbristylis miliacea (L.) Vahl. among sedges, Monochoria vaginalis (Burm. 4) Pers., Ludwigia perennis Roxb., Nymphaea nouchali Burm., Marsilia quadrifolia Linn. and Sphenoclea zeylanica Gaertn. among broadleaved weeds were present in puddled rice fields at Mannuthy, Kerala (Mohankumar, 1995).

Rangiah et al. (1974) observed 21 weed species in transplanted rice out of which Echinochloa crusgalli (L.) Beauv., Marsilea quadrifolia Linn. and Cyperus spp. were the most common. Echinochloa spp. and Cyperus spp. were the predominant weeds in transplanted rice in Punjab and Haryana (Chauhan and Ramakrishnan, 1981). Shah et al. (1990) reported Echinochloa crusgalli (L.) Beauv., E. colonum (L.) Link., Cyperus difformis (L.), Potamageton distinctus, Rotala indica Koehne., Marsilea quadrifolia Linn., Salvinia natans Linn., Scirpus juncoides Roxb., Polygonum aviculare (L.) Lindernia procumbens, Monochoria vaginalis (Burm. 4) Pers. and Cyperus iria (L.) as the major weeds in rice fields at Jammu and Kashmir. At Shillong, Varshney (1990) reported that monocot weeds were predominant which constituted 56.9 and 68.1 per cent of total weed population. Echinochloa colonum (L.) Link., E. crusgalli (L.) Beauv., Leptochloa chinensis (L.) Nees., Monochoria vaginalis (Burm. 4) Pers., Ludwigia adsadens, Marsilea quadrifolia Linn., Cyperus difformis (L.) and C. iria (L.) were predominant at Banglore (Janardhan and Muniyappa, 1992). Scirpus spp., Eriocaulon spp., Panicum repens Jacq., Rotala verticillaris, Lindernia antipoda (L.) Alston. and Gnapholium abtusifolum (L.) were the major weeds in transplanted rice at Karnataka (Prasad et al., 1992). Gogoi and Kalita (1993) noticed Echinochloa crusgalli (L.) Beauv., E. colonum (L.) Link., Paspalum conjugatum Berg., Fimbristylis miliacea (L.) Vahl., Cyperus iria (L.), Brachiaria mutica (Forsk.) Stapf., Leersia hexandra Sw., Monochoria vaginalis (Burm. 4) Pers. and Ludwigia octovalis as the major weeds in transplanted rice. The rice fields of Punjab were infested with 56 weed species of which 12 were grasses, 32 broadleaved and 12 sedges (Sandhu and Singh, 1993).

2.2. Crop-weed competition in rice

Weeds reduce crop yields by competing with the crop for water, nutrients, light and space. Yield reduction due to weeds can vary from 15-20 per cent in transplanted rice, 30-35 per cent in wet seeded rice and over 50-60 per cent in upland rice (Smith, 1968).

2.2.1. Critical period of crop weed competition

Critical period is that particular length of time of crop growth, during which lack of proper weed control measures will result in irrepairable damage to the crop, there by causing significant reduction in crop returns.

According to Shetty and Gill (1974), the most critical period of crop-weed competition in transplanted rice was between 4-6 weeks. Ali et al. (1977) observed that weed-free condition upto 21 days from planting was sufficient for getting economic yield in transplanted rice and maintaining weed-free condition beyond three weeks did not enhance the rice yields significantly. Weeding delayed to 40th day significantly reduced the grain yield and additional weeding after 40 days did not improve the yield significantly (Singh and Tandon, 1982).

Varghese and Nair (1986) reported that more than 50 per cent of the nutrient uptake by weeds occurred by 40th day and after that rate of uptake got reduced, indicating that the competition was severe during 21-40 days even though it continued up to harvest. Weed-free environment upto 45 DAT recorded significantly higher number of panicles per unit area and a grain yield of 5.4 t per ha (Arokiaraj et al., 1989).

2.2.2. Effect of weeds on growth of rice

Several research reports are available on the effect of stress due to weeds on growth attributes of rice. Plant height was decreased due to competitive stress in unweeded plot (Noda et al., 1968). Sreedevi (1979) reported a reduction in plant height due to severe weed infestation in dry seeded rice. Mc Gregor et al. (1988) found that a population between 100 and 150 of Brachiaria platyphylla per m^2 reduced the height of rice. High weed density and weed competition reduced the height of crop (Palaikudy, 1989). According to Singh et al. (1990), excellent control of wrinkle grass with oxyflourfen resulted in a better plant height compared to unweeded control. Similarly Kurian (1995) reported that butachlor application registered significantly higher plant height at the time of harvest over unweeded control.

Ali et al. (1977) reported that butachlor @ 1.0 kg per ha resulted in better tillering comparable with weeded control. Highest number of tillers per plant was recorded in oxyflourfen and anilofos treated plots (Mohankumar, 1995).

Crop dry matter was negatively correlated with weed dry weight or weed density (Patel et al., 1985). Jayasree (1987) reported similar trend with a higher negative correlation particularly at initial growth stages of rice. Singh and Dash (1988) too observed a negative correlation between weed dry weight and crop dry weight. Rice dry matter production was reduced due to weed competition (Varshney, 1990). Kurian (1995) reported that dry matter production of crop was significantly influenced by weed control treatments at all the stages of crop growth.

2.2.3. Effect of weeds on yield attributes

Arai (1967) found out that Cyperus difformis reduced tillering, panicle numbers and spikelets per ear. The lowest number of productive tillers per m^2 was recorded in unweeded control (Rethinam and Sankaran, 1974). Weeds reduced the number of fertile tillers (Patel et al., 1986). Rathore et al. (1992) noted that the later emerged weeds interfered with crop growth causing the reduction in panicles per m^2 and grains per panicle to the extent of 5.64 and 9.8 per cent, respectively as compared to one supplementary weeding with the herbicides. Swamy et al. (1993) observed more number of productive tillers when weeds were effectively controlled.

Sheik et al. (1974) observed no significant difference in test weight of grains between various herbicide treatments. However Azad et al. (1990) reported that all the weed control treatments including handweeding produced higher test weight as compared to unweeded check. The grain weight was lower in the case of unweeded check in transplanted rice (Varshney, 1990).

2.2.4. Effect of weeds on yield of rice

Several reports are traceable in literature on the yield reduction due to weed competition in rice.

A negative correlation between the grain yield and weed weight was obtained by Verma and Mani (1967). De Datta et al. (1968) noted that grasses caused more yield reduction compared to broadleaved weeds and sedges. Smith (1968) observed that yield reduction due to weeds could vary from 15-20 per cent in transplanted rice. Chang (1973) opined that reduction in yield due to weeds varied with weed species, weed density, season, soil fertility and rice variety.

Higher weed dry matter at harvest in unweeded check resulted in grain yield reduction (Purushothaman et al. 1988). Unchecked weed growth decreased the grain yield by 2.53 t per ha (Varshney, 1990). Joy et al. (1993) reported that weeds caused an yield loss of about 29-60 per cent in wet seeded rice in Kerala. Singh and Singh (1993) reported a loss of 40 - 50 per cent in grain yield in unweeded rice fields.

2.2.5. Effect of weeds on nutrient removal

Weeds compete with rice severly for the absorption of nutrients. Reduction in uptake of nutrients by crops in presence of weeds was reported by several workers.

2.2.5.1. Nutrient uptake by crops

Swain (1967) reported a three times increase in the nitrogen uptake by rice in the absence of weeds. Significant reduction in uptake of nutrients by crops in the presence of weeds was reported by Sankaran et al. (1974). Shetty and Gill (1974) noted that the total uptake of nutrients by the crop and weeds together in the unweeded plot was less than the uptake of nutrients by the crop alone in the weed free plot. In both direct seeded and transplanted paddy, weed control measures improved the plant nutrition (Kakati and Mani, 1977). In a study, Nanjappa and Krishnamoorthy (1980) observed the highest N uptake of 98.4 kg per ha in weed-free plot and a 45 per cent decrease in N uptake in unweeded plots. The nitrogen uptake by the crop in the weed free plot was more than the combined uptake of nitrogen by the crop and weed in the weedy plot and the phosphorus and potassium uptake by crop was doubled in the absence of weeds (Lakshmi et al., 1987). Shrivastava and Solanki (1993) observed that N uptake by rice grain was 46.2 kg per ha in weedy check, while in butachlor applied treatment it was 68.9 kg per ha.

2.2.5.2. Nutrient removal by weeds

Mani (1975) reported that competition for nitrogen limited crop yields. Weeds have a large requirement for nutrients and their tissues have higher mineral nutrient content than crop plants (Alkamper, 1976). Substantial quantities of nutrient removal by weeds were reported by several workers (Rangiah et al., 1976 and Moody, 1981). Varghese and Nair (1986) reported that weeds in unweeded check removed 24, 7.9 and 30.5 kg of N, P_2O_5 and K_2O per ha in transplanted rice. The demand for the nutrients were in the order of K > N >P by crop and weed. John and Sadanandan (1989) estimated the nitrogen removal in unweeded plots to the tune of 16.2 kg per ha as compared to 2.2 kg per ha in handweeded plots in low land direct seeded rice in Kerala. Varshney (1990) reported that in weedy check nutrient uptake in kg per ha was 169 and 240.8 N, 4.94 and 12.39 P, 108.7 and 235.4 K by monocot and dicot weeds, respectively.

2.3. Chemical weeding in rice

Of all the methods of weed control, usage of herbicides is assuming importance in recent years due to prohibitive cost of labour. Rangiah et al. (1974) reported that pre-emergence application of butachlor granules was more effective and economic than post-emergence application of stam F-34. Herbicides like oxadiazon 0.5 kg per ha, butachlor 1.25 kg per ha, thiobencarb 2.0 kg per ha, pendimethalin 2.0 kg per ha, oxyfluorfen 0.1 to 0.15 kg per ha as pre-emergence application have been found effective for weed control in transplanted rice, besides being economical compared to handweeding (Krishnamurthy et al., 1983, Sawant and Jadhav, 1985, Singh and Bhandari, 1985, Patel et al., 1987). Handweeding could control the weeds efficiently and give highest total returns but recorded the lowest return per rupee invested compared to herbicidal treatments, due to the high cost of labour (Thomas, 1994 and Mohankumar, 1995).

2.3.1. Efficiency of pre-emergent herbicides in rice

The research reports on the use of butachlor, anilofos and oxyflourfen for pre-emergence weed control in rice are given below.

2.3.1.1. Butachlor

Ali et al. (1977) reported low population and dry matter production of weeds per unit area in butachlor treated plots. Balu and Sankaran (1977) reported that weed control efficiency and crop yield was maximum for penoxalin followed by butachlor. EC formulations of butachlor resulted in poorer control of weeds than granular formulations (Narayanaswamy and Sankaran, 1977). Singh and Singh (1982) reported that butachlor application was on par with two handweedings. The efficacy of butachlor in controlling weeds in transplanted rice was also reported by Verma et al., 1987 and Balaswamy and Kondap, 1989. Butachlor was found effective against many annual grasses, sedges and some broadleaved weeds (Mandal, 1990). Prusty et al. (1990) noted that weed control efficiency of butachlor was 59 per cent against 81 per cent for handweeding. Prasad et al. (1992) found that butachlor at 1.25 kg per ha was effective on broadleaved weeds, than sedges and gave yield comparable to handweeding. It could also save energy input upto 75 per cent in weed management besides giving 20 per cent more energy output than handweeding. Butachlor @ 1.5 kg ai per ha followed by one handweeding at 45 DAT was comparable to three handweedings (Rathore et al., 1992). Walia et al. (1992) reported that application of butachlor @ 1.5 kg per ha effectively controlled Echinochloa crusgalli. Application of butachlor 50 EC @ 1.5 kg ai per ha effectively controlled weeds with a weed control efficiency of 86.7 per cent (Jena et al., 1994).

Nair et al. (1974) noted that Machete @ 1 kg per ha was safe to young rice plants and caused mild leaf injury when the dose was increased to 1.5 kg per ha. Sandhu et al. (1988) reported that herbicides like butachlor, thiobencarb, oxadiazon and pendimethalin were well tolerated by rice seedlings even at higher doses when applied as sand mixed broadcasting. According to Singh et al. (1990) butachlor 1.5 kg per ha, and 2 kg per ha caused a significant reduction in plant height, dry matter accumulation and in number of tillers per m^2. However as the growth period advanced, the crop recovered.

2.3.1.2. Oxyflourfen

The effectiveness of oxyflourfen in controlling weeds and in increasing grain yields in rice was reported by many workers (Richardson et al., 1976, Chauhan and Ramakrishnan, 1981 and Rao and Gupta, 1981). Verma et al. (1987) observed that application of oxyflourfen @ 0.2 kg ai per ha provided good control of weeds than it's lower dose in transplanted rice. Effective rates of oxyflourfen were 0.24 kg ai per ha when applied at 3 DAT (Yasin et al., 1988). Varshney (1990) found that granular formulation of oxyflourfen @ 0.1 kg ai per ha was effective with a weed control efficiency of 92.2 per cent and performed significantly better than two handweedings.

Oxyflourfen gave good initial weed control without decreasing the rice seedling population (CIAT, 1979). Mukhopadhyay and Mandal (1982) reported that oxyflourfen caused yellowing of rice plants, but they recovered after two to three weeks. Similar phytotoxic effect of oxyflourfen to rice was reported by Singh and Bhandari (1985). Singh et al. (1990) noted that oxyflourfen 0.5 kg per ha caused a significant reduction in plant height and dry matter accumulation as compared to handweeding.

2.3.1.3. Anilofos

Ali and Rajan (1985) reported that *Echinochloa crusgalli* in transplanted rice was effectively controlled by pre-emergence application of 0.45 kg anilofos per ha followed by one late hoeing. Efficacy of anilofos in controlling weeds in rice was reported by several other workers (Munegowda et al., 1990; Janardhan and Muniyappa, 1992., Joy et al., 1992 and Walia et al., 1992).

About the phytotoxicity of anilofos to rice, Munegowda et al. (1990) reported that anilofos applied @ 0.6 kg per ha showed some leaf curling and discolouration, but phytotoxicity disappeared with increasing age of the crop. Joy et al. (1993) observed high toxicity to rice seedlings when anilofos was applied @ 0.4 and 0.6 kg per ha at 6 DAS. Sreedevi and Thomas (1993) also observed that application of anilofos at 0.3 to 0.45 kg per ha was toxic to rice and toxicity decreased when spraying was delayed to 10 DAS.

