INTEGRATED WEED MANAGEMENT IN TRANSPLANTED MEDIUM DURATION RICE

BY

BEENA MAHESWARI, S. K

THESIS

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR
THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURE (AGRONOMY)
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

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DECLARATION

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

Beena Maheswari

BEENA MAHESWARI, S.K.

College of Agriculture,
Vellayani,
27-4-1987

CERTIFICATE

Certified that this thesis entitled "Integrated Weed Management in transplanted medium duration rice" is a record of research work done independently by Smt.Beena Maheswari,S.K., under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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INTRODUCTION

1. INTRODUCTION

Rice is the staple food of the people of Kerala and Kerala accounts for about 2.1 per cent of the area under rice in India. The spread of the high yielding fertilizer responsive dwarf varieties have now aggravated the problem of weeds in rice culture. The weeds form a serious negative factor in crop production and they must be controlled at the right time to get the desired production. According to the recent estimates in India the extent of yield reduction that the weeds cause in rice was around 15-20 per cent in transplanted rice, 30 to 35 per cent in direct seeded rice under puddled conditions and over 50 to 60 per cent in upland rice (Smith, 1985). The weeds compete with the crop for light, air and nutrients and they also adversely affect the micro-climate around the plant, harbour disease organisms and pests, increase the cost of production and lower the quantity and quality of the crop. Data on the comparative estimates of losses caused by weeds, insects and diseases indicate that weeds are more damaging to crops than insect pests and diseases (Bendixen, 1972). Despite this fact, insect pests and plant diseases have drawn greater attention of the farmers and researchers than weeds. This is because injuries caused by insect pests and pathogens to crops are easily noticeable, whereas the weeds wage a hidden war on the crop plants.

Transplanted rice crop, as it is constantly kept under considerable flood, is not likely to be invaded by terrestrial grass weeds. But intermittently drained fields often grow many grasses. Thus weed control forms one of the important farm operations in rice culture. In Japan it was found that the farmers needed over 500 labour hours per hectare for weeding rice fields accounting to 23.4 per cent of the total labour requirement which reflects the huge expenditure on weeding. There are different methods of weed control - manual, mechanical, chemical and biological. Each of these methods has its own merits and demerits and a prudent farmer can make use of any one of these or a combination of these to control weeds efficiently and economically. Manual method of weed control is expensive and in areas where labour is scarce and costly, chemical weed control can be adopted. But a sudden switch over from handweeding to chemical control may not alleviate the weed problem in rice culture. Moreover the rate at which several herbicides are recommended, are sometimes high, resulting in a high financial implication. So the recent approach is 'integrated weed management' by integrating all the available technologies for the control of weeds. Herbicidal control of perennial grasses has not been found always feasible. Therefore when such weeds pose a serious problem in rice, a combination of herbicidal control and manual weeding is resorted to (Gupta and Lamba, 1978). A combination of practices helps to minimize the build up of a single noxious weed or a group of weeds.

Therefore the present study was undertaken using a medium duration variety under transplanted condition during the Mundakan season (second crop) of 1985-86, in the Instructional Farm, College of Agriculture, Vellayani with the following objectives.

(i) To find out a suitable weed management technique for transplanted medium duration rice.

(ii) To find out the effect of herbicide treatment on the weed species in rice.

(iii) To compare the effect of herbicide when it is applied as a spray or as a granule.

(iv) To find out the effect of the method of weed control on the growth, yield and quality of rice.

(v) To work out the economics of weed management in rice.

(vi) To study the residual toxicity of the herbicides on the subsequent pulse crop

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Weeds are considered as the fourth group of agricultural posts. They not only reduce crop yields but also affoct the quality of produce. They compete with the crop for nutrients, light, space and water. They are to be controlled for increasing crop production. So the present study was undertaken to develop a method of weed control - chemical, cultural or combination of the chemical and cultural method, in a medium duration transplanted rice. Literature on the various aspects of weed interference in crop production, methods of control, etc. are cited here under.

2.1. Weed Species Present in Rice Fields.

Rethinam et al.(1974) reported that *Echinochloa colonum*, *Echinochloa crus-galli*, *Cyperus rotundus* and *Marsilea sp* were the predominant weed species of rice in the wet lands of Tamil Nadu Agricultural University. Nair and Sadanandan (1975) reported that the most important weeds found at Rice Research Station, Pattambi were *Echinochloa crus-galli*, *Brachiaria* spp, *Cleome* spp and *Fimbristylis miliacea*. According to Gopalakrishna Pillai (1977) the most common weeds infesting rice fields were grassy weeds like

Echinochloa colonum, Echinochloa crus-galli and Paspalum spp, sedges like Fimbristylis miliacea and Cyperus difformis and broad leaved weeds like Monochoria vaginalis, Ipomoea reptans, Sphenochloa zeylanica and Ludwigia parviflora. Ravindran et al.(1978) reported that Echinochloa spp, Cyperus spp, Fimbristylis miliacea, Ammania multiflora and Ludwigia parviflora were the common weeds in the rice fields of Vellayani, Kerala.

According to Nair et al.(1979) Cynodon dactylon, Cyperus iria, Cyperus cyperinus, Cyperus difformis, Amaranthus viridis, Ageratum conyzoides, Eupatorium odoratum, Tridax procumbens and Phyllanthus niruri were the more widely prevalent weeds in the paddy fields of Mannuthy. Gill and Kolar (1980) stated that under the agroclimatic conditions of Punjab, Echinochloa crus-galli, Echinochloa colonum and some sedges were the major concern in transplanted rice. Nanjappa and Krishnamurthy (1981) reported that some of the important weed species observed in rice fields at University of Agricultural Sciences, Bangalore, were grasses like Echinochloa crus-galli, Echinochloa colonum, Panicum repens, sedges like Cyperus difformis and Cyperus iria and broad leaved weeds Marsilea quadrifoliata and Jussiea repens. Sukumari (1982) found that the important weeds of rice in the experimental fields of Vellayani were Echinochloa crus-galli, Echinochloa colonum, Brachiaria ramosa, Ischaemum rugosam, Fimbristylis miliacea, Cyperus iria and Monochoria vaginalis.

Lakshmi (1983) observed that the predominant weed species in the experimental site of Onattukkara region in Kerala were Echinochloa colonum, Echinochloa crus-galli, Sacciolepis indica, Cyperus iria, Cyperus rotundus, Cleome viscosa and Monochoria vaginalis. Subbian (1983) reported that among the weeds infesting transplanted rice, Marsilea quadrifoliata dominated followed by Cynodon dactylon and Cyperus rotundus. In a field experiment conducted at Gujarat Agricultural University, Navsar, the common weeds found in transplanted rice fields were Echinochloa crus-galli, Echinochloa colonum, Panicum colonum and Sporobolus indicus among monocots, Ammania baccifera, Alternanthera sessilis, Ludwigia octovalvis, Eclipta alba and Blumla spp among dicots and Cyperus iria, Cyperus difformis, Fimbristylis spp. and Scirpus juncoides among sedges (Patel and Patel, 1984).

Patro and Panigrahi (1985) classified the major lowland rice weeds of Orissa into sedges which included Cyperus rotundus, Cyperus iria, Cyperus imbricatus, *Cyperus amabilis*, *Cyperus exaltatus*, *Cyperus difformis*, *Cyperus articulatus*, *Cyperus compactus*, *Fimbristylis miliacea*, *Fimbristylis dichotoma*, *Scirpus articulatus* and *Rhynchospora corymbosa*, grasses like *Echinochloa colonum*, *Echinochloa crus-galli*, *Brachiaria distachya* *Leptochloa chinensis*, *Digitaria sanguinalis*, *Eleusine indica*, *Panicum texanum*, *Dactyloctenium aegyptium*, *Eragrostis atrovirens* and wild rice; and broad leaved weeds like *Commelina diffusa*, *Ludwigia perennis*, *Sesbania exaltata*, *Aeschynomene indica*, *Heteranthera reniformis*, *Oxalis corniculata*, *Portulaca oleracea* and *Hydrolea zeylanica* and Ferns like *Marsilea quadrifoliata*. Patel et al.(1986) found that *Echinochloa colonum*, *Cyperus iria*, *Rotala indica*, *S.cheonopectum corymbosus*, *Zizania* sp, *Geissaspis tenelli*, *Eriocaulus hookeri*, *Pennisetum* sp., *Sacciolepis interrupta*, *Eragrostis unioloides* and *Paspalum conjugatum* were the important weeds infesting rice at RRS, Mudigere.

Thus a brief review on the weed flora in wet-lands suggest that among grassy weeds *Echinochloa* spp are the foremost, while *Cyperus* spp and *Fimbristylis* spp among the sedges, *Monochoria vaginalis* and *Marsilea quadrifoliata* accounts for the broad leaved group.

