WEED MANAGEMENT IN RICE BASED CROPPING SYSTEM

BY

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THESIS

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DECLARATION

I hereby declare that this thesis, entitled "Weed management in rice based cropping system" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

College of Agriculture,
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Certified that this thesis, entitled "Weed management in rice based cropping system" is a record of research work done independently by Sri. Soman. P.S, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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INTRODUCTION

INTRODUCTION

Rice *Oryza sativa* (L) is the staple food crop of Kerala and it is the main source of energy to more than 50 percent of world population. Total area under paddy in our state is 7.78 lakh hectares producing 13.06 lakh tonnes (Anon, 1985). Thus the average yield of rice in our state is very low (1678 kg/ha). Among the many factors that contribute to this low yield, the part played by weeds is quite substancial.

Without weed control, yield reduction would occur despite improvement in any of the cultural practices. Weeds are probably present in every hectare of rice grown in the world. Therefore it is often pointed out that "agriculture is a fight against weeds". To achieve the level of rice production, required to feed an ever increasing population, new strategies for weed management must be developed and old strategies re-examined (De Datta, 1981).

Gopalakrishna Pillai and Rao (1974) estimated that the reduction in rice yield due to weeds alone is to the tune of 15-20 percent in transplanted rice, 30 - 35 percent in direct seeded rice under puddled condition where as it exceeds 50 percent in direct seeded upland rice.

Based on 108 dry season trials and 176 wet season trials in farmers fields in Philippines, 11 - 13 percent yield gap is accounted for between farmers weed control practices and improved weed control techniques (De Datta, 1981).

Out of the total area under rice in Kerala, 3.43 lakh hectares are cultivated during Virippu season, 3.52 lakh hectares during Mundakan season and 0.83 lakh hectares during summer season. Of these weed problem is more during the first crop Virippu season. Sizable area of first crop and majority area of second and third (summer) crops are transplanted (Anon, 1985).

Weed management has always been one of the major inputs for rice production, because a large portion of the total labour required traditionally has been devoted to weeding. Competition between weed and crop plants are mainly for nutrients, water, sunlight and space. Direct and most important loss due to weeds is the reduction in crop yield resulting from the competition for the above factors. Further the weed infestation deteriorates the quality of rice, increases cost of operations such as harvesting, drying and cleaning. By altering the micro climate and serving as alternate host, the weeds harbour pest and disease organisms.

Till now weed research in our state has been concentrated more on weeds and weed control for individual crops in individual seasons. Now the strategy requires a change. Cropping system approach has to be adopted for effective and economic weed management.

Weed research in cropping system concentrates on the management of weeds by all available methods throughout the cropping pattern. Since the weed community in our field is determined largely by previous cultural practices, we are interested in the long-term effects of our control measures. With intensive cropping under high management, weed species commonly shift towards the difficult to control grasses and sedges (Anon,1974).

With high rates of chemicals continuously being applied, the weed community rapidly shifts. In a two season weed study at I R R I, it was found that butachlor at the rate of 1.2 kg a.i./ha shifted the weeds in the second season to an almost uniform stand of the difficult to control *Cyperus rotundus* under low corn population (Anon, 1974). It was also found that in all crops tested, the weeds shifted towards *Cyperus* spp. as chemical rates increased.

Repeated application of herbicides at high rates, season after season may lead to high residual toxicity in the field. It will also affect the employment potential of human labour available in our country. Unscientific use of herbicides at exorbitant rates may lead to the pollution of atmosphere and water. This will be detrimental to other organisms living in water and associated media, besides causing health hazards to human beings and other animals.

So a suitable weed management technique for a rice based cropping system is highly essential.

The present investigation was undertaken to find out a suitable weed management technique for a Rice-Rice cropping system with the following objectives.

1. To find out a suitable weed management technique for low land rice.
2. To find out the effect of herbicide treatment on weed species in rice crop.
3. To find out the residual effect of herbicides on weeds of succeeding crop.
4. To find out the effect of weed management on yield and quality of rice.
5. To work out the economics of weed management in rice cultivation.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Research on weed management in rice based cropping system is in its infancy and as such available literature on this aspect is very meagre. A brief review of the work done on weed control in rice fields especially in transplanted rice is presented in this chapter under the following headings.

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WEED SPECTRUM IN RICE FIELDS

Weed flora varies widely with respect to varying cropping situations and regions. The weed flora found in the upland rice is different from those in wetland rice. The weeds associated with the cultivated crop gets all the favourable conditions given to the crop for its growth and multiplication. In the case of rice, weed flora has been studied in detail all over the world. The review on the weed spectrum in rice fields is summarized below.

Predominant weeds found in the rice fields of Coimbator were Echinochloa crus-galli, E. colonum, Cyperus difformis, C. iria and Marsilea quadrifolia (Mohamed Ali and Sankaran, 1975). In the rice fields of Pattambi, Kerala, weeds commonly found were Echinochloa crus-galli, Brachiaria spp., Cleome spp. and Fimbristylis miliacea (Nair et al, 1975).

In a survey, Horng (1976) found 39 species of weeds in Taiwan covering a total of 282 sample paddy fields during the first and second crops under flooded condition. Among them Monochoria vaginalis, Cyperus difformis, Echinochloa crus-galli, Rotala indica and Lindernia pyxidaria were the most widely distributed.

Important weeds found in Tamil Nadu according to Mohamed Ali et al (1977), were Echinochloa crus-galli (L) Beauv, E. colona, Digitaria sanguinalis (L) Scrop, Paspalam spp., Dactyloctenium aegyptium (L) Beauv, Leptochloa panicoides (Presl) Hichts, Cyperus difformis (L), Scirpus spp., Ipomoea reptans Poir, Melochia corchorifolia (L), Leucas aspera Sprong, Phyllanthus niruri (L), Marsilia quadrifoliata, Eichhornia crassipes (Mart) Solms, Ammania baccifera (L) and Monochoria vaginalis.

At the Rice Research Station and Instructional Farm, Mannuthy, Sreedevi (1979) observed 32 different species of weeds in the first crop season of 1978 of which broad leaved weeds dominated followed by grasses and sedges. According to De Datta (1981) most important weeds under transplanted rice culture in India were Echinochloa spp., Ischaemum rugosum, Cyperus spp., Scirpus spp., Bergia ammannioides, Cyanotis axillaris, Eclipta alba, Ludwigia parviflora, Marsilia quadrifoliata and Sphaeranthus indicus. John (1981) reported that important weeds observed in the rice fields at Moncompu, Kerala were Echinochloa crus-galli and E. colonum among grasses, Cyperus iria, C. difformis and Fimbristylis miliaceae among sedges and, Monochoria vaginalis Ludwigia parviflora, Marsilia quadrifolia and Lindernia sp. among broad leaved weeds.

The predominant weeds found at Vellayani by Sukumari (1982) were Echinochloa crus-galli, E. colona, Brachiaria ramosa, Ischaemum rugosum, Fimbristylis miliacea, Cyperus iria, Monochoria vaginalis, Ludwigia parviflora and Marsilia quadrifolia. Weed species commonly found in the irrigated wet lands of International Rice Research Institute were Echinochloa crus-galli, E. glabrescens, Monochoria vaginalis and Paspalam distichum (Anon, 1983).

Predominant weeds found at Kayamkulam, Kerala during the first crop season were Brachiaria ramosa, Echinochloa colona, E. crus-galli, Sacciolepis indica, Cyperus iria, C. rotundus, Cleome viscosa and Monochoria vaginalis (Lakshmi, 1983). In the Kharif (monsoon) and winter seasons of 1983-84, dominant weeds found in Tamil Nadu by Subramanian and Ali (1985) were Echinochloa crus-galli among grasses, Cyperus difformis among sedges and Eclipta alba among broad leaved weeds.

Shad (1986) reported that the major grass weeds found in Pakistan were Echinochloa spp., Paspalam distichum,

P. scrobiculatum and Cynodon dactylon. Scirpus sp., Cyperus spp., and Fimbristylis littoralis were the important weed sedges while Sphenoclea zeylanica, Marsilia minuta, Sagittaria spp. and Ipomoea aquatica represent the main broad leaved weeds.

Summarizing the findings of above workers, most important weeds widely seen in rice can be listed as follows:

Grasses - Brachiaria platyphylla (Griseb) Stapf
Cynodon dactylon (L) Pers
Echinochloa colona (L) Link
Echinochloa crus-galli (L) Beauv
Ischaemum rugosum Salisb

Sedges - Cyperus difformis (L)
Cyperus iria (L)
Cyperus rotundus (L)
Fimbristylis miliacea (L) Vahl

Broad leaved weeds -
Ammania baccifera (L)
Ammania multiflora (L)
Eclipta alba (L)
Eichhornia crassipes (Mart) Solms
Ludwigia parviflora Roxb
Marsilia quadrifoliata (L)
Monochoria vaginalis Presl

CROP WEED COMPETITION

1. Critical periods of growth

Chang (1970) reported that weeds emerging at 15, 30, 45 and 60 days after transplanting reduced yields by 69, 47, 28 and 11 percent respectively. According to Gill and Kolar (1980), the most critical period of crop-weed competition in rice crop was four to six weeks after transplanting.

Mohamed Ali et al (1977) found that the period of weed free condition required was 20 days after transplanting which ensured more productive tillers and higher yields in rice. They also opined that maintaining weed free condition beyond three weeks did not enhance the yield significantly. Singlachar et al (1978) observed that the minimum weed free period after transplanting for optimum grain yield in the dwarf and tall types were 45 and 30 days respectively.

For the short duration variety Triveni, the critical period of competition was found to be between 21 and 40 days after transplanting (Abraham Varughese, 1978). Tillering was reported to be the critical growth phase most affected by weed competition. Competition prior to panicle initiation stage affected the development and the number of spikelets (Ghosrial,1981). Sukumari (1982) revealed that grain and straw yields suffered maximum from weed competition during 21 to 40 days after sowing the rice variety Triveni.

Ali and Sankaran (1984) reported that for higher yield in low land rice, the crop should be kept free from weeds during the first 50 days in the monsoon season and 30 days in the summer season. They also found that *Echinochloa crus-galli* competed with rice at all stages while competition of *Cyperus difformis* was severe in early stages.

The review of critical periods of crop-weed competition shows that competition caused by weed is severe in the early stages of crop growth and it varied with the type of rice culture and the duration. For transplanted rice, the minimum weed free period required is 20 to 45 days.

2. Competition for nutrients

Factors like nutrients, water and light were considered to be of major importance in determining the nature and extend of crop-weed competition (Moolani and Sachan, 1966). Since the present investigation mainly pertains to nutrients, literature on competition for nutrients alone is presented.

Ravindran (1976) opined that nitrogen uptake by weed was negatively correlated with nitrogen uptake by the crop.

Kakati and Mani (1977) found that increasing the levels of nitrogen suppressed weed growth and Iruthayaraj (1981) observed that weed growth was greater under low levels of nitrogen. Sukumari (1982) reported that unchecked weed growth in rice removed 44.21 kg N, 15.90 kg P and 21.48 kg K per ha at harvest. According to De . . . . and Mukhopadhyay (1983), among the weed species, *Monochoria vaginalis* (L) and *Ammania baccifera* (L) were the heavy feeders of nitrogen, while *Eclipta alba* and *Monochoria vaginalis* were the high phosphate consumers and *Monochoria vaginalis* (L) and *Ludwigia parviflora* (Roxb) were the ranked potassium absorbers. According to Lakshmi (1983), weeds competed with rice crop for nitrogen upto the 60th day of dibbling and in the case of Phosphorus and potassium upto harvest. Mukhopadhyay et al (1985) reported that uncontrolled weeds in rice removed 4.50 kg N, 1.87 kg P_2O_5 and 6.85 kg K_2O per ha at 60 days after transplanting.

Above review shows that even though competition for nutrients existed through out the crop period, maximum competition is in the first half of the growing season and the competition is more for nitrogen followed by potassium and least by phosphorus. *Monochoria vaginalis* compete for all the major nutrients.

3. Influence of competition on growth, yield components, yield and quality of rice.

Weeds cause two types of crop losses. The most important one is the direct effect on yield resulting from competition. Second is the indirect effect from reduced crop quality. Weeds increase the cost of operations such as weeding, harvesting drying and cleaning (Moody, 1977).

Echinochloa crus-galli (L) Beauv and Cyperus difformis (L) emerging 15 days after transplanting caused 72 and 60 percent yield reduction respectively. Weed infestation of 100-200 weeds per m^2 reduced grain yield by 51 to 64 percent compared to weed free plot (Chang, 1970).

Gopalakrishna Pillai and Rao (1974) estimated the yield reduction in rice due to weeds as around 15-20 percent for transplanted rice and according to them the potential loss in production of rice in India would be about 15 million tonnes per annum. Tiller number, panicle number and number of grains per panicle were reduced due to weed competition in the unweeded plots (Narayana Samy, 1976). Yamo gishi et al (1976) found that leaf area index of crop plant was decreased in weed infested plots. The extent of yield reduction in unweeded plots at twelve locations of All India Coordinated

Rice Improvement Project was reported to be around 35 percent (Anon, 1977).

According to Ghosrial (1981), tillering was the critical growth phase most affected by weed competition. Competition at panicle initiation stage affected the development and the number of spikelets. He calculated that weed competition lowered panicle number per unit area by 37 percent, number of filled grains per panicle by 13 percent and weight of thousand grains by four percent. At International Rice Research Institute, De Datta and Hoque (1982) recorded the yield losses due to weeds from 9 to 83 percent.

At Vellayani, Kerala, Sukumari (1982) found that all the growth and crop yield characters except plant height, LAI and test weight of grains were affected by the weed competition. She recorded the least protein content in unweeded control plot. She also reported highest protein in grains obtained from plots which were kept weed-free from 1-60 days. Yield attributing factors like number of productive tillers per hill, length of the panicle, weight of the panicle and number of filled grains per panicle, were adversely influenced by competition with weeds. Ali and Sankaran (1984) reported that during the monsoon and summer seasons, unchecked weed growth in low land rice caused 53 percent reduction in paddy yield.

The review reveals that unchecked weed growth adversely affects the growth and yield characters like tillering, panicle number, number of total grains as well as percentage of filled grains and quality of rice. The yield reduction due to weeds in transplanted rice varied from 10 to 40 percent.

METHODS OF WEED CONTROL

Based on 108 dry season trials and 176 wet season trials in farmers fields in Philippines, 11 to 13 percent of the yield gap is accounted for between farmers weed control practices and improved weed control practices (De Data and Garica, 1980).

Among the different methods of weed control being adopted by farmers, important ones are hand weeding and chemical weed control.

1. Hand weeding

Scolari and Young (1975) found that two hand weedings 20 and 40 days after sowing decreased weed population and nutrient uptake by them and gave higher grain yields.

They concluded that for small holdings, using family labour, traditional methods remain the most economical.

Chang et al (1976) reported that the cost of manual weed control is about 10 times more than chemical weed control. Ravindran (1976) opined that, hand weeding on 20th and 40th day of transplanting rice though increased the yield, the net profit was lowered due to increased labour charges. Experiments conducted at Indian Agricultural Research Institute, by Kaushik and Mani (1978) revealed that hand weeding treatments (hand weeding alone and hand weeding plus 3 percent urea) gave most effective weed control and increased grain yield and plant productivity.

Sukumari (1982) suggested two hand weedings on 20th and 40th day to be as effective as weed-free condition during 21-40 days or keeping field weed free from 1 to 60 days. Under semidry condition, Lakshmi (1983) observed that hand weedings on 15th and 30th days suppressed total weed population which was as good as the chemical treatments. She also reported that herbicide treatment gave higher net profit than hand weeding. Ali and Rao (1985) opined that hand weeding twice was less effective in controlling <u>Echinochloa crus-galli</u> (L) compared to herbicide combinations.

Hand weeding is still the most effective and common method of weed control in almost all countries especially under unfavourable conditions. When the area is limited and family labour is available or local labour is cheap, hand weeding is economical.

2. Chemical weed control

Modern farming relies heavily on chemicals for protecting crops from weeds. In many instances, herbicides offer the most practical, effective and economical means of reducing weed competition, crop losses and production costs. Effect of commonly used pre-emergent herbicides in rice like nitrofen, butachlor, thiobencarb, fluchloralin and pendimethalin and their herbicidal activity are reviewed here.

1. Nitrofen.

Pre-emergence application of nitrofen at the rate of 2.5 kg per ha gave selective control of grasses, sedges and broad leaved weeds and promoted yield in heavy soils of medium fertility (Verma et al, 1978). Singh et al (1979) observed that nitrofen at the rate of 2 kg per ha as post-emergence gave good weed control in rice.

Mukhopadhyaya and Mondal (1981) found that nitrofen 2 kg per ha in granular form applied on the sixth day of transplanting rice in the Kharif season of 1979 gave the highest grain yield. Granular formulations of nitrofen 3 kg per ha broadcasted on the third day of transplanting, reduced weed population than hand weeding and gave higher paddy yield (Rao and Gupta, 1981).

Under semi-dry condition, Lakshmi (1983) observed that nitrofen at 1.875 kg a.i. per ha controlled monocot weed population throughout the crop growth and suppressed weed dry matter accumulation. Nitrofen also recorded a weed control efficiency of more than 76 percent.

ii. Butachlor.

Tosh (1975) reported that granular formulation of butachlor at the rate of 20 kg/ha controlled grasses effectively, but did not control sedges and broad leaved weeds. In transplanted heavy soils during Kharif 1975 Verma et al (1978) observed that butachlor 1.5 kg per ha gave selective control of grasses, sedges and broad leaved weeds and promoted grain yield.

Among the granular herbicides evaluated by Fareira and Ghosh (1980) in transplanted Kharif rice, butachlor 3 kg per ha was found to be the most effective treatment along with thiobencarb 3 kg per ha, both in terms of weed control and rice yield. Application of 1.5 kg butachlor a.i. per ha 2-3 days after transplanting four rice cultivars gave paddy yields similar to those obtained in weed free plots (Chela and Gill, 1981).

A comparative study conducted in rabi season of 1981 by Sathasivan et al (1981) to evaluate butachlor emulsion when applied as a spray or mixed with sand for control of weeds in transplanted rice, revealed that there was no difference in field performance and crop safety. Singh and Sharma (1981) recorded reduced weed dry matter production and also increased grain yield from 2137 kg to 3500 kg per ha due to butachlor EC and G application in transplanted rice. Shahi (1985) observed that butachlor (std. herbicide) had equivalent herbicidal effect to that of 1.5 kg thiobencarb and pendimethalin. Samar Singh et al (1986) observed that Machete increased grain yield by 68.51 percent compared to weedy check (2.35 t per ha), decreased weed infestation to 3 weeds per m^2 and in the second experimental year, yield was increased by 67.85 percent over the control.

iii. Thiobencarb.

Obien and Calora (1976) reported that thiobencarb at 1.50 kg per ha was effective against Echinochloa spp., Cyperus difformis and Sphenoclea zeylanica but ineffective against <u>Monochoria vaginalis</u>. Ravindran (1976) observed in a trial during the third crop season in which six herbicides were applied six days after transplanting rice as spray that, thiobencarb 2 kg per ha was the most effective one and gave highest yield. Yang et al (1980) reported that Saturn is the only herbicide which reduced the total amount of perennial weeds and controlled annuals in rice fields.

Application of 2-3 kg thiobencarb a.i. per ha, two to three days after transplanting four rice cultivars gave paddy yields similar to those obtained in weed free plots (Chela and Gill, 1981). De Datta (1981) reported that thiobencarb was highly effective against most annual grasses, sedges and broad leaved weeds for a longer period. Gill and Mehra (1981) observed that thiobencarb 1.5 to 3.0 kg per ha applied three to four days after transplanting rice increased yield components and yield. Under semi-dry condition, Lakshmi (1983) noted that thiobencarb 2.0 kg a.i. per ha controlled monocot weed population and suppressed weed dry matter accumulation throughout the crop growth period, Thiobencarb 2.0 kg per ha and 1.5 kg per ha recorded a Weed Control Efficiency of more than 76 percent and 66-70 percent respectively.

Dhananji Singh et al (1985) got yield comparable to hand weeding in transplanted rice by applying benthiocarb

1.5 kg old and new formulations. The effective control of Echinochloa crus-galli, E. colonum, Cyperus spp. and other weeds in transplanted rice was obtained by applying 1.5 kg thiobencarb per ha within 4 DAT and resulted in a higher yield (Shahi, 1985). Singh and Singh (1985) observed that Thiobencarb was most effective in controlling weeds than butachlor, basalin and two hand weedings. Patil et al (1986) reported that, application of 2.0 kg thiobencarb per ha two days after transplanting reduced weed dry weight at harvest from 58.2 to 0.2 g per m^2 and increased yield to 5.70 t per ha.

iv. Fluchloralin.

Pre-emergence application of fluchloralin at 0.75 kg per ha provided selective control of grasses, sedges and broad leaved weeds and promoted grain yield in heavy soils during Kharif 1975 and 1976 (Verma et al, 1978).

Kahlon and Mukand Singh (1978) observed 194 and 74 percent increased yield by the use of fluchloralin over weedy and weeded check respectively. Among the herbicides tested by Misra et al (1981), fluchloralin at 0.8 kg per ha applied as a soil spray before planting rice was most promising at all levels of water management. Granular herbicide formulation of fluchloralin at 2 kg per ha applied seven days after transplanting recorded yield which was on par with that of nitrofen and butachlor (Mukhopadhyay and Mondal, 1981).

Kondap et al (1982) revealed that Basalin 45 EC (fluchloralin) recorded the same level of yield and weed dry matter production as that of two hand weedings. Singh and Ghosh (1983) noted that total number of sedges as well as total number of weeds were significantly lower in plots treated with fluchloralin. Use of Basalin (fluchloralin) as a pre-emergence herbicide in transplanted rice was also suggested by Samar Singhet al (1986).

v. Pendimethalin.

Ravindran (1976) reported that penoxalin (pendimethalin) at 1.5 kg a.i. per ha on sixth day after transplanting brought down the weed growth and increased the yield; pendimethalin (G) gave the highest number of productive tillers per m^2 and panicle weight.

Balu and Sankaran (1977) recommended an economic dose of 1.5 kg pendimethalin per ha and they recorded maximum weed control and rice yield with pendimethalin applied six days after transplanting. But Abud (1978) advocated pendimethalin at 2.5 to 3.5 litres of the product per ha for rice. Moursi et al

(1978) detected the greatest reduction in fresh and dry weight of Cyperus difformis with stomp 33 EC at 2.5 litre per feddan (5.95 litres per ha) which was the most effective herbicide against Echinochloa colona and reduction in fresh weight of E. crus-galli was 80.9 percent with stomp at 1.0 litre per feddan (2.381 litres per ha). Stomp was less effective when applied as post-emergence than pre-emergence. Effective control of E. crus-galli, E. colonum, Cyperus spp. etc. was also obtained in trials conducted by Shahi (1985) in transplanted rice using 1.5 kg pendimethalin per ha.

The use of herbicides in rice have indicated that the yield recorded in many instances were better than or on par with hand weeding. Review further reveals that thiobencarb 1.5 to 2.0 kg a.i. per ha and butachlor 1.0 - 2.0 kg a.i. per ha can safely be used for transplanted rice for effective weed control and higher yield, closely followed by nitrofen 1.5 - 2.0 kg a.i. per ha, fluchloralin 0.75-1.50 kg a.i. per ha and pendimethalin 1.5 - 2.5 kg a.i. per ha.

3. Weed Management in Cropping Systems

The perennial sedge Scirpus maritimus persisted under continuous low land rice, but not Cyperus rotundus. Low land rice grown in rotation with upland crops given no weed control measures had fewer weeds than did continuous low land rice. This shows the advantages of planned crop rotations for reducing weeds and for reducing yield losses through weed competition (Datta and Jereza, 1976).

Moody (1977) while reviewing the crop sequences in rice fields, has cautioned the importance of weed management in cropping system.

At the International Rice Research Institute as a part of component technology development and evaluation of cropping systems, two trials were being evaluated for (a) hand weeding, (b) chemical weeding and (c) no weeding in continuous cropping of transplanted rice. Preliminary results show that rice grains were highest in 'a' followed by 'b' and least in 'c' (Anon, 1978).

Studies conducted by Bhandari and Moody (1981) on the weed communities of cropping systems, show that the weed community was less diverse in the herbicide treated plots and the number of weed species decreased significantly by the herbicide for a longer duration in transplanted, than in dry sown rice. Weed control practices applied to the dry sown crop reduced the total weed weight in the transplanted rice.

Repeated annual application of butachlor at 1.50 kg, thiobencarb + simetryne 2.55 kg, nitrofen 2.10 kg and 2, 4-D isopropyl 0.90 kg per ha four to six days after transplanting rice on loam soil to control annual weeds caused an increase in weed dry weight creating a predominance of the annual and perennial sedges. These species increased from 45 percent of the total weed population after the first years treatment to 69 percent after the fourth year and broad leaved weeds decreased from 45 percent to 10 percent over the same period (ANN et al, 1976).

In field trials conducted by Yang et al (1980), eight herbicides were applied annually to rice from 1972-77, plant height and number of culms per hill were a little higher in herbicide treatments than in hand weeded plots in the first year, but decreased slightly with each successive year of herbicide application and at ripening, herbicides decreased stem length, panicle length and number of panicles per hill. With six of the herbicides, yields in the sixth year were 17-45 percent lower than in the hand weeded control (6.04 t per ha), but yields with 20 kg saturn per ha applied 10 days after transplanting was similar to those of the hand weeded control.

Butachlor applied to the dry sown first crop in a rainfed cropping pattern in Bangladesh gave excellent weed control until 15 days after crop emergence. However there was a significant reduction in stand count of BR-6 rice and yield. Weed weights and counts taken at four weeks after transplanting show that butachlor had no residual effect on the weed growth of the second crop (Ahmed and Zahidul Hoque, 1981).

Bhargava et al (1982) conducted trials on cultural and chemical methods of controlling weeds in rice-rice and other crop rotations. Weed control treatments were applied only to the first crop of a rotation and their residual effect on the second crop were determined. In rice-rice rotation, 2 hand weedings or butachlor at 1.5 kg a.i. per ha applied 8 days after transplanting were effective against weeds and increased paddy yields.

The above review reveals that, though there is a decrease in weed count during second crop season especially certain species of weeds in herbicide treated plots, the residual effect is not sufficient to suppress the weed growth. In some cases, continuous application of herbicides was found to have adverse effect on the yield components compared to hand weeding. However, by planned crop rotation, weeds and crop loss can be reduced.

EFFECT OF HERBICIDES ON GROWTH, YIELD COMPONENTS, YIELD AND QUALITY OF RICE.

Among several granular herbicides tried, highest number of tillers, increased panicle number and maximum yield were recorded in the thiobencarb treated plots. Sridhar et al (1974) attributed this to the better weed control efficiency and least phytotoxicity of thiobencarb. Chang et al (1976) observed that grain yield was closely related to the number of panicles per m^2. They got highest grain yield by the application of 3.9 kg thiobencarb followed by 1.5 kg butachlor per ha.

Ravindran (1976) found that herbicide treatment influenced productive tillers per m^2, percentage of productive tillers, weight of panicle and percentage of filled grains. Thiobencarb EC 2 kg per ha recorded the highest grain yield (4191 kg per ha) and straw yield (4756 kg per ha) which were on par with penoxalin (G), hand weeding and butachlor (G). Penoxalin (G) treatment gave the highest grain protein of 7.97 percent. Atwell et al, (1978) reported increase in rice quality or grade through the elimination of weed seeds by the use of herbicides. Experiments at IRRI showed that thiobencarb 2.0 kg per ha recorded highest grain yield (Anon, 1979).

Application of 1.5 to 3.0 kg a.i. per ha of butachlor or thiobencarb three to four days after transplanting seedlings of five rice cultivars grown under almost weed free conditions in 1978-'79 increased yield components and paddy yields (Gill and Mehra, 1981). Experiments conducted by Lakshmi (1983) showed that thiobencarb 2.0 kg a.i. per ha and nitrofen 1.875 kg a.i. per ha favoured plant height, tiller number per m^2 and LAI as similar to complete weed free condition. Thiobencarb 2.0 kg a.i. per ha gave highest productive tillers per hill which was on par with weed free condition. Thiobencarb 2.0 kg, nitrofen 1.875 kg, and thiobencarb 1.5 kg a.i. per ha produced 14.8, 9.9 and 3.5 percent higher yields respectively than the local practice of hand weeding twice. She also recorded a better cost benefit ratio with herbicides than hand weeding twice.

The above review reveals that chemical weed control in general favoured vegetative characters like plant height, tiller number and panicle characters like length, weight and number of filled grains per panicle and ultimately increased yield over hand weeding and unweeded control. Among the chemicals reviewed thiobencarb 2.0 kg a.i. per ha ranks top in achieving maximum growth and yield of rice.

UPTAKE OF NUTRIENTS BY WEEDS AND CROPS

Sankaran et al (1974) reported that weeds in unweeded control removed 62.1, 20.0, and 65.3 kg N, P_2O_5 and K_2O per ha respectively in rice. Shetty and Gill (1974) revealed that the total uptake of nutrients by the crop and weed together in a weeded plot was less than the uptake of nutrients by the crop alone in the weed free treatments.

Ravindran (1976) found that unchecked weed growth depleted soil 'N' to 20.86 kg per ha while a single application of penoxalin (G) at 1.50 kg per ha brought down the uptake of 'N' by weeds to 0.96 kg per ha and considerably improved the uptake by the crop (99.95 kg N per ha) while unchecked weed growth resulted in an uptake of 65.54 kg N per ha by the crop. In the same station, Abraham Varughese (1978) observed that the nutrient removal in weedy check was 23.99, 7.92 and 30.48 kg per ha of N, P_2O_5 and K_2O by weeds and 57.54, 28.44 and 70.04 kg per ha of N, P_2O_5 and K_2O by the crop.

In weed free plots maximum uptake of nutrients by the crop recorded as 108.8 kg N, 67.4 kg P_2O_5 and 178.6 kg K_2O per ha and in unweeded control plots the values were 94.89 kg N, 61.91 kg P_2O_5 and 180.76 kg K_2O for crops + weeds; indicating an adverse effect of the crop weed competition on N and P uptake (Nanjappa and Krishnamurthy, 1980).

At Vellayani, Kerala again, maximum uptake of nutrients by crop was seen in plots kept weed free from 01-60 days after sowing (Sukumari, 1982). Under semi-dry conditions, nitrogen removed by weeds was lower in herbicide treated plots than in hand weeded ones and weeds competed with rice crop for nitrogen upto 60th day of dibling and in the case of phosphorus and potassium upto harvest (Lakshmi, 1983).

Under all conditions, the uptake of nutrients by the crop plants was highest in herbicide treated plots than the hand weeded plots. Quantity of nutrients absorbed by the crop in weed free plot exceeded the nutrients removed jointly by the crop and weed in weedy check. Thiobencarb caused an increase in the total dry matter production by improving growth components there by enabled the crop for better nutrient utilization.

HERBICIDE RESIDUE IN RICE FIELDS

Trials conducted at Taiwan revealed that, one application of herbicides such as butachlor, (MO-401) nitrofen and thiobencarb in rice does not have residues in amounts toxic to several upland crops that follow rice (Anon, 1973). Rangiah et al (1974) found that Machete (G) at 2.0-5.0 kg per ha applied 4 weeks after transplanting followed by one handweeding five weeks after planting provided effective weed control but the chemicals themselves lacked adequate residual activity against perennial weed growth.

Ravindran (1976) also found that herbicides (butachlor, thiobencarb and penoxalin) did not affect the germination of cowpea seeds in the experimental area sown immediately after the harvest. Application of butachlor at the rate of 1.00 kg a.i. per ha as pre-emergence herbicide to the transplanted rice left no residual effect on the succeeding crops of finger millet, black gram, cotton and sesamum (Mohamed Ali and Sankaran, 1979 and 1981).

Ahmed and Zahidul (1981) found that butachlor applied to the dry sown first crop rice had no residual effect on the weed growth of the second transplanted crop raised in sequence. Even application of butachlor at 4.00 kg per ha to rice had no residual toxicity on green gram in clay soil (Anon, 1984). Subramanian and Ali (1985) reported that application of 1.5 kg thiobencarb, 1.5 kg butachlor and 0.8 kg fluchloralin did not show any residual toxicity to the following crops such as cowpea and black gram.

MATERIALS AND METHODS

MATERIALS AND METHODS

A field experiment was undertaken to find out a suitable weed management technique for a rice based cropping system. The materials used and methods adopted are detailed below.

Materials

1. Experimental Site and Cropping History.

The experimental site having irrigation and drainage facilities was selected in blocks E4, E5 and E6 located on the western side of the Instructional Farm, College of Agriculture, Vellayani. The experimental field is situated at 8.5° N latitude and 76.9° E longitude and at an altitude of 29.5 m above MSL. The area was under a bulk crop of rice during the previous seasons.

2. Season.

The trial was conducted during the Virippu (first crop) and Mundakan (second crop) seasons and a germination test of cowpea crop during the Punja (third crop) season of 1984-85 (May to December 1984).

3. Weather conditions.

The experimental site enjoys a humid tropical weather condition. The meteorological parameters recorded were rainfall, maximum-minimum temperature and relative humidity. The weekly averages of all these parameters for the crop period, and the mean of the weekly averages for the past ten years are presented in Fig. 1 and Appendix 1.

4. Soil.

The texture of soil is sandy clay loam and acidic in nature. The physico-chemical composition of the soil is given below (Table 1).