2.3.2. Effect of chemicals on soil fauna

Several reports are traceable in literature on the effect of chemicals on the soil fauna. Russell and Hutchinson (1909) were among the first to observe the temporary decrease in the nitrifying capacity of soil by disinfectants. Raghu and Mac Rae (1967) reported that certain insecticides stimulated nitrogen fixation in flooded soils possibly by stimulating the growth of blue green algae. Insecticides, fungicides, fumigants and biocides enhanced mineralization by destroying a part of the soil population but repeated treatment with such pesticides did not continue to increase available soil nitrogen once the population is destroyed (Jenkinson and Powlson, 1970). Dubey (1970) reported that repeated applications of pesticides, especially dithiocarbamates, to a sugar cane cultivated soil, inhibited mineralization of nitrogen and caused nitrogen deficiency. Some herbicides were highly toxic to blue green algae (Ibrahim, 1972). Grossbard and cooper (1974) observed that in some instances, nitrogen mineralization was decreased as in the case of paraquat treated barley straw (*Hordeum vulgare* L.) which decayed more slowly in soil. Certain herbicides such as haloxyfop-methyl and pendimethalin were found to be slightly detrimental to the nodulating bacteria on pigeon pea when these herbicides were used for pre-emergence weed control in pigeon pea (Thomas et al., 1994).

2.4. Emulsifiable concentrate Vs Homemade granular preparation

The high cost of sprayers and labour charges makes it economic to broadcast granules rather than spraying herbicides. But the expensive granular formulations necessitated the use of homemade granular preparations by coating emulsifiable concentrate on fine sand.

2.4.1. Effect on weeds

Zahran and Ibrahim (1975) noted that granular formulations obtained by mixing liquid herbicides with sand were superior to liquid formulations. Sand mix of oxyflourfen performed better than granular formulation when tried at the same dose (Chauhan and Ramakrishnan, 1981). Patel and Patel (1981) reported that butachlor sand mix was an effective method of herbicide application. The effectiveness of sand mix application of butachlor in weed control was also reported by Ali (1984). Hui et al. (1989) observed improved weed control when Goal 2E was diluted with water prior to sand mixing. According to Reddy and Bharghavi (1989) butachlor applied in water as spray was more effective than sand mixed application of the same. Application of sand mixed herbicide significantly reduced weed dry weight and recorded the highest weed control efficiency of 73.7 per cent than its liquid form (Srinivasan and Choudhary, 1993).

2.4.2. Crop selectivity

Sathasivan et al. (1981) observed no marked difference in field performance between spray and sand mix application of butachlor with regard to yield or crop safety. However, Kumar and Gill (1982) reported that pre-emergence application of molinate sand mix gave better performance in terms of crop selectivity than its post-emergence spray. Mohankumar (1995) reported that sand mix broadcasting of herbicides were less toxic than spray in all the herbicides except pertilachlor plus safener.

2.4.3. Growth and yield of rice

Kahlon and Singh (1978) observed that liquid formulation of machete gave good results when applied by broadcasting after mixing with sand or urea. Srinivasan (1989) observed that anilofos + 2, 4-D ethyl ester when applied as sand mixed broadcast, provided higher grain yield than handweeding in transplanted rice. According to Gogoi and Kalita (1993) broadcasting of EC sand-mix was on par with broadcasting of butachlor granules in transplanted rice in weed control and increasing crop yield.

2.5. Joint application of herbicide and fertilizer

2.5.1. Fertilizer as a herbicide synergist

Addition of ammonium sulfate to spray mixtures of certain foliar - applied herbicide enhances herbicide efficacy. The first report of this effect was 50 years ago when it was reported to "activate" the phenol herbicide DNOC (Harris and Hyslop, 1942). Brady (1970) reported that addition of ammonium nitrate greatly increased the adsorption of isocotyl ester of 2, 4, 5-T by tree leaves. Similarly ammonium sulfate and other ammonium salts have been reported to enhance the efficacy of a number of foliar - applied herbicide including glyphosate (Blair, 1975). Addition of ammonium sulphate at 0.5 per cent (w/v) concentration to glyphosate solution enhanced control of Imperata cylindrica (Rao et al., 1979).

Turner and Loader (1980) also obtained increased phytotoxicity to Agropyron repens of sprays containing 0.2 to 0.5 kg per ha glyphosate with the addition of 1 to 10 per cent (w/v) of ammonium sulfate. Salisbury et al. (1991) observed that very high rate of ammonium sulfate @ of 14 kg per ha were not desirable for enhanced glyphosate or SC-0224 activity, thus indicating the antagonistic effect of the two chemicals. Gronwald et al. (1993) reported that approximately twice as much imazethapyr was absorbed by quack grass leaves when the herbicide was applied with non ionic surfactant plus ammonium sulfate than when the herbicide was applied with non-ionic surfactant alone. The use of 28 per cent urea ammonium nitrate increased ^{14}C bentazon absorption in common cocklebur and velvet leaf, when compared with crop oil concentrate and with no adjuvant (Levene and Owen, 1994).

Guha and Singh (1988) observed that 2, 4-D, propanil, nitrofen and butachlor were compatible with urea and mixed foliar application of urea with propanil or nitrofen seemed to be synergistic. Tank mixing thiobencarb with urea was equally effective to thiobencarb alone in respect of weed control (Varshney, 1993).

2.5.2. Fertilizer as a herbicide carrier

Dickinson and Carpenter (1977) reported that liquid form of 2, 4-D @ 1 kg ai per ha mixed with top dressed urea in rice gave complete weed control. Kahlon and Singh (1978) reported that liquid formulation of machete gave good results when applied by broadcasting after mixing with sand or urea. Herbicides were more effective when formulated as wettable powders than incorporated into fertilizer granules (Ostofic and Lodeta, 1979). Arthur (1988) gave an account of the concept of impregnating fertilizer granules with herbicides immediately before application. Yadav et al. (1993) reported that application of isoproturon at pre or post emergent stage or as mixed with superphosphate applied as basal or topdressed with urea controlled weeds effectively and increased wheat yield. John and Sadanandan (1995) observed that joint application of the herbicide 2, 4-D and fertilizer urea resulted in efficient and economic weed control in transplanted rice.

MATERIALS AND METHODS

A field experiment was conducted during the first crop season of 1994, to find out the effect of combined application of granular preparation of pre-emergent herbicides and fertilizers in rice. The details of the materials used and the methods followed are presented.

3.1. Site, climate and soil

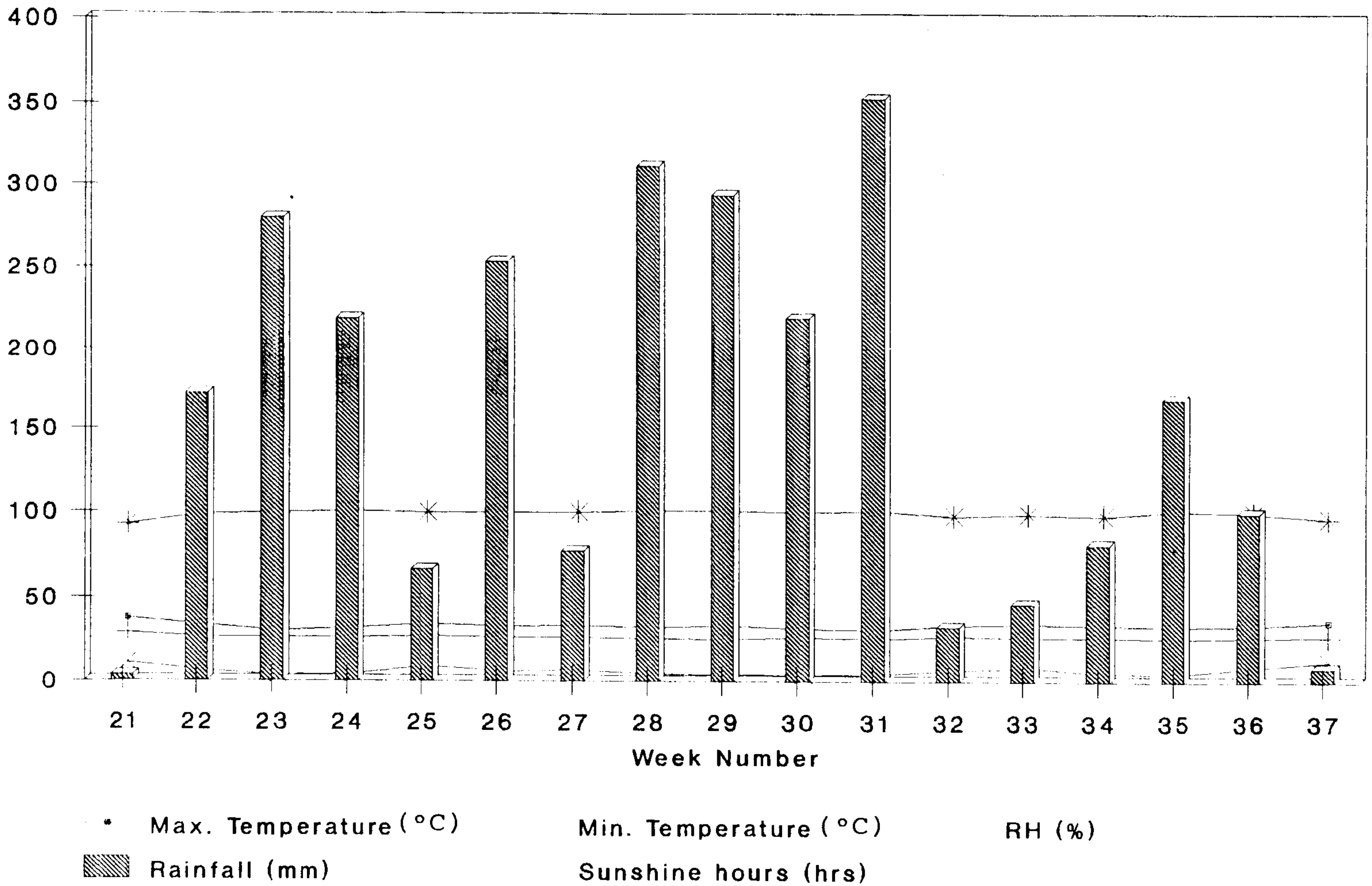
The experiment was conducted at the Agricultural Research Station, Mannuthy under Kerala Agricultural University. The research station is located at 12°32' N latitude and 74°20'E longitude. The experimental field lies at an altitude of 22 m above MSL and enjoys a typical humid tropical climate. The meteorological data during the period of investigation are presented in Fig. 1 and Appendix I.

The experimental area was a double cropped irrigated paddy and had been under vegetables during the previous season. The soil of the experimental field was sandy loam in texture. The physical and chemical properties of the soil are presented in Table 1.

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

Particulars	Value	Method	Reference
A. Mechanical composition			
Coarse sand	39.8 %		
Fine sand	22.5 %	Robinson's International Pipette method	Piper (1942)
Silt	18.5 %		
Clay	17.7 %		
Texture	sandy loam		
B. Chemical composition			
pH	5.6	pH meter	Jackson (1973)
Organic C	0.7 %	Walkely-Black	Jackson (1973)
Available P	42 kg per ha	Ascorbic acid-blue	Watanabe and Olsen (1965)
Available K	190 kg per ha	Direct reading	Jackson (1973)

Fig. 1. Weather parameters during the study period



3.2. Variety

Rice variety Annapurna with a duration of 90-100 days was used. This is a medium tillering variety with a mean height of 92 cm at harvest and has red kernels and short, bold grains.

3.3. Design and treatments

The experiment was laid out in a randomised block design with three replications. The details of treatments are as follows.

T_1	Spray application of butachlor at 3 DAT and fertilizer application at 6 DAT	Bs 3 DAT and F 6 DAT
T_2	Spray application of butachlor and fertilizer application at 3 DAT	Bs and F 3 DAT
T_3	Broadcast application of granular preparation of butachlor at 3 DAT and fertilizer application at 6 DAT	Bg 3 DAT and F 6 DAT
T_4	Combined broadcast application of granular preparation of butachlor and fertilizer at 3 DAT	(Bg+F) 3 DAT
T_5	Spray application of oxyflourfen at 3 DAT and fertilizer application at 6 DAT	Os 3 DAT and F 6 DAT
T_6	Spray application of oxyflourfen and fertilizer application at 3 DAT	Os and F 3 DAT

T_7	Broadcast application of granular preparation of oxyflourfen at 3 DAT and fertilizer application at 6 DAT	Og 3 DAT and F 6 DAT
T_8	Combined application of granular preparation of oxyflourfen and fertilizers at 3 DAT	(Og+F) 3 DAT
T_9	Spray application of anilofos at 3 DAT and fertilizer application at 6 DAT	As 3 DAT and F 6 DAT
T_{10}	Spray application of anilofos and fertilizer application at 3 DAT	As and F 3 DAT
T_{11}	Broadcast application of granular preparation of anilofos at 3 DAT and fertilizer application at 6 DAT	Ag 3 DAT and F 6 DAT
T_{12}	Combined application of granular preparation of anilofos and fertilizer at 3 DAT	(Ag+F) 3 DAT
T_{13}	Hand weeding twice on 20th and 40th DAT and fertilizer application at 3 DAT	HW and F 3 DAT
T_{14}	Unweeded control and fertilizer application at 3 DAT	Control and F 3 DAT