2.2. Losses caused by Weeds in Rice Yields.

Weeds are one of the major causes for low crop yields through out the world. Besides, weeds also reduce crop quality and increase the cost of cultural operations, harvesting, drying and cleaning and increase pest and disease infestations.

Ten per cent yield reduction in rice has been reported by Bharadwaj and Verma (1969). Shetty and Gill (1974) observed that there was a decline in grain yield of rice by 10 q/ha when the time of weed removal was extended by 6 to 8 weeks after transplanting. According to Swain et al.(1975) when high populations of *Cyperus difformis* competed with rice for the whole of the growing season, rice yields were reduced by 22 to 43 per cent. Ravindran (1976) found that the yield reduction caused by weeds in transplanted rice was 28.7 per cent as shown by weed index. The extent of yield reduction in rice due to weeds alone was estimated to be around 15 to 20 per cent in transplanted rice, 30 to 35 per cent in direct seeded rice under puddled conditions and over 50 to 60 per cent in upland rice as evident from the data collected over a number of seasons at many locations in India under the multilocation testing programme of the All India Co-ordinated Rice Improvement Project (Gopalakrishna Pillai, 1977).

Abraham Varughese (1978) reported an yield reduction of 25.47 per cent in transplanted rice due to the presence of weeds. Smith and Moody (1979) stated that in the U.S.A., the total estimated direct losses in rice from weeds and the cost of their control represented 28 per cent of the value of the crop annually during 1975-77. Keith Moody (1980) reported that yield reduction due to uncontrolled weed growth ranged from 20 to 25 per cent for transplanted rice and 40 to 50 per cent for rice that is broadcast seeded in puddled soil. Sukumari (1982) stated that weeds cause an yield reduction of 43.47 per cent in direct sown rice under semidry conditions.

Lakshmi (1983) found that reduction in yield by the presence of weeds was 18.79 per cent in semi dry dibbled crop of rice. In an evaluation of the relative effects of annual weeds, it was revealed that Cyperus rotundus alone reduced grain yield by 67 per cent (Datta and Llagas, 1984). Singh (1985) reported that in India the extent of yield reduction in rice due to weeds alone was estimated to be around 15 to 20 per cent in transplanted rice, 30 to 35 per cent in direct seeded rice under puddled conditions and over 50 to 60 per cent in upland rice.

Thus the above review indicates the severity of damage caused by weeds in rice fields. The yield reduction in transplanted rice due to weeds varied from 10 to 20 per cent in general.

2.3. Crop-Weed Competition.

Competition begins when crop and weeds grow in close proximity to one another and when the supply of an essential factor falls below their demands. Weeds are indeed the robbers of all the inputs supplied to the crop and more so the nutrients supplied in the form of fertilizers (Shetty and Krishnamurthy, 1975).

2.3.1. Critical Period of Competition

The effect of weeds emerging at different stages on transplanted rice was investigated by Chang (1970) and he reported that weeds emerging at 15, 30, 45 and 60 days after transplanting rice reduced the grain yields by 69, 47, 28 and 11 per cent respectively in the first crop. In the second crop weeds emerging at 10 and 20 days after transplanting reduced the yield by 52.5 and 13 per cent respectively whereas the weeds which emerged later did not affect yields. According to Park and Kim (1971) weed competition substantially influenced grain yield during the first 30 days after transplanting wetland rice and for the first 50 to 60 days after sowing upland rice. Shetty and Gill (1974) reported that the most critical period of crop-weed competition was between 4 and 6 weeks after transplanting. Nair et al. (1975) noticed that weed competition was more critical during early vegetative phase and the longest period of weed competition that the upland rice could tolerate was 30 days from sowing without adverse effect on yield. Swain et al.(1975) pointed out that weed removal prior to tillering led to rice yields significantly higher than, those obtained when weeds were removed after tillering.

According to Abraham Varughese (1978) the critical period of crop-weed competition was between 21 and 40 days after transplanting. Sukumari (1982) reported that the most critical period of weed competition with regard to grain and straw yield was 20 to 40 days after sowing. Sahai et al.(1983) stated that the critical period of weed competition is between 15 and 45 days after sowing and if the crop is kept weed free for the initial 45 days, it escapes severe effects of weed competition. According to Shashidhar (1983) weed competition was critical during the first 40 days after transplanting, but yields were not significantly depressed by the presence of weeds thereafter. Ali and Sankaran (1984) reported that for higher yields in lowland rice, the crop should be kept free from weeds during the first 50 days in the monsoon season and 60 days in summer. The weeds emerging after the first 25 to 33 per cent of the life cycle of rice have less effect on yield (Singh, 1985).

Thus the critical period of weed competition has been found to be between 20 and 45 days after transplanting rice.

2.3.2. Competition for Light and Space

Clements (1907) realized that the amount and deposition of leaf surface defined a decisive plant competition factor. King (1966) reported that the rate of growth of some weed species enabled them to suppress crop growth and eventually to crowd them out altogether. According to Smith (1968) barnyard grass shaded rice during the crop season and competition was purely for light when water was not limiting. Competition for light, one of the most common forms of competition in the plant community, may occur whenever one leaf blocks off light from another leaf, either on the same or a different plant. In fact competition for light in field crops may operate throughout the crop cycle except when plants are young (Zimdahl, 1980). Gu and Zhao (1984) reported that Echinochloa spp grow faster than rice competing for light and nutrients and decreasing the crop yield.

Thus significant yield reduction in rice is caused by the weeds competing for light and space.

2.3.3. Competition for Nutrients

Barnyard grass competing in rice fields, removed 60 to 80 per cent nitrogen from the soil (Swain, 1967). Noda et al.(1968) reported that maximum competition for nitrogen between rice and barnyard grass was during the first half of the growing season. Smith (1968) found that weeds competed with the crop thoroughly for nutrients when water was not limiting. Shetty and Gill (1974) reported that competition for nutrients between weeds and crop was maximum during the early period of growth and competition for soil nitrogen was maximum during 6 to 8 weeks after transplanting. According to Mani (1975) weed growth usurped substantial quantity of nitrogen within 5 to 6 weeks of crop sowing. He also concluded that comparatively lower amount of nitrogen depletion by weed growth in transplanted rice indicated that puddling operations prior to transplantation effectively checked the weed growth thus incapacitating its ability to usurp nitrogen from the soil. Shetty and Krishnamurthy (1975) found that competition for nitrogen is maximum and weeds were as efficient in taking nitrogen as rice. But rice was more efficient in absorbing P_2O_5 and K_2O.

Okafor and De Datta (1976) reported that application of nitrogen to weedy upland rice fields benefitted the purple nutsedge more than the rice. Crop-weed competition under high weed intensity exerted some adverse effects on the uptake and utilization of nutrients by crop and weeds to the expected level (Nanjappa and Krishnamurthy, 1980). They also found that the rice crop could alone absorb 109 kg N/ha in the weed free treatment whereas the crop and weeds together absorbed only 94 kg/ha in the unweeded control, thus some amount of nitrogen remained unabsorbed in the soil. Likewise significant amounts of P_2O_5 and K_2O were left unabsorbed in the soil.

This brief review on the nutrient depletion by weeds undoubtedly brings out the fact that weeds are major robbers of plant nutrients. Hence during the present day shortage of fertilizers, the importance of growing crops under weed free condition is emphasized.

2.4. Metnods of Weed Control.

One of the best guides for choosing appropriate method of weed control is the relative cost of labour and herbicides. Selection of an appropriate method of weed control technology should be based not on the degree of weed control or cost of yield alone. All these factors should be used to determine the weed control method that provides the highest returns per unit invested.

2.4.1. Manual Weed Control

According to Mukhopadhyay (1967), the cultural methods of controlling weeds (handweeding, wheelhoeing etc.) were comparatively less effective than chemical or chemical plus cultural method of weeding in reducing weeds or increasing the yield of rice. The manual method of weed control is laborious, back breaking and time consuming (Mani and Gautam, 1973). Gupta et al.

(1975) found that the local practice of handweeding thrice was inferior to herbicide treatments like C 19490 (Piperophos) and Machete G (butachlor) and he attributed this to the subsequent recuperation of weeds after handweeding and also the damage done to the crop during the early stages of crop growth. Rangiah et al.(1975) reported that handweeding and working rotary weeder recorded maximum yields and net profit and also effectively controlled the weeds. For small holdings, use of traditional methods of weed control continues to be the most economical method (Scolari and Young, 1975).