Soil characteristics of the experimental field

A. Mechanical analysis		
1. Coarse sand	..	43.24 percent
2. Fine sand	..	18.26 percent
3. Silt	..	03.18 percent
4. Clay	..	32.20 percent
B. Chemical analysis		
1. Available nitrogen	..	311.0 kg per ha
2. Available P_2O_5	..	45.0 kg per ha
3. Available K_2O	..	57.0 kg per ha
4. pH	..	5.6
5. Organic matter content	..	3.1 per cent

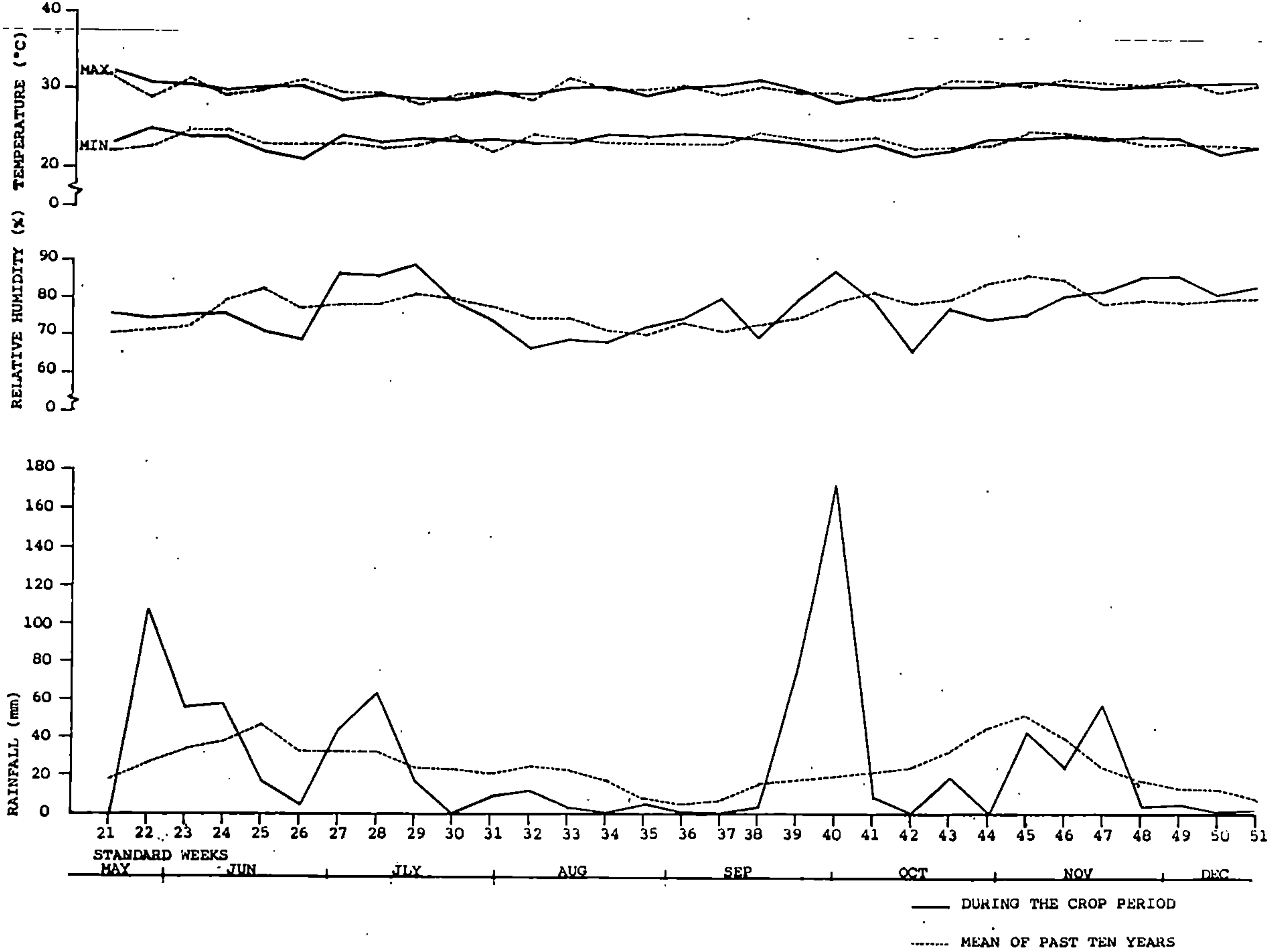


FIG.1 WEATHER CONDITIONS DURING THE CROP PERIOD (21-5-84 TO 23-12-84) AND THAT OF THE PAST 10 YEARS MEAN

5. Varieties.

The rice variety selected for the experiment was Triveni - the progeny of a cross between Annapurna and Ptb.15, released by Central Rice Research Station, Pattambi, Kerala. It is a short duration high yielding variety with moderate tillering habits and maturing in 95-105 days. It is widely cultivated in Kerala during all the three seasons. Rice seeds with 90 percent germination obtained from the Department of Agriculture, Kerala State was used for the experiment.

Cowpea seeds (C-152) having 95 percent germination supplied by National Seeds Corporation Ltd. was used for conducting the residual toxicity test (germination test) during the third crop season.

6. Manures and Fertilizers.

Cattle manure containing 0.4 percent N, 0.3 percent P_2O_5 and 0.2 percent K_2O was used for the experiment.

Urea analysing 46 percent N, super phosphate analysing 16 percent P_2O_5, muriate of potash analysing 60 percent K_2O and lime having a neutralising value of 165 were used for the experiment.

7. Herbicides.

i. Thiobencarb (Saturn 50 EC).

Saturn is a carbamate herbicide formulation containing 50 percent active ingredient-thiobencarb- [S-4 (Chloro benzyl) N, N-diethyl thiocarbamate]. It is a product of Kumiai Chemical Industry Company Limited, Tokyo-Japan, which is marketed by Pesticides India, Udaipur. This is highly selective between rice and barnyard grass and applied as pre-emergence herbicide. It is available in EC and G.

ii. Butachlor (Delchlor 50 EC).

Delchlor is a proprietory product of Coromandel Indag Products (P) Ltd., Madras. The product containing the active ingredient butachlor (2-Choro-2' 6' diethyl-N-Butoxy methyl acetanilide) is available in the form of 50 percent EC. It is a pre-emergence herbicide with good efficiency for controlling annual grasses and broad leaved weeds. It is applied as pre-emergence herbicide.

iii. Pendimethalin (Stomp 33 EC).

Stomp is a proprietory product of Cynamid India Limited Bombay. It contains the active ingredient pendimethalin

[N-(1-ethyl propyl)-2, 6-dinitro 3, 4-Xylidine] which is the present name of penoxalin. It is available in the form of EC and G. This is a pre-emergence herbicide used for selective weed control in rice. The weeds are controlled by inhibiting seedling development.

iv. Nitrofen (Tok E-25).

It is a phenyl ether compound used as a pre-emergence selective contact herbicide and it contains 25 percent active ingredient, nitrofen (2, 4-dichloro phenyl-P nitrophenyl ether). This is marketed by Indofil Chemicals Private Limited, Bombay. Nitrofen is available as EC and G.

v. Fluchloralin (Basalin).

Basalin is a product marketed by BASF-India Limited, Madras, containing 48 percent of the active ingredient fluchloralin [N-(2-Chloro ethyl) 2, 6 dinitro-N-Propyl-4-trifuoro methyl aniline]. It is a pre-emergence or pre-sowing herbicide used for selective control of annual grasses and broad leaved weeds. The susceptible weeds are affected during germination or seedling emergence.

8. <u>Sand</u>.

Clean dry river sand of 2.0 mm size was collected and used for preparing herbicide granules.

9. Wind screen.

A temporary wind screen made of cloth was utilised to prevent spray drift while spraying different herbicides in the experimental plots.

10. Observation frame.

An iron frame of 0.5 x 0.5 m was used for taking periodical weed counts.

METHODS

Experimental details

1. Design and Layout.

i. First crop-Rice (*Virippu*)

The experiment was laid out in simple Randomised Block Design with three replications. There were eight treatments. The layout plan is given in Fig. 2a and treatments are given below.

ii. Second crop-Rice (*Mundakan*)

In the second crop season, the experimental design was split plot with non-factorial structure in RBD using the first crop season layout. Total number of treatments were 18 and replication three. The layout plan is given in Fig. 2b and treatments are given below.

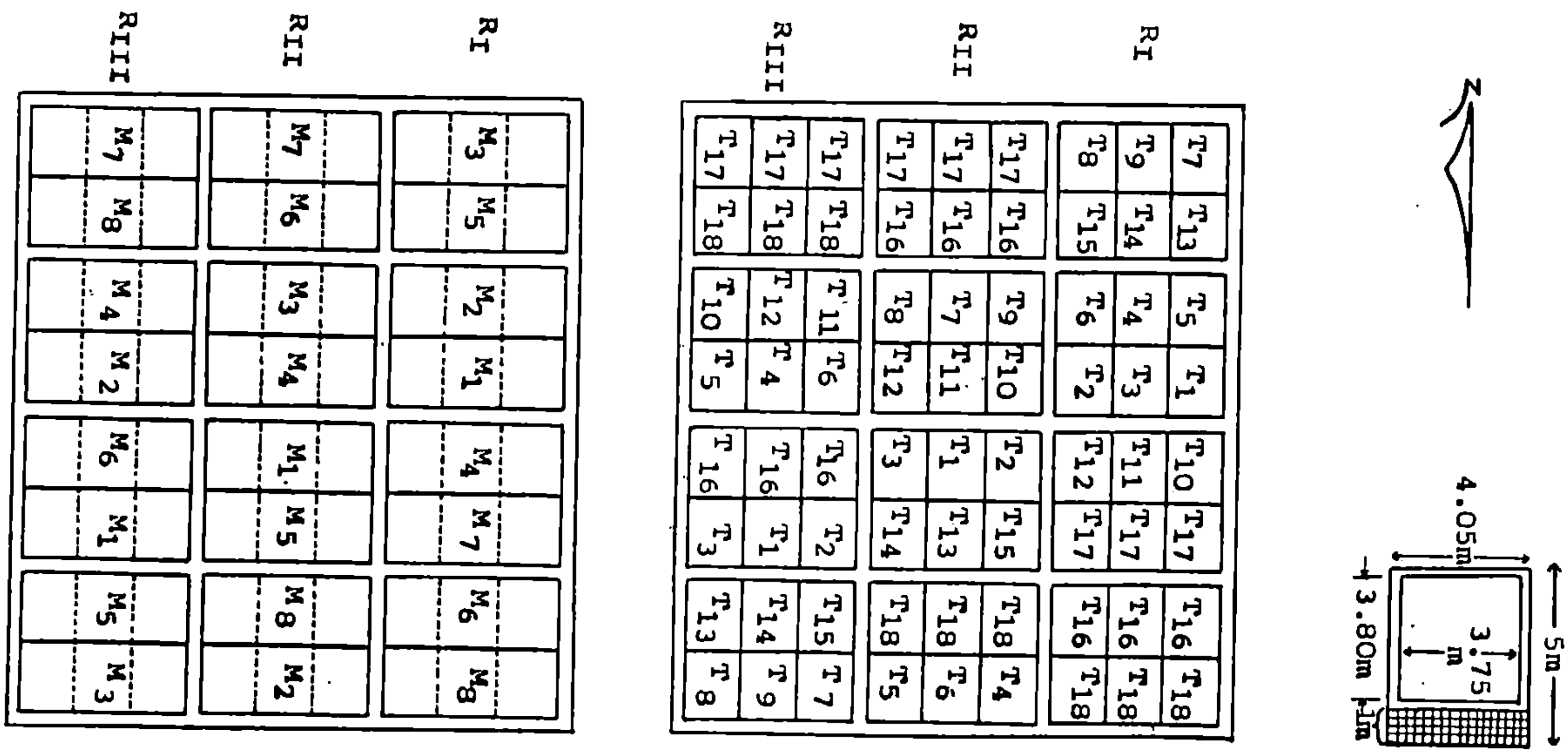
TREATMENTS

First crop

M_1 - Thiobencarb 1.5 kg a.i./ha
M_2 - Butachlor 1.0 kg a.i./ha
M_3 - Pendimethalin 1.0 kg a.i./ha
M_4 - Nitrofen 1.875 kg a.i./ha
M_5 - Fluchloralin 1.0 kg a.i./ha
M_6 - Hand weeding
M_7 - Completely weed free
M_8 - Weedy check

Second crop

T_1 - Thiobencarb-no weeding
T_2 - Thiobencarb-hand weeding
T_3 - Thiobencarb-thiobencarb 1.5 kg a.i./ha
T_4 - Butachlor-no weeding
T_5 - Butachlor-hand weeding
T_6 - Butachlor-butachlor 1.0 kg a.i./ha
T_7 - Pendimethalin-no weeding
T_8 - Pendimethalin-hand weeding
T_9 - Pendimethalin-pendimethalin 1.0 kg a.i./ha
T_{10} - Nitrofen-no weeding
T_{11} - Nitrofen-hand weeding
T_{12} - Nitrofen-nitrofen 1.875 kg a.i./ha
T_{13} - Fluchloralin-no weeding
T_{14} - Fluchloralin-hand weeding
T_{15} - Fluchloralin-fluchloralin 1.0 kg a.i./ha
T_{16} - Hand weeding-hand weeding
T_{17} - Weed free-weed free
T_{18} - Weedy check-weedy check



a. LAY OUT PLAN OF FIRST CROP
(RBD)

b. LAY OUT PLAN OF SECOND CROP
(SPLIT PLOT WITH
NON-FACTORIAL STRUCTURE)

c. LAY OUT OF A
SINGLE PLOT

WEED OBSERVATION AREA

NET PLOT

FIG.2 LAY OUT PLAN OF THE EXPERIMENT

2. Treatments.

		Virippu		Mundakan
M_1	a.	Thiobencarb(1.5 kg a.i./ha)	-	T_1 No weeding
	b.	-do-	-	T_2 Hand weeding
	c.	-do-	-	T_3 Thiobencarb(1.5 kg a.i./ha)
M_2	a.	Butachlor(1.0 kg a.i./ha)	-	T_4 No weeding
	b.	-do-	-	T_5 Hand weeding
	c.	-do-	-	T_6 Butachlor(1.0 kg a.i./ha)
M_3	a.	Pendimethalin(1.0 kg a.i./ha)	-	T_7 No weeding
	b.	-do-	-	T_8 Hand weeding
	c.	-do-	-	T_9 Pendimethalin(1.0 kg a.i./ha)
M_4	a.	Nitrofen(1.875 kg a.i./ha)	-	T_{10} No weeding
	b.	-do-	-	T_{11} Hand weeding
	c.	-do-	-	T_{12} Nitrofen(1.875 kg a.i./ha)
M_5	a.	Fluchloralin(1.0 kg a.i./ha)	-	T_{13} No weeding
	b.	-do-	-	T_{14} Hand weeding
	c.	-do-	-	T_{15} Fluchloralin(1.0 kg a.i./ha)
M_6	a.	Hand weeding	-	T_{16} Hand weeding
	b.	-do-	-	-do-
	c.	-do-	-	-do-
M_7	a.	Completely weed free	-	T_{17} Completely weed free
	b.	-do-	-	-do-
	c.	-do-	-	-do-
M_8	a.	Weedy check	-	T_{18} Weedy check
	b.	-do-	-	-do-
	c.	-do-	-	-do-

Individual gross plot size = 4.05 x 5.00 m
Weed observation area = 4.05 x 1.00 m
Net plot = 3.75 x 3.80 m
(Two rows allround were left as border rows)

In order to give the same herbicide in three plots each during the first crop season, three adjacent plots of size 4.05 x 5.00 m were grouped together and applied the same treatment. So although there are 24 plots in a block, only 8 treatments are applied during first crop season.

During the second crop season, three adjacent plots (previously grouped and received same treatment) are taken as three independent plots and alloted three treatments each viz. (i) No weeding, (ii) hand weeding and (iii) same level of same herbicide. The last three groups of plots of first crop season ie. hand weeding, completely weed free and unweeded control were maintained as such in second crop season also.

All the treatments were alloted randomly.

3. <u>Standardisation of sprayer</u>.

A hand sprayer of 1.5 litre capacity was used for spraying herbicides. The discharge rate of the nozzle was tested and walking time was adjusted so as to apply one litre spray solution per 20.25 m^2. All the herbicides at the prescribed doses were applied at the rate of one litre spray solution per plot.

4. Herbicide application.

The herbicides dose and pre-emergence application of herbicides on the 6th DT were fixed based on the findings of earlier workers. Considering the availability of the herbicides in the market and variation observed in its herbicidal action, both fluchloralin and pendimethalin were included under the treatments.

In Kerala, major area of the first crop is dibbled or broadcasted where as during second crop season, it is transplanted. So herbicides were sprayed during first crop season and it is applied as granules during second crop season.

To compare the effect of weed management with herbicides and complete removal of weeds, the treatment "completely weed free" is also included. As cowpea is widely cultivated during the third crop season, it is taken as test crop for residual toxicity study.

During the first crop season, all the herbicides were applied as spray on the sixth day of transplanting, after draining the plots uniformly. The herbicide solution was applied as a blanket spray in the respective plots in the early hours of the day to prevent spray drift. Further, wind screen was used to prevent any possible wind drift during spraying.

During second crop season, all the herbicides were applied in granular form on the sixth day of transplanting. Since all herbicides are not available in granular form and those available are in different concentrations, two percent granules of all herbicides were formulated in the laboratory and used for the experiment. For this clean dry river sand of 2.0 mm size was mixed with individual herbicides as shown in Table 2, so as to get two percent granules. EC forms of herbicides and sand were mixed thoroughly using hand gloves and kept for 24 hours for drying in the laboratory.

Table 2

Table showing details of preparation of 2% granular herbicide for the second crop

Active ingrediant	Qty. of Commercial product (ml)	Qty. of Active ingrediant (g)	Qty. of sand	Total qty. of Two percent granules per plot (g)
Thiobencarb (50 EC)	6.00	3.00	147.00	150.00
Butachlor (50 EC)	4.00	2.00	98.00	100.00
Pendimethalin (33 EC)	6.00	2.00	98.00	100.00
Nitrofen (25 EC)	15.00	3.75	183.75	187.50
Fluchloralin (48 EC)	4.20	2.00	98.00	100.00

Note: The commercial products were accurately measured with graduated pipette and vaquopet.

Then applied uniformly by hand protected with rubber gloves in individual plots after maintaining a very thin film of standing water.

5. Weeding operations.

For the hand weeding treatment, weeds were pulled out manually on the 20th day of transplanting (20th DT) and 40th day of transplanting (40th DT).

In order to maintain the completely weed free condition in plots of treatment number M_7 during first crop season and treatment number T_{17} during second crop season, regular hand weedings were done as and when the weeds appeared.

Details of cultivation

All the cultural practices except weed management were carried out as per the package of practices (1982) recommended by the Kerala Agricultural University.

1. Nursery.

The nursery to get sufficient number of rice seedlings was raised under wet system.

2. Main field.

The experimental area was initially ploughed with bullocks.

Plots of 4.05 x 5.00 m size were laid out with 24 plots in each block. The plots and blocks were separated with bunds of 30 and 60 cm width respectively. Irrigation and drainage channels were provided for all plots. The plots were dug twice, puddled and levelled individually.

Cattle manure at the rate of 5 t per ha and lime at the rate of 360 kg per ha were applied uniformly to all plots, at the time of first digging.

Fertilizers were applied in split doses so as to get 70 kg N, 35 kg P_2O_5 and 35 kg K_2O per ha. Fifty percent N, full P_2O_5 and 50 percent K_2O were applied as basal dose just before planting and the balance 50 percent N and 50 percent K_2O were applied as top dressing at panicle initiation stage.

Eighteen day old seedlings were transplanted at a spacing of 15 x 10 cm and at the rate of two seedlings per hill.

Date of sowing, transplanting and harvesting are furnished below.

	First crop	Second crop
Sowing in the nursery	25-5-84	1-9-84
Transplanting	12-6-84	19-9-84
Harvest	6-9-84	8-12-84
Total duration	104 days	98 days

3. Plant protection.

Three prophylactic sprayings with (i) Nuvacron 40 EC at the rate of 600 ml per ha at tillering stage (ii) Sevin 50 WP at the rate of 2.5 kg per ha at flowering and (iii) Sevin 50 WP at the rate of 2.5 kg per ha at milk stages were given for both the rice crops. There was no serious attack of pests and diseases. General stand of the crop was good.

4. Water management.

The water level was maintained at about 1.5 cm during transplanting. There after it was gradually increased to about five cm upto 10 days prior to harvesting, after which the plots were completely drained.

5. Harvesting.

All the border rows and plants left in the weed observation area were harvested first. Then the net plots were harvested individually, bundled and numbered and taken for post harvest operations.

6. Herbicide residual toxicity study.

To find out the residual toxicity of the herbicides applied during first and second crop seasons, an area of one sq.m. in the middle of each plot was prepared after the harvest of second crop of rice, for sowing cowpea seeds. Rhizobium treated 100 seeds of cowpea cv C-152 were uniformly sown in each of the treatment plots on 15-12-84 and germination was assessed on 10th day of sowing and recorded.

OBSERVATIONS

An area of 4.05 x 1.00 m was set apart on the same side of each plot for periodical weed observations. Biometric observations and yield were recorded from the remaining area of 4.05 x 4.00 m discarding two border rows allround.

Observation on Weeds

1. Weed species.

The weeds collected from the experimental site before the experiment and during the experiment were identified and grouped into grasses, sedges and broad leaved weeds.

Even though weed species identified were grouped into grasses, sedges and broad leaved weeds, while counting them at periodical observations, they were grouped into monocots and dicots. This has become necessary because at the time of counting and weed removal it has become difficult to differentiate grass and sedge seedlings due to their very small size.

2. Weed population.

Weeds were collected from an area of one m^2 from the weed observation area on the 20th DT and 40th DT and at harvest. They were pulled out, washed and identified; grouped into monocots and dicots and counted separately. Weed population was expressed as number of monocot, dicot and total weeds per m^2.

3. Dry weight of weeds.

The weeds taken as mentioned above were first sun-dried and later oven-dried at 70°C till it recorded constant weight. The dry weight of total weeds were recorded on the 20th DT and 40th DT and at harvest and expressed in g per m^2.

4. Weed control efficiency.

Weed control efficiency was calculated by using the following formula

$$WCE = \frac{x-y}{x} \times 100$$

x = Weed count from the unweeded control plot or treatment which recorded maximum number of weeds.

y = Weed count from the treatment for which weed control efficiency is to be worked out.

Observation on Crop

1. <u>Crop growth characters</u>.

For periodical observations, three sampling units of two hills x two hills were randomly selected in each plot (Gomez, 1972) and the following observations were recorded.

i. Height of the plant.

Plant height in cm was recorded on the 20th DT and 40th DT and at harvest from one hill per sampling unit. Height was measured from the base of the plant to the tip of the longest leaf or to the tip of the longest earhead whichever was taller (Gomez, 1972).

ii. Number of tillers per m^2.

Tillers on all the four hills of each sampling unit were counted at maximum tillering stage and the number of tillers per m^2 was worked out.

iii. Leaf Area Index.

Leaf Area Index (LAI) was computed at the flowering stage as suggested by Gomez (1972).

Ten sample hills (at random) were selected from each plot and the tiller number of each sample hill was counted. Maximum width and length of each leaf of the middle tiller were measured and computed the area of each leaf based on the length-width-factor method. LAI was computed as shown below.

Value of adjustment factor used is K = 0.67 on the 20th day of transplanting and at harvest and 0.75 on the 40th day of transplanting.

$$LAI = \frac{\text{Sum of leaf area per hill of six sample hills}(cm^2)}{\text{Area of land covered by six hills }(cm^2)}$$

2. <u>Yield components.</u>

i. Panicle number per m^2.

At harvest, productive tillers from the three sampling units (12 hills) were counted and number of productive tillers per m^2 worked out.

ii. Length of the panicle.

Length of the main culm panicles of all hills in a sampling unit were measured and mean worked out and expressed in cm.

iii. Weight of the panicle.

All the panicles in the sampling unit were weighed and computed as weight per panicle.

iv. Number of filled grains per panicle.

The main culm panicles from all the 12 hills were separated based on height, threshed and the number of filled grains (f), the number of unfilled grains (u) and the weight of filled grains (w) were determined.

The rest of the panicles from all the 12 hills were threshed and the number of unfilled grains (u) and the weight of filled grains (W) assessed.

From this data, the number of filled grains per panicle was calculated using the formula given below (Gomez, 1972).

$$\text{Number of filled grains per panicle} = \frac{f}{w} \times \frac{W + w}{P}$$

where P is the total number of panicles from all the 12 hills.

v. Thousand grain weight.

From the values obtained for calculating the number of filled grains per panicle, thousand grain weight was calculated and adjusted to 14 percent moisture using the following formula given by Gomez (1972).

$$\text{Thousand grain weight} = \frac{100-M}{86} \times \frac{W}{f} \times 1000$$

where M is the moisture content of filled grains.

3. <u>Yield</u>.

i. Grain yield.

Dry weight of grain was recorded from the net harvested area after cleaning and drying and the weight adjusted to 14 percent moisture and expressed as yield in kg per hectare.

ii. Straw yield.

The straw harvested from the net plot was cleaned by separating weeds, uniformly dried in sunlight, weighed and expressed as yield in kg per hectare.

iii. Crop dry matter production.

Dry matter production of the crop was estimated at harvest. The sum total of grain and straw yield on oven dry basis was taken and expressed in kg per hectare.

iv. Total grain yield of first and second crops.

Total grain yield obtained from the experimental plots during the first and second crop seasons were added together and statistically analysed.

4. Weed Index.

Weed Index was computed by following the formula suggested by Gill and Vijayakumar (1969).

$$WI = \frac{x-y}{x} \times 100$$

where WI = Weed Index

x = Yield from weed free plot or the treatment which recorded minimum weeds.

y = Yield from the treatment for which weed index is to be worked out.

5. Economics of weed management.

Cost of different herbicides, cost of its application and expenditure incured in hand weeding were worked out. Calculated the increased yield obtained due to different treatments and the income obtained based on market price of the produce and herbicides and local labour charges. From this, net income obtained by different weed management techniques were computed.

6. Germination of cowpea seeds.

Germination of cowpea seeds sown as reported earlier was assessed on the 10th day of sowing and expressed as percentage.

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CHEMICAL ANALYSIS

A. Plant analysis

The total nitrogen, phosphorus and potassium content of the weed samples collected on the 20th DT, 40th DT and at harvest were estimated. Nutrients removed by the weeds at these stages were estimated separately and expressed in kg per hectare.

Four rice hills from the weed observation area of each treatment plot were carefully pulled out at random on the 20th DT, 40th DT and at harvest and washed to remove the adhering soil particles. Then dried first in sunlight and later in the hot air over at 70°C till it recorded constant dry weight.

This was used for estimating the total nitrogen, phosphorus and potassium uptake of the crop and expressed in kg per hectare.

1. Total Nitrogen.

Total nitrogen content was estimated by Microkjeldahl digestion method (Jackson, 1967).

2. Total phosphorus.

Total phosphorus content was estimated colorimetrically by Vanadomolybdo phosphoric acid yellow colour method after triple acid extraction. The colour was read in a Klett summerson photo-electric colorimeter at 470 nm (Jackson, 1967).

3. Total potassium.

Total potassium content of the samples were estimated by Flame photometric method after triple acid digestion with EEL Flame photometer (Jackson, 1967).

4. Protein content of grains.

Protein content of grains was computed by multiplying the N content of whole grain by the factor 6.25 (Simpson et al, 1965).

B. Soil analysis

Composite soil samples collected prior to the commencement of the experiment were analysed to determine the physical and chemical composition and they are given in Table 1.

1. Mechanical analysis.

Percentage of coarse sand, fine sand, silt and clay were determined by International Pipette method based on stoke's law.

2. Chemical analysis.

Available nitrogen, available phosphorus and available potassium were estimated and expressed in kg per hectare.

i. Available nitrogen.

It was determined by the Alkaline permanganate method of Subbiah and Asija (1956).

ii. Available phosphorus.

Available phosphorus in the soil sample was estimated by Bray's method (Jackson, 1967).

iii. Available potassium.

Available potassium was estimated by the ammonium acetate method (Jackson, 1967).

iv. pH of the soil.

pH of the soil (1:2.5 soil solution) was estimated using a digital pH meter.

STATISTICAL ANALYSIS

ANOVA technique was used to analyse the data on all characters under study. The data on variables which do not follow the basic assumptions of ANOVA were transformed to suitable forms before the statistical analysis.

The data on all characters under study of the first crop were analysed as that of a simple Randomised Block Design. The data on all characters of the second crop were analysed as that of a split plot with non-factorial structure (Federer, 1955).

The ANOVA of the second crop experiment with p = 8 (main plots), q = 3 (sub plots) and r = 3 (replications) is given below.

Source		df
Total	-	pqr-1 = 71
Replication	-	r-1 = 2
Main plot	-	p-1 = 7
Error (1)	-	(r-1)(p-1) = 14
Between treatments within main plot 1		= q-1 = 2
Between treatments within main plot 2		= q-1 = 2
Between treatments within main plot 3		= q-1 = 2
Between treatments within main plot 4		= q-1 = 2
Between treatments within main plot 5		= q-1 = 2
Between control treatments within main plot 6, 7 and 8 (Others)		= 3x2 = 6
Error (2)	-	p (r-1)(q-1) = 32

CD for comparison between the main plot treatments $= t_{14}\sqrt{\frac{2\ MSE_1}{r \times q}}$

CD for comparison between the sub plot treatments $= t_{32}\sqrt{\frac{2\ MSE_2}{r}}$

CD for comparison of sub plot treatments with control $= t_{32}\sqrt{MSE_2\ (1/3 + 1/9)}$

RESULTS

RESULTS

During the first and second crop seasons, the experiments were conducted with different statistical designs. Hence the results and discussion are presented separately.

FIRST CROP SEASON (VIRIPPU)

Observation on Weeds

1. Weed species.

Weeds were collected from the experimental plots before and during the experimentation. Weed species were identified and grouped into grasses, sedges and broad leaved weeds and presented in Table 3. The predominant weeds were *Brachiaria ramosa*, *Echinochloa colona*, *E. crus-galli*, *Cyperus iria*, *Fimbristylis miliacea*, *Ludwigia parviflora*, *Marsilia quadrifoliata* and *Monochoria vaginalis*.

2. Weed population.

Weed observations were taken on the 20th day of transplanting (20th DT) and 40th day of transplanting (40th DT) before hand weeding the plots. M_7 plot was kept weed free through out the period by removing weeds as and when appeared. Since weed count in M_7 was always zero, it is not mentioned separately. Herbicides were applied on the sixth day of transplanting.

Table 3

List of weeds found in the experimental field

No.	Scientific name	Family	
A.	Grasses		
1.	Brachiaria ramosa (Griseb) Stapf	Gramineae (Poaceae)	p
2.	Dactyloctenium aegypti um (L) Beauv	-do-	
3.	Echinochloa colona (L) Link	-do-	a
4.	Echinochloa crus-galli (L) Beauv	-do-	a
5.	Ischaemum rugosum Salish	-do-	a
6.	Oryza sativa var. fatua (L)	-do-	a
7.	Panicum repens (L)	-do-	p
B.	Sedges		
1.	Cyperus difformis (L)	Cyperaceae	a
2.	Cyperus iria (L)	-do-	a
3.	Cyperus rotundus (L)	-do-	p
4.	Fimbristylis miliaceae (L) Vahl	-do-	a
5.	Scirpus articulatus (L)	-do-	p
C.	Broad leaved weeds		
1.	Alternanthera sessilis (L) R.Br. Roth	Amaranthaceae	a
2.	Ammania multiflora (L)	Lythraceae	a
3.	Ludwigia parviflora (L) Roxb	Onagraceae	a
4.	Limnophila heterophylla Benth	Scrophulariaceae	
5.	Marsilia quadrifoliata (L)	Marsileaceae	p
6.	Monochoria vaginalis (Burm.f) Presl	Pontederiaceae	a

a = annual
p = perennial

Monocot, dicot and total weed population were taken from a sampling area of 0.5 m^2 and converted to weed count per square metre and analysed after $\sqrt{x + 1}$ transformation. Mean values of weed count are presented in Table 4.

A. Monocot weeds

i. 20th day of transplanting.

The data presented in Table 4 show that the lowest weed count was in M_4 which was on par with M_1 followed by M_2 which in turn was on par with M_3 and M_5. Highest weed count was in M_6 which was on par with M_8; but both were significantly inferior to all other treatments.

ii. 40th day of transplanting

The lowest weed population was observed in M_4 which was on par with M_1, M_2, M_6 and M_3. M_3 inturn was on par with M_5. The highest weed population was observed in M_8 which was also on par with M_5.

iii. At harvest

M_4 continued to record the lowest weed count and it was on par with M_1, M_6, M_2, M_3 and M_5. M_8 which recorded the highest weed count was significantly inferior to all other treatments.

Table 4

Weed population per m^2 - stage wise - first crop

Group	Treatments	20th DT		40th DT		Ar harvest	
a. Monocot weeds	M_1	31.26	(5.68)	178.56	(13.40)	200.64	(14.20)
	M_2	77.68	(8.87)	222.50	(14.95)	267.96	(16.40)
	M_3	103.04	(10.20)	259.18	(16.13)	312.64	(17.71)
	M_4	19.43	(4.52)	117.16	(10.87)	194.44	(13.98)
	M_5	113.49	(10.70)	341.62	(18.51)	382.38	(19.58)
	M_6	203.20	(14.29)	229.74	(15.19)	228.52	(15.15)
	M_7	0	(1.00)	0	(1.00)	0	(1.00)
	M_8	198.09	(14.11)	529.38	(23.03)	555.49	(23.59)
	$F_{7, 14}$	29.49**		9.30**		5.19**	
	CD	2.610		6.579		6.534	
	SE	0.86		2.17		2.15	
b. Dicot weeds	M_1	13.62	(3.69)	25.52	(5.15)	21.09	(4.70)
	M_2	19.10	(4.37)	24.40	(5.04)	20.90	(4.68)
	M_3	18.45	(4.41)	21.85	(4.78)	22.62	(4.86)
	M_4	9.89	(3.30)	22.52	(4.85)	21.94	(4.79)
	M_5	16.64	(4.20)	24.60	(4.96)	21.28	(4.72)
	M_6	35.00	(6.00)	28.92	(5.47)	26.56	(5.25)
	M_7	0	(1.00)	0	(1.00)	0.	(1.00)
	M_8	35.48	(6.04)	62.84	(7.99)	42.03	(6.56)
	$F_{7, 14}$	4.85**		6.41**		4.01*	
	CD	2.028		2.344		2.462	
	SE	0.67		0.77		0.81	
c. Total weeds	M_1	44.02	(6.71)	218.04	(14.80)	236.16	(15.40)
	M_2	100.20	(10.06)	259.82	(16.15)	299.33	(17.33)
	M_3	114.56	(10.75)	294.15	(17.18)	347.94	(18.68)
	M_4	29.91	(5.56)	142.52	(11.98)	220.41	(14.88)
	M_5	130.79	(11.48)	372.26	(19.32)	413.72	(20.34)
	M_6	236.16	(15.40)	259.82	(16.15)	246.43	(15.73)
	M_7	0	(1.00)	0.	(1.00)	0	(1.00)
	M_8	230.65	(15.22)	591.43	(24.34)	598.27	(24.48)
	$F_{7, 14}$	35.07**		11.23**		10.48**	
	CD	2.523		6.318		6.397	
	SE	0.83		2.08		2.11	

Note: Figures in paranthesis are the $\sqrt{x + 1}$ transformed figures.
** significant at 0.01 level

B. Dicot weeds

i. 20th day of transplanting

M_4 recorded the lowest weed count and was on par with all other herbicidal treatments. M_8 which recorded the highest weed count was on par with M_6 and both were significantly inferior to all herbicide treatments.

ii. 40th day of transplanting

The lowest weed population was observed in M_3 which was on par with M_4, M_5, M_2, M_1 and M_6. M_8 which recorded the highest weed population, was significantly inferior to all other treatments.

iii. At harvest

M_2 recorded the lowest weed count which was on par with all other treatments and M_8 recorded the highest weed count.