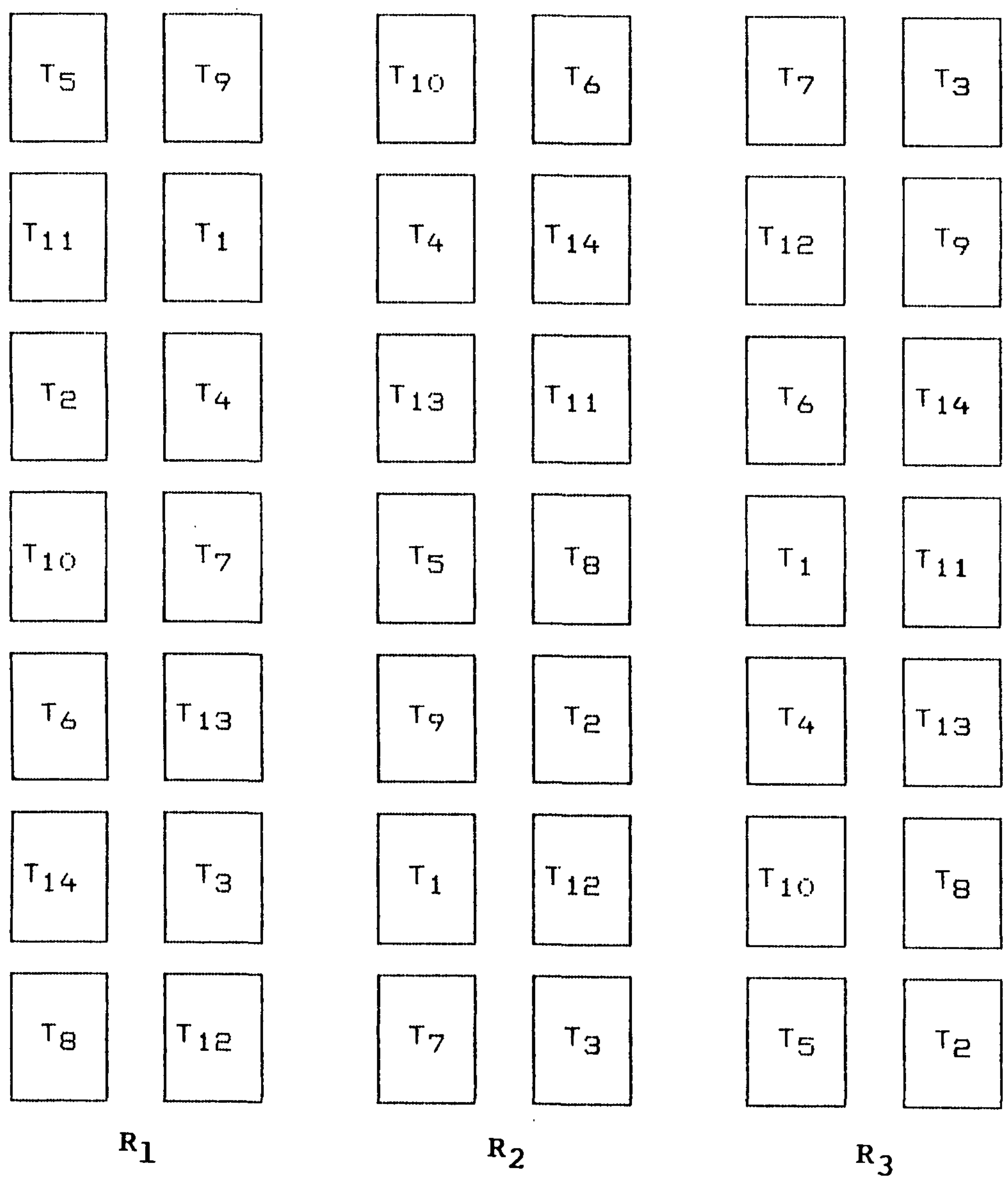
3.4 Plot size - 5 x 4 m

One m strip along the 4 m side was left for destructive sampling.

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

Fig. 2. Plan of layout



T_1 - Bs 3 DAT and F 6 DAT

T_2 - Bs and F 3 DAT

T_3 - Bg 3 DAT and F 6 DAT

T_4 - (Bg+F) 3DAT

T_5 - Os 3 DAT and F 6 DAT

T_6 - Os and 3 DAT

T_7 - Og 3 DAT and F 6 DAT

T_8 - (Og+F) 3 DAT

T_9 - As 3 DAT and F 6 DAT

T_{10} - As and F 3 DAT

T_{11} - Ag 3 DAT and F 6 DAT

T_{12} - (Ag+F) 3 DAT

T_{13} - HW and F 3 DAT

T_{14} - Control and F 3 DAT

500 l per ha. Granular preparations of herbicides were made by giving a uniform physical coating of the required EC formulation on 60 kg per ha dry fine sand immediately before application.

3.6. Herbicides

The details of herbicides used are given below

Chemical name	Commercial name	Manufacturer	Formulation
Butachlor	Machete	Monsanto chemicals	50 % EC
Oxyflourfen	Goal	Indofil chemicals	23.5 % EC
Anilofos	Aniloguard	Gharda Chemicals	30 % EC

3.7. Field culture

The soil was ploughed and puddled twice with tractor and then levelled. Seedlings were raised by wet nursery method using the seeds obtained from the Agricultural Research Station, Mannuthy. Twenty one day old seedlings were transplanted @ three seedlings per hill at a spacing of 20 X 10 cm on 16th June, 1994.

Fertilizer application was done according to the package of practices recommendations (KAU, 1993) for high yielding short duration varieties. The basal dose of half N, full P and half K were applied as per the treatments. In the case of combined application, fertilizers were thoroughly mixed with herbicide-coated sand just before broadcasting. The fertilizer materials used were factomphos and muriate of potash. One fourth dose of N and half of K were applied at maximum tillering stage in the form of urea and muriate of potash, respectively. Remaining one fourth dose of N was applied as urea one week before panicle initiation stage. Treatments were applied in a thin film of standing water in the fields. Maintaining water level at 5 cm depth was not always successful due to the sandy nature of soil, however the field was always kept under saturated condition.

3.8. Details of data collection

3.8.1. Data on soil

Soil samples were taken from four locations with the help of a spade and were mixed to make one composite sample and a representative subsample was drawn for each replication.

Soil samples were collected at 15 and 30 DAT to a depth of 15 cm for the estimation of NH_4^+ - N, NO_3^-- N and available P and K.

For soil sample collection, a circular plastic tube of 15 cm diameter and 20 cm length was pushed into the soil between four hills of rice. The flood water was removed by sucking into a wash bottle without causing any soil disturbance. The soil to a depth of 15 cm was then scooped out with hand into a polythene bag. At each sampling time, three samples were taken from each plot and combined, mixed and then subsamples were taken for extraction and moisture determination.

3.8.2. Data on weeds

The observations on weeds were taken using an iron quadrat of 50 cm x 50 size from two locations in the sampling area. The details are as follows:

a. Weed count

Number of grasses, sedges and broadleaved weeds from the sampling unit in each plot was recorded as number per m^2 at 20 DAT.

b. Dry matter production

The weeds from the sampling unit in each plot were uprooted, washed thoroughly, air dried and then dried in a hot air oven at $70^{\circ}C$. Dry weight of the weeds was recorded in g per m^2 at 20 DAT, 40 DAT and at the time of harvest.

c. Weed control efficiency

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

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

Where

X = Dry matter production of weeds in the unweeded check (g per m^2)

Y = Dry matter production of weeds in the respective treatments (g per m^2)

3.8.3. Data on crop

a. Phytotoxicity

The rice seedlings were observed for phytotoxic symptoms like discolouration and destruction of the crop due to herbicide application. Toxicity rating was done using 0-9 scale (Rao, 1983), on 2nd, 5th, 7th and 9th day after herbicide application.

b. Crop growth characters

i. Dry matter production

Four hills were cut at the base from sampling units, air dried, then oven dried and the dry matter production was recorded as g per hill. The observations were taken at 30, 45, 60 DAT and at the time of harvest,

ii. Plant height

Plant height was measured from the bottom of the culm to the tip of the longest leaf at the above mentioned intervals. Mean height of four hills at 3 locations was recorded as plant height.

iii. Number of tillers

The number of tillers were counted at 30, 45 and 60 DAT from the sampling units and the average number of tillers per hill was recorded.

c. Yield attributes

i. Productive tillers

The number of productive tillers were counted from eight hills and the average was expressed as number of productive tillers per hill.

ii. Number of filled grains per panicle

The total number of filled grains were taken from the selected four hills and the average was worked out.

iii. Thousand grain weight

Thousand filled grains were taken randomly from net plot and the weight was recorded in grams.

d. Yield of grain and straw

The grains from each net plot was dried to 14 per cent moisture and weight was recorded in t per ha. The straw from each net plot was dried under sun and weight was recorded in t per ha.

e. Weed index

Weed index of different treatments was calculated using the formula

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

Where

X = Yield obtained from the treatment that produced highest yield

Y = Yield obtained from the respective treatments

3.9 Laboratory studies

3.9.1. Soil analysis

a. NH_4^+ - N and NO_3^- - N

For the determination of NH_4^+ -N and NO_3^- - N, steam distillation method (Bremner, 1965) was followed. Wet soil samples were used for extraction and distillation. The values were expressed in kg per ha by using the formula given below :

$$\text{kg per ha} = \frac{\mu\text{g per g N x bulk density x depth of soil in cm}}{10}$$

$$\text{where, } \mu\text{g per g} = \frac{\text{ppm in extract x volume of extract in ml}}{\text{soil dry weight (g)}}$$

b. Available P and K

The soil samples were air dried, powdered gently and passed through a two mm sieve and kept for available P and K determination.

Available P in the soil was extracted by Bray No. 1 extractant and P content was determined by ascorbic acid blue colour method (Watanabe and Olsen, 1965) in a spectronic - 20 spectrophotometer. Available K in the soil was extracted by neutral normal ammonium acetate and read in EEL flame photometer (Jackson, 1973).

3.9.2. Crop and weed analysis

Crop and weed samples were oven dried at 70°C powdered well and analysed for N, P and K content.

Total nitrogen content of the samples was determined by microkjeldahl distillation method (Jackson, 1973). Total phosphorus and potassium contents were estimated using triacid extract (HNO_3 : H_2SO_4 : $HClO_4$ in the ratio 10:1:4). Phosphorus was determined by Vanadomoly-bdophosphoric yellow colour method (Jackson, 1973) and potassium using EEL flame photometer. Grains were also analysed in the same manner as that of crop and weed samples.

Nitrogen, phosphorus and potassium contents in the crop at at harvest were determined and the corresponding uptakes were worked out. The nitrogen, phosphorus and potassium uptakes by weeds at 20 DAT, 40 DAT and at harvest were calculated from the dry matter production of the weed and their nutrient contents.

3.10. Statistical analysis

The data relating to each character were analysed statistically by applying the technique of analysis of variance and the significance was tested by 'F' test. (Panse and Sukhatme, 1985).

Results and Discussion

RESULTS AND DISCUSSION

The results of the experiment conducted to find out the effect of combined application of granular preparations of pre-emergent herbicides and fertilizers in rice are presented and discussed below.

4.1. Studies on weeds

4.1.1. Weed spectrum

The weed spectrum observed at 20 DAT in handweeded plots and·unweeded treatments showed that the broadleaved weeds and sedges were more in number than grasses (Table 2). Among broadleaved weeds Monochoria vaginalis (Burm. 4) Pers. and Sphenoclea zeylanica Gaertn. dominated the field. Other broadleaved weeds found were Dopatrium junceum, Roxb., Nymphaea nouchali Burm. and Ludwigia parviflora Roxb. Along with these broadleaved weeds, sedges like Schoenoplectus lateriflorus Gaertn., Cyperus difformis (L.) and Eriocaulon quinquangulare (L.) had a widespread occurrence. Echinochloa colonum (L.) Link., Saccolepis interrupta Stapf. and Isachne miliaceae Roth. were the important grasses.

At 20 DAT, Sphenoclea zeylanica Gaertn., Schoenoplectus lateriflorus Gmel. and Monochoria vaginalis (Burm. 4) Pers.

were dominant. It was further observed that at 40 and 60 DAT the weed flora were mostly of the same type. However, at harvest, the weed spectra consisted of *Ludwigia parviflora* Roxb., *Ammania baccifera* Linn., *Fimbristylis miliacea* (L.) Vahl., *Cyperus iria* (L.) and *Saccolepis interrupta* Stapf.

4.1.2. Weed population

The data on population of broadleaved weeds, sedges, grasses and total population at 20 DAT are presented in Table 2. In all the cases the population in handweeded treatment was observed to be similar to that of unweeded control since the observation on weed count was taken before the handweeding treatment was imposed.

4.1.2.1. Broadleaved weeds

At 20 DAT, all the herbicide treatments recorded significantly lower broadleaved weed population when compared to unweeded control and handweeded plots. Among different herbicides, oxyflourfen recorded the lowest number of broadleaved weeds, closely followed by butachlor. Among the different methods of application all the anilofos treatments i.e. spray or granular preparation (GP) alone or GP combined with fertilizer could bring down the population of broadleaved weeds than unweeded control. This was also true in the case of butachlor.

Table 2. Effect of different treatments on weed population at 20 DAT (plans/m^2)

Treatments	No. of broad leaved weeds	No. of sedges	No.of Grasses	Total weed population
1. Bs 3 DAT and F 6 DAT	1.38 (2)*	2.06 (4.33)	1.58 (2.67)	2.99 (9.00)
2. Bs and F 3 DAT	1.41 (2)	2.07 (4.33)	1.81 (3.33)	3.09 (9.67)
3. Bg 3DAT and F 6 DAT	1.79 (3.33)	1.96 (4.00)	1.63 (2.67)	3.12 (10.00)
4. (Bg+F) 3 DAT	1.38 (2)	2.08 (4.33)	1.61 (2.67)	2.99 (9.00)
5. Os 3 DAT and F 6 DAT	1.13 (1.33)	1.00 (1.00)	1.14 (1.33)	1.90 (3.67)
6. Os and F 3 DAT	1.38 (2.0)	1.14 (1.33)	1.33 (2.00)	2.27 (5.67)
7. Og 3 DAT and F 6 DAT	1.00 (1.00)	1.00 (1.00)	1.58 (2.67)	2.14 (4.67)
8. (Og+F) 3 DAT	1.14 (1.33)	1.00 (1.00)	1.14 (1.33)	1.91 (3.67)
9. As 3 DAT and F 6 DAT	2.37 (5.67)	1.79 (3.33)	2.43 (6.00)	3.87 (15.00)
10. As and F 3 DAT	2.32 (5.67)	1.96 (4.00)	2.51 (6.33)	3.99 (16.00)
11. Ag 3 DAT and F 6 DAT	2.55 (6.67)	1.91 (3.67)	2.49 (6.33)	4.06 (16.67)
12. (Ag+F) 3 DAT	2.69 (8.0)	1.99 (4.00)	2.43 (6.00)	4.15 (17.33)
13. HW and F 3 DAT	4.61 (21.33)	4.72 (22.33)	4.31 (18.67)	7.89 (62.33)
14. Control and F 3 DAT	5.31 (29.00)	4.93 (24.67)	4.07 (16.67)	8.36 (70.33)
SEm±	0.25	0.19	0.22	0.24
CD(0.05)	0.74	0.58	0.65	0.65

* Original values are given in parenthesis

Though oxyflourfen controlled broadleaved weeds efficiently, since it was highly phytotoxic to rice crop (section 4.3.1.) and resulted in lower grain yield (section 4.3.3.4.), application of oxyflourfen @ 0.15 kg a.i./ha in transplanted rice is not advisable. This is in contrast to the report that oxyflourfen @ 0.25 kg a.i. per ha at 5 DAT and repeated 15 days later if necessary gave higher yields than other herbicides (CIDAT, 1979).

