SEQUENTIAL AND COMBINED APPLICATION OF HERBICIDES IN DRY SOWN RICE

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree

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1989

In Loving Memory of

My Father

Shri John Chacko

DECLARATION

I hereby declare that this thesis entitled "Sequential and Combined application of Herbicides in Dry sown Rice" is a bonafide 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 similar title of any other University or Society.

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We, the undersigned, members of the Advisory Committee of Smt.JOLLY CHACKO PALAIKUDY, a candidate for the degree of Master of Science in Agriculture with Major in Agronomy, agree that the thesis entitled "Sequential and Combined application of Herbicides in Dry sown Rice" may be submitted by Smt.JOLLY CHACKO PALAIKUDY, in partial fulfilment of the requirement for the degree.

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Introduction

INTRODUCTION

Direct seeding of rice is a common practice among farmers in rainfed areas to take advantage of early rains for crop establishment. In Kerala rice is the principal crop, occupying an area of 6.64 lakh hectares. Out of this, 1.86 lakh hectares are cultivated during the virippu season, about 87% of which is under semi dry system of rice (FIB, 1989). So in this semi dry system of cultivation intermittent rains lead to alternate wetting and drying of soils, creating great weed problem by emerging with the crop and competing vigorously for nutrient, space and sunlight and thereby reducing the grain yield. Major portion of weed population is constituted by grassy C_4 plant type which are aggressive and competition is therefore greater with C_3 rice.

In dry seeded rice the yield losses due to weeds is very huge and vary to a great extent depending on the weed intensity, weed competition, cultivar used and the management level adopted. Pillai and Rao (1974) and Singh (1985) have estimated the extent of yield reduction in India to be around 15-20% in transplanted rice, 30-35% in direct seeded rice under puddled conditions and over 50-60% in upland rice.

The most common methods of weed control practiced from time immemorial are the mechanical and cultural method of which hand weeding is the most common. But hand weeding is a slow and labour intensive activity and require repeated operation for successful weed control. With labour becoming more scarce and costly, now-a-days herbicides offer a great potential.

There are nearly two hundred herbicides, chemically and functionally diverse and highly selective available for use in various crops including rice throughout the world. However, in dry sown rice the range of herbicides that could be effectively used against the weeds without causing harm to rice seedlings is very limited.

Herbicides like butachlor and thiobencarb are widely recommended for pre-emergence application in dry sown (semi-dry) rice. Studies indicate that weed free condition upto 40-60 days is essential for getting good yields in dry sown rice (Ali and Sankaran, 1984a; KAU, 1984b). It is seen that the residual activity of these herbicides will last only for about three weeks and hence there is every chance of weed emergence and competition from about one month after sowing.

A single herbicide treatment with pre-emergence herbicides like butachlor and thiobencarb alone is found unsatisfactory (IRRI, 1978, 1980). To control the weeds emerging after the effect of the pre-emergence herbicide is over, a post-emergence spraying with propanil at 30 DAS @ 1.5 kg/ha or a hand weeding around 40 DAS is found to be effective. However, propanil is comparatively costlier and is not freely available in market always. Hand weeding too is not economical, as the labour charges are very high.

Some of the recent studies conducted by Arceo and Mercado (1981); Ali and Sankaran (1984b); IRRI (1984) and Sharma and Bisen (1985) revealed that combined application of butachlor or thiobencarb with propanil as early post-emergence at 15-20 DAS of the crop is more effective than their individual application, sequentially.

A second application of the pre-emergence herbicide at a stage when the activity of the first applied is over, may help to extend the weed free condition. If this can be achieved, rice crop can be freed from weed competition during the critical stages completely and this will also bring down the cost of weed control as the unit cost of butachlor and thiobencarb is only about 50% of that of propanil or hand weeding.

Considering all these aspects, the present investigation was taken up with the following objectives:

(i) To evaluate the feasibility of repeated application of pre-emergence herbicides for weed control in dry sown rice.

(ii) To develop a cheaper and efficient herbicide sequence for season long weed control in dry sown rice.

(iii) To assess the crop weed competition in dry sown rice in relation to the different weed control methods.

(iv) To find out the efficiency of combined application of herbicides for weed control in rice.

Review of Literature

2. REVIEW OF LITERATURE

In direct seeded dry sown rice weed problem is very severe whether traditional or chemical methods of control are used. In modern agriculture where high yielding cultivars and adequate fertilizers are used, improved weed control is necessary to obtain high yields, especially in monsoon Asia, where weed control and land preparation are poor. In order to elicit optimum response from costly inputs like fertilizer, irrigation, water etc. and to improve the cost benefit ratio, effective weed control measures based on the major weed flora of the field are necessary. Scarcity of labour and increasing wages, make hand weeding costlier and hence modern farming has to rely heavily on chemicals for protecting crops from weeds. Chemical weed control by pre-sowing, pre-emergence and post-emergence herbicides or their combinations are all effective to control weeds. Many studies have been conducted to assess the weed problems in rice and to develop effective weed control measures, in various parts of the world which have been recently reviewed by Sankaran and De Datta (1985). In this chapter the results of some trials, with special reference to dry sown rice are reviewed.

2.1. Weed Spectrum in Dry sown Rice

About 350 species in more than 150 genera and 60 plant families have been reported as weeds of rice (De Datta, 1977 and Barett and Seaman, 1980). Smith Jr. (1983) reported Poaceae (Gramineae) as the most common weed family with more than 80 species reported as weeds of rice. Cyperaceae rank next in abundance with more than 50 species reported as weeds of rice (Holm *et al.*, 1977). Other families with ten or more species reported as weeds of rice include Alismataceae, Asteraceae, Tabaceae, Lythraceae and Scrophulariaceae.

Out of 350 species infesting low land and upland rice, *Echinochloa glabrescens*, *E. crusgalli*, *E. colona* are the common grass weeds, while *Fimbristylis miliaceae*, *Cyperus* spp., *Scirpus maritimus* are the important weed sedges and *Sphenoclea zeylanica*, *Monochoria vaginalis*, *Ludwigia octovalvis*, *Commelina benghalensis*, *Marsilea minuta*, *Ammania baccifera* and *Eclipta alba*, the main broad leaved weeds (Raju and Reddy, 1986). Holm et al. (1977) reported *Echinochloa crusgalli* as the most troublesome weed of rice in the world and *Echinochloa colona* as the second in importance. Among the 14 common weeds of rice identified by Ahmed and Moody (1980) at flowering stage *Echinochloa colona* and *Leptochloa chinensis* were the most important ones. Other world important weeds of rice included

Cyperus difformis, C. rotundus, C. iria, Eleusine indica, Fimbristylis littoralis, Ischaemum rugosum, Monochoria vaginalis and Sphenochlea zeylanica. Ali and Sankaran (1981) reported Echinochloa colona in grasses, Cyperus iria in sedges and Eclipta alba in broad leaved as the major weed species found in association with rice. Sahai and Bhan (1982) and Ali and Sankaran (1986) observed E. colona to be the most competitive weed in rice.

Smith and Moody (1979) reported that weed species that cause problem in rice vary with soil, climate, latitude, altitude, rice culture, seeding method, water management, fertility level and weed control technology. Based on survey of weed flora in paddy fields in mid hills of Himachal Pradesh, Dhiman and Aswathi (1977) concluded that among the various families, the weeds belonging to Gramineae alone constituted 86.45% of the total weed population and in Gramineae family, 83.54% of weeds belonged to Echinochloa sp. In direct seeded upland rice Biswas and Thakur (1983) observed that out of the total weed population 14% was constituted by Echinochloa sp. and 22% by other grasses. Cyperus sp. constituted 23% and broad leaved weeds 41%. Bhandari and Moody (1983) reported that out of 51 weed species observed in direct seeded rice more than 60% were broad leaved, 19.6% grasses and only 17.6% sedges. Moody (1977a) reported that in direct seeded rice, grasses tend to dominate. In upland rice greater infestation of grasses and sedges were reported by several workers (Moody and Drost, 1983; Singh et al., 1986 and Jayasree, 1987). On the other hand in transplanted rice broad leaved and grassy weeds dominated and in broad cast rice, sedges dominated (Venugopal et al., 1983).

In India the common grass weeds that normally infest upland dry seeded rice include Echinochloa spp., Eleusine indica, Paspalum spp., Panicum spp., Setaria spp., Digitaria spp., Cynodon dactylon and Leptochloa sp. Among sedges Cyperus rotundus, C. iria, C. difformis and Fimbristylis spp. are the major weeds and among broad leaved weeds Commelina spp., Euphorbia spp., Amaranthus spp. and Cleome viscosa are the common ones (Singh, 1985).

Field experiments at IARI, New Delhi in unpuddled direct sown rice showed that grasses constituted more than 50% of the total weed flora. Among monocots Echinochloa colona, Eleusine indica, Cyperus rotundus, C. iria and Commelina benghalensis dominated whereas among dicots Digera muriata, Trianthema portulacastrum and Corchorus acutangularis were the major weeds (Kaushik and Mani, 1980). The major weeds of upland irrigated rice in Marathwada included Acalypha indica, Dinebra ritroflexa, Corchorus aestuans, Digera arvensis, Cynodon dactylon, Alysicarpus rugosus, Abutilon indicum and Cyperus rotundus (Shelke et al., 1986). Singh et al. (1987) in three trials in upland rice at G.B. Pant University, Nainital identified Echinochloa colona, Scirpus grossus, Dactyloctenium aegyptium, Cyperus rotundus, C. iria and Trianthema monogyna as the major weed species. In trials at Research Farm of Banaras Hindu University, Varanasi, major upland rice weeds were Cynodon dactylon and Echinochloa colona among grasses; Cyperus rotundus is sedges; and Cyanotis axillaris, Euphorbia hirta, Phyllanthus niruri and Eclipta alba among broad leaved weeds (Singh et al., 1986).

In the trials conducted in dry seeded bunded rice at TNAU Coimbatore, Ali and Sankaran (1986) noted Echinochloa colona, Cynodon dactylon, Dactyloctenium aegyptium, Panicum repens, Paspalum sanguinale, Chloris barbata, Dinebra arabica among grasses; Cyperus iria and C. rotundus among sedges and Eclipta alba, Trianthema monogyna, Amaranthus viridis, Asteracantha longifolia, Chrozophora rotteri, Spilanthes paniculata, Euphorbia hirta, Phaseolus trilobus, Tridax procumbens, Phyllanthus niruri, Comphrena decumbens, Cleome chilidonii, Sesbania exaltata and Corchorus olitorus among broad leaved weeds as the major weed flora. In upland rice in Karnataka state *Cyperus iria*, *Echinochloa colona*, *Eragrostis laminaris*, *Commelina benghalensis*, *Amaranthus viridis*, *Cynodon dactylon*, *Digitaria marginata* and *Fimbristylis miliacea* were the major weeds (UAS, 1986). In upland rice in Andhra Pradesh Raghavulu and Sreeramamurthy (1973) reported *Echinochloa colona*, *Cyperus* sp., *Chloris barbata*, *Dactyloctenium aegyptium* and *Commelina benghalensis* as the major weeds. This trial carried out at Regional Agricultural Research Station, Rudrur, Nizamabad also revealed that grasses dominated the weed flora of upland rice.

In Kerala, Nair *et al*. (1974) reported *Echinochloa crusgalli*, *Cyperus* sp., *Fimbristylis miliacea* and *Monochoria vaginalis* as the major weeds in direct seeded rice. The predominant weeds observed at RRS Mannuthy, Kerala under semi-dry conditions included *Cynodon dactylon*, *Cyperus iria*, *C. cyperinus*, *C. difformis*, *Amaranthus viridis*, *Ageratum conyzoides*, *Eupatorium odoratum*, *Tridax procumbens* and *Phyllanthus niruri* (Nair *et al*., 1979). Experiments conducted at Regional Agricultural Research Station, Pilicode in rice under semi-dry system identified *Echinochloa crusgalli*, *E. colona*, *Ischaemum rugosum*, *Cyperus* sp., *Marselia quadrifolia* and *Eichhornea crassipes* as the predominant weeds (Sudhakara and Nair, 1986). From Rice Research Station, Pattambi, Pillai *et al.* (1980) have reported *Echinochloa colona*, *Cynodon dactylon* and *Brachiaria ramosa* as the important grasses, *Cyperus rotundus* and *C. difformis* as the dominant sedges and *Amaranthus viridis*, *Phyllanthus niruri*, *Cleome viscosa* and *Ludwigia parviflora* as the important broad leaved weeds. In a recent trial at Agricultural Research Station, Mannuthy, Jayasree (1987) identified *Isachne miliacea*, *Saccoleppis interrupta* and *Echinochloa colona* among grasses and, among sedges, *Cyperus iria* as the dominant weeds in rice under dry sown condition. She has further reported that grasses and sedges constituted major portion of the weed flora. At 30 days, grasses accounted for 59.22% of the weed flora while sedges accounted for only 39.62 per cent. The corresponding figures at harvest were 85% and 80% respectively.

The above review on weed flora of rice indicate that the weeds in wet land and upland rice vary greatly. In dry sown/upland rice, grasses dominate the flora whereas in wet land rice, broad leaved weeds are more in abundance. Among grasses *Echinochloa colona* was the most serious weed and in sedges *Cyperus iria* dominated.

2.2. Crop-Weed Competition in Rice

Crops and weeds compete for the same resources to grow and develop and competition is severe when they grow in close proximity and when the supply of the necessary factors fall below the demands of both. Crop-weed competition is severe between plants having similar growth habits because they make the same demand upon the environment. Total loss of crop or very low yield can result if the weeds are not removed in time.

In rice, the crop-weed competition varies with the type of culture, method of planting (transplanting or direct seeding), cultivar (tall or semi-dwarf, low or high tillering) and the cultural practices. Greater crop-weed competition in direct seeded rice than in transplanted rice has been reported by several workers (Pillai, 1977; Smith Jr., 1983 and Sahai *et al*., 1983).

2.2.1 Critical period of crop-weed competition.

In almost all crops, there is a critical period of weed competition, when the competition seriously affects crop growth and yield. In direct seeded rice Balyan (1982) has reported severe weed competition at the early stage of the crop due to simultaneous emergence of weeds along with rice crop. Studies conducted by several workers have shown that increase in duration of competition reduced crop yield to a great extent (Vega et al., 1967 and Moody, 1981). Singlachiar et al. (1978) reported that increase in weed free duration resulted in more number of panicles and ultimately higher yield.

According to Moody (1977b) only little competition existed between rice and weeds during the 1st 20 days for short cultivars and 30 or 40 days for taller, leafier cultivars. He concluded that the weeds germinating after 25-33% of the life cycle of rice crop had little effect on yield. Nair et al. (1975) reported that rice crop has the ability to compete with weeds without adversely affecting yield upto 30 days from the time of sowing. They further reported that weed competition was more severe during vegetative phase of the crop and weed free condition at this stage favoured higher grain production.

Shelke et al. (1985) reported that the most critical period for crop-weed competition in direct seeded rice was during the 1st 30 to 45 days. Reviewing the critical period for weed competition, Sankaran and De Datta (1985) have suggested a weed free period of 50 days after sowing in upland rice. Based on grain yield, Mukhopadhyay et al.

(1971) and Tosh (1977) have opined a weed free period of 55 days under upland condition during monsoon. Trials conducted by Ali and Sankaran (1984a) upland bunded rice in Tamil Nadu revealed that a weed free period of 60 days in monsoon and 70 days in summer was required to ensure optimum yield. Singh et al. (1987) estimated the influence of duration of crop weed competition on grain yield and recorded an yield reduction of 38.1% when competition lasted for the 1st 30 days while competition for the 1st 45 days and 60 days resulted in 48.2 and 74.5 per cent reduction in grain yield.

A weed free period of 0-15 DAS for direct seeded upland rice is essential according to the trials conducted at Rajendra Agricultural University, Pusa (Pusa, 1988).

A weed free period between 11-40 days produced more number of productive tillers (Ali and Sankaran, 1975).

Sahai et al. (1983) and Singh et al. (1987) reported the period 15-45 DAS to be the most critical for crop-weed competition in upland rice. They have observed that the weeds emerging during the 1st 15 DAS had no significant effect on grain yield while weeds emerging between 15 and 30 DAS competed with the crop resulting in reduced grain yield. However, Singh et al. (1987) estimated a loss of 91.4% in grain yield in rice when a weed free condition was maintained only for the 1st 15 days and this was found to be on par with weedy condition for the 1st 75 days or upto harvest.

The above review indicates that the adverse effect of weed competition on crop yield started only from 15 days after sowing and a weed free condition from 2 weeks after sowing to 50 or 60 days is required to ensure better yield in dry sown rice.

2.2.2 Effect of weeds on growth and yield components.

The adverse effect of weed competition on crop growth and yield have been studied by several researchers. Apart from the effect of weed competition on dry matter production, the important yield components influenced include the number of panicles/unit area and the number of filled grains/ panicle.

(a) Growth

(i) Plant height

Reduction in plant height due to weed competition was reported by Mukhopadhyay and Bag (1967), Tasic et al. (1980)

and TNAU (1985). Reduction in plant height and hastening of maturity has been reported by Chang (1973) due to weed competition. Sreedevi (1979) from Kerala reported that the height of plant in unweeded plot (61.74 cm) was lesser than hand weeded plot (74.25 cm). However, Noda et al. (1968) and Jayasree (1987) reported increased plant height due to competitive stress.

(ii) Dry matter production

Chakraborthy (1973) recorded reduction in crop dry matter production due to weed competition. Jayasree (1987) also obtained maximum crop dry matter production in hand weeded plot and herbicide treated plot, while at all stages of crop growth, the unweeded check recorded the minimum crop dry matter. Patel <u>et al</u>. (1985) reported that in rice nurseries crop dry matter weight was negatively correlated with weed dry weight. Highest crop dry weight (45 gm^{-2}) was produced when lowest weed dry weight (6 gm^{-2}) was got. Jayasree (1987) also obtained negative correlation between the dry matter production by crop and weed at all stages of the crop with more correlation coefficient at the initial stages, indicating the importance of weed free condition during the early stages of the crop.

(b) Yield attributes

Reduction in productive tillers due to weed competition have been reported by Sreedevi (1979) and Ramamurthy *et al.* (1974). Jayasree (1987) noticed reduction in number of productive tillers/hill, length of panicle and number of grains/panicle due to increased weed density. Kaushik and Mani (1980) and Jayasree (1987) observed that weed control treatments improved grain filling and plumpiness, 1000 grain weight and number of grains per panicle. Sudhakara and Nair (1986) also reported better tillering, higher panicle weight with effective weed control.

According to Swain (1967), the effect of *Echinochloa* sp. in tillering was the main factor for reduction in yield. Arai (1967) reported that *Cyperus difformis* reduced tillering, panicle numbers and spikelets per ear. Noda (1973) reported that in Japan *Echinochloa crusgalli* was most competitive with rice at maximum tillering or the early ripening stage. According to him, competition during maximum tillering reduced the number of panicles, while competition at early ripening stage reduced grain weight and quality.

Ghobrial (1981) estimated reduction in panicle number per unit area by 37%, number of filled grains/panicle by 13% and 1000 grain weight by 4% due to weed competition.

The above review clearly indicates that weed competition adversely affects the growth, dry matter production as well as the yield attributes of dry sown rice.

2.2.3 Yield reduction due to weed competition

Crop yield losses from weeds usually are proportional to the amount of water, light and nutrients used by the weeds at the expense of the crop. According to Moody (1977a), yield reduction results mainly due to competition for nutrients, especially during early growth stages.

In India, an annual loss of 15 million tons of rice equivalent to 28% of annual production is estimated due to weed competition (Pillai and Rao, 1974). All season competition may reduce grain yields by 11% in transplanted rice, 20% in direct wet seeded rice and 46% in direct dry seeded rice (De Datta, 1979).

Uttaman (1949) reported losses ranging from 5% decline in grain yield to total failure of crop due to weed competition. Other estimates on losses due to weeds ranged between 10 to 98% (Mukhopadhyay et al., 1972); 30 to 40% (Singlachiar, 1977) and 60 to 75% (Babiker, 1982).

Trials conducted at CRRI Cuttack in direct seeded rice by Dubey et al. (1976) showed total loss of crop with no weeding. In another trial at CRRI Cuttack Moorthy and Dubey (1981) estimated an yield reduction of 59% due to weeds in upland rainfed rice. In West Bengal Mukhopadhyay (1981) estimated a yield loss as high as 70 to 90% due to weed competition. In Tamil Nadu a yield reduction of 53% in direct seeded low land rice and 91% in upland rice under unchecked weed growth has been reported by Ali and Sankaran (1984a). Jayasree (1987) from Kerala reported a yield reduction of 73.59% due to weed competition.

In direct seeded rice, in Philippines, sedges and broad leaved weeds reduced grain yields by 24% while grasses reduced yield by 86% and their combination 100% (De Datta, 1979). Bhan et al. (1980) also reported that grassy weeds were more influential in reducing grain yield compared to broad leaved weeds.

Experiments conducted under AICRPWC indicated that *Echinochloa* infestation to an extent of 17% decreased the yield to about 50% (UAS, 1985). Yield reduction of 40% in rice with 10 plants/m^2 of *Echinochloa* sp. was reported by Gupta (1984), when the weed was allowed to compete for four weeks. Matthews (1986) concluded that yield reduction of significant importance occurred when more than 1 weed/sq. ft. ie. approximately 11 weeds per sq. m was present. Dense weed infestation (more than 100 weeds/m^2) by common rice weeds reduced yields by 70% or more.

From the above literature it can be concluded that in dry sown rice, yield losses are very severe and uncontrolled weed competition may even result in complete failure of the crop.

2.2.4 Nutrient uptake.

2.2.4.1 Nutrient drain by weeds

Weeds have larger requirement of nutrients and have higher mineral nutrient content than crop plants (Alkamper, 1976 and Singh et al. 1986). Weeds grow faster than crop plants and absorb the available nutrients earlier, thus depriving the supply of nutrients to the crop plants (Jayakumar et al., 1987).

Many workers have estimated the competition for nutrients by weeds in rice. Kakati (1976) reported that the weeds deprive the crop of nitrogen to the extent of 64% of the normal uptake. Jayakumar et al. (1987) worked out the NPK removal by weeds as 31.05 kg N; 10 kg P and 32.6 kg K per hectare. Nutrient removal in unweeded plot was nearly 10 times more than the nutrient removal in chemical or manual weeding methods. According to Sankaran et al. (1974), the uptake of nutrients by weeds was 62.1 kg N; 20 kg P and 65.3 kg K per hectare which was nearly nine times more than the removal in chemical or manual weed control methods.

Swain (1967) reported serious competition for nitrogen and potassium in rice. According to Chakraborthy (1973) competition for nitrogen was more during the first half of rice crop. He found higher N content in weed species than the crop at the vegetative, flowering and post flowering stages, indicating severe competition for N throughout the upland rice growing season. Grass weeds are found to remove higher amount of N/ha (37.1 kg) than sedges and broad leaved weed (Mukhopadhyay et al., 1972). Verma and Mani (1970) reported that unchecked weed growth depleted soil nitrogen to the extent of 20 kg/ha. A loss of 26.3 kg N/ha in unweeded treatment was reported by Manna and Moorthy (1980). Jayasree (1987) reported a loss as high as 99.2 kg N/ha in unweeded check compared to only 4.9 kg N/ha in hand weeded plot.

Verma and Mani (1970) reported that unweeded control depleted 11.8 kg P/ha through weeds. Jayasree (1987) reported that in weedy plots phosphorus removal could go upto 8.71 kg/ha, whereas the same in hand weeded plot was only 0.54 kg/ha.

Maximum removal of K was also noted in unweeded check 65.3 kg/ha while in hand weeded, it was only 7.5 kg/ha (Sankaran et al., 1974). Jayasree (1987) estimated that 103.31 kg K_2O/ha was removed by weeds in unweeded plot, while it was only 5.72 kg in hand weeded check.

2.2.4.2 Crop uptake

The uptake of nutrients by crop showed a reverse trend.

Sankaran et al. (1974) studied the nutrient uptake of rice crop and reported the NPK uptake by crop as 56.6, 19.4 and 74.3 kg/ha respectively in unweeded plot and the corresponding figure in hand weeded check was 102.5, 38.3 and 124.6 kg/ha. Jayasree (1987) from Kerala reported maximum uptake of NPK in hand weeded plot (180.5 kg N/ha, 20.7 kg P/ha and 239.1 kg K/ha) while in unweeded plot it was 55.7 kg N/ha, 6.7 kg P/ha and 68.3 kg K/ha.

2.3 Chemical Weed control in Dry sown Rice

2.3.1 Pre-emergence herbicides.

Application of pre-emergence herbicides has a special significance in direct seeded dry sown rice since weeds and crop seedlings emerge simultaneously and herbicide treatment can eliminate weed competition.

A number of herbicides like butachlor, thiobencarb, oxyfluorfen, oxadiazon, pendimethalin, nitrogen, piperphos, dimethametryn etc. have been found effective for pre-emergence weed control in dry sown rice. Sankaran and De Datta (1985) have reviewed the work on the use of some of the above pre-emergence herbicides in upland rice.