C. Total weeds

i. 20th day of transplanting

The lowest weed count was observed in M_4 which was on par with M_1 and both were significantly superior to other treatments, while M_2 was on par with M_3 and M_5. The highest weed population recorded by M_6 was on par with M_8 and both were significantly inferior to all other treatments.

ii. 40th day of transplanting

M_4 which recorded the lowest weed count was on par with M_1, M_2, M_6 and M_3. The highest weed count recorded by M_8 was significantly inferior to all other treatments.

iii. At harvest

M_4 continued to record the lowest weed population which was on par with all other treatments except M_8 which recorded the highest weed population.

3. <u>Dry matter production by weeds</u>

Mean values of dry matter of weeds at different stages are presented in Table 5.

i. 20th day of transplanting

The data presented in Table 5 show that the lowest weed dry matter production recorded in M_4, was on par with M_1 and M_2 and M_2 in turn was on par with M_3 and M_5. Highest DM was found in M_6 which was on par with M_8 and both were significantly inferior to all other treatments.

ii. 40th day of transplanting

The lowest weed dry weight was recorded in M_6 which was on par with M_4, M_1 and M_2, while M_1 and M_2 in turn were on par with M_3 and M_5. The highest weed dry weight was recorded in M_8 and was significantly inferior to all other treatments.

Table 5

Dry matter production of weeds (g/m^2)-first crop

Treatments	20th DT	40th DT	At harvest
M_1	8.03	20.42	43.03
M_2	13.27	24.40	44.67
M_3	17.27	25.60	52.00
M_4	7.18	17.32	42.83
M_5	19.38	31.58	72.00
M_6	32.67	11.60	42.73
M_7	0	0	0
M_8	31.33	61.43	105.17
$F_{7, 14}$	14.46**	16.85**	18.62**
CD	9.195	13.243	20.939
SE	3.03	4.37	6.90

**Significant at 0.01 level.

iii. At harvest

M_6 produced the lowest weed dry matter and it was on par with M_4, M_1, M_2 and M_3; M_3 in turn was on par with M_5. All the treatments were significantly superior to M_8 which recorded the highest weed dry matter.

4. Weed Control Efficiency.

As the total weed population was highest in M_8 through out the crop period, it was taken as the base for calculating WCE and the calculated values are presented in Table 6.

i. 20th day of transplanting

The highest WCE was obtained from M_4 closely followed by M_1. Next in order were M_2, M_3 and M_5 and M_6 recorded a negative value.

ii. 40th day of transplanting

M_4 recorded the highest WCE followed in order by M_1, M_2, M_6, M_3 and M_5.

iii. At harvest

M_4 continued to record the highest WCE followed by M_1, M_6, M_2, M_3 and M_5.

Table 6

Weed Control Efficiency - first crop

Treatments	Weed Control Efficiency		At harvest
	20th DT	40th DT	
M_1	81	63	61
M_2	57	56	50
M_3	50	50	42
M_4	87	76	63
M_5	43	37	31
M_6	2	56	59

5. Nutrient removal by weeds.

Mean values are presented in Table 7. In the case of M_7 (weed free plot), the observations on weeds were recorded as zero and as such it was not mentioned separately.

A. Nitrogen.

i. 20th day of transplanting

The weeds in M_4 removed the lowest quantity of nitrogen which was on par with M_1 and M_2 and was superior to other treatments. It was followed by M_3 which was on par with M_5. M_6 removed the highest nitrogen content which was on par with M_8 and both were significantly inferior to all other treatments.

ii. 40th day of transplanting

The lowest nitrogen removal was recorded by M_6 which was on par with M_4, M_1 and M_2 while M_1 and M_2 were on par with M_3 and M_5. The highest nitrogen removal was recorded by M_8 which was significantly inferior to all other treatments.

iii. At harvest

Though the weeds in M_6 removed least nitrogen, it was on par with M_4, M_1, M_2 and M_3 and M_3 in turn was on par with M_5. M_8 was significantly inferior to all other treatments.

B. Phosphorus.

i. 20th day of transplanting

Phosphorus removal was the lowest in M_4 which was on par

Table 7

Nutrient removal by weeds (kg/ha) - first crop

Nutrient	Treatments	20th DT	40th DT	At harvest
a. Nitrogen	M_1	1.76	4.29	8.18
	M_2	2.92	5.12	8.49
	M_3	3.80	5.38	9.88
	M_4	1.58	3.64	8.14
	M_5	4.26	6.63	13.68
	M_6	7.19	2.44	8.12
	M_7	0	0	0
	M_8	6.89	12.90	19.98
	$F_{7, 14}$	14.49**	16.86**	15.01**
	CD	2.022	2.780	3.991
	SE	0.67	0.92	1.32
b. Phosphorus	M_1	0.62	1.57	3.31
	M_2	1.18	1.88	3.44
	M_3	1.33	1.97	4.00
	M_4	0.55	1.33	3.30
	M_5	1.49	2.43	5.54
	M_6	2.52	0.89	3.29
	M_7	0	0	0
	M_8	2.41	4.73	7.86
	$F_{7, 14}$	13.58**	16.85**	14.25**
	CD	0.728	1.020	1.611
	SE	0.24	0.34	0.53
c. Potassium	M_1	1.21	2.84	5.16
	M_2	2.05	3.49	5.49
	M_3	2.73	3.74	6.50
	M_4	1.07	2.44	5.14
	M_5	3.06	4.58	9.07
	M_6	5.36	1.65	5.04
	M_7	0	0	0
	M_8	5.23	9.34	13.46
	$F_{7,14}$	15.49**	18.79**	20.46**
	CD	1.488	1.917	2.378
	SE	0.49	0.63	0.78

**Significant at 0.01 level.

with M_1 and M_2 and, M_2 in turn was on par with M_3 and M_5. The highest phosphorus removal was observed in M_6 which was on par with M_8 and both were significantly inferior to all other treatments.

ii. 40th day of transplanting

M_6 recorded the lowest phosphorus removal which was on par with M_4, M_1 and M_2; M_1 and M_2 were on par with M_3 and M_5. M_8 recorded the highest phosphorus removal and was significantly inferior to all other treatments.

iii. At harvest

Phosphorus removal was the lowest in M_6 which was on par with M_4, M_1, M_2 and M_3 and, M_3 in turn was on par with M_5. M_8 recorded the highest phosphorus removal and was significantly inferior to all other treatments.

C. Potassium.

i. 20th day of transplanting

Weeds in M_4 removed the lowest quantity of potassium which was on par with M_1 and M_2, and M_2 in turn was on par with M_3 and M_5. The highest potassium removal was in M_6 which was on par with M_8 and both were significantly inferior to all other treatments.

ii. 40th day of transplanting

M_6 recorded the lowest potassium removal which was on par with M_4, M_1 and M_2. M_1 and M_2 in turn were on par with M_3 and M_5. The highest potassium removal was recorded by M_8 which was significantly inferior to all other treatments.

iii. At harvest

Weeds in M_6 removed the lowest quantity of potassium which was on par with M_4, M_1, M_2 and M_3, and M_3 in turn was on par with M_5. All other treatments were significantly superior to M_8 which recorded highest potassium removal.

Observation on Crop

1. <u>Crop growth characters</u>

A. Height of Plants

Mean values are presented in Table 8.

i. 20th day of transplanting

The tallest plants were recorded in M_7 which was significantly superior to all other treatments. Next ranked treatment was M_1 which was on par with M_5, M_2 and M_3. The plant height was the lowest in M_4 which was on par with M_6, M_8, M_3, M_2 and M_5.

ii. 40th day of transplanting

M_7 produced the highest plant height which was on par with M_1, M_4, M_2 and M_6. It was followed by M_3 which was on par with M_5. M_8 was significantly inferior to all other treatments.

iii. At harvest

M_7 continued to record the highest plant height which was significantly superior to all other treatments also. It was followed by M_1 which was on par with M_6, M_4 and M_2. The next in the order were M_3 and M_5 which were on par. The plant height was the lowest in M_8 which was significantly inferior to all other treatments.

Table 8

Crop growth characters - first crop

Treatments	Height of plants (cm)			Tiller number per m^2	LAI
	20th DT	40th DT	At harvest		
M_1	35.04	63.01	74.22	460.70	4.16
M_2	33.31	60.31	72.12	459.70	3.95
M_3	33.09	57.03	66.49	430.20	3.58
M_4	31.78	60.56	72.85	461.90	4.24
M_5	33.38	56.03	65.50	438.53	3.70
M_6	32.56	60.29	73.62	464.43	4.27
M_7	37.10	63.12	80.00	476.60	4.32
M_8	32.78	47.92	61.11	401.33	3.36
$F_{7, 14}$	11.16**	26.59**	35.06**	4.44**	26.27**
CD	2.139	2.921	3.065	34.884	0.214
SE	0.70	0.96	1.02	11.50	0.07

**Significant at 0.01 level.

B. Tiller number per m^2.

Mean values are presented in Table 8.

The largest number of tillers was recorded in M_7 which was on par with M_6, M_4, M_1 and M_2 where as M_6, M_4, M_1 and M_2 were on par with M_5 and M_3. The lowest number of tillers was produced by M_8 which was on par with M_3.

C. Leaf Area Index.

The LAI was calculated at the flowering stage and the data analysed. Mean values are presented in Table 8.

The highest LAI was observed in M_7 which was on par with M_6, M_4 and M_1, and M_1 in turn was on par with M_2 followed by M_5 and M_3. M_8 which recorded the lowest LAI was significantly inferior to all other treatments.

2. <u>Yield components</u>.

The data on yield components viz. Panicle number per m^2, length of panicle, weight of panicle and thousand grain weight were analysed and mean values are presented in Table 9.

A. Panicle number per m^2.

The highest number of panicles was produced by M_7 which was superior to all other treatments. It was followed by M_6 which was on par with M_4 and M_1. The next in order were M_2 and M_5; M_5 was on par with M_3. M_8 was significantly inferior to all other treatments.

Table 9

Yield components - first crop

Treatments	No. of panicles per m^2	Length of panicle (cm)	Weight of panicle (g)	No. of filled grains per panicle	Thousand grain weight (g)
M_1	371.63	20.12	1.79	51.09	23.15
M_2	357.73	18.43	1.73	45.70	23.25
M_3	339.23	19.28	1.61	38.58	23.79
M_4	374.90	19.90	1.85	57.40	22.92
M_5	342.00	16.88	1.58	39.18	23.37
M_6	378.90	19.03	1.71	47.86	23.06
M_7	406.53	22.10	2.01	59.20	23.15
M_8	277.67	13.87	1.35	26.64	23.25
$F_{7, 14}$	248.84**	22.50**	8.92**	44.79**	N.S
CD	7.375	1.570	0.201	4.874	-
SE	2.43	0.52	0.07	1.61	-

**Significant at 0.01 level.

N.S - Not significant.

B. Length of panicle

M_7 produced the longest panicle and was significantly superior to all other treatments. M_7 was followed by M_1, which was on par with M_4, M_3 and M_6. The shortest panicle was produced by M_8 which was significantly inferior to all other treatments. M_2 and M_5 were ranked in between M_6 and M_8.

C. Weight of panicle

The heaviest panicle was produced by M_7 which was on par with M_4. M_4 in turn was on par with M_1, M_2 and M_6, while M_2 and M_6 were on par with M_3 and M_5. The lowest panicle weight was recorded by M_8 which was significantly inferior to all other treatments.

D. Number of filled grains per panicle

The number of filled grains was highest in M_7 which was on par with M_4 and both were significantly superior to all other treatments. It was followed by M_1 which was on par with M_6 and M_6 in turn was on par with M_2. M_2 was followed by M_5 which was on par with M_3. M_8 was significantly inferior to all other treatments.

E. Thousand grain weight

There was no significant difference among the treatments for this character.

3. Grain yield, straw yield, Crop dry matter production and Protein content.

A. Grain yield.

The highest grain yield was obtained from M_7 which was significantly superior to all other treatments (Table 10). The next highest yield was obtained from M_4 which was on par with M_1, M_6 and M_2. The next in order were M_5 and M_3 and they were on par. The lowest yield was obtained from M_8 which was significantly inferior to all other treatments.

B. Straw yield.

The highest straw yield was obtained from M_7 which was significantly superior to all other treatments (Table 10). It was followed by M_6 which was on par with M_1, M_4 and M_2. The next in order was M_5 which was on par with M_3. M_8 was significantly inferior to all other treatments.

C. Crop dry matter production.

M_7 recorded the highest crop dry matter production and was significantly superior to all other treatments (Table 10). The next in order was M_6, which was on par with M_4, M_1 and M_2. The lowest crop dry matter production was in M_8 which was significantly inferior to all other treatments.

D. Protein content of grains.

Although there were no significant difference among the treatments, M_8 recorded the lowest protein content (Table 10).

Table 10

Grain yield, straw yield, crop dry matter and protein content of grains - first crop

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Total dry matter (kg/ha)	Protein content of grains (%)
M_1	3764	3998	7195	8.36
M_2	3687	3857	6990	8.21
M_3	3315	3539	6355	8.18
M_4	3790	3986	7206	8.33
M_5	3382	3544	6617	8.18
M_6	3759	4022	7214	8.24
M_7	3954	4204	7563	8.44
M_8	2360	2576	4580	8.01
$F_{7, 14}$	127**	76**	98**	N.S
CD	136.6	178.6	287.4	-
SE	45	59	95	-

**Significant at 0.01 level.

N.S - Not significant.

4. Weed Index.

Weed Index is the reduction in yield due to the presence of weeds in comparison with the plots having minimum weeds.

M_7 was taken as the base for the calculation of Weed Index as it recorded the highest grain yield. Weed indices calculated are presented in Table 11.

The lowest Weed Index was worked out in M_4 closely followed by M_1 and M_6. The next in order were M_2, M_5 and M_3 and, M_8 recorded the highest Weed Index.

5. Nutrient uptake by the Crop

Mean values of NPK uptake by the crop are presented in Table 12.

A. Nitrogen.

i. 20th day of transplanting

The data presented in Table 11 show that the highest nitrogen uptake was in M_7 which was on par with M_1 and M_1 in turn was on par with M_2 while M_2 was on par with M_4, M_3 and M_5. M_8 recorded the lowest nitrogen uptake which was on par with M_6 and M_5.

ii. 40th day of transplanting

The nitrogen uptake was the highest in M_7 and was

Table 11 - Weed Index

Treatments	Weed Index
M_1	4.81
M_2	6.75
M_3	16.16
M_4	4.15
M_5	14.52
M_6	4.93
M_7	-
M_8	40.31

Table 12

Nutrient uptake by the crop (kg/ha) - first crop

Nutrient	Treatments	20th DT	40th DT	At harvest
a. Nitrogen	M_1	48.45	72.77	86.25
	M_2	44.56	67.29	82.80
	M_3	42.08	54.99	72.94
	M_4	43.55	71.56	87.21
	M_5	41.21	56.01	73.80
	M_6	37.67	67.86	84.93
	M_7	50.68	78.86	92.80
	M_8	37.22	47.90	48.24
	$F_{7,\ 14}$	12.51**	29.77**	141.12**
	CD	4.063	5.873	3.570
	SE	1.34	1.94	1.18
b. Phosphorus	M_1	18.61	29.82	30.58
	M_2	16.49	27.58	29.04
	M_3	15.69	20.23	23.16
	M_4	17.67	29.56	31.37
	M_5	15.30	21.47	23.91
	M_6	14.07	26.72	28.79
	M_7	19.32	32.87	34.16
	M_8	13.73	17.69	18.34
	$F_{7,\ 14}$	14.07**	46.90**	34.03**
	CD	1.624	2.367	2.698
	SE	0.53	0.78	0.89
c. Potassium	M_1	33.18	45.65	48.65
	M_2	29.56	43.36	45.62
	M_3	28.57	35.72	37.17
	M_4	29.56	44.76	48.07
	M_5	27.74	36.25	38.02
	M_6	24.80	43.35	45.20
	M_7	34.25	50.27	52.59
	M_8	24.44	28.02	32.52
	$F_{7,\ 14}$	14.87**	140.08**	30.83**
	CD	2.755	1.817	3.620
	SE	0.91	0.60	1.19

**Significant at 0.01 level.

significantly superior to all other treatments. M_7 was followed by M_1 which was on par with M_4, M_6 and M_2. The next in order were M_5 and M_3 which were on par. M_8 was significantly inferior to all other treatments.

iii. At harvest

M_7 continued to record the highest nitrogen uptake and was superior to all other treatments. It was followed by M_4 which was on par with M_1 and M_6; M_1 and M_6 in turn were on par with M_2. The next in order was M_5 which was on par with M_3. M_8 was significantly inferior to all other treatments.

B. Phosphorus.

i. 20th day of transplanting

The phosphorus uptake was the highest in M_7 which was on par with M_1 where as M_1 was on par with M_4 and M_4 in turn was on par with M_2. M_2 was also on par with M_3 and M_5. Phosphorus uptake was the lowest in M_8 which was on par with M_6 and both were significantly inferior to all other treatments.

ii. 40th day of transplanting

The highest phosphorus uptake was observed in M_7 which was significantly superior to all other treatments. It was followed by M_1 which was on par with M_4 and M_2 while M_2 in turn was on par with M_6. Next in order was M_5 which was on par with M_3. M_8 was significantly inferior to all other treatments.

iii. At harvest

M_7 continued to record the highest phosphorus uptake and was significantly superior to all other treatments. It was followed by M_4 which was on par with M_1, M_2 and M_6. Next in order was M_5 which was on par with M_3. M_8 was significantly inferior to all other treatments.

C. Potassium.

i. 20th day of transplanting

The highest potassium uptake was observed in M_7 which was on par with M_1 and both were significantly superior to all other treatments. They were followed by M_2 which was on par with M_4, M_3 and M_5. The lowest potassium uptake was observed in M_8 which was on par with M_6 and both were significantly inferior to all other treatments.

ii. 40th day of transplanting

M_7 with the highest potassium uptake was significantly superior to all other treatments. Next in order was M_1 which was on par with M_4 while M_4 was on par with M_2 and M_6.

It was followed by M_5 which was on par with M_3. M_8 was significantly inferior to all other treatments.

iii. At harvest

M_7 continued to record the highest potassium uptake, and was significantly superior to all other treatments. It was followed by M_1 which was on par with M_4, M_2 and M_6. Next in order was M_5 which was on par with M_3. M_8 was significantly inferior to all other treatments.

6. <u>Economics of weed management</u>.

Mean values are presented in Table 13.

M_1 recorded the highest net profit which was on par with M_2 and M_4, and was superior to other treatments. Next ranked treatment M_6 was on par with M_5 and was followed by M_3. M_7 recorded a negative value and was inferior to all other treatments.

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Table 13

Economics of weed management - first crop

Treatments	Increased yield over weedy check (kg/ha)		Monetary value of increased yield (Rs/ha)	Total cost of weed control operation (Rs/ha)	Net Return (Rs/ha)	
	Grain	Straw				
M_1	1404	1422	3570	496	3074	(4074)
M_2	1327	1281	3286	376	2910	(3910)
M_3	955	963	2513	460	1933	(2933)
M_4	1430	1410	3558	791	2770	(3770)
M_5	1022	968	2517	424	2093	(3093)
M_6	1399	1446	3530	1188	2342	(3342)
M_7	1593	1628	4007	4554	-547	(453)
					$F_{6, 12}$	145**
					CD	316
					SE	104

**Significant at 0.01 level.

Figures in paranthesis are the "x + 1000" transformed values.

SECOND CROP (MUNDAKAN)

During the first crop season, main plots were treated with five herbicides (M_1, M_2, M_3, M_4 and M_5) hand weeding (M_6), completely weed free (M_7) and weedy check (M_8).

During the second crop season, each herbicide treated main plot was divided in to three sub plots in which one sub plot each was kept unweeded (T_1, T_4, T_7, T_{10} and T_{13}), one hand weeded (T_2, T_5, T_8, T_{11} and T_{14}) and the third was treated with the same herbicide (T_3, T_6, T_9, T_{12} and T_{15}). The hand weeded, complete weed free and weedy check main plots were also divided in to three sub plots each but the same treatments were repeated (T_{16}, T_{17} and T_{18} respectively).

Hand weeding was given on the 20th DT and 40th DT to those plots which were allotted for the same. Weed observations in these plots were taken before hand weeding. In the case of completely weed free plot, weed observations were recorded as zero and so it was not mentioned separately in the results and discussion given below.

Data recorded during the second crop season were statistically analysed as a split plot experiment with non-factorial structure. So the main plot effect is not considered here for results and discussion.

In the presentation of the results, the following comparisons were made and their notations (a to i) are followed as such.

a. Comparison among the sub plot treatments within each main plot of first crop. (CD_2)

b. Comparison of herbicides with hand weeding (T_{16}) and weed free (T_{17}) of both the seasons. (CD_3)

c. Comparison of weeded sub plot treatments in second crop season with hand weeding (T_{16}) and weed free (T_{17}) of both the seasons. (CD_3)

d. Comparison of unweeded sub plot treatments with hand weeding (T_{16}) and weed free (T_{17}) of both the seasons. (CD_3)

e. Comparison of unweeded sub plot treatments in second crop season with continuous weedy check (T_{18}). (CD_3)

f. Comparison among the continuous herbicide sub plot treatments. (CD_2)

g. Comparison among the herbicide-hand weeding sub plot treatments. (CD_2)

h. Comparison among the herbicide-unweeded sub plot treatments. (CD_2)

i. Comparison among all the 18 sub plot treatments. (CD_3)

Examples of notation used in presenting the treatments for interpreting the results of second crop season are shown below.

herbicide treated sub plots	-	means sub plots which received herbicides during both the seasons.
hand weeded sub plots	-	means sub plots which received herbicides during the first crop followed by hand weeding twice during the second crop.
Unweeded sub plots	-	means sub plot which received herbicides during the first crop season followed by no weeding during second crop.
Thiobencarb-thiobencarb	-	means sub plots in which thiobencarb was applied in both the seasons.
Thiobencarb-hand weeding	-	means thiobencarb applied in the first crop season followed by hand weeding in the second crop.
Thiobencarb-no weeding	-	means thiobencarb applied in the first crop season followed by no weeding in the second crop.

Hand weeding-hand weeding - means hand weeding twice in the first crop followed by hand weeding twice in the second crop.

Weed free plot - means completely weed free during both the seasons.

Weedy check - means continuously unweeded plot during both the seasons.

Unlike other biometric observations, in the case of observation on weeds, treatments which recorded low values of weed number, weed dry weight and low nutrient removal were reckoned as significantly superior ones (treatment).

Observation on Weeds

1. <u>Weed species</u>.

Weeds were collected from the experimental plots. Weed species were identified and grouped in to grasses, sedges and broad leaved weeds. They were same as that observed during the first crop season and presented in Table 3.

2. <u>Weed population</u>.

A. Monocot weeds.

Mean values are presented in Table 14 and analysis of variance in Appendix II.

Table 14

Monocot weed population per m^2 - Second crop

Treatments	20th DT		40th DT		At harvest	
T_1	79.28	(8.96)	323.00	(18.00)	357.34	(18.93)
T_2	86.61	(9.36)	123.10	(11.14)	142.09	(11.92)
T_3	24.20	(5.02)	130.79	(11.48)	176.96	(13.34)
T_4	91.16	(9.60)	339.03	(18.44)	372.26	(19.32)
T_5	88.87	(9.48)	136.83	(11.74)	163.10	(12.81)
T_6	35.12	(6.01)	146.87	(12.16)	192.77	(13.92)
T_7	95.84	(9.79)	352.82	(18.81)	394.21	(19.88)
T_8	99.60	(10.03)	133.40	(11.55)	179.36	(13.43)
T_9	44.16	(6.72)	154.75	(12.48)	208.09	(14.46)
T_{10}	100.61	(10.08)	332.79	(18.27)	371.10	(19.29)
T_{11}	102.43	(10.17)	124.66	(11.21)	157.51	(12.59)
T_{12}	25.32	(5.13)	123.55	(11.16)	171.92	(13.15)
T_{13}	101.62	(10.13)	349.06	(18.71)	378.08	(19.47)
T_{14}	83.64	(9.20)	135.89	(11.70)	173.77	(13.22)
T_{15}	41.12	(6.49)	157.26	(12.58)	204.35	(14.33)
CD_2		0.409		0.371		1.692
T_{16}	88.49	(9.46)	158.26	(12.62)	170.30	(13.05)
T_{17}	0	(1.00)	0	(1.00)	0	(1.00)
T_{18}	119.78	(10.90)	381.59	(19.56)	431.11	(20.79)
CD_3		0.334		0.303		1.382
SE		0.12		0.11		0.48

Figures in paranthesis are the $\sqrt{x + 1}$ transformed values.

i. 20th day of transplanting

a. All the herbicide treated sub plots were superior to the respective hand weeded and unweeded sub plots where as all hand weeded sub plots were on par with the respective unweeded sub plots.

b. All the herbicide treated sub plots recorded significantly lesser number of weeds than T_{16}.

c. Compared to T_{16}, treatments T_{14}, T_2 and T_5 were on par and, T_8 and T_{11} inferior.

d. T_1 was superior, T_4 and T_7 on par and, T_{10} and T_{13} were inferior to T_{16}.

e. All unweeded sub plots were superior to T_{18}.

f. Among the herbicide treated sub plots, T_3 and T_{12} were on par and superior to other herbicides. T_6 was superior to T_{15} and T_9 which were on par.

g. T_2 recorded less weed count which was on par with T_5 and superior to other hand weeded sub plots. Weed count recorded by T_{14} was on par with T_8 and T_{11}.

h. T_1 was significantly superior to all other unweeded sub plots followed by T_4 which was on par with T_7. T_{13} recorded higher number of weeds which was on par with T_{10}.

i. Among all the sub plots, T_3 recorded the lowest number of monocot weeds. This was on par with T_{12} and superior to all other sub plot treatments. T_{18} recorded the highest number of monocot weeds.

ii. 40th day of transplanting

a. T_2 and T_3 and, T_{11} and T_{12} were on par; T_5, T_8 and T_{14} were superior to T_6, T_9 and T_{15} respectively. All these herbicide treated and hand weeded sub plots were superior to the respective unweeded sub plots.

b. T_{12}, T_3 and T_6 were superior to T_{16} and, T_9 and T_{15} were on par with T_{16}.

c. All hand weeded sub plots were superior to T_{16}.

d. All unweeded sub plots were inferior to T_{16}.

e. All unweeded sub plots were superior to weedy check.

f. T_{12} ranked first which was on par with T_3, followed by T_6 and T_9. T_{15} recorded highest number of weeds.

g. Weed count was the lowest in T_2 and was on par with T_{11}; T_{11} in turn being on par with T_8. T_8 was on par with T_{14} and T_5.

h. T_1 was superior to T_4, T_{13} and T_7 and was on par with T_{10}. T_{10} was on par with T_4 which in turn was statistically equal to T_{13} and T_7.

i. T_2 recorded the lowest weed population among all the sub plots and it was on par with T_{12}, T_{11} and T_{13}. The highest weed count was observed in the weedy check.

iii. At harvest

a. All herbicide treated sub plots were on par with the respective hand weeded sub plots and both were superior to unweeded sub plots.

b. All herbicide treated plots except T_9 was on par with T_{16} where as T_9 was inferior to T_{16}.

c. There was no significant difference between hand weeded sub plots and T_{16}.

d. All unweeded sub plots were inferior to T_{16}.

e. Among the unweeded sub plots, T_1, T_{10} and T_4 were superior to T_{18} and, T_7 and T_{13} were on par with T_{18}.

f. Even though T_{12} ranked first, all the herbicide treated sub plots were on par with each other.

g. T_2 recorded lowest weed count and it was on par with all other hand weeded sub plots.

h. Though lowest number of weeds was observed in T_1, it was on par with all other unweeded sub plots.

i. Among all the sub plots, lowest weed count was recorded in T_2 which was on par with T_{11}, T_5, T_{12} and T_{14}, and highest weed number was in T_{18}.

B. Dicot weeds.

Mean values are presented in Table 15 and analysis of variance in Appendix II.

i. 20th day of transplanting

a. All the herbicide treated sub plots were statistically superior to the respective hand weeded and unweeded sub plots.

b. T_{12} recorded lowest number of weeds and all herbicide treated sub plots were superior to T_{16}.

c. T_{14}, T_2 and T_5 were superior to T_{16} and, T_8 and T_{11} were on par with T_{16}.

d. Among the unweeded sub plots, T_1 and T_{10} were superior to T_{16} while T_4, T_7 and T_{13} were on par with T_{16}.

e. T_1 and T_{10} were superior to T_{18} and, T_4, T_7 and T_{13} were on par with T_{18}.

f. There was no significant difference between the herbicide treated sub plots.

g. T_{14} was on par with T_2 and T_5 but superior to T_8 and T_{11}.

h. Lowest weed count was in T_1 which was on par with T_{10} and T_4 while T_4, T_7 and T_{13} were on par with each other.

i. Among all the treatments T_{12} produced lowest weed number which was on par with T_3, T_{15}, T_9 and T_6.

Table 15

Dicot weed population per m^2 - second crop

Treatments	20th DT		40th DT		At harvest	
T_1	7.41	(2.90)	60.31	(7.83)	54.20	(7.43)
T_2	7.29	(2.88)	13.29	(3.78)	19.34	(4.51)
T_3	3.28	(2.07)	11.97	(3.46)	13.29	(3.78)
T_4	10.63	(3.41)	67.06	(8.25)	58.91	(7.74)
T_5	8.24	(3.04)	10.97	(3.46)	13.90	(3.86)
T_6	4.24	(2.29)	6.90	(2.81)	8.00	(3.00)
T_7	11.39	(3.52)	65.26	(8.14)	58.29	(7.70)
T_8	9.89	(3.30)	16.64	(4.20)	18.98	(4.47)
T_9	4.67	(2.16)	6.62	(2.76)	7.29	(2.88)
T_{10}	8.24	(3.04)	60.94	(7.87)	52.29	(7.30)
T_{11}	10.09	(3.33)	10.56	(3.40)	14.52	(3.94)
T_{12}	2.31	(1.82)	5.60	(2.57)	8.00	(3.00)
T_{13}	12.18	(3.63)	65.91	(8.18)	58.60	(7.72)
T_{14}	6.08	(2.66)	7.29	(2.88)	13.82	(3.85)
T_{15}	3.58	(2.14)	6.62	(2.76)	8.00	(3.00)
CD_2		0.581		0.451		0.482
T_{16}	12.40	(3.66)	8.00	(3.00)	12.18	(3.63)
T_{17}	0	(1.00)	0	(1.00)	0	(1.00)
T_{18}	13.67	(3.83)	68.56	(8.34)	47.30	(6.95)
CD_3		0.475		0.368		0.393
SE		0.16		0.13		0.14

Figures in paranthesis are the $\sqrt{x + 1}$ transformed values.

ii. 40th day of transplanting

a. T_2 and T_3 and, T_{14} and T_{15} were on par; T_6, T_9 and T_{12} were superior over T_5, T_8 and T_{11} respectively and all these treatments were superior to the respective unweeded sub plots.

b. Compared to T_{16}, treatment T_{12} was superior, T_6, T_9 and T_{15} were on par and T_3 inferior.

c. T_{11} and T_{14} were on par with T_{16} while T_2, T_5 and T_8 were inferior to T_{16}.

d. All unweeded sub plots were statistically inferior to T_{16}.

e. T_1 and T_{10} were superior and, T_4, T_7 and T_{13} were on par with T_{18}.

f. Lowest weed count was recorded in T_{12} which was on par with T_6, T_9 and T_{15} while T_3 was inferior to T_{12}.

g. Among the hand weeded sub plots lowest weed count was in T_{14} which was superior to other hand weeded sub plots. Next in order was T_{11} which was on par with T_5 and T_2, and the highest weed number was observed in T_8.

h. Eventhough T_1 recorded the lowest weed count, it was on par with all other unweeded sub plots.

i. Among all the sub plot treatments, T_{12} continued to produce less number of dicot weeds and was on par with T_9, T_{15}, T_6 and T_{14} and greatest number of weeds was counted in T_{18}.

iii. At harvest

a. All the herbicide treated sub plots were superior over the respective handweeded sub plots and both were in turn superior to the unweeded sub plots.

b. All herbicide treated sub plots except T_3 were superior to T_{16} while T_3 was on par with T_{16}.

c. Among hand weeded sub plots, T_5, T_{11} and T_{14} were on par with T_{16} and, T_2 and T_8 were inferior to T_{16}.

d. All the unweeded sub plots were significantly inferior to T_{16}.

e. Among unweeded sub plots T_{10} was on par with T_{18} and, T_1, T_7, T_{13} and T_4 were inferior to it.

f. There was no significant difference among the herbicide treated sub plots except T_3 which recorded highest weed count.

g. T_{14} recorded less number of dicot weeds and it was on par with T_5 and T_{11} followed by T_8 and T_2.

h. There was no significant difference among the unweeded sub plots.

i. Lowest dicot weed population was observed in T_9 compared to all other sub plots and it was statistically equal to T_6, T_{12} and T_{15}. The highest dicot weed population was found in T_4.