4.1.2.2. Sedges

Unweeded control recorded significantly higher sedge population followed by handweeding than the herbicidal treatments. All the anilofos and butachlor treatments recorded similar population, while oxyflourfen treatments significantly reduced the sedge population than other herbicidal treatments. Spray or GP of butachlor and anilofos applied alone or in combination with fertilizer could bring down the sedge population in a similar manner. On an average, butachlor and anilofos treatments brought down the sedge population by 59 and 40 per cent respectively compared to unweeded control.

4.1.2.3. Grass population

All the herbicides recorded significantly lower grassy weed population than handweeded and control plots. Among different herbicides, oxyflourfen recorded lowest grass population and was on par with butachlor treatments. Butachlor spray or GP alone, or in combination with fertilizer recorded similar grass population. This was true in the case of anilofos also. Butachlor and anilofos could reduce the grassy weed population to 58 and 61 per cent respectively, compared to unweeded control. The effectiveness of butachlor against many annual grasses, sedges and some broadleaved weeds was reported by Mandal (1990). The effectiveness of oxyflourfen, anilofos and butachlor in reducing the weed density was also reported by Varshney (1990). The results indicated that anilofos or butachlor can be effectively used for the control of weeds in transplanted rice, either as spray or as GP, alone or in combination with fertilizer. Due to the severe phytotoxicity, oxyflourfen cannot be recommended at the rate used in this experiment for rice weed control.

4.1.2.4. Total weed population

Broadleaved weeds, sedges and grasses constituted 41, 35 and 24 per cent of total weed population respectively. The mean weed population in unweeded control was 70 plants per m^2.

All the herbicidal treatments recorded significantly lower weed population than unweeded control. Oxyflourfen could significantly bring down the total weed population than anilofos and butachlor. However, oxyflourfen caused severe injury to the crop as evident from the high phytotoxicity rating shown in Table 9 and resulted in significant yield loss (section 4.3.3.4.). Thus oxyflourfen cannot be recommended @ 0.15 kg a.i. per ha in transplanted rice, either as spray or as GP. Next to oxyflourfen, butachlor treatments were efficient in controlling weeds, closely followed by anilofos treatments. Different methods of application of butachlor or anilofos did not show any difference in reducing total weed population. Handweeding was least effective in controlling weeds compared to different herbicides tried.

4.1.3. Dry matter production by weeds

The data on dry matter production by weeds during different stages of crop growth are given in Table 3. At 20 DAT, all the herbicidal treatments recorded significantly lower dry matter production than unweeded control. Weed dry matter production in handweeded plots was similar to that in unweeded control, the reason has been discussed earlier. Anilofos, butachlor and oxyflourfen recorded similar weed dry matter production. Spray and GP of these herbicides applied alone, or in combination with fertilizer could reduce the weed dry matter significantly than unweeded control.

Table 3. Effect of different treatments on weed dry matter production (g/m^2) and weed control efficiency (%)

Treatments	20 DAT	40 DAT	Harvest	Weed control efficiency
1. Bs 3 DAT and F 6 DAT	15.00	26.67	40.00	81.35
2. Bs and F 3 DAT	16.00	26.00	40.67	82.00
3. Bg 3DAT and F 6 DAT	11.67	15.33	22.67	88.76
4. (Bg+F) 3 DAT	9.33	12.67	21.33	90.74
5. Os 3 DAT and F 6 DAT	3.67	17.33	49.33	87.63
6. Os and F 3 DAT	9.67	19.67	45.33	86.25
7. Og 3 DAT and F 6 DAT	10.33	17.00	46.00	87.60
8. (Og+F) 3 DAT	4.67	18.00	50.00	87.49
9. As 3 DAT and F 6 DAT	13.33	19.33	34.00	86.39
10. As and F 3 DAT	14.00	23.00	37.67	83.97
11. Ag 3 DAT and F 6 DAT	13.33	18.33	24.00	87.26
12. (Ag+F) 3 DAT	14.33	16.67	32.00	88.10
13. HW and F 3 DAT	70.00	5.33	15.33	95.87
14. Control and F 3 DAT	75.33	149.33	262.00	-
SEm$\pm$	3.92	4.34	10.17	
CD (0.05)	11.41	12.61	29.58	

At 40 DAT, all the herbicides and handweeding recorded significantly lower weed dry matter production than unweeded control. Weed dry matter production at 40 DAT in herbicidal treated plots was higher than handweeded plots, the reason for which might be that the pre-emergent herbicides was effective in controlling weeds only in the early stage of crop growth as evident from the lower weed dry matter production at 20 DAT. The weeds that occurred later contributed to the higher weed dry matter production in these plots at later stages. However, the higher weed dry matter in herbicidal treatments during later stages did not cause any reduction in grain yield and was comparable with that of handweeded plots (section 4.3.3.4.). Application of GP of butachlor combined with fertilizer was effective in reduing the weed dry matter than its spray application. But butachlor spray or spray and fertilizer applied on the same day did not show any significant difference in weed dry matter. No significant difference was shown by the different anilofos treatments and were on par with butachlor GP and GP combined with fertilizer.

At harvest, all the herbicides and handweeding recorded significantly lower weed dry matter than unweeded control. Handweeding recorded significantly lower weed dry matter than oxyflourfen treatments but was on par with all other butachlor and anilofos treatments. The higher weed dry matter in oxyflourfen treated plots as against the trend followed during previous samplings might be because of the enhanced weed growth in the open space due to poor crop stand consequent to the phytotoxicity. Spray or GP of butachlor and anilofos applied alone or in combination with fertilizer recorded similar drymatter production by weeds. Since no significant difference was observed between spray and GP of butachlor and anilofos applied alone, or in combination with fertilizer, application of GP and fertilizer mixture could be easier and cheaper and can be recommended against the spraying of these herbicides in transplanted rice.

4.1.4. Weed control efficiency

The weed control efficiency was estimated at 40 DAT. The highest weed control efficiency of 95.87 per cent was recorded by handweeding twice (Table 3). All the herbicides recorded higher and more or less similar weed control efficiency. In general, GP of butachlor and anilofos alone or in combination with fertilizer recorded higher weed control efficiency than their corresponding sprays. This might be due to the more efficient and uniform distribution of herbicide in soil obtained through the use of granular preparations. However, such a difference was not observed in the different formulations of oxyflourfen as that of butachlor and anilofos. Oxyflourfen is a pre-emergent contact herbicide while the other two being pre-emergent systemic herbicides, their granular preparations broadcasted in the soil might have enhanced the absorption of the herbicide into the germinating weed seeds and resulted in greater weed control. Gogoi and Kalita (1993) too reported that butachlor granules or EC as sandmix controlled weeds effectively.

4.1.5. Nutrient removal by weeds

4.1.5.1. Nitrogen

Nitrogen removal by weeds at different stages of crop growth are presented in (Table 4). At 20 DAT, nitrogen removal by weeds in all the herbicide treated plots was significantly lower than unweeded control. Handweeded plots too recorded significantly higher nitrogen removal similar to unweeded control due to their similar weed dry matter production. No significant difference was shown by butachlor or anilofos as spray or as GP alone, or when combined with fertilizer. However, there was significant difference between spray and GP of oxyflourfen.

At 40 DAT, unweeded control recorded significantly higher nitrogen removal by weeds than all other treatments

Table 4. Effect of different treatments on the content (%) and removal (Kg/ha) of N by weeds at various stages of crop growth

Treatments	20 DAT		40 DAT		Harvest	
	Content	Removal	Content	Removal	Content	Removal
1. Bs 3 DAT and F 6 DAT	1.41	2.13	2.16	5.80	1.19	4.80
2. Bs and F 3 DAT	1.47	2.41	2.48	6.32	1.35	5.48
3. Bg 3 DAT and F 6 DAT	1.46	1.75	2.30	3.49	1.62	3.52
4. (Bg+F) 3 DAT	1.42	1.34	2.08	2.64	1.36	2.89
5. Os 3 DAT and F 6 DAT	2.25	0.65	2.85	4.92	1.44	7.09
6. Os and F 3 DAT	2.41	2.36	3.56	7.03	1.49	6.78
7. Og 3 DAT and F 6 DAT	2.41	2.51	2.79	4.79	4.52	6.97
8. (Og+F) 3 DAT	2.20	1.03	2.99	4.92	1.57	7.87
9. As 3 DAT and F 6 DAT	1.38	1.86	1.87	3.62	1.44	4.85
10. As and F 3 DAT	1.43	2.01	2.22	5.10	1.26	4.75
11. Ag 3 DAT and F 6 DAT	1.62	2.16	2.09	3.90	1.39	3.33
12. (Ag+F) 3 DAT	1.71	2.43	2.04	3.42	1.40	4.49
13. HW and F 3 DAT	1.52	10.67	2.15	1.19	0.91	1.38
14. Control and F 3 DAT	1.53	11.50	2.50	37.38	1.40	36.70
SEm±	0.61		1.16		1.37	
CD (0.05)	1.78		3.38		4.00	

including handweeding which recorded the lowest nitrogen removal by weeds.

At harvest, all the herbicidal treatments recorded significantly lower nitrogen removal by weeds than unweeded control. Handweeding recorded the lowest nitrogen removal and was significantly superior to unweeded control and oxyflourfen treatments. Different methods of application of anilofos and butachlor alone, or in combination with fertilizer, did not differ in nitrogen removal by weeds, consequent to the similar dry matter accumulation of weeds and N content of weeds.

A correlation of -0.33 was observed between grain yield and nitrogen removal by weeds, while Varghese and Nair (1986) reported a correlation of -0.74. The relatively low correlation of -0.33 obtained might be due to the lesser weed dry matter production consequent to the low weed density in the experimental field.

4.1.5.2. Phosphorus

At 20 DAT, P removal by weeds was significantly higher in unweeded control and in handweeded plots than all other herbicidal treated plots (Table 5). The herbicides controlled weeds efficiently as is evident from the high weed control efficiency values and resulted in low dry

Table 5. Effect of different treatments on content (%) and removal (kg/ha) of P by weeds at various stages of crop growth

Treatments	20 DAT		40 DAT		Harvest	
	Content	Removal	Content	Removal	Content	Removal
1. Bs 3 DAT and F 6 DAT	0.66	0.43	1.06	1.14	1.19	1.42
2. Bs and F 3 DAT	0.58	0.34	1.05	1.11	1.24	1.56
3. Bg 3 DAT and F 6 DAT	0.52	0.29	0.82	0.67	0.86	0.76
4. (Bg+F) 3 DAT	0.47	0.22	0.75	0.57	0.79	0.62
5. Os 3 DAT and F 6 DAT	0.33	0.11	0.95	0.90	1.40	1.96
6. Os and F 3 DAT	0.58	0.34	1.02	1.05	1.37	1.88
7. Og 3 DAT and F 6 DAT	0.62	0.39	0.93	0.87	1.37	1.88
8. (Og+F) 3 DAT	0.41	0.17	0.97	0.96	1.42	2.01
9. As 3 DAT and F 6 DAT	0.60	0.36	0.90	0.81	1.04	1.10
10.As and F 3 DAT	0.58	0.34	0.97	0.94	1.14	1.31
11.Ag 3 DAT and F 6 DAT	0.57	0.32	0.91	0.85	0.90	0.82
12.(Ag+F) 3 DAT	0.59	0.35	0.87	0.76	1.02	1.04
13.HW and F 3 DAT	1.34	1.85	0.46	0.22	0.68	0.47
14.Control and F 3 DAT	1.43	2.08	2.75	7.58	2.66	7.10
SEm±		0.14		0.18		0.25
CD (0.05)		0.41		0.53		0.73

Table 8. Available P_2O_5 and K_2O in the soil at 15 and 30 DAT (kg/ha)

Treatments	P_2O_5		K_2O	
	15 DAT	30 DAT	15 DAT	30 DAT
1. Bs 3 DAT and F 6 DAT	75	70	360	283
2. Bs and F 3 DAT	79	66	323	272
3. Bg 3 DAT and F 6 DAT	85	78	355	235
4. (Bg+F) 3 DAT	79	72	351	243
5. Os 3 DAT and F 6 DAT	94	77	382	292
6. Os and F 3 DAT	92	68	390	290
7. Og 3 DAT and F 6 DAT	88	67	394	292
8. (Og+F) 3 DAT	88	71	375	291
9. As 3 DAT and F 6 DAT	83	74	366	216
10.As and F 3 DAT	86	69	343	258
11.Ag 3 DAT and F 6 DAT	82	67	366	227
12.(Ag+F) 3 DAT	85	67	321	276
13.HW and F 3 DAT	73	65	306	289
14.Control and F 3 DAT	74	71	302	284
SEm±	3.97		13.61	16.51
CD (0.05)	11.55	NS	39.57	47.99

4.2.5. Available K_2O

Data on available K_2O in the soil at 15 and 30 DAT are given in Table 8. Handweeded and unweeded control recorded the lowest available K at 15 DAT. Similar to the available N and P content in soil, the available K_2O was higher in oxyflourfen treated plots. No significant difference was obtained between butachlor and anilofos. Among the different methods of application, there was no difference irrespective of the herbicides. The removal of K_2O by weeds present in unweeded and handweeded plots caused the depletion of the same in the other treatments.