Ravindran (1976) reported that handweeding on the 20th and 40th day after transplanting rice, although gave higher yields, the net profit was lower due to increased labour charges. Keith Moody (1977) suggested that in transplanted rice one manual weeding (at the most two) was sufficient to control weeds adequately. He also found that manual weeding methods are most effective on young weeds. Ahmad (1978) reported that rice cv. IR-8 gave maximum yields when handweeded twice at 20 and 35 or 20 and 40 days after planting, while cv. Basmati gave highest yield with three handweedings, but in both cultivars, maximum benefit-cost ratio was obtained with one handweeding at 20 days after planting. According to Rami Reddy et al.(1980), among the weed control treatments, manual weeding was the best in increasing fertilizer use efficiency and it resulted in 44.4 per cent increase in rice yield compared with no weeding. Yang et al.(1980) found that plant height and number of culms per hill were a little higher in herbicide treatments than in handweeded plots in the first year, but decreased slightly with each successive year of herbicide application. Munroe et al.(1981) obtained high yields using a labour intensive weed control practice of several cultivations and handweedings. Patel and Patel (1981) reported that handweeding at 20 and 40 days after transplanting recorded the minimum population and dry weight of weeds and maximum weed control efficiency.

Sukumari (1982) found that two handweedings on 20th and 40th day for dibbled crop, were as effective as continuous weeding during 21 to 40 days and keeping the field weed free from 1 to 60 days. Lakshmi (1983) noticed that among the handweeding treatments, complete weed free condition produced the maximum grain yield followed by handweeding on 15th and 30th days. Also handweeding once (either 15th or 30th day) did not produce good yields. Chandrakar and Chandrawanshi (1985) reported that the handweeded plots recorded the highest number of panicles per m^2, highest grain yield and the least dry weight of weeds. Preliminary evaluation of weed control practices in transplanted rice revealed that yield increase due to handweeding in the farmers' fields ranged from 4 to 29 per cent (Elliot et al.1985). Singh (1985) reported that handweeding provided fairly good control because weeds from both inter and intra rows are removed, but it was very laborious and expensive. The cost-benefit ratio showed a negative return to weeding mainly due to a very high cost of labour input.

Thus it is seen that the traditional method of handweeding continued to exhibit good weed control and record better yields. Where labour is cheap and plentiful this method can be followed.

2.4.2. Chemical Weed Control

Though handweeding is the common practice of weed control in rice, due to increased cost of labour and inadequate availability at the optimum time the situation has changed, necessitating the use of chemicals. The use of pre-emergence herbicides keep the crop competition-free during initial and crucial stages of growth. Several pre-emergence herbicides like thiobencarb, butachlor, propanil etc. are used to control weeds in transplanted rice. Thiobencarb control annual and broadleaved weeds effectively. Butachlor is effective against many annual grasses, sedges and some broadleaved weeds. Literature is cited on the efficiency of weed control by thiobencarb and butachlor.

2.4.2.1. Thiobencarb

Kimura (1971) who described the general properties of this chemical, reported that it inhibited the growth of germinating weeds. Although rice is sensitive to thiobencarb upto the coleoptile stage, barnyard grass can be controlled from germination to the two leaf stage in flooded field. Kimura et al. (1971) reported that the mode of action of thiobencarb was similar to that of EPTC and that it inhibited protein synthesis of plants through competition in the auxin-acting sites. According to Smith (1973) benthiocarb (thiobencarb) applied alone or in mixtures with propanil, control weeds effectively and does not injure rice. Agarkov and Gaidarev (1976) reported that saturn at 3-7 kg a.i/ha applied before sowing rice decreased weed population by 81 to 98 per cent. Ravindran (1976) found that benthiocarb (thiobencarb) controlled monocot weed population effectively. It was found by Baker (1977) that thiobencarb at 3 lb/acre + propanil 0.75, 1.5 and 3 lb and propanil by itself at 1.5 and 3 lb gave excellent control of all weeds, but thiobencarb by itself and the lowest rate of propanil tested (0.75 lb) were less satisfactory. Souza et al.(1977) found that Saturn at 4 and 5 kg/ha pre-emergence gave the most effective control of infesting weeds which included Eclipta alba and Cuphea carthagenesis.

Gill and Mehra (1981) found that benthiocarb (thiobencarb) 1.5-3.0 kg a.i/ha applied 3-4 days after transplanting rice was highly effective. Balyan (1982) reported that application of thiobencarb at 2.0 kg a.i/ha as pre-emergence produced the lowest weed dry weight while post-emergence application of thiobencarb 2.0 kg gave the minimum weed control efficiency of 30.7 per cent. Lakshmi (1983) reported that benthiocarb (thiobencarb) 2.0 kg a.i/ha, nitrofen 1.875 kg a.i/ha, bentazon 2.0 kg a.i/ha and benthiocarb (thiobencarb) 1.5 kg a.i/ha suppressed weed dry matter accumulation throughout the crop growth. Pandey(1984) found that application of thiobencarb in transplanted rice gave effective control of weeds.

Thus thiobencarb has been found to be efficient in controlling weeds associated with upland and transplanted rice.

2.4.2.2. Butachlor

Nair et al.(1974) reported that Machete could be safely used for weed control in direct seeded flooded rice fields. Ravindran (1976) reported that butachlor gave good control of dicot weeds in transplanted rice. Significant reduction in the number and dry matter production of weeds in transplanted rice was obtained with butachlor, oxadiazon, C-288 (piperophos + dimethametryn) and penoxalin (pendimethalin) by Balu and Sankaran (1977). They also found that among the herbicidal treatments, weed control efficiency was in the order of penoxalin, butachlor and oxadiazon at 1.0 kg a.i/ha. Mehrotra and Ghosh (1977) evaluated the effectiveness of certain herbicides in transplanted rice and found that the best weed control was obtained with butachlor 1.0 kg/ha, followed by pendimethalin 2.0 kg/ha. Results recorded from the trials as well as from the demonstrations conducted on farmers' field revealed that all the grassy and other weeds infesting rice crop can be controlled effectively by using new herbicides like butachlor, fluchloralin, nitrofen and dichlormate as pre-emorgence application (Verma et al. 1978).

Chela and Gill (1980) reported that butachlor at 1.0-1.5 kg a.i/ha applied 3 days after transplanting gave effective control of Echinochloa crus-galli and decreased its dry weight by 95.6 per cent. They also concluded that butachlor applied 8 days after transplanting was inferior to its application 3 days after transplanting. Pillai and Sreedevi (1980) found that butachlor was the best herbicide for controlling weeds in direct seeded upland rice. At 2.0 kg/ha butachlor gave excellent control of weeds in dry sown rice until 15 days after crop emergence (Ahmed and Hoque, 1981). Munroe et al. (1981) reported that if time and labour are constraints, an application of butachlor can eliminate all post-emergence cultivations and substantially reduce the number of handweedings for upland rice. Kolhe et al. (1982) stated that butachlor at concentration of 2 to 4 kg/ha when applied alone or in combination with propanil reduced the dry matter of weeds in transplanted rice. Elliot et al.(1984) found that 80 to 90 per cent control of the major weeds especially <u>Echinochloa colona</u> was observed in plots treated with 1.5 kg/ha butachlor. It was found by Borgohain (1985) that all the grassy and other weeds infesting rice crop can be controlled effectively using new herbicides like dichlormate, nitrofen, butachlor, fluchloralin, alachlor and oxadiazon as pre-emergence application. Elliot et al.(1985) reported that butachlor at 0.45 kg/ha failed to reduce weed weight whereas butachlor at 0.6 and 0.75 kg/ha reduced weed weight. The relative effectiveness of butachlor applied

4 days after transplanting to control weed population was better in comparison with propanil applied 20 days after transplanting as it had less weed population and dry matter accumulation of weeds (Singh and Singh, 1985).

From the above review it is evident that butachlor gives effective control of annual weeds when applied as pre-emergence application.

2.4.3. Integrated Weed Control

Reliance on a single method of weed control such as continuous use of the same or similar herbicides could create serious problem by perennial weeds. So the recent approach in weed control is the development of integrated method of weed control using limited quantities of low cost chemicals in combination with direct and indirect weed control techniques which may be the most effective alternative from agronomic, economic and ecological points of view.

Rangiah et al.(1974) reported that Machete granules and Stam F-34 were very effective to control the weeds in transplanted rice, when they were supplemented with one handweeding five weeks after planting. Vijayaraghavan (1974) recommended one handweeding in addition to pre-emergence application of Machete or Tok E-25 for efficient control of weeds. Rangiah et al.(1976) found that the lowest weed weight was recorded when butachlor at 2.5 kg a.i/ha was supplemented with one hand weeding. Granular herbicides like Machete 1.5 kg a.i/ha or Saturn 1.5 kg a.i/ha when mixed with sand and applied uniformly, their persistence last only for 45 days after application and so a late manual weeding was recommended (Anon. 1977). Weed management studies in upland paddy by Singh and Chauhan (1978) showed that pre-emergence application of butachlor at 2.0 kg/ha + one handweeding effectively controlled weeds. Rati and Tewari (1979) reported that Machete (butachlor 72 per cent) at 4 litres (produce)/ha applied as pre-emergence followed by one handweeding 25 days after sowing gave good control of weeds. Singh and Singh (1982) reported that pre-emergence application of butachlor at 2.0 kg/ha supplemented with handweeding 45 days after sowing gave better control of weeds.