2.3.1.1 Butachlor

Butachlor, a pre-emergence herbicide is found effective against many annual grasses, sedges and some broad leaved weeds. Best results are obtained when applied at 1-2 kg ai/ha (Moody, 1977b).

Pawan and Gill (1981) reported favourable effect of butachlor on yield attributing characters like plant height, number of fertile tillers, panicle length, number of spikelets/panicle and test weight. Good weed control and higher grain yield with pre-emergence herbicide butachlor has been reported by Tasic *et al.* (1980) and Singh and Dash (1986) in upland rice. Kennard (1973) used butachlor for control of grassy weeds in direct seeded rice. Control of sedges with butachlor in rice nursery was reported by Patel *et al.* (1985). Complete control of *Cyperus* sp. with butachlor was reported by Nair *et al.* (1974) and Moorthy and Manna (1984).

In green house trials adverse effect on root and/or shoot length and dry matter production of rice was reported by Ahmed and Moody (1979) when butachlor at 2 kg ai/ha was applied immediately after seeding. Olofintoye (1982) noted that, though the rate of butachlor between 0 to 3 kg ai/ha did not appreciably reduce the germination of rice seeds, rates exceeding 1.5 kg ai/ha significantly reduced seedling establishment. At IRRI an experiment in upland rice showed poor control of grasses with butachlor (IRRI, 1977). Bhol and Singh (1987) also reported poor control of grassy weeds with butachlor due to rapid decomposition by ultra violet light under irrigated conditions and quick degradation by soil microbes decreased its effectiveness.

Moody (1979) concluded that the erratic performance of butachlor in Philippines in dry seeded rice was due to the difference in weed population, soil properties and climatic conditions. In upland rice, particularly in dry seeded rainfed rice, when ponding of water occurs on the surface of soil, phytotoxicity has been observed where the herbicide is applied pre-emergence in dry soil (Singh, 1985). In the trials conducted at CRRI Cuttack, Chandraka and Manna (1981) has concluded that phytotoxicity of butachlor to germinating rice seeds is unavoidable if heavy rainfall occurs 4 to 5 days after sowing.

2.3.1.2 Thiobencarb

Thiobencarb, a pre-emergence and early post-emergence herbicide is used effectively against most annual grasses and some broad leaved weeds in rice (Singh, 1985). It is safe on direct seeded and transplanted rice and can be applied from 3 days before sowing to 7 days after sowing (Moody, 1977b).

Thiobencarb has been found to be effective for control of weeds in rice by many workers (Mukhopadhyay and Bag, 1967; Tosh, 1977; Santos et al., 1983; KAU, 1984a; Singh and Singh, 1985b and KAU, 1986b). Pillai and Ghosh (1980) found that both grassy and dicot weeds were controlled by thiobencarb application. Investigations conducted at Regional Agricultural Research Station, Pattambi, Kerala, in direct sown rice, revealed that during both first and second crop seasons thiobencarb controlled the weeds most effectively (KAU, 1984a). Thiobencarb @ 1.5 kg ai/ha was found to be more effective during punja season where grasses and all other weeds were present (KAU, 1986a).

Balyan (1982) reported that thiobencarb 2 kg/ha as pre-emergence in direct seeded rice produced more or less equal grain yield as obtained under weed free condition. The herbicide was significantly superior in reducing dry matter production of weeds. Bhan et al. (1985) reported the population and dry weight of weeds to be lowest in direct sown rice when 1-2 kg thiobencarb/ha was applied as pre-emergence. In an herbicide trial conducted at CIAT thiobencarb 3 kg/ha pre-emergence gave higher yield than butachlor at 2.7 kg/ha applied as pre-emergence (CIAT, 1981). Manipon et al. (1981) also reported higher yield with thiobencarb application due to increased tillering. They further stated that the time required for hand weeding could be reduced when herbicides were used. Singh & Singh (1985a) reported that 1.6 kg thiobencarb as pre-emergence application was effective in minimising nitrogen depletion by weeds and maximising nitrogen uptake by the crop.

Pande (1982); Trivedi et al. (1986); Dwivedi (1987) and Tiwari et al. (1987) reported effective control of Echinochloa sp. with thiobencarb. However, Colon et al. (1984) reported that thiobencarb was not effective against Cyperus iria. In the trials under the AICRPWC at Jabalpur (JNVVK, 1987) also poor control of Cyperus iria in thiobencarb applied plots was noticed. Tiwari et al. (1987) also reported the inefficiency of thiobencarb to control sedges and dicots.

As in the case of butachlor Moorthy and Manna (1982) reported toxicity of thiobencarb to rice seedlings, when rain occurred immediately after application of thiobencarb.

2.3.2 Post-emergence herbicide.

2.3.2.1 Propanil

Propanil is a selective post-emergence, contact herbicide that controls many annual grasses. It is effective against some broad leaved weeds and sedges also, if these plants have emerged and are in the seedling stage at the time of application.

Manna and Dubey (1972); Thiagarajan *et al.* (1974) and Lasso and Parlomino (1982) have reported effective control of weeds and increase in grain yield by the application of propanil. Experiments conducted at Batangas (IRRI, 1977) observed good control of weeds and high yields with propanil. Effective control of grasses, broad leaved weeds and particularly sedges with propanil was also reported by Singh *et al.* (1986). Kaushik *et al.* (1973) and Nair *et al.* (1974) have reported effective control of *Echinochloa* sp. and *Cyperus* sp. by the use of propanil resulting in higher yield of rice.

Effectiveness of post-emergence application of propanil at 1 to 4 leaf stage, regardless of the stage of crop, was reported by Smith (1965). Sharma and Bisen (1985) observed that 1.5 to 2 kg propanil/ha was quite promising as single herbicide. Singh and Dash (1984) found that propanil @ 3 kg/ha post-emergence was very effective in decreasing weed population, weed dry weight and weed nitrogen uptake. Mukhopadhyay and Bag (1967) observed increase in plant height when propanil was applied at 4 weeks and yield of grain when propanil was applied at 2 and 4 weeks after planting. This was due to more effective reduction of weeds and consequent production of large number of effective tillers and length of ears under these treatments.

The foregoing review shows that at many places propanil was effective especially for grass weed control. However, in the experiments conducted at IRRI, propanil alone failed to control weeds even when applied at 3-5 leaf stage of the weed (IRRI, 1981a). According to Babiker (1982) post-emergence application of propanil alone could give poor control of grasses, eventhough it had no adverse effect on crop stand. Moody (1977a) has also stated that propanil applied once as post-emergence was not satisfactory for weed control in upland rice.

2.3.3 Residual action of herbicides.

Beetman and Deming (1974) observed that butachlor had a short soil half life and that microbial decomposition was the major avenue of dissipation. Half life of butachlor was reported to be between 9 to 18 days (Kulshrestha *et al.*, 1981), 17.75 days (TNAU, 1987). When weather was hot and clear, rapid degradation of butachlor occured (Chen and Chen, 1979 and Maxima *et al.*, 1986). The half life of thiobencarb was 2-3 weeks under aerobic conditions and 6-8 months under anaerobic condition (WSSA, 1983). Experiments on herbicide residue studies in rice conducted in Tamil Nadu Agricultural University observed that thiobencarb had a half life of

19.07 days (TNAU, 1987). Half life of propanil ranged between 5-9 days and did not persist for more than 26 days in the soil (Kulshrestha *et al.*, 1981). Smith (1984) in his soil persistence studies with propanil, found that over 95% of the applied propanil was degraded within seven days. Average persistence at recommended rates (3.36 to 6.7 kg/ha) in rice is reported to be one to three days under warm, moist conditions (WSSA, 1983).

2.3.4 Herbicide combinations and sequential application.

Herbicide combinations can be applied at pre-emergence or soon after emergence and can be sequentially continued to provide good weed control and produced yields equivalent to those obtained from hand weeding (IRRI, 1981b). Manna and Moorthy (1984) reported that, in upland rice, combined use of herbicides controlled weeds effectively.

In Philippines, single application of a pre-emergence herbicide did not give sustained weed control but when followed by post-emergence herbicide, recorded better yield (IRRI, 1981b). Singh (1985) also reported that the use of pre-emergence herbicide kept the crop competition free only during initial and crucial stage but failed to provide season-long protection and, to get season-long control, a post-emergence application was needed. Similarly, single application of propanil alone was not sufficient for good weed control and had to be repeated twice to get yields on par with hand weeding (Mukhopadhyay and Bag, 1967).

Experiments conducted at IRRI (IRRI, 1980) showed sustained weed control and maximum yields when pre-emergence herbicides were followed by hand weeding. Similar results have been reported by Ahmed and Moody (1982). Sudhakara and Nair (1986), Deshmukh _et al_. (1987) found that economic weed control in direct sown rice can be achieved with application of thiobencarb followed by a manual weeding at 30 DAS. Balyan (1982) observed that thiobencarb in combination with hand weeding at 45 DAS was significantly superior in reducing dry matter production of weeds and in increasing grain yield. Manna and Moorthy (1982) reported that in upland rice, butachlor and thiobencarb, supplemented with one hand weeding, increased grain yield by 20-45%. Higher yields was obtained when butachlor (Singh and Dash, 1986) or thiobencarb (Singh and Singh, 1985b) was followed by a hand weeding.

Singh _et al_. (1973) reported that pre-emergence treatment of rice with butachlor followed by late post-emergence weed control with propanil can maintain rice fields weed free for full season. Bhol and Singh (1987) reported that sequential application of butachlor (4-5 DAS)with propanil (21 DAS) was more effective than their individual application. According to Sharma and Bisen (1985) thiobencarb and propanil applied 10 and 14 DAS rice respectively was the most effective herbicide combination which gave excellent control of most of the weeds and increased paddy yields.

Studies in effective combination and concentration of herbicides showed that early post-emergence application of butachlor or thiobencarb, in combination with propanil, resulted in effective residual weed control and higher grain yield (Dusky, 1984). Sankaran and De Datta (1985) also obtained yields comparable to hand weeding by the use of herbicide combinations. Trials conducted by and at IRRI (IRRI, 1980) showed that propanil, in combination with butachlor, gave excellent weed control. Yamane <u>et al</u>. (1975); Ali and Sankaran (1984b) and Singh and Singh (1985a) recorded highest yield with thiobencarb and propanil combination. Experiment conducted at IRRI indicated that sequential and tank mixtures of pre-emergence butachlor with propanil reduced weed dry weight by 89% and increased leaf area, panicle number and grain filling which led to high yields (IRRI, 1984). The total dry weight of weeds had a strong negative relationship with grain yield indicating that effective weed control is necessary for high yields in upland rice. Similar results have been reported by Singh and Singh (1985a) and Singh et al. (1986). Pawan and Gill (1982) reported the bioefficiency of thiobencarb was improved when applied as tank mix with propanil at 2-3 leaf stage of the weed. Higher grain yields were obtained with combination of thiobencarb and propanil applied 16 DAS (Ali and Sankaran, 1984b). Studies conducted at IITA (IITA, 1983) resulted in good weed control with propanil and thiobencarb combination applied as post-emergence.

From the above review it can be concluded that pre-emergence herbicides have short residual life and hence are effective only for one month and hence a repeated application of a pre-emergence herbicide at the stage when the activity of the first applied chemical has ceased or a hand weeding around 40 days or the application of a post-emergence herbicides at one month are all effective to give season long control. The review also shows better control of weeds with pre-emergence and post-emergence combination applied 15-20 DAS.

Materials and Methods

3. MATERIALS AND METHODS

During the Virippu season of 1987, a field study was conducted to evaluate the efficiency of repeated application of pre-emergence herbicides as well as combined application of a pre-emergence and post-emergence at early post-emergence stage of rice so as to develop a cheaper and efficient herbicide sequence for season long weed control in dry sown rice. The materials used and techniques followed in the experiment are discussed below.

3.1 Site, Climate and Soil

The field experiment was conducted during the viruppu (1st crop season) of 1987 ie. from June to September at Agricultural Research Station, Mannuthy of the Kerala Agricultural University, Vellanikkara, Kerala. This research station is located at 12° 32' N latitude and 74° 20' E longitude at an altitude of 22.5 m above MSL and enjoys a typical tropical climate.

The details of meteorological observations for the experimental period are presented in Table 1 and illustrated in Fig. 1.

Table 1. Mean weekly weather parameters for the crop period: May - September, 1987

Standard week		Temperature(°C) Max	Temperature(°C) Min	Relative humidity (%)	Total rainfall (mm)	Number of bright sunshine hrs.
22	May 28 - June 3	34.7	25.0	72.5	152.8	6.6
23	June 4 - June 10	31.8	23.5	68.5	42.6	4.4
24	June 11 - June 17	29.6	23.6	89.5	231.3	1.4
25	June 18 - June 24	31.0	23.9	81.0	278.4	5.7
26	June 25 - July 1	29.7	23.6	84.5	164.0	3.7
27	July 2 - July 8	29.9	23.0	88.5	125.7	2.4
28	July 9 - July 15	29.7	23.6	85.0	133.7	4.2
29	July 16 - July 22	30.7	23.8	83.5	25.6	7.8
30	July 23 - July 29	30.7	23.7	81.0	18.6	8.3
31	July 30 - August 5	30.7	23.9	82.0	20.6	6.7
32	August 6 - August 12	30.7	23.3	84.0	41.5	4.4
33	August 13 - August 19	28.7	23.4	89.0	122.6	1.5
34	August 20 - August 26	29.1	23.3	89.5	179.9	2.2
35	August 27 - September 2	30.1	24.2	83.2	25.3	6.7
36	September 3 - September 9	30.8	23.5	80.0	30.9	7.9
37	September 10 - September 16	32.1	24.5	77.0	21.4	9.4
38	September 17 - September 23	31.7	24.1	81.0	12.2	5.8

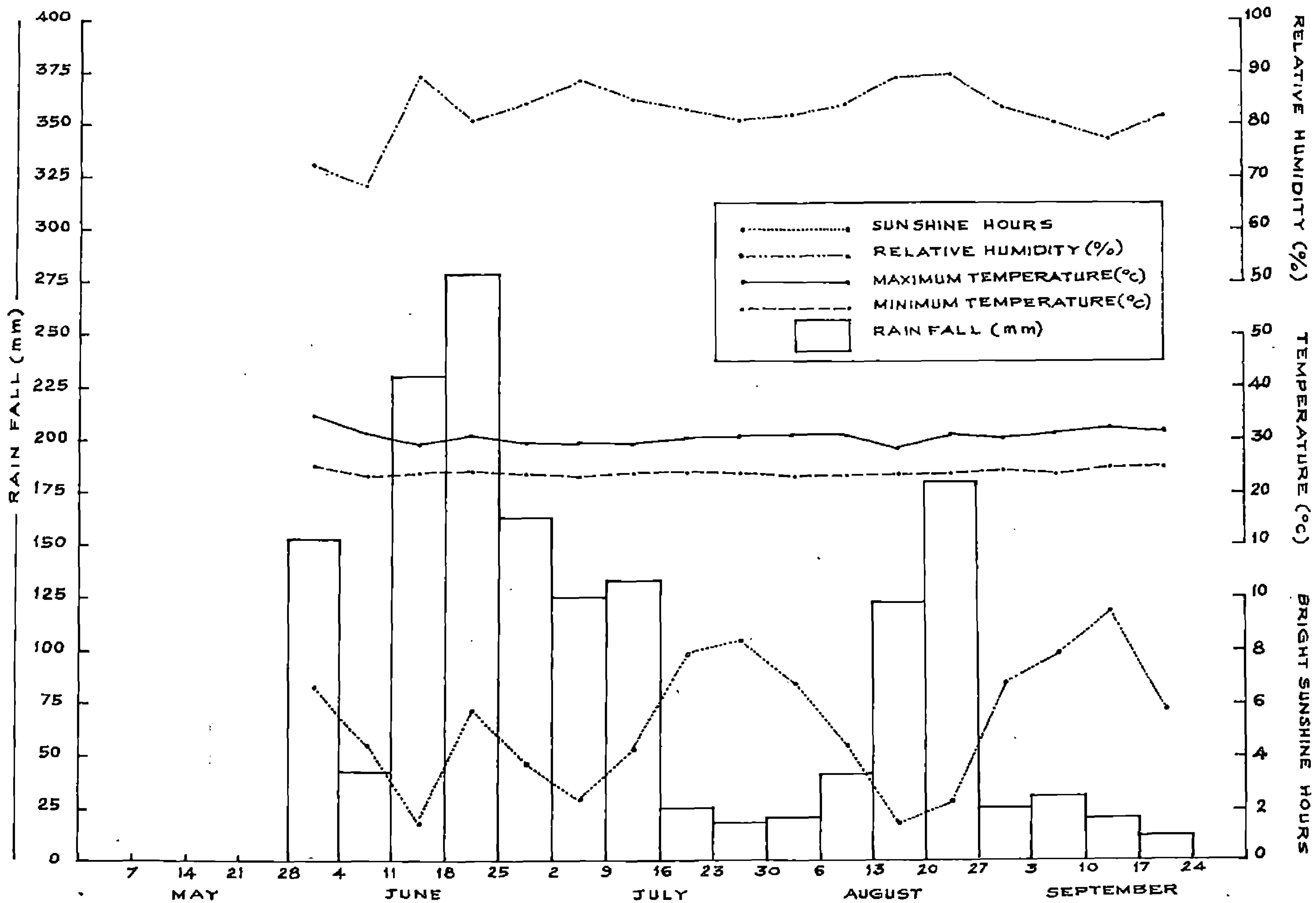


FIG. 1. METEOROLOGICAL OBSERVATIONS DURING THE EXPERIMENTAL PERIOD.

The soil of the experimental field is sand clay loam in texture. The physical and chemical nature of the soil are presented in Table 2.

The experimental area is a double cropped wet land and was under bulk crop of paddy for the last two years.

3.2 Treatments

The treatments were so selected to have an understanding of the relative efficiency in the application of butachlor and thiobencarb at sowing and repeated at 20 or 30 days with that of (a) single application at sowing alone (b) single basal application followed either by hand weeding or post emergence application of propanil, or (c) a combined application of butachlor or thiobencarb with propanil at early post emergence stage.

There were 15 treatments as detailed below:

Treatment	Abbreviation given
1. Unweeded control	U.W.
2. Hand weeding (3 hand weedings at 21, 40 and 55 days after sowing)	H.W.
3. Thiobencarb @ 1.5 kg/ha at sowing	To
4. Thiobencarb @ 1.5 kg/ha at sowing + Thiobencarb @ 1.5 kg/ha 20 DAS	To + 20
5. Thiobencarb @ 1.5 kg/ha at sowing + Thiobencarb @ 1.5 kg/ha 30 DAS	To + 30

Table 2. Physical and chemical nature of soil of the experimental field

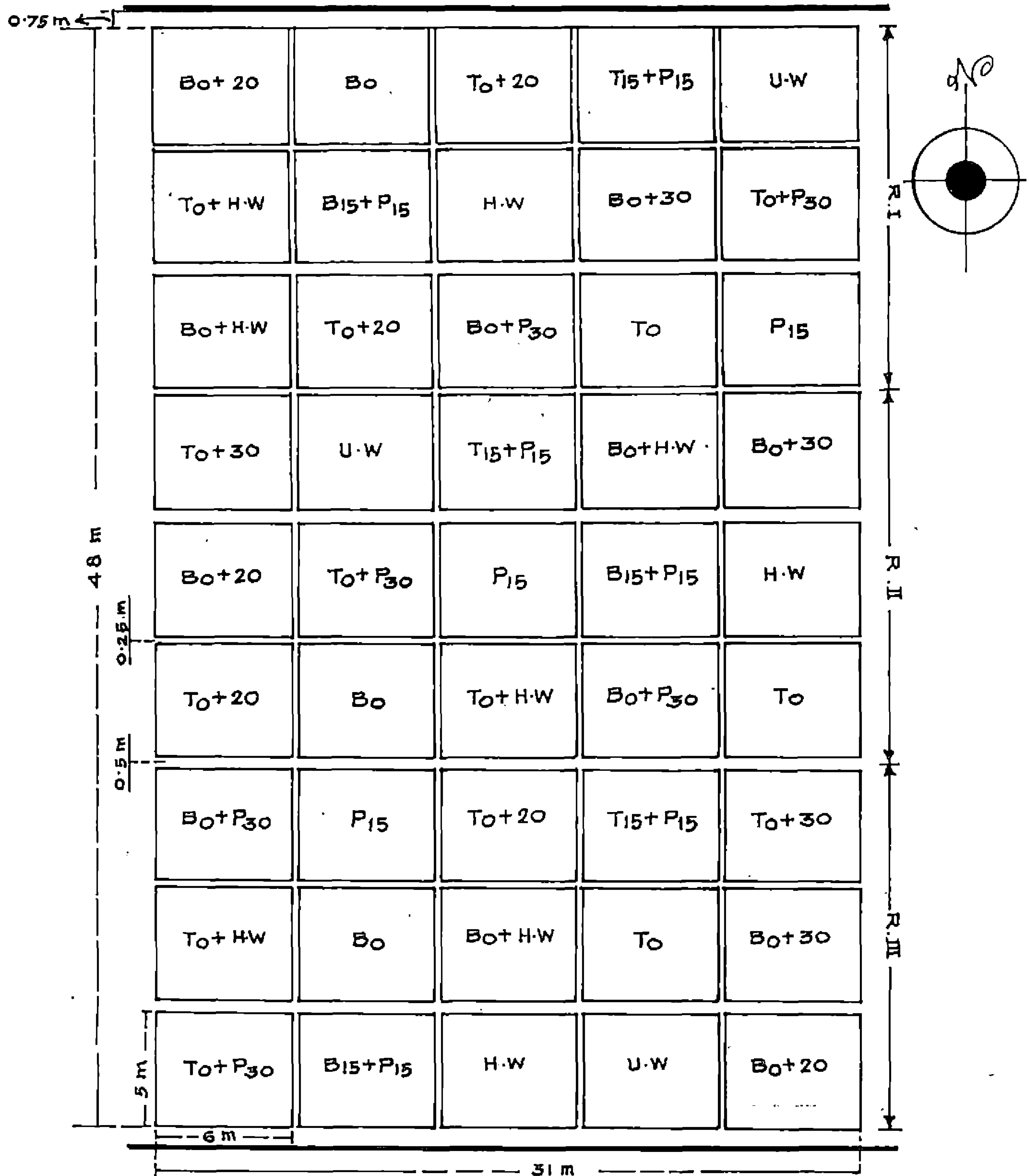
Particulars		Value	Method employed
A. <u>Physical characters</u>			
Mechanical composition			
Coarse sand	(%)	27.2	Robinsons international Pipette Method (Piper, 1942)
Fine sand	(%)	23.8	
Silt	(%)	22.6	
Clay	(%)	26.4	
Bulk density		1.52	Core Sampler Method (Piper, 1942)
B. <u>Chemical composition</u>			
Organic carbon	(%)	0.661	Walkley and Black Method (Soil Survey Staff, 1967)
Total N	(%)	0.138	Semi Micro-Kjeldahl Method (Soil Survey Staff, 1967)
Available P	(Kg/ha)	32.06	Bray I extractant, Molybdophosphoric acid method (Jackson, 1958)
Available K	(Kg/ha)	172.08	Neutral normal ammonium acetate extract, flame photometry (Jackson, 1958)
pH		5.84	1 : 2.5 soil-water suspension, using a pH meter (Jackson, 1958)

6.	Thiobencarb @ 1.5 kg/ha at sowing + Propanil @ 1.75 kg/ha 30 DAS	To + P 30
7.	Thiobencarb @ 1.5 kg/ha at sowing + 1 HW at 40 DAS	To + H.W.
8.	Thiobencarb @ 1.5 kg/ha + Propanil 1.75 kg/ha (tank mix) 15 DAS	T + P 15
9.	Butachlor @ 1.5 kg/ha at sowing	Bo
10.	Butachlor @ 1.5 kg/ha at sowing + Butachlor @ 1.5 kg/ha 20 DAS	Bo + 20
11.	Butachlor @ 1.5 kg/ha at sowing + Butachlor @ 1.5 kg/ha 30 DAS	Bo + 30
12.	Butachlor @ 1.5 kg/ha at sowing + Propanil @ 1.75 kg/ha 30 DAS	Bo + P 30
13.	Butachlor @ 1.5 kg/ha at sowing + 1 HW at 40 DAS	Bo + H.W.
14.	Butachlor @ 1.5 kg/ha + Propanil 1.75 kg/ha (tank mix) 15 DAS	B + P 15
15.	Propanil alone @ 1.75 kg/ha 15 DAS	P 15

3.3 Design and Layout

1. Design : Randomised Block Design
2. Replication : 3
3. Plot size
   - i) Gross plot size : 5 m x 6 m = 30 m^2
   - ii) Border : 0.5 m on all sides
   - iii) Sampling area : One metre strip along the 5 m side inside the border area
   - iv) Net plot size : 4 m x 4 m = 16 m^2

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



A. TREATMENTS

1. T_0 - THIOBENCARB AT 0 DAS.
2. T_0+20 - THIOBENCARB AT 0 DAS+20 DAS.
3. T_0+30 - THIOBENCARB AT 0 DAS+30 DAS.
4. T_0+P_{30} - THIOBENCARB AT 0 DAS+PROPANIL AT 30 DAS.
5. T_0+H·W - THIOBENCARB AT 0 DAS+HAND WEEDING AT 40 DAS.
6. B_0 - BUTACHLOR AT 0 DAS.
7. B_0+20 - BUTACHLOR AT 0 DAS+20 DAS.
8. B_0+30 - BUTACHLOR AT 0 DAS+30 DAS.
9. B_0+P_{30} - BUTACHLOR AT 0 DAS+PROPANIL AT 30 DAS.
10. B_0+H·W - BUTACHLOR AT 0 DAS+HAND-WEEDING AT 40 DAS.
11. P_{15} - PROPANIL AT 15 DAS.
12. $T_{15}+P_{15}$ - THIOBENCARB AND PROPANIL (TANK MIX) 15 DAS.
13. $B_{15}+P_{15}$ - BUTACHLOR AND PROPANIL (TANK MIX) 15 DAS.