C. Total weeds.

Mean values are presented in Table 16 and analysis of variance in Appendix II.

i. 20th day of transplanting

a. All herbicide treated sub plots were statistically superior to the respective hand weeded and unweeded sub plots.

b. All the herbicide treated sub plots were superior to T_{16}.

c. Compared to hand weeding-hand weeding, T_{14} and T_2 were superior, T_5 on par and, T_8 and T_{11} were inferior.

d. Among the unweeded sub plots, T_1 was superior, T_4 and T_7 were on par and T_{10} and T_{13} were inferior to T_{16}.

e. All unweeded sub plots were superior to weedy check (T_{18}).

f. T_3 recorded the lowest number of weeds which was on par with T_{12} followed by T_6, T_{15} and T_9.

g. T_{14} ranked first and T_{11} last. T_{14} and T_2, T_2 and T_5 and, T_8 and T_{11} were on par respectively.

h. T_1 was superior to the other unweeded sub plots followed by T_4 which was on par with T_7. Next in order were T_{10} and T_{13}.

i. T_3 and T_{12} recorded the lowest number of weeds and were superior to other treatments. T_{18} recorded the highest number of weeds.

Table 16

Total weed population per m^2 - second crop

Treatments	20th DT		40th DT		At harvest	
T_1	86.80	(9.37)	376.52	(19.43)	411.50	(20.31)
T_2	93.93	(9.74)	136.59	(11.73)	160.54	(12.71)
T_3	27.52	(5.34)	141.80	(11.95)	154.75	(12.48)
T_4	101.82	(10.14)	405.83	(20.17)	431.22	(20.79)
T_5	97.21	(9.91)	147.84	(12.20)	177.22	(13.35)
T_6	39.45	(6.36)	153.75	(12.44)	200.64	(14.20)
T_7	106.54	(10.37)	418.84	(20.49)	452.26	(21.29)
T_8	109.46	(10.51)	149.06	(12.25)	198.37	(14.12)
T_9	47.86	(6.99)	161.56	(12.75)	215.38	(14.71)
T_{10}	109.04	(10.49)	393.82	(19.87)	423.36	(20.60)
T_{11}	113.28	(10.69)	135.19	(11.67)	172.19	(13.16)
T_{12}	27.62	(5.35)	129.19	(11.41)	179.90	(13.45)
T_{13}	113.92	(10.72)	414.75	(20.39)	437.06	(20.93)
T_{14}	88.87	(9.48)	143.24	(12.01)	188.06	(13.75)
T_{15}	44.70	(6.76)	163.87	(12.84)	229.74	(15.19)
CD_2		0.378		0.269		1.490
T_{16}	101.13	(10.11)	162.84	(12.80)	181.52	(13.51)
T_{17}	0	(1.00)	0	(1.00)	0	(1.00)
T_{18}	133.68	(11.60)	450.14	(21.24)	478.61	(21.90)
CD_3		0.309		0.220		1.221
SE		0.11		0.08		0.42

Figures in paranthesis are the $\sqrt{x + 1}$ transformed values.

ii. 40th day of transplanting

a. T_2 and T_3 were on par and superior to T_1; T_5 and T_6 were on par and superior to T_4; T_8 was superior to T_9 and both were superior to T_7; T_{11} and T_{12} were on par and were superior to T_{10}; T_{14} was superior to T_{15} and both were superior to T_{13}.

b. T_3, T_6 and T_{12} were superior and, T_9 and T_{15} were on par with T_{16}.

c. All the hand weeded sub plots were superior to T_{16}.

d. All unweeded sub plots were significantly inferior to T_{16}.

e. All unweeded sub plots were statistically superior to weedy check (T_{18}).

f. Among the herbicide sub plots, lowest weed count was observed in T_{12} and it was superior to the other herbicidal treatments.

g. T_{11} recorded lesser weed count among hand weeded sub plots which was on par with T_2 and superior to T_{13}, T_5 and T_8.

h. T_1 was superior to other unweeded sub plots. Next in order were T_{10}, T_4, T_{13} and T_7.

i. Among all the sub plots, lowest weed count in T_{12} was superior to all other treatments. Next in order was T_{11} which was on par with T_2. Highest number of total weeds was found in T_{18}.

iii. At harvest

a. No statistical difference in weed count was observed among the respective hand weeded and herbicide treated sub plots; however the counts were significantly less compared to the respective unweeded sub plots.

b. All herbicide treated sub plots except T_{15} were on par with hand weeding-hand weeding (T_{16}) while the former was inferior to T_{16}.

c. There was no significant difference in the weed count of hand weeded sub plots compared to T_{16}.

d. All unweeded sub plots were significantly inferior to T_{16}.

e. T_1 and T_{10} were superior and T_4, T_7 and T_{13} were on par with weedy check.

f. Among the herbicide treated sub plots, low weed count was in T_3 which was on par with T_{12} and superior to the other treatments.

g. Eventhough T_2 recorded the lowest weed count, it was on par with all other hand weeded sub plots.

h. Similarly, total number of weeds was less in T_1 and it was on par with all the other unweeded sub plots.

i. Among all the sub plots, thiobencarb-thiobencarb recorded the lowest number of weeds which was on par with T_2, T_{11}, T_5, T_{12} and T_{16}. Weedy check recorded the highest number of total weeds.

3. Dry matter production by weeds.

Mean values are presented in Table 17 and analysis of variance in Appendix III.

i. 20th day of transplanting

a. All the herbicide treated sub plots produced significantly less DM than the respective hand weeded and unweeded sub plots.

b. Significantly less DM was observed in all the herbicide treated sub plots compared to hand weeding-handweeding (T_{16}).

c. T_2, T_5 and T_{11} were superior and T_8 and T_{14} were on par with T_{16}.

d. Compared to T_{16}, treatment T_1 and T_{10} were superior and, T_4, T_7 and T_{13} were on par.

e. Dry matter production of weeds was significantly less in all the unweeded sub plots than the weedy check.

f. The lowest DM was in T_{12} which was on par with T_3, T_6 and T_9, and the highest DM was in T_{15}.

g. T_2 recorded the lowest DM and was superior to all other hand weeded treatments. It was followed by T_{11}, which was on par with T_5 and, T_5 in turn was on par with T_{14} and T_8.

h. The lowest DM was in T_1 which was superior to the other unweeded sub plots. T_{10}, T_4 and T_{13} were on par and superior to T_7.

i. Among all the sub plots DM of weeds was the lowest in nitrofen-nitrofen which was on par with T_3, T_6 and T_9. The highest DM was recorded in weedy check.

Table 17

Dry matter production of weeds (g/m^2) - Second crop

Treatments	20th DT	40th DT	At harvest
T_1	7.27	40.88	78.41
T_2	6.93	14.58	30.33
T_3	3.43	13.59	35.83
T_4	8.47	43.31	82.17
T_5	8.30	15.79	33.24
T_6	3.82	14.67	36.36
T_7	9.12	44.70	82.84
T_8	8.83	15.93	36.78
T_9	3.93	16.28	38.50
T_{10}	8.21	42.03	78.91
T_{11}	7.83	14.44	30.15
T_{12}	3.42	12.33	32.65
T_{13}	8.70	44.26	72.79
T_{14}	8.69	15.29	34.11
T_{15}	4.47	16.15	38.32
CD_2	0.783	1.624	9.846
T_{16}	9.01	18.06	33.73
T_{17}	0	0	0
T_{18}	10.67	48.00	92.14
CD_3	0.639	1.326	8.039
SE	0.22	0.46	2.79

ii. 40th day of transplanting

a. T_{12} was significantly superior to T_{11} and the treatments T_3, T_6, T_9 and T_{15} were on par with T_2, T_5, T_8 and T_{14} respectively. All the herbicide treated and hand weeded sub plots were significantly superior to the unweeded sub plots.

b. All the herbicide treated sub plots were significantly superior to T_{16}.

c. Dry matter of weeds was significantly less in all the hand weeded sub plots compared to T_{16}.

d. Compared to T_{16}, DM of weeds was statistically greater in all the unweeded sub plots.

e. Compared to T_{18}, DM of weeds was significantly lower in all the unweeded sub plots.

f. T_{12} recorded the lowest DM of weed and it was on par with T_3 and superior to T_6, T_{15} and T_9. The latter three treatments were on par.

g. There was no significant difference among the hand weeded sub plots but the lowest DM was recorded in T_{11}.

h. T_1 recorded the lowest DM and was on par with T_{10}; while T_{10} was on par with T_4 which in turn was on par with T_{13} and T_7.

i. Among all the sub plots, the lowest dry matter accumulation of weed was observed in nitrofen-nitrofen, which was on par with thiobencarb-thiobencarb. The highest DM was recorded in the weedy check.

iii. At harvest

a. All the herbicide treated sub plots were on par with the respective hand weeded sub plots and both were superior to the unweeded sub plots.

b. No statistical difference in DM was observed between the various herbicide treated sub plots and T_{16}.

c. Similarly no difference was found between hand weeded sub plots and T_{16} in DM.

d. All the unweeded sub plots were significantly inferior to T_{16}.

e. All the unweeded sub plots were superior to T_{18}.

f. Though the lowest weed DM was recorded in T_{12}, it was on par with all the other herbicide treated sub plots.

g. No significant difference was observed among the hand weeded sub plots.

h. The lowest DM was observed in T_{13} which was on par with T_1, T_{10} and T_4, and was superior to T_7.

i. Among all the sub plots thiobencarb-thiobencarb recorded lowest DM and it was on par with T_2, T_{11}, T_5, T_{12} and T_{16}. Highest DM was produced by the weedy check.

4. Weed Control Efficiency.

Weed Control Efficiency is calculated on the basis of reduction in weed count in comparison with the weed count of weedy check and expressed in percentage.

Since the total weed population was highest in weedy check through out the crop period it was taken as the base for calculating the WCE.

Weed Control Efficiency worked out at different stages of crop growth are presented in Table 18.

i. 20th day of transplanting

T_3 and T_{12} recorded the highest WCE followed by T_6, T_{15} and T_9. Lowest value was noticed in T_{11} and T_{13}.

ii. 40th day of transplanting

Among the various weed management techniques tried, highest WCE was observed in T_{12}, followed by T_2 and T_{11}, T_3, T_{14}, T_5, T_8, T_6, T_{16}, T_9 and T_{15}. Lowest weed indices were worked out in the unweeded sub plots.

iii. At harvest

T_3 recorded the highest WCE followed by T_2, T_{11} and T_5, T_{12}, T_{16}, T_{14}, T_8, T_6, T_9 and T_{15}. As observed on the 40th DT, all unweeded sub plots registered very low values of weed indices.

Table 18

Weed Control Efficiency - second crop

Treatments	20th DT	40th DT	At harvest
T_1	35	16	14
T_2	30	70	66
T_3	79	69	68
T_4	24	10	10
T_5	27	67	63
T_6	70	66	58
T_7	20	07	05
T_8	18	67	59
T_9	64	64	55
T_{10}	18	13	12
T_{11}	15	70	64
T_{12}	79	71	62
T_{13}	15	08	09
T_{14}	34	68	61
T_{15}	67	64	52
T_{16}	24	64	62

5. <u>Nutrient removal by weeds</u>.

The nutrient removal by weeds were recorded on the 20th DT, 40th DT and at harvest with respect to nitrogen, phosphorus and potassium and analysed separately.

A. Nitrogen.

The mean values of nitrogen removal by weeds are presented in Table 19 and analysis of variance in Appendix IV.

i. 20th day of transplanting

a. Weeds in all herbicide treated sub plots removed significantly less nitrogen than the respective hand weeded sub plots and unweeded sub plots. The hand weeded sub plots and unweeded sub plots were on par.

b. All herbicide treated sub plots removed significantly less quantity of nitrogen than T_{16}.

c. In comparison with T_{16}, the treatments T_2, T_{11} and T_5 were superior and, T_8 and T_{14} were on par with T_{16}.

d. T_1 and T_{10} were superior, and T_4, T_7 and T_{13} were on par with T_{16}.

e. Weeds in all unweeded sub plots removed less nitrogen and were superior to weedy check.

f. Lowest nitrogen removal was observed in T_3 which was on par with other herbicide treated sub plots.

Table 19

Nitrogen removal by weeds (kg/ha) - Second crop

Treatments	20th DT	40th DT	At harvest
T_1	1.56	7.77	13.58
T_2	1.48	2.81	5.02
T_3	0.72	2.63	6.09
T_4	1.81	8.69	15.06
T_5	1.79	3.03	6.10
T_6	0.81	2.93	6.66
T_7	1.95	8.66	15.02
T_8	1.89	3.05	6.74
T_9	0.83	3.12	7.06
T_{10}	1.76	8.11	14.46
T_{11}	1.68	2.66	5.37
T_{12}	0.73	2.26	5.95
T_{13}	1.86	8.82	15.85
T_{14}	1.86	2.95	6.25
T_{15}	0.94	3.15	7.05
CD_2	0.50	0.419	0.251
T_{16}	1.93	3.40	6.18
T_{17}	0	0	0
T_{18}	2.28	9.45	16.90
CD_3	0.135	0.342	0.205
SE	0.05	0.12	0.07

g. Weeds in T_2 recorded lowest quantity of nitrogen removal which was on par with the other hand weeded sub plots.

h. Lowest quantity of nitrogen removal was observed in T_1 which was on par with all the other unweeded sub plots.

i. Among all the plots, T_3 recorded the lowest nitrogen removal which was on par with T_{12} and T_6, and was superior to all other treatments. Highest nitrogen removal was from weedy check.

ii. 40th day of transplanting

a. All the herbicide treatments were on par with the respective hand weeded sub plots and both were superior to unweeded sub plots.

b. T_{12}, T_3 and T_6 were superior and T_9 and T_{15} were on par with T_{16}.

c. All hand weeded sub plots were superior to hand weeding-hand weeding.

d. All unweeded sub plots were significantly inferior to T_{16}.

e. All unweeded sub plots removed significantly less nitrogen and thus superior to weedy check.

f. Among the herbicide treated sub plots, T_{12} removed the least quantity of nitrogen which was superior to T_6, T_9 and T_{15} where as it was on par with T_3.

g. Weeds in T_{11} removed lowest quantity of nitrogen and it was on par with all the other hand weeded plots.

h. Weeds in T_1 removed significantly less nitrogen and was superior to T_7, T_4 and T_{13} where as it was on par with T_{10}.

i. Among all the treatments, lowest nitrogen removal was from T_{12}, which was on par with T_3 and T_{11} and was superior to the other treatments. Weedy check recorded higher nitrogen and was significantly inferior to other treatments.

iii. At harvest

a. All hand weeded sub plots were found superior to the respective herbicide treated sub plots and both were in turn superior to the unweeded sub plots.

b. Compared to T_{16}, T_{12} was superior, T_3 on par and T_6, T_{15} and T_9 were inferior.

c. In comparison with T_{16}, treatments T_2 and T_{11} were superior, T_5 and T_{14} on par and T_8 inferior.

d. All unweeded sub plots removed higher nitrogen and were significantly inferior to T_{16}.

e. Compared to weedy check, all unweeded sub plots recorded significantly less nitrogen removal.

f. Among the herbicide treated plots, T_{12} recorded the lowest nitrogen removal which was on par with T_3 and superior to T_6, T_{15} and T_9.

g. Lowest nitrogen removal in T_2 was superior to other treatments. Next in order were T_{11}, T_5, T_{14} and T_8.

h. T_1 recorded lowest nitrogen removal and it was superior to all the other unweeded sub plots.

i. Among all the treatments, thiobencarb-hand weeding recorded significantly low nitrogen removal and was superior to all the other treatments. Next best treatments were T_{11}, T_{12}, T_3 and T_5. Weedy check recorded significantly higher nitrogen removal and was inferior to all other treatments.

B. Phosphorus.

Mean values are presented in Table 20 and analysis of variance in Appendix IV.

Table 20

Phosphorus removal by weeds (kg/ha) - Second crop

Treatments	20th DT	40th DT	At harvest
T_1	0.53	2.94	5.10
T_2	0.51	1.05	1.97
T_3	0.25	0.98	2.33
T_4	0.62	3.09	5.34
T_5	0.61	1.14	2.16
T_6	0.28	1.06	2.36
T_7	0.67	3.22	5.38
T_8	0.65	1.15	2.39
T_9	0.29	1.17	2.51
T_{10}	0.60	3.03	5.13
T_{11}	0.57	1.04	1.96
T_{12}	0.25	0.89	2.12
T_{13}	0.64	3.19	4.73
T_{14}	0.64	1.10	2.22
T_{15}	0.33	1.16	2.49
CD_2	0.057	0.116	0.640
T_{16}	0.66	1.30	2.19
T_{17}	0	0	0
T_{18}	0.78	3.46	5.99
CD_3	0.047	0.095	0.522
SE	0.02	0.03	0.18

i. 20th day of transplanting

a. All herbicide treated sub plots were significantly superior to both hand weeded and unweeded treatments.

b. All herbicide treated sub plots were statistically superior to T_{16}.

c. Compared to T_{16}, treatments T_2, T_{11} and T_5 were superior and T_{14} and T_8 were on par.

d. T_1 and T_{10} were superior and T_4, T_{13} and T_7 were on par with T_{16}.

e. All unweeded sub plots were superior to T_{18}.

f. Among the herbicide treated plots, weeds in T_{12} removed lowest phosphorus, and was on par with other herbicides except T_{15}.

g. T_2 was superior to all the other hand weeded plots. Next best was T_{11}. T_{14} recorded the highest removal of phosphorus.

h. T_1 was statistically superior to all the other unweeded sub plots. Next best was T_4. The highest phosphorus removal was observed in T_{13}.

i. Among all the treatments, weeds in T_{12} removed the lowest quantity of phosphorus and was on par with T_3, T_6, T_9 and T_{12} whereas highest quantity of phosphorus was removed by T_{18}.

ii. 40th day of transplanting

a. T_{12} was superior to T_{11}; T_6 was superior to T_5 whereas in other cases herbicide treated sub plots were on par with hand weeded plots. In all cases unweeded sub plots were significantly inferior to both herbicide treated and hand weeded plots.

b. All herbicide treated plots were superior to T_{16}.

c. All hand weeded sub plots were superior to T_{16}.

d. All unweeded sub plots were inferior to T_{16}.

e. All unweeded sub plots were superior to T_{18}.

f. Among the herbicide treated plots, T_{12} recorded the lowest phosphorus removal. It was superior to T_6, T_{15} and T_9, and was on par with T_3.

g. Weeds in T_{11} removed the lowest quantity of phosphorus and was on par with all the other hand weeded plots.

h. T_1 recorded the lowest phosphorus removal which was on par with T_{10} and was superior to other unweeded plots.

i. Among all the treatments, nitrofen-nitrofen which recorded the lowest phosphorus removal was on par with thiobencarb-thiobencarb and was superior to the other treatments. Weedy check removed the highest quantity of phosphorus and was inferior to all the other treatments.

iii. At harvest

a. All hand weeded sub plots were on par with the respective herbicide treated plots and both in turn were superior to the unweeded plots.

b. All herbicide treated plots were on par with T_{16}.

c. All hand weeded sub plots were on par with T_{16}.

d. All unweeded sub plots were significantly inferior to T_{16}.

e. All unweeded sub plots were significantly superior to T_{18}.

f. T_{12} recorded lowest phosphorus removal and was on par with other herbicide treated plots.

g. There was no significant difference in phosphorus removal among the hand weeded sub plots.

h. No significant difference was observed among the unweeded sub plots in phosphorus removal.

i. Among all the treatments, lowest phosphorus removal was observed in T_{11}, which was on par with T_2, T_{12}, T_5, T_{16}, T_{14}, T_3, T_6 and T_8. The highest phosphorus removal was from weedy check which was significantly inferior to all other treatments.

C. Potassium.

Mean values of potassium removal are presented in Table 21 and analysis of variance in Appendix IV.

1. 20th day of transplanting

a. Weeds in all the herbicide treated sub plots removed significantly less potassium than the hand weeded and unweeded plots.

b. All herbicide treatments were significantly superior to T_{16}.

c. Treatments T_2, T_{11} and T_5 were superior and T_{14} and T_8 were on par with T_{16}.

d. T_1 and T_{10} were superior and, T_4, T_7 and T_{13} were on par with T_{16}.

e. All unweeded sub plots were superior to weedy check.

f. Nitrofen-nitrofen recorded significantly less potassium removal than T_9 and T_{15}, and was on par with T_3 and T_6.

g. Thiobencarb-hand weeding was significantly superior to the other hand weeded sub plots.

h. Thiobencarb-no weeding was significantly superior to the other unweeded sub plots.

i. Comparing all the treatments, T_{12} which recorded the lowest potassium removal was found to be on par with T_3 and T_6 and superior to all the other treatments. The highest potassium removal was noticed in T_{18} which was inferior to all other treatments.

Table 21

Potassium removal by weeds (kg/ha) - Second crop

Treatments	20th DT	40th DT	At harvest
T_1	0.76	2.78	3.37
T_2	0.72	0.99	1.30
T_3	0.35	0.92	1.54
T_4	0.88	2.94	3.53
T_5	0.87	1.07	1.43
T_6	0.39	1.00	1.56
T_7	0.95	3.04	3.56
T_8	0.92	1.03	1.58
T_9	0.40	1.11	1.65
T_{10}	0.86	2.86	3.39
T_{11}	0.82	0.97	1.30
T_{12}	0.35	0.84	1.40
T_{13}	0.91	3.01	3.13
T_{14}	0.91	1.04	1.47
T_{15}	0.45	1.07	1.64
CD_2	0.047	0.106	0.424
T_{16}	0.94	1.23	1.45
T_{17}	0	0	0
T_{18}	1.11	3.26	3.96
CD_3	0.066	0.087	0.346
SE	0.02	0.03	0.12

ii. 40th day of transplanting

a. All herbicide treated sub plots were on par with the hand weeded sub plots and both in turn were superior to the respective unweeded sub plots except T_{12} which was superior to both T_{10} and T_{11}.

b. All herbicide treated sub plots were significantly superior to hand weeding-hand weeding.

c. All hand weeded sub plots were significantly superior to T_{16}.

d. All unweeded sub plots were significantly inferior to T_{16}.

e. All unweeded sub plots were significantly superior to T_{18}.

f. T_{12} recorded lowest potassium removal and it was on par with T_3 and superior to T_6, T_{15} and T_9.

g. Weeds in T_{11} removed lowest potassium and it was on par with T_2, T_{14} and T_5, and superior to T_8.

h. T_1 recorded lowest potassium removal and it was on par with T_{10} and superior to T_4, T_{13} and T_7.

i. Among all the treatments, T_{12} which recorded lowest potassium removal was on par with T_3 and superior to other treatments. Weeds in weedy check removed the highest quantity of potassium and was significantly inferior to all other treatments.

iii. At harvest

a. All hand weeded sub plots were on par with herbicide treated plots and both in turn were superior to unweeded sub plots.

b. All herbicide treated sub plots were on par with T_{16}.

c. All hand weeded sub plots were on par with T_{16}.

d. All unweeded sub plots were significantly inferior to T_{16}.

e. Compared to weedy check, all unweeded sub plots were superior.

f. T_{12} recorded low potassium removal which was on par with other herbicide treatments.

g. Though T_{11} recorded low potassium removal, there was no significant difference among the hand weeded sub plots.

h. Weeds in T_{13} removed less potassium and it was on par with other unweeded sub plots except T_7.

i. Among all the treatments, lowest potassium removal was observed in T_{11} which was statistically equal to T_2, T_{12}, T_5, T_{16}, T_4 and T_3. Highest potassium removal was observed in T_{18} which was significantly inferior to all other treatments.

Observation on Crop

1. <u>Crop growth characters.</u>

A. Height of Plants.

The mean values of plant height are presented in Table 22 and analysis of variance in Appendix V.

i. 20th day of transplanting

a. All the hand weeded sub plots were on par with the respective unweeded sub plots and all the herbicide treated sub plots except T_{12} were superior to both the hand weeded and unweeded sub plots. T_{12} was on par with T_{10} and T_{11}.

b. T_3 and T_6 were superior, T_{15} and T_9 were on par and T_{12} inferior to T_{16}. All these herbicide treated sub plots were inferior to T_{17}.

c. T_2 and T_{11} were on par with T_{16} while T_5, T_{14} and T_8 were inferior to T_{16}. All these hand weeded sub plots were inferior to T_{17}.

d. T_1 and T_{10} were on par with T_{16} while T_4, T_{13} and T_7 were inferior to T_{16}. All these unweeded sub plots were inferior to T_{17}.

e. All the unweeded sub plots were on par with weedy check.

Table 22

Crop growth characters - second crop

Treatments	Height of plants (cm)			Tiller number/m^2 at maximum tillering stage	LAI at flowering stage
	20th DT	40th DT	At harvest		
T_1	23.84	44.67	49.66	348.85	2.64
T_2	23.20	55.80	64.50	429.34	3.31
T_3	25.90	55.53	62.80	433.65	3.55
T_4	21.71	42.40	46.97	349.51	2.59
T_5	22.00	54.60	61.63	420.50	3.29
T_6	24.94	54.27	60.73	426.95	3.50
T_7	21.40	41.03	44.87	331.00	2.47
T_8	20.23	51.13	59.07	420.74	3.20
T_9	23.50	50.27	56.43	386.71	3.43
T_{10}	22.80	42.40	46.37	347.52	2.65
T_{11}	22.43	55.80	65.00	432.02	3.28
T_{12}	21.30	55.30	62.13	438.22	3.61
T_{13}	21.50	41.07	47.37	341.84	2.49
T_{14}	22.00	52.97	59.53	429.25	3.22
T_{15}	24.37	53.25	58.50	458.57	3.45
CD_2	1.618	1.493	2.362	49.927	0.045
T_{16}	23.59	53.36	59.49	414.22	3.27
T_{17}	27.50	60.66	68.00	437.08	3.72
T_{18}	22.73	39.42	44.23	338.93	2.43
CD_3	1.321	1.219	1.928	40.765	0.037
SE	0.46	0.42	0.67	14.14	0.01

f. The highest plant height was obtained in T_3 which was on par with T_6 and T_{15}; T_3 was superior to T_9 and T_{12}.

g. The tallest plants were observed in T_2 which was on par with T_{11}, T_5 and T_{14} and was suporior to T_8.

h. Among the unweeded sub plant, the plant height was more in T_1 which was on par with T_{10} and superior to T_4, T_{13} and T_7.

i. Among all the sub plots, tallest plants were observed in T_{17}. Next tallest plants were recorded in T_3 which was on par with T_6. The shortest plant was found in T_8.

ii. 40th day of transplanting

a. No statistical difference in plant height was observed among the respective herbicide treated and hand weeded plots. However the plant height in both the plots were significantly higher compared to the respective unweeded sub plots.

b. Compared to T_{16}, the treatments T_3 and T_{12} were superior, T_6 and T_{15} were on par and T_9 was inferior in plant height. But all the herbicide treated sub plots were inferior to T_{17}.

c. Compared to T_{16}, significant increase in plant hoight was noticed in T_2, T_{11} and T_5; plant height was on par in T_{14}

and less in T_8. T_{17} was superior to all the hand weeded sub plots.

d. The plant height in all the unweeded sub plots were inferior to T_{16} and T_{17}.

e. Compared to T_{18}, plant height was superior in all the unweeded sub plots.

f. T_3 recorded the highest plant height which was superior to T_9 and T_{15}, and was on par with T_{12} and T_6.

g. The plant height in T_2 was the highest which was on par with T_{11} and T_{15} and superior to T_{14} and T_8.

h. The highest plant height was observed in T_1 which was superior to the other unweeded sub plots.

i. Among all the sub plots, weed free plot produced plants significantly taller than all the other sub plots. Lowest plant height was measured in weedy check.

iii. At harvest

a. T_2 and T_3, T_5 and T_6, and T_{14} and T_{15} were on par while T_8 and T_{11} were superior to T_9 and T_{12} respectively. All these treatments were superior to the respective unweeded sub plots.

b. Compared to T_{16}, the treatments T_3 and T_{12} were superior,

T_6 and T_{15} were on par and T_9 was inferior in plant height. Weed free plot was significantly superior to all other treatments.

c. In comparison with T_{16}, plant height in T_2, T_5 and T_{11} were found to be superior and that in T_8 and T_{14} were on par. Weed free plot was significantly superior to all the other treatments.

d. Plant height recorded in all the unweeded sub plots were inferior to that of T_{16} and T_{17}.

e. T_1, T_4, T_{10} and T_{13} were superior and T_7 on par with weedy check.

f. The highest plant height was recorded in T_3 which was on par with T_{12} and T_6, and superior to T_{15} and T_9 which in turn were on par.

g. The plant height was more in T_{11} which was on par with T_2 and superior to all the other sub plots. Next in order were T_5, T_{14} and T_8.

h. T_1 recorded higher plant height, followed by T_{13}, which was on par with T_4 and T_{10}. The lowest plant height was in T_7.

i. Among all the treatments, T_{17} continued to produce taller plants followed by T_{11} which was on par with T_2. Next in order were T_3, T_{12}, T_5 and T_6 and the lowest plant height was observed in T_{18}.

B. Tiller number per m^2.

Number of tillers produced per square metre at maximum tillering stage was counted and analysed. Mean values are presented in Table 22 and analysis of variance in Appendix V.

a. All the herbicide treated sub plots were on par with the respective hand weeded sub plots and both were significantly superior to the unweeded sub plots.

b. Compared to T_{16}, T_{15} was superior and, T_{12}, T_3, T_6 and T_9 were on par. Compared to T_{17}, treatments T_{15}, T_{12}, T_3 and T_6 were on par and T_9 inferior.

c. There was no significant difference in tiller number between the hand weeded sub plots and that of T_{16} and T_{17}.

d. Tiller number in all the unweeded sub plots were significantly less than that of T_{16} and T_{17}.

e. No statistical difference in tiller number was observed between the unweeded sub plots and that of T_{18}.

f. The highest number of tillers was produced by T_{15} which was on par with T_{12}, T_3 and T_6 and superior to T_9.

g. There was no significant difference in tiller number of hand weeded sub plots.

h. There was no statistical difference in tiller production among the unweeded sub plots.

i. Among all the sub plots, highest number of tiller per m^2 was observed in T_{15} followed by T_{12}, T_{17}, T_3, T_{11}, T_2, T_{14} and T_6, and the lowest tiller number was in the weedy check.

C. Leaf Area Index

Leaf Area Index was calculated at flowering stage. Mean values are presented in Table 22 and analysis of variance in Appendix V.

a. All the herbicide treated sub plots were significantly superior to the respective hand weeded sub plots and both in turn were superior to the unweeded sub plots.

b. LAI in all the herbicide treated sub plots were more than that of T_{16}, but less than that of T_{17}.

c. All the hand weeded sub plots recorded LAI on par with T_{16} and less than T_{17}.

d. LAI in all the unweeded sub plots were significantly less than that of T_{16} and T_{17}.

e. All the unweeded sub plots recorded higher LAI than that of T_{18}.

f. LAI was higher in T_{12} which was superior to other herbicides. Next in order were T_3, T_6 and T_{15}. Lowest LAI was recorded in T_9.

g. Higher LAI was observed in T_2 which was on par with T_5 and T_{11}. Next in order were T_{14} and T_8.

h. T_{10} recorded higher LAI and was on par with T_1. It was followed by T_4, T_{13} and T_7.

i. Among all the sub plots, highest LAI was observed in T_{17} which was superior to all the other sub plots. Second highest LAI was in T_{12} followed by T_3, T_6, T_{15}, T_9 and T_2 and lowest LAI was computed in weedy check.

2. <u>Yield components</u>.

Mean values of yield components viz. number of panicles, length of panicle, weight of panicle, number of filled grains per panicle and thousand grain weight are presented in Table 23 and analysis of variance in Appendix VI.

A. Panicle number per m^2

a. No significant difference in panicle number was observed between the herbicide treated sub plots and hand weeded sub plots. And both of them were superior to the respective unweeded sub plots.

b. Panicle number in T_{16} was found to be on par with all the herbicide treated sub plots. Compared to T_{17}, treatments T_{12}, T_3 and T_6 were on par and T_{15} and T_9 were inferior.

c. All the hand weeded sub plots recorded panicle number nearer to that of T_{16}, T_2, T_{11}, T_5 and T_{14} were on par and T_8 was inferior to T_{17}.

d. All the unweeded sub plots were significantly inferior to T_{16} and T_{17}.

e. No significant difference in panicle number was observed between the unweeded sub plots and T_{18}.

f. No statistical difference was observed among the herbicide treated sub plots in panicle number.

Table 23

Yield components - second crop

Treatments	No. of panicle per m^2	Length of panicle (cm)	Weight of panicle (g)	No. of filled grains/ panicle	Thousand grain weight (g)
T_1	237.74	14.45	1.22	30.97	22.17
T_2	332.86	19.68	1.55	53.27	23.05
T_3	320.55	20.23	1.60	56.13	23.61
T_4	238.40	13.92	1.21	28.97	22.24
T_5	319.39	17.72	1.53	47.27	23.24
T_6	318.82	17.91	1.54	49.83	22.81
T_7	219.86	13.80	1.19	28.37	22.85
T_8	314.63	16.60	1.47	41.27	23.25
T_9	312.26	16.81	1.43	44.07	23.59
T_{10}	236.41	14.31	1.25	30.47	22.28
T_{11}	330.90	19.73	1.55	52.07	23.15
T_{12}	323.77	19.49	1.64	58.27	23.82
T_{13}	230.39	13.94	1.12	28.17	22.68
T_{14}	319.47	16.90	1.49	41.37	23.37
T_{15}	313.46	16.50	1.45	42.27	22.44
CD_2	21.503	1.193	0.128	6.195	0.540
T_{16}	321.08	17.77	1.55	47.80	23.01
T_{17}	333.61	20.08	1.66	60.11	22.95
T_{18}	230.05	13.14	1.08	28.13	22.87
CD_3	17.557	0.974	0.107	5.058	0.441
SE	6.09	0.34	0.04	1.75	0.15

g. Similarly no difference in panicle number was observed among the hand weeded sub plots.

h. All the unweeded sub plots were statistically similar in the production of panicles.

i. Among all the sub plots, highest number of panicles per unit area was observed in Weed free plot, which was on par with T_2, T_{11}, T_{12}, T_{16}, T_3, T_{14}, T_5, T_6 and T_8 and lowest number was recorded in T_7.