Mohankumar and Singh (1983) recommended pre-emergence application of butachlor 1.0 kg a.i/ha to be supplemented by one handweeding for efficient weed control in upland direct-seeded rice. Bhagwan Singh and Dash (1984) found that in direct sown rice pre-emergence application of butachlor in combination with one handweeding 30 days after sowing decreased the values of the weed control parameters. Application of butachlor at 1.25 kg a.i/ha when followed by handweeding, 40 days after transplanting recorded the lowest dry weight of weeds (0.5 q/ha) and highest weed control efficiency of 98.2 per cent (Patel and Patel, 1984). In weed control treatments which included 2 kg butachlor/ha, 1 kg butachlor/ha + 1 handweeding, 2 kg thiobencarb/ha and 1 kg/ha thiobencarb + 1 handweeding, it was found that the higher rate of both the herbicides were superior to their lower rates in decreasing weed populations (Chandrakar et al.1985). Singh and Singh (1985) reported that among the weed control methods tried in transplanted rice, thiobencarb application followed by one handweeding registered the lowest weed population and dry matter.

In general a review of integrated weed control indicated that more efficient weed control can be achieved by the integration of chemical and cultural methods.

2.5. Efficiency of Types of Formulations.

The chemicals presently used in rice are applied either in liquid or granular forms. The latter is favoured by the farmers as it required no special skill to apply and is much simpler in application. Literature in the efficiency of different types of formulation of thiobencarb and butachlor is given below.

Datta et al.(1968) observed that granular herbicides had low toxicity level for rice but gave good weed control and increased grain yield. Yogeswara Rao and Padmanabhan (1972) found that granular herbicides have performed better than herbicidal sprays. Green and Uchida (1974) reported that liquid formulations caused more initial phytotoxicity compared to granules. According to Zahran and Ibrahim (1975) the granular formulations obtained by mixing liquid herbicides with sand were significantly superior to liquid formulations. Ravindran (1976) stated that granular formulations of butachlor and benthiocarb (thiobencarb) gave good control of weeds in the early stages of crop growth while E.C. formulations gave better control at later stages. Narayanaswamy and Sankaran (1977) reported that E.C. formulations of all herbicides gave comparatively poorer control of weeds than the granular forms. Soundar Rajan et al.(1980) found that all emulsifiable forms of herbicides controlled weeds effectively comparable to handweeding but granular forms were ineffective in checking weed dry matter production. Advanced trials on irrigated transplanted rice in farmers' fields of Cagayan Province, Philippines revealed that in general weed control with granular formulations was inferior because of lack of water one week after herbicide application (Anon. 1981).

Thus contradictory results have been obtained by different workers regarding the effectiveness of granular and liquid formulations of herbicides.

2.5.1. Thiobencarb as Spray and Granules

Sundaru (1971) reported that benthiocarb(thiobencarb) granules 3 kg/ha applied 4 days after transplanting gave the best early and late control of weeds, but it was weak against broadleaved weeds such as Monochoria vaginalis. Chang and De Datta (1974) found that benthiocarb (thiobencarb) granules when applied at 6 days after seeding, injured rice plants slightly but gave adequate weed control. Tobar (1974) reported excellent control of grass weeds and in particular Echinochloa colonum by Saturn 50 EC applied 7 days after sowing in upland rice. At Bhubaneswar application of thiobencarb(liquid) in two splits @ 1.5 kg a.i/ha each after 3 days and 20 days of germination in upland rice proved to be as efficient as weed-free check (Anon 1974-75). Mehta (1975) reported that granular formulations of Saturn gave effective weed control when applied 4 days after transplanting. According to Sridhar et al.(1976) benthiocarb (thiobencarb) granules at 1.5 kg a.i/ha controlled wide spectrum of weeds which is evident from the lesser number of narrow leaved, broadleaved and sedge weeds and reduced crop-weed competition leading to higher number of tillers and panicles in rice. In direct sown irrigated rice thiobencarb at 1 kg/ha and avirosan at 1.5 kg a.i/ha gave the best selective weed control (Anon. 1977). Mandal (1977) reported that in broadcast and transplanted wet land rice, thiobencarb granules (1kg/ha) was found to be very effective for the control of all common weeds like barnyard grass, pickral and sedges except Salvinia.

Ravindran et al.(1978) reported that out of six herbicides applied to rice 6 days after transplanting, thiobencarb E.C. 2 kg/ha was the most effective one. Gill and Kolar (1980) found that thiobencarb E.C. 1.5 kg a.i/ha when applied as pre-emergence to weeds gave an effective control of Echinochloa crus-galli. Pandey and

Sharma (1980) reported that thiobencarb granules at 1.5 kg a.i/ha applied 4 days after transplanting gave good weed control and gave a weed count of $63/m^2$ as against $161/m^2$ in unweeded control and $56/m^2$ in handweeded plot. Pande (1982) noticed that good control of Echinochloa spp. and annual sedges was obtained by the application of thiobencarb at 1.5 kg a.i/ha in E.C. formulation 7 days after sowing in rice nursery. Lakshmi (1983) reported that pre-emergent application of thiobencarb @ 2 kg a.i/ha as spray recorded a weed control efficiency of 76 per cent while thiobencarb at 1.5 kg a.i/ha recorded 66-70 per cent efficiency.

2.5.2. Butachlor as Spray and Granules

Atar Singh and Dhama (1973) stated that the granular form of butachlor controlled weeds better and resulted in higher net profit. Rethinam and Sankaran (1974) found out that pre-emergence application of butachlor granules at 2.0 kg a.i/ha and a post-emergent spray of propanil at 3 litre a.i/ha gave best and economical weed control both under direct sown and transplanted conditions. They also concluded that butachlor granules and hand-weeding recorded the minimum dry matter production of weeds. Gupta et al.(1975) reported the effectiveness of butachlor granules at 1 kg/ha. Maharudrappa et al.(1975) noticed that butachlor granules at 1.5 kg/ha was on par with hand-weeded control in respect of number of weeds. Ravindran (1976) reported that butachlor (G) gave better control of dicot weeds in the early stages of crop growth while butachlor (E.C) at harvest.

Chakraborthy and Mukhopadhyay (1977) found that granular herbicides like C-288(Piperophos + dimethametryn), butachlor/2,4-D IPE and 2,4-D IPE showed good potential to control weeds. Similarly Singlachar (1977) found that granular chemicals like butachlor, 2,4-D IPE, MON 0358 and EPTC-M had shown good weed control comparable to hand-weeded treatments. Kahlon and Singh (1978) reported that liquid formulations of Basalin (fluchloralin) and Machete (butachlor) gave very good results when broadcasted after mixing with sand or urea. Shahi et al.(1978) pointed out that out of tho various herbicides tried Machete granular gave promising results and it was highly effective against barnyard grass. Application of butachlor liquid after blending with 10 kg of well sieved sand was effective in controlling the weeds in transplanted rice. Also this method reduced the application cost and avoided the handling of sprayers (Anon 1979). De and Mukhopadhyay (1979) reported that application of butachlor granules at 2 kg a.i/ha resulted in better weed control and the number of weeds was even less than handweeding (twice).

SoundarRajan et al. (1980) found that pre-plant application (15 days before seeding) of emulsifiable form of butachlor at 0.90 kg/ha controlled weeds effectively comparable to hand weeding as reflected in low weed dry weight. Ahmed and Hoque (1981) reported that butachlor sprayed at 2.0 kg/ha gave excellent weed control and there were no weeds in the butachlor treated plots until 15 days after crop emergence. Mukhopadhyay and Mondal (1981) stated that application of butachlor granules at 2 kg/ha, 6 days after transplanting greatly reduced the dry weight of weeds as did two handweedings. Pillai et al. (1983) reported that application of 0.2 kg oxyfluorfen granules, 0.75 kg oxadiazon granules or 1 kg butachlor granules/ha 5-6 days after transplanting rice seedlings gave excellent control of weeds. Mukhopadhyay and De (1984) noticed that greatest decrease in weed populations were given by 2 kg butachlor granules per hectare broadcasted 5 days after transplanting. Kerni et al.(1985) reported a linear decrease in weed population with increase in rates of butachlor granules from 5-30 kg/ha applied

4 days after transplanting rice seedlings.

Thus a general review on the different formulations of butachlor and thiobencarb indicate that granular formulations are superior to liquid formulations with regard to weed control efficiency and crop yield.