B. CONTROLS

H·W - HAND WEEDING. U·W - UNWEEDED.

FIG. 2.
PLAN OF LAY OUT.

3.3.1 Herbicides.

The details of herbicides used are given below:

Herbicide	Commercial formulation used	Manufacturer	Active ingredient
Thiobencarb	Saturn 50 EC	Pesticides India Limited	50%
Butachlor	NOCIL Butachlor 50 EC	Pest Control Co.	50%
Propanil	Stam F-34	Indofil Chemicals	35%

The technical details of the above chemicals are furnished in Appendix-I.

3.3.2 Method of application.

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

3.4 Variety

Rice variety 'Jyothi' was used for the study. This variety with a duration of 100 to 125 days has red, long and bold grains. This is moderately tolerant to brown plant hopper and blast and is susceptible to sheath blight.

3.5 Field Culture

The crop was sown on June 1st 1987. The cultivation practices recommended for 'Jyothi' by the Kerala Agricultural University (KAU, 1986) were followed. The seeds were dibbled at a spacing of 15 cm x 10 cm. There was no serious incidence of diseases or pests except for rice bug attack at milk stage, which was controlled by spraying Malathion 0.1%. All the cultural operations except weed control were followed as per KAU package of practices recommendations. Weed control as per the treatments were given to different plots. The crop was harvested on 18th September after 110 days, when 80% of the grain had matured in the experimental field.

3.6 Observations

3.6.1 Observations on weeds.

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

(a) Weed count

The weed count from the sampling unit in each plot was made species wise and recorded as number/m^2. The observation was taken at 30, 40, 50 and 60 days after sowing and at harvest. Seperate analysis was done for count of major weeds as well as for total grass, sedge and broad leaved weed and total weed population.

(b) Dry matter production

The weeds from the sampling area in each plot were uprooted, dried in a hot air oven and the weed dry weight recorded in g/m^2 at 30, 40, 50 and 60 days after sowing and at harvest.

(c) Weed control efficiency

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

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

where X = Dry matter production of weeds in unweeded chec

Y = Dry matter production of weeds in the treatment

3.6.2 <u>Observations on the crop.</u>

(a) Phytotoxicity

The rice seedlings were observed for any phytotoxicity symptoms like scorching, retarded growth etc. due to herbicide application.

(b) Crop growth characters

(i) Dry matter production

From 0.25 m^2 area using the sampling quadrat, crop samples were also taken, oven dried and the dry matter production recorded in g/m^2. The observations were taken at 30, 40, 50 and 60 days after sowing and at harvest.

(ii) Height

The plant height in centimeters was recorded on the day of harvest. The height was measured from the bottom of the culm to the tip of the longest leaf or tip of ear head, whichever was the tallest.

(iii) Number of tillers

The total number of tillers were counted from ten hills and the average expressed as number of tillers per hill.

(c) Yield attributes

(i) Productive tillers

The number of productive tillers were counted from ten hills and their average expressed as number of productive tillers per hill.

(ii) Length of panicle

The length of panicle was measured from the neck to the tip of the panicle and recorded in centimeters.

(iii) Number of grains per panicle

The number of grains in each panicle was recorded.

(iv) Thousand grain weight

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

(d) Yield

(i) Grain y

The grain harvested from each net plot was dried to 14 per cent moisture, cleaned, winnowed and the weight recorded in quintals/ha.

(ii) Straw yield

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

(e) Weed index

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

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

where X = Yield obtained from no weed plot (Hand weeded plot)

Y = Yield from the treatment

3.7 Chemical Analysis

The weed plants and crop plants collected from the sampling area were dried separately in a hot air oven to constant weight, powdered well in Wiley mill and analysed for nitrogen, phosphorus and potassium contents.

The methods used for analysis were:

1. Nitrogen : Nessler's Reagent Method (A.O.A.C. 1960) using Spectronic 20 Spectrometer
2. Phosphorus : Vanadomolybdophosphoric yellow colour method using Spectronic 20 Spectrometer (Jackson, 1958)
3. Potassium : Diacid extract method using flame photometer (Jackson, 1958)

The crop and weed samples were analysed for N, P and K contents at 30, 40, 50 and 60 days after sowing and at harvest. At harvest stage the analysis for grain and straw was done separately.

The dry matter of the weeds and crop was multiplied with their respective nutrient content to arrive at the nitrogen, phosphorus and potassium removal by weeds and crop.

3.8 Statistical Analysis

The data recorded for different characters were compiled, tabulated and analysed by applying the analysis of variance technique (Panse and Sukhatme, 1978). Where ever the 'F' tests were significant, appropriate critical difference (CD) were calculated to test the significance of treatment differences. Coefficient of correlation between the important characters were also worked out.

Analysis of variance for the data on weed population was carried out after square root $(\sqrt{x + 1})$ transformation. In the analysis of variance for the data on individual weed population, the treatments having the same values for all the three replications were not included.

3.9 Economics

The net return per rupee invested under different treatments were computed in the basis of prevailing labour charges, cost of other inputs and the market price of grain and straw at the time of harvest.

Results and Discussion

4. RESULTS AND DISCUSSION

The results of the experiment conducted in dry sown rice are presented and discussed in this chapter under the following heads:

4.1 Studies on weeds
4.1.1 Weed spectrum
4.1.2 Weed population
4.1.3 Dry matter production by weeds
4.1.4 Weed control efficiency
4.2 Observations on the crop
4.2.1 Phytotoxicity
4.2.2 Crop growth characters
4.2.3 Yield attributes
4.2.4 Yield
4.2.5 Weed index
4.3 Nutrient uptake studies
4.3.1 Nutrient drain by weeds
4.3.2 Nutrient uptake by crop
4.4 Economics of different treatments

4.1 Studies on Weeds

4.1.1 Weed spectrum

The weed flora in the experimental field comprised mainly of grass weeds like Isachne miliacea, Echinochloa colona and Saccoleppis interrupta and sedge Cyperus iria. Broad leaved weeds were lesser in intensity and among them the main ones were Ludiwigia parviflora and Ammania baccifera. The list of weeds observed in the field are presented in Appendix.II.

Grasses constituted the major proportion of the weed flora. The results of statistical analysis indicates that at all stages the proportion of grasses was higher than sedges and broad leaved weeds. At 30 days, the grass weeds accounted for about 67% and sedges 33% of the weed flora. The proportion of grasses and sedges in weedy check at 60 days were about 94% and 6% respectively. The population of sedges reduced towards harvest since the life period of Cyperus sp is 80 to 90 days. Trivedi et al. (1985) have reported that Cyperus iria completed its life cycle before the harvest stage of paddy. Grass and broad leaved weed count also slightly declined towards harvest. The above observations are in accordance with the results of

Mukhopadhyay *et al*. (1972), Dhiman and Aswathi (1977) who have reported dominance of grass weeds in upland paddy.

4.1.2 Weed population.

4.1.2.1 Grasses

(a) *Isachne miliacea*

Effect of weed control treatments on the population of *Isachne miliacea* is presented in Table 3.

The weed control treatments significantly reduced the population of *Isachne* compared unweeded control. Even though propanil application at 15 days, either alone or in combination with butachlor, could reduce the *Isachne* population significantly, it had higher *Isachne* count than the other herbicide treatments. Combination of propanil with thiobencarb at 15 days was better than its combination with butachlor and the differences were significant at most of the stages.

At 30 days all the treatments involving application of thiobencarb immediately after sowing (whether or not combined with hand weeding, propanil or repeated application at 20 or 30 days) were statistically on par except

Table 3. Effect of treatments on the population of <u>Isachne miliacea</u> (plants/m^2)

Treatments	30 DAS		40 DAS		50 DAS		60 DAS		Harvest	
	T	O	T	O	T	O	T	O	T	O
To	5.66	31.04	5.38	27.94	10.45	108.2	9.76	94.26	9.17	83.09
To + 20	2.86	7.18	3.92	14.37	4.41	18.45	3.73	12.91	2.69	62.36
To + 30	5.66	31.04	3.45	10.9	4.71	21.18	4.66	20.72	4.26	17.15
To + P 30	5.5	29.25	3.18	9.11	4.85	22.52	4.90	23.01	4.32	17.66
To + H.W	5.57	30.04	5.53	29.58	2.61	5.81	2.08	3.33	7.83	60.31
Bo	7.71	58.44	16.89	284.27	21.01	440.42	18.29	333.52	19.48	378.47
Bo + 20	6.34	39.2	11.90	140.6	12.05	144.2	12.54	156.25	10.9	117.81
Bo + 30	8.04	63.64	12.86	164.38	13.77	188.61	12.22	148.33	16.53	272.24
Bo + P 30	7.98	62.68	12.51	155.5	11.87	139.9	10.02	99.4	7.25	51.56
Bo + H.W	7.72	58.6	5.53	30.7	3.08	8.49	3.67	12.47	7.02	48.28
P 15	14.01	195.28	30.89	953.18	26.3	690.69	24.61	604.65	20.18	406.23
T 15 + P 15	8.19	66.08	13.04	169.04	14.74	216.27	14.62	212.74	16.11	258.53
B 15 + P 15	13.24	174.3	22.72	515.2	25.68	658.46	20.86	434.14	23.3	541.89
H.W	3.40	10.56	5.75	32.06	2.75	6.56	–	–	4.52	19.43
U.W	20.81	432.06	49.95	2494.00	46.66	2176.16	45.63	2081.1	41.89	1753.77
SEm±	1.047		3.363		4.279		2.914		3.735	
CD (0.05)	3.031		9.74		12.393		8.473		10.818	

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

T 15 + P 15. Hand weeding was on par with the thiobencarb treatments.

At 40 days after sowing To + P 30 recorded least count of Isachne and all the treatments involving thiobencarb except T 15 + P 15 were on par with this treatment. Among the butachlor treatments, application of butachlor at zero days followed by repeated application at 20 or 30 days or in combination with propanil at 30 days or a hand weeding at 40 days was on par with the above treatments. At 50 days similar results were obtained.

At 60 days hand weeded plot recorded zero count of Isachne because the last hand weeding was given at 55th day. At this stage also all the treatments involving thiobencarb except To and T 15 + P 15 recorded lower Isachne count, on par with hand weeded plot. At this stage among the treatments involving butachlor Bo + H.W recorded the least count of Isachne. This was on par with hand weeded plot and was significantly superior to all the other butachlor treatments. Towards harvest To + 20 recorded least count of Isachne. The hand weeded plot and all the butachlor and thiobencarb herbicide treatments and their combinations except Bo + 30, Bo and the plot where propanil was applied at 15 days either alone or as a tank mix with the pre-emergence herbicides recorded weed count on par with To + 20.

The result shows that thiobencarb was very efficient in controlling *Isachne*. In the combination treatments secondary germination of weeds were also controlled thereby resulting in values on par with hand weeded plot. Application of propanil at 15 days either alone or in combination with butachlor was not very effective as weeds had already germinated by 15 days and complete control could not be achieved by post-emergence herbicide propanil.

(b) *Saccoleppis interrupta*

Effect of weed control treatments on the population of *Saccoleppis interrupta* is presented in Table 4.

The unweeded check recorded the maximum count of this weed at all stages of the crop growth. Among the thiobencarb treatments To + 20 and To + H.W recorded lower *Saccoleppis* population at all stages. The treatments To + 30 and To + P 30 were on par with these two treatments at all stages eventhough they recorded higher *Saccoleppis* count. Among the treatments involving thiobencarb application at zero days To recorded higher *Saccoleppis interrupta* count and this effect was significant at 40 days and at harvest stage.

Butachlor treatments recorded lesser count of this weed and among them highest values were recorded by B 15 + P 15

Table 4. Effect of treatments on the population of <u>Saccoleppis interrupta</u> (plants/m^2)

Treatments	Stages									
	30 DAS		40 DAS		50 DAS		60 DAS		Harvest	
	T	O	T	O	T	O	T	O	T	O
To	3.37	10.36	4.60	20.16	5.42	28.38	5.43	28.48	8.12	64.93
To + 20	1.41	0.99	1.41	0.99	2.71	6.34	2.49	5.2	2.33	4.43
To + 30	2.28	4.2	3.06	8.36	3.95	14.6	3.9	14.21	4.28	17.32
To + P 30	3.58	11.82	2.08	3.33	4.07	15.56	4.49	19.16	5.79	32.52
To + H.W	1.41	0.99	3.94	14.52	1.41	0.99	2.54	5.45	4.10	15.81
Bo	3.66	12.4	5.69	31.38	7.36	53.17	10.54	110.09	10.85	116.72
Bo + 20	3.39	10.49	4.57	19.88	4.49	19.16	4.82	22.23	7.27	51.85
Bo + 30	3.92	14.37	4.30	17.49	6.4	39.96	7.68	57.98	7.71	58.44
Bo + P 30	3.53	11.46	4.10	15.8	4.08	15.65	6.01	35.12	7.09	49.27
Bo + H.W	3.8	13.44	5.87	33.46	1.41	0.99	3.58	11.82	5.24	26.46
P 15	6.08	35.97	8.06	63.96	10.47	108.62	14.45	207.8	14.05	196.4
T 15 + P 15	4.42	18.54	5.74	31.95	8.44	70.23	9.54	90.01	11.46	130.33
B 15 + P 15	5.85	33.22	7.21	50.98	9.84	95.83	13.9	192.21	13.86	191.1
H.W	2.19	3.8	2.99	7.94	1.82	2.31	1.41	0.99	3.00	8.0
U.W	7.21	50.99	9.34	86.24	11.56	132.63	16.03	255.96	18.78	351.68
SEm±	0.773		1.071		0.951		2.302		1.766	
CD (0.05)	2.24		3.103		2.753		6.667		5.113	

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

and Bo whose difference with other butachlor treatment were significant at 50, 60 days and at harvest stage. Among these treatments Bo + P 30, Bo + 20 and Bo + H.W recorded comparable control of Saccoleppis with that of thiobencarb, at most of the stages.

The result on Saccoleppis interrupta population showed almost the same trend as that of Isachne miliacea and might be due to the reason already discussed.

(c) Echinochloa colona

Table 5 presents the data on the population of Echinochloa colona under different weed control treatments at various stages of the crop.

Complete control of this weed was noted wherein thiobencarb was applied at zero days and followed either by a second application of the pre-emergence herbicide or propanil application at 30 days or a hand weeding at 40 days. At all stages of the crop except at 60 days and at harvest stage thiobencarb applied at the day of sowing alone (To) also recorded complete control of Echinochloa colona. The unweeded control recorded maximum count of this weed at all stages of the crop growth. Propanil applied at 15 days either alone or as tank mix with butachlor recorded higher count of this weed at most stages of the crop.

Table 5. Effect of treatments on the population of <u>Echinochloa colona</u> (plants/m^2)

Treatments	Stages									
	30 DAS		40 DAS		50 DAS		60 DAS		Harvest	
	T	O	T	O	T	O	T	O	T	O
To	-	-	-	-	-	-	2.08	3.33	2.54	5.45
To + 20	-	-	-	-	-	-	-	-	-	-
To + 30	-	-	-	-	-	-	-	-	-	-
To + P 30	-	-	-	-	-	-	-	-	-	-
To + H.W	-	-	-	-	-	-	-	-	-	-
Bo	2.87	7.24	6.16	37.19	5.61	30.47	7.24	51.42	5.88	33.57
Bo + 20	1.82	2.31	4.13	16.06	4.15	16.22	4.44	18.71	2.86	7.18
Bo + 30	2.24	4.02	4.76	21.66	4.19	16.56	5.25	26.56	3.78	13.29
Bo + P 30	2.08	3.33	4.24	16.98	1.82	2.31	3.62	12.1	2.71	6.34
Bo + H.W	2.45	5.0	5.87	33.46	0.00	0.00	2.45	5.0	2.54	5.45
P 15	7.51	55.4	8.27	67.39	7.31	52.44	8.83	76.97	8.43	70.06
T 15 + P 15	2.49	5.2	4.12	15.97	5.08	24.81	5.58	30.14	5.16	25.63
B 15 + P 15	6.15	36.82	7.59	56.61	5.35	27.62	6.38	39.7	6.18	37.19
H.W	1.67	1.79	2.91	7.47	0.00	0.00	1.41	0.99	1.67	1.79
U.W	6.60	42.56	9.81	95.24	11.33	127.37	13.00	168.0	11.00	120.00
SEm±	0.832		1.531		1.647		0.749		0.974	
CD (0.05)	2.472		4.55		4.995		2.209		2.874	

T = $\sqrt{x + 1}$ transformed value   O = Re-transformed original value

At 30 days minimum count of Echinochloa colona was noted in hand weeded plot which was on par with the treatments involving butachlor whether applied alone or in combination with propanil or a hand weeding or repeated after 20 or 30 days and T 15 + P 15. Almost similar trend was noted in all the subsequent stages.

The result clearly shows the effectiveness of thiobencarb for controlling Echinochloa colona the most troublesome grass weed in rice fields. Eventhough butachlor could bring about significant reduction in the population of this grass, it was inferior to thiobencarb at all stages.

In a previous study Jayasree (1987) has also reported complete control of Echinochloa colona upto 60 days stage, when thiobencarb was applied immediately after sowing (To). This suggests that the effect of this pre-emergence herbicide is lasting only for a few weeks and calls for follow up weed control operations, either chemical or manual methods, for higher yields.

(d) Total grass weed population

Effect of treatments on the population of grass weed at different stages of observation are presented in Table 6.

Table 6. Effect of treatments on the total grass weed population (plants/m^2)

Treatments	Stages									
	30 DAS		40 DAS		50 DAS		60 DAS		Harvest	
	T	0	T	0	T	0	T	0	T	0
To	6.52	41.51	7.72	58.60	12.03	143.72	11.49	131.02	12.56	156.75
To + 20	3.27	9.69	4.03	15.24	5.46	28.81	4.4	18.36	3.57	11.74
To + 30	6.13	36.58	4.43	18.62	6.4	39.96	6.13	36.58	6.28	38.44
To + P 30	6.5	41.25	4.26	17.15	6.61	42.69	6.62	42.8	7.17	50.4
To + H.W	5.71	31.6	7.25	51.56	2.75	6.56	3.37	10.36	8.79	76.26
Bo	9.01	80.18	18.91	356.59	23.70	560.69	23.51	551.72	23.32	542.82
Bo + 20	7.7	58.29	13.46	180.17	14.43	207.22	15.20	230.04	14.03	195.84
Bo + 30	9.17	83.09	14.65	213.62	16.85	282.92	16.20	261.44	19.05	361.9
Bo + P 30	9.05	80.9	13.78	188.89	12.73	161.05	12.36	151.77	11.14	123.1
Bo + H.W	8.95	79.1	10.48	108.83	3.99	14.92	5.94	34.28	9.10	81.81
P 15	16.99	287.66	34.54	1192.01	29.56	872.79	31.04	962.48	27.34	746.48
T 15 + P 15	9.55	90.2	15.05	225.5	18.88	355.45	19.97	397.8	20.45	417.20
B 15 + P 15	15.91	252.13	25.3	639.09	28.10	788.6	26.07	678.64	27.85	774.62
H.W	4.49	19.16	8.02	63.32	3.2	9.24	1.67	1.79	5.6	30.36
U.W	22.95	525.7	51.83	2685.35	50.1	2509.01	45.63	2081.1	47.54	2259.05
SEm±	1.051		2.824		3.872		2.229		3.379	
CD (0.05)	3.044		8.178		11.216		6.455		9.788	

T = $\sqrt{x + 1}$ transformed value   0 = Re-transformed original value

All the weed control treatments significantly reduced the grass weed population compared to unweeded control. In general, thiobencarb treatments were significantly better than the corresponding butachlor treatments except for the combination of pre-emergence herbicide with propanil or hand weeding which were on par at most of the stages. Both thiobencarb and butachlor resulted in considerable reduction in grass weed population when the single pre-emergence application was combined with a repeated application, propanil or hand weeding. Among these combinations To + 20 recorded the least grass weed count at all stages except at 50 and 60 days after sowing wherein To + H.W and hand weeded plot recorded the least grass count respectively. However, there was no significant difference between To + 20; To + 30; To + P 30 and To + H.W which were on par with hand weeding except that To + P 30 recorded significantly higher grass count than To + 20 at 30 DAS. Propanil either alone or in combination with butachlor or thiobencarb could not result in satisfactory control of grass weeds.

The result shows that thiobencarb was very efficient in controlling grass weed population. However, butachlor does not show much promise for grass weed control. Propanil applied at 15 days either alone or as tank mix with butachlor were inferior compared to other herbicide treatments.

In the analysis of the population of major grass weeds individually also showed the relative superiority of thiobencarb over butachlor in all the cases, hence the same result is reflected in the total grass weed population also.

It is also clear, as already discussed that single basal application of the pre-emergence herbicide is not sufficient to bring about reasonable weed control during the crop period. It is necessary to augment the basal pre-emergence treatment with hand weeding or a subsequent application of propanil or the same pre-emergence herbicide. Among these three, repeated application of the same pre-emergence herbicide have resulted in better results in the present trial.

4.1.2.2 Sedges

Among sedges, *Cyperus iria* was the most prominent one present in the field.

(a) *Cyperus iria*

Effect of treatments on the population of *Cyperus iria* at 30, 40, 50 and 60 days and at harvest are presented in Table 7.

The unweeded check recorded significantly higher count of this weed than other treatments at almost all stages of

Table 7. Effect of treatments on the population of <u>Cyperus iria</u> (Plants/m^2)

Treatments	Stages									
	30 DAS		40 DAS		50 DAS		60 DAS		Harvest	
	T	O	T	O	T	O	T	O	T	O
To	8.48	70.91	8.13	65.1	8.42	69.9	7.81	60.0	2.75	6.56
To + 20	7.17	50.41	4.24	16.98	3.27	9.69	3.15	8.92	1.41	0.99
To + 30	8.64	73.65	5.01	24.1	4.99	23.9	3.61	12.03	1.82	2.31
To + P 30	8.46	70.57	4.46	18.89	4.72	21.28	4.44	18.71	1.67	1.79
To + H.W	8.73	75.21	7.98	62.68	1.67	1.79	2.08	3.33	1.67	1.79
Bo	-	-	2.46	5.05	3.4	10.56	2.91	7.47	-	-
Bo + 20	-	-	-	-	-	-	-	-	-	-
Bo + 30	-	-	-	-	1.41	0.99	1.41	0.99	-	-
Bo + P 30	-	-	1.82	2.31	1.82	2.31	1.67	1.79	-	-
Bo + H.W	-	-	3.08	8.49	1.4	0.96	1.41	0.99	1.67	1.79
P 15	9.51	89.44	10.84	116.51	9.57	90.58	8.98	79.64	4.04	15.32
T 15 + P 15	9.96	98.2	10.41	107.37	9.28	85.12	8.05	63.8	3.4	10.56
B 15 + P 15	8.99	79.82	9.64	91.93	7.52	55.55	7.34	52.88	2.75	6.56
H.W	4.19	16.56	2.33	4.43	1.87	2.5	-	-	1.41	0.99
U.W	16.25	263.06	15.74	246.75	10.25	104.06	11.76	137.30	5.75	32.06
SEm±	1.029		1.039		1.488		0.535		0.565	
CD (0.05)	3.058		3.034		4.326		1.563		1.666	

T = $\sqrt{x + 1}$ transformed value   O = Re-transformed original value

the crop growth. Complete control of *Cyperus iria* through out the crop growth was obtained in Bo + 20. All the other butachlor treatments except B 15 + P 15 also brought in significant reduction in the population of *Cyperus iria*. Even though thiobencarb controlled *Cyperus iria* to a certain extent, this effect was inferior to that of butachlor in general. Except at 50 days the population of *C. iria* was significantly higher in the treatments where propanil was applied at 15 days, even though they too had lower counts than the unweeded check.

At all stages of observation, butachlor treatments (either alone or combined with hand weeding or propanil or repeated application at 20 or 30 days) was found to be better than thiobencarb or propanil treatments even though the differences were not statistically significant at some stages.

The count of sedges towards harvest declined because the sedge flowered and completed its life cycle earlier than the crop, as already discussed under weed spectrum.