4.3. Studies on crop

4.3.1. Phytotoxicity

Phytotoxicity rating at 0 to 9 scale at different days after application (DAA) of the herbicide are presented in Table 9. In general, all the butachlor and anilofos treatments except anilofos spray did not show any crop injury and recorded a phytotoxicity rating of '0' similar to non-herbicidal treatments. Rice plants in the anilofos spray treated plots showed a very slight discolouration and recorded a phytotoxicity rating of '1' upto 5 DAA. All the oxyflourfen treatments, showed high crop injury and their phytotoxic rating was in the order oxyflourfen spray =

oxyflourfen spray and fertilizer applied on the same day > oxyflourfen GP > combined application of oxyflourfen GP and fertilizer.

All the oxyflourfen treatments at 5 DAA recorded higher phytotoxicity rating than at 2 DAA. The crops in these treatments seemed to be nearly destroyed. But at 9 DAA the crop in the combined application of oxyflourfen GP and fertilizer recovered slightly and while crops in anilofos spray recover completely (Table 9).

In general it was observed in the field that, after two to three weeks, 40-50 per cent of the crops recovered from phytotoxicity in oxyflourfen spray treated plots while in oxyflourfen spray and fertilizer applied on the same day, only 20-30 per cent of the crops recovered. In oxyflourfen GP or in combined application of oxyflourfen GP and fertilizer, 60-70 per cent of the crops recovered. The recovered crops utilized the available nutrients and space and could complete their life cycle successfully. Mukhopadhyay and Mandal (1982) too had reported that oxyflourfen caused yellowing of rice plants, but they recovered after two to three weeks.

Butachlor and anilofos under different methods of application alone or when combined with fertilizer did not matter production by weeds, thereby a low P removal by the weeds. Spray or GP of all the herbicides alone or in combination with fertilizer did not show any difference in P removal by weeds.

At 40 DAT, all the herbicidal treatments recorded lower P removal and the difference was significant compared to unweeded control. Handweeding recorded the lowest P removal by weeds.

At harvest, the same trend was noticed. Unweeded control recorded significantly higher P removal by weeds than all other treatments. Handweeding too recorded significantly lower P removal by weeds. However, the response of GP of butachlor alone or jointly applied with fertilizer towards P removal is notable. They ranked next to handweeding and there was significant difference between the spray application and joint application GP and fertilizers.

A correlation of -0.41 was obtained between the grain yield and P removal by weeds, while a correlation of -0.84 was observed by Varghese and Nair (1986).

4.1.5.3. Potassium

At 20 DAT, all the herbicides recorded significantly lower K removal by weeds than unweeded control (Table 6).

Table 6. Effect of different treatments on content (%) and removal (kg/ha) of K by weeds at various stages of crop growth.

Treatments	20 DAT		40 DAT		Harvest	
	Content	Removal	Content	Removal	Content	Removal
1. Bs 3 DAT and F 6 DAT	2.47	3.72	2.61	7.00	2.37	9.52
2. Bs and F 3 DAT	2.45	3.94	2.62	6.80	2.36	9.59
3. Bg 3 DAT and F 6 DAT	2.46	2.87	2.59	3.97	2.49	5.63
4. (Bg+F) 3 DAT	2.55	2.37	2.68	3.39	2.48	5.26
5. Os 3 DAT and F 6 DAT	3.05	1.12	3.24	5.60	2.96	14.68
6. Os and F 3 DAT	3.08	2.92	3.32	6.50	2.95	13.41
7. Og 3 DAT and F 6 DAT	3.13	3.24	3.32	5.66	2.97	13.66
8. (Og+F) 3 DAT	3.02	1.41	3.37	6.03	2.84	14.18
9. As 3 DAT and F 6 DAT	2.48	3.31	2.58	4.99	2.38	8.10
10.As and F 3 DAT	2.59	3.62	2.69	6.19	2.51	9.44
11.Ag 3 DAT and F 6 DAT	2.62	3.50	2.76	5.05	2.66	6.37
12.(Ag+F) 3 DAT	2.60	3.70	2.69	4.48	2.58	8.25
13.HW and F 3 DAT	2.70	18.73	2.82	1.48	2.65	4.05
14.Control and F 3 DAT	2.38	17.87	2.47	36.80	2.69	70.14
SEm±		0.89		0.97		2.48
CD (0.05)		2.60		2.82		7.22

Handweeding recorded K removal similar to unweeded control as in the case of N and P. All the three herbicides recorded lower K removal by weeds, due to the lower weed dry matter in these plots as a result of efficient control of weeds by these herbicides. Different methods of application of these herbicides alone, or in combination with fertilizer did not show any significant difference in K removal by weeds.

At 40 DAT, unweeded control recorded significantly higher K removal than all other treatments. Handweeding recorded the lowest K removal. Butachlor GP and GP combined with fertilizer recorded significantly lower K removal than its spray and spray and fertilizer applied on the same day. This might be because of the lower dry matter production by weeds in these treatments than its spray and spray and fertilizer applied on the same day. However, anilofos applied as spray or as GP, alone or combined with fertilizer recorded similar K removal by weeds.

At harvest too the same trend was noticed. A correlation of -0.33 was observed between grain yield and K removal by weeds. However a correlation of -0.8 was obtained by Varghese and Nair (1986).

With regard to the content of nutrients in weeds a general observation was that the weeds in the oxyflourfen treated plots contained greater per cent of nutrients particularly at 20 and 40 DAT, keeping the similar trend towards harvest, than other two herbicides. This might be because of the poor crop stand in these treatments, which resulted in more nutrient availability to the weeds. Moreover the weeds dominated the field wherever the crop stand was poor. It has been reported that weeds have a large requirement for nutrients and their tissues have higher mineral nutrient content than crop plants (Alkamper, 1976 and Pons and Utomo, 1979).

With regard to the nutrient removal by weeds during the initial 20 days of rice, handweeding happened to be the most ineffective weed control treatment due to its similarity with unweeded control. The early growth stage of rice upto 40 days is reported to be critical for rice (Shetty and Gill, 1974, Singh and Tandon, 1982, Varghese and Nair, 1986).

The competition for nutrients and space was critical though water was not limiting at this stage for wet land rice. Considerable quantities of N, P and K removal by weeds during the initial 20 days in handweeded treatments as was evident from Table 4, 5 and 6, pointed to the use of highly selective pre-emergent herbicides which gave least chance of nutrient removal by weeds.

4.2. Available nutrients in soil

The study on available nutrients in soil at 15 and 30 DAT was specifically made to know whether there is any change in the available nutrients when the fertilizers were combined with the granular preparation of herbicides.

4.2.1. NH_4^+ - N

Extractable NH_4^+- N in the top 0-15 cm soil (Table 7) was significantly higher in plots treated with oxyflourfen at both 15 and 30 DAT. This is obviously due to relatively lower removal of N by weeds and rice plants. The complete kill of weeds and severe phytotoxicity to rice seedlings in oxyflourfen treated plots will be discussed later (section 4.3.1.). The least amount of available N was observed in unweeded control and handweeded plots at 15 DAT and both in handweeded and unweeded treatments at 30 DAT. This is possibly due to the N removal by weeds present in these treatments.

There was significantly higher amount of soil extractable NH_4^+ - N in butachlor GP combined with fertilizer treatments than butachlor spray and fertilizer applied on the same day at both 15 and 30 DAT. Though not significant, a similar trend was followed in the case of oxyflourfen and anilofos. The greater amount of NH_4^+ - N in these treatments would be due to either less removal of N by weeds

Table 7. NH_4^+ - N and NO_3^- - N in the soil at 15 and 30 DAT (kg/ha)

Treatments	NH_4^+-N		NO_3^--N	
	15 DAT	30 DAT	15 DAT	30 DAT
1. Bs 3 DAT and F 6 DAT	63	41	20	18
2. Bs and F 3 DAT	59	39	21	17
3. Bg 3 DAT and F 6 DAT	65	40	21	17
4. (Bg+F) 3 DAT	63	43	20	18
5. Os 3 DAT and F 6 DAT	75	66	27	22
6. Os and F 3 DAT	75	63	28	21
7. Og 3 DAT and F 6 DAT	84	65	31	23
8. (Og+F) 3 DAT	89	68	28	22
9. As 3 DAT and F 6 DAT	60	41	21	17
10.As and F 3 DAT	60	39	21	17
11.Ag 3 DAT and F 6 DAT	60	40	21	17
12.(Ag+F) 3 DAT	61	39	20	17
13.HW and F 3 DAT	55	42	21	17
14.Control and F 3 DAT	54	37	21	16
SEm±	3.85	1.80	1.03	0.74
CD (0.05)	11.20	5.24	3.00	2.16

or by rice plants or a reduced rate of nitrification of NH_4^+ - N. The N removal by weeds at 20 DAT was similar in these two sets of treatments for all the three herbicides. The same, at 40 DAT was more in herbicide spray and fertilizer applied on the same day than combined application of GP and fertilizer, however the difference was not found significant (Table 4). The **N** uptake by rice plant estimated at harvest was obviously more in combined application of GP and fertilizer than in spray and fertilizer applied on the same day (Table 15). It can be possibly assumed that the herbicide was instrumental in bringing down the nitrification and hence a greater quantity of extractable NH_4^+ - N present in soil. There have been reports earlier that repeated application of pesticides especially dithiocarbamates inhibited mineralization of N and caused N deficiency (Dubey, 1970).

4.2.2. NO_3^- - N

The NO_3^-- N in the soil at 15 and 30 DAT (Table 7) showed a similar trend in case of oxyflourfen. All the oxyflourfen treatments recorded significantly higher NO_3^--N at both stages than the other treatments.

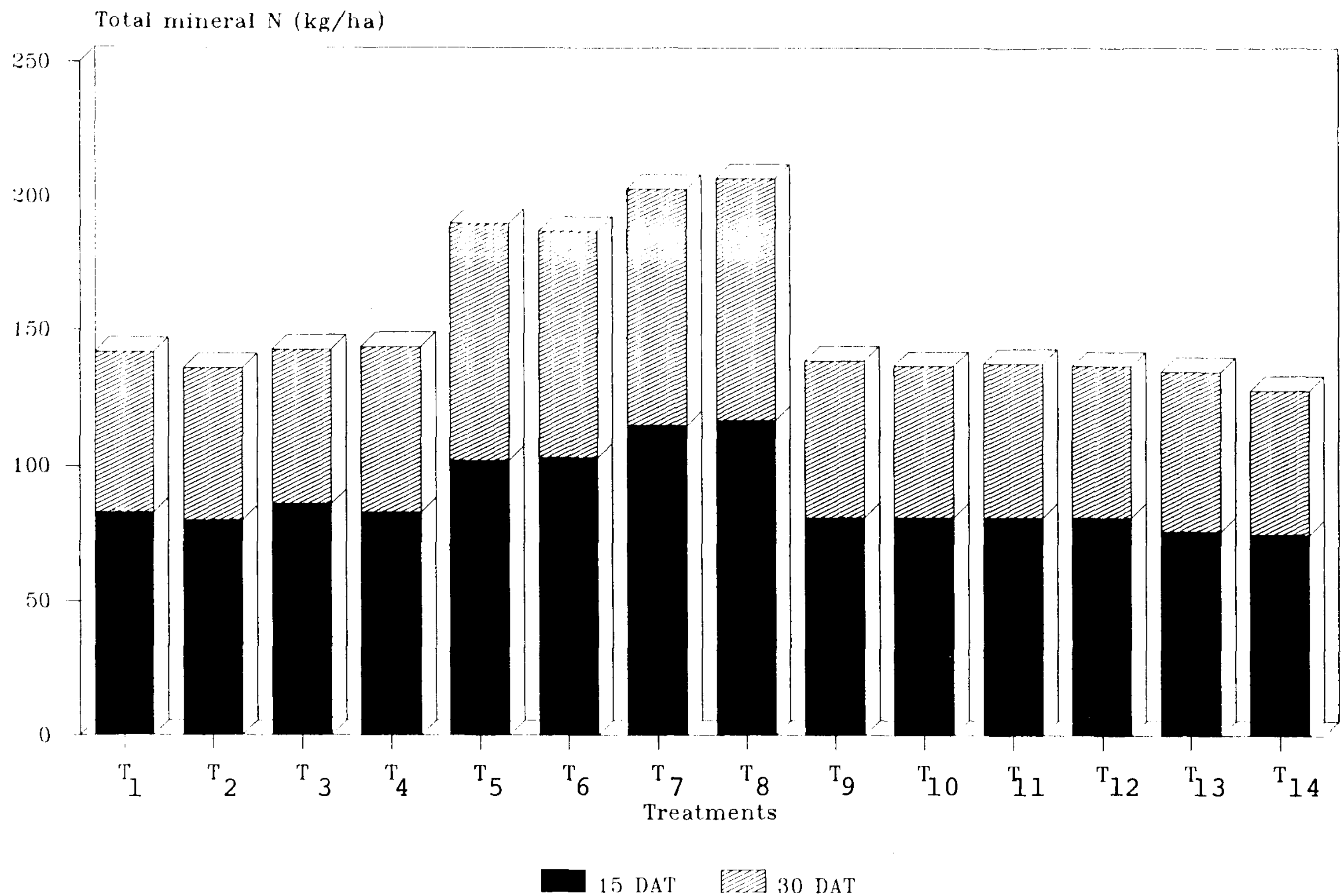
No difference was observed among the three herbicides or among their different methods of application in the case of NO_3^- - N accumulation.

4.2.3. Total mineral N (NH_4^+ - N and NO_3^--N)

Fig. 3 shows the total mineral N at 15 and 30 DAT. In general, the total soil extractable N was high at 15 DAT, but was reduced at 30 DAT. This might be due to the lower removal of total mineral N at 15 DAT. But as the crop grew, it removed the nutrients more efficiently and hence the decreased total mineral N at 30 DAT. Moreover, the N might have been subjected to various kinds of losses. However, the reduction in total mineral N in unweeded control might be due to the removal by both crop and weeds.

All the butachlor and anilofos treatments did not show any difference in the total mineral N in soil at 15 and 30 DAT. Oxyflourfen treatments recorded relatively higher values for total mineral N at both 15 and 30 DAT. Oxyflourfen spray alone, or spray and fertilizer applied on the same day recorded only a small reduction in total mineral N at 30 DAT, while oxyflourfen GP and combined application of GP and fertilizer recorded higher reduction in total mineral N. The reason for this might be the better crop stand in oxyflourfen GP and combined application of GP and fertilizer than in oxyflourfen spray and spray and fertilizer applied on the same day (section 4.3.1.), where the crop uptake of N caused a reduction in the total mineral N at 30 DAT. However, in oxyflourfen spray

Fig. 3. Total mineral N (NH_4^+–N + NO_3^-– N) at 15 and 30 DAT (kg/ha)



and in spray and fertilizer applied on the same day, crop stand was poor and hence only low removal of total mineral N took place.