2.6. Effect of Weed Control on Nutrient Uptake by Crop and Weeds.

Chakraborthy (1973) reported that the nitrogen content was significantly higher in weeds than in rice straw. The weeds removed 29.9 and 30.9 kg/ha of nitrogen in two years and three handweedings brought down the nitrogen depletion to 2.66 and 9.88 kg/ha. He also noted that the weed species contained much nitrogen at the vegetative, flowering and post-flowering stages. Ramamoorthy et al. (1974) stated that strong negative correlation could be obtained between the uptake of nutrients by weeds and grain yield except in the case of phosphorus uptake at 90 days which was not significant. Rethinam and Sankaran (1974) observed the NPK uptake by the weeds as 62.1, 20.0 and 65.3 kg/ha and the crop as 56.6, 19.4 and 74.3 kg/ha respectively in weedy check. Also the nutrient removal by weeds was minimum under butachlor(G) and handweeding treatments. According to Vijayaraghavan (1974) in unweeded check the weeds removed 44.07 kg N, 22.23 kg P_2O_5 and 50.7 kg K_2O/ha in unweeded check at 90 days which was nearly half the quantity of N, P_2O_5 and two third of K_2O removed by a rice crop yielding 6000 kg/ha. Mani (1975) opined that the use of herbicides resulted in a substantial decrease in nitrogen depletion by weeds, thus improving the uptake of nitrogen by the crop. Correlation studies between depletion of nitrogen by weeds and the grain yield indicated that there was a high significant negative correlation of 0.717 and 0.674 in the first and second seasons respectively (Rangiah et al. 1975).

Okafor and De Datta (1976) observed a negative correlation between the total nitrogen uptake by weeds and rice grain yield for all levels of nitrogen applied in all seasons (r = 0.72). Rangiah et al.(1976) reported that the loss of plant nutrients due to weeds in the unweeded check were 61.84 kg N, 13.27 kg P_2O_5 and 62.12 kg K_2O/ha while it was 22.84, 5.28 and 19.18 kg of N, P_2O_5 and K_2O/ha in the butachlor treated plot. They also observed that the uptake was further reduced to 16.13, 3.72 and 14.45 kg/ha of N, P_2O_5 and K_2O when butachlor was supplemented with one hand weeding. Ravindran (1976) stated that a negative correlation exists between nitrogen uptake by weeds and nitrogen uptake by crop. Abraham Varughese (1978) reported that negative correlations exist between nutrient uptake by the weed and the crop yield and also nutrient uptake by the crop and the weed. He also found that the demand for nutrients was in the order of K > N > P by crop and weeds. According to Nanjappa and Krishnamurthy (1980) the total uptake of N, P_2O_5 and K_2O by rice crop plus weeds in an unweeded control treatment was less than the uptake of nutrients by the crop alone in weed free plots. Lakshmi (1983) reported that N and K_2O uptake by the crop was higher than P_2O_5 uptake at all stages of growth. She also found that thiobencarb 2.0 kg a.i/ha, nitrofen 1.875 kg a.i/ha, thiobencarb 1.5 kg a.i/ha and bentazon 2.0 kg a.i/ha recorded lower uptake values by weeds than handweeding twice. Mohankumar and Singh (1983) observed that pre-emergence application of butachlor 1.0 kg a.i/ha or post-emergence application of bentazon 1 kg a.i/ha with propanil 2 kg a.i/ha each supplemented with one handweeding, raised the nitrogen uptake by rice crop and reduced nitrogen depletion by weeds. According to Singh and Sharma (1984) rice direct sown into puddlod soil accumulated more nitrogen during the first 35 days after sowing but by 75 days after sowing and at harvest, the transplanted rice had accumulated most. They also noticed that rice accumulated most nitrogen after treatment with butachlor, propanil and thiobencarb.

Kondap et al.(1985) reported that the uptake of N, P and K by weeds was 30.51, 6.52 and 25.0 kg/ha respectively in weedy control plots. Singh and Reddy (1985) observed that butachlor 1.5 kg/ha when combined with one handweeding or two mechanical weedings or 1.0 kg propanil gave lower nitrogen loss through weeds than their separate application. Singh and Singh (1985) reported that all the weed control treatments significantly improved the nitrogen uptake by crop over unweeded control. They found that maximum uptake of 48.0 kg N/ha was recorded by handweeding twice followed by thiobencarb combined with one handweeding (45.3 kg N/ha) as against 33.1 kg N/ha in weedy check.

Thus under all conditions it was found that uptake of nutrients by crop was reduced by the presence of weeds, and weeds removed more nutrients than the crop.

2.7. Effect of Weed Control on the Growth, Yield and Quality of Transplanted Rice.

Chang and De Datta (1972) reported that application of benthiocarb (thiobencarb) granules can be reduced from the recommended rate of 3.0 kg to 1.5 kg a.i/ha without sacrificing appreciably the grain yield and for granular butachlor the recommended rate of 1.5 kg a.i/ha itself was enough. Rethinam and Sankaran (1974) studied the comparative efficiency of herbicides on IR-20 and found that maximum productive tillers and maximum dry matter production of crop were obtained in plots treated with butachlor granules at 2 kg a.i/ha. The height of plants at harvest and the various yield attributes like panicle length, number of grains per earhead and thousand grain weight were not influenced by the different weed control methods. Sankaran et al.(1974) found that maximum seed yield of 5100 kg/ha was obtained in the machete applied plots. According to Gomez and De Datta (1975) improved water management and weed control increased both protein content and grain yield. Gupta et al. (1975) stated that butachlor at 1 kg a.i/ha when applied as granules was more effective in increasing the yield. Maharudrappa et al.(1975) reported that butachlor granules at 1.5 kg a.i/ha produced lesser thousand grain weight.

Rangiah et al.(1975) reported that highest yield in transplanted rice was given by handweeding and propanil gave better yield than butachlor. Also handweeding recorded the lowest weed index of 1.65 per cent as compared to 13.61 and 10.69 per cent in butachlor and propanil treatments. Experiment conducted to test the efficacy of some new herbicides revealed that maximum panicle weight was recorded in C 19490 (Piperophos) which was 54.8 per cent more than in handweeded plots and this was followed by Machete which was 29.2 per cent more than in handweeding (Subbiah et al.1975).

In trials at CRRI, Cuttack, benthiocarb (thiobencarb) granules at 1.5 kg a.i/ha at pre-weed emergence gave 44 per cent yield increase in transplanted rice (Dubey 1976). Rangiah et al.(1976) found that reduction in yield due to weed infestation in the control plot was 45 per cent as shown by weed index. The reduction in the herbicide plots were 7.45 with butachlor at 2.0 kg a.i/ha and 10.28 with propanil at 3.0 kg a.i/ha when compared with the system of weed control involving butachlor and a hand-weeding. Gill et al.(1977) observed that application of butachlor gave higher yields when compared to handweeding twice and unweeded control. Kakati and Mani (1977) reported that a single application of butachlor @ 20 kg/ha gave as much grain yields as manual weeding. Hoque et al. (1978) found that transplanted rice has less weed infestation and showed no significant reduction in yield between the control and herbicide-alone plots. But a low dose of herbicide combined with one handweeding, however increased yields by 97 per cent over the control. Kahlon and Singh (1978) reported that Machete granules gave 193.3 per cent and 73.7 per cent increase in yield over control and handweeding respectively. In a weed control experiment on transplanted rice, it was found that there was no significant difference among the treatments with regard to the number of productive tillers and the yield of grain and straw (Rajaram et al. 1978). However, they found that Machete when combined with one handweeding gave higher yield than those obtained by the use of Machete alone. Ravindran et al.(1978) found that application of benthiocarb (E.C) recorded the highest grain yield which was on par with penoxalin (G), handweeding and butachlor (G). Shahi et al.(1978) reported that application of Machete at 1.0, 1.5, 2.0 and 2.5 kg a.i/ha gave an increase in yield of 20 q/ha over unweeded control and was on par with handweeding. Gidnavar and Shivanandiah (1979) observed that butachlor granular at

30 kg product/ha produced the highest grain and straw yields and the next best yield was obtained with liquid butachlor at 2.5 kg a.i/ha mixed with sand.

Gill and Kolar (1980) reported that benthiocarb(G) at 2.0 kg a.i/ha increased the number of grains per panicle and number of effective tillers per m^2 with a consequent increase in grain yield over the weedy check. They also noticed that neither thiobencarb nor butachlor induced any phytotoxic effect on the crop height. Chela and Gill (1981) reported that butachlor at 3 kg/ha reduced the number of tillers per m^2 and grain yield. But benthiocarb (thiobencarb) at 2 and 3 kg a.i/ha did not have adverse effect on grain yield. Gill and Mehra (1981) stated that yield attributes of rice viz. effective tillers, panicle length, number of grains per panicle and test weight of grain were not adversely affected by the application of butachlor and benthiocarb(thiobencarb) even at higher concentration. Nanjappa and Krishnamurthy (1981) found that herbicides like AC92253 E.C.(Pendimethalin), butachlor (G) and butachlor (E.C.) performed better in recording the highest grain and straw yields. Patel and Patel (1981) reported that handweeding recorded the highest grain and straw yields and maximum number of panicles per m^2. Also no phytotoxic effect was observed in butachlor treatment.