From the above observations it can be concluded that butachlor was more efficient in controlling this weed at all stages of the crop growth. The efficiency of butachlor in controlling the sedge population in rice has already been reported by Moorthy and Manna (1984) and Nair *et al*. (1974).

Poor control of Cyperus iria with thiobencarb has also been reported by Jayasree (1987). The result suggests that in a field where Cyperus iria weeds are severe butachlor should be preferred over thiobencarb which is more effective against grass weeds.

4.1.2.3 Broad leaved weeds

Table 8 presents the data on the total broad leaved weed population in the experimental field as affected by the different weed control treatments.

The broad leaved weed emergence was noted in the experimental field only after 30 days. Propanil application at 15 days either alone or as tank mix with thiobencarb or butachlor was effective in controlling broad leaved weeds in general though P 15 and T 15 + P 15 showed higher population of broad leaved weeds towards harvest. The low count of broad leaved weeds in unweeded control may be due to the high population of tall sedges and grasses in these plots which have resulted in severe competition for light and thus prevented the emergence of other weeds. Thiobencarb or butachlor applied at zero days of sowing proved to be poor in controlling broad leaved weeds at later stages of crop growth. In the initial stages To + P 30 and Bo + P 30

Table 8. Effect of treatments on total broad leaved weeds (plants/m^2)

Treatments	Stages							
	40 DAS		50 DAS		60 DAS		Harvest	
	T	O	T	O	T	O	T	O
To	8.57	72.44	9.85	96.02	13.37	177.76	10.81	115.86
To + 20	6.40	39.96	6.58	42.3	5.67	31.15	5.9	33.81
To + 30	6.19	37.32	8.26	67.23	10.05	100.0	8.77	75.91
To + P 30	4.28	17.32	6.11	36.33	9.76	94.26	10.24	103.86
To + H.W	8.69	74.52	2.71	6.34	5.9	33.81	7.72	58.60
Bo	7.9	61.41	10.75	114.56	14.54	210.41	12.19	147.6
Bo + 20	6.7	43.89	6.96	47.44	11.97	142.28	5.54	29.69
Bo + 30	7.54	55.85	9.24	84.38	13.52	181.79	7.49	55.1
Bo + P 30	6.02	35.24	6.28	38.44	7.39	53.61	9.83	95.63
Bo + H.W	9.34	86.24	2.19	3.8	6.21	37.56	6.31	38.82
P 15	3.92	14.37	11.00	120.0	6.43	40.34	10.32	105.5
T 15 + P 15	-	-	3.76	13.14	4.31	17.58	10.45	108.2
B 15 + P 15	1.41	0.99	6.27	38.31	3.41	10.63	-	-
H.W	6.0	35.0	3.00	8.0	-	-	4.44	18.71
U.W	6.37	39.58	7.95	62.2	-	-	4.82	22.23
SEm±	1.824		2.12		1.914		2.012	
CD (0.05)	5.303		6.141		5.588		5.85	

$T = \sqrt{x+1}$ transformed value O = Re-transformed original value was found to be efficient in controlling broad leaved weeds probably due to the effect of propanil. From the above result it can be concluded that combined application of propanil with butachlor was better in controlling broad leaved weeds than the other treatments, however the differences between the treatments were not generally significant to draw any definite conclusions.

4.1.2.4 Total weed population

The effect of different treatments on the total weed population is presented in Table 9.

All the weed control treatments significantly reduced the population of weeds compared to unweeded control. At almost all stages except at 40 and 50 days the hand weeded check recorded the least count of weeds. The plot where propanil was applied at 15 days alone or as tank mix with butachlor showed higher weed population, though it was significantly lesser than the count in unweeded control at all stages.

At 30 days all the butachlor involving treatments whether applied alone or repeated after 20 or 30 days or in combination with propanil at 30 days or a hand weeding at 40 days and To + 20 recorded weed count on par with

Table 9. Effect of treatments on the total weed population (plants/m^2)

Treatments	Stages									
	30 DAS		40 DAS		50 DAS		60 DAS		Harvest	
	T	O	T	O	T	O	T	O	T	O
To	10.68	113.06	14.65	213.62	18.34	335.36	23.37	545.16	18.00	323.0
To + 20	7.87	60.94	8.82	76.79	9.69	92.9	11.59	133.33	8.42	69.9
To + 30	10.57	110.72	9.56	90.39	12.18	147.35	16.70	277.89	12.47	154.5
To + P 30	10.68	113.06	9.18	83.27	10.64	112.21	15.46	238.01	13.73	187.5
To + H.W	10.50	109.25	14.47	208.38	4.71	21.18	10.25	104.06	12.36	151.77
Bo	9.01	80.18	21.68	469.02	26.70	711.89	31.29	978.06	26.90	722.6
Bo + 20	7.70	58.29	15.07	226.1	16.27	263.71	19.39	374.97	16.88	283.93
Bo + 30	9.17	83.09	16.54	272.57	22.68	513.38	23.00	528.0	20.74	429.15
Bo + P 30	9.05	80.9	15.55	240.8	14.59	211.87	19.11	364.19	16.00	255.00
Bo + H.W	8.95	79.1	14.67	214.21	4.56	19.79	11.73	136.59	13.09	170.35
P 15	19.58	382.38	36.67	1343.69	33.92	1149.57	35.33	1247.21	29.72	882.28
T 15 + P 15	13.98	194.44	18.48	340.51	22.41	501.21	24.92	620.0	24.84	616.03
B 15 + P 15	18.35	335.72	27.2	738.84	31.23	974.31	27.47	753.6	28.85	831.32
H.W	6.13	36.58	10.42	107.58	5.20	26.04	2.45	5.0	7.68	57.98
U.W	28.11	789.17	55.24	3050.46	53.48	2860.11	47.16	2223.07	48.19	2321.28
SEm±	1.072		2.417		3.294		2.877		3.253	
CD (0.05)	3.105		6.999		9.540		8.332		9.421	

T = $\sqrt{x+1}$ transformed value   O = Retransformed original value hand weeded plot. However the plots where thiobencarb was applied either alone or repeated after 20 or 30 days or in combination with propanil or a hand weeding did not differ significantly with Bo + 20 which recorded the least count of weeds among butachlor treatments.

At 40 days To + 20 recorded the least count of weeds the treatment To + 30; To + P 30; To + H.W; Bo + 20; Bo + P 30 and Bo + H.W were on par with this.

At 50 days all the treatments involving a hand weeding recorded the least count of weeds evidently due to the effect of hand weeding given at 40 days, the treatments wherein thiobencarb was applied at zero days and repeated at 20 or 30 days or in combination with propanil was on par with Bo + H.W. Single application of butachlor alone at zero days and propanil application at 15 days either alone or as tank mix with butachlor recorded higher weed counts even though weed control was better than the unweeded control.

At 60 days the hand weeded plot recorded the least count of weeds and only the treatment To + H.W was on par with it. The single application of thiobencarb or butachlor at zero days recorded higher weed counts than their repeated applications or combination with propanil or hand weedings given at 40 days. Propanil application at 15 days either alone or as tank mix with butachlor or thiobencarb was not effective for the control of weeds even though they recorded significantly lesser weed population than the unweeded control.

At harvest except Bo + 30 all the treatments where the pre-emergence application of thiobencarb or butachlor was repeated or combined with propanil or a hand weeding recorded weed count on par with hand weeded plot which recorded the least count of weeds.

The result shows that both thiobencarb and butachlor were statistically on par on their effect on total weed population. However in the early sections it was found that thiobencarb is very effective in controlling the grass weeds (see 4.1.2.1) and butachlor in controlling the sedges (4.1.2.2). When the total weed population is analysed these two effects get averaged out and hence both the chemicals were showing almost the same results.

4.1.3 Dry matter production by weeds

The effect of different treatments on the weed dry matter production, at different stages of the crop is presented in Table 10 and in Fig. 3, the effect of

Table 10. Effect of treatments on the dry matter production by weeds (g/m^2)

Treatments	Stages									
	30 DAS		40 DAS		50 DAS		60 DAS		Harvest	
	T	O	T	O	T	O	T	O	T	O
To	1.82	6.13	4.28	17.32	4.89	22.91	7.89	61.25	5.24	26.46
To + 20	1.24	0.54	2.69	6.24	3.2	9.24	4.38	18.18	2.68	6.18
To + 30	1.82	2.31	3.2	9.24	3.83	13.67	6.23	37.81	5.03	24.30
To + P 30	2.88	7.29	3.68	12.54	3.67	12.47	6.30	38.69	4.56	19.79
To + H.W	2.07	3.28	4.7	21.09	2.32	4.38	2.51	5.30	3.31	9.96
Bo	3.4	10.56	7.09	49.27	7.43	54.2	11.90	140.61	12.64	158.77
Bo + 20	2.75	6.56	4.51	19.34	3.41	10.63	5.63	30.7	7.89	61.25
Bo + 30	3.78	13.29	5.06	24.6	5.42	28.38	8.73	75.21	9.43	87.92
Bo + P 30	2.75	6.56	4.47	18.98	4.55	19.7	8.31	68.06	6.34	39.2
Bo + H.W	2.85	7.12	7.09	49.27	1.99	2.96	2.88	7.29	4.66	20.72
P 15	5.31	27.2	7.94	62.04	10.53	109.88	14.43	207.22	14.98	223.43
T 15 + P 15	3.66	12.4	7.19	50.7	6.06	35.72	10.93	118.46	12.80	162.84
B 15 + P 15	4.49	19.16	7.67	57.83	9.64	91.93	13.72	187.24	13.06	169.56
H.W	1.63	1.66	2.63	5.92	2.32	4.38	2.05	3.2	2.07	3.28
U.W	6.93	47.02	14.09	197.53	16.14	259.5	18.51	341.62	18.59	344.59
SEm±	0.383		0.668		0.978		1.515		1.379	
CD (0.05)	1.11		1.933		2.833		4.387		3.994	

$T = \sqrt{x + 1}$ transformed value   O = Re-transformed original value

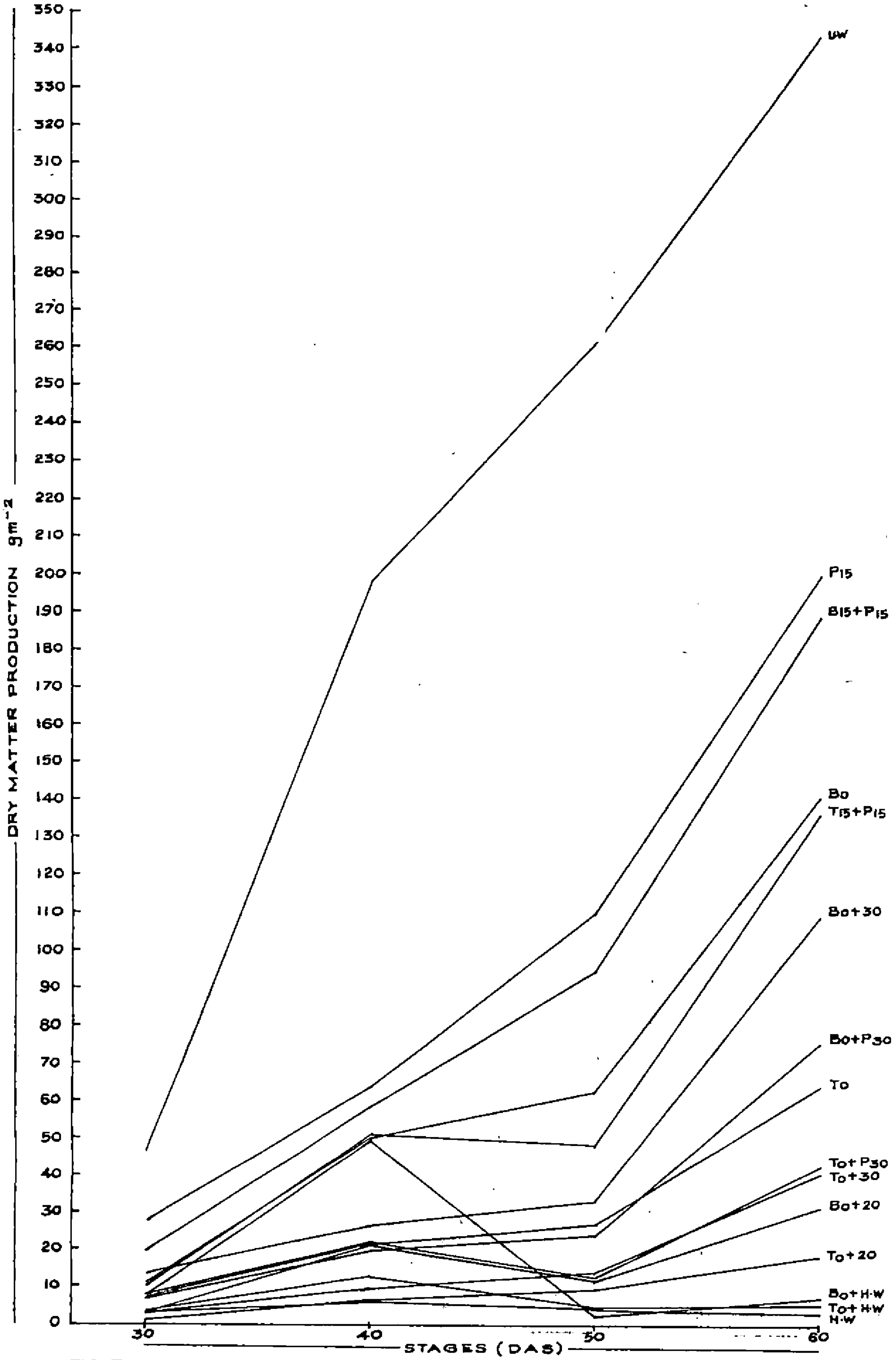


FIG. 3. EFFECT OF TREATMENTS ON DRY MATTER PRODUCTION BY WEEDS DURING CRITICAL STAGES FOR WEED COMPETITION.

treatments on dry matter production by weeds during critical stages for weed competition is illustrated.

At 30 days all the treatments produced significantly lower weed dry matter than the unweeded check. In general, the treatments involving application of thiobencarb were better than those involving butachlor. At this stage To + 20 recorded the least weed dry matter and was on par with To, To + 30, To + H.W and hand weeded check. Propanil applied alone or in combination with thiobencarb or butachlor at 15 DAS was not as effective as the pre-emergence application of the latter two herbicides.

At 40 days the hand weeded check recorded least dry matter and unweeded check the maximum. All the herbicide treatments produced significantly lesser weed dry matter production than unweeded check. The second application of thiobencarb at 20 or 30 days could reduce the weed growth, and this effect was statistically significant for To + 20 treatment. In the case of butachlor, significant reduction in weed growth could be obtained when the basal (Bo) application of butachlor was followed with butachlor at 20 or with propanil at 30 days. At this stage also propanil application at 15 DAS was not very promising, whether applied alone or as tank mix with thiobencarb or butachlor.

At 50 days the least dry matter was recorded by the treatments involving a hand weeding (Handweeding, To + H.W and Bo + H.W) evidently due to the effect of handweeding given at 40 days. The treatments To + 20, To + 30, To + P 30, Bo + 20 and Bo + P 30 were statistically on par with these treatments, indicating that second application of any of these herbicides could reduce the weed growth to a great extent. At this stage also the effect of propanil was not very promising even though the tank mix application of propanil with thiobencarb or butachlor could give better results.

At 60 days when thiobencarb at zero days was followed by another application of thiobencarb at 20 or 30 days or propanil at 30 days could reduce the weed dry matter production to a level statistically on par with that of hand weeded check. In the case of butachlor also there was reduction in weed dry matter production due to second application of the herbicides and this effect was significant in Bo + 20 which recorded dry matter statistically on par with hand weeded plot. A single application of propanil at 15 DAS could not effect any significant reduction in weed dry matter production at this stage also. However, when it was combined with thiobencarb or butachlor as tank mix, the reduction in dry matter production was significant.

The observation on weed dry matter production at harvest stage also showed better effect of follow up application of the herbicides, after their initial application. The treatments involving hand weeding recorded very low weed dry matter at this stage also. The result shows that thiobencarb is better than butachlor in reducing dry matter production by weeds. This is because of the fact that thiobencarb could more effectively control the grass weeds which accounted for the major part of the weed flora in the field, as is clear from the data on the population of grass weeds (Table 6). It is also evident that a second application of the same pre-emergence herbicide (20 or 30 days) or propanil (30 days) after the basal application (0 days) of the pre-emergence herbicide is sufficient to give an effect equivalent to a hand weeding given around 40 days. Since the effect of pre-emergence herbicides butachlor and thiobencarb will last only for few weeks, they can keep the field relatively weed free for about one month only. A hand weeding around 45 days (Ahmed and Moody, 1982; Manna and Moorthy, 1982; Singh and Dash, 1986) or propanil application (Bhol and Singh, 1987; Yamane et al., 1975; Singh and Singh, 1985b; Sharma and Bisen, 1985) is usually recommended to control these weeds. The results of this trial shows that a second application of thiobencarb or butachlor at 20 days stage can extent the weed control effect of pre-emergence herbicides applied at zero days, thereby giving an effect equivalent to hand weeding or propanil application. The effect of propanil application alone at 15 days was not very promising because of the reasons already discussed. However, combination of propanil with thiobencarb or butachlor as tank mix application resulted in better effect as the pre-emergence herbicides could check the further germination of the weeds. Similar results have been reported by Pawan and Gill (1982), Ali and Sankaran (1984b) and IITA (1983).

Fig. 3 clearly shows that even though the single application of thiobencarb or butachlor at zero days could control the weeds effectively upto 30 days, there was gradual increase in the weed competition afterwards. In treatments where the application of pre-emergence herbicide was repeated or followed by propanil application or hand weeding the weed competition was kept down upto 60 days by which time the crop would have passed the critical stage for weed competition.

A correlation study between the total weed population and the dry matter production by weeds at different stages of crop growth (Table 11) showed that there was significant positive correlation between these two parameters at all stages of observation.

Table 11. Correlation between total weed count and weed dry matter at different stages

Stages	Correlation coefficient
30 DAS	0.9339*
40 DAS	0.8481*
50 DAS	0.8901*
60 DAS	0.976*
Harvest	0.7973*
Critical values (13 df)	0.514

4.1.4 Weed control efficiency

The effect of different treatments on weed control efficiency is presented in Table 12 and Fig. 4, illustrates the effect of treatments on weed control efficiency during critical stages.

The observation at 30 days showed that To + 20 recorded the maximum weed control efficiency which was even better than the hand weeded plot. All the treatments where thiobencarb was applied at zero days were on par with To + 20.

Table 12. Effect of treatments on the weed control efficiency (%)

Treatments	Stages				
	30 DAS	40 DAS	50 DAS	60 DAS	Harvest
To	93.33	88.67	90.00	80.33	91.67
To + 20	98.33	97.00	96.00	94.00	97.67
To + 30	94.33	94.67	94.00	88.00	92.33
To + P 30	84.00	87.67	94.33	86.67	94.00
To + H.W	92.67	93.00	98.00	98.00	96.67
Bo	73.33	74.00	77.00	58.33	53.33
Bo + 20	85.33	88.00	94.67	90.33	78.67
Bo + 30	70.67	85.67	88.00	68.00	64.67
Bo + P 30	85.33	90.00	91.00	78.00	88.00
Bo + H.W	83.67	74.33	98.67	97.33	93.33
P 15	40.33	64.00	52.00	38.33	34.33
T 15 + P 15	78.00	73.33	83.33	61.33	51.33
B 15 + P 15	59.00	69.67	63.33	44.33	46.33
H.W	94.00	96.33	97.67	98.33	98.33
SEm±	5.742	4.195	5.167	9.036	9.46
CD (0.05)	16.696	12.199	15.025	26.273	27.505

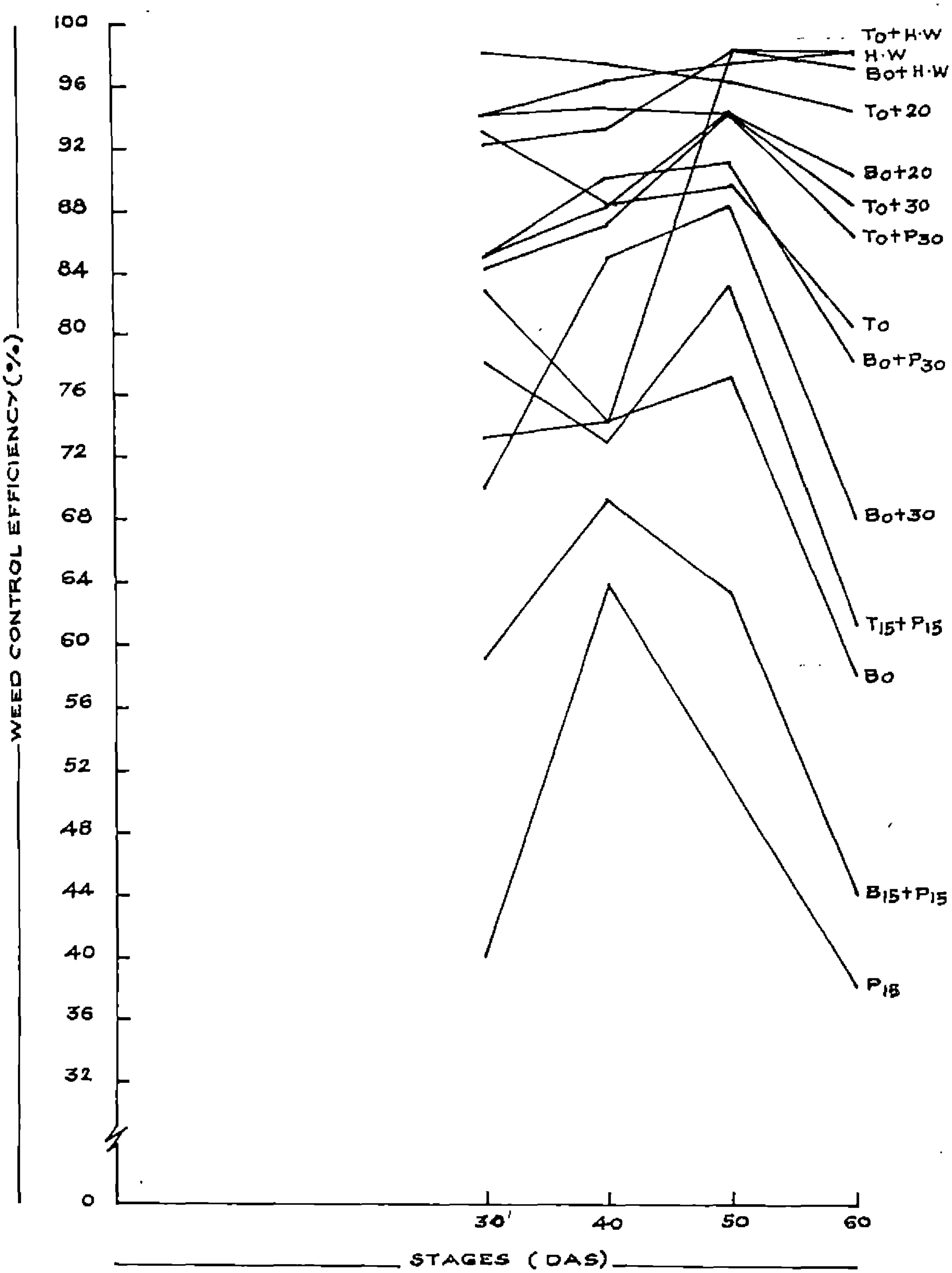


FIG. 4. EFFECT OF TREATMENTS ON WEED CONTROL EFFICIENCY (%) DURING CRITICAL STAGES.

However, butachlor in general recorded lower weed control efficiency than thiobencarb, even though the differences were not statistically significant at all cases. The lowest weed control efficiency was recorded by propanil applied alone at 15 DAS followed by the tank mix application of propanil with butachlor.

At 40 days also To + 20 recorded maximum weed control efficiency as at 30 days. All treatments where thiobencarb was applied at zero days were on par with To + 20 at this stage also. Repeated application of butachlor also could enhance weed control efficiency compared to application at zero days (Bo) and Bo + H.W. The lowest weed control efficiency was recorded by propanil applied alone. The weed control efficiency of tank mix application of propanil with butachlor and thiobencarb at 15 days was also poor.

At 50 days, the treatments involving a hand weeding recorded higher values of weed control efficiency (Bo + H.W, To + H.W and hand weeded check) followed by repeated application of thiobencarb and butachlor and the differences between these treatments were not statistically significant. Even though the 0 DAS application of thiobencarb was statistically on par with these treatments, 0 DAS application of butachlor recorded significantly lower weed control efficiency. As at earlier stages, treatments involving propanil recorded lower weed control efficiency.

Almost the same trend was observed at 60 days and also at harvest stage.