The available N status in the form of soil extractable NH_4^+ - N and NO_3^- - N was only positively affected by combined application of GP form of herbicides and fertilizers. The method of application would be cheaper, easy and time saving than spray application.

4.2.4. Available P_2O_5

The available P_2O_5 observed from 0-15 cm soil at 15 DAT (Table 8) showed more or less a similar trend as that of available N. Higher quantity was observed in oxyflourfen treated plots. However, among the different methods of application, available P_2O_5 content was similar pointing to the adoption of easy and cheaper method of combined application of GP of herbicide and fertilizer.

At 30 DAT, there was no significant difference in the available P_2O_5, either among herbicides or methods of application. This non significance is probably due to the formation of an equilibrium with course of time in the quantities of available and fixed P, irrespective of the method of application.

cause any crop injury, while all the oxyflourfen treatments were highly phytotoxic to the crop. Therefore, even though oxyflourfen treatments were efficient in controlling weeds as discussed earlier, it caused injury to the crop and reduced grain yields substantially (section 4.3.3.4.). It cannot be recommended @ 0.15 kg a.i per ha in transplanted rice for weed control.

4.3.2. Growth characters

4.3.2.1. Plant height

The observations on height of plants at various growth stages presented in Table 10 revealed that, plant height differed significantly among treatments, only during the early stages of crop growth.

At 30 DAT, unweeded control recorded significantly lower plant height than all other treatments. However, oxyflourfen treatments recorded significantly lower plant height even than unweeded control. Anilofos and butachlor treatments produced plants with comparable height to handweeding. Significant increase in height was observed for GP application than spray application of butachlor.

At 45 DAT, lower plant height was recorded in unweeded control, while oxyflourfen spray alone, or spray and

Table 10. Effect of different treatments on the height of rice crop (cm)

Treatments	30 DAT	45 DAT	60 DAT	Harvest
1. Bs 3 DAT and F 6 DAT	64.77	65.67	78.35	87.17
2. Bs and F 3 DAT	70.20	72.00	78.93	85.00
3. Bg 3 DAT and F 6 DAT	70.23	71.00	79.63	87.97
4. (Bg+F) 3 DAT	68.87	70.83	80.37	87.93
5. Os 3 DAT and F 6 DAT	49.13	59.83	78.50	87.10
6. Os and F 3 DAT	43.77	51.00	78.77	87.57
7. Og 3 DAT and F 6 DAT	54.70	65.50	79.97	91.30
8. (Og+F) 3 DAT	54.73	69.17	78.33	92.03
9. As 3 DAT and F 6 DAT	67.73	70.97	82.03	86.86
10.As and F 3 DAT	65.13	67.67	78.00	85.60
11.Ag 3 DAT and F 6 DAT	65.78	68.00	81.63	86.23
12.(Ag+F) 3 DAT	69.63	72.00	80.27	89.20
13.HW and F 3 DAT	66.07	68.50	79.73	84.80
14.Control and F 3 DAT	59.90	61.50	71.77	80.83
SEm±	1.61	1.49		
CD (0.05)	4.67	4.34	NS	NS

fertilizer applied on the same day recorded even lower plant height than unweeded control. Anilofos and butachlor treatments recorded plant height similar to handweeding.

At 60 DAT and at harvest no significant height difference was observed among the three herbicides or their different methods of application. Unweeded plots produced plants with the lowest height. Decreased plant height due to competitive stress in unweeded plot was earlier reported by Noda et al. (1968).

4.3.2.2. Tiller production per hill

Number of tillers per hill at various growth stages are presented in Table 11. At 30 DAT, a lower number of tillers per hill was recorded in unweeded control, while even lower number of tillers were recorded in oxyflourfen treated plots. Severe crop-weed competition in unweeded control might be the reason for lower number of tillers per hill in these plots. The reduced tiller production in oxyflourfen treated plots might be due to the severe crop injury caused by this herbicidal treatment. Butachlor and anilofos treatments recorded similar number of tillers and was comparable to handweeding. The different methods of application of these herbicides alone or when combined with fertilizer produced similar number of tillers per hill.

Table 11. Effect of different treatments on the number of tillers per hill

Treatments	30 DAT	45 DAT	60 DAT
1. Bs 3 DAT and F 6 DAT	9.25	10.08	11.50
2. Bs and F 3 DAT	9.73	10.97	10.83
3. Bg 3 DAT and F 6 DAT	10.99	11.33	12.50
4. (Bg+F) 3 DAT	10.07	12.17	12.92
5. Os 3 DAT and F 6 DAT	5.30	11.67	10.50
6. Os and F 3 DAT	4.85	8.83	10.86
7. Og 3 DAT and F 6 DAT	7.33	10.50	12.92
8. (Og+F) 3 DAT	7.33	11.33	11.42
9. As 3 DAT and F 6 DAT	10.63	11.67	13.83
10.As and F 3 DAT	9.10	11.83	12.47
11.Ag 3 DAT and F 6 DAT	8.98	9.67	10.33
12.(Ag+F) 3 DAT	10.62	11.50	10.50
13.HW and F 3 DAT	10.46	12.00	11.83
14.Control and F 3 DAT	7.67	9.33	9.28
SEm$\pm$	0.63		0.95
CD (0.05)	1.82	NS	2.76

At 45 DAT, no significant difference was observed among different treatments. At 60 DAT, all the herbicides recorded higher tiller number than unweeded control. Anilofos and butachlor treatments and their different methods of application recorded similar tillers as that of handweeded plots.

4.2.3. Dry matter production

Dry matter production by the crop at various crop stages are given in Table 12. Unweeded control produced lower dry matter than anilofos and butachlor treatments. This might be because of the shorter plants and lower number of tillers in these plots due to severe crop-weed competition. Oxyflourfen treated plots recorded low dry matter, even lower than unweeded control which might be due to the severe crop injury caused in these treatments. Reduced dry matter production in rice due to weed competition was earlier reported by Balaswamy and Kondap (1988) and by Varshney (1990).

Butachlor and anilofos spray or GP alone or when combined with fertilizer recorded similar dry matter. In the initial crop stage, dry matter in the handweeded plot was lower than butachlor and anilofos treatments. This might be due to the weed pressure in handweeded plots for the initial 20 days. The weeds in the butachlor and

Table 12. Effect of different treatments on the dry matter production by crop (g/hill)

Treatments	30 DAT	45 DAT	60 DAT	Harvest
1. Bs 3 DAT and F 6 DAT	3.75	4.42	8.28	12.43
2. Bs and F 3 DAT	3.83	4.25	8.42	12.61
3. Bg 3 DAT and F 6 DAT	3.96	6.17	8.42	12.63
4. (Bg+F) 3 DAT	3.67	5.83	7.83	11.75
5. Os 3 DAT and F 6 DAT	1.03	2.67	8.58	12.88
6. Os and F 3 DAT	0.77	2.58	8.62	12.93
7. Og 3 DAT and F 6 DAT	1.95	4.17	8.05	11.83
8. (Og+F) 3 DAT	1.12	4.00	6.17	9.25
9. As 3 DAT and F 6 DAT	3.59	5.97	8.4	13.56
10.As and F 3 DAT	3.48	3.83	8.25	12.33
11.Ag 3 DAT and F 6 DAT	3.75	5.38	8.83	13.25
12.(Ag+F) 3 DAT	3.84	6.00	8.25	12.38
13.HW and F 3 DAT	3.05	4.00	7.70	11.55
14.Control and F 3 DAT	2.72	4.17	6.67	8.33
SEm±	0.37	0.83	0.49	0.77
CD (0.05)	1.07	2.42	1.42	2.24

anilofos treated plots were controlled initially itself and hence no crop-weed competition occurred. At 60 DAT and at harvest dry matter production in the handweeded plot was similar to butachlor and anilofos treated plots and was higher than unweeded control. Since the weeds were removed at 20 DAT and 40 DAT in handweeded plots, the weed pressure during the later stages of crop growth was less and resulted in less crop-weed competition and consequent increased dry matter. In general, oxyflourfen treated plots recorded lower plant height and lower number of tillers and hence low dry matter production due to severe phytotoxicity. However, during the later crop-stages, the recovered plants were subjected to minimum crop to crop or weed to crop competition and availed more space and nutrients. This resulted in taller plants, higher number of tillers per hill and thereby comparable dry matter production per hill to that of other treatments.

These observations show that crop-weed competition for the initial 20 days can cause reduction in dry matter production by crop and hence the application of pre-emergent herbicides assumes importance.

4.3.3. Yield and yield attributes

4.3.3.1. Productive tillers per hill

The data presented in Table 13 showed that unweeded control recorded the lowest productive tillers per hill.

Table 13. Effect of different treatments on yield attributes

Treatments	Productive tillers/hill	No. of filled grains/panicle	1000 grain weight (g)
1. Bs 3 DAT and F 6 DAT	7.31	74.30	25.00
2. Bs and F 3 DAT	6.59	68.60	25.57
3. Bg 3 DAT and F 6 DAT	7.62	60.73	24.83
4. (Bg+F) 3 DAT	6.94	71.57	24.63
5. Os 3 DAT and F 6 DAT	10.74	62.90	24.37
6. Os and F 3 DAT	9.81	56.73	25.10
7. Og 3 DAT and F 6 DAT	8.67	63.38	24.37
8. (Og+F) 3 DAT	10.62	64.87	24.73
9. As 3 DAT and F 6 DAT	7.93	79.47	25.70
10.As and F 3 DAT	8.39	69.63	25.07
11.Ag 3 DAT and F 6 DAT	7.81	68.70	26.77
12.(Ag+F) 3 DAT	7.48	66.63	24.90
13.HW and F 3 DAT	7.18	71.13	25.20
14.Control and F 3 DAT	5.42	66.11	24.00
SEm±	0.46	2.31	
CD (0.05)	1.33	6.71	NS

Handweeding recorded significantly higher number of productive tillers per hill than unweeded control and butachlor treatments. The different methods of application of these herbicide alone, or in combination with fertilizer did not show difference in the number of productive tillers per hill. All the oxyflourfen treatments produced even higher number of productive tillers per hill than all other treatments. This might be due to the increased space availability to individual rice plants, consequent to the phytotoxicity caused by oxyflourfen treatments resulting in poor crop stand as discussed earlier. Higher number of productive tillers per plant in oxyflourfen spray treated plots was also reported by Mohankumar (1995).

4.3.3.2. Number of filled grains per panicle

The data on number of filled grains per panicle presented in Table 13 revealed that all the anilofos and butachlor treatments recorded higher number of filled grains per panicle though non significant. Significant increase in number of fertile spikelets per panicle in butachlor treated plots was also reported by Azad et al. (1990).

Oxyflourfen treatments recorded lower number of filled grains per panicle than unweeded control. This might be due to the initial phytotoxic effects where the seedlings took time to recover which resulted in delayed production of panicles. Although, individual crop plants produced more number of productive tillers due to increased availability of space and nutrients as a result of poor crop stand, delayed production of panicles resulted in incomplete filling up of grains at the time of harvest. Moreover, the panicles were shorter which might have resulted in lesser number of grains per panicle. All the butachlor and anilofos treatments except anilofos spray were on par with handweeding. Among different methods of application, anilofos spray proved significantly better than all other anilofos treatments, while butachlor applied as spray or GP alone or in combination with fertilizer were on par with each other.

4.3.3.3. Test weight of grain

Neither the different herbicides tested nor the different methods of application could bring about any significant effect on test weight of grains. However, unweeded control recorded the lowest test weight. Varshney (1990) had also reported similar results.

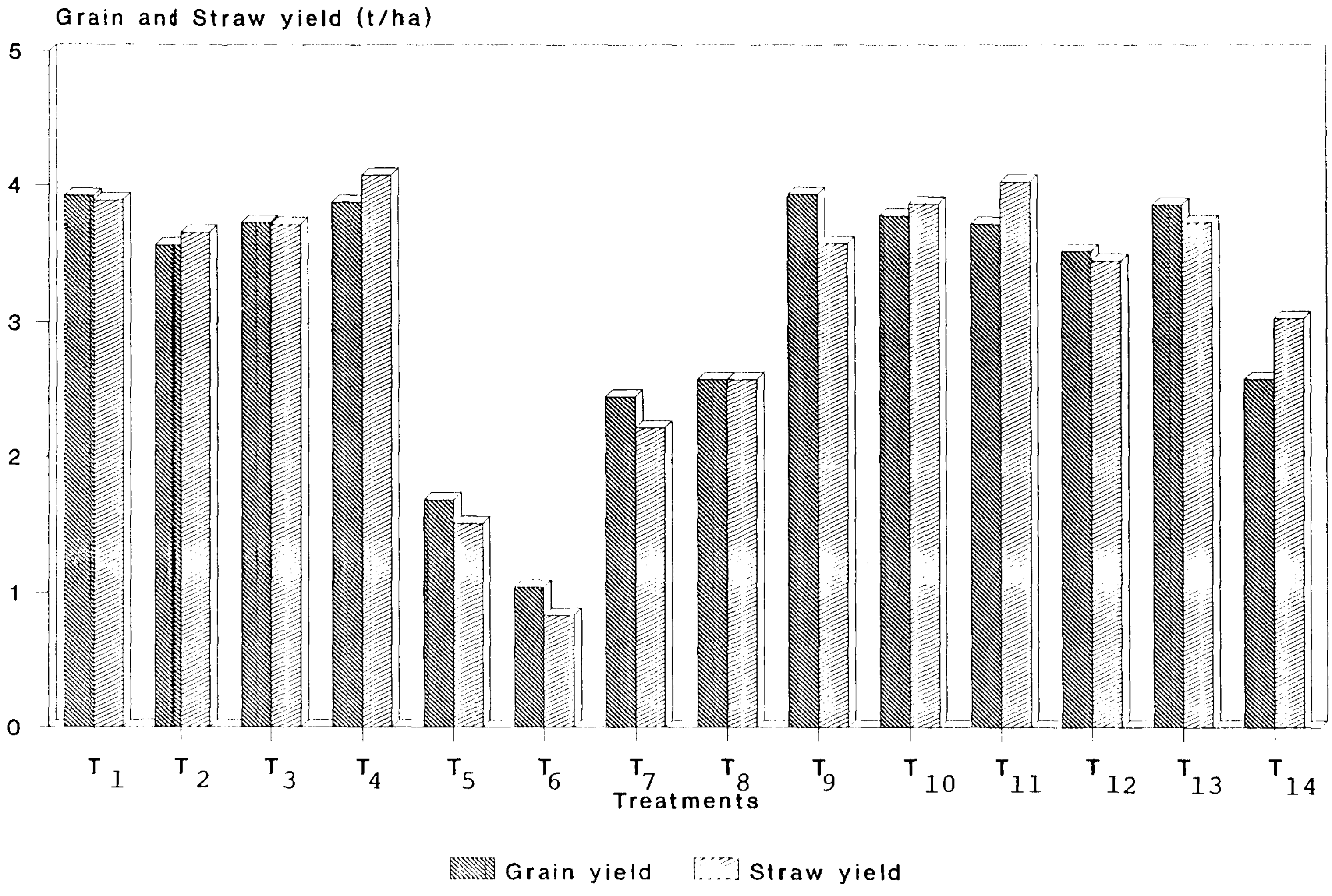
4.3.3.4. Grain yield

Data on grain yield is presented in Table 14 and Fig. 4. Unweeded control recorded significantly lower grain yield than plots applied with butachlor or anilofos and

Table 14. Effect of different treatments on grain yield, straw yield and weed index.