B. Length of panicle

a. Length of panicle produced by the herbicide treated sub plots were similar to that of the respective hand weeded sub plots and both were superior to the unweeded sub plots.

b. Compared to T_{16}, treatments T_3 and T_{12} were superior, T_6 and T_9 were on par and T_{15} inferior. But in comparison with T_{17}, treatments T_3 and T_{12} were on par and, T_6, T_9 and T_{15} were inferior.

c. Panicle length of T_2 and T_{11} were superior to T_{16} whereas that of T_5 and T_{14} were on par and T_8 inferior to T_{16}. Compared to T_{17}, treatments T_2 and T_{11} were on par and T_5, T_{14} and T_8 were inferior.

d. All the unweeded sub plots were significantly inferior to that of T_{16} and T_{17}.

e. T_1 and T_{10} were superior to T_{18} while T_4, T_{13} and T_7 were on par with it.

f. T_3 produced the longest panicle and it was statistically equal to T_{12}, followed by T_6, T_9 and T_{15}.

g. T_2 and T_{11} produced panicles having more or less equal length and they were superior to the other hand weeded sub plots. Next in order were T_5, T_{14} and T_8.

h. No statistical difference was observed among the unweeded sub plots in panicle length.

i. Among all the treatments longest panicle was in T_3 and it was on par with T_{17}, T_{11}, T_2 and T_{12}. Shortest panicle was observed in weedy check.

C. Weight of panicle

a. All the herbicide treated sub plots were on par with the respective hand weeded sub plots and both were significantly superior to the unweeded sub plots.

b. Panicle weight of all herbicide treated sub plots were on par with that of T_{16} except T_9 which was inferior. T_{12} and T_3 were on par with T_{17} and T_6, T_{15} and T_9 were inferior to it.

c. No significant difference in weight of panicle was observed between the hand weeded sub plots and T_{16}. Compared to T_{17}, treatments T_2 and T_{11} were on par and T_5, T_{14} and T_8 were inferior.

d. All the unweeded sub plots were significantly inferior to both T_{16} and T_{17}.

e. Compared to T_{18}, treatments T_{10}, T_1 and T_4 were superior and T_7 and T_{13} were on par.

f. T_{12} recorded the greatest weight of panicle and it was on par with T_3 and T_6 while T_6 in turn was on par with T_{15} and T_9.

g. Weight of panicle was more in T_2 and it was on par with all the other hand weeded sub plots.

h. No difference in panicle weight was observed among the unweeded sub plots.

i. Greatest weight of panicle was observed in T_{17} (weed free) and it was on par with T_{12}, T_3, T_2 and T_{11}. Lowest panicle weight was recorded by weedy check.

D. Number of filled grains per panicle.

a. All herbicide treated sub plots were on par with the respective hand weeded sub plots except T_{12} which was superior to T_{11}. All these sub plots were superior to the respective unweeded sub plots.

b. Compared to T_{16}, the treatments T_{12} and T_3 were superior, T_6 and T_9 were on par and T_{15} inferior, while T_{12} and T_3 were on par with T_{17}, and treatments T_6, T_9 and T_{15} were inferior to T_{17}.

c. With regard to number of filled grains, T_2 was superior, T_{11} and T_5 on par and T_{14} and T_8 were inferior to T_{16}. All the hand weeded sub plots were inferior to T_{17}.

d. All the unweeded sub plots were inferior to both T_{16} and T_{17}.

e. No difference in number of filled grains was observed between the unweeded sub plots and T_{18}.

f. Number of filled grains was more in T_{12} which was on par with T_3. Next in order were T_6, T_9 and T_{15}.

g. T_2 produced higher number of filled grains per panicle and it was on par with T_{11} and T_5 while T_5 in turn was on par with T_{14} and T_8.

h. There was no significant difference among the unweeded sub plots.

i. Among all the sub plots, number of filled grains was more in T_{17} which was on par with T_{12} and T_{13}, followed by T_2, T_{11} and T_6. Lowest number of filled grains was in T_{18}.

E. Thousand grain weight.

a. T_3 was superior to T_2 and both were superior to T_1; T_5 and T_6 were on par and both were superior to T_4; T_8 and T_9 were on par and both were superior to T_7; T_{12} was superior to T_{11} and both were superior to T_{10}; and T_{14} was superior to T_{15} and T_{13}.

b. T_{12}, T_3 and T_9 were superior to T_{16} while T_6 was on par and T_{15} inferior to T_{16}. In comparison with T_{17} also, T_{12}, T_3 and T_9 were superior and, T_6 and T_{15} were on par.

c. No significant difference was observed in thousand grain weight between hand weeded sub plots and T_{16} while in comparison with T_{17}, T_{14} was superior and T_8, T_5, T_{11} and T_2 were on par.

d. Thousand grain weight of T_7 and T_{13} were on par with both T_{16} and T_{17} while T_{10}, T_4 and T_1 were inferior to both T_{16} and T_{17}.

e. Compared to T_{18}, the treatments T_7 and T_{13} were on par and T_{10}, T_4 and T_1 were inferior.

f. T_{12} recorded higher grain weight and it was on par with T_3 and T_9. Next in order was T_6 which was on par with T_{15}.

g. No significant difference in grain weight was observed among the hand weeded sub plots.

h. T_7 recorded higher grain weight and it was statistically equal to T_{13} while T_{13} in turn was on par with T_{10}, T_4 and T_1.

i. Among all the sub plots, greatest thousand grain weight was observed in T_{12} followed by T_3, T_9, T_{14}, T_8, T_5, T_{11}, T_2, T_{16}, T_{17}, T_7 and T_6 and the lowest test weight was recorded in T_1.

3. <u>Yield</u>.

Mean values of grain yield, straw yield, total dry matter and protein content of grains are presented in Table 24 and analysis of variance in Appendix VI.

A. Grain yield

a. All hand weeded sub plots were superior to the respective herbicide treated sub plots except T_5 which was on par with T_6. All these hand weeded and herbicide treated sub plots were superior to the respective unweeded sub plots.

b. Compared to T_{16}, the treatments T_3 and T_{12} were superior and T_6, T_{15} and T_9 were inferior. T_{17} was superior to all the herbicide treated sub plots.

c. T_{11} and T_2 were superior, T_5 on par and T_{14} and T_8 inferior to T_{16}. All hand weeded sub plots were inferior to T_{17}.

d. All unweeded sub plots were inferior to both T_{16} and T_{17}.

e. All unweeded sub plots were superior to T_{18} except T_{13} which was on par with T_{18}.

f. Higher grain yield was produced by T_3 and it was superior to all the other herbicide treated sub plots. In the order of high grain yield, T_3 was followed by T_{12}, T_6, T_{15} and T_9.

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Table 24

Grain yield, Straw yield, Crop dry matter and Protein content of grains - second crop

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Total dry matter (kg/ha)	Protein content of grains (%)
T_1	2189	3094	4946	8.21
T_2	2880	4043	6480	8.30
T_3	2857	3914	6332	8.30
T_4	2129	3014	4815	8.19
T_5	2779	3945	5966	8.24
T_6	2769	3710	6055	8.24
T_7	2081	2944	4705	8.19
T_8	2761	3870	6207	8.20
T_9	2698	3596	5880	8.22
T_{10}	2157	3052	4877	8.21
T_{11}	2895	4064	6513	8.29
T_{12}	2833	3827	6226	8.30
T_{13}	2052	2845	4547	8.21
T_{14}	2766	3886	6227	8.28
T_{15}	2721	3714	6017	8.27
CD_2	21.2	38.0	247.5	N.S
T_{16}	2790	3898	6179	8.21
T_{17}	3034	4157	6725	8.30
T_{18}	2042	2833	4611	8.18
CD_3	17.3	31.1	202.1	N.S
SE	5.6	10.8	70.1	-

g. T_{11} recorded higher grain yield which was on par with T_2. Next in order was T_5 which was on par with T_{14} while T_{14} in turn was on par with T_8.

h. Higher grain yield was produced by T_1 which was superior to the other unweeded sub plots. Next in order were T_{10}, T_4, T_7 and T_{13}.

i. Among all the plots, highest grain yield was obtained from T_{17} which was superior to all other treatment. Next in order were T_{11}, T_2, T_3, T_{12}, T_5 and T_6, and the Lowest yield was recorded in T_{18}.

B. Straw yield

a. Hand weeded sub plots were found to be superior to the respective herbicide treated sub plots and both were superior to the unweeded sub plots.

b. T_3 was on par and T_{12}, T_{15}, T_6 and T_9 were inferior to T_{16}. All herbicide treated sub plots were inferior to T_{17}.

c. Compared to T_{16}, the treatments T_{11}, T_2 and T_5 were superior and T_{14} and T_8 were on par. All these treatments were inferior to T_{17}.

d. All unweeded sub plots were inferior to both T_{16} and T_{17}.

e. All unweeded sub plots were superior to T_{18} except T_{13} which was inferior to T_{18}.

f. Higher straw yield was produced by T_3 and it was superior to the other herbicide treated sub plots. T_3 was followed by T_{12}, T_{15}, T_6 and T_9.

g. T_{11} recorded more straw yield and it was on par with T_2. Next in order were T_5, T_{14} and T_8.

h. Among the unweeded sub plots, more straw yield was produced by T_1 which was superior to others. T_1 was followed by T_{10}, T_4, T_7 and T_{13}.

i. Among all the plots, highest straw yield was obtained from T_{17} which was superior to all the other treatments. It was followed by T_{11}, T_2, T_5, T_3, T_{16} and T_{14} and the lowest yield was recorded in T_{13} which was significantly inferior to all the other treatments.

C. Crop dry matter production.

a. Comparison of sub plot treatments within each main plot revealed that T_8 and T_{11} were superior to T_9 and T_{12} respectively and all other hand-weeded sub plots were on par with the respective herbicide treated sub plots. All these hand weeded and herbicide treated sub plots were superior to the respective unweeded sub plots.

b. All herbicides treated sub plots were on par with T_{16} except T_9 which is inferior to T_{16}. In comparison with weed free plot, all these treatments were significantly inferior.

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c. Compared to T_{16}, treatments T_2 and T_{11} were superior, T_8 and T_{14} were on par and T_5 inferior where as all the hand weeded sub plots were inferior to T_{17}.

d. All unweeded sub plots were inferior to both T_{16} and T_{17}.

e. In comparison with T_{18}, treatments T_1, T_4 and T_{10} were superior and T_7 and T_{13} were on par.

f. Among the herbicide treatments T_3 recorded highest total DM which was on par with T_{12} and superior to T_6, T_9 and T_{15}. T_{12} in turn was on par with T_6 and T_{15} and, superior to T_9.

g. T_{11} recorded the highest total DM which was on par with T_2 and superior to T_5, T_8 and T_{14}.

h. Treatment T_1 produced higher DM which was on par with T_4, T_7 and T_{10} and was superior to T_{13}.

i. Among all the treatments, weed free plot recorded highest DM which was superior to all other treatments. Second highest DM was produced by T_{11} and it was on par with T_2 and T_3 followed by T_{14}, T_{12}, T_8, T_{16}, T_6 and T_{15}. Lowest DM was registered by T_{13} which was on par with T_7 and T_{18}.

D. Protein content of grains.

There was no significant difference among the treatments for this character.

4. Weed Index.

Weed Index explain the reduction in yield due to the presence of weeds in a particular treatment plot in comparison with the yield obtained from the weed free plot or the treatment which recorded lowest number of weeds. Weed free plot was taken as the base for the calculation of Weed Index as it recorded the highest grain yield.

Weed indices worked out for the different treatments are presented in Table 25.

Among the herbicide treated sub plots, T_3 recorded lowest Weed Index followed by T_{12}, T_6, T_{15} and T_9.

Among the hand weeded sub plots, lowest Weed Index was worked out in T_{11} followed by T_2, T_5, T_{14} and T_8.

Table 25 - Weed Index

Treatments	Weed Index
T_1	27.85
T_2	5.08
T_3	5.83
T_4	29.83
T_5	8.41
T_6	8.73
T_7	31.41
T_8	9.00
T_9	11.07
T_{10}	28.91
T_{11}	4.58
T_{12}	6.63
T_{13}	32.37
T_{14}	8.83
T_{15}	10.32
T_{16}	8.04
T_{17}	32.70

T_1 recorded the lowest weed index among unweeded sub plots followed by T_{10}, T_4, T_7 and T_{13}.

Hand weeding-hand weeding registered a weed index value of 8.

Among all the 17 sub plots, the best treatments in the order of ranking were T_{11}, T_2, T_3, T_{12}, T_{16}, T_5, T_6, T_{14} and T_8. The highest weed index value of 32.7 was worked out in weedy check.

5. <u>Nutrient uptake by the crop.</u>

A. Nitrogen.

The treatment difference were significant in the crop uptake of nitrogen as is seen in the data presented in Table 26 The analysis of variance corresponding to the 20th DT, 40th DT and at harvest are presented in Appendix VII.

i. 20th day of transplanting

a. All herbicide treated sub plots were superior to the respective hand weeded plots except T_{12} which was on par with T_{11} and T_{10}. All hand weeded sub plots were on par with the respective unweeded sub plots.

b. All herbicide treated sub plots were on par with T_{16} and significantly inferior to T_{17}.

Table 26

Nitrogen uptake by the crop (kg/ha) - Second crop

Treatments		20th DT	40th DT	At harvest
T_1		40.62	46.47	61.87
T_2		39.82	68.76	82.67
T_3		45.97	70.10	82.01
T_4		38.54	41.56	60.42
T_5		37.85	61.05	80.24
T_6		43.55	66.61	78.85
T_7		34.76	41.79	58.86
T_8		35.82	57.55	79.19
T_9		43.86	59.28	76.37
T_{10}		37.84	46.67	61.01
T_{11}		36.91	69.01	83.09
T_{12}		40.81	70.28	80.63
T_{13}		35.02	44.10	56.89
T_{14}		35.96	51.16	75.80
T_{15}		41.53	60.39	77.86
	CD_2	5.627	4.317	2.190
T_{16}		41.68	66.86	79.82
T_{17}		54.36	80.32	88.27
T_{18}		38.59	39.12	57.77
	CD_3	4.595	3.525	1.788
	SE	1.59	1.22	0.62

c. Compared to T_{16}, treatments T_2 and T_5 were on par and T_8, T_{11} and T_{14} were inferior where as in comparison with T_{17}, all the hand weeded sub plots were significantly inferior.

d. All unweeded sub plots were statistically inferior to T_{17} where as in comparison with T_{16}, treatment T_1, T_4 and T_{10} were on par and T_7 and T_3 were inferior.

e. All unweeded sub plots were statistically equal to T_{18}.

f. T_3 recorded higher nitrogen uptake and it was on par with other herbicides.

g. Rice plants in T_2 absorbed greater quantity of nitrogen and it was on par with other hand weeded sub plots.

h. Higher nitrogen uptake was observed in T_1 and it was on par with T_4, T_{10} and T_{13} and superior to T_7.

i. Among all the treatments, T_{17} recorded highest nitrogen uptake and it was superior to all other treatments. Next best treatments were T_3, T_9 and T_6. Lowest nitrogen uptake was recorded by T_7.

ii. 40th day of transplanting

a. T_3, T_9 and T_{12} were on par with T_2, T_8 and T_{11} respectively;

T_6 and T_{15} were superior to T_5 and T_{14} respectively. All herbicide treated and hand weeded sub plots were superior to the respective unweeded sub plots.

b. T_{12}, T_3 and T_6 were on par with T_{16} where as T_{15} and T_9 were inferior to T_{16}. All these treatments in turn were inferior to T_{17}.

c. Compared to T_{16}, treatment T_{11} and T_2 were on par and T_5, T_8 and T_{14} were inferior. All hand weeded sub plots were inferior to T_{17}.

d. All unweeded sub plots were inferior to both T_{16} and T_{17}.

e. Compared to T_{18}, treatments T_{10}, T_1 and T_3 were superior and T_7 and T_4 were on par.

f. Nitrogen uptake was higher in T_{12} which was superior to T_{15} and T_9, and T_{12} was on par with T_3 and T_6.

g. T_{11} recorded high nitrogen uptake which was similar to T_2 and superior to T_5, T_8 and T_{14}.

h. Nitrogen uptake was higher in T_{10} and it was on par with T_1 and T_{13} and superior to T_7 and T_4.

i. Among all the treatments, highest nitrogen uptake was recorded by weed free plot which was significantly superior to all other treatments. Next best treatments were T_{12}, T_3, T_{11}, T_2 and T_{16}. Lowest nitrogen uptake was from weedy check which is significantly inferior to all other treatments except T_4 and T_7.

iii. At harvest

a. T_2, T_5 and T_{14} were on par with T_3, T_6 and T_{15} respectively whereas T_8 and T_{11} were superior to T_9 and T_{12} respectively. But all these treatments were superior to the respective unweeded sub plots.

b. Compared to T_{16}, T_3 was superior, T_{12} and T_6 were on par and, T_{15} and T_9 were inferior; where as all these herbicide treatments were inferior to T_{17}.

c. In comparison with T_{16}, treatments T_{11} and T_2 were superior; T_5 and T_8 on par and, T_{14} was inferior. All these hand weeded sub plots were inferior to T_{17}.

d. All unweeded sub plots were inferior to both T_{16} and T_{17}.

e. Compared to T_{18}, treatments T_1, T_{10} and T_4 were superior, and T_7 and T_{13} were on par.

f. Nitrogen uptake was more in T_3 which was superior to T_6, T_{15} and T_9 and was on par with T_{12}.

g. T_{11} recorded higher nitrogen uptake which was on par with T_2 and superior to T_5, T_8 and T_{14}.

h. Nitrogen uptake was higher in T_1 which was on par with T_{10} and T_4 and superior to T_7 and T_{13}.

i. Among all the treatments, greatest nitrogen uptake was in T_{17}, and it was significantly higher than all the other treatments. Next best treatments were T_{11}, T_2, T_3, T_{12}, T_5 and T_{16}. Weedy check recorded lowest nitrogen uptake which was significantly inferior to all treatments except T_{13} and T_7.

B. Phosphorus.

Mean values are presented in Table 27 and analysis of variance in Appendix VII.

i. 20th day of transplanting

a. T_4, T_5 and T_6 were on par; T_{10}, T_{11} and T_{12} were on par; T_3 was superior to T_2 but on par with T_1; T_9 was superior to T_8 and T_7; and T_{15} was superior to T_{14} and T_{13}.

b. All herbicide treated plots were on par with T_{16} and inferior to T_{17}.

c. Compared to T_{16}, treatments T_2 and T_5 were on par and T_{11}, T_{14} and T_8 were inferior, but all hand weeded sub plots were significantly inferior to T_{17}.

d. In comparison with T_{16}, treatments T_1, T_4 and T_{10} were on par and T_{13} and T_{11} were inferior where as all unweeded sub plots were inferior to T_{17}.

e. All unweeded sub plots were on par with T_{18}.

f. Though T_3 recorded higher uptake of phosphorus, there was no significant difference among the treatments.

g. Similarly T_2 recorded higher uptake of phosphorus, but they were on par.

h. T_1 was on par with T_4 and T_{10} but superior to T_{13} and T_7.

i. Among all the treatments, highest phosphorus uptake was observed in T_{17} which was superior to all other treatments. Next best treatments were T_3, T_9, T_6, T_{15} and T_{12}. Lowest phosphorus uptake was recorded in T_7.

Table 27

Phosphorus uptake by the crop (kg/ha) - Second crop

Treatments	20th DT	40th DT	At harvest
T_1	13.61	18.60	23.33
T_2	13.34	25.54	30.58
T_3	15.25	26.53	29.85
T_4	12.90	16.55	22.73
T_5	12.78	23.69	29.72
T_6	14.43	25.52	28.52
T_7	11.63	16.61	22.21
T_8	11.98	22.60	29.29
T_9	14.83	22.83	27.69
T_{10}	12.66	18.75	23.02
T_{11}	12.35	26.93	30.74
T_{12}	13.54	27.11	29.33
T_{13}	11.70	17.76	21.46
T_{14}	12.01	20.23	29.38
T_{15}	14.06	23.38	28.35
CD_2	1.892	1.695	0.221
T_{16}	13.90	26.48	29.53
T_{17}	17.88	31.13	31.70
T_{18}	13.01	15.39	21.82
CD_3	1.545	1.384	0.181
SE	0.54	0.48	0.06

ii. 40th day of transplanting

a. T_3, T_9 and T_{12} were on par with T_2, T_8 and T_{11} where as T_6 and T_{15} were superior to T_5 and T_{14} respectively. All these treatments were superior to the respective unweeded sub plots.

b. Compared to T_{16}, treatments T_{12}, T_3 and T_6 were on par and T_{15} and T_9 were inferior. All of them were significantly inferior to T_{17}.

c. In comparison with T_{16}, treatments T_{11} and T_2 were on par but T_5, T_8 and T_{14} were inferior. All hand weeded sub plots were significantly inferior to T_{17}.

d. All unweeded sub plots were statistically inferior to both T_{16} and T_{17}.

e. Compared to T_{18}, treatments T_{10}, T_1 and T_{13} were superior where as T_7 and T_4 were on par.

f. On par with T_3 and T_6, treatment T_{12} recorded higher phosphorus uptake and it was superior to T_{15} and T_9.

g. On par with T_2, T_{11} absorbed higher quantity of phosphorus and it was superior to T_5, T_8 and T_{14}.

h. Phosphorus uptake recorded in T_{10} was superior to T_7 and T_4 and, was on par with T_1 and T_{13}.

i. Among all the treatments highest phosphorus uptake recorded in weed free plot was significantly superior than all other treatment. Next best treatments were

T_{12}, T_{11}, T_3, T_{16} and T_2. Lowest uptake of phosphorus was observed in weedy check which was inferior to all other treatments except T_4 and T_7.

iii. At harvest

a. All the hand weeded sub plots were significantly superior to both the herbicide treated and unweeded sub plots.

b. Compared to T_{16}, T_3 was superior, T_{12}, T_6, T_{15} and T_9 were inferior. All herbicide treated sub plots were inferior to T_{17}.

c. In comparison with T_{16}, treatments T_{11}, T_2 and T_5 were superior, T_{14} on par and T_8 inferior. But all hand weeded sub plots were inferior to T_{17}.

d. All unweeded sub plots were significantly inferior to both T_{16} and T_{17}.

e. All unweeded sub plots were significantly superior to T_{18} except T_{13}.

f. Highest phosphorus uptake was observed in T_3 which was superior to other herbicides.

g. On par with T_2, T_{11} absorbed higher phosphorus and it was superior to other hand weeded treatments.

h. T_1 which absorbed highest quantity of phosphorus was superior to other unweeded sub plots.

i. Among all the treatments, highest phosphorus uptake was in weed free plot which was significantly superior to all other treatments. Next best treatments were T_{11}, T_2, T_3, T_5, T_{16} and T_{12}. Lowest phosphorus uptake was recorded in weedy check which was significantly inferior to all other treatments except T_{13}.

C. Potassium.

Mean values are presented in Table 28 and analysis of variance in Appendix VII.

i. 20th day of transplanting

a. T_9 was superior to T_8 and T_7; T_{15} was superior to T_{14} and T_{13}; T_3, T_6 and T_{12} were on par with the respective hand weeded and unweeded sub plots.

b. All herbicide treated sub plots were on par with T_{16}, but were inferior to T_{17}.

c. Compared to T_{16}, treatments T_2 and T_5 were on par, and T_{11}, T_{14} and T_8 were inferior.

d. In comparison with T_{16}, treatments T_1, T_4 and T_{10} were on par and T_7 and T_{13} were inferior where as all unweeded sub plots were inferior to T_{17}.

e. All unweeded sub plots were on par with T_{18}.

Table 28

Potassium uptake by the crop (kg/ha) - Second crop

Treatments	20th DT	40th DT	At harvest
T_1	26.20	27.33	36.40
T_2	25.69	39.38	53.15
T_3	29.10	40.01	51.86
T_4	24.82	24.25	35.37
T_5	24.61	34.98	51.56
T_6	27.55	37.98	49.63
T_7	22.44	24.39	34.52
T_8	23.12	33.16	50.78
T_9	28.86	34.24	48.12
T_{10}	24.43	27.31	35.88
T_{11}	23.83	39.44	53.49
T_{12}	25.84	40.28	51.13
T_{13}	22.64	25.76	33.36
T_{14}	23.25	29.56	50.94
T_{15}	27.75	34.87	49.72
CD_2	3.664	4.604	0.455
T_{16}	26.88	38.66	51.07
T_{17}	34.01	46.70	55.42
T_{18}	24.35	20.85	33.38
CD_3	2.992	3.759	0.370
SE	1.04	1.30	0.13

f. T_3 which recorded higher potassium uptake was on par with other herbicide treated plots.

g. T_2 which recorded higher potassium uptake was on par with other hand weeded treatments.

h. Thiobencarb-no weeding was superior to T_{10} and T_7, and was on par with T_4 and T_{13}.

i. Among all the treatments, highest potassium uptake was observed in weed free plot and it was superior to all other treatments. Next best treatments were T_3, T_9, T_{15}, T_6, T_{16}, T_{12} and T_2. Lowest potassium uptake was observed in T_7.

ii. 40th day of transplanting

a. All herbicide treated sub plots were on par with the respective hand weeded plots and both were in turn superior to the respective unweeded sub plots except T_{15} which was superior to both T_{14} and T_{13}.

b. Compared to T_{16}, treatments T_{12}, T_3 and T_6 were on par and, T_9 and T_{15} were inferior where as all the herbicide treated plots were inferior to T_{17}.

c. In comparison with T_{16}, treatments T_2, T_5 and T_{11} were on par and T_8 and T_{14} were inferior where as all the hand weeded sub plots were inferior to T_{17}.

d. All unweeded sub plots were significantly inferior to both T_{16} and T_{17}.

e. Compared to T_{18}, treatments T_1, T_{10} and T_{13} were superior, and T_3 and T_7 were on par.

f. T_{12} which recorded higher potassium uptake was on par with T_3 and T_6 and superior to T_9 and T_{15}.

g. T_{11} which recorded higher potassium uptake was superior to T_8 and T_{14}, and was on par with T_2 and T_5.

h. No significant difference in potassium uptake was observed among the unweeded sub plots.

i. Among all the treatments, weed free plot which recorded highest potassium uptake was superior to all other treatments. Next ranked treatments were T_{12}, T_3, T_{11}, T_2, T_{16} and T_6. Lowest potassium uptake was observed in weedy check.

iii. At harvest

a. All hand weeded sub plots were superior to the herbicide treated sub plots and both in turn were superior to the respective unweeded sub plots.

b. Compared to T_{16}, treatments T_3 was superior, T_{12} on par and T_6, T_9 and T_{15} were inferior. All herbicide treated sub plots were inferior to T_{17}.

c. T_2, T_5 and T_{11} were superior to T_{16} whereas T_8 and T_{14} were on par with T_{16}. All the hand weeded sub plots were inferior to T_{17}.

d. All unweeded sub plots were significantly inferior to both T_{16} and T_{17}.

e. All unweeded sub plots were superior to T_{18} except T_{13} which was on par with T_{18}.

f. Among the herbicide treated plots, thiobencarb-thiobencarb was significantly superior to other herbicides followed by T_{12}, T_{15}, T_6 and T_9.

g. T_{11} recorded significantly high potassium uptake than all the other hand weeded treatments except T_2 which was on par with it. Next in order were T_5, T_{14} and T_8.

h. T_1 was significantly superior to all other unweeded sub plots followed by T_{10}, T_4, T_7 and T_{13}.

i. Among all the treatments, T_{17} recorded highest potassium uptake which was significantly superior to the other treatments. Next in order were T_{11}, T_2, T_3, T_5, T_{12}, T_{16}, T_{14} and T_8. T_{13} recorded the lowest potassium uptake which was on par with T_{18}.

6. <u>Economics of weed management.</u>

Mean values are presented in Table 29 and analysis of variance in Appendix VIII.

Table 29

Economics of weed management - second crop

Treatments	Increased yield over control (kg/ha)		Monetary value of increased yield (Rs/ha)*	Total cost of weed control operations (Rs/ha)	Net return (Rs/ha)	
	Grain	Straw				
T_1	147	211	412	0	412	(2412)
T_2	838	1160	2320	1100	1220	(3220)
T_3	815	1031	2188	496	1692	(3692)
T_4	87	131	247	0	247	(2247)
T_5	737	1062	2070	1100	970	(2970)
T_6	727	827	1888	376	1512	(3512)
T_7	39	61	113	0	113	(2113)
T_8	719	987	1985	1100	885	(2885)
T_9	656	713	1680	461	1219	(3219)
T_{10}	115	169	325	0	325	(2325)
T_{11}	853	1181	2362	1100	1262	(3262)
T_{12}	791	944	2085	791	1294	(3294)
T_{13}	-30	-38	-81	0	-81	(1919)
T_{14}	724	1003	2005	1100	905	(2905)
T_{15}	679	831	1804	424	1380	(3380)
CD_2						164.2
T_{16}	748	1015	2057	1100	957	(2957)
T_{17}	992	1274	2677	4444	-1767	(233)
CD_3						141.6
SE						49

Figures in paranthesis are the "x + 2000" transformed figures.
*Price of produce Grain Rs 1.80/kg, Straw Rs 0.70/kg.

a. Comparison of sub plots within each main plot reveals that herbicide treatments were superior to the respective hand weeded sub plots except T_{12} which was on par and both herbicide treatments and hand weeding were superior to the corresponding unweeded sub plots.

b. All the herbicide treatments were significantly superior than T_{16} and T_{17}.

c. Compared to T_{16}, treatments T_2 and T_{11} were superior, T_8 and T_{14} on par and T_5 inferior where as these hand weeded treatments were superior to T_{17}.

d. All unweeded sub plots were significantly inferior to T_{16} but superior to T_{17}.

f. Among the herbicide treatments, high net profit was recorded by T_3 which was superior to all the other herbicides and closely followed by T_6.

g. T_{11} recorded high net profit among the hand weeded treatments which was on par with T_2 and both were superior to the other hand weeded treatments.

h. Highest net profit was obtained from T_1 among the unweeded sub plots and it was superior to all other unweeded sub plots.

i. Among all the treatments, highest net profit was obtained from T_3, which was superior to all other treatments. It was followed by T_6, T_{15}, T_{12}, T_{11}, T_2 and T_9. The most uneconomic treatment was found to be the completely weed free treatment which recorded a negative value.

7. Total Grain yield of First and Second Crops.

Mean values are presented in Table 30 and analysis of variance in Appendix VIII.

a. All hand weeded sub plots were on par with the respective herbicide treated plots and both were superior to the unweeded sub plots.

b. Compared to hand weeding-hand weeding, T_3 and T_{12} were superior and T_6, T_9 and T_{15} were inferior. All these herbicide treatments were inferior to weed free plot.

c. Similarly, T_2 and T_{11} were superior and T_5, T_8 and T_{14} were inferior to T_{16}. All these hand weeded sub plots were inferior to T_{17}.

d. All unweeded sub plots were significantly inferior to T_{16} and T_{17}.

e. All unweeded sub plots were significantly superior to T_{18}.

f. Among the herbicides, nitrofen-nitrofen ranked first and was on par with T_3 and both were superior to other herbicides.

g. T_{11} recorded higher grain yield and it was superior to other hand weeded treatments, followed by T_2 which was also superior to T_5, T_8 and T_{14}.

h. T_1 registered higher grain yield among the unweeded sub plots and it was on par with T_{10} and both were superior to other unweeded sub plots.

i. Among all the treatments, T_{17} recorded highest grain yield which was significantly superior to all other treatments. Next ranked treatments were T_{11}, T_2, T_{12}, T_3, T_{16}, T_5, T_6, T_{14}, T_{15}, T_8 and T_9. Lowest grain yield was recorded by T_{18} which was significantly inferior to all other treatments.

Table 30

Total grain yield of first and second crops

Treatments	Total grain yield (kg/ha)
T_1	5953
T_2	6644
T_3	6621
T_4	5816
T_5	6477
T_6	6457
T_7	5396
T_8	6076
T_9	6013
T_{10}	5947
T_{11}	6685
T_{12}	6623
T_{13}	5393
T_{14}	6148
T_{15}	6103
CD_2	19.8
T_{16}	6549
T_{17}	6989
T_{18}	4402
CD_3	16.2
SE	5.6

8. Herbicide Residual Toxicity Study.

To find out the residual toxicity of the herbicides applied in the first crop and second crop seasons on the succeeding crop, 100 seeds of cowpea cv C152 were sown in each of the treatment plots during the third crop season. Germination of cowpea seeds was assessed on the 10th day of sowing. Mean values are presented in Table 31 and analysis of variance in Appendix VIII.

Observation on the germination of cowpea seeds as influenced by the residual toxicity of herbicides shows that there was no significant difference among the various treatments.

Table 31

Germination of cowpea seeds as affected by the residues of herbicides (%)

Treatments	Germination %
T_1	87.33
T_2	87.33
T_3	86.33
T_4	87.00
T_5	86.67
T_6	86.67
T_7	87.00
T_8	86.33
T_9	86.00
T_{10}	86.33
T_{11}	87.33
T_{12}	86.00
T_{13}	85.33
T_{14}	84.67
T_{15}	84.67
CD_2	N.S
T_{16}	86.34
T_{17}	85.44
T_{18}	85.44
CD_3	N.S

N.S - Not significant.

DISCUSSION

DISCUSSION

A field experiment was undertaken to find out a suitable weed management technique for rice based cropping system under transplanted condition, using rice variety Triveni. The experiments were conducted at the College of Agriculture, Vellayani, during the Virippu-Mundakan seasons of 1984-85. Results obtained from the experiments were statistically analysed and are discussed here under.

FIRST CROP

Observation on Weeds

1. Weed species.

Observation on weed species (Table 3) revealed that grasses, sedges and broad leaved weeds competed with rice plant. But the competition was mostly by grasses followed by sedges and broad leaved weeds. Most important grass weeds identified were *Brachiaria ramosa*, *Echinochloa colona* and *E. crus-galli*. *Cyperus iria* and *Fimbristylis miliacea* dominated among sedges where as *Ludwigia parviflora*, *Marsilia quadrifoliata* and *Monochoria vaginalis* were the prominent among broad leaved weeds. Most of them were annuals and were completing their life cycle along with the rice crop. Ravindran (1976), Abraham Varughese (1978) and Sukumari (1982) also made similar observations.