The first hand weeding given on 21st day after sowing was not sufficient for complete weed control. Some flushes of weeds emerged after the first hand weeding as indicated by a lower weed control efficiency value than some of the chemical treatments for the hand weeded treatment at 30 and 40 days, while the hand weedings given at 40th and 55th days controlled most of the weeds, thereby giving higher weed control efficiency for the hand weeded plot at 50 and 60 days and at harvest. At these stages butachlor and thiobencarb at 0 DAS followed by a hand weeding at 40 days also recorded higher weed control efficiency. These results indicate that 2 to 3 manual weedings is necessary to get control of the new flushes of weeds emerging during the critical stages, when no herbicide treatments are adopted and when pre-emergence herbicide treatments are adopted, a manual weeding given to control the weeds after the activity of the pre-emergence herbicides applied has exhausted also will control weed competition with crop at critical stages. Earlier studies by Singh and Dash (1986); Singh and Singh (1985b) and Bhol and Singh (1987) also showed the necessity for follow up weed control operation after pre-emergence herbicide application at sowing.

Repeated application of pre-emergence herbicides at the time when the residual activity of the first applied herbicide was over, also showed promise for maintaining weed free condition almost throughout the crop period.

Fig. 4 clearly indicates that To + 20 showed a high weed control efficiency consistently through out the critical period for weed competition. Single application of the pre-emergence herbicides, even though recorded high weed control efficiency initially, showed decline in weed control efficiency at later stages, but when combined with hand weeding the weed control efficiency could be maintained.

4.2 Observations on the crop

4.2.1 Phytotoxicity

Some phytotoxicity symptoms were noticed on the rice seedlings. The symptom was expressed as delay in germination, yellowing and drying of leaf tips and margin. These symptoms persisted for 2 to 3 weeks but subsequently the crop recovered.

In many of the studies no phytotoxicity symptoms for these herbicides were noted (Olofintoye, 1982; Sudhakara and Nair, 1986 and Jayasree, 1987). However, Manipon et al. (1981) has reported toxic effect of thiobencarb to germinating seedlings. Experiments conducted at CRRI, Cuttack also observed poor seedling growth for about 2 weeks, when thiobencarb was applied @ 2 kg/ha but the seedlings recovered after one month (CRRI, 1987). Ahmed and Moody (1979) also observed adverse effect on shoot and/or root length and dry matter production of rice with butachlor @ 2 kg ai/ha. Singh (1985) observed phytotoxicity in dry seeded rainfed upland rice when ponding of water occurred at soil surface. Chandraka and Manna (1981) has also reported that phytotoxicity is likely to occur due to butachlor to germinating rice seeds due to heavy rainfall after sowing.

In this study also there was heavy rainfall after the application of the pre-emergence herbicides at zero days which might be responsible for the expression of the phytotoxicity symptoms. The influence of rainfall on phytotoxicity is very clear from the fact that there was no such phytotoxicity symptom observed for thiobencarb by Jayasree (1987) in her trial conducted in the same station, when there was no rainfall for few days after application of the herbicide.

4.2.2 Crop growth characters

(a) Height

The data on the mean height of the crop plants at harvest under the different treatments are presented in Table 13.

The maximum height of 85.57 cm was noted in the hand weeded check. All treatments except the unweeded check was statistically on par with this treatment. However, the treatments involving one hand weeding (To + H.W and Bo + H.W) as well as the repeated application of thiobencarb (To + 20 and To + 30) resulted in taller plants, though their difference with unweeded check was not statistically significant.

From the above results it is clear that the unweeded check resulted in shorter rice plants which may be due to high weed density resulting in very high crop-weed competition for nutrients (Table 20, 21 and 22) affecting the crop growth.

Similar observation of reduction in plant height was also reported by Mukhopadhyay and Bag (1967); Chang (1973); Sreedevi (1979) and Tasic *et al*. (1980).

Table 13. Effect of treatments on the height and tiller production of rice

Treatments	Height of plant (cm)	Tillers (No./hill)
To	74.2	6.67
To + 20	78.93	8.8
To + 30	76.32	7.42
To + P 30	76.47	7.00
To + H.W	83.07	8.33
Bo	71.53	4.27
Bo + 20	77.01	6.67
Bo + 30	72.82	5.67
Bo + P 30	76.28	6.67
Bo + H.W	77.8	7.3
P 15	70.4	4.07
T 15 + P 15	73.37	5.47
B 15 + P 15	71.43	5.19
H.W	85.57	8.93
U.W	69.7	3.83
SEm±	5.399	0.953
CD (0.05)	15.64	2.76

(b) Number of tillers

The effect of treatments on the total number of tillers/hill is presented in Table 13.

The weed control treatments had significant influence on tiller production by the crop. Maximum number of tillers were noticed in the hand weeded check which was statistically on par with the treatments involving a basal application of thiobencarb, whether followed with a second application of thiobencarb, propanil or one hand weeding. However, in the case of butachlor only the treatments receiving a basal application of butachlor followed by butachlor at 20 days or propanil at 30 days or a hand weeding at 40 days were on par with hand weeded check. All the other treatments recorded lower tiller number which was not statistically different from the unweeded check which recorded the least tiller production.

Increase in duration of crop-weed competition has adversely affected the tillering capacity of the crop and the plots with maximum weed density recorded lower number of tillers/hill. Similar reduction in tiller production have been noticed by Sreedevi (1979) and Jayasree (1987).

(c) Dry matter production

The data on the dry matter production by the crop at different stages are presented in Table 14.

At all stages the maximum dry matter production by crop was recorded in hand weeded plot and the least by unweeded plot. Propanil applied alone or as tank mix with either butachlor or thiobencarb recorded lesser crop dry matter when compared to other herbicide treatments. At 30 days, the treatments involving application of thiobencarb at sowing recorded dry matter production on par with hand weeded plot. In butachlor applied plots the dry matter production was lesser.

From 40 days onwards, observations showed that only the treatment To + 20 recorded dry matter on par with that of hand weeded plot at all stages. The treatments To + 30, To + P 30, To + H.W, To, Bo + P 30 and Bo + H.W also recorded higher dry matter production, even though they were not statistically significant with hand weeded plot at all stages. The repeated application of thiobencarb and butachlor resulted in an increase in dry matter production of the crop compared to their single application at zero days alone, even though the differences were not significant

Table 14. Effect of treatments on the dry matter production by crop (g/m^2)

Treatments	Stages				
	30 DAS	40 DAS	50 DAS	60 DAS	Harvest
To	58.67	104.67	167.33	222.33	619.4
To + 20	64.0	130.00	220.00	362.67	940.13
To + 30	58.67	124.00	208.00	250.00	753.41
To + P 30	57.33	116.00	174.00	293.33	761.47
To + H.W	56.00	109.33	200.00	327.33	821.4
Bo	43.33	80.00	152.67	166.67	547.33
Bo + 20	53.33	116.00	162.00	242.00	678.87
Bo + 30	46.67	104.00	162.00	204.67	573.12
Bo + P 30	43.67	118.00	164.00	292.67	756.09
Bo + H.W	47.00	102.67	207.33	316.67	755.32
P 15	31.67	76.00	92.00	147.33	449.8
T 15 + P 15	39.33	96.33	98.67	161.33	544.53
B 15 + P 15	41.00	92.00	94.00	159.33	462.81
H.W	65.33	147.33	246.67	384.00	977.93
U.W	29.67	69.33	60.67	142.00	383.83
SEm±	3.909	8.189	15.788	9.157	26.4
CD (0.05)	11.32	23.72	45.73	26.52	76.462

in all cases. This effect was more pronounced where the pre-emergence herbicide was repeated at 20 days.

A critical analysis of the dry matter production of the crop shows that even though there was no significant difference between the different treatments of a particular pre-emergence herbicide, there was difference due to repeated application of pre-emergence herbicide or giving a hand weeding when compared with basal application alone. This is due to the fact that the herbicide at sowing could check the weeds only for about a month, by which time they would have degraded hence there was serious weed competition in plots where thiobencarb and butachlor alone was applied at 0 days compared to treatments involving a repetition, as evidenced by the results on the dry matter production and population of weeds (Section 4.1.3 and 4.1.2.4). This must be the reason for better results for a second weed control operation (Herbicide/hand weeding) as obtained in this study. It can also be noted that the treatments where dry matter production was higher had higher values for tiller production and height of the crop as these characters have profound influence on the dry matter production of the crop. A correlation study on dry matter production of crop and weed at corresponding stages (Table 15) indicates that at all stages there was a significant negative correlation between them. A negative correlation between crop and weed dry matter production has been reported earlier by Patel et al. (1985) and Jayasree (1987).

Table 15. Correlation between crop and weed dry matter production

Stages	Correlation coefficient
30 DAS	-0.5313*
40 DAS	-0.5522*
50 DAS	-0.6867*
60 DAS	-0.7102*
Harvest	-0.7648*
Critical values (13 df)	0.514

4.2.3 Yield attributes

The effect of different treatments on the yield attributes taken at harvest are given in Table 16.

(a) Productive tillers/hill

The hand weeded plot produced the maximum number of productive tillers and this was followed by thiobencarb repeated at 20 days or 30 days or followed by hand weeding

Table 16. Effect of treatments on the yield attributes

Treatments	Productive tiller (No./hill)	Length of panicle (cm)	No. of grains/ panicle	Thousand grain weight (g)
To	5.2	13.97	73.83	26.87
To + 20	7.0	17.0	94.8	28.57
To + 30	6.67	15.12	90.27	28.07
To + P 30	6.53	14.0	84.8	28.1
To + H.W	6.59	17.18	90.37	28.33
Bo	4.27	12.0	67.17	25.6
Bo + 20	6.47	14.30	85.47	26.87
Bo + 30	4.8	13.75	72.07	26.5
Bo + P 30	5.87	13.97	81.97	26.9
Bo + H.W	6.4	15.15	88.57	28.17
P 15	3.0	11.39	68.53	25.0
T 15 + P 15	4.15	13.15	65.3	26.6
B 15 + P 15	3.53	12.44	66.73	24.97
H.W	7.53	16.99	104.47	28.77
U.W	2.85	8.83	39.83	23.77
SEm±	0.632	0.161	4.77	0.042
CD (0.05)	1.83	0.468	13.813	NS

or propanil at 30 days, butachlor repeated after 20 days or combined with hand weeding or combined with propanil at 30 days, which were all statistically on par. The unweeded check gave the least number of productive tillers. Propanil applied either alone or as tank mix with butachlor or thiobencarb at 15 days and butachlor applied alone were on par with this treatment.

(b) Length of panicle

Thiobencarb applied at zero days and combined with hand weeding produced the longest panicle (17.18 cm) which was on par with To + 20 and hand weeding. All the other treatments were statistically inferior to these treatments. The unweeded check produced the shortest panicle (8.83 cm). However, all the weed control treatments were significantly superior to this treatment.

(c) Number of grains/panicle

The hand weeded plot recorded the maximum number of grains/panicle and the treatment thiobencarb repeated after 20 days was statistically on par with this treatment. The unweeded check which produced the least number of grains/panicle was statistically inferior to all other treatments.

(d) Thousand grain weight

There was no significant difference between the treatments with respect to thousand grain weight, even though the unweeded plot showed a lower value and a higher value in weed controlled plots.

Among the yield attributes discussed, all components were adversely affected by severe weed infestation. With increase in weed density, the number of productive tillers, length of panicle and number of grains per panicle were reduced. The reduction in yield attributes due to heavy weed infestation and weed dry matter production has been reported by several researchers; Rethinam _et al_. (1974); Singlachiar _et al_. (1978); Sreedevi (1979); Sudhakara and Nair (1986) and Jayasree (1987).

4.2.4 Yield

The data on the grain and straw yield as affected by different treatments at different stages ofthe crop growth are presented in Table 17 and illustrated in Fig.5.

(a) Grain yield

Highest grain yield of (36.75 q/ha) was recorded by hand weeded plot. The only other treatment which produced an yield statistically on par with this treatment was To + 20, which recorded an yield of (33.85 q/ha). The treatment To + H.W recorded yield on par with To + 20. A second weed control operation could significantly increase the yield in the butachlor applied plots compared to its single application at zero days. Propanil applied alone or as tank mix with either thiobencarb or butachlor at 15 days could not result in satisfactory yield, even though the yields were higher than the unweeded check.

The grain yield obtained in hand weeded control which was the highest was about 15.84 times more than that of the weedy check. The data shows that effective weed control equal to frequent hand weeding could be obtained by application of thiobencarb at sowing and a second application at 20 days. It can also be seen that the repeated application of thiobencarb is even better than the present recommendation of a basal application of thiobencarb followed by a hand weeding/propanil application. In the present context of high labour charges substitution of hand weeding with thiobencarb application which is much cheaper can significantly increase the farmers profit (Table 26). Since thiobencarb is much cheaper than propanil it has to be preferred to increase the profit. In this trial butachlor proved to be inferior to thiobencarb probably due to the

Table 17. Effect of treatments on the yield (q/ha) of rice

Treatments	Grain yield	Straw yield
To	25.63	60.42
To + 20	33.85	72.00
To + 30	29.89	57.89
To + P 30	26.0	61.22
To + H.W	31.33	67.00
Bo	20.03	54.8
Bo + 20	26.4	53.78
Bo + 30	23.0	48.44
Bo + P 30	25.89	63.14
Bo + H.W	28.39	59.15
P 15	7.15	33.00
T 15 + P 15	22.85	48.4
B 15 + P 15	10.5	40.6
H.W	36.75	75.06
U.W	2.32	11.77
SEm±	1.146	1.748
CD (0.05)	3.318	5.062

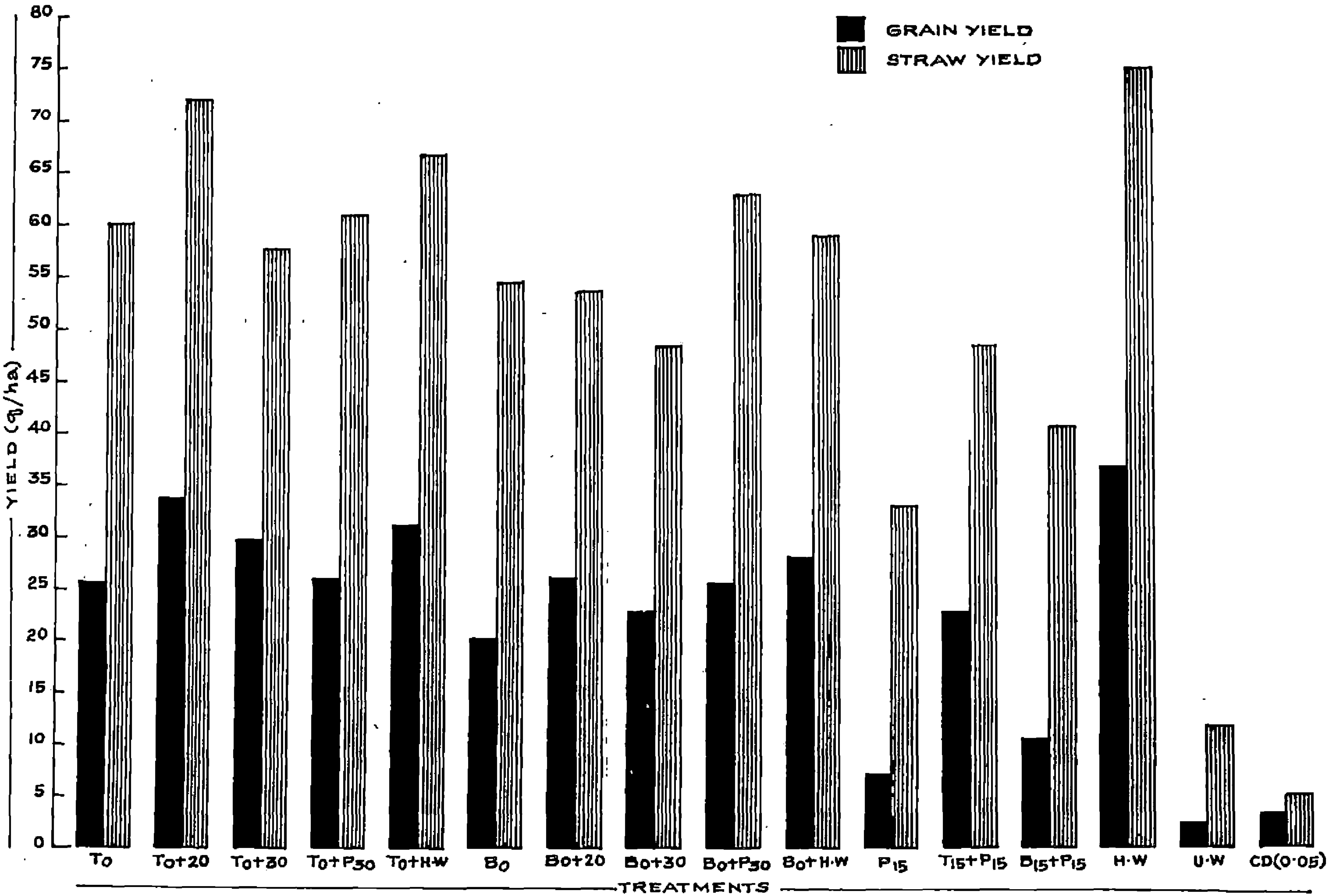


FIG.5. EFFECT OF TREATMENTS ON GRAIN AND STRAW YIELD.

fact that grass weeds accounted for major portion of the weed population. Even though propanil was better than unweeded control it was not as efficient as the pre-emergence herbicides. Propanil alone applied at 15 days could not bring out complete control of the weeds. But, when propanil was sprayed along with either thiobencarb or butachlor at 15 days (tank mix) higher yields were obtained as propanil could control some of the existing and the pre-emergence herbicides could check the germination and establishment of new flushes of weeds for sometime. However this treatment was not efficient as the repeated application of pre-emergence herbicides as propanil could not bring about complete control of already germinated weeds. When propanil was applied at 30 days in the field already treated with pre-emergence herbicide butachlor or thiobencarb at sowing it could enhance the efficiency of weed control by the pre-emergence herbicides whose effect would have been over by about three weeks.

(b) Straw yield

The maximum straw yield (75.06 q/ha) was observed in the hand weeded plot and this treatment was statistically significant only with To + 20. These treatments were followed by To + H.W. All other treatments were statistically inferior to these three treatments. The other treatments which recorded higher straw yield wer Bo + P 30, To + P 30, To, Bo + H.W all these treatments were on par and was significantly superior to other herbicide treatments except for To + 30 which was on par with To + P 30, To and Bo + H.W. The least straw yield was recorded by unweeded control which produced significantly poor yield than all others.

The treatments where in weed control was effective resulted in better crop growth resulting in higher yield as already discussed in case of grain yield and dry matter production of crop. Similar studies where straw yield was higher in weed controlled plots have been reported by Ramamoorthy et al. (1974).

Fig. 5 clearly indicates that straw yield and grain yield is highest in hand weeded plot closely followed by To + 20. The thiobencarb treatments (To; To + 20; To + 30; To + P 30 and To + H.W) yielded higher compared to their corresponding butachlor treatments (Bo; Bo + 20; Bo + 30; Bo + P 30 and Bo + H.W). T 15 + P 15 gave higher grain yield compared to Bo; which was better than B 15 + P 15 and P 15.

Table 18. Effect of treatments on the grain:straw ratio and harvest index

Treatments	Grain:straw ratio	Harvest index
To	0.42	0.3
To + 20	0.47	0.32
To + 30	0.51	0.34
To + P 30	0.42	0.3
To + H.W	0.46	0.32
Bo	0.37	0.27
Bo + 20	0.49	0.33
Bo + 30	0.47	0.32
Bo + P 30	0.41	0.29
Bo + H.W	0.47	0.32
P 15	0.21	0.18
T 15 + P 15	0.46	0.32
B 15 + P 15	0.25	0.21
H.W	0.48	0.33
U.W	0.17	0.17
SEm±	0.024	0.016
CD (0.05)	NS	NS

(c) Grain : straw ratio and harvest index

The data on the grain : straw ratio and harvest index are given in Table 18.

The grain : straw ratio and harvest index were not significantly influenced by the different treatments. However it could be seen that in the treatments where weed control was effective the grain : straw ratio and harvest index were higher. Yield attributing characters like length of ear head and number of grains/ear head (Table 16) were higher for these treatments, which would have led to a higher proportion of grain compared to straw yield.

4.2.5 <u>Weed index</u>

Table 19 and Fig. 6 presents the weed index values as affected by different treatments.

Thiobencarb repeated after 20 days gave minimum weed index value of (7.39). Only To + H.W was on par with this treatment. The highest weed index value (93.96) was recorded in unweeded check and all treatments were significantly superior to weedy check.

Table 19. Effect of treatments on the weed index

Treatments	Weed index
To	29.83
To + 20	7.39
To + 30	17.53
To + P 30	29.15
To + H.W	14.33
Bo	45.15
Bo + 20	27.83
Bo + 30	37.18
Bo + P 30	29.83
Bo + H.W	22.30
P 15	80.42
T 15 + P 15	37.63
B 15 + P 15	71.30
H.W	0.00
U.W	93.96
SEm±	3.5
CD (0.05)	9.99

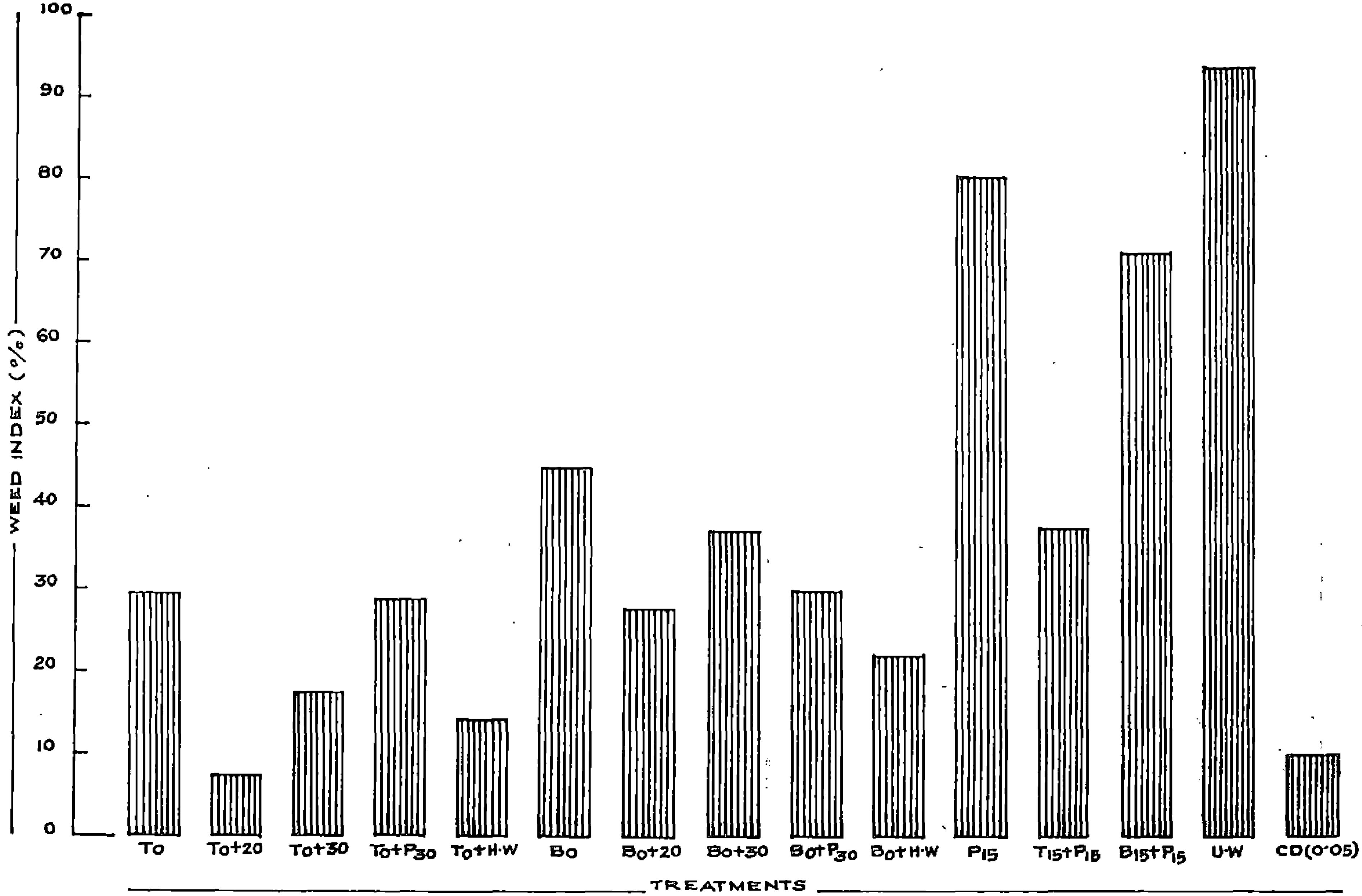


FIG. 6. EFFECT OF TREATMENTS ON WEED INDEX.

Propanil applied either alone or as tank mix with butachlor showed higher weed index value followed by butachlor application at zero days which was however significantly superior to the above two herbicide treatments. From the graph (Fig. 6) also it is clear that more than 90% of the crop produce is lost due to weed competition, but in the treatment To + 20 this loss could be reduced to as low as to a level even lower than 10 per cent.