Treatments	Grain yield t/ha	Straw yield t/ha	Weed index
1. Bs 3 DAT and F 6 DAT	3.92	3.89	0.16
2. Bs and F 3 DAT	3.56	3.65	9.05
3. Bg 3 DAT and F 6 DAT	3.72	3.71	5.31
4. (Bg+F) 3 DAT	3.87	4.07	1.42
5. Os 3 DAT and F 6 DAT	1.68	1.51	57.50
6. Os and F 3 DAT	1.04	0.83	73.62
7. Og 3 DAT and F 6 DAT	2.43	2.20	38.00
8. (Og+F) 3 DAT	2.56	2.56	34.95
9. As 3 DAT and F 6 DAT	3.93	3.57	0.00
10.As and F 3 DAT	3.77	3.86	4.10
11.Ag 3 DAT and F 6 DAT	3.71	4.02	5.54
12.(Ag+F) 3 DAT	3.51	3.44	10.69
13.HW and F 3 DAT	3.85	3.72	2.13
14.Control and F 3 DAT	2.56	3.02	34.86
SEm±	0.21	0.22	
CD (0.05)	0.61	0.65	

Fig. 4. Effect of different treatments on grain yield and straw yield (t/ha)



handweeded plots. An yield reduction of 35 per cent was observed in unweeded control when compared to the best treatment. Singh and Singh (1993) reported a loss of 40 - 50 per cent grain yield in unweeded rice fields. The relatively less yield loss due to weeds, in this experiment was due to the low density of weeds as evident from low weed population (Table 2).

All the oxyflourfen treatments recorded grain yields even lower than unweeded control. Even though the productive tillers per hill was higher in oxyflourfen treated plots, number of filled grains per panicle was low. Moreover, due to severe phytotoxicity crop stand also was poor. All the butachlor and anilofos treatments and handweeded plots gave similar grain yield. The increase in grain yield in herbicide treated and handweeded plot was due to significant reduction in weed density and their dry matter accumulation. The decrease in crop weed competition thus helped the crop in utilizing the input resources effectively.

The greater accumulation of available nitrogen in terms of extractable NH_4^+ - N and NO_3^- - N (section 4.2.3.) in these plots also might have resulted in enhanced plant growth and higher yield. The yield increase due to suppression of weeds in transplanted rice was also reported by Gogoi and Kalita (1993). The effective control of weeds resulted in healthier crop with more number of productive tillers per hill, number of filled grains per panicle and test weight of grains. Butachlor and anilofos were also quite safe to the crop thus not causing any reduction in plant population. These herbicides under different methods of application brought about an yield increase of 27 to 35 per cent over unweeded control. Thus the herbicides butachlor and anilofos as spray or GP were found compatible with fertilizer.

4.3.3.5. Straw yield

Higher straw yield (Fig. 4) was recorded in all the anilofos, butachlor and in handweeded plots. This was due to better weed control and combined effects of desirable growth and yield contributing characters arising from the weed free conditions under which the rice plants got maximum available nutrients, moisture and light. The lowest straw yield as in the case of grain yield was recorded in oxyflourfen treated plots. Unweeded control too recorded lower straw yield, which might be due to heavy weed infestation resulting in severe crop - weed competition for input resources. Similar reduction in straw yields in weedy plots was reported by Gogoi and Kalita (1993).

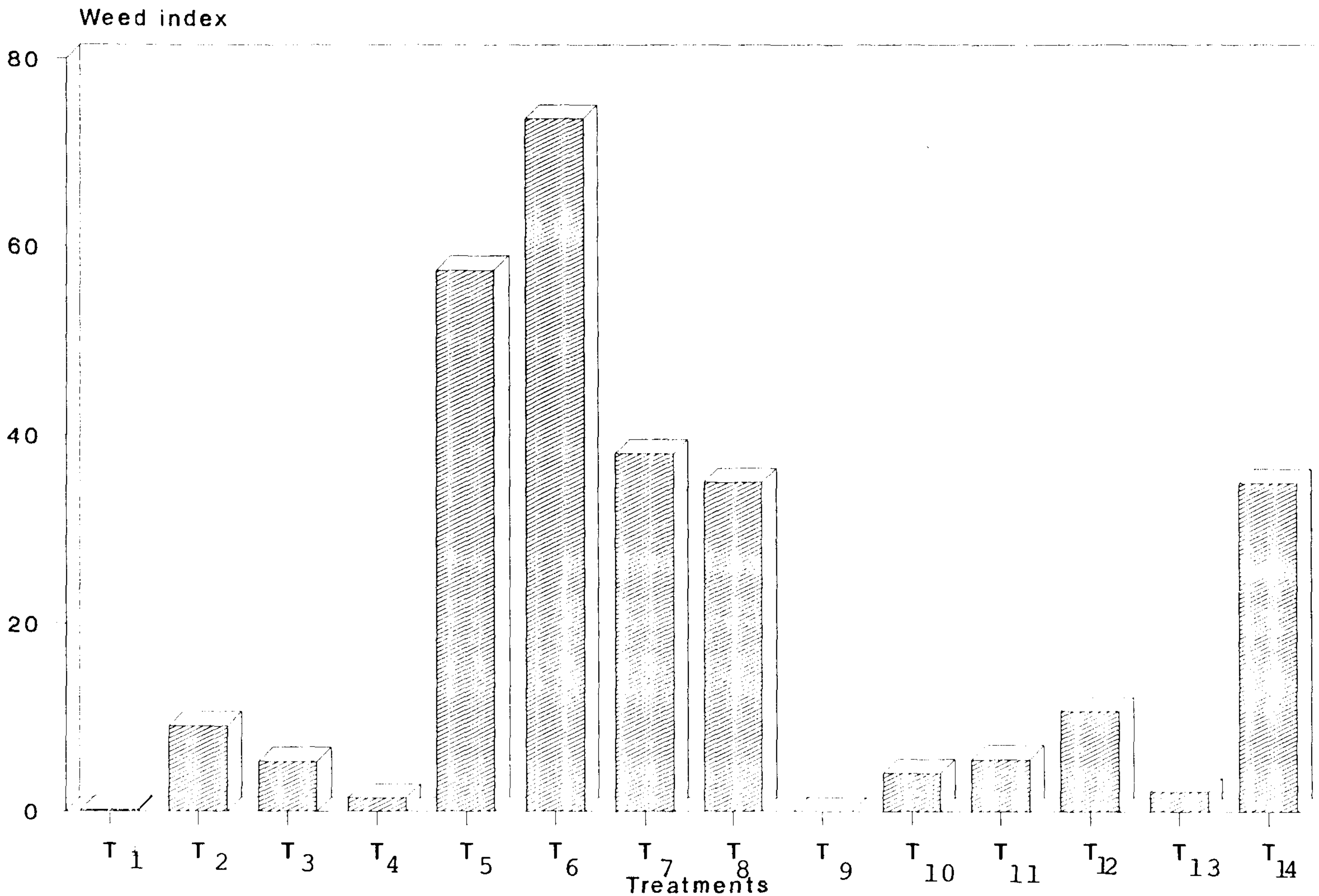
4.4. Weed index

The efficacy of herbicides can be assessed by weed index values which is calaculated as $\frac{(X-Y)}{Y} \times 100$, where X is the yield from weed free handweeded plots, Y the yield from treatment plots. Lesser the weed index, better is the efficiency of that herbicide. Here the weed index was estimated based on the best treatment i.e. anilofos spray that gave maximum grain yield (Table 14 and Fig. 5).

High weed index values were recorded by oxyflourfen treatments and unweeded control. Phytotoxicity of oxyflourfen resulted in poor crop stand which in turn caused a reduction in grain yield, which might be the reason for high weed index values. While in unweeded control, severe crop-weed competition might have resulted in significant yield loss. John and Sadanandan (1989) also reported a high weed index value of 42.3 in unweeded control. A weed index round about 10 or less was observed to give higher grain yield in this experiment.

Anilofos and butachlor under different methods of application gave low weed index values indicating their efficiency in controlling weeds and thereby increasing grain yields. Handweeded plots also gave lower weed index values. Lower weed indices were recorded in herbicide treated plots and in handweeded plots by Mohankumar (1995).

Fig. 5. Effect of different treatments on weed index



4.5. Nutrient uptake by crop

4.5.1. Nitrogen

Nitrogen uptake by crop at harvest is presented in Table 15 and Fig. 6. All the oxyflourfen treatments and unweeded control recorded lower N uptake than other treatments. This might be due to the lower dry matter production in oxyflourfen plots as a result of phytotoxicity and severe crop-weed competition in unweeded control. Anilofos and butachlor spray or GP alone or in combination with fertilizer recorded similar total N uptake.

4.5.2. Phosphorus

All the oxyflourfen treatments and unweeded control recorded significantly lower P uptake by the crop at the time of harvest (Table 16 and Fig. 6.). All the anilofos and butachlor treatments recorded similar P uptake as in handweeded plots. Butachlor spray and fertilizer applied on the same day, was superior to combined application of butachlor GP and fertilizer but was on par with butachlor spray, while all the anilofos treatments were on par. Lower P uptake by oxyflourfen treated plots might be due to the lower dry matter in those plots.

Table 15. Effect of different treatments on content (%) and uptake (kg/ha) of N by rice at harvest.

Treatments	Straw		Grain		Total Uptake
	Content	Uptake	Content	Uptake	
1. Bs 3 DAT and F 6 DAT	0.74	28.63	1.05	40.85	69.48
2. Bs and F 3 DAT	0.68	24.80	1.14	40.79	65.59
3. Bg 3 DAT and F 6 DAT	0.66	24.65	1.20	44.72	69.38
4. (Bg+F) 3 DAT	0.71	28.92	1.19	46.23	75.15
5. Os 3 DAT and F 6 DAT	0.75	11.41	1.13	19.05	30.46
6. Os and F 3 DAT	0.79	6.62	1.17	11.69	18.32
7. Og 3 DAT and F 6 DAT	0.83	18.19	1.37	33.07	51.26
8. (Og+F) 3 DAT	0.78	19.90	1.35	34.83	54.74
9. As 3 DAT and F 6 DAT	0.67	23.90	1.13	44.45	68.35
10. As and F 3 DAT	0.67	26.00	1.08	40.84	60.80
11. Ag 3 DAT and F 6 DAT	0.66	26.51	1.11	41.28	67.79
12. (Ag+F) 3 DAT	0.66	22.80	1.40	48.82	71.52
13. HW and F 3 DAT	0.69	25.77	1.04	40.01	54.01
14. Control and F 3 DAT	0.41	12.30	1.00	25.46	37.76
SEm±		0.23		0.26	0.44
CD (0.05)		5.02		7.92	16.37

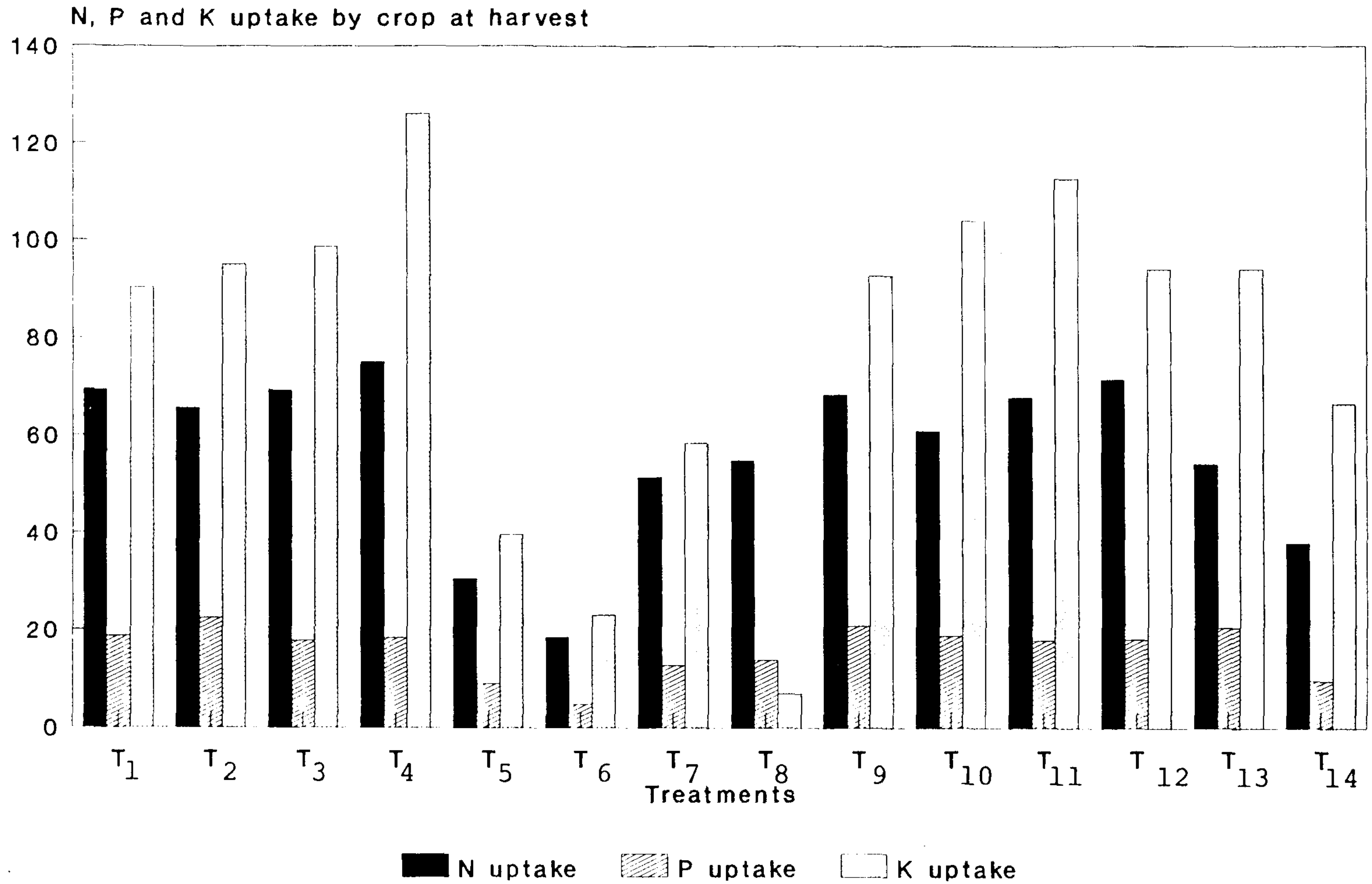
Table 16. Effect of different treatments on content (%) and uptake (kg/ha) of P by rice at harvest