2. Weed population.

Monocot and dicot weed population were estimated seperately and recorded on the 20th DT, 40th DT and at harvest. The data presented in Table 4 show that the monocots out numbered the dicots through out the crop period. The monocot weed population constituted more than 85 percent of the total weeds. The monocot weeds having similar growth habits of rice could compete more efficiently with the crop especially dwarf indices. They also persisted throughout the crop period. During the later stages of growth, the canopy of the rice crop suppressed the dicots growth, where as it could not suppress monocots like Echinochloa colona, E. crùs-galli etc. This might be the reason for the presence of more number of monocots compared to dicots. This is in agreement with the findings of Ravindran (1976), Abraham Varughese (1978) Sukumari (1982) and Shahi (1985). Figure 3 reveals that the weed population in weedy check increased almost steadily up to the 40th DT and there after the increase in number was negligible.

A. Monocot weeds.

The results of the weed count presented in Table 4 show that the monocot weed population in the weedy check increased from 198 on the 20th DT to 529 on the 40th DT and to 555 at harvest. In terms of competition the weed number per rice plant works out to 1.48 on the 20th DT, 3.95 on the 40th DT and 4.14 at harvest.

Among the herbicides tried, nitrofen and thiobencarb were superior in the early stages of growth, while during the later stages, they were on par with all other herbicides and hand weeding. The number of weeds per rice plant in nitrofen and thiobencarb treated plots were only 0.15 and 0.23 on the 20th DT, 0.87 and 1.33 on the 40th DT and, 1.45 and 1.50 at harvest respectively. Similar trends in weed number and competition on the 40th DT and at harvest were seen in other herbicide treated plots also. After 40th DT, the increase in weed number was not substantial. This also proves that the weed number and there by competition was severe from the 20th to 40th DT.

Abraham Varughese (1978) and Sukumari (1982) observed that the weed growth and competition within 40 days have significant influence on the rice yield.

In the hand weeded plot, the monocot weed count was on par with weedy check on the 20th DT because on both the plots no weed control measures were taken up to this stage. The number of weeds increased from 203 on the 20th DT to 230 on the 40th DT and decreased to 229 at harvest. This shows that hand weeding carried out on the 20th and 40th DT did not prevent further germination and establishment of weeds. In terms of per plant competition, the weed numbers were 1.5, 1.7 and 1.7 on the 20th DT, 40th DT and at harvest respectively, which shows that by hand weeding the number of weeds competing with the rice crop could not be reduced substantially.

From the above discussion, it can be inferred that by hand weeding or by herbicide treatment, the monocot weed population can be considerably reduced and thus competition can be minimised compared to weedy check. Similar results were reported by Mukhopadhyaya and Mondal (1981), Rao and Gupta (1981) and Dhananjai Singh et al (1985).

B. Dicot weeds.

In general the dicot weed population was comparatively low in all the plots (Table 4). The dicot weed population was lowest in the plot treated with nitrofen on the 20th DT where as it was lowest in the plot treated with pendimethalin on the 40th DT; however the effect of other chemicals was also on par. At all stages of crop growth the highest number of dicot weeds was observed in weedy check.

Among the treatments, nitrofen and pendimethalin were found to be most effective in reducing the dicot weed population during the critical periods of crop growth.

Mukhopadhyaya and Mondal (1981) got similar results with nitrofen. Verma et al (1978) and Lakshmi (1983) observed that the dicot weed population can be effectively controlled by herbicide treatment.

C. Total weeds.

It may be noted from the Table 4 that the total weed population in the weedy check increased from 231 per m^2 on the 20th DT to 591 on the 40th DT, after which the increase was only 6.84 weeds at harvest. In terms of competition, the weed number per rice plant increased from 1.72 on the 20th DT to 4.41 on 40th DT and 4.46 at harvest. This shows that the competition from weeds is very severe from the 20th DT to 40th DT in the weedy check.

Among the herbicides tried, nitrofen and thiobencarb were found to be superior to other herbicides on the 20th DT and there after all chemicals and hand weeding were on par except fluchloralin on the 40th DT. While studying the total number of weeds competing with a rice plant in the nitrofen and thiobencarb treated plots, it was found to be in the order of 0.22 and 0.33 on the 20th DT, 1.06 and 1.63 on the 40th DT, and 1.64 and 1.76 at harvest respectively. Similar trend of competition was observed in other herbicide treated plots also. From this it becomes clear that after the 40th DT, the increase in weed number was negligible which again proves that the weed number and thereby weed competition was severe in the early stages of crop growth (up to 40th DT). Similar observations were made by Abraham Varughese (1978) and Sukumari (1982).

In the hand weeded plot, the total weed population was on par with weedy check on the 20th DT, because no weed control measures were attempted in these plots upto 20th DT.

The data presented in Table 4 show that hand weeding done on the 20th DT did not prevent further germination and establishment of weeds between the 20th DT and 40th DT. Actually the number of weeds was more (260) than that was available on the 20th DT (236). The number of weeds per rice plant on the 20th DT, 40th DT and at harvest were 1.76, 1.94 and 1.84 respectively. At the time of hand weeding, soil is stirred, which might have induced germination of weed seeds and also seeds lying below were brought to surface.

During the process of hand weeding due to human error, some small weeds are left unnoticed, and some weeds get broken at ground level and regenerated, which may not give a tough competition as fully grown weed. This may be the reason why the hand weeding was found to be on par with all the herbicides on 40th DT and at harvest.

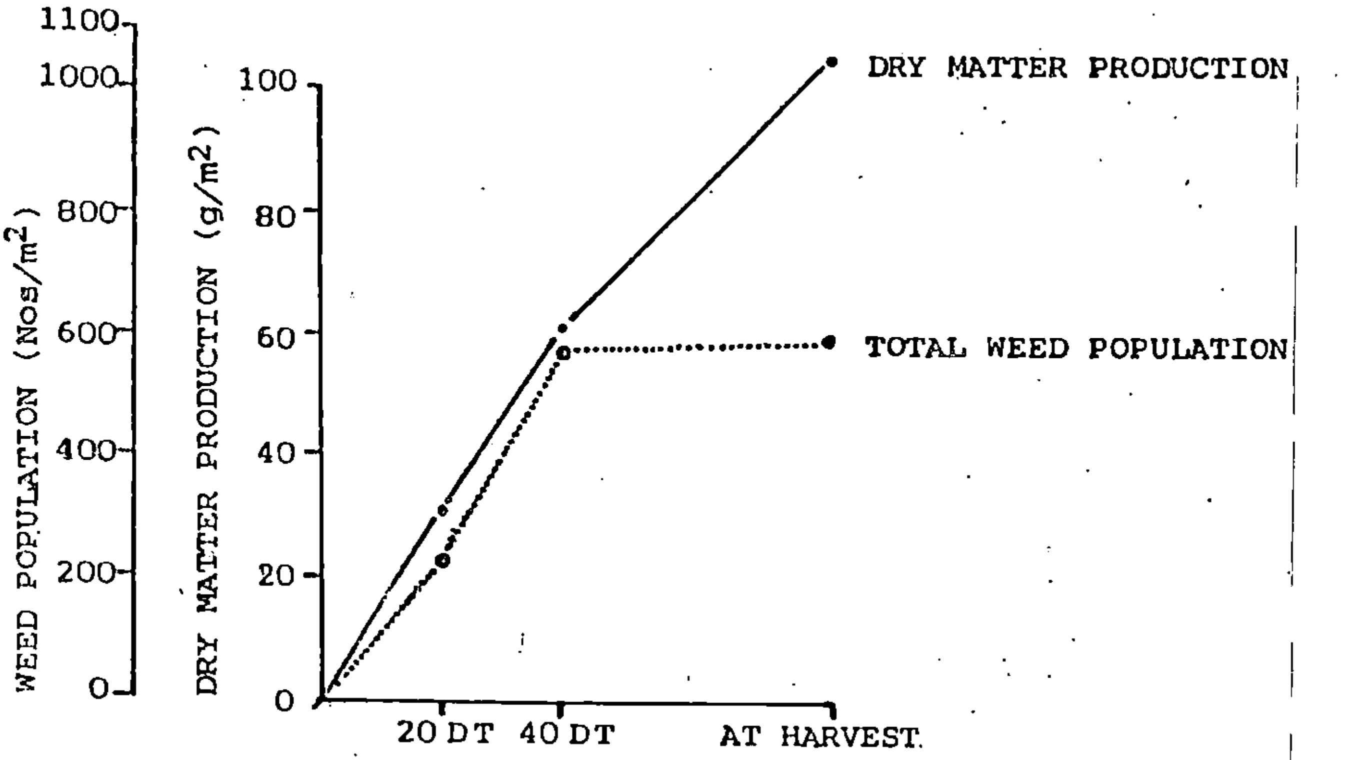

FIG.3 WEED POPULATION AND WEED DMP IN WEEDY CHECK-FIRST CROP

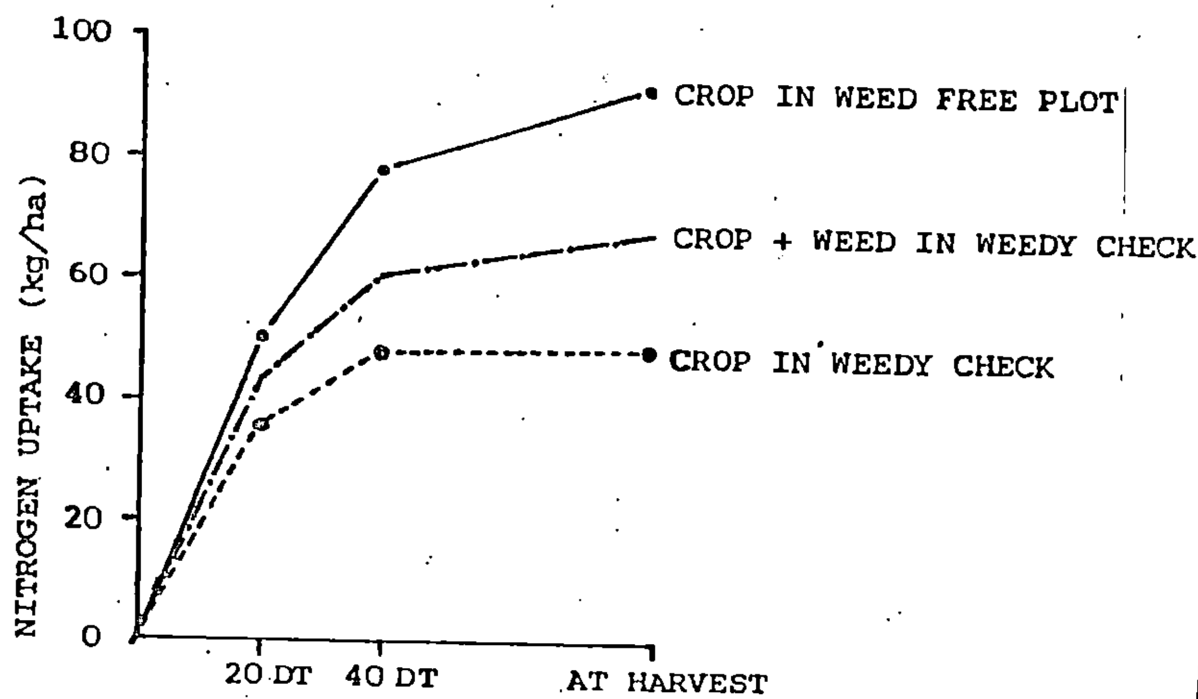

FIG.4 PATTERN OF NITROGEN UPTAKE IN THE FIRST CROP

In general, it may be seen that by herbicide treatment and by hand weeding, the total weed population can be reduced which in turn provide a congenial environment for growth and establishment of rice crop.

Singh et al (1979), Mukhopadhyaya and Mondal (1981) and Lakshmi (1983) have reported the superior herbicidal action of nitrofen while Ravindran (1976), Chela and Gill (1981), De Datta (1981) and Shahi (1985) got better weed control with thiobencarb.

3. <u>Dry matter production by weeds.</u>

An appraisal of the data presented in Table 5 and Fig. 3 reveals that the total weed DM in weedy check was the highest on the 40th DT and at harvest. However, the DM was almost proportional to the total number of weeds on the 20th and 40th DT. But at harvest, eventhough the incremental increase in total weed population per m^2 was the lowest (6.84), the DM was more (0.18 g per weed) compared to the 40th DT (0.10 g) and the 20th DT (0.14 g). Unchecked weed growth might have enabled to absorb nutrients in greater amounts and thus produced highest DM.

Among the herbicides, nitrofen, thiobencarb and butachlor decreased the total weed DM at all stages of crop growth. The reduction in the total DM in these herbicide treated plots was more due to the reduction in weed number per unit area, rather than due to individual plant accumulation. Rao and Gupta (1981) and Lakshmi (1983) found reduction in DM by the application of nitrofen while De Datta (1981) and Shahi (1985) proved that thiobencarb was more effective in reducing DM in transplanted rice. Pareira and Ghosh (1980), Singh and Sharma (1981) and Shahi (1985) recorded reduced DM by the application of butachlor in transplanted rice.

In the hand weeded plot, the DM was more or less equal to that of weedy check in the early stage of growth, since no weed control measure was taken in both the plots upto 20th DT.

The DM per weed on the 20th DT, 40th DT and at harvest in the hand weeded plot was 0.14, 0.14 and 0.17 respectively. Probably weeds could not accumulate sufficient dry matter during the period from the 20th DT to 40th DT as in the early and later stages. This may be due to the severe competition of the rice crop and in the later stages of growth (after the 40th DT) the weeds got nearly 45 days for growth and dry matter accumulation. On the 40th DT and at harvest, hand weeding was on par with nitrofen, thiobencarb and butachlor. Similar findings were reported by Dhananjai Singh et al (1985) and Patil et al (1986).

In general it can be seen that the variation in DM was more due to the weed population rather than due to individual contribution.

4. Weed Control Efficiency.

Weed control efficiency worked out for various treatments are presented in Table 6.

The highest weed control efficiency of 76-87 percent during the critical period of crop growth was found in nitrofen treated plot, closely followed by thiobencarb (63-81 percent). Next highest efficiency was shown by hand weeding (56 percent). Pendimethalin had a weed control efficiency of 50 percent only. Fluchloralin had the least efficiency.

In general, the above discussion reveal that nitrofen and thiobencarb have the highest weed control efficiency, which is higher than hand weeding. This is in conformity with the findings of Mohammed Ali and Sankaran (1975), Ravindran (1976), Sreedevi (1979) and Lakshmi (1983).

5. Nutrient removal by weeds.

It is seen from the Table 7 that in general, nutrient removal by weeds at all stages of growth was highest in the weedy check. This reveals that large quantities of the available nutrients in the soil have been exploited by weeds for their growth and development which in turn adversely affected the yield of the crop (Table 10).

Weeds in the weedy check removed nitrogen, phosphorus and potassium at the rate of 6.89 kg, 2.41 kg and 5.23 kg per ha on the 20th DT; 12.90 kg, 4.73 kg and 9.34 kg per ha on the 40th DT; and 19.98 kg, 7.86 kg and 13.46 kg per ha at harvest respectively.

Among the herbicides tried, nitrofen and thiobencarb treated plots closely followed by butachlor showed lowest NPK removal by weeds compared to other treatments.

Weeds in hand weeded plot removed almost equal amount of NPK as in the case of weedy check on the 20th DT, probably due to non-weeding till that stage. But on the 40th DT the nutrient removal in this treatment was lowest and at harvest second lowest as compared to other treatments.

In general, nitrofen, thiobencarb, hand weeding and butachlor significantly reduced the NPK removal by weeds compared to other treatments at all stages of growth.

It can also be noticed that the nutrient removal is directly related to the dry matter accumulation of weeds. Among the treated plots, the trend of removal of NPK is almost the same at all stages and no preferential absorption of any of the nutrients by weeds was observed in these plots. John (1981) and Lakshmi (1983) also expressed this view.

In general, the nutrient removal was more in the case of nitrogen followed by potassium and phosphorus. Similar observations were made by Ravindran (1976), John (1981) and Lakshmi (1983).

Observation on Crop

Results of observations on biometric characters, yield attributes, yield and chemical analysis of plant parts are discussed below.

1. Crop growth characters.

A. Height of plants.

Completely weed free treatment produced the tallest plants at all stages of growth (Table 8) and shortest plants were recorded in the weedy check on the 40th DT and at harvest. This corroborates with the findings of Patil et al (1986).

In the early stage of crop growth, there was not much difference in plant height in herbicide treated plot, hand weeded plot and weedy check except in nitrofen treated plot. On the 40th DT, thiobencarb, nitrofen and butachlor were found to be on par with hand weeding as well as completely weed free. This shows that in the early stage the plant height was not adversely affected by the weed competition as well as by the chemical effect of the herbicides on the crop.

At harvest, thiobencarb, nitrofen and butachlor continued to show parity with hand weeding in producing tallest plants. This reveals that these herbicides and hand weeding suppressed the weed growth both in number as well as total DM. So the crop plants were able to establish well and produce nearly uniform height as in the case of weed free plot. But in weedy check the plant height was significantly reduced on the 40th DT and at harvest. Mohamed Ali and Sankaran (1975) and Yamogishi et al (1976) expressed similar views.

B. Tiller number.

The tiller count was taken at maximum tillering stage and the data presented in Table 8 show that completely weed free plot which produced highest number of tillers (476.60 per m^2) was on par with hand weeding, nitrofen, thiobencarb and butachlor. This shows that these herbicides could effectively contain weed competition and increased the tiller production equal to that of weed free situation.

Due to severe weed competition, tiller number was lowest in weedy check (401.33 per m^2). Experiments of Narayana Swamy (1976), Gill and Mehra (1981) and Shahi (1985) recorded identical results.

The highest tiller count of 476.60 per m^2 obtained in the weed free plot may be due to the additional benefit of soil stirring given at the time of weeding there by providing better aeration in the root zone. The hand weeded plot also received such a benefit twice compared to herbicide treatments.

C. Leaf Area Index.

The leaf area index was the lowest (3.36) in the weedy check (Table 8). Severe weed competition in this plot adversely affected the vegetative characters and growth of the plant which was reflected in the low plant height and least tiller number recorded in that plot. Similar results were obtained in trials conducted by Yamogishi et al (1976) and Sreedevi (1979).

Among the herbicides, nitrofen and thiobencarb had LAI as good as that of hand weeding (4.27) and completely weed free (4.32) treatments. This shows that the crop had a normal growth and the remaining weeds could not significantly influence this character in these plots. The LAI of butachlor treated plot was nearly equal to that of thiobencarb treatment.

This result indicate that the thiobencarb, nitrofen and hand weeding treatments produced LAI as good as that of weed free plot. Since there was no competition for nutrients, space and sunlight from the weeds, the weed free plot was able to express pronounced growth parameters including the LAI where as in weedy check, severe weed competition retarded the crop growth and registered the lowest LAI.

The above discussion points to the fact that weeds growing in association with the crop will reduce the vegetative potential of the crop.

2. Yield components.

Comparative study revealed that all the herbicidal treatments as well as hand weeding significantly influenced almost all yield components.

A. Panicle number.

The data presented in Table 9 show that all the treatments had significant and favourable effect on panicle number over weedy check. Highest number of panicle (407 per m^2) was produced in completely weed free plot, followed by hand weeding (379 per m^2). Complete removal of weeds has created a condition conducive for maximum tiller production and highest number of panicles per unit area.

The panicle number in nitrofen and thiobencarb treatments were the highest among the herbicides tried and these two herbicides were on par with hand weeding. This is in conformity with the findings of Ravindran (1976) and Lakshmi (1983).

Percentage of productive tillers also show that weed free plot had the highest (85.3 percent) followed by hand weeding, (81.6 percent) nitrofen (81.2 percent) and thiobencarb (80.7 percent).

Extreme weed competition in weedy check adversely affected the tillering of rice plant and lowered the panicle number to 278 per m^2. Findings of Mohamed Ali and Sankaran (1975), Ghosrial (1981) and Patil et al (1986) highlights the reduction in panicle number due to weed competition.

B. Length of panicle.

As in the case of panicle number, the length of panicle was also significantly influenced by the various treatments (Table 9). Weed free treatment produced the largest panicles (22.10 cm), followed by thiobencarb, nitrofen, pendimethalin and hand weeding. All these three herbicides and hand weeding were on par with respect to this character. May be due to heavy competition for nutrients, space and sunlight, the length of panicle recorded in weedy check was significantly reduced (13.87 cm). Narayana Swamy (1976), Sukumari (1982) and, De Datta and Hoque (1982) observed decrease in length of panicle due to weed competition.

C. Weight of panicle and number of filled grains per panicle.

The greatest weight of panicle (2.01 g) and the largest number of filled grains (59.20) were produced by the plants in weed free plot. These characters were also on par with that of nitrofen treatment, which revealed that rice plant in weed free plot and nitrofen treatment could enhance their photosynthetic activity and store more photosynthote in their reproductive parts.

Out of the five herbicides tested, nitrofen, thiobencarb and butachlor produced panicles with greater weight and they were on par with hand weeding while nitrofen was superior to other herbicides and hand weeding with respect to the total number of filled grains. Weed competition in these plots was effectively checked there by the crop was able to express its maximum potential to produce these attributes.

Weedy check recorded the lightest panicle (1.35 g) with the lowest number of filled grains per panicle (26.64). Sreedevi (1979) and John (1981) have also reported adverse effect of weed growth on the panicle weight and number of filled grains per panicle.

D. Thousand grain weight.

None of the treatments could significantly influence the thousand grain weight. Grain weight being more or less a genetic character, the presence or absence of weeds might not have significantly influenced this character. Similar observations were made earlier by Ravindran (1976) and Sukumari (1982).

3. Yield.

A. Grain yield.

It is clear from the Table 10 and Fig. 5 that the grain yield was significantly influenced by various weed control treatments. The highest grain yield was obtained from the plots free of weeds (67.54 percent increase over control) and the lowest yield was from weedy check. Zero weed competition enabled the rice crop in weed free plot to exploit the nutrients, light and space for its normal growth and development to the maximum extent. This high yield of 3954 kg per ha is the overall effect of the superior yield attributes such as panicle number, panicle length, panicle weight and number of filled grains per panicle observed in the weed free plot.

Weedy check produced the lowest grain yield of 2360 kg per ha due to severe weed competition as evidenced in Table showing yield attributing factors. Nitrofen recorded the highest grain yield among the herbicides followed by thiobencarb and butachlor and they recorded an increase in yield to the tune of 60.0 percent, 59.5 percent and 56.2 percent respectively, over the weedy check. But they were on par with hand weeding which recorded an yield of 3759 kg per ha and an increase of 59.3 percent over control treatment. Ravindran (1976) and Lakshmi (1983) recorded identical yield with nitrofen 1.875 kg a.i. per ha. Above yield of thiobencarb was supported by

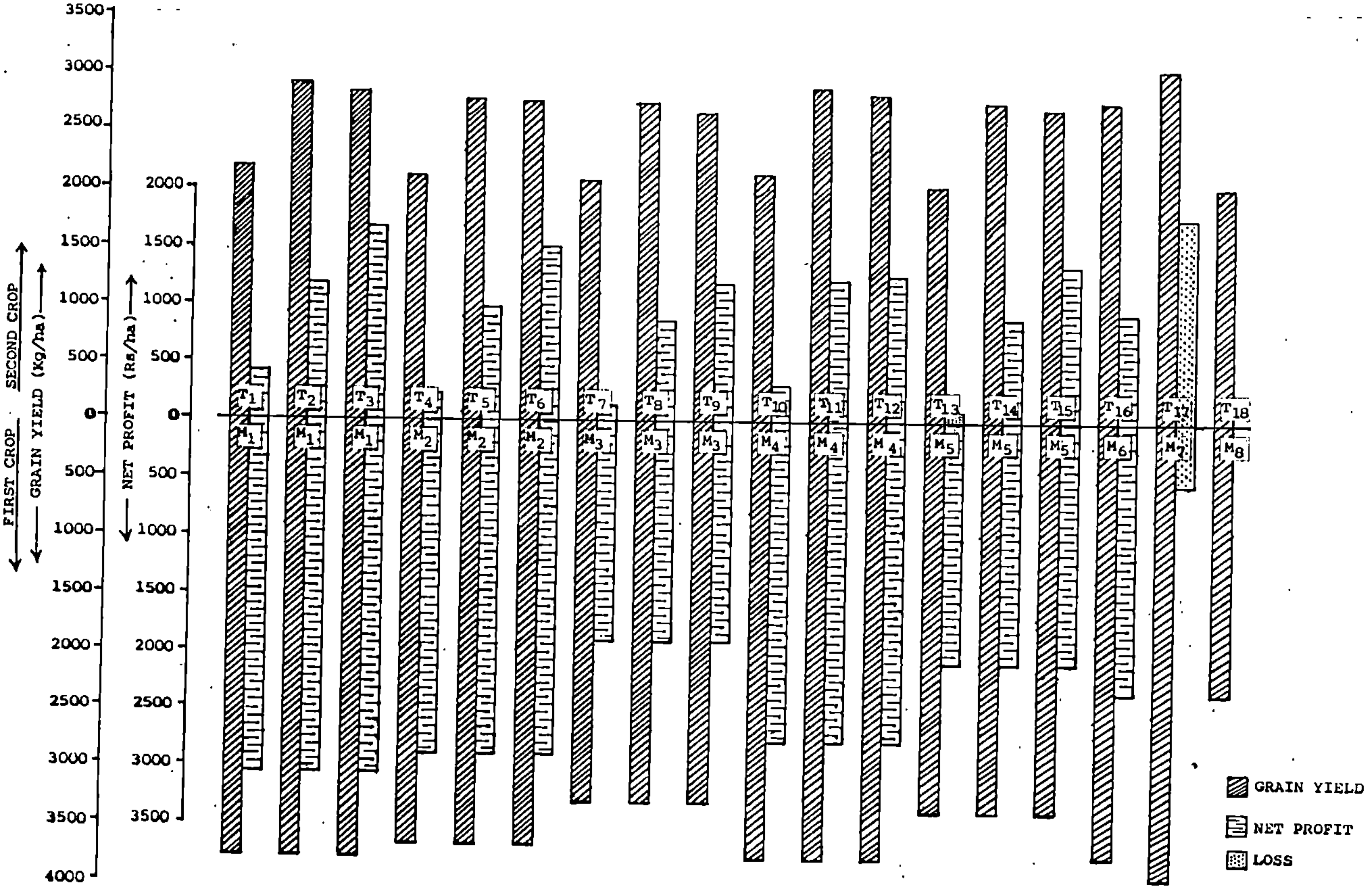

FIG.5 TOTAL GRAIN YIELD AND NET PROFIT OVER WEEDY CHECK - FIRST AND SECOND CROPS

Shahi (1985) and, Singh and Singh (1985a). Comparable yield of butachlor was reported by Pareira and Ghosh (1980) and Samar Singh et al (1986).

B. Straw yield.

A study of the data presented in Table 10 reveals that straw yield was significantly influenced by the various treatments. As in the case of grain yield, lowest straw yield of 2576 kg per ha was recorded in the weedy check, where the plant height and tiller production were lesser due to severe weed competition. Weed free treatment produced the highest straw yield of 4204 kg per ha which is contributed by the high plant height, larger leaf area and more number of tillers and higher absorption of nutrients by the crop.

Among the herbicides, thiobencarb produced 55.2 percent higher straw yield than weedy check followed by nitrofen (54.8 percent higher) and butachlor (49.7 percent higher) and they were equal to that of hand weeding.

Second highest straw yield was obtained from hand weeded treatment (4022 kg per ha). Hand weeding not only remove the weeds but also provides favourable soil conditions. Ravindran (1976) John (1981) and Lakshmi (1983) also got similar results. Patil et al (1986) reported that unchecked weed growth reduced straw yield significantly.

C. Crop dry matter production.

Study of the data presented in Table 10 revealed that various treatments had significant effect on the total crop dry matter production. Crop plant in the weed free plot was in the most advantageous situation, where they could exploit all the available nutrients and other inputs and produced highest DM of 7563 kg per ha. On the contrary, unrestricted weed growth, reduced the crop DM in weedy check to 60 percent of that of weed free plot. It may be noted that lowest values of almost all growth characters and yield were registered by the weedy check. This is in agreement with the findings of Ravindran (1976) and, Ali and Sankaran (1984).

Next to weed free plot, hand weeded plot produced higher crop dry matter which was statistically equal to that of nitrofen, thiobencarb and butachlor. These herbicides showed the efficiency in countering the weed competition equal to two hand weeding and created a congenial atmosphere where the crop could exhibit its normal growth and development. Similar results were reported by Dubey and Rao (1985) and Patil et al (1986).

D. Protein content of grains.

Data presented in Table 10 show that there was no significant difference among the protein percentage recorded by various treatments. Thus it is evident that presence or absence of weeds could not influence the protein content of grains.

4. Weed Index.

The lowest weed index of 4.15 (Table 11) was worked out for nitrofen closely followed by thiobencarb (4.81), hand weeding (4.93) and butachlor (6.75). This shows that nitrofen and thiobencarb were better than hand weeding. Next in order having high efficiency were fluchloralin and pendimethalin.

The control plot showed a very low efficiency compared to the herbicides referred above and hand weeding. And it recorded the highest value of weed index (40.31). Lowering of weed index by proper control of weeds was reported by Ravindran (1976), Sreedevi (1979) and John (1981) and the present findings are in agreement with these earlier findings.

5. Nutrient uptake by the crop.

Results of the study on the pattern of NPK uptake by the crop (Table 12) revealed that, in all the treatment plots N and K uptake was more than P through out the crop period. Sukumari (1982) and Lakshmi (1983) reported similar trend in nutrient absorption by the crop.

The weedy check registered the lowest uptake of nutrients at all stages of growth and it was 48.24 kg N, 18.34 kg P and 32.52 kg K per ha at harvest. Compared to the weed free treatment which recorded the highest nutrient uptake the unchecked weed growth in the control plot reduced the absorption of NPK by the crop to the tune of 52 percent, 54 percent and 62 percent respectively.

On 20th DT, the NPK uptake in weed free plot was the highest and it was on par with that of thiobencarb and they were closely followed by butachlor and nitrofen.

Nutrient uptake on the 40th DT and at harvest also was highest in weed free plot and was superior to the herbicides tried and hand weeding. Thiobencarb, nitrofen, butachlor and hand weeding treatments showed next higher uptake in general.

Taking the whole crop growth in to consideration, it may be noted that uptake of nutrients by the crop was more where the weeds were comparatively less. Comparative study of data in Table 5 and 10 revealed that wherever the dry matter production of weed was higher, the dry matter production of crop was low and vice versa. This was reflected in the nutrient uptake pattern also. Figure 4 show that the total uptake of nitrogen by the crop + weed in the weedy check was less than that of crop alone in the weed free plot. This might be due to the crop weed antagonism. Same trend was noticed in the uptake of phosphorus and potassium also.

Significant influence of herbicides and hand weeding on nutrient uptake of rice has been reported by Shahi (1985) and Singh and Singh (1985 b).

It can also be seen that upto the 20th DT, the crop plant did not suffer significantly from the weed competition. This is in agreement with the views expressed by Moody (1977) and Sukumari (1982).

6. Economics of weed management.

Application of thiobencarb resulted in the highest net return of Rs. 3074 per ha and was as good as butachlor and nitrofen. Data presented in Table 10 and 13 show that on par with farmers practice of hand weeding these herbicides produced an increased yield of 59 percent, 56 percent and 60 percent respectively over weedy check where as the cost of manual weeding in hand weeded plot was about 2.4, 3.2 and 1.5 times greater than these herbicides.

Labour charge incured for maintaining the weed free condition was about nine times more than that of thiobencarb treatment and thus eventhough it registered the highest grain yield, weed free treatment was found to be a loss.

Above discussion revealed that application of thiobencarb or butachlor or nitrofen was the most profitable weed management technique for rice in first crop season. Chang et al (1976), John (1981) and Lakshmi (1983) also reported that herbicide treatment gave higher net profit than hand weeding treatment.

SECOND CROP

Observation on Weeds

1. Weed species.

Weed species collected and identified from the experimental plot during the second crop season were compared with those present during the first crop season. It was found to be the same as that observed during the first crop season (Table 3). It revealed that there was no shift in weed species during the second crop season due to the application of herbicides during the first crop season. The low rate of the herbicides used in this study may be the reason for the above observation.

2. Weed population.

The data presented in Table 14 and 15 revealed that the number of monocot weeds was always higher than the dicot weed population throughout the crop growth period. The incremental increase in weed population in general was more in the early stage than in the later stages. This was the trend observed during the first crop season also.

A. Monocot weeds.

With respect to monocot weed population, the previous season's herbicide application had not influenced their number during the second crop season (Table 14). In the early stages of crop growth during the second crop season, herbicide application suppressed the number of weeds and as the growth continued, both herbicides and hand weeding suppressed the population compared to the unweeded sub plot. So it may be concluded that the monocot weed population could not be controlled substantially in the second crop season by the application of herbicides in the first crop season.

Comparing the monocot weed population of herbicide treated sub plots with the plots hand weeded in both the seasons, it was observed that in the early stages of crop growth, all the herbicides suppressed the weed population. Nitrofen, thiobencarb and butachlor were superior to others in all the stages of crop growth.

On 20th DT, fluchloralin-hand weeding, thiobencarb-hand weeding and butachlor-hand weeding were superior to hand weeding-hand weeding. As the growth advanced, the herbicides-hand weeding plots were on par and at harvest stage even superior over hand weeding-hand weeding. This indicates that the residual effect of herbicide application was not effective for suppressing monocots during the second crop.

With respect to herbicide residual study, ie: herbicide-no weeding, results indicate that only on the 20th DT, thiobencarb-no weeding was superior to hand weeding-hand weeding, while butachlor-no weeding and pendimethalin-no weeding were on par and nitrofen-no weeding and fluchloralin-no weeding were inferior. This indicate that thiobencarb-no weeding showed a tendency of suppressing monocot weed population in the second crop season.

Keeping the plots unweeded continuously during second crop season substantially increased the monocot weed population compared to herbicide-no weeding plot. This is natural because there was no hindrance either mechanical or chemical in the establishment of this group of weeds in the weedy check.

In compa ring the herbicide treated sub plots, it was found that thiobencarb and nitrofen suppressed the monocots throughout the crop period and at harvest all the treatments were on par. This show that repeated application of thiobencarb and nitrofen were superior than other herbicides.

Superior herbicidal effect of thiobencarb was also reported by Dubey and Rao (1985) and Patil et al (1986).