Weed index denotes the relatively decrease in yield of crop due to weed competition compared to hand weeded plot. The results of this trial indicates that uncontrolled weed growth can result in a decrease in yield by about 94%. The result also shows that repeated application of thiobencarb could significantly reduce the losses due to weed competition. The other treatments which showed promise were the combination of a pre-emergence herbicide with a hand weeding or propanil and repeated application of pre-emergence herbicides.

4.3 Nutrient Uptake Studies

4.3.1 Nutrient drain by weeds

(a) Nitrogen

Table 20 presents nitrogen removed by weeds at different stages of the crop and the corresponding nitrogen contents are given in Appendix-III.

Table 20. Effect of treatments on the nitrogen removal by weeds (kg/ha)

Treatments	Stages				
	30 DAS	40 DAS	50 DAS	60 DAS	Harvest
To	0.59	4.05	4.0	10.82	4.27
To + 20	0.15	1.33	1.58	2.99	0.89
To + 30	0.67	1.77	2.66	6.1	3.65
To + P 30	1.61	4.18	1.43	7.25	3.1
To + H.W	0.77	2.41	0.79	1.01	1.4
Bo	2.49	9.87	12.53	21.1	23.85
Bo + 20	1.67	4.55	2.16	4.43	12.84
Bo + 30	3.2	5.33	5.0	16.35	18.0
Bo + P 30	1.53	3.8	3.95	10.55	6.05
Bo + H.W	1.61	9.87	0.45	1.54	3.2
P 15	6.72	13.44	20.9	37.68	40.62
T 15 + P 15	2.45	10.64	9.18	24.48	26.45
B 15 + P 15	4.06	10.44	17.99	28.25	33.12
H.W	0.6	1.14	0.93	0.62	0.6
U.W	10.89	45.54	54.81	75.24	65.49
SEm±	0.646	1.666	2.776	4.997	5.425
CD (0.05)	1.87	4.824	8.041	14.473	15.713

At all stages the unweeded check recorded maximum removal of N by weeds. Except at 30 and 50 days hand weeded control recorded minimum N removal by weeds. At 30 days N removal by weeds was least in To + 20. All the treatments where thiobencarb was applied as basal was on par with this treatment. Repeated application of butachlor 0 and 20 days (Bo + 20), Bo + P 30 and Bo + H.W were also on par with these treatments. At 40 days all the treatments involving hand weeding, thiobencarb application (either basal or repeated) and repeated application of butachlor and combined application of pre-emergence and propanil had lower N removal by weeds, the differences between these treatments were not significant. All these treatments recorded their effect in reducing N removal by weeds at all subsequent stages upto harvest.

(b) Phosphorus

Table 21 presents the phosphorus removal by weeds at different stages and in Appendix-IV the corresponding phosphorus content is presented.

At all stages of the crop growth the unweeded check recorded the maximum removal of P by weeds and differed significantly with all the other treatments. At 30 days

Table 21. Effect of treatments on the phosphorus removal by weeds (kg/ha)

Treatments	Stages				
	30 DAS	40 DAS	50 DAS	60 DAS	Harvest
To	0.05	0.41	0.45	0.83	0.35
To + 20	0.01	0.13	0.16	0.26	0.08
To + 30	0.05	0.17	0.27	0.61	0.32
To + P 30	0.13	0.4	0.2	0.51	0.27
To + H.W	0.06	0.25	0.09	0.09	0.12
Bo	0.20	0.99	1.13	2.39	2.39
Bo + 20	0.1	0.43	0.19	0.38	0.93
Bo + 30	0.21	0.56	0.6	1.64	1.56
Bo + P 30	0.1	0.38	0.47	0.98	0.52
Bo + H.W	0.13	1.04	0.05	0.11	0.24
P 15	0.48	1.28	1.98	3.77	3.39
T 15 + P 15	0.17	1.06	0.77	2.31	2.48
B 15 + P 15	0.31	1.1	1.23	3.01	2.57
H.W	0.05	0.11	0.08	0.05	0.04
U.W	0.76	3.96	5.22	5.47	5.17
SEm±	0.05	0.159	0.25	0.48	0.431
CD (0.05)	0.144	0.46	0.723	1.389	1.248

all treatments except Bo, Bo + 30, T 15 + P 15, B 15 + P 15, P 15 and unweeded treatments recorded P removal on par with To + 20 which recorded the least P removal. At 40 days hand weeded plot showed least removal of P. At this stage all the treatments involving thiobencarb (whether or not repeated after 20 or 30 days or combined with propanil or hand weeding) were on par with this treatment. Among butachlor treatments repeated application of butachlor at 20 or 30 days or combination with propanil at 30 days were on par with hand weeded check. At 50 days Bo + H.W recorded least P removal and was on par with all the thiobencarb and butachlor involving treatments except Bo. At 60 days and towards harvest hand weeded plot recorded the least P removal. At these stages all the herbicide treatments and their combination except Bo, Bo + 30 and propanil at 15 days alone or as tank mix with the pre-emergence herbicides were on par with hand weeded plot. At harvest stage Bo + 30 was also on par with hand weeded plot.

(c) Potassium

The potassium drain by weeds at different stages (30, 40, 50, 60 days and at harvest) is presented in Table 22 and their corresponding potassium contents in Appendix-V.

Table 22. Effect of treatments on the potasium removal by weeds (kg/ha)

Treatments	Stages				
	30 DAS.	40 DAS	50 DAS	60 DAS	Harvest
To	0.48	4.69	4.27	10.82	4.8
To + 20	0.09	1.6	1.4	2.24	0.95
To + 30	0.37	2.24	2.1	6.1	3.89
To + P 30	1.17	4.62	2.28	7.25	3.31
To + H.W	0.5	3.04	0.75	1.01	1.8
Bo	1.81	8.88	9.4	21.1	23.85
Bo + 20	0.87	3.68	2.04	5.7	11.41
Bo + 30	2.13	4.53	4.67	19.62	18.0
Bo + P 30	1.07	4.6	2.96	12.05	6.45
Bo + H.W	1.17	10.36	0.48	1.32	3.2
P 15	4.76	12.16	13.2	29.31	36.11
T 15 + P 15	1.92	11.65	5.8	20.4	28.08
B 15 + P 15	3.87	12.18	17.04	28.25	31.28
H.W	0.29	1.44	0.56	0.73	0.53
U.W	8.52	35.64	41.76	64.98	65.49
SEm±	0.508	1.568	2.132	5.233	5.07
CD (0.05)	1.471	4.542	6.175	15.155	14.683

Maximum removal of potassium was observed in unweeded check throughout the crop growth and differed significantly with all other treatments. Treatments involving propanil application at 15 days also showed higher removal of potassium than other herbicide treatments. At 30 days To + 20 and at 50 days Bo + H.W recorded least removal of potassium while at all other stages hand weeded plot recorded least removal of potassium. Difference between the K uptake of weeds in thiobencarb treatments (alone or repeated or combination with hand weeding or propanil) did not differ significantly. Most of the treatments involving butachlor were also on par with hand weeded control in K removal by weeds.

The effect of the treatments on NPK removal by weeds was similar to that of the weed dry matter production as there was not much variation in the respective nutrient content of the weeds at a particular stage. Hence the treatments where weeds were controlled better resulted in lesser removal of N P and K by weeds. The data shows that thiobencarb was better than butachlor in reducing nutrient uptake by weeds. This is a reflection of the effect of thiobencarb in reducing the grass weed population which accounted for major share of weed flora in the plot. It can also be seen that upto 40 days, the repeated application of the pre-emergence herbicides resulted in lesser nutrient uptake by weeds than the combination of the pre-emergence herbicides with propanil and hand weeding. This reduction in nutrient removal by weeds at the early stages is more pronounced in case of To + 20 which could control the weeds effectively and this effect is also reflected in the yield data also wherein the yield recorded by To + 20 is better than that of To + H.W.

4.3.2 <u>Nutrient uptake by crop</u>

(a) Nitrogen

Nitrogen uptake by crop at different stages are presented in Table 23 and Appendix-VI presents the corresponding nitrogen contents (%) in the plant samples analysed.

At all stages of the crop growth hand weeded plot recorded maximum uptake of nitrogen and unweeded plot the minimum except at 30 days when P 15 recorded the least value. The N uptake in hand weeded plot was followed by the treatments where thiobencarb was applied at 0 days, either alone (To) or repeated after 20 or 30 days and the difference between them were not significant. Butachlor treatments recorded lesser nitrogen uptake than thiobencarb

Table 23. Effect of treatments on the nitrogen uptake by crop (kg/ha)

Treatments	Stages				
	30 DAS	40 DAS	50 DAS	60 DAS	Harvest
To	12.91	21.98	33.46	46.69	88.61
To + 20	14.72	28.6	50.6	94.29	132.88
To + 30	12.91	29.76	47.84	57.5	106.51
To + P 30	12.61	27.84	36.54	70.4	122.97
To + H.W	12.32	25.15	48.0	81.83	124.68
Bo	8.67	16.8	33.59	33.33	77.78
Bo + 20	11.2	25.52	34.02	50.82	98.81
Bo + 30	9.33	22.88	30.78	42.98	82.36
Bo + P 30	9.61	25.96	34.44	70.24	100.64
Bo + H.W	9.87	23.61	45.61	76.0	103.53
P 15	5.7	15.2	18.4	27.99	64.13
T 15 + P 15	7.47	19.27	20.92	32.27	75.92
B 15 + P 15	7.79	19.32	17.86	31.87	66.38
H.W	15.03	35.36	56.73	103.68	139.84
U.W	6.23	13.86	10.92	24.14	53.74
SEm±	0.825	1.8	3.555	2.131	4.372
CD (0.05)	2.388	5.213	10.295	6.172	12.664

treatments and only Bo + 20 was on par with thiobencarb treatments. The treatments involving propanil application at 15 days recorded lesser nitrogen uptake. At 40 days the combination of pre-emergence application (0 DAS) of thiobencarb with repeated application, propanil or hand weeding did not differ significantly even though their difference with hand weeding was significant. Same was the case between the different butachlor treatments. At 50 days To + 20, To + H.W and To + 30 were on par with the hand weeded plot. Among the butachlor treatments Bo + H.W recorded significantly higher nitrogen uptake which was on par with the better thiobencarb treatments. At 60 days among the different herbicide treatments To + 20 was significantly superior, even though it recorded significantly lower N uptake than hand weeded plot. However at harvest stage To + 20 was on par with hand weeded control and it was followed by To + H.W and To + P 30, the difference between the latter two were not significant.

(b) Phosphorus

The data on phosphorus uptake by crop at different stages (Table 24) and the corresponding phosphorus contents in crop sample (Appendix-VII) are shown.

Table 24. Effect of treatments on the phosphorus uptake by crop (kg/ha)

Treatments	Stages				
	30 DAS	40 DAS	50 DAS	60 DAS	Harvest
To	1.06	2.72	3.51	6.0	9.74
To + 20	1.02	3.64	6.16	11.24	13.29
To + 30	0.88	3.60	5.2	7.75	10.76
To + P 30	1.03	3.37	4.35	7.63	11.78
To + H.W	1.00	3.28	5.6	8.5	11.94
Bo	0.65	2.16	3.36	4.33	8.66
Bo + 20	0.96	2.9	4.21	6.29	10.41
Bo + 30	0.79	2.81	3.89	5.32	9.06
Bo + P 30	0.79	3.19	4.26	7.9	10.91
Bo + H.W	0.8	3.08	5.81	9.82	10.82
P 15	0.44	1.67	1.47	3.54	7.89
T 15 + P 15	0.71	2.41	2.07	4.2	9.02
B 15 + P 15	0.74	2.39	2.07	4.14	7.89
H.W	0.92	4.27	6.91	12.89	13.98
U.W	0.48	2.01	1.1	3.27	6.78
SEm±	0.066	0.226	0.427	0.262	0.414
CD (0.05)	0.19	0.655	1.237	0.757	1.198

In general hand weeded plot recorded the maximum and unweeded the minimum uptake of phosphorus. Butachlor applied as basal application alone and propanil applied at 15 days either alone or in combination with the pre-emergence herbicides recorded lower P uptake in general. Among butachlor involving treatments butachlor applied as basal application recorded lowest phosphorus uptake at all stages of the crop.

At 30 days treatments involving thiobencarb with a second application of either thiobencarb at 20 or 30 days or propanil at 30 days or a hand weeding at 40 days did not differ significantly. At 40 days also the treatments involving combination of thiobencarb at 0 days with its repeated application, propanil or hand weeding were on par and recorded higher P uptake than all other herbicide treatments even though the differences were not significant in all cases. This trend was continued at subsequent stages also. However from 60 days onwards To + 20 recorded significantly higher P uptake than the other thiobencarb combinations. At all the stages combination of butachlor with a second application at 20 days, propanil application at 30 days or a hand weeding at 40 days recorded batter P uptake than the single basal application of butachlor alone.

(c) Potassium

Table 25 and Appendix-VIII presents the potassium uptake by crop and the corresponding potassium contents respectively at different stages of the crop.

At 30 days maximum uptake of potassium by crop was recorded by To + 20 and at all other stages maximum uptake was recorded by hand weeded plot. At 30 days all the treatments involving thiobencarb were on par with To + 20. At this stage all the treatments involving butachlor whether applied alone or repeated after 20 or 30 days or in combination with propanil at 30 days or a manual weeding at 40 days showed no significant difference.

At 40 days treatments involving application of thiobencarb and its repetition at 20 or 30 days resulted in potassium uptake on par with hand weeded plot. The treatments involving a second application of either butachlor or propanil or a hand weeding after the application of butachlor at zero days showed no significant difference between them, even though they were lower than that of the thiobencarb treatments.

At 50 days treatments involving a manual weeding at 40 days after the application of the pre-emergence herbicides

Table 25. Effect of treatments on the potassium uptake by crop (kg/ha)

Treatments	Stages				
	30 DAS	40 DAS	50 DAS	60 DAS	Harvest
To	13.49	21.98	35.14	48.91	120.24
To + 20	16.00	31.21	50.6	83.41	193.76
To + 30	13.49	32.24	45.76	57.5	147.32
To + P 30	13.39	26.68	38.28	64.53	160.87
To + H.W	12.88	25.15	50.00	75.29	170.87
Bo	10.4	18.38	32.06	35.00	99.26
Bo + 20	12.8	29.00	35.64	53.24	131.61
Bo + 30	10.73	27.04	34.02	42.98	112.8
Bo + P 30	10.48	29.5	34.44	64.39	156.86
Bo + H.W	10.81	24.64	51.83	72.83	151.38
P 15	6.97	15.96	19.32	30.94	81.27
T 15 + P 15	9.44	22.16	21.71	33.88	101.62
B 15 + P 15	9.44	20.24	20.68	33.46	85.74
H.W	15.68	35.36	56.73	92.16	196.78
U.W	6.82	16.64	12.13	29.82	67.96
SEm±	1.351	1.963	3.669	2.035	5.228
CD (0.05)	3.913	5.684	10.627	5.893	15.141

at zero days and To + 20 were on par with the hand weeded plot. At 60 days stage hand weeded plot and at harvest stage hand weeded plot and To + 20 recorded significantly higher potassium uptake than all the other treatments.

The results on the nutrient uptake by the crop at different stages shows that in the treatments where nutrient uptake by weeds was less (Table 20, 21 and 22) the corresponding nutrient uptake by crop was higher. This is due to the lack of nutrient competition from weeds, resulting in better growth and dry matter production of crop (Table 14). The NPK content of the crop (Appendix-VI, VII, VIII) in different treatments did not show much variation between them and hence the differences in the uptake of nutrients by crop is actually due to the differences in the dry matter production. In earlier studies Sankaran et al. (1974) and Jayasree (1987) have reported higher nutrient uptake by crop in hand weeded plot compared to unweeded control.

4.4 Economics of Different Treatments

The data on the economics of the different treatments is presented in Table 26 and illustrated in Fig. 7. The details of cost of cultivation and returns are given in Appendix-IX(a) and (b).

Table 26. Economics of rice cultivation under different weed control treatments

Treatments	Total cost of cultivation (Rs./ha)	Total returns (Rs./ha)	Net profit (Rs./ha)	Return/Rupee invested (Rs.)
To	4566.00	10,975.55	6409.55	2.4
To + 20	5032.00	13,988.75	8956.75	2.77
To + 30	5032.00	11,982.60	6950.6	2.38
To + P 30	5351.00	11,129.30	5778.3	2.07
To + H.W	5574.00	12,970.75	7396.75	2.32
Bo	4555.2	9,070.25	4515.05	1.99
Bo + 20	5010.4	10,755.70	5745.30	2.14
Bo + 30	5010.4	9,473.60	4463.2	1.89
Bo + P 30	5340.2	11,223.85	5883.65	2.10
Bo + H.W	5563.2	11,652.00	6088.8	2.09
P 15	4885.00	4,111.25	-773.75	0.84
T 15 + P 15	5191.00	9,429.75	4238.75	1.81
B 15 + P 15	5020.2	5,526.5	506.3	1.1
H.W	7180.0	14,985.15	7805.15	2.08
U.W	4100.0	1,403.05	-2696.95	0.34

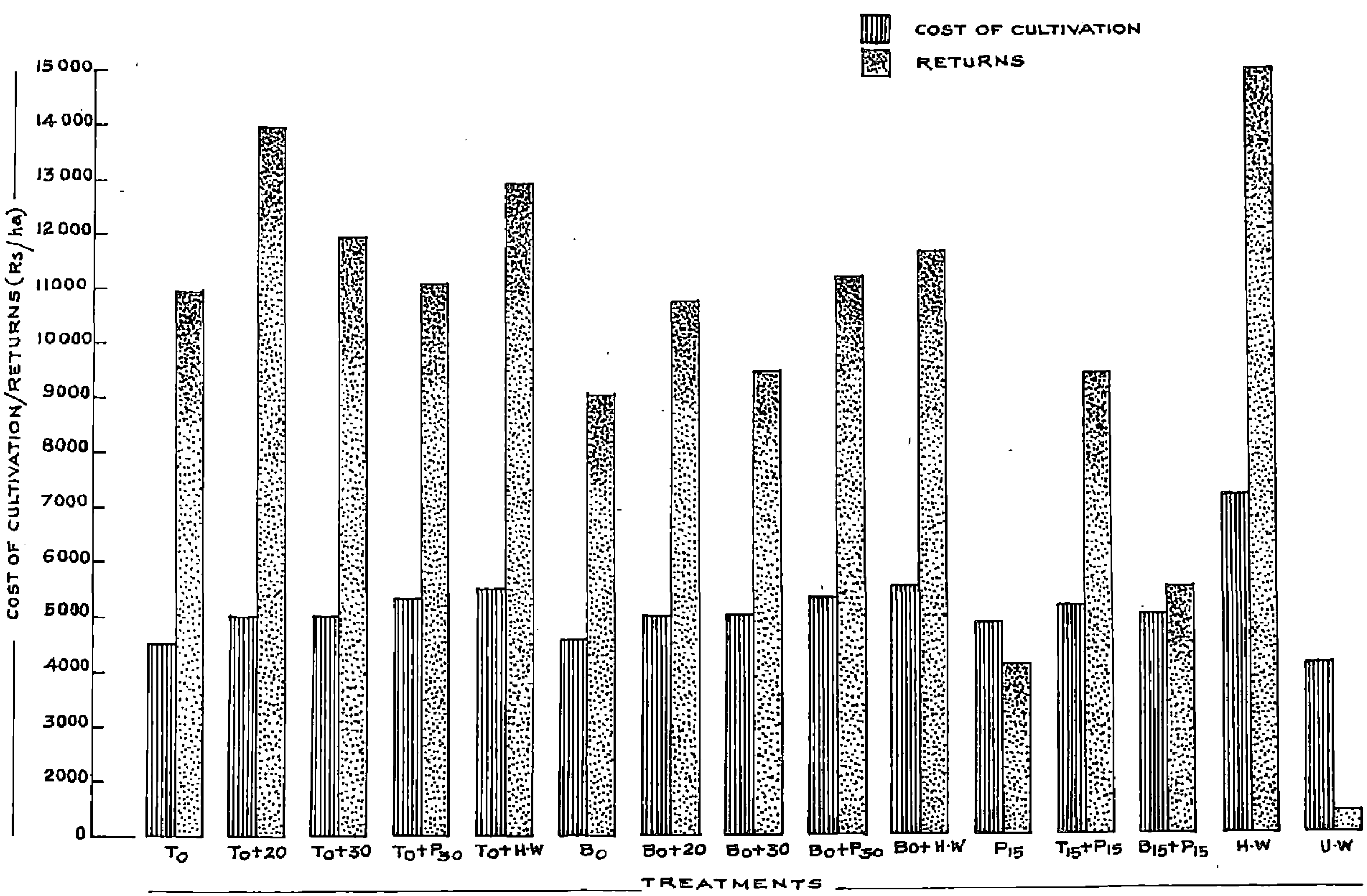


FIG.7. EFFECT OF TREATMENTS ON COST OF CULTIVATION AND RETURNS.

The net profit was highest in To + 20 plot (Rs.8956.75 ps/ha) followed by hand weeded plot (Rs.7805.15 ps/ha). Compared to these treatments the unweeded plot recorded a loss of Rs.2696.95 ps/ha.

The highest return per rupee invested was obtained in To + 20 treatment (Rs.2.77 ps) followed by thiobencarb applied alone (Rs.2.40 ps); To + 30 (Rs.2.38 ps); To + H.W (Rs.2.32 ps). Among butachlor treatments Bo + 20 (Rs.2.14 ps) and Bo + P 30 (Rs.2.10 ps) were found to be superior. All the above treatments recorded higher return per rupee invested than the hand weeded plot. Propanil whether applied alone or in combination with butachlor or thiobencarb and Bo + 30 gave low return per rupee invested. Unweeded control recorded the least return of Rs.0.34 ps per rupee invested.

In terms of total returns, the hand weeded plot, seemed to be superior giving a return of Rs.14,985.15 ps/ha (Fig. 7) but when the high cost of labour is considered the net profit and thereby return per rupee invested was lower in this treatment.

The result suggests that to get maximum returns per rupee invested it is preferable to go for chemical weed control, either complete (repeated application of pre-emergence herbicide) or a combination of pre-emergence application and a subsequent hand weeding. The poor return and net profit from propanil treatments is due to the higher cost of the herbicide coupled with a lower crop yield, compared to other herbicide treatments.

Summary

5. SUMMARY

A field experiment was conducted at the Agricultural ₹esearch Station, Mannuthy under the Kerala Agricultural ᴉniversity, during the first crop season of 1987 to evaluate :he efficiency of repeated application of pre-emergence ıerbicides as well as combined application of a pre-emergence ınd a post-emergence herbicide at early post-emergence stage ›f rice. The main objective was to develop a cheaper and ›fficient herbicide sequence for season long weed control in ıry sown rice. The experiment was laid out in randomised ›lock design, with three replications. Treatments comprised ›f pre-emergence herbicide thiobencarb/butachlor applied at ;ero days alone or repeated after 20 or 30 days, combination ›f pre-emergence application with propanil at 30 days or a ıand weeding at 40 days and application of propanil at 15 ıays alone or as tank mix with one of the pre-emergence ıerbicides at 15 days. Efficiency of these treatments were :ompared with two controls viz., weedy check and hand weeded :heck. The salient findings of the experiment are summarized ›elow:

Grasses and sedges constituted major part of the weed :lora in the experimental field. A few broad leaved weeds ₹ere also present from 40 days onwards. Among the grasses,

Isachne miliacea, *Saccoleppis interrupta* and *Echinochloa colona* and among sedges, *Cyperus iria* were the prominent weeds.

The grass weeds were very effectively controlled with thiobencarb application and repeated application of the same pre-emergence herbicide (To+20) had resulted in better effects while butachlor application at zero days and repeated after 20 days (Bo+20) controlled the sedges completely. When the total weed population was analysed both thiobencarb and butachlor were statistically on par.

Thiobencarb was better than butachlor in reducing dry matter production by weeds. In this trial a second applicat-ion of thiobencarb or butachlor at 20 days stage extended the weed control effect of the pre-emergence herbicide applied at zero days and thus gave an effect equivalent to hand weeding or propanil application. A significant positive correlation was found to exist between total weed population and weed dry matter production during all the stages. The highest weed control efficiency during critical stages (upto 60 days) was noted in hand weeded plots (H.W; To+H.W; Bo+H.W) and To+20 treatment.

Both the herbicides thiobencarb and butachlor produced slight phytotoxicity on crop due to heavy rainfall after the application of the pre-emergence herbicides at zero days.

High weed density and weed competition reduced the height, tiller number and dry matter production of crop. The dry matter production by crop was higher in plots where the pre-emergence herbicides were repeated or a hand weeding given. Negative correlation was found to exist between crop dry matter production and weed dry matter production.

Maximum number of productive tillers per hill and number of grains per panicle was noticed in hand weeded control followed by thiobencarb repeated after 20 days (To+20). To+H.W recorded maximum length of panicle. There was no significant difference between thousand grain weight in different treatments. Maximum grain yield was produced by hand weeded control which was on par with To+20. The straw yield was maximum in hand weeded plot. In treatments where weed control was effective the grain : straw ratio and harvest index were higher. Yield attributing characters like length of earhead and number of grains/earhead were higher for these treatments, which would have led to a higher proportion of grain compared to straw yield.