Trials in different regions of India showed that application of 1 kg butachlor granules/ha 5 to 6 days after transplanting rice seedlings, markedly increased the paddy yields (Pillai et al. 1983). Subbian (1983) obtained increased paddy yields by the application of 0.6-1.0 kg 2,4-D EE 4 per cent or butachlor 5 per cent granules/ha. Patel and Patel (1984) obtained highest grain yield in rice by keeping weed-free upto 60 days after transplanting which was at par with that due to weeding at 20 and 40 days after transplanting, butachlor + weeding at 40 days after transplanting and fluchloralin + weeding 40 days after transplanting. Ali and Sankaran (1985) reported that application of thiobencarb and butachlor at 1.5 kg a.i/ha increased the number of productive tillers and grain yield in transplanted rice.

According to Singh and Singh (1985) maximum grain yield of rice was produced by two handweedings which was closely followed by butachlor applied at 2.5 kg a.i/ha, one handweeding and propanil at 2.0 kg a.i/ha. Dubey and Harbans Singh (1986) reported that pendimethalin, butachlor and benthiocarb (thiobencarb) oach at 1.5 kg a.i/ha did not differ significantly from weed-free check with regard to grain yield. Jayakumar et al.(1986) found that the yield parameters and paddy yield wore not affected by the higher levels of butachlor.

Thus application of butachlor and thiobencarb enhanced the grain and straw yields of transplanted rice and further improvement of the yield attributes was brought about by combining the chemicals with manual weeding.

2.8. Economics of Integrated Weed Management.

The possibility of using pre-emergence soil applied herbicides at half or less than half the recommended doses with a view to supporting rather than replacing manual weeding by the small holders has been tried by several workers. Literature is cited below on the economical aspects of using this combined method of weed control.

Sahu and Pitambar Das (1969) observed that when MCPA was followed by handweeding it gave the highest return of Rs.615.65 in broadcast crop and Rs.733.55 in drilled crop. Rangiah et al. (1974) reported that machete granules at 2.5 kg a.i/ha is more effective and economical than Stam F-34 at 3.0 kg a.i/ha individually and in combination with one handweeding. They obtained maximum net profit when machete granules were supplemented by one handweeding. Vijayaraghavan (1974) observed that handweeding twice, machete plus handweeding and Stam F-34 plus handweeding gave higher net profit over control. When the economics of cultural and herbicide treatments was compared there was only a marginal net profit due to the application of herbicides. But herbicides followed by cultural method gave better results (Rangiah et al.1976). Nanja Reddy and Ramanna (1978) found that the total cost of weed control through the use of 2,4-D or machete combined with some handweeding was Rs.78.11/acre (Rs.192.94/ha) while the cost of weeding purely by manual labour was Rs.101.22/acre (Rs.250.01/ha). Rajaram et al.(1978) reported that a net return of Rs.3100/ha was derived from the application of machete alone, while machete + 1 handweeding gave a net return of Rs.2975/ha. Application of pre-emergence herbicides at low dosage rates in combination with manual weeding reduced weeding cost for small holders by about 40 per cent as compared to handweeding or herbicide application at the recommended rate (Versteeg and Maldonado, 1978). Elliot et al. (1984) found that butachlor applied 1 day after sowing followed by handweeding 3 weeks after emergence cost Pese 323/ha which was Pese 40 greater than that spent for hoeing followed by two hand weedings. But the time spent on weed control was considerably less for the herbicide plus handweeding treatment.

Thus under all conditions, the use of herbicide in combination with handweeding has been found to be economical.

2.9. Herbicide Residues and It's Effect on the Succeeding Crop.

Chang (1973) found that one application of herbicides such as butachlor, M.O 401, nitrofen and benthiocarb(thiobencarb) in rice left residues in amounts toxic to several upland crops that follow rice. Herbicides like Machete and Stam F-34 lack residual activity and do not control effectively the regeneration of perennial weeds (Rangiah et al. 1974). According to Vijayaraghavan (1974) application of Machete and Stam F-34 to rice had no adverse effect on the stand, yield and nodulation of the succeeding pulse crop of greengram. At Bhubaneswar application of thiobencarb (liquid) in two splits @ 1.5 kg a.i/ha each after 3 days and 20 days of germination gave effective weed control in rice and gave maximum yield of the succeeding rabi crop of cowpea (Anon 1974-75). Maharudrappa et al.(1975) noticed that herbicides like, 2,4-D sodium salt, propanil and butachlor applied to Kharif rice showed no significant residual effect on the following *rabi* crop of rice. Studies conducted at Bhubaneswar revealed that butachlor at 3.0 kg a.i/ha, benthiocarb (thiobencarb) at 3 kg a.i/ha, benthiocarb (thiobencarb) 2 kg a.i/ha applied to upland rice produced no toxicity on the *rabi* crop of fodder cowpea. (Anon 1975-76). Ravindran (1976) reported that there was no residual effect left in the experimental area due to application of thiobencarb, butachlor and penoxalin on the succeeding cowpea crop. According to Balu and Sankaran (1978) nitofen, butachlor, penoxalin, dichlormate and avirosan applied to rice did not affect the germination percentage of the crops raised after its harvest. They concluded that butachlor and penoxalin increased the dry matter production of green gram and sunflower. Patro and Prusty (1978) reported that propanil and butachlor applied to *Kharif* crop of rice had no residual toxicity for the succeeding crop of groundnut. Application of pre-emergence herbicides like butachlor(G) and Sirmate(G) and post-emergence spray of Stam F-34 to transplanted rice caused no significant yield difference of the subsequent Co-2 black gram crop(Rajaram et al. 1978).

Chela and Gill (1980) observed that thiobencarb, butachlor, propanil, avirosan or nitrofen applied to rice had no phytotoxic effect on wheat, rye, or oil-seed flax sown after rice. According to Ahmed and Hoque (1981) application of butachlor to dry seeded rice had no residual effect on the weed growth in transplanted rice raised after it. Subramanian and Ali (1985) also observed no residual effect of butachlor or thiobencarb on crops like cowpea, blackgram, soybean, gingelly, fingermillet and cotton raised after rice. In a rice/green gram rotation, rice was treated with butachlor and green gram dibbled in rice stubbles and given 0.75 kg fluchloralin or no fluchloralin. It was found that the seed yield of the green gram was similar in both fluchloralin treated and untreated plots (Jayakumar et al.1986).

Thus it is seen that in general, butachlor and thiobencarb leave little residue in soil to suppress weed growth or decrease the yield of the succeeding crops like pulses.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

A field experiment was conducted to evolve a suitable weed management technique for transplanted medium duration rice and its effect on the succeeding crop of cowpea.

3.1. Experimental site and cropping history.

The experimental site was selected at Palappoor area, on the western side of the Instructional Farm, College of Agriculture, Vellayani. The college is located at 8°N latitude and at an altitude of 29 m above MSL. The experimental area was under a bulk crop of rice during the previous two seasons.

3.2. Season.

The experiment was conducted during the *Mundakan* (Second crop) season of 1985-86.

3.3. Climate.

The experimental area enjoys a humid tropical climate. The meteorological parameters recorded were rainfall, maximum and minimum temperatures, their weekly averages during the crop period, the mean of the weekly average for the past five years and the variation between them are presented in Fig.1 and Appendix I.