Thiobencarb-hand weeding showed its superiority in suppressing monocot weed population throughout the crop growth period and it was closely followed by nitrofen-hand weeding.

Among the unweeded sub plots, it was again found that thiobencarb-no weeding reigned supreme in the early stages of crop growth compared to the other unweeded sub plots.

Comparison of all the sub plots of the second crop season, it was found that thiobencarb-thiobencarb was effective in the early stages followed by thiobencarb-hand weeding.

It can be concluded that herbicide-herbicides was better than herbicide-hand weeding or herbicide-no weeding in the early stage of growth and in the reproductive phase herbicides-hand weeding and herbicide-herbicide were superior. Taking the monocot weed population it may be concluded that repeated application of thiobencarb in both the seasons was more effective than other herbicides.

Effective control of monocot weeds by thiobencarb was reported by Lakshmi (1983) and Patil et al (1986) and, that of nitrofen by Lakshmi (1983). Dubey and Rao (1986) found that equal weed control can be achieved by two hand weedings. The present findings are in agreement with these results.

B. Dicot weeds.

At all stages of crop growth repeated application of herbicides could reduce the dicot weed population better than herbicide-hand weeding (Table 15). Application of herbicides in the previous season did not reduce the number of dicots substantially during second crop season. On the 40th DT, butachlor and fluchloralin, followed by same treatment or hand weeding in the second crop had equal effect.

Compared to hand weeding-hand weeding, repeated application of nitrofen, pendimethalin, fluchloralin and butachlor were superior at all stages of crop growth; nitrofen-hand weeding, butachlor-hand weeding and thiobencarb-hand weeding gave better performance than hand weeding-hand weeding upto the 40th DT; but at harvest, they were all equal.

Throughout the crop period, dicot weed population was more in unweeded sub plots than hand weeding-hand weeding which shows that herbicide application during the first crop season did not reduce the weed population in the succeeding season; but in the plots of thiobencarb-no weeding and nitrofen-no weeding, dicot weed population was less than weedy check. The possible reduction in weed seed number in the soil by the action of herbicides might have resulted in the above reduction of dicot weed population.

Among the herbicide treated sub plots, nitrofen controlled dicot weeds more efficiently upto the 40th DT followed by pendimethalin and fluchloralin, while at harvest, the weed population was levelled off.

Considering the dicot weed population as a whole , fluchloralin, nitrofen and butachlor in the first crop season followed by hand weeding in the second crop season could reduce dicot weed population at later stage of crop growth.

Summarizing the above discussion, it can be concluded that hand weeding in the second crop preceded by nitrofen, butachlor or thiobencarb or other herbicides in the first crop were better than hand weeding-hand weeding.

Verma et al (1978), Singh et al (1979) and Lakshmi (1983) observed that the dicot weed population can be effectively controlled by herbicide treatment and or on par with hand weeding.

C. Total weeds.

Herbicides applied during the first crop season alone have not influenced substantially the total weed population during the second crop season. In an experiment with butachlor, Ahmed and Zahidul Hoque (1981) found that this herbicide had no residual effect on the weed growth of the second crop. In the early stage of crop growth, the herbicides applied during the second crop season suppressed the number of weeds and as the growth continued both herbicides and hand weeding suppressed the weed population compared to the unweeded sub plots.

Comparison of the herbicide treated sub plots with the hand weeding-hand weeding shows that on the 20th DT, all the herbicides suppressed the weed population; on the 40th DT, thiobencarb, butachlor and nitrofen were superior and at later stage, they were equal to hand weeding-hand weeding.

Compared to hand weeding-hand weeding, thiobencarb-hand weeding and fluchloralin-hand weeding were superior and butachlor-hand weeding was equal in the early stage of crop growth and at harvest there was no difference between herbicide-herbicide and hand weeding-hand weeding.

Regarding the residual effect (ie. comparison of no weeding sub plots) thiobencarb-no weeding shows a substantial reduction in total weed population in the early stage and as the crop growth advanced, none of the herbicide showed any residual effect in reducing the total weed population in the second crop season.

In weedy check, the total number of weeds were very high compared to herbicide-no weeding plots.

Among the plots in which herbicides were applied in both the seasons, thiobencarb and nitrofen effectively checked the total weed population throughout the crop period.

Throughout the crop period, thiobencarb-hand weeding ranked first and on the 40th DT, it was on par with nitrofen-hand weeding. This revealed that thiobencarb application in the first crop season and hand weeding during second crop season was the best combination in the system approach. This was again illustrated by the fact that among the unweeded sub plots, lowest weed count was observed in thiobencarb-no weeding treatment.

A comparison of all the sub plots during the second crop season, it was found that application of thiobencarb and nitrofen in both the seasons were very effective in the early stages of crop growth followed by thiobencarb-hand weeding. Unchecked weed growth in two consecutive seasons resulted in the production of highest total number of weeds in weedy check.

It can be concluded in general that total weed population of second crop could not be reduced by the residual effect of herbicides applied during the first crop season. Among the herbicides, thiobencarb and nitrofen very effectively checked the weed growth during the critical stages of crop growth, followed by thiobencarb-hand weeding and nitrofen-hand weeding.

Singh et al (1979), and Mukhopadhyaya and Mondal (1981) reported the superior herbicidal action of nitrofen, while Dubey and Rao (1985) and Patil et al (1986) found better weed control with thiobencarb (equal to hand weeding).

3. Dry matter production by Weeds.

Comparison of sub plots within each main plot revealed that dry matter production in herbicide treated sub plots were the lowest and the application of herbicide during the first crop season had not significantly influenced the DM of weeds during the second crop season (Table 17). Similar observation was made by Ahmed and Zahidul Hoque (1981) also. No difference was observed between hand weeded and unweeded sub plots in the early stage as they were subjected to same conditions upto the 20th DT. On the 40th DT and at harvest, DM was statistically equal in the respective herbicides treated and hand weeded plots and both produced significantly less weed dry matter than unweeded sub plots.

Up to the 40th DT, dry matter production in all the herbicide-herbicide sub plots were less than hand weeded-hand weeded plots. The herbicides not only reduced the germination of weeds, but also could suppress the further growth and development of weeds already germinated, compared to hand pulling. At harvest stage, the effect of herbicides was not significant.

Similarly upto the 40th DT, thiobencarb-hand weeding, butachlor-hand weeding and nitrofen-hand weeding were superior in reducing the DM than the hand weeding-hand weeding. Significant control of weed flora during the first crop season by the use of herbicides might have helped in the reduction of weed population and DM during the second crop season. In the case of hand weeding such control was not possible because of the human error. This might have resulted in a higher number of weeds in the hand weeded-hand weeded plots compared to herbicide treated plots.

Compared to hand weeding-hand weeding, unweeded sub plots of second crop produced more weed dry matter whereas in comparison with weedy check, herbicide-no weeding recorded less DM. This may be due to the possible reduction of the weed flora during the first crop season in the previously herbicide treated plots or due to the highest number of weeds germinated, grown and multiplied in the weedy check.

Among the herbicides, highest DM by weeds was in nitrofen treated sub plot followed by thiobencarb, which show that they could reduce the germination and establishment of weeds better than other herbicides.

With respect to reduction in dry matter production of weeds in the hand weeded sub plots, though thiobencarb-hand weeding was superior in the early stage, there was no statistical difference in the later stages.

Among all the sub plots of second crop season, upto the 40th DT, lowest weed DM was found in nitrofen-nitrofen plot followed by thiobencarb-thiobencarb sub plot. At harvest stage nitrofen-hand weeding, followed by thiobencarb-hand weeding and nitrofen-nitrofen plots were better.

In general weed DM in herbicide-no weeding sub plots was less than that in weedy check. In the system approach lowest weed DM was noticed in nitrofen-nitrofen and thiobencarb-thiobencarb plots followed by nitrofen-hand weeding and thiobencarb-hand weeding. It can therefor be inferred that efficient weed control methods can supress weed competition and reduce the weed dry matter accumulation.

Rao and Gupta (1981), and Lakshmi (1983) observed reduction in weed DM by the application of nitrofen where as Dubey and Rao (1985), and Shad (1986) recommended thiobencarb for reducing the DM of weeds.

4. Weed Control Efficiency.

In general it was observed that Weed Control Efficiency of all herbicide treatments manifests its maximum effect in the early stages and that of hand weeded sub plots on the 40th DT (Table 18). It slowly decreased towards the harvest.

On 20th DT, all herbicide treated sub plots showed WCE above 64 percent with a highest value of 79 scored by thiobencarb-thiobencarb and nitrofen-nitrofen. All hand weeded sub plots as well as unweeded sub plots at this stage recorded low values of WCE (less than 35 percent). It may be noted that upto the 20th DT, no weed control operations were attempted in these plots.

On the 40th DT, highest WCE was observed in nitrofen-nitrofen (71 percent) closely followed by thiobencarb-hand weeding (70 percent) and nitrofen-hand weeding (70 percent), and thiobencarb-thiobencarb (69 percent). At this stage lowest WCE was noticed in pendimethalin-no weeding (7 percent) and fluchloralin-no weeding (8 percent). The highest number of total weeds found in these plots on the 40th DT itself shows the low efficiency of these treatments.

At harvest, highest WCE was shown by thiobencarb-thiobencarb (68 percent) followed by thiobencarb-hand weeding (66 percent), thiobencarb-no weeding (64 percent), butachlor-hand weedy (63 percent), nitrofen-nitrofen (62 percent) and hand weeding-hand weeding (62 percent). Pendimethalin-no weeding and fluchloralin-no weeding recorded the lowest WCE of 5 percent and 9 percent respectively.

Lakshmi (1983) and, Dubey and Rao (1985) reported high WCE of thiobencarb and nitrofen.

5. Nutrient removal by weeds.

The data presented in Table 19 to 21 revealed that, the nutrient removal by weeds varied with the type of nutrient and stage of the crop. Different weed management techniques adopted also affected the nutrient absorption by weeds.

While comparing the nutrient removal of sub plots within each main plot, it was found that on the 20th DT, weeds in all herbicide treated sub plots removed significantly less NPK than that removed from the respective hand weeded and unweeded sub plots. But on the 40th DT, herbicide treatment and hand weeded treatments could equally reduce the nutrient removal than the no-weeding treatment. This trend was noticed at harvesting stage also with respect to P and K removal, where as weeds in hand weeded plots removed only less nitrogen than those in herbicide treated plots and unweeded plots.

Compared to hand weeding-hand weeding, weeds in all herbicide treated sub plots, thiobencarb-hand weeding, nitrofen-hand weeding, butachlor-hand weeding, thiobencarb-no weeding and nitrofen-no weeding sub plots could remove less NPK only on the 20th DT. This may be due to the reduced number of weeds present and low levels of weed dry matter accumulation observed in these plots. On the 40th DT also, all hand weeded sub plots and thiobencarb-thiobencarb, nitrofen-nitrofen and butachlor-butachlor could effectively reduce NPK removal than hand weeding-hand weeding.

Though nitrofen-nitrofen, thiobencarb-thiobencarb and nitrofen-hand weeding maintained their superiority in checking the nutrient removal by weeds, compared to hand weeding-hand weeding, there was no significant difference in the nutrient removal of other herbicides and hand weeded sub plots.

The weed growth in all the unweeded sub plots in general removed higher quantity of nitrogen (13.6 to 15.8 kg per ha), phosphorus (4.7 to 5.4 kg per ha) and potassium (3.1 to 3.6 kg per ha) than hand weeding-hand weeding (6.2, 2.2 and 1.5 kg NPK per ha respectively), but less than that of weedy check which registered a nutrient removal of 16.9 kg N, 6.0 kg P and 4.0 kg K per ha.

Among the various herbicides used in the second crop, there was no significant difference in NPK removal in any of the stages except nitrofen-nitrofen and thiobencarb-thiobencarb which could reduce NPK removal more effectively than other herbicides in the early stages.

Among the various hand weeded sub plots, there was no significant difference except thiobencarb-hand weeding which was superior in reducing P and K removal on the 20th DT and N removal at harvest whereas nitrofen-hand weeding recorded less NPK removal at later stages.

Though thiobencarb-no weeding recorded comparatively low nutrient removal in most of the stages, there was no significance among the unweeded sub plot treatments.

Up to the 40th DT, thiobencarb-thiobencarb or nitrofen-nitrofen significantly reduced NPK removal by weeds while butachlor-butachlor could suppress NPK removal only in the early stage, which may be due to the suppressing effect on weed growth by the former treatments for a longer period than butachlor-butachlor.

At harvest repeated application of nitrofen or thiobencarb or butachlor and or in combination with hand weeding, and hand weeding-hand weeding could reduce NPK removal of weeds with equal effect, except thiobencarb-hand weeding which recorded significantly low nitrogen removal.

The NPK removal by weeds in the weedy check was very high (16.9, 6.0, 4.0 kg per ha respectively) when compared to all other treatments. This showed that a larger quantity of available nutrients in the soil have been exploited by the uncontrolled weeds for their growth and development which adversely affected the yield of the crop.

Experiments conducted by Ravindran (1976), Sreedevi (1979) and John (1981) revealed that weeds in weedy check absorbed higher quantity of NPK and that the nutrient removal by weeds could be reduced by the application of herbicides and hand weeding.

Observation on Crop

1. Crop growth characters.

Study of the observations taken show that the treatments have influenced all the crop growth characters (Table 22).

A. Height of plants.

Comparing the sub plots of each main plot, it was found that in general herbicides in the early stages and herbicides-hand weeding in the later stages significantly influenced plant height in relation to the unweeded sub plots of each main plot.

Application of thiobencarb during the first and second crop seasons significantly and favourably influenced plant height throughout the growth period while nitrofen-nitrofen and hand weeding-hand weeding showed its superior efficiency from the 40th DT onwards. These herbicides were superior than hand weeding-hand weeding.

Compared to hand weeding-hand weeding, thiobencarb-hand weeding, nitrofen-hand weeding and butachlor-hand weeding significantly influenced the plant height in the later stages of crop while, they were as good as hand weeding-hand weeding on the 20th DT except butachlor-hand weeding. Thiobencarb-hand weeding and nitrofen-hand weeding could control the weed growth and could help the crop better than hand weeding-hand weeding in increasing the plant height where as butachlor-hand weeding could not help the crop plant upto this level on 20th DT.

Plant height was significantly reduced in the unweeded sub plots compared to hand weeding-hand weeding and weed free plot from 40th DT onwards. In the early stage, the plant height was erratic. Upto the 20th DT, no hand weeding was given to any of these plots and so the plant height was not influenced at the time of observation. Hand weeding given on the 20th DT had influenced the crop in increasing the height by suppressing the weed competition and by providing more aeration consequent to soil stirring. Crop plants in hand weeded sub plots received the same benefits on the 40th DT also.

Comparing the unweeded sub plots with weedy check, it was found that though the plant height was not influenced in the early stage, it was noted that at later stages, the unweeded sub plots showed a significant increase in plant height. This may be due to the fact that, at the time of land preparation, comparatively large quantity of weed seeds and vegetative parts of weed plants available in the weedy check were brought to surface and established quickly.

Thus competition became severe in the weedy check compared to other unweeded sub plots.

Continuous application of thiobencarb and butachlor significantly influenced the plant height throughout the crop period, while influence of nitrofen was noted in the later stages only.

In the comparison of the hand weeded sub plots, it was found that thiobencarb-hand weeded sub plots significantly increased plant height and was on par with butachlor-hand weeding and nitrofen-hand weeding during the 20th DT and 40th DT, while at harvest butachlor could not maintain its parity with thiobencarb and nitrofen.

In general, among the unweeded treatments, thiobencarb-unweeded plot has significantly higher plant height compared to all other unweeded sub plots through out the crop period, thus indicating that thiobencarb not only suppresses weed population and DM of weeds but also encourages the height of the crop plant.

In comparing all the sub plots it was found that highest plant height throughout the crop period was recorded in completely weed free situation (27.5 to 68.0 cm). This depicts the maximum utilization of nutrients, water, light and space. Next best treatment in general was found to be nitrofen-hand weeding (22.4 to 65.0 cm).

Taking all the situation in to consideration it may be noted that thiobencarb, nitrofen and butachlor either repeatedly applied in both the season or concerned herbicide followed by hand weeding, significantly helped in increasing the plant height and they were nearly as good as completely weed free situation. The influence may be the resultant effect in the reduction in weed competition either in the previous season and or in the second crop season.

Mohamed Ali and Sankaran (1975) observed that unchecked weed growth reduced the plant height. Singh et al (1979), and Lakshmi (1983) reported that nitrofen could effectively control weeds and increase plant height where as Dubey and Rao (1985) and Patil et al (1986) found that thiobencarb suppressed weed competition and increased plant height. Beneficial effect of butachlor was reported by Samar Singh et al (1986) and Patil et al (1986).

B. Tiller number.

The study on the production of tillers indicates that both herbicides and hand weeding given to the sub plots during second crop helped in increasing the tiller number and the unweeded sub plots reduced the number substantially. The weeds compete with crop plants for water, nutrients and light affecting the photosynthetic activity of the crop and reflecting the same on the production of tiller number per unit area.

Continuous application of fluchloralin, nitrofen, thiobencarb and butachlor produced the highest number of tillers which were statistically equal to complete weed free situation or hand weeding-hand weeding.

While compairing all the sub plots, highest number of tillers were recorded by the fluchloralin applied in both the seasons, which was on par with nitrofen-nitrofen, weed free situation, thiobencarb-thiobencarb and nitrofen-hand weeding. This increase in tiller number may be due to the favourable environmental condition obtained by the crop for its establishment and unobstructed photosynthetic activity.

Findings of Narayana Swamy (1976) and Shahi (1985) revealed that tiller production can be enhanced by adopting proper weed control measures, while Samar Singh et al (1986) reported that fluchloralin increased the tiller number per unit area.

C. Leaf Area Index.

A comparison of the sub plots of each main plot revealed that the herbicide treated sub plots recorded significantly higher LAI followed by hand weeded sub plots and both were superior to unweeded sub plots. Though all the unweeded sub plots recorded LAI higher than the weedy check, the above result show that, in general, the residual effect of the herbicides applied during the previous season could not influence the second crop to increase the LAI.

In comparison with hand weeding-hand weeding, the LAI was in general higher in the herbicide treated sub plots and among the herbicides, nitrofen-nitrofen helped the crop plant to produce significantly higher LAI followed by thiobencarb-thiobencarb and butachlor-butachlor.

Reduction in weed number and growth caused by these herbicide treatments might have helped the crop plants to exhibit their vegetative potential to a high degree and this was reflected in the higher LAI.

Enhanced LAI was recorded in trials conducted by Yamogishi et al (1976) and Lakshmi (1983) by the application of herbicides.

All the hand weeded sub plots recorded LAI as good as hand weeding-hand weeding and among them thiobencarb-hand weeding ranked first followed by butachlor-hand weeding and nitrofen-hand weeding. Manual removal of weeds helped the crop plant to have a normal growth and the remaining weeds could not influence the crop to any appreciable extent.

Leaf area index in all the unweeded sub plots were less than that of weed free situation and hand weeding-hand weeding, but higher than weedy check. Lowest LAI was recorded in the weedy check. This low LAI observed in these unweeded plots was due to the reduced photosynthetic activity of the rice plant under high weed competition.

Yamogishi et al (1976) reported reduced LAI due to sever weed competition.

Comparing all the sub plots, highest LAI was produced by completely weed free plot which is quite natural and this was followed by nitrofen-nitrofen. Above discussion reveals that in general thiobencarb and nitrofen either applied in both the seasons or followed by hand weeding in second crop season significantly enhanced the LAI compared to other treatments. This pronounces the superiority of these two herbicides.

2. Yield components.

Comparison of the data (Table 23) show that all the treatments have significantly influenced almost all yield components viz. panicle number, length of panicle, weight of panicle, number of filled grains per panicle and thousand grain weight.

A. Panicle number.

Both the treatments herbicides-herbicides and herbicides-hand weeding were found to have equal effect and produced significantly higher number of panicles than the unweeded sub plots. These herbicides and hand weeded sub plots were also found to be as good as hand weeding-hand weeding. This illustrate that the residual effect of herbicides applied during the first crop was not present in the second crop to have a favourable effect in checking the weed growth and there by increase the number of productive tillers.

Repeated application of thiobencarb or nitrofen in both the seasons or these herbicides in the first crop followed by hand weeding in the second crop and or hand weeding in both the seasons were found to have equal effect of weed free situation in the production of higher number of panicles. This indicates that these treatments reduced weed competition and enabled the crop to make use of available nutrients effectively and converted most of the tillers in to productive tillers.

Reduction in productive tillers due to unchecked weed growth was reported by Mohamed Ali and Sankaran (1975), Ghosrial (1981) and Patil et al (1986). Lakshmi (1983) observed that application of thiobencarb and nitrofen enhanced the panicle number.

B. Length of panicle.

Hand weeded and herbicide treated sub plots during second crop season had equal effect in producing lengthy panicles. As in the case of number of panicle, heavy competition of weeds in the unweeded plots significantly reduced the panicle length 35 percent less than the weed free plot. But thiobencarb-no weeding and nitrofen-no weeding could produce comparatively higher panicle length than weedy check.

Thiobencarb-hand weeding and nitrofen-hand weeding produced even superior panicle length than hand weeding-hand weeding. Among all the hand weeded and herbicide treated sub plots, greatest panicle length was measured in thiobencarb-thiobencarb, nitrofen-hand weeded, thiobencarb-hand weeded and nitrofen-nitrofen plots and they were equal to that of completely weed free situation (20 cm). These treatments could record nearly 50 percent increase in panicle length compared to weedy check.

As in the case of panicle number, repeated application of thiobencarb or nitrofen and or these herbicides in first crop followed by hand weeding in second crop could produce panicle length equal to that of weed free condition.

Dubey and Rao (1985) and Samar Singh et al (1986) reported beneficial effect of herbicides in increasing the panicle length.

C. Weight of panicle.

Repeated application of herbicides in both the seasons, and herbicide in the first crop season followed by hand weeding in the second crop season had equal effect on the weight of panicle. They were also equal to hand weeding-hand weeding.

In general, in all the sub plots where weeds were allowed to grow freely during second crop season, panicle weight was significantly lowered than other treatments. Competition of weeds in these plots might not have allowed the crop plant to absorb nutrients freely and produce more photosynthates which was required for increasing the panicle weight. In the weedy check, the weight of panicle was reduced by 35 percent compared to weed free plot. Compared to weedy check, nitrofen-no weeding, thiobencarb-no weeding and butachlor-no weeding produced heavier panicles. Here the reduction in the weight of panicle was 32 percent.

Among all the treatments, combinations of nitrofen or thiobencarb and hand weeding produced heaviest panicles equal to weed free situation (1.66 g). This reveals that for the second crop season, to get higher panicle weight, best treatments were repeated application of nitrofen or thiobencarb in both the seasons and thiobencarb or nitrofen in the first crop followed by hand weeding in the second crop season.

Sreedevi (1979), John (1981) and, De Datta and Hoque (1982) have reported the adverse effect of weed competition on the panicle weight.

D. Number of filled grains per panicle.

As in other yield parameters, number of filled grains in all the unweeded sub plots as well as weedy check was less (28-31) compared to other treatments (above 41). Weeds in unweeded plots competed for nutrients and sunlight which directly affected the photosynthetic activity of the plant as well as conversion of photosynthate in to grains. Repeated application of herbicides in both the seasons and herbicides-hand weeding have almost equal effect.

Though complete weed free situation recorded highest number of filled grains per panicle, equal result was produced by nitrofen-nitrofen and thiobencarb-thiobencarb. Compared to hand weeding-hand weeding, nitrofen-nitrofen, thiobencarb-thiobencarb and thiobencarb-hand weeding were superior.

It can therefore be concluded that unchecked weed growth significantly reduced the number of filled grains per panicle and repeated application of nitrofen and thiobencarb in both the seasons were as good as completely weed free condition.

Ravindran (1976) and Sukumari (1982) reported significant effect of weed growth on the number of filled grains per panicle. Lakshmi (1983) recommended nitrofen and thiobencarb for increasing the number of filled grains per panicle.

E. Thousand grain weight.

Except in the main plots of thiobencarb and nitrofen, herbicide treatment and hand weeding during second crop season showed equal effect and all of them were superior to unweeded sub plots, whereas thiobencarb-thiobencarb and nitrofen-nitrofen were found to have superior thousand grain weight than thiobencarb-hand weeding and nitrofen-hand weeding respectively.

Among all the treatments, greatest test weight was observed in nitrofen-nitrofen, followed by thiobencarb-thiobencarb and butachlor-butachlor and all these treatments were found to be superior to completely weed free situation.

This revealed that repeated application of nitrofen, thiobencarb and butachlor in both the seasons gives thousand grain weight better than weed free treatment for reasons unknown.

The inferences arrived at in the light of the above discussion are;

i. Weed free situation recorded highest values of panicle number, panicle weight, number of filled grains per panicle and second lengthy panicle.

ii. Compared to completely weed free condition, thiobencarb-hand weeding, nitrofen-hand weeding, nitrofen-nitrofen and thiobencarb-thiobencarb recorded more or less equal values with respect to number of panicle, length of panicle and weight of panicle, thus showing the efficiency of these treatments in reducing weed growth.

iii. Weedy check produced the shortest panicle, lightest panicle and lowest number of filled grains per panicle.

3. Yield.

The results reveal that various treatments have significantly influenced grain yield, straw yield and crop dry matter production (Table 24).

A. Grain yield.

Highest grain yield of 3034 kg per ha was produced by completely weed free plot which was significantly superior to other treatments. This superior yield was the sum effect of the enhanced number of panicles, highest panicle weight and higher number of filled grains per panicle, obtained under better conditions.

Lowest yield was obtained from the weedy check (nearly 67 percent of weed free plot) which also recorded the lowest values of panicle length, panicle weight and number of filled grains per panicle. From these observations, it is evident that the high weed population and high weed dry matter accumulation as observed in the weedy check might have lead to severe crop-weed competition and consequent reduction in growth and yield attributes of rice.

Ali and Sankaran (1981) and Patil et al (1986) also expressed similar views.

In general, herbicides-hand weeding were found to be better than herbicides-herbicides.

Compared to hand weeding-hand weeding, thiobencarb combinations and nitrofen combinations gave superior yield where as butachlor combinations produced equal effect. Among the herbicide treated sub plots, thiobencarb significantly out yielded all other herbicides. Similarly among the hand weeded sub plots, nitrofen-hand weeding and thiobencarb-hand weeding registered higher grain yield. This show the comparative efficiency of these treatments in containing the weed competition.

Though highest grain yield was obtained from the completely weed free situation, considering the cost of production, it becomes most uneconomic and also impracticable under field conditions.

Among all the weed management techniques tested for the second crop, highest grain yield was produced by nitrofen-hand weeding, thiobencarb-hand weeding, thiobencarb-thiobencarb and nitrofen-nitrofen. It may be noted that these treatments could produce yield attributes such as number of panicle, length of panicle and weight of panicle almost equal to that of weed free situation.

Summarizing the above, it can be concluded that, though weed free condition produced highest grain yield, nitrofen-hand weeding, thiobencarb-hand weeding, thiobencarb-thiobencarb and nitrofen-nitrofen gave superior yield than hand weeding repeated in both the seasons.

Comparable increase in grain yield over weedy check by the application of thiobencarb was reported by Anon (1977), Dubey and Rao (1985) and Patil et al (1986) where as Kaushik and Mani (1978) favoured hand weeding. Lakshmi (1983) also observed that application of nitrofen increased the grain yield.

B. Straw yield.

Comparing the sub plots of each main plot, it was found that hand weeded sub plots produced significantly higher quantity of straw than the respective herbicide treated plots;

but unweeded plots were inferior to both the hand weeded and herbicide treated plots. Aeration of the soil consequent to soil stirring could be the additional advantage of hand weeding.

With all favourable conditions existed in the weed free situation, rice plant could exhibit the vegetative potential to the highest degree and thus could produce highest straw yield.

Nitrofen, thiobencarb or butachlor followed by hand weeding recorded higher straw yield than hand weeding-hand weeding and thiobencarb-thiobencarb was found to have equal effect. This could be attributed to the higher plant height, large number of tillers and greater leaf area observed in these plots under better weed management.

Higher yield recorded by the unweeded sub plots in comparison with weedy check could be due to the indirect effect of reduced weed flora present in those plots.

Among the herbicide treated sub plots, thiobencarb was found superior and among the hand weeded sub plots nitrofen-hand weeding and thiobencarb-hand weeding recorded higher yield. This show the efficiency of these treatments in checking the weed competition which created a conducive atmosphere for the growth of rice. While evaluating the residual effect, none of the unweeded sub plots was found significant; but among them, thiobencarb-no weeding ranked first.

Among all the herbicide treated and hand weeded treatments, higher straw yield was obtained from the nitrofen-hand weeding, thiobencarb-hand weeding, butachlor-hand weeding and thiobencarb-thiobencarb. This yield was found to be statistically equal to the hand weeding-hand weeding.

It can therefore be concluded that, as seen in the grain yield, though complete weed free condition was most ideal for growth and development of rice, it was uneconomic and impracticable. Treatments such as nitrofen-hand weeding, thiobencarb-hand weeding, butachlor-hand weeding and thiobencarb-thiobencarb were as good as hand weeding-hand weeding.

Shad (1986) recommended butachlor and thiobencarb for better weed control and high straw yield where as Lakshmi (1983) advocates thiobencarb and nitrofen for getting higher straw yield.

C. Crop dry matter production.

Study of the sub plot treatments within each main plots showed that pendimethalin-hand weeding and nitrofen-hand weeding were superior than pendimethalin-pendimethalin and nitrofen-nitrofen respectively (Table 24). Dry matter production in other hand weeded sub plots were similar to that of the respective herbicide treated sub plots. It was also found that all these treatments, either hand weeded or herbicide treated plots, produced significantly higher DM than the respective unweeded sub plots. At the same time, treatments thiobencarb-no weeding, butachlor-no weeding and nitrofen-no weeding could produce higher crop DM compared to weedy check. This revealed that though these herbicides applied in the first crop has influenced the total crop DM of the second crop, it was not sufficient to keep the field unweeded during the second crop season and to get a profitable yield. This revealed that the crop DM of second crop season was not significantly influenced by the residual effect of the herbicides applied in the first crop.

As observed in the case of grain yield and straw yield, weed free condition enabled the crop plant to produce the greatest DM of 6725 kg per ha, which is 46 percent more than the weedy check.

As the germination and growth of weeds was not restricted, in general, crop plants in all the unweeded sub plots and weedy check produced significantly less dry matter.

Thiobencarb-hand weeding and nitrofen-hand weeding produced higher DM than hand weeding-hand weeding. This proved that these treatments were better than repeated hand weeding in checking weed competition and there by increasing the crop dry matter. Dry matter production of pendimethalin-hand weeding, fluchloralin-hand weeding and all herbicide treated sub plots except pendimethalin-pendimethalin were as good as hand weeding-hand weeding in reducing the weed competition and in increasing the crop DM.

From the above results it has been brought out that thiobencarb-hand weeding and nitrofen-hand weeding were better than hand weeding-hand weeding and in general other hand weeded sub plots and herbicide treated sub plots were as good as hand weeding-hand weeding in reducing the weed DM and in increasing crop DM.

Kaushik and Mani (1978) got high yield with hand weeding where as Dubey and Rao (1985) could increase total yield by chemical weed control.

D. Protein content of grains.

There was no significant difference among the protein percentage recorded by various treatments (Table 24). Presence or absence of weeds could not influence the protein content of grains.

4. <u>Weed Index.</u>

Data presented in Table 25 show that thiobencarb-thiobencarb recorded the lowest Weed Index value of 5.8 among the herbicide treated sub plots followed by nitrofen-nitrofen (6.6) and butachlor-butachlor (8.7). Compared to weedy check (32.7), these values works out to approximately 18 to 27 percent only.

Among the hand weeded sub plots, the lowest WI was noticed in nitrofen-hand weeding (4.6). Next best were thiobencarb-hand weeding (5.1) and butachlor-hand weeding (8.4). These values also works out to 14 to 26 percent of weedy check. Hand weeding-hand weeding recorded a WI of 8.0 and all the unweeded sub plots recorded higher values of weed indices. The low values of weed indices on these treatments show the superior efficiency in containing the weed competition and in increasing the crop yield.

Considering all the treatments, lowest value of WI was noted against nitrofen-hand weeding (4.6) followed by thiobencarb-hand weeding, thiobencarb-thiobencarb, nitrofen-nitrofen and hand weeding-hand weeding. Weedy check recorded the highest WI (32.7) ie: about 7 times than that of nitrofen-hand weeding.

Reduction in Weed Indices by proper weed control measures were reported by Ravindran (1976), Sreedevi (1979) and Lakshmi (1983).

5. Nutrient uptake by the crop.

Study on the uptake pattern showed that the crop absorbed nutrients through out the crop period and weeds competed with crop plants at all stages (Table 26 to 28). Data also revealed that various treatments have significantly influenced the NPK uptake by the crop.

Completely weed free condition recorded highest NPK uptake (88.27 Kg N, 31.70 Kg P and 55.42 Kg K per ha) and plants in weedy check absorbed lowest quantity of NPK (57.77, 21.82 and 33.38 kg per ha respectively). Unlike in the weed free plot, unchecked weed growth competed with rice plant at all stages of crop growth in the absorption of nutrients. Similar observations were made by Ravindran (1976), John (1981) and Sukumari (1982).

A comparative study of the total NPK uptake revealed that, the combined absorption of NPK by weeds and crop in weedy check was (74.67, 27.81 and 37.34 kg per ha) less than that of crop alone in the weed free plot (88.27, 31.70 and 55.42 kg per ha). This could be due to crop-weed antagonism. This is in agreement with the findings of Shetty and Gill (1974).

Comparison of sub plots within each main plot revealed that in the early stage, application of herbicides helped the crop plant to absorb significantly higher N than other treatments; but P and K removal in the plots treated with nitrofen and butachlor were almost equal to that of hand weeding and no weeding treatments. On the 40th DT, butachlor and fluchloralin maintained their superiority over hand weeded and unweeded plots in the uptake of N and P where as in other cases, there was no difference in nutrient uptake among herbicide treatments and hand weeded sub plots. This may be due to the hand weeding operation done on the 20th DT and in the treated plots the herbicidal effect of these chemicals might have got reduced. At harvest, crops in hand weeded plots could record significantly higher P and K uptake than other plots. With respect to N uptake, butachlor-butachlor was found better, whereas nitrofen-nitrofen recorded high K removal. There was no difference between other herbicide treated and hand weeded sub plots.