Repeated application of thiobencarb (To+20) gave maximum weed index value and only To+H.W was on par with this treatment.

Nutrient uptake by weeds and crop showed almost opposite trend. The N, P and K removal by weeds were minimum in To+20. The treatments where weeds were controlled better resulted in lesser removal of N, P and K by weeds and higher uptake of these nutrients by crop.

The net returns and return per rupee invested was maximum in To+20 treatment. Although the total returns from hand weeded plot was higher, the high cost of hand weeding brought down the return per rupee invested.

From the results of the study it could be concluded that repeated application of thiobencarb (To+20) was the most efficient treatment for controlling the weeds and increasing the yield of dry sown rice.

References

REFERENCE

Ahmed, N.U. and Moody, K. 1979. Tolerance of crops to butachlor and pendimethalin applied at different growth stages. Philipp. J. Weed Sci. 6: 10-22.

Ahmed, N.U. and Moody, K. 1980. Effect of method of seeding and weed control on weed growth and yield of two rice crops grown in sequence. Trop. Pest Management. 26(3): 303-308.

Ahmed, N.U. and Moody, K. 1982. Weed control in dry seeded wet land rice (Oryza sativa L.). Philipp. Agricist. 65. 1-15.

Ali, M.A. and Sankaran, S. 1975. Efficiency of herbicide stomp in transplanted rice. Pesticides. 9: 41-43.

Ali, M.A. and Sankaran, S. 1981. Studies on weed control in direct sown puddled and non-puddled rice. Abstracts papers ISWS/UAS Weed Sci. Conf. Bangalore, 7(17). p.1133.

*Ali, M.A. and Sankaran, S. 1984a. Crop-Weed competition in direct seeded lowland and upland bunded rice. Indian J. Weed Sci. 16(2): 90-96. Field Crop Abstr. 1986. 39(8):5808.

*Ali, M.A. and Sankaran, S. 1984b. Effect of time of application and residual effect of herbicides in direct seeded flooded and rainfed bunded rice. Int. Rice. Res. Newsl. 9(2): 21. Weed Abstr. 1985. 34(1):17.

Ali, M.A. and Sankaran, S. 1986. Effect of butachlor, thiobencarb and pendimethalin on Echinochloa colonum in dry seeded bunded rice (Var.) Bhavani. Madras agric. J. 73(5): 287-293.

*Alkamper, J. 1976. Influence of weed infestation on effect of fertilizer dressings. Pflanzenschutz. Nachr. Bayer. 29: 191-235.

*A.O.A.C. 1960. Official Methods of analysis. Association of Official Agricultural Chemists, Washington D.C. p.225-226.

*Arai, M. 1967. Competition between rice plants and weeds. Proc. Asian-Pacific Weed Control Interchange. 1. p.37.

Arceo, L.M. and Mercado, G.L. 1981. Improving crop safety of butachlor in wet seeded rice. Philipp. J. Weed Sci. 18: 19-24.

Babiker, A.G.T. 1982. Chemical weed control in irrigated direct-seeded rice in the Sudan Geizera. Weed Res. 22(2): 117-121.

Balyan, R.S. 1982. Paddy herbicides. Weed Control and residual effect. Pesticides. 16(12): 15-16.

*Barrett, S.C.H. and Seaman, D.E. 1980. The weed flora of Californian rice fields. Aquatic Bot. 9: 351-376.

Beetman, G.B. and Deming, J.M. 1974. Dissipation of acetanilide herbicides from soils. Agron. J. 66: 308-311.

Bhan, V.M., Balyan, R.S., Malik, R.K. and Rathee, S.S. 1985. Effect of time of application of thiobencarb on weed control in direct seeded rice. Abstracts of paper Conf. Indian Soc. Weed Sci. 1985. Weed Abstr. 35(4):1113.

Bhan, V.M., Naidu, N.G. and Singh, D. 1980. Influence of grassy and broad leaved weeds on crop-weed competition in drilled rice. Abstracts of papers ISWS/OUAT Weed Sci. Conf. Bhubaneswar. p.13.

*Bhandari, D.C. and Moody, K. 1983. XX-2 Ecology and Management of weed communities in rice based cropping system. In Arya, H.C., Sankhla, N., Tewari, M.N., Sekhawat, N.S. and Purohit, S.D. (ed Proc. Nat. Symp. Adv. Frontier's Pl. Sci. Univ. Jodhpur, India. p.220-221.

Bhol, B.B. and Singh, K.N. 1987. Effect of methods of seeding and herbicide application in upland direct seeded rice. I. Composition and distribution of weed flora. Indian. J. Agron. 32(2): 136-139.

Biswas and Thakur. 1983. Weed control in direct seeded upland rice. Int. Rice Res. Newsl. 8(6): 20-25.

*Chakraborthy, T. 1973. Nature of competition between weeds and rice for nitrogen under dry land condition. Expl. Agric. 9(3): 219-223.

Chandraka, B.L. and Manna, G.B. 1981. Effect of soil moisture on the phytotoxicity of butachlor to upland rice. Trop. Pest. Management. 27(4): 516-517.

Chang, W.L. 1973. Chemical weed control practices for rice in Taiwan. PANS 19: 514-522.

Chen, Y.L. and Chen, J.S. 1979. Photo decomposition and dissipation of herbicide butachlor in paddy fields. J. Pesticide Sci. 4: 431-438.

*CIAT. 1981. Rice Program. Centro International De Agricultura Tropical annual report, 1980. CIAT, Cali, Columbia: 39. Weed Abstr. 1983. 32(1):p.2

*Colon, C., Antigua, G. and Almarales, P. 1984. Evaluation of pre-emergence herbicides for rice. Ciencia Y T'eenica en la Agricultura. Arroz. 7(2): 27-43. Field Crop Abstr. 1986. 39(12):9319.

CRRI. 1987. Differential responses of crop cultivars to herbicides. AICRPWC Project Co-ordination Report 1986. Central Rice Research Institute, Cuttack. p.63-64.

De Datta, S.K. 1977. Approaches in the control and management of perennial weeds in rice. Proc. Asian-Pac. Weed Sci. Soc., Changmai, Thailand. 6(1). p.205-226.

*De Datta, S.K. 1979. Weed problems and methods of control in tropical rice. In symposium on weed control in tropical crops. Pub. Weed Sci. Soc. Philipp. Inc; and Philippine council for Agriculture and Resources Research. p.9-44.

Deshmukh, M.R., Trivedi, K.K. and Tiwari, J.P. 1987. Response of upland rice to weed control methods. Int. Rice Res. Newsl. 12(4): 47.

Dhiman, P.C. and Aswathi, O.P. 1977. A survey of weed flora in paddy fields in mid hills of Himachal. Indian J. agric. Res. 11(3): 181-184.

*Dubey, A.N., Rao, M.V., Singh, R.P. and Nigam, R.K. 1976. Weed rice with butachlor. Intensive Agric. 13(11): 13. Indian Weed Sci. Res. Abstr. 570:283.

*Dusky, J.A. 1984. Weed management systems for rice in Florida. Research Report, Bella Glade Research and Education Centre, Florida. 10. p.9-16. Weed Abstr. 1985. 34(7):1504.

*Dwivedi, R.N. 1987. Weed control and top dressing in paddy. Seeds and Farms. 13(16): 20-22. Weed Abstr. 1988 37(2):464.

FIB 1983. Farm Guide 1983. Farm Information Bureau, Government of Kerala, Trivandrum. p.9-35.

Ghobrial, G.I. 1981. Weed control in irrigated dry seeded rice. Weed Res. 21(5): 201-204.

Gill, G.S. and Vijaykumar. 1969. "Weed index" a new method for reporting weed control trials. Indian J. Agron. 14(1): 96-98.

Gupta, O.P. 1984. Scientific weed management in the tropics and sub-tropics. Today and Tommorrow Printers and Publishers, New Delhi, India. 474.

*Holm, G.L., Plucknett, D.L., Pancho, J.V. and Herberger, J.P. 1977. "World's Worst Weeds, Distribution and Biology". Univ. Hawaii Press, Honolulu. pp.609.

IITA. 1983. Upland Rice Weed Control. International Institute of Tropical Agriculture Annual Report for 1982. Ibadan, Nigeria. p.148-149.

IRRI. 1977. Upland rice. Annual Report for 1976. Int. Rice Res. Inst. Los Banos, Philippines. p.185.

IRRI. 1978. Annual Report for 1977. Int. Rice Res. Inst. Los Banos, Laguna Philippines. pp.548.

IRRI. 1980. Herbicide combinations for weed control in dry seeded rainfed rice. Int. Rice Res. Inst. A. Rep. for 1979. Los Banos, Laguna, Philippines. pp.548.

IRRI. 1981a. Dry land rice. Int. Rice Res. Inst. Annual Report for 1980. Los Banos, Laguna, Phillippines. p.223-224.

IRRI. 1981b. Weed Control in dry seeded bunded rice. Int. Rice. Res. Inst. Research highlights for 1981. p.63-64.

IRRI. 1984. Seed bed preparation techniques and herbicide mixtures. Int. Rice Res. Inst. Annual Report for 1983. Los Banos,Laguna Phillippines. p.216.

Jackson, M.L. 1958. Soil Chemical Analysis. Prentice Hall Inc. U.S.A. pp.498.

Jayakumar, K., Siddeswaran, K., Premsekar, M., Kempuchetty, N. and Subramanian, S. 1987. Nutrient uptake by certain field crops and associated weeds and its effect on yield. Pesticides 21(11): 37-43.

Jayasree, P.K. 1987. Efficiency of thiobencarb in dry sown rice. M.Sc. thesis, Kerala Agricultural University. pp.115.

JNVVK. 1987. Susceptibility of paddy varieties to Oxadiazon and thiobencarb. 3rd Annual Report 1986-87. All India Co-ordinated Research Project on Weed Control, Jabalpur Centre. p.79-80.

Kakati, N.N. 1976. Chemical weed control in rice in relation to fertilizer use. Ph.D. Dissertation, Indian Agric. Res. Inst. pp.144.

KAU. 1984a. Weed control in direct sown ri... ...... Agricultural University Research Report 1981-82, Vellanikkara - 680654, Trichur, Kerala. p.82.

KAU. 1984b. Critical periods of weed infestation of direct sown rice. Kerala Agricultural University, Vellanikkara - 680 654, Trichur, Kerala, India. p.103.

KAU. 1986. Package of Practices Recommendations. Kerala Agricultural University. Directorate of Extension. pp.239.

KAU. 1986a. Weed control in direct sown rice. Kerala Agricultural University Research Report for 1983-84 Vellanikkara-680654, Trichur, Kerala, India. p.121-124.

KAU. 1986b. Weed control methods for semi-dry dibbled rice crop. Research Report 1983-84, Directorate of Research, Kerala Agricultural University, Vellanikkara-680654, Trichur, Kerala, India. p.641.

Kaushik, S.K., Gupta, R.S., Sewa Ram and Mani, V.S. 1973. Chemical control of weeds in nursery beds of rice. Indian J. Agron. 18(4): 416-419.

Kaushik, S.K. and Mani, V.S. 1980. Chemical weed control in direct seeded rice. Ann. agric. Res. 1(2): 169-175.

Kennard, C.P. 1973. Control of weeds in direct seeded rice with some of the newer herbicides. Int. Rice Commn. Newsl. 17(1): 15-17.

*Kulshrestha, Gita, Yaduraju, N.T. and Mani, V.S. 1981. Dissipation of butachlor and propanil herbicides in rice crop. Proc. 8th Asian-Pacific Weed Sci. Soc. Conf. Bangalore, India: pp.469-473. Indian Weed Sci. Res. Abstr. pp.857.

*Lasso, R. and Palomino, B. 1982. Herbicide trials with dry land rice. Instituto de Investigacion Agropecuaria de Panama, Panama City, (5) 15. Weed Abstr. 1985 34(11):2884.

Manipon, E.F., Ruscoe, A.W. and Moody, K. 1981. Yield of dry seeded rice as influenced by cultivar and weed control treatment. Philipp. J. Weed Sci. 8: 30-40.

Manna, G.B. and Dubey, A.N. 1972. Weed control in direct sown rice on puddled soil. Indian Weed Sci. Res. 247.

Manna, G.B. and Moorthy, B.T.S. 1980. Chemical weed control in direct sown upland rice (Kharif, 1980). Central Rice Research Institute, Cuttack. Annual Report for 1980. p.65.

Manna, G.B. and Moorthy, B.T.S. 1982. Chemical weed control in upland rice (Kharif, 1981). Central Rice Research Institute, Cuttack. Annual Report 1981. p.35.

Manna, G.B. and Moorthy, B.T.S. 1984. Management of uplands chemical weed control in uplant rice (Kharif). Central Rice Research Institute, Annual Report 1982. p.13.

Matthews, L.J. 1986. Weed control component of integrated pest control in rice in South and S.E. Asia. Int. Rice Commn. Newsl. 35(1): 53-60.

Maxima Mabbayad, Moody, K. and Argente, A.M. 1986. Effect of soil type, temperature and soil moisture on butachlor dissipation. Philipp. J. Weed Sci. 13: 1-10.

*Moody, K. 1977a. Weed control in sequential cropping in rainfed lowland rice growing areas in tropical Asia. In Weed control in small scale farms. Proc. 6th Asian-Pacific Weed Sci. Soc. Conf. 11-1' July 1977, Jakarta, Indonesia.

*Moody, K. 1977b. Weed control in rice. In 5th Biotrop Weed Science Training Course, 14 Nov-23 Dec 1977, Rubber Research Institute, Kuala Lumpur, Malaysia (lecture note). p.374-424.

Moody, K. 1979. Weed control in rice and sugarcane cropping systems. In K. Moody (ed) Weed control in tropical crops. Weed Sci. Soc. Philippines College, Laguna, Philippines. p.56-74.

Moody, K. and Drost, D.C. 1983. The role of cropping systems on weeds in rice. Int. Rice Res. Inst. Weed control in rice. Los Banos, Laguna Philippines. p.73-88.

Moorthy, B.T.S. and Dubey, A.N. 1981. Relative efficacy of different herbicides for control of weeds in upland rainfed rice. Indian J. Weed Sci. 13(1): 56-62.

Moorthy, B.T.S. and Manna, G.B. 1982. Chemical weed control in upland rice. Central Rice Res. Inst. Annual Report for 1981. p.35.

Moorthy, B.T.S. and Manna, G.B. 1984. Herbicides for weed control in puddle seeded rice. Indian J. Weed Sci. 16(13): 148-155.

Mukhopadhyay, S.K. 1965. Control of weeds in wheat and rice. Indian J. Agron. 10(1): 72-81.

*Mukhopadhyay, S.K. 1981. Weed problems and their control measures for important crops with particular reference to W. Bengal. Visva Bharati College of Agriculture (P.S.S.) Res. Inf. Bull. 1. p.1-12.

Mukhopadhyay, S.K. and Bag, S. 1967. New herbicides for controlling weeds in upland rice. Indian J. Agron. 12(3): 253-256.

Mukhopadhyay, S.K., Ghosh, A.C. and Maity, H. 1971. Weed problem in upland rice and approaches to solve the problem by use of new herbicides. Oryza. 8: 269-274.

Mukhopadhyay, S.K., Khara, A.B. and Ghosh, B.C. 1972. Nature and intensity of competition of weeds with direct seeded upland IR-8 rice crop. Int. Rice Commn. Newsl. 21(2): 10-14.

Nair, G.K.B., Pillai, B.P., Nair, K.P.M. and Sasidhar, V.K. 1979. Relative efficiency of different herbicides on rice under semi-dry conditions. Agric. Res. J. Kerala. 17(1): 14-17.

Nair, R.R., Vidyadharan, K.K., Pisharody, P.N. and Gopalakrishnan, R. 1974. Comparative efficiency of new herbicides for weed control in direct seeded rice fields. Agri. Res. J. Kerala. 12(1): 24-27.

Nair, R.R., Pillai, G.R., Pisharody, P.N. and Gopalakrishnan, R. 1975. Investigations on the competing ability of rice with weeds in the rainfed uplands. Agric. Res. J. Kerala. 13(2): 146-151.

*Noda, K. 1973. Competitive effects of barnyard grass (Echinochloa crus-galli) on rice. Proc. Asian-Pacific Weed Sci. Soc. Conf. 4. p.145-150.

*Noda, K., Ozawa, K. and Ibraki, K. 1968. Studies on the damage to rice plants due to weed competition. Kyushu Agrl. Expt. Stn Bull. 13. p.345-367.

*Olofintoye, J.A. 1982. Influence of tillage, mulching, weed control methods and butachlor application on certain soil properties, weeds and performance of upland rice. Ph.D. thesis (unpubl) University of the Phillippines, Los Banos, Laguna, Phillippine

*Pande, P.N. 1982. Benthiocarb for weed control in rice nursery. Abstracts of papers Ann. Conf. ISWS. Haryana, Agricultural University, Hissar. p.10.

Panse, V.G. and Sukhatme, P.V. 1978. Statistical methods for Agricultural Workers. ICAR, New Delhi. p.347.

*Patel, C.L., Patel, Z.G., Patel, R.B. and Patel, H.R. 1985. Herbicides for weed control in rice nurseries. Int. Rice Res. Newsl. 10(5): Weed Abstr. 1986. 35(4):1117.

Pawan Kumar and Gill, H.S. 1981. Herbicidal control of weeds in direct seeded rice (Oryza sativa L.) under non-puddled conditions and their residual effect on wheat, Brassica and Linseed. Indian J. Weed Sci. 13(1): 50-51.

Pawan Kumar and Gill, H.S. 1982. Weed control in direct seeded rice under puddled conditions. Oryza. 19(3 & 4): 162.

Pillai, K.G. 1977. Integrated weed management in rice. Indian Fmg. 26(12): 17-23.

*Pillai, K.G.K. and Rao, M.V. 1974. Current status of herbicides research on rice in India. Paper presented at Annual International Rice Research Conference held at IRRI Manila, Philippines from 22nd to 25th April, 1974.

*Pillai, S.J. and Ghosh, A.K. 1980. Influence of different herbicides on weed control in direct seeded flooded rice. Abstracts of paper ISWS/OUAT Weed Sci. Conf. Bhubaneswar. Indian Weed Sci. Res. Abstr. 700. pp.352.

*Pillai, S.J., Kuriakose, T.F., Nair, K.P.M. and Saifudeen, N. 1980. Chemical weed control in rice under semi-dry condition. Abstracts of papers ISWS/OUAT Weed Sci. Conf., Bhubaneswar. p.43.

Piper, C.S. 1942. Soil and plant Analysis. Hans Publishers, Bombay. p.368.

Pusa. 1988. Crop-weed competition studies in direct seeded upland rice. Ist Annual Report (1986-87). AICRPWC Pusa Centre, Rajendra Agricultural University, Bihar, Pusa. p.18-21.

Raghavulu, P. and Sreeramamurthy. 1973. Weed control in direct sown upland rice. Andhra agric. J. 20(1&2): 47-49.

*Raju, R.A. and Reddy, M.N. 1986. Protecting the world's rice crops. Agrl. Inf. Developt. Bull. 8(2): p.17-18. Weed Abstr. 1987 36(2):321.

Ramamoorthy, R., Kulandaisamy, S.S. and Sankaran, S. 1974. Effect of propanil and weed growth and yield of IR-20. Madras agric. J. 307-311.

Rethinam, P., Thirunavukarasu, D.R. and Sankaran, S. 1974. Studies on the rates, formulations and methods of application of butachlor and propanil herbicides in rice (var. IR-20). Madras agric. J. 61:710-711.

*Sahai, B. and Bhan, V.M. 1982. Competition for nitrogen between weeds and drilled rice - effect of time of weed removal. Abstracts of papers Annual Conf., ISWS. Rice Abstr. 7(10):1902.

Sahai, B., Bhan, V.M. and Balyan, R.S. 1983. Weed emergence and competition in drilled upland rice in India. Trop. Pest. Management. 29(2): 125-128.

Sankaran, S. and De Datta, S.K. 1985. Weeds and weed management in upland rice. Adv. Agron. 38. 284-337.

Sankaran, S., Rethinam, P., Rajan, A.V. and Raju, K. 1974. Studies on the nutrient uptake of certain field crops and associated weeds and its effect on seed production. Madras agri. J. 61(9): 624-628.

*Santos, C.A.L. Dos. and Garciab, H. 1983. Weeds and herbicides on rice (Oryza sativa L.) crops. Trials by herbicide section for the period 1965 to 1982. Biologico. 49(6). p.131-152. Weed Abstr. 1985. 34(5):859.

*Sharma, P.B. and Bisen, C.R. 1985. Chemical weed control in direct seeded upland rainfed rice (Oryza sativa L.). JNKVV Research Journal. J.N. Krishi Vishwa Vidyalaya, Jabalpur, M.P., India. 17(½): p.103-107. Weed Abstr. 1987 36(1):33.

*Shelke, D.K., Bhosle, R.H. and Jadhav, N.S. 1985. Studies on crop-weed competition in irrigated upland rice (var. Prabhavati). Abstract of papers Conf. Indian Soc. Weed Sci. 6-7 May 1985, Anand, Gujarat, India. p.83.

Shelke, D.K., Bhosle, R.H. and Jadhav, N.S. 1986. Integrated weed management in upland irrigated rice in Marathwada. Int. Rice Res. Newsl. 11(4): 39-40.

*Singh, B. and Dash, B. 1984. Effect of methods of weed control on growth of weeds and uptake of nitrogen by weeds in direct seeded unpuddled rice. Agric. Sci. Digest, India. 4(4): p.231-233. Weed Abstr. 1986. 35(7):2302.

*Singh, B. and Dash, B. 1986. Efficiency of different weed control methods in increasing grain yield of direct seeded unpuddled rice under irrigated conditions. Oryza 23(1): p.50-52. Weed Abstr. 1987. 36(9):2683.

Singh, C.M. 1985. Control of weeds in dry seeded rice. Indian Fmg. 35(2): p.31-33.

Singh, G., Yadav, S.R. and Singh, D. 1987. Crop/Weed competition studies in upland rice. Trop. Pest Management. 33(1): 19-21.

Singh, M., Singh, K. and Srivastava, V.K. 1986. Effect of herbicides on weed growth and nitrogen depletion pattern in upland rice under varying nitrogen levels. Andhra agric. J. 33(1): 5-11.

Singh, M., Singh, R.A. and Sharma, H.C. 1973. Six tonnes of food from one hectare dry land. Indian Fmg. 23(3): 34-35.

*Singh, R.P. and Singh, V.P. 1985a. Comparative study of thiobencarb on N uptake and drain in direct seeded upland rice. Abstracts of papers Ann. Conf. Indian Soc. Weed Sci. p.11-12. Weed Abstr. 1986 35(6):1886.

*Singh, R.P. and Singh, O.N. 1985b. Integrated method of weed control in direct sown upland rice. Abstracts of papers Ann. Conf. Indian Soc. Weed Sci. p.65-66. Inst. Agric. Sci. Banaras Hindu Univ., Varanasi, U.P., India. Weed Abst. 1986. 35(6):1891.

*Singlachiar, M.A. 1977. Studies on chemical weed control in transplanted rice. Unpublished paper submitted to the All India Weed Science Conference, January, 17-20.

Singlachiar, M.A., Shivappa, T.G. and Rao, Y.B. 1978. Effect of weed free duration on the performance of dwarf and tall rice types.. Mysore J. agric. Sci. 12: 210-212.

Smith, A. 1984. Soil persistence studies with bromoxynil, propanil and (^{14}C) dicamba in herbicidal mixtures. Weed Res. 24(4): 291-295.

*Smith, R.J. Jr. 1965. Propanil and mixtures with propanil for weed control in rice. Weeds. 13: 236-238.

Smith, R.J. Jr. 1983. Weeds of major economic importance in rice and yield comes due to weed competition. In weed control in rice. IRRI. Int. Weed Sci. Soc.

Smith, R.J. Jr. and Moody, K. 1976. Kommedahl (ed). Weed control practices in rice. Integrated plant protection for agricultural crops and forest trees. Proc. Symposia IX Int. Cong., Plant Protection, Washington, D.C. 2. p.458-462.

Soil Survey Staff. 1967. Soil Survey Laboratory Methods and Procedures for collecting soil samples. Soil Survey Investigation Report No.1, U.S.D.A., U.S. Govt., Printing Office, Washington. pp.50.

Sreedevi, P. 1979. Studies on the performance of rice variety 'Aswathy' under different methods of direct seedings and weed control. M.Sc. thesis, Kerala Agricultural University. pp.109.

Sudhakara, K. and Nair, R.R. 1986. Weed control in rice under semi-dry system. Agric. Res. J. Kerala. 24(2): 211-215.

wain, D.J. 1967. Controlling barnyard grass in rice. Agric. Gaz., N.S.W. 78(8). p.473-475. Weed Abstr. 17(1):55. 1968.