3.4. <u>Soil.</u>

The soil of the site is sandy clay in texture. The physical and chemical composition of the soil is given below:

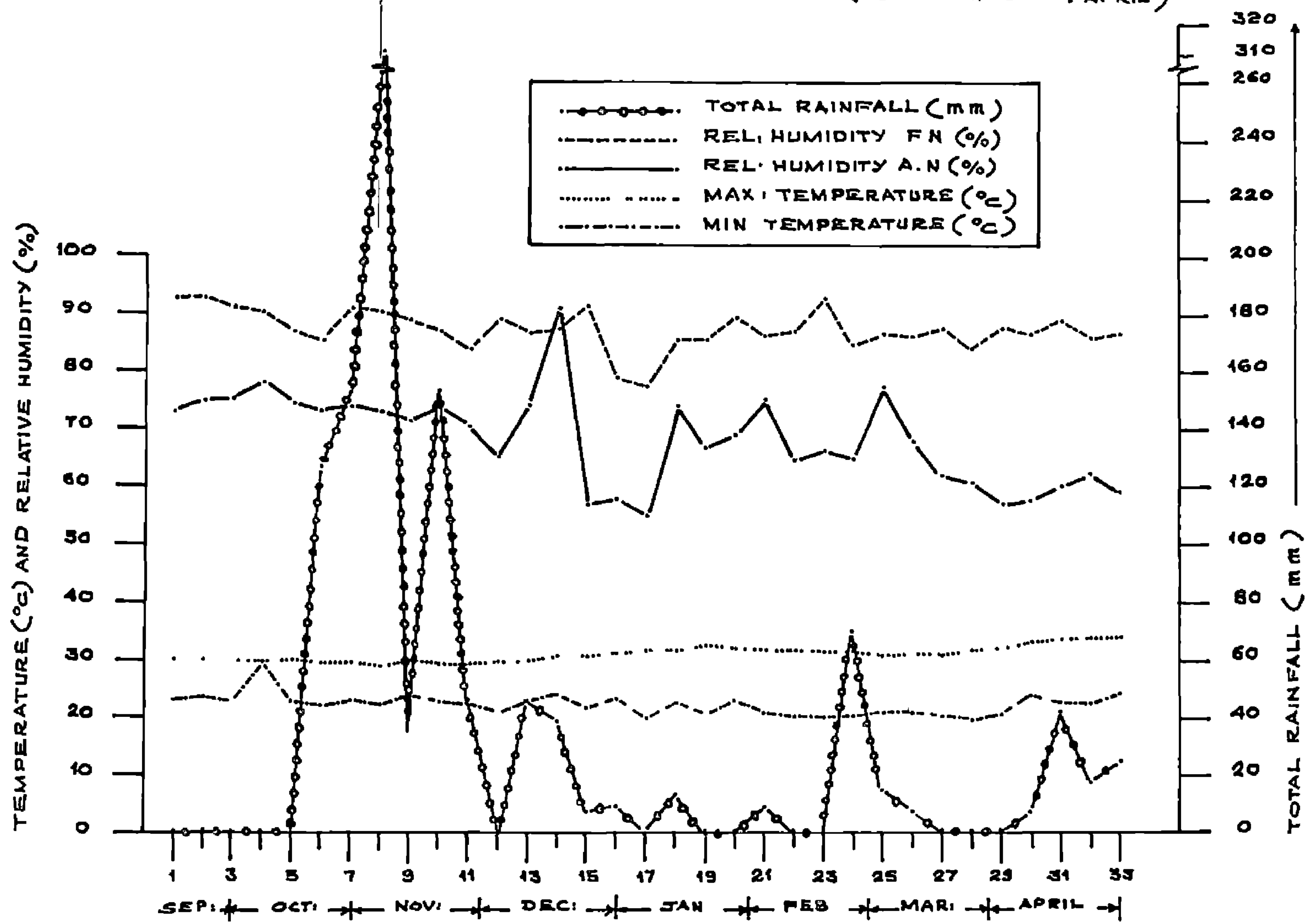
Physical composition

Coarse sand	42.00 per cent
Fine sand	15.28 "
Silt	7.80 "
Clay	31.20 "

Chemical composition

Total Nitrogen	0.0924 per cent (Microkjeldahl method)
Available P_2O_5	16 kg/ha (Bray's method)
Available K_2O	176 kg/ha (Ammonium acetate method)
pH	5.2

FIG. 1 WEATHER CONDITIONS DURING THE CROP SEASON (10th SEPT. TO 29th APRIL)



3.5. MATERIALS

3.5.1. Experiment No.1 (Main Experiment)

3.5.1.1. Variety

The rice variety used for the experiment was Jaya - a medium duration variety which takes about 120-125 days to mature.

Paddy seeds with 96 per cent germination obtained from the Government Seed Farm, Ulloor, Trivandrum was used for the experiment.

3.5.1.2. Fertilizers

Urea analysing to 46 per cent N, Super phosphate analysing to 16 per cent P_2O_5 and Muriate of potash analysing to 60 per cent K_2O were used for the experiment.

3.5.1.3. Herbicides

The herbicides Thiobencarb and Butachlor were applied in spray form and in granular form according to treatments.

3.5.1.3.1. Thiobencarb (Saturn)

Saturn is a carbamate herbicide formulation containing 50 per cent active ingredient - thiobencarb [S-4-(Chlorobenzyl) - N, N-diethyl thiolcarbamate]. It is a product of Kumiai Chemical Industry Company Limited, Tokyo, Japan which is marketed by Pesticides India, Udaipur. Thiobencarb is a pre-emergence and early post-emergence herbicide used in rice for the control of many annual grasses and broad-leaved weeds.

3.5.1.3.2. Butachlor (Delchlor)

Delchlor is an acetamide herbicide formulation containing 50 per cent active ingredient - butachlor [N-(butoxymethyl)-2-chloro-2',6'-diethylacetanilide]. It is a product of Coromandel Indag Ltd., Madras. Butachlor controls most annual grasses and some broad-leaved weeds in transplanted and direct-seeded rice. It is used as a pre-emergence and early post-emergence herbicide.

3.5.2. Experiment No.2 (Residual studies).

The same soil and climatic conditions prevailed during the second experiment also.

3.5.2.1. Season

The experiment was conducted during the Puncha (third crop season) of 1985-86.

3.5.2.2. Variety

The cowpea seeds (variety Krishnamony) obtained from the District Farm, Peringamala were used for the experiment.

3.5.2.3. Rhizobium culture

The cowpea seeds were treated with rhizobium culture received from the Department of Plant Pathology, College of Agriculture, Vellayani as per Package of Practices of K.A.U. (Anon. 1982).

3.5.2.4. Fertilizers

The same fertilizers used for the first experiment were used in the second experiment also.

3.6. METHODS

3.6.1. <u>Experiment No.1</u>

3.6.1.1. Experimental details

The experiment was laid out in simple randomised block design with 15 treatments and 3 replications. The layout plan is given in Fig.2.

3.6.1.1.1. Treatments

T_1 - Thiobencarb 1.5 kg a.i/ha spray

T_2 - Thiobencarb 1.5 kg a.i/ha granules

T_3 - Thiobencarb 1.0 kg a.i/ha spray

T_4 - Thiobencarb 1.0 kg a.i/ha granules

T_5 - Thiobencarb 1.0 kg a.i/ha spray + 1 Handweeding 35 DAT*

T_6 - Thiobencarb 1.0 kg a.i/ha granules + 1 Handweeding 35 DAT*

T_7 - Butachlor 1.5 kg a.i/ha spray

T_8 - Butachlor 1.5 kg a.i/ha granules

T_9 - Butachlor 1.0 kg a.i/ha spray

T_{10} - Butachlor 1.0 kg a.i/ha granules

T_{11} - Butachlor 1.0 kg a.i/ha spray + 1 Handweeding 35 DAT*

T_{12} - Butachlor 1.0 kg a.i/ha granules + 1 Handweeding 35 DAT*

T_{13} - Handweeding twice (20 DAT and 35 DAT)