Treatments	Straw Content	Straw Uptake	Grain Content	Grain Uptake	Total Uptake
1. Bs 3 DAT and F 6 DAT	0.16	6.33	0.31	28.57	18.64
2. Bs and F 3 DAT	0.21	7.59	0.37	14.82	22.41
3. Bg 3 DAT and F 6 DAT	0.16	5.81	0.32	11.87	17.67
4. (Bg+F) 3 DAT	0.19	7.71	0.27	10.56	18.28
5. Os 3 DAT and F 6 DAT	0.20	3.04	0.35	5.93	8.98
6. Os and F 3 DAT	0.20	1.75	0.29	2.97	4.71
7. Og 3 DAT and F 6 DAT	0.22	4.82	0.33	7.82	12.64
8. (Og+F) 3 DAT	0.19	4.93	0.34	8.78	13.70
9. As 3 DAT and F 6 DAT	0.21	7.39	0.34	13.35	20.75
10.As and F 3 DAT	0.20	7.71	0.29	10.99	18.69
11.Ag 3 DAT and F 6 DAT	0.20	7.91	0.26	9.75	17.66
12.(Ag+F) 3 DAT	0.22	7.44	0.30	10.55	17.99
13.HW and F 3 DAT	0.19	7.19	0.34	13.19	20.38
14.Control and F 3 DAT	0.10	3.12	0.25	6.48	9.60
SEm±		0.23		0.26	0.44
CD (0.05)		1.53		3.32	3.91

Table 17. Effect of different treatments on content (%) and uptake (kg/ha) of K by rice at harvest

Treatments	Straw Content	Straw Uptake	Grain Content	Grain Uptake	Total Uptake
1. Bs 3 DAT and F 6 DAT	2.05	79.89	0.27	10.46	90.36
2. Bs and F 3 DAT	2.25	82.05	0.37	13.00	95.06
3. Bg 3 DAT and F 6 DAT	2.38	89.37	0.25	9.29	98.67
4. (Bg+F) 3 DAT	2.42	98.64	0.22	8.63	126.08
5. Os 3 DAT and F 6 DAT	2.22	35.16	0.25	4.42	39.58
6. Os and F 3 DAT	2.40	20.53	0.22	2.34	22.87
7. Og 3 DAT and F 6 DAT	2.25	49.62	0.35	8.63	58.24
8. (Og+F) 3 DAT	2.32	60.22	0.35	8.88	6.91
9. As 3 DAT and F 6 DAT	2.27	81.04	0.27	11.65	92.71
10.As and F 3 DAT	2.40	92.58	0.30	11.33	103.91
11.Ag 3 DAT and F 6 DAT	2.55	102.36	0.27	10.16	112.53
12.(Ag+F) 3 DAT	2.50	85.88	0.23	8.16	94.05
13.HW and F 3 DAT	2.25	83.60	0.27	10.50	94.10
14.Control and F 3 DAT	2.05	61.97	0.18	4.65	66.62
SEm±		0.45		0.17	0.51
CD (0.05)		17.99		2.51	23.00

Fig. 6. Effect of different treatments on N, P and K uptake by crop at harvest (kg/ha)



4.5.3. Potassium

Potassium uptake by the crop at the time of harvest is given in Table 17 and Fig. 6. Unweeded control recorded significantly lower K uptake than all anilofos and butachlor treatments and handweeded plots. Oxyflourfen treatments recorded lower K uptake than other herbicidal treatments and handweeding due to the reasons mention earlier.

4.6 Economics of weed control

The details of economics of weed control operations are given in Table 18. It revealed that total return was highest in butachlor treatments followed by anilofos treatments which were comparable to handweeding. When cost of chemical weed control expressed as a percentage of handweeding, anilofos and butachlor treatments recorded very low values, pointing out the feasibility of adopting pre-emergence application of butachlor and anilofos for weed control in trasnplanted rice.

The return per rupee invested on weed control was calculated from the additional return from weed control and the cost of weed control operation. The highest return per rupee was obtained from anilofos treatments followed by butachlor treatments and were highly superior to handweeding. If the cost of fertilizer application is

Table 18. Economics of weed control

Treatments	Cost of weed control operation Rs./ha	Gross return Rs./ha	Additional return from weed control	Return per rupee invested on weed control	Expenditure for chemical weed control as % age of Handweeding
1. Bs 3 DAT and F 6 DAT	790	23475	7425	9.4	17.5
2. Bs and F 3 DAT	790	21495	5445	6.9	17.5
3. Bg 3 DAT and F 6 DAT	610	22305	6255	10.3	13.5
4. (Bg+F) 3 DAT	610	23520	7470	12.2	13.5
5. Os 3 DAT and F 6 DAT	1050	9825	-6225	-	23.3
6. Os and F 3 DAT	1050	5925	-10125	-	23.3
7. Og 3 DAT and F 6 DAT	870	14235	-1815	-	19.3
8. (Og+F) 3 DAT	870	15360	-690	-	19.3
9. As 3 DAT and F 6 DAT	488	23040	6990	14.3	10.8
10. As and F 3 DAT	488	22755	6705	13.7	10.8
11. Ag 3 DAT and F 6 DAT	308	22725	6675	21.7	6.84
12. (Ag+F) 3 DAT	308	20955	4905	15.9	6.84
13. HW and F 3 DAT	4500	22905	6855	1.5	100.00
14. Control and F 3 DAT		16050	-	-	-

Cost of Oxyflourfen - Rs. 1250/l   Price of paddy Rs. 450 /q
,, Butachlor - Rs. 180/l   Price of straw Rs. 150/q
Anilofos - Rs. 210/l

Handweeding - 90 W @ Rs. 50 /woman
Broadcasting - 2 M @ Rs. 70 /man
Spraying - Rs. 5 /spraying (10 l)

accounted along with the cost of weed control operations, an additional cost of Rs. 140 /ha would be incurred for broadcasting the fertilizers, for all other herbicidal treatments except for combined application of GP of herbicides with fertilizer. Mixing cost alone will be incurred for GP+fertilizer application, which is neglible. Thus there is a saving of Rs 140 /ha in the case of combined application of herbicides and fertilizers, besides saving time and energy. Thus it would be more economical to apply granular preparations of anilofos and butachlor combined with fertilizer.

Future line of work

There are several reports on the use of oxyflourfen @ 0.15 to 0.2 kg a.i per ha. But in this experiment, oxyflourfen @ 0.15 kg ai per ha was found to be phytotoxic to rice crop. Thus future line of work may be directed to the use of lower doses of this herbicide and the effect of its combined application with fertilizers may be studied. New herbicides being tried in rice weed control, may be tested for their combined application with fertilizers. Due to the shift from transplanting to direct sowing in rice cultivation, the above works may be tried under direct - sown condition too.

Summary

SUMMARY

A field experiment was conducted at the Agricultural Research Station, Mannuthy during the first crop season to find out the effect of combined application of granular preparations (GP) of pre-emergent herbicides and fertilizers in rice. The experiment was laid out in randomised block design, with three replications. The treatments included the application of three pre-emergence herbicides, butachlor, oxyflourfen and anilofos applied a: 3 DAT as spray or GP alone, or in combination with fertilizer. These were compared with handweeding twice and with unweeded control. The important findings of the expe:iment are given below.

The weed spectrum of the fəld comprised mainly of broadleaved weeds and sedges. Aong broadleaved weeds, *Monochoria vaginalis* and *Sphenocle zeylanica* dominated the field. *Shoenoplectus lateriflorus* ad *Cyperus difformis* were the sedges present in the field. Wile *Echinochloa colonum*, *Saccolepis interrupta* and *Rane miliacea* were the important grasses present.

All the three herbicide:der different methods of application reduced the w population. Total weed

population was lowest in oxyflourfen treated plots. But oxyflourfen was highly toxic to crop also and resulted in poor crop stand and low grain yield.

Lowest dry matter production by weeds was recorded in herbicide treated plots, due to the efficient weed control in the initial crop stage itself, irrespective of their methods of application. At 20 DAT, weed dry matter production in handweeded plot was similar to unweeded control, because the weed samples were taken before the handweeding treatment was imposed. However at 40 DAT and at harvest, handweeding recorded lower weed dry matter production.

Highest weed control efficiency at 40 DAT was recorded in handweeded plots. All the butachlor and anilofos treatments either as spray or as GP, alone or in combination with fertilizer recorded similar weed control efficiency values at 40 DAT.

All the oxyflourfen treatments developed phytotoxic symptoms in rice seedlings and hence resulted in poor crop stand which in turn led to the poor crop dry matter production. Butachlor and anilofos under different methods of application were found to be safe to the rice crop and produced higher crop dry matter than unweeded control.

Plant height was found to be affected by different treatments only during the early stage of crop growth. Butachlor and anilofos as spray or as GP, alone or when combined with fertilizer produced higher but similar plant heights and tillers per hill, than unweeded control and oxyflourfen treatments.

Butachlor and anilofos under different methods of application produced higher number of productive tillers per hill. Filled grains per panicle and test weight of grains did not differ among the different methods of application of anilofos and butachlor. All the butachlor and anilofos treatments produced significantly higher but similar grain yields than unweeded control and oxyflourfen treatments.

Nutrient uptake by crop and weeds was negatively correlated. Lower N, P and K removal by weeds were recorded in anilofos and butachlor treatments. The available nutrients in the soil was not affected by the combined application of anilofos or butachlor GP with fertilizer.

The highest return per rupee was obtained from anilofos treatments followed by butachlor treatments.

Among various treatments, combined application of GP of anilofos or butachlor with fertilizer resulted in efficient weed control, higher grain yield and high return per rupee invested, besides saving time and energy in chemical weed control.

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* Originals not seen

Appendix

APPENDIX I

Mean weekly weather parameters during the study period

Week No.	Maximum temperature	Minimum temperature	RH	Rainfall (mm)	Sunshine hours
21	33.9	25.3	89	3.5	7.6
22	30.2	22.8	95	171.8	2.8
23	26.6	22.9	96	280.0	0.08
24	28.4	22.7	97	219.2	0.72
25	30.9	23.7	96	66.6	5.8
26	29.5	22.7	96	253.8	2.7
27	29.7	22.8	96	77.0	3.2
28	28.8	22.0	97	311.5	1.1
29	29.9	21.9	97	293.7	1.0
30	28.2	22.7	96	219.3	0.4
31	27.4	22.1	97	352.9	1.3
32	30.2	23.7	94	32.4	3.5
33	31.0	22.9	95	46.0	5.0
34	30.1	22.7	94	80.6	2.0
35	29.6	22.5	97	167.9	1.7
36	30.3	23.1	96	99.2	5.3
37	32.2	23.4	93	8.2	9.0

COMBINED APPLICATION OF GRANULAR PREPARATIONS OF PRE-EMERGENT HERBICIDES AND FERTILIZERS IN RICE

By

BINDU N. K.

ABSTRACT OF A THESIS

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ABSTRACT

A field experiment was conducted at the Agricultural Research Station, Mannuthy under the Kerala Agricultural University during the first crop season of 1994 to find out the effect of pre-emergent herbicides and fertilizers in rice. The experiment was laid out in a randomised block design and consisted of fourteen treatments with three replications.

Broadleaved weeds and sedges dominated the field. Among broadleaved weeds, *Monochoria vaginalis* and *Sphenoclea zeylanica* were predominant. *Shoenoplectus lateriflorus* and *Cyperus difformis* were the prominent sedges present in the field and *Echinochloa colonum*, *Saccolepis interrupta* and *Isachne miliacea* were the important grasses present.

Butachlor, anilofos and oxyflourfen under different methods of application reduced the weed population. Though oxyflourfen recorded high weed control efficiency, it was highly phytotoxic to the rice crop and resulted in poor crop stand. Butachlor and anilofos applied as home made granular (GP) preparation or as spray alone, or in combination with fertilizer was safe to the crop.

The available nutrients in the soil was not affected by the different methods of application of butachlor and anilofos, alone or when combined with fertilizer.

Butachlor and anilofos as spray or as GP applied alone, or in combination with fertilizer recorded similar crop growth characteristics, yield and yield attributes.

Nutrient uptake by weeds was lower in butachlor and anilofos treatments. Lower weed index values were recorded in butachlor and anilofos treatments. The highest return per rupee was obtained from anilofos treatments followed by butachlor treatments. In general, combined application of anilofos or butachlor GP with fertilizer gave efficient control of weeds, produced higher grain yields and high return per rupee invested. It also reduced cost, energy and time of weed control operation.