Among the various herbicide treated plots, there was no significant difference in nutrient uptake in the early stage; but rice plant in all these herbicide treatments were able to absorb more NPK than hand weeding-hand weeding. On the 40th DT, highest uptake of nutrients by the crop was in nitrofen treated plot and it was as good as thiobencarb, butachlor and hand weeding-hand weeding where as pendimethalin and fluchloralin could not check the weeds and increase NPK uptake of crop. At later stages, thiobencarb treated plants absorbed higher NPK and it was as good as nitrofen, but superior to other herbicides. In comparison with hand weeding-handweeding also, N and P uptake was superior in thiobencarb treated plots where as N and K uptake was equal in nitrofen and butachlor. This shows that these herbicides effectively suppressed weed population throughout the crop period and there by provided favourable atmosphere for the uptake of nutrients by the crop.

Nitrogen, phosphorus and potassium uptake by the crop in all hand weeded plots were statistically same on the 20th DT, but in comparison with hand weeding-hand weeding, thiobencarb-hand weeding and butachlor-hand weeding plots absorbed equal quantity of NPK and other treatments were inferior. As the crop growth advanced, thiobencarb-handweeding and nitrofen-hand weeding increased the NPK uptake than other hand weeding treatments as well as handweeding-handweeding. This trend was observed in total weed population also.

Since no weed control operations were attempted in the unweeded sub plots and in hand weeded-handweeded plots upto the 20th DT, there was not much variation in their NPK uptake. Further, no residual effect of any of the herbicides was seen at a level favourably affecting the nutrient uptake in the second crop. In later stages, though thiobencarb-no weeding and nitrofen-no weeding recorded comparatively high NPK uptake than weedy check, all unweeded treatments were significantly inferior than continuous hand weeding.

Considering all the treatments and stages of crop growth, highest NPK uptake next to weed free situation was observed in treatments such as thiobencarb-thiobencarb, nitrofen-nitrofen or butachlor-butachlor or these herbicides in the first crop followed by hand weeding in the second crop treatments and hand weeding-hand weeding.

The results discussed revealed that treatments such as repeated application of thiobencarb or nitrofen or butachlor in both the seasons or these herbicides applied in the first crop followed by hand weeding in the second crop could reduce weed population and weed dry matter accumulation and thus help the crop plants to absorb maximum quantity of nutrients and there by increase the yield.

Significant influence of herbicides and hand weeding on nutrient uptake of rice has been reported by Shahi (1985) and, Singh and Singh (1985 b).

6. Economics of weed management.

The data presented in Table 29 and Fig 5 show that in general chemical weed management was more economical than local practice of hand weeding twice. Weed management either by chemical or by manual weeding has given high monetary returns than keeping the field unweeded in the second crop.

Eventhough weed free condition produced higher yield, the increased income was not reflected in net profit due to the high labour charge involved and it recorded a loss of Rs.1767 per hectare. Hand weeding repeated in both the seasons which is the local farmers practice scored a net profit of Rs.957 per ha only.

Among the various techniques tried, highest net monetary return was given by the application of thiobencarb-thiobencarb (Rs.1692 per ha) which is about 77 percent more than the treatment hand weeding-hand weeding. This might be due to the high yield and thus high income obtained against a comparatively low weed management cost.

Next best treatments in terms of net profit were butachlor-butachlor, fluchloralin-fluchloralin, nitrofen-nitrofen, nitrofen-hand weeding and thiobencarb-hand weeding which gave a net return of Rs.1512, 1380, 1294, 1262, 1220 per ha respectively. From the table it can also be found that weed free condition is not only impracticable but also uneconomical. Chang et al (1976), John (1981) and Lakshmi (1983) also reported that herbicide treatment gave higher net profit than hand weeding treatment.

Considering the total economics of weed management in first and second crop seasons (Table 12 and 27, and Fig 5) it may be noted that, treatment combinations thiobencarb-thiobencarb, butachlor-butachlor and thiobencarb-hand weeding are the ranked weed management techniques in the system approach. They gave a net profit of Rs. 4932, 4613 and 4460 per ha respectively. These treatments have also registered an increased yield of 50 percent, 47 percent and 51 percent respectively over weedy check (Table 30).

7. <u>Total grain yield of first and second crops.</u>

Analysis of the total grain yield obtained from the first and second crop seasons (Table 30 and Fig 5) shows that, rice plant in weed free condition could utilize all the inputs required for crop production to the maximum extent and could produce 1594 kg and 992 kg additional yield over weedy check during the first and second crop seasons respectively. It may also be noted that almost all yield attributing factors were superior in the weed free plot (Table 9 and 23).

Application of thiobencarb and nitrofen in both the seasons or application of these herbicides in the first crop followed by hand weeding in the second crop significantly influenced the grain yield than hand weeding-hand weeding. They recorded an increased yield of 72, 74, 95 and 136 kg respectively over hand weeding-hand weeding. This may be due to the better management of weeds attained by these treatments which in turn helped the crop plants to absorb more nutrients and produce more photosynthate, which ultimately yielded more grains.

Though the residual effect of herbicides applied in the first crop was not adequate enough to reduce the weed competition significantly in the second crop, these unweeded sub plots recorded higher grain yield than the weedy check. This may be due to the higher grain yield produced by these plots in the first crop season with the application of herbicides.

Though highest grain yield was obtained under weed free situation, it may not be economical and practical. Compared to nitrofen-hand weeding plot, this treatment could give only an additional quantity of 304 kg in both the seasons together.

Taking all the treatments of both the seasons in to consideration, highest grain yield was produced by nitrofen-hand weeding, thiobencarb-hand weeding and butachlor-hand weeding. This revealed that, in the system approach, for getting higher grain yield, application of herbicides such as nitrofen, thiobencarb and butachlor in the first crop followed by hand weeding in the second crop is the best weed management technique for rice-rice-cropping pattern.

Preliminary results of the cropping system trials conducted at the International Rice Research Institute shows that rice grains were higher with hand weeding treatment followed by chemical weeding (Anon, 1978).

8. Residual toxicity of herbicides.

The result clearly shows that the various herbicides used in this experiment did not affect the germination of cowpea seeds sown in the experimental area immediately after the harvest of the second crop. No significant difference in the germination percentage was observed among the different weed management techniques tried. This revealed that though herbicides were repeatedly applied in both the seasons, residues of any of these herbicides was not present in the soil in amounts toxic to the succeeding cowpea crop.

Absence of residual toxicity of herbicides applied in a single season was reported by Ravindran (1974), John (1981), Mohamed Ali and Sankaran (1979 and 1981) and Anon (1984).

SUMMARY

SUMMARY

A field experiment was undertaken to find out a suitable weed management technique for rice based cropping system at the College of Agriculture, Vellayani during the Virippu - Mundakan seasons of 1983-84 using the rice variety Triveni.

In the first crop season, five herbicides viz. thiobencarb 1.5 kg a.i. per ha, butachlor 1.0 kg a.i. per ha, pendimethalin 1.0 kg a.i. per ha, nitrofen 1.875 kg a.i. per ha and fluchloralin 1.0 kg a.i. per ha were compared with three control treatments - hand weeding twice, weed free condition and weedy check.

In order to find out a suitable combination of management techniques for the Rice-Rice cropping pattern, during the second crop seasons, each herbicide treated plots of first crop season was divided into three and subjected to three treatments - one unweeded, one hand weeded and in the third repeated the same herbicide at the same rate. The three control treatments of first crop season were also repeated in the second crop.

To find out the residual toxicity of the herbicide applied in the two seasons on the succeeding crop, cowpea

seeds were sown in each of the treatment plots in the third crop season and assessed the germination percentage.

Biometric characters on weeds such as weed species, weed population, dry matter accumulation by weeds, Weed Control Efficiency and on crops such as plant height, tiller number, Leaf Area Index, panicle characters, grain and straw yield, crop dry matter production, Weed Index and quality of rice (protein content) were studied. Nutrient uptake by the crop as well as weed and economics of weed management were also computed. Salient findings of the experiment are summarized as follows.

First crop

1. Most important grass weeds identified were *Brachiaria ramosa*, *Echinochloa colona* and *E. crus-galli*. *Cyperus iria* and *Fimbristylis miliaceae* were the predominant sedges and, *Ludwigia parviflora*, *Marsilia quadrifoliata* and *Monochoria vaginalis* were dominant among the broad leaved weeds.

2. The monocot weeds out numbered the dicot weeds through out the crop period and the monocot weed population constituted 85-93 percent of the total weed population.

3. The competition was severe from the 20th to 40th day of transplanting.

4. Monocot weed population was significantly reduced by the nitrofen and thiobencarb treatments. In the early stages they were superior than other treatments while at later stage, they were as good as other herbicides and hand weeding.

5. Nitrofen and pendimethalin were most effective in reducing the dicot weed population during the critical periods of crop growth.

6. In suppressing the total weed flora, nitrofen and thiobencarb were found to be superior to other treatments on the 20th DT and there after all chemicals and hand weeding were equal.

7. Among the herbicides, nitrofen, thiobencarb and butachlor significantly decreased the total weed dry matter at all stages of crop growth. On the 40th DT and at harvest, hand weeding was equal to these herbicides. Up to the 40th DT, the increase in weed dry matter was more due to the weed population where as after the 40th DT, it was due to the individual contribution.

8. Nitrofen and thiobencarb had the highest

Weed Control Efficiency of 76-87 percent and 63-81 percent respectively where as hand weeding recorded a Weed Control Efficiency of 56 percent only.

9. The nutrient removal was more in the case of nitrogen, followed by potassium and phosphorus.

10. Weeds in the weedy check removed NPK at the rate of 6.89, 2.41 and 5.23 kg per ha on the 20th DT; 19.20, 4.73 and 9.34 kg per ha on the 40th DT; and 19.98, 7.86 and 13.46 kg per ha at harvest respectively. Nitrofen, thiobencarb, hand weeding and butachlor significantly reduced the NPK removal by weeds compared to other treatments at all stages of growth.

11. In the early stage, the plant height was not much affected by the weed competition. In later stages, thiobencarb, nitrofen and butachlor helped the crop plant in increasing the plant height equal to that of hand weeding.

12. Nitrofen, thiobencarb, hand weeding and butachlor produced tiller number on par with weed free condition and the Leaf Area Index recorded by the former three treatments was as good as that of weed free plot.

13. In general, weed free plot recorded the highest values of all yield components and yield while weedy check

was significantly inferior to all other treatments with respect to yield components and yield.

14. The panicle number in nitrofen and thiobencarb treatments was the highest among the herbicides tried and these two herbicides were on par with hand weeding.

15. Thiobencarb, nitrofen and pendimethalin produced the longest panicles among herbicides and they were on par with hand weeding.

16. Nitrofen enhanced the weight of panicle and the number of filled grains per panicle and were on par with weed free treatment. Out of the five herbicides, nitrofen, thiobencarb and butachlor produced panicles with greater weight equal to that of hand weeding.

17. Thousand grain weight was not significantly influenced by the various treatments.

18. Weed free treatment produced the highest grain and straw yield. Nitrofen recorded the highest grain yield among the herbicides, followed by thiobencarb and butachlor and they recorded an increase in yield to the tune of 60.0 percent, 59.5 percent and 56.2 percent respectively over weedy check. These herbicides were on par with hand weeding.

19. On par with hand weeding, thiobencarb, nitrofen and butachlor produced 55.2 percent, 54.8 percent and 49.7 percent increased straw yield over weedy check.

20. Various treatments had significant effect on the crop dry matter production. It was highest in weed free plot and lowest in weedy check. Dry matter produced by the hand weeded plot was statistically equal to that of nitrofen, thiobencarb and butachlor.

21. Protein content of grains was not significantly influenced by the weed competition.

22. Weed Index was the lowest in nitrofen treatment (4.15) closely followed by thiobencarb (4.81), hand weeding (4.93) and butachlor (6.75).

23. Nitrogen and potassium uptake were more than phosphorus uptake through out the crop period. Crop plant in weed free condition could absorb significantly higher quantity of NPK at all stages of growth (92.80, 34.16 and 52.59 kg per ha respectively at harvest) where as weedy check reduced NPK uptake by 52, 54 and 62 percent respectively. In general, thiobencarb, nitrofen and butachlor helped the crop plant to absorb more NPK, equal to or more than that of hand weeding twice.

24. Application of thiobencarb or butachlor or nitrofen was the most profitable weed management technique for rice in the first crop season. They gave a net profit of Rs.3074, Rs.2910, Rs.2770 per hectare respectively. Cost of manual weeding in hand weeded plot was about 2.4, 3.2 and 1.5 times greater than these herbicides.

Second crop

25. Weed species observed in the second crop season were same as that observed during the first crop season and there was no shift in weed species due to the application of herbicides in the first crop.

26. Number of monocot weeds was higher than the dicot weeds through out the crop growth period. The incremental increase in weed population was more upto the 40th day of transplanting than in the later period. There was a general reduction in the weed population in all the plots previously treated with herbicides, but it (the residual effect of herbicides applied in the first crop) was not sufficient to keep the field unweeded during the second crop season.

27. Repeated application of herbicides was better than herbicide-hand weeding or herbicide-no weeding in the early

stage of growth and in the reproductive phase both herbicide-hand weeding and herbicide-herbicide were superior in reducing the number of monocot weeds. Among the treatments, thiobencarb-thiobencarb was most effective during the critical periods, followed by thiobencarb-hand weeding, nitrofen-nitrofen and nitrofen-hand weeding.

28. At all stages of crop growth repeated application of herbicides could reduce the dicot weed population than herbicide-hand weeding. Application of herbicides in the previous season alone did not reduce the number of dicots substantially during the second crop season. Repeated application of nitrofen, pendimethalin and thiobencarb effectively controlled dicot weeds than other treatments.

29. Total weed population of second crop was significantly reduced by repeated application of thiobencarb or nitrofen followed by thiobencarb-hand weeding and nitrofen-no weeding.

30. Up to the 40th DT, lowest weed dry matter production was found in nitrofen-nitrofen treatment followed by thiobencarb-thiobencarb. At harvest stage nitrofen-hand weeding followed by thiobencarb-hand weeding and nitrofen-nitrofen were better. In general weed

dry matter in herbicide-no weeding sub plots was less than that in weedy check.

31. Up to the 40th DT, repeated application of thiobencarb or nitrofen recorded a Weed Control Efficiency of more than 68 percent while from the 40th DT to harvest, thiobencarb-hand weeding, thiobencarb-thiobencarb, butachlor-hand weeding, nitrofen-hand weeding and hand weeding-hand weeding resulted in a Weed Control Efficiency of more than 62 percent.

32. The nutrient removal by weeds varied with the type of nutrient and stage of the crop. Treatments such as thiobencarb-thiobencarb, nitrofen-nitrofen, thiobencarb-hand weeding, nitrofen-hand weeding and butachlor-hand weeding effectively suppressed the nutrient removal by weeds through out the crop period. Highest nutrient removal was from the weedy check at all stages of crop growth.

33. Thiobencarb, nitrofen and butachlor either repeatedly applied in both the seasons or these herbicides in the first crop followed by hand weeding in the second crop significantly increased the height of crop plants and they were nearly as good as weed free situation.

34. Tiller number produced in fluchloralin, nitrofen and thiobencarb treated plots and in nitrofen-hand weeding was statistically equal to that of weed free situation.

35. Highest Leaf Area Index was recorded by completely weed free treatment. Thiobencarb and nitrofen either applied in both the seasons or these herbicides applied in the first crop followed by hand weeding in the second crop season significantly enhanced Leaf Area Index compared to other treatments.

36. Thiobencarb-hand weeding, nitrofen-hand weeding, nitrofen-nitrofen and thiobencarb-thiobencarb produced number of panicles, panicle length and panicle weight more or less equal to that of weed free situation. Weedy check recorded shortest panicle, lightest panicle and less number of filled grains per panicle.

37. Weed free condition recorded the highest grain yield, straw yield and total crop dry matter production.

38. Among all the weed management techniques tested for the second crop, highest grain yield was produced by nitrofen-hand weeding (2895 kg per ha), followed by thiobencarb-hand weeding (2880 kg per ha), thiobencarb-thiobencarb and nitrofen-nitrofen.

39. Highest straw yield next to weed free condition was obtained from the nitrofen-hand weeding (4064 kg per ha) and thiobencarb-hand weeding (4043 kg per ha) followed by butachlor-hand weeding and thiobencarb-thiobencarb. This yield was statistically equal to the hand weeding repeated in both the seasons.

40. Crop dry matter of second crop was not significantly influenced by the residual effect of herbicides applied in the first crop. Thiobencarb-hand weeding and nitrofen-hand weeding were better than hand weeding-hand weeding in producing higher dry matter. In general, other hand weeded sub plots and herbicide treated sub plots were as good as hand weeding-hand weeding in reducing weed dry matter and in increasing crop dry matter.

41. Protein content of grains was not significantly influenced by the treatments.

42. Nitrofen and thiobencarb either applied in both the seasons or these herbicide applied in the first crop followed by hand weeding in the second crop recorded weed indices less than 6.65 where as all the unweeded plots recorded values of Weed Index above 27.80.

43. Due to crop-weed antagonism, the total NPK uptake by the crop + weed in weedy check was less than that of crop

alone in weed free plot. Highest NPK uptake next to weed free situation was observed in treatments such as repeated applications of thiobencarb, nitrofen and butachlor in both the seasons or these herbicides applied in the first crop followed by hand weeding in the second crop.

44. In general, chemical weed management was more economical than local farmers practice of hand weeding twice. Weed management either by chemical or by manual weeding have given highemonetary returns than keeping the field unweeded in the second crop. Eventhough weed free condition produced higher yield, the increased income was offsetted by the high labour charge incured. Thus it was found to be un-economical.

45. Highest monetary return was given by the application of thiobencarb-thiobencarb which was about 77 percent more than the local practice of hand weeding twice. Next best treatment was butachlor-butachlor followed by fluchloralin and nitrofen treatments.

46. In the system approach, considering the economics of both the seasons together, thiobencarb-thiobencarb was the best weed management technique for the rice-rice cropping pattern followed by butachlor-butachlor and

thiobencarb-hand weeding. They gave a net profit of ₨.4766, ₨.4422, and ₨.4294 per hectare respectively.

47. Taking all the treatments of both the seasons in to consideration, highest grain yield was produced by nitrofen-hand weeding, thiobencarb-hand weeding and butachlor-hand weeding. So in the system approach, for getting higher grain yield, application of herbicides such as nitrofen, thiobencarb and butachlor in the first crop and hand weeding in the second crop is the best weed management technique for rice-rice cropping pattern.

48. Study on the residual toxicity of herbicides repeatedly applied in both the seasons shows that, residues of any of the herbicides was not present in the soil in amounts toxic to the succeeding cowpea crop.

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*Original not seen.

APPENDICES

APPENDIX - I

Weather data during the crop period (21-5-84 to 23-12-84) and its variation from the past 10 years mean

Sl. No.	Standard week No.	Period		Temperature (°C)				Average Humidity (percentage)		Total Rainfall (mm)	
				Maximum		Minimum					
		From	To	CP	V	CP	V	CP	V	CP	V
1	21	21-5-1984	27-5-1984	32.07	+0.60	23.21	+0.14	75.14	+4.75	02.0	-16.8
2	22	28-5-84	3-6-84	30.81	+1.12	25.11	+0.22	74.11	+2.43	107.2	+80.1
3	23	4-6-84	10-6-84	30.64	-0.78	24.17	-0.30	75.14	+2.82	54.8	+20.5
4	24	11-6-84	17-6-84	29.79	+1.42	23.93	-0.18	75.86	-8.71	57.0	+18.4
5	25	18-6-84	24-6-84	30.18	+0.58	22.39	-0.64	71.00	-12.14	17.2	-30.6
6	26	25-6-84	1-7-84	30.43	-0.76	20.14	-2.90	69.21	-8.46	04.5	-28.8
7	27	2-7-84	8-7-84	28.71	-0.22	24.07	+0.72	86.57	+8.97	44.0	+12.3
8	28	9-7-84	15-7-84	29.29	+0.36	23.36	+0.27	85.79	+7.32	63.6	+31.7
9	29	16-7-84	22-7-84	28.62	+0.34	23.54	-0.25	88.79	+7.54	17.6	-07.5
10	30	23-7-84	29-7-84	28.86	-0.38	23.61	-0.39	78.57	-1.38	00.0	-23.9
11	31	30-7-84	5-8-84	29.75	-0.22	23.55	+1.12	74.14	-3.62	08.8	-12.8
12	32	6-8-84	12-8-84	29.39	+0.38	23.11	-0.95	66.71	-8.11	12.0	-13.4
13	33	13-8-84	19-8-84	30.11	-1.40	23.18	-0.22	68.57	-6.30	03.0	-20.7
14	34	20-8-84	26-8-84	30.18	+0.18	24.39	+0.05	68.00	-3.22	00.0	-18.4
15	35	27-8-84	2-9-84	29.43	-0.64	23.93	+0.15	72.21	+1.46	05.0	-04.4
16	36	3-9-84	9-9-84	30.21	-0.30	24.39	+1.03	74.14	+1.22	00.0	-05.6
17	37	10-9-84	16-9-84	30.14	+0.72	23.86	+0.69	79.79	+8.13	00.0	-09.7
18	38	17-9-84	23-9-84	31.18	+0.44	23.82	-0.31	69.64	-3.31	03.0	-12.6
19	39	24-9-84	30-9-84	30.04	+0.22	23.11	-0.73	79.29	+4.30	75.0	+55.7
20	40	1-10-84	7-10-84	28.46	-0.86	22.04	-1.45	87.64	+8.24	172.3	+151.3
21	41	8-10-84	14-10-84	29.25	+0.44	23.11	+0.76	78.93	-2.66	09.6	-12.8
22	42	15-10-84	21-10-84	30.11	+0.90	21.71	+0.55	69.36	-9.12	00.0	-25.1
23	43	22-10-84	28-10-84	30.25	-0.74	22.46	-0.14	76.57	-3.22	19.9	-13.1
24	44	29-10-84	4-11-84	30.32	-0.22	23.71	+0.38	74.21	-10.43	00.0	-46.0
25	45	5-11-84	11-11-84	30.75	+0.45	23.93	-0.85	75.93	-12.51	42.5	-09.5
26	46	12-11-84	18-11-84	30.64	-0.36	24.04	-0.14	79.79	-4.60	25.2	-14.9
27	47	19-11-84	25-11-84	30.21	-0.48	23.50	-0.71	81.71	+3.14	58.3	+33.5
28	48	26-11-84	2-12-84	30.36	-0.20	23.86	+0.26	85.00	+5.63	04.6	-13.9
29	49	3-12-84	9-12-84	30.54	+0.10	23.50	+0.12	85.07	+6.21	05.4	-09.6
30	50	10-12-84	16-12-84	30.78	+1.23	21.57	+0.26	80.14	+2.82	00.0	-14.5
31	51	17-12-84	23-12-84	30.67	+0.81	22.30	+0.13	82.30	+3.20	02.0	-7.5

CP = during the crop period.
V = variation from the past 10 years mean.
+ = more than 10 years mean.
- = less than 10 years mean.

APPENDIX - II

Abstract of ANOVA of Weed population - second crop

Source	df	MS								
		Monocot weeds			Dicot weeds			Total weeds		
		20th DT	40th DT	At harvest	20th DT	40th DT	At harvest	20th DT	40th DT	At harvest
Total	71									
Replication	2	3.17	1.39	2.70	3.41	0.79	0.53	5.12	2.28	1.30
Main plot	7	79.09**	247.20**	282.56**	6.60**	38.46**	25.90**	89.33**	289.67**	342.87**
Error (1)	14	0.08	0.13	0.76	0.20	0.13	0.08	0.13	0.10	0.55
Between treatments within										
main plot-1	2	17.21**	44.78**	41.13**	0.67**	17.74**	11.19**	17.87**	57.65**	51.78**
-do- 2	2	12.50**	42.20**	36.37**	0.96**	26.44**	19.17**	13.48**	61.69**	57.16**
-do- 3	2	10.24**	46.80**	35.98**	1.60**	23.32**	18.12**	11.95**	64.04**	50.55**
-do- 4	2	24.98**	50.29**	41.39**	1.92**	24.38**	15.31**	27.50**	69.50**	59.96**
-do- 5	2	8.23**	43.72**	31.42**	1.72**	28.77**	19.02**	12.27**	64.03**	33.51**
Others	6	0.85	0.03	0.24	0.03	0.01	0.02	0.02	0.01	0.27
Error (2)	32	0.06	0.05	1.04	0.12	0.07	0.08	0.05	0.03	0.81

**Significant at 0.01 level.

APPENDIX - III

Abstract of ANOVA of dry matter production of weeds - second crop

Source	df	MS		
		20th DT	40th DT	At harvest
Total	71			
Replication	2	10.454	50.800	39.087
Main plot	7	86.710**	1531.557**	5747.315**
Error (1)	14	0.563	1.791	28.460
Between treatments within main plot-1	2	13.512**	718.952**	2077.224**
-do- 2	2	20.873**	789.516**	2251.345**
-do- 3	2	25.482**	817.681**	2045.259**
-do- 4	2	21.272**	824.047**	2262.151**
-do- 5	2	17.889**	814.997**	1351.462**
Others	6	0.712*	0.165	5.575
Error (2)	32	0.223	0.960	35.286

*Significant at 0.05 level.

**Significant at 0.01 level.

APPENDIX - IV

Abstract of ANOVA of Nutrient removal by weeds - second crop

Source	df	MS								
		Nitrogen			Phosphorus			Potassium		
		20th DT	40th DT	At harvest	20th DT	40th DT	At harvest	20th DT	40th DT	At harvest
Total	71									
Replication	2	0.480	0.927	1.074	0.056	0.266	0.165	0.100	0.244	0.072
Main plot	7	3.971**	59.842**	194.931**	0.462**	7.938**	24.284**	0.943**	7.080**	10.627**
Error (1)	14	0.026	0.130	0.732	0.003	0.009	0.120	0.006	0.008	0.053
Between treatments within main plot-1	2	0.641**	25.503**	65.156**	0.072**	3.729**	8.777**	0.154**	3.323**	3.843**
-do- 2	2	0.988**	32.639**	75.690**	0.112**	3.995**	9.511**	0.238**	3.650**	4.162**
-do- 3	2	1.201**	31.084**	66.086**	0.136**	4.238**	8.633**	0.285**	3.780**	3.783**
-do- 4	2	0.985**	31.927**	77.637**	0.113**	4.271**	9.562**	0.239**	3.831**	4.182**
-do- 5	2	0.840**	33.323**	79.005**	0.096**	4.227**	5.713**	0.206**	3.817**	2.503**
Others	6	0.032*	0.006	2.194**	0.011**	0.001	0.068	0.026**	0.001	0.008
Error (2)	32	0.010	0.064	0.023	0.001	0.005	0.149	0.002	0.004	0.065

*Significant at 0.05 level.
**Significant at 0.01 level.

APPENDIX - V

Abstract of ANOVA of Crop growth characters - second crop

Source	df	MS				
		Plant height			Tiller number	LAI
		20th DT	40th DT	At harvest		
Total	71					
Replication	2	0.746	46.587	67.270	4407.010	0.748
Main plot	7	29.995**	318.614**	399.160**	7534.500**	1.142**
Error (1)	14	4.950	4.531	3.610	1024.710	0.001
Between treatments within main plot-1	2	5.976**	121.042**	198.036**	6844.125**	0.668**
-do- 2	2	9.572**	144.888**	202.531**	5539.070**	0.675**
-do- 3	2	8.222**	94.014**	171.121**	6157.455**	0.745**
-do- 4	2	1.832	173.110**	301.846**	7702.590**	0.711**
-do- 5	2	7.036**	144.846**	136.402**	11063.030**	0.755**
Others	6	2.945	1.940	2.970	1447.395	0.006**
Error (2)	32	0.953	0.811	2.030	907.35	0.001

**Significant at 0.01 level.

APPENDIX - VI

Abstract of ANOVA of yield components and yield - second crop

Source		df	MS							
			No. of panicles per m^2	Length of panicle	Weight of panicle	No. of filled grains/ panicle	Thousand grain weight	Grain yield	Straw yield	Crop dry matter
Total		71								
Replication		2	3629.07	117.26	0.20	227.56	4.42	5267.60	9853.43	19712
Main plot		7	8454.25**	38.76**	0.26**	804.11**	0.20*	715402.98**	1227759.10**	3265024**
Error (1)		14	470.73	1.79	0.02	25.81	0.07	198.26	583.38	26916.57
Between treatments within main plot-	1	2	8027.67**	30.52**	0.13**	569.25**	1.58	925132.00**	794008.50**	2146976**
-do-	2	2	6513.05**	15.21**	0.11**	388.30**	0.75**	833032.71**	703888.50**	1436016**
-do-	3	2	8762.91**	8.46**	0.07**	210.36**	0.41*	845837.94**	674019.00**	1871808**
-do-	4	2	8306.02**	28.15**	0.13**	638.92**	1.79**	1006396.40**	840237.00**	2290896**
-do-	5	2	7435.76**	7.76**	0.12**	186.93**	0.69**	1074716.60**	933754.50**	2515200**
Others		6	1341.33**	1.78*	1.06**	100.99**	2.86**	7977.90**	2686.76**	71832**
Error (2)		32	168.31	0.52	0.01	13.97	0.11	164.20	526.91	22076

*Significant at 0.05 level.

**Significant at 0.01 level.

APPENDIX - VII

Abstract of ANOVA of nutrient uptake by the crop - second crop

Source	df	MS								
		Nitrogen			Phosphorus			Potassium		
		20th DT	40th DT	At harvest	20th DT	40th DT	At harvest	20th DT	40th DT	At harve
Total	71									
Replication	2	186.560	235.720	8.699	21.187	36.473	0.477	78.681	80.474	1.484375
Main plot	7	273.284*	1315.376**	675.829**	26.807*	194.819**	72.825**	92.610*	501.964**	359.6697**
Error (1)	14	79.974	126.524	1.682	8.891	19.458	0.028	33.028	46.979	0.069196
Between treat-ments within										
main plot-1	2	33.469	528.834**	79.273**	3.197	56.061**	47.747**	10.191	153.166**	260.6953**
-do- 2	2	29.026	519.155**	37.866**	2.527	67.368**	41.987**	8.102	156.151**	234.5772**
-do- 3	2	74.318**	278.658**	364.006**	9.218**	37.267**	41.350**	37.412**	87.498**	228.2901**
-do- 4	2	12.476	528.791**	439.361**	1.153	68.500**	50.650**	3.175	157.909**	274.1807**
-do- 5	2	37.124	200.094**	400.985**	4.955*	23.763**	55.674**	23.404*	62.770**	289.1328**
Others	6	71.522**	58.832**	223.467**	8.530**	15.292**	0.113**	29.598**	83.878**	0.3520*
Error (2)	32	11.526	6.784	1.746	1.303	1.046	0.018	4.887	7.716	0.0746

*Significant at 0.05 level.

**Significant at 0.01 level.

APPENDIX - VIII

Abstract of ANOVA of Economics of weed management - second crop, Total grain yield of first and second crops and Germination of cowpea seeds

Source	df	MS		
		Economics of weed management †	Total grain yield of first and second crops	Germination of cowpea seeds
Total	71			
Replication	2	6000	133760**	1.9875
Main plot	7	9220517**	5413413**	5.116071
Error (1)	14	9152	18633.14	5.008928
Between treatments within main plot-1	2	1258416**	462560**	1.
-do- 2	2	1220852**	416528**	0.109375
-do- 3	2	964760**	422912**	0.78125
-do- 4	2	909608**	503216**	1.445313
-do- 5	2	1665224**	537344**	0.4453125
Others	6	16942.766**	3968**	1.2265626
Error (2)	32	9642.642	142	3.478027

† Data was analysed after deleting the treatment T_{18}.

*Significant at 0.05 level.

**Significant at 0.01 level.

ABSTRACT

A field experiment was undertaken at the College of Agriculture, Vellayani, to find out a scientific and profitable weed management technique for a Rice-Rice Cropping System, under transplanted condition during the Virippu - Mundakan seasons of 1984-85.

The first crop with five herbicides (thiobencarb 1.5 kg, butachlor 1.0 kg, pendimethalin 1.0 kg, nitrofen 1.875 kg and fluchloralin 1.0 kg a.i. per ha) and three controls (hand weeding, completely weed free and weedy check) was laid out in RBD.

Using the same lay out, in the second crop, each herbicide treated main plots was divided in to three sub plots and allotted no weeding, hand weeding and same herbicide treatments and the results analysed as that of a split plot with non-factorial structure. The salient findings of the experiments are as follows.

First Crop

Weed number and competition was severe upto the 40th DT and monocots out numbered dicots. Nitrofen and thiobencarb reduced weed population, weed dry matter

accumulation, nutrient removal by weeds and achieved high Weed Control Efficiency than hand weeding.

Nitrofen and thiobencarb improved plant growth characters, enhanced yield components, increased grain and straw yield and accelerated nutrient uptake, followed by butachlor. These herbicides recorded low Weed Index values. Application of thiobencarb, butachlor or nitrofen was more profitable than hand weeding twice.

Second Crop

There was no shift in weed species due to herbicides. Weed number and competition were severe upto the 40th DT and monocot weed population was higher than dicots. Though there was a general reduction in the population and dry matter of weeds due to herbicide application of first crop, their residual effect was not enough to keep the field unweeded during the second crop season. Weed number, weed dry matter and nutrient removal by weeds were reduced by the repeated application of thiobencarb or nitrofen or these herbicides-hand weeding combinations. They recorded Weed Control Efficiency of more than 62 percent.

Plant growth characters, yield components, grain and straw yield, and nutrient uptake by the crop were favourably influenced by the above herbicides in combination with hand weeding or when repeatedly applied equal to or better than farmers practice of hand weeding. They recorded low values of Weed Indices. The residual effect of herbicides applied in the first crop was not significant in the above characters. Thousand grain weight and protein content were not influenced by the treatments.

In the system approach, highest total grain yield was produced by thiobencarb-hand weeding, nitrofen-hand weeding and butachlor-hand weeding where as highest net profit was obtained by the repeated application of thiobencarb and butachlor. Herbicide residual toxicity was not observed to the succeeding cowpea crop.