Tasic, R.C., Marilyn, P.S. and Balairos, J.B. 1980. Philipp. J. Weed Sci. 7:76-79 cited by Sankaran, S. and De Datta, S.K. 1985. Weeds and weed management in upland rice. Adv. Agron. 38: 284-337.

Thiagarajan, C.P., Vijayakumar, M. and Sreeramulu. 1974. Control of weeds in paddy fields with Stam F-34 and Rogue. Pesticides. 8(9): 35.

Tiwari, J.P., Bisen, C.R. and Trivedi, K.K. 1987. Herbicides to control weeds in paddy nursery. Pesticides. 21(11): 21-22.

TNAU. 1985. Crop-weed competition in upland bunded rice. AICRPWC-Weed Research and herbicide residue studies in cultivated crops. Tamil Nadu Agricultural University Third Annual Progress Report 1-4-1984 to 31-3-1985, Coimbatore Centre. p.61-63.

TNAU. 1987. Herbicide residue studies in rice. All India Co-ordinated Project on Weed Control, Coimbatore Centre 1st Annual Progress Report 1987. p.93-95.

Tosh, G.C. 1977. New herbicides for the control of weeds in direct sown upland rice. Indian J. Farm. Sci. 3: 60-63.

*Trivedi, K.K., Tiwari, J.P. and Lokras, V.G. 1985. Chemical weed control in upland drilled paddy. Abstracts of papers. Ann. Conf. Indian Soc. Weed. Sci. Pantnagar, 1985. p.40.

Trivedi, K.K., Tiwari, J.P. and Bisen, C.R. 1986. Integrated weed control in upland drilled rice. Pesticides. 20(11): 29-33.

UAS. 1985. Competition of Echinochloa sps. on growth and production of transplanted rice. AICRPWC 7th Annual Report (April, 1984 to March 31, 1985) University of Agricultural Sciences GKVK Campus, Bangalore. p.20-23.

UAS. 1986. Survey on weed flora. 8th Ann. Rep. 1985-86. All India Co-ordinated Research Project on Weed Control, University of Agricultural Sciences GKVK Campus, Bangalore. p.7-9.

Uttaman, P. 1949. An introduction to the study of *Striga lutea* as a root parasite on rice in Malabar. Madras agric. J. 36: 303-307.

Vega, M.R., Ona, J.D. and Paller, E.C. 1967. Weed control in upland rice. University of Philippines, College of Agriculture. Philipp. Agric. 51: 397-411.

*Venugopal, P.V.K.S.N., Kundap, S.M. and Reddy, B.B. 1983. Efficiency of herbicides in rice cultivars under different methods of cultivation. Indian J. Weed Sci. 15(2): 207-213.

*Verma, J.K. and Mani, V.S. 1970. Efficiency and selectivity of herbicides in rice production. Proc. 10th Br. Weed Control Conf. p.705-710.

WSSA. 1983. Weed Science Society of America Herbicide hand book 5th (ed) 1983. Thiobencarb. p.462-464.

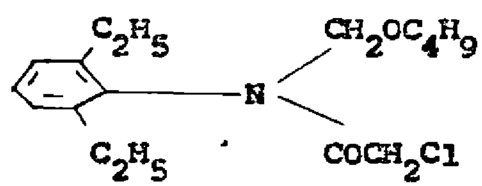
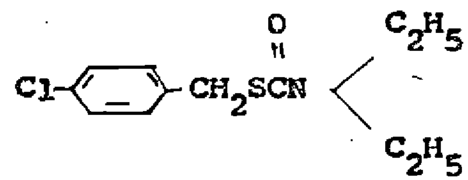
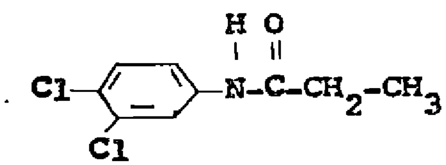
*Yamane, K., Kushio, H. and Takami, T. 1975. The use of mixtures of propanil and benthiocarb for weed control in dry seeded rice, later flooded. Hyogo Prefectural Agricultural Expt. Station, Akashi, Hyogo. Personal Communication.

* Originals not seen

Appendices

Appendix-I

Details of herbicides

	Butachlor	Thiobencarb	Propanil
	1	2	3
1. Chemical name	N-(butoxymethyl)-2-Chloro 2', 6'-diethyl acetanilide	S [(C4-Chlorophenyl) methyl] diethyl carbomothivate	3', 4'-dichloropropion-anilde
2. Structural formula			
3. Herbicide family	Amides	Thiocarbamates	Amides
4. Manufacturer	Pest Control Co.	Pesticides India Ltd., Udaipur, Rajasthan.	Indofil Chemicals
5. Trade name	Butachlor 50 EC	Saturn 50 EC	Stam F-34
6. Formulation	EC 50	EC 50	EC 35
7. Physical properties	Molecular weight 311.9. Slightly sweet aromatic amber liquid. Melting point less than -5°C. Boiling point 156°C at 0.5 mm Hg. Solubility in water -23 ppm at 24°C. Soluble in ether, acetone, benzene, alcohol, ethyl acetate and hexane at room temperature.	Molecular weight 257.8 Oily liquid with pale amber to light yellow colour. Melting point 3.3°C. Boiling point 126 to 129°C at 0.008 mm Hg. Soluble in organic solvents like Acetone, Ethyl alcohol and Xylene. Solubility in water 30 ppm at 20°C stable in acid and alkali	Molecular weight 218.0. Light brown to gray-black liquid. Melting point 85 to 89°C. Solubility in water 0.05%, solubility in organic solvents 25%.

Contd.

Appendix-I. Continued

	1	2	3
8. Rates	Approximately 1.12 to 4.48 kg ai/ha as a broadcast treatment depending on type of application, crops, weed, stage of growth etc.	3.4 to 4.5 kg/ha	3.36 to 6.7 kg/ha
9. Mode of action	Information incomplete. Based on modes of action of other chloroacetanilides, butachlor probably inhibits protein synthesis in susceptible plants.	Inhibits protein biosynthesis and gibberlin biosynthesis.	Contact herbicide.
10. Method of application	Pre-emergence soil surface treatment, application in water with transplanted rice and as a post emergence application in combination with propanil.	Pre-emergence to early post-emergence application in rice.	Ground or aerial application used for selective post emergence control of grass (Echinochloa) and broad leaved weeds in cultivated rice.
11. Absorption character	Absorbed mainly by the germinating plant shoots, secondarily by roots.	Absorbed by roots, stem and leaves. Translocated acropetally and basipetally.	Moves from leaf to growing point, then back to the leaves.
12. Average persistence at recommended rates	6 to 10 weeks, varies with soil type and climatic conditions.	2 to 3 weeks under aerobic conditions and 6 to 8 months under anaerobic conditions.	one to 3 days under warm, moist conditions typical of time of application

Source: WSSA (1983). Herbicide Hand Book of the Weed Science Society of America. Fifth edition. Weed Science Society of America, Illinois. 515pp.

APPENDIX-II

Weed flora in the experimental field

Botanical name	Common name	Malayalam name	Family
A. Monocots			
(i) Grasses			
1. *Echinochloa colona* (L) Link	Jungle rice	Kavada	Gramineae
2. *Eleusine indica* (L) Gaertn	Goose grass		Gramineae
3. *Isachne miliacea* Roth		Chovaripullu	Gramineae
4. *Saccoleppis interrupta* L.		Polakkapottan (Polappullu)	Gramineae
(ii) Sedges			
1. *Cyperus iria* (L)	Riceflat sedge	Muthanga	Cyperaceae
2. *Cyperus difformis* L.		Thalaekettan	Cyperaceae
3. *Eriocaulon* sp			Eriocaulaceae
4. *Fimbristylis miliacea* Vahl.	Hoorah grass	Mung	Cyperaceae
(iii) Broad leaved			
1. *Ammania baccifera* Linn	Blistering Ammania	Kallarvanchi	Lythraceae
2. *Lindernia* sp			Scrophulariaceae
3. *Ludwigia parviflora*, Roxb.		Nirgrambu	Onagraceae
4. *Monochoria vaginalis* Prestl.		Neelolpalam (Karimkoovalam)	Pontederiaceae
5. *Sphaeranthus indicus*, Linn.		Adakkamanian	Compositae
6. *Sphenochlea zeylanica*, Gaertn.			Campanulaceae
7. *Emilia sonchifolia*		Moyalcheviyan	Compositae

Appendix-III

Nitrogen content of weeds at different stages (%)

Treatments	Stages				
	30 DAS	40 DAS	50 DAS	60 DAS	Harvest
To	2.2	1.9	1.5	1.7	1.6
To+ 20	2.2	2.0	1.7	1.6	1.4
To + 30	2.5	1.9	1.9	1.5	1.5
To + P 30	2.2	1.9	1.5	1.7	1.5
To + H.W	2.3	1.9	1.7	1.9	1.4
Bo	2.2	2.0	2.0	1.5	1.9
Bo + 20	2.5	2.1	1.8	1.4	1.8
Bo + 30	2.4	2.0	1.5	1.5	1.5
Bo + P 30	2.3	1.9	1.6	1.4	1.5
Bo + H.W	2.2	2.0	1.7	2.1	1.5
B 15	2.4	2.1	1.9	1.8	1.8
T 15 + P 15	2.3	2.1	1.9	1.8	1.6
B 15 + P 15	2.1	1.8	1.9	1.5	1.8
H.W	2.5	1.9	2.0	1.7	1.8
U.W	2.3	2.3	2.1	2.2	1.9

Appendix-IV

Phosphorus content of weeds at different stages (%)

Treatments	Stages				
	30 DAS	40 DAS	50 DAS	60 DAS	Harvest
To	0.17	0.19	0.17	0.13	0.13
To + 20	0.16	0.2	0.17	0.14	0.12
To + 30	0.18	0.18	0.19	0.15	0.13
To + P 30	0.18	0.18	0.16	0.17	0.13
To + H.W	0.19	0.2	0.19	0.16	0.12
Bo	0.18	0.2	0.18	0.17	0.15
Bo + 20	0.15	0.2	0.16	0.12	0.13
Bo + 30	0.16	0.21	0.18	0.15	0.13
Bo + P 30	0.16	0.19	0.19	0.13	0.13
Bo + H.W	0.17	0.21	0.19	0.15	0.11
P 15	0.17	0.2	0.18	0.18	0.15
T 15 + P 15	0.16	0.21	0.16	0.17	0.15
B 15 + P 15	0.16	0.19	0.13	0.16	0.14
H.W	0.19	0.19	0.17	0.14	0.12
U.W	0.16	0.2	0.2	0.16	0.15

Appendix-V

Potassium content of weeds at different stages (%)

Treatments	Stages				
	30 DAS	40 DAS	50 DAS	60 DAS	Harvest
To	1.8	2.2	1.6	1.7	1.8
To + 20	1.4	2.4	1.5	1.2	1.5
To + 30	1.4	2.4	1.5	1.5	1.6
To + P 30	1.6	2.1	1.8	1.7	1.6
To + H.W	1.5	2.4	1.6	1.9	1.8
Bo	1.6	1.8	1.5	1.5	1.5
Bo + 20	1.3	1.7	1.7	1.8	1.6
Bo + 30	1.6	1.7	1.4	1.8	1.5
Bo + P 30	1.6	2.3	1.2	1.6	1.6
Bo + H.W	1.6	2.1	1.8	1.8	1.5
P 15	1.7	1.9	1.2	1.4	1.6
T 15 + P 15	1.8	2.3	1.2	1.5	1.7
B 15 + P 15	2.0	2.1	1.8	1.5	1.7
H.W	1.1	2.4	1.2	2.0	1.6
U.W	1.8	1.8	1.6	1.9	1.9

Appendix-VI

Nitrogen content of crop at different stages (%)

Treatments	Stages					
					Harvest	
	30 DAS	40 DAS	50 DAS	60 DAS	Grain	Straw
To	2.2	2.1	2.0	2.1	1.6	1.3
To + 20	2.3	2.2	2.3	2.6	1.8	1.2
To + 30	2.2	2.4	2.3	2.3	1.6	1.3
To +P30	2.2	2.4	2.1	2.4	1.9	1.4
To + H.W	2.2	2.3	2.4	2.5	1.8	1.3
Bo	2.0	2.1	2.2	2.0	1.6	1.3
Bo + 20	2.1	2.2	2.1	2.1	1.7	1.3
Bo + 30	2.0	2.2	1.9	2.1	1.7	1.2
Bo + P 30	2.2	2.2	2.1	2.4	1.8	1.2
Bo + H.W	2.1	2.3	2.2	2.4	1.8	1.1
P 15	1.8	2.0	2.0	1.9	1.5	1.4
T 15 + P 15	1.9	2.0	2.1	2.0	1.6	1.3
B 15 + P 15	1.9	2.1	1.9	2.0	1.5	1.4
H.W	2.3	2.4	2.3	2.7	1.8	1.2
U.W	2.1	2.0	1.8	1.7	1.4	1.4

Appendix-VII

Phorphorus content of crop at different stages (%)

Treatments	Stages					
	30 DAS	40 DAS	50 DAS	60 DAS	Harvest	
					Grain	Straw
To	0.18	0.26	0.21	0.27	0.2	0.13
To + 20	0.16	0.28	0.28	0.31	0.18	0.12
To + 30	0.15	0.29	0.25	0.31	0.18	0.12
To + P 30	0.18	0.29	0.25	0.26	0.18	0.13
To + H.W	0.18	0.3	0.28	0.26	0.18	0.12
Bo	0.15	0.27	0.22	0.26	0.2	0.13
Bo + 20	0.18	0.25	0.26	0.26	0.19	0.13
Bo + 30	0.17	0.27	0.24	0.26	0.19	0.13
Bo + P 30	0.18	0.27	0.31	0.27	0.19	0.12
Bo + H.W	0.17	0.3	0.28	0.31	0.18	0.12
P 15	0.14	0.22	0.16	0.24	0.21	0.16
T 15 + P 15	0.18	0.25	0.21	0.26	0.2	0.15
B 15 + P 15	0.18	0.26	0.22	0.26	0.21	0.15
H.W	0.14	0.29	0.28	0.33	0.18	0.12
U.W	0.16	0.29	0.18	0.23	0.21	0.16

Appendix-VIII

Potassium content of crop at different stages (%)

Treatments	Stages					
					Harvest	
	30 DAS	40 DAS	50 DAS	60 DAS	Grain	Straw
To	2.3	2.1	2.1	2.2	0.8	2.5
To + 20	2.5	2.4	2.3	2.3	0.9	2.7
To + 30	2.3	2.6	2.2	2.3	0.9	2.6
To + P 30	2.3	2.3	2.2	2.2	0.9	2.7
To + H.W	2.3	2.3	2.5	2.3	0.9	2.7
Bo	2.4	2.3	2.1	2.1	0.8	2.5
Bo + 20	2.4	2.5	2.2	2.2	0.9	2.6
Bo + 30	2.3	2.6	2.1	2.1	0.8	2.6
Bo + P 30	2.4	2.5	2.1	2.2	0.9	2.7
Bo + H.W	2.3	2.4	2.5	2.3	0.9	2.7
P 15	2.2	2.1	2.1	2.1	0.7	2.3
T 15 + P 15	2.4	2.3	2.2	2.1	0.7	2.4
B 15 + P 15	2.3	2.2	2.2	2.1	0.8	2.4
H.W	2.4	2.4	2.3	2.4	0.9	2.7
U.W	2.3	2.4	2.0	2.1	0.7	2.3

Appendix-IX(a)

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

Particulars	Cost of input	Labour charges			Total
		Tractor	Men	Women	
1 Land preparation (Tractor-12 hrs + 9 M + 3 W)	-	600	261	84	945
2 Seeds (125 kg)	375	-	-	-	375
Sowing (3 M)		-	87	-	87
3 Fertilizer					
Urea (155 kg)	387.5	-	-	-	387.5
Mussoriphos (175 kg)	175.0	-	-	-	175.0
M.O.P. (58 kg)	101.5	-	-	-	101.5
Application (3 M)	-	-	87	-	87.0
4 Plant Protection					
Malathion (1000 ml)	85	-	-	-	85

Contd.

Appendix-IX(a). Continued

Particulars	Cost of input	Labour charges			Total
		Tractor	Men	Women	
Application (2 M)	-	-	58	-	58
Water management (5 M)	-	-	145	-	145
5. Harvest operations					
Harvesting (22 W)	-	-	-	616	616
Threshing (20 W)	-	-	-	560	560
Cleaning and drying (2 M + 15 W)	-	-	58	420	478
Total	1124	600	696	1680	4100

Seeds	Insecticides	Fertilizers	Labour charges
Paddy seed @ Rs.3/kg	Malathion @ Rs.85/lit	Urea @ Rs.2.50/kg	Men @ Rs.29/day
		Mussoriphos @ Rs.1/kg	Women @ Rs.28/day
		M.O.P. @ Rs.1.75/kg	Tractor @ Rs.50/hr

Appendix-IX(b)

Economics of different treatments (Rs./ha)

Treatments	Cost of cultivation excluding cost for weed control	Cost of weed control operation	Total cost of cultivation	Return from grain yield	Return from Straw yield	Total return
To	4,100.00	466.00	4,566.00	7,048.25	3,927.30	10,975.55
To + 20	4,100.00	932.00	5,032.00	9,308.75	4,680.00	13,988.75
To + 30	4,100.00	932.00	5,032.00	8,219.75	3,762.85	11,982.60
To + P 30	4,100.00	1,251.00	5,351.00	7,150.00	3,979.30	11,129.30
To + H.W	4,100.00	1,474.00	5,574.00	8,615.75	4,355.00	12,970.75
Bo	4,100.00	455.20	4,555.2	5,508.25	3,562.00	9,070.25
Bo + 20	4,100.00	910.4	5,010.4	7,260.00	3,495.70	10,755.70
Bo + 30	4,100.00	910.4	5,010.4	6,325.00	3,148.60	9,473.60
Bo + P 30	4,100.00	1,240.20	5,340.2	7,119.75	4,104.10	11,223.85
Bo + H.W	4,100.00	1,463.20	5,563.2	7,807.25	3,844.75	11,652.00
P 15	4,100.00	785.00	4,885.00	1,966.25	2,145.00	4,111.25
T 15 + P 15	4,100.00	1,091.00	5,191.00	6,283.75	3,146.00	9,429.75
B 15 + P 15	4,100.00	920.2	5,020.2	2,887.50	2,639.00	5,526.5
H.W	4,100.00	3,080.00	7,180.00	10,106.25	4,878.9	14,985.15
U.W	4,100.00	–	4,100.00	638.00	765.05	1,403.05

Price of paddy @ Rs.275/Quintal
Price of straw @ Rs.65/Quintal
Cost of thiobencarb (Saturn 50 EC) @ Rs.102/litre
Cost of butachlor (Butachlor 50 EC) @ Rs.98.40/litre

Cost of propanil (Stam F-34) @ Rs.125/litre
Hand weeding (3 hand weedings) [illegible] @ Rs.28/W[illegible]
Spray application, 5 Men @ Rs.32/[illegible]

Appendix-X

Abstract of analysis of variance

Character	Mean sum of squares						
	Source	df	30 DAS	40 DAS	50 DAS	60 DAS	Harvest
1	2	3	4	5	6	7	8
Studies on weeds							
Isachne sp. count	Treatment	14	64.4*	489.35*	441.73*	(13) 400.92*	321.63*
	Error	28	3.29	33.93	54.93	(26) 25.47	41.85
Saccoleppis sp. count	Treatment	14	8.18*	14.24*	33.29*	66.69*	65.61*
	Error	28	1.79	3.44	2.71	15.9	9.35
Echinochloa sp. count	Treatment	9	14.96*	14.32*	(7) 23.34*	(10) 34.06*	(10) 25.22*
	Error	18	2.08	7.04	(14) 8.14	(20) 1.68	(20) 2.85
Total grass weed count	Treatment	14	83.53*	511.85*	509.15*	448.08*	411.33*
	Error	28	3.31	23.92	44.99	14.9	34.26
Cyperus sp. count	Treatment	9	26.97*	(12) 53.13*	(13) 33.96*	(12) 34.9*	(10) 5.61*
	Error	18	3.18	(24) 3.24	(26) 6.64	(24) 0.86	(20) 0.96
Broad leaved weed count	Treatment	13	-	13.4*	(14) 24.55*	(12) 42.5*	18.85*
	Error	26	-	9.98	(28) 13.49	(24) 10.99	12.15
Total weed count	Treatment	14	101.53*	461.48*	531.3*	375.11*	333.62*
	Error	28	3.45	17.52	32.55	24.83	31.74

NB: Values in paranthesis indicate the degree of freedom for those characters whose df is different from the general df in the 3rd column.

Contd.

Appendix-X. Continued

1	2	3	4	5	6	7	8
Weed dry matter	Treatment	14	6.54*	35.2*	44.88*	69.45*	77.14*
	Error	28	0.44	1.34	2.87	6.88	5.7
Weed control efficiency	Treatment	13	733.11*	350.43*	585.69*	1209.05*	1506.96*
	Error	26	98.92	52.8	80.11	244.95	268.45
<u>Studies on crop</u>							
Crop dry matter	Treatment	14	368.04*	1326.23*	8611.33*	19818.52*	93603.0*
	Error	28	45.83	201.16	747.82	251.55	2090.86
<u>Nutrient uptake</u>							
Drain by weeds Nitrogen	Treatment	14	24.28*	360.53*	600.84*	1162.95*	969.43*
	Error	28	1.25	8.32	23.12	74.91	88.3
Phosphorus	Treatment	14	0.118*	2.735*	5.24*	7.71*	7.034*
	Error	28	0.007	0.076	0.19	0.69	0.557
Potassium	Treatment	14	15.19*	219.57*	344.65*	849.56*	1001.721*
	Error	28	0.77	7.38	13.64	82.14	77.104
<u>Uptake by crop</u>							
Nitrogen	Treatment	14	26.09*	103.31*	546.62*	1915.43*	2075.01*
	Error	28	2.04	9.72	37.91	13.62	57.35

Contd.

Appendix-X. Continued

1	2	3	4	5	6	7	8
Phosphorus	Treatment	14	0.11*	1.45*	9.33*	23.75*	12.47*
	Error	28	0.01	0.15	0.55	0.21	0.51
Potassium	Treatment	14	22.18*	102.18*	535.63*	1244.49*	4907.14*
	Error	28	5.48	11.56	40.38	12.42	81.99
<u>Observations at harvest</u>							
Total tillers/hill	Treatment	14			8.1*		
	Error	28			2.73		
Height of plant	Treatment	14			261.93*		
	Error	28			87.44		
Productive tillers/ hill	Treatment	14			7.02*		
	Error	28			1.2		
Length of panicle	Treatment	14			15.29*		
	Error	28			0.08		
Grains/panicle	Treatment	14			754.04*		
	Error	28			68.23		
Thousand grain weight	Treatment	14			6.82		
	Error	28			3.98		

Contd.

Appendix-X. Continued

1	2	3	
Grain yield	Treatment	14	285.14*
	Error	28	3.94
Straw yield	Treatment	14	776.06*
	Error	28	9.16
Grain : Straw	Treatment	14	0.04
	Error	28	0.022
Harvest index	Treatment	14	0.0112
	Error	28	0.05
Weed index	Treatment	14	2136.12*
	Error	28	35.69

*Significance at 5% level

SEQUENTIAL AND COMBINED APPLICATION OF HERBICIDES IN DRY SOWN RICE

By

JOLLY CHACKO PALAIKUDY

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture
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Department of Agronomy
COLLEGE OF HORTICULTURE
Vellanikkara - Trichur

1989

ABSTRACT

Field experiments were conducted during Virippu (1st crop season) of 1987 ie. from June to September at Agricultural Research Station, Mannuthy under the Kerala Agricultural University, Vellanikkara, Kerala with the objective of evaluating the efficiency of repeated application of pre-emergence herbicides as well as combined application of pre-emergence and post-emergence at early post-emergence stage of rice so as to develop a cheaper and efficient herbicide sequence for season long weed control in dry sown rice. Fifteen treatments were compared with farmers practice of hand weeding, unweeded control and post-emergence application of propanil alone. The experiment was carried out in R.B.D. with three replications.

The dominant weeds were *Isachne miliacea*, *Saccoleppis interrupta* and *Echinochloa colona* in grasses, *Cyperus iria* in sedges and *Ludwigia parviflora* and *Ammania baccifera* in broad leaved weeds. Control of *Echinochloa colona* and other grasses were most effective in the treatment where thiobencarb was repeated at zero and 20 DAS whereas repeated application of butachlor at 0 and 20 DAS controlled the sedges effectively. Higher weed control index and weed control efficiency were noticed when thiobencarb applied at

zero days was repeated after 20 or 30 days or followed up with propanil at 30 days or a handweeding at 40 days, compared with the single pre-emergence application of thiobencarb at zero days only.

Weed management through the thiobencarb 0 + 20 days treatment was more effective in improving the growth, yield attributes and yield of rice and gave higher grain yield on par with that of hand weeded plot.

The benefit/cost ratio also worked out to be maximum in the thiobencarb 0 + 20 treatment, proving it to be the most effective and cheapest method of weed control in dry sown rice.