T_{14} - Completely weedfree plot

T_{15} - Unweeded control

* Days after transplanting

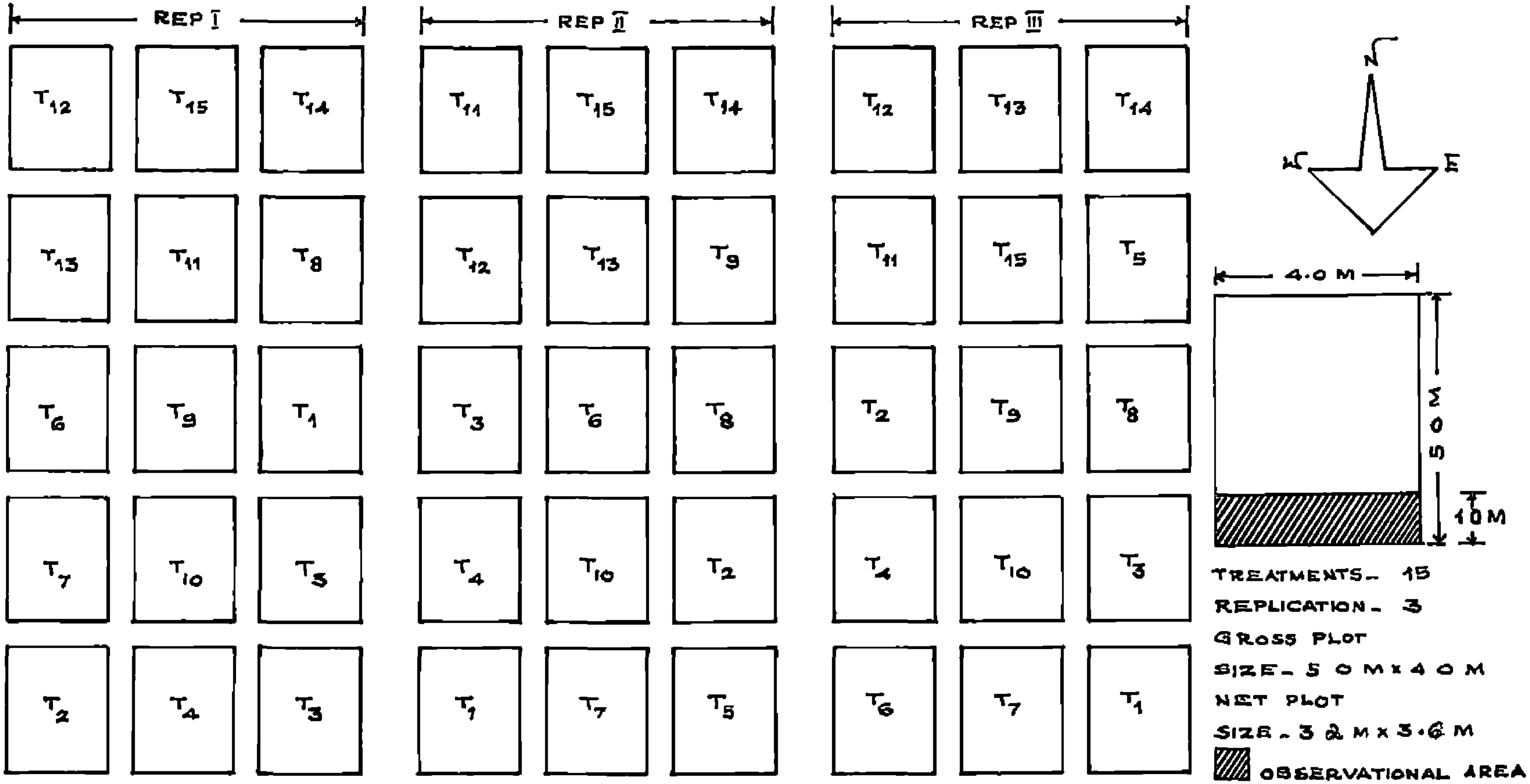
Gross plot size	- 5.0 x 4.0 m
Net plot size	- 3.2 x 3.6 m
Spacing	- 20 x 10 cm

An area of 1 x 4 m was left as observation area on the same side of all the plots for taking periodical weed observations and crop plant sampling. Two rows of plants were left as border on all the sides of the remaining plot.

3.6.1.1.2. Herbicide Application

Herbicides in the spray form were applied uniformly on the soil surface on the 6th day after transplanting by

FIG 2 LAY-OUT PLAN - RANDOMISED BLOCK DESIGN



TREATMENTS

- T_1 - THIOBENCARB SPRAY 1.5 kg a.i/ha
- T_2 - THIOBENCARB GRANULES 1.5 kg a.i/ha
- T_3 - THIOBENCARB SPRAY 1.0 kg a.i/ha
- T_4 - THIOBENCARB GRANULES 1.0 kg a.i/ha
- T_5 - THIOBENCARB SPRAY 1.0 kg a.i/ha + 1 HANDWEEDING 35 DAT*
- T_6 - THIOBENCARB GRANULES 1.0 kg a.i/ha + 1 HANDWEEDING 35 DAT
- T_7 - BUTACHLOR SPRAY 1.5 kg a.i/ha
- T_8 BUTACHLOR GRANULES 1.5 kg a.i/ha
- T_9 - BUTACHLOR SPRAY 1.0 kg a.i/ha
- T_{10} - BUTACHLOR GRANULES 1.0 kg a.i/ha
- T_{11} - BUTACHLOR SPRAY 1.0 kg a.i/ha + 1 HANDWEEDING 35 DAT
- T_{12} - BUTACHLOR GRANULES 1.0 kg a.i/ha + 1 HANDWEEDING 35 DAT
- T_{13} - HANDWEEDING TWICE (20 DAT & 35 DAT)
- T_{14} - COMPLETELY WEED FREE CONDITION
- T_{15} - UNWEEDED CONTROL

* - DAYS AFTER TRANSPLANTING

using a sprayer of 1½ litre capacity after the plots were drained. The spray solution was prepared and applied as suggested by Fisher and Sabio (1984).

Uniformly 5 per cent granules of both the herbicides were made in the laboratory by mixing in the ratio of 10 litres product with 95 kg dry sieved river sand. After mixing, the granules were uniformly spread in trays and kept overnight to allow the granules to dry. Doctors' gloves were used for mixing the herbicide and sand. These granules were broadcast uniformly in the concerned treatment plots after maintaining a thin film of water on the 6th day after transplanting.

3.6.1.1.3. Weeding Operation

In order to maintain a completely weedfree condition throughout the crop period in T_{14} plot regular handweedings were done once in 2 days. Two handweedings were done on 20th and 35th day after transplanting in treatment T_{13}. As per the requirement of T_5, T_6, T_{11} and T_{12} plots in which lower doses of the herbicides were applied, one handweeding was done on the 35th day after transplanting.

3.6.1.2. Cultivation Details.

3.6.1.2.1. Nursery preparation

The nursery area of 90 m^2 was ploughed well and raised beds of 1 m width and 15 cm height were prepared with drainage channels in between. Cowdung was applied and incorporated with the soil. Sprouted seeds were broadcasted uniformly on 14th September 1985. A seed rate of 75 kg/ha was adopted.

Irrigation was commenced on the 5th day after sowing and the depth of water level was maintained at 5 cm depending upon the growth of the seedlings.

3.6.1.2.2. Main field

The main field was ploughed twice and plots of 5.0 x 4.0 m were laid out with 15 plots in each block. There were three such blocks. The blocks and plots were separated with bunds of 30 cm and 20 cm width respectively. Irrigation and drainage channels were provided for all plots as shown in Fig.2.

Cowdung was applied @ 5 t/ha and incorporated with the soil. About 10 days before transplanting, lime was applied @ 600 kg/ha. The fertilizer schedule for medium duration variety as per Package of Practices Recommendations of Kerala Agricultural University (Anon., 1982) was followed.

Twentyfive day old healthy seedlings were transplanted in the main field at a spacing of 20 x 10 cm and at the rate of 2 seedlings per hill. Transplanting was done on the 9th October 1985. Ten days later gap-filling was done wherever necessary. A water level of 1.5 cm was maintained initially and later increased to 5 cm.

One spraying with Metacid and two sprayings with Sevin were given to the crop as a prophylactic measure. The stand of the crop was moderately good.

About 10 days before harvest the field was drained. Harvesting was done on the 17th January 1986.

3.6.1.3. Observations.

Observations on weeds and crop were taken from the area set apart for the purpose.

3.6.1.3.1. Observation on Weeds.

3.6.1.3.1.1. Weed Species

The weeds present in the experimental area before the start of the experiment and those collected during the experiment were identified and grouped into grasses, sedges and broad-leaved weeds.

3.6.1.3.1.2. Weed Count

Weed samples were collected from an area of 0.5 m^2 from each plot on the 20th, 35th and 60th day after transplanting and at harvest. These weeds were washed and classified into monocots and dicots and their counts taken. The weed population is expressed as the number of monocots, dicots and total weeds per m^2.

3.6.1.3.1.3. Dry Weight of Weeds

The weeds collected from the plots as mentioned above were dried in the shade and then oven-dried till it recorded constant weight. The dry weight of weeds was thus found out at 20th, 35th and 60th day after transplanting and at harvest and expressed as g per m^2.

3.6.1.3.1.4. Weed Control Efficiency

Weed control efficiency was calculated by the following formula and expressed in percentage.

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

x = weed count from the unweeded control plot

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

3.6.1.3.2. Observation on Crop.

These observations were taken from the same 0.5 m^2 area from which weed observations were taken.

3.6.1.3.2.1. Growth Characters

3.6.1.3.2.1.1. Height of the plant

The height of the plants was measured on 20th, 35th and 60th day after transplanting and at harvest. Height was measured from the base of the plant to the tip of the longest leaf or to the tip of the longest ear-head whichever was taller (Gomez, 1972).

3.6.1.3.2.1.2. Number of tillers per m^2

Total number of tillers in the 0.5 m^2 area were counted at 20th, 35th and 60th day after transplanting and expressed as number of tillers per m^2.

3.6.1.3.2.1.3. Leaf Area Index

Leaf Area Index was calculated at flowering. LAI was computed by the method suggested by Gomez (1972). 'n' sample hills (6) were selected. The maximum width 'W' and length 'L' of all the leaves or the middle tiller were noted and LAI was calculated as below:

Leaf area of a single leaf = K x L x W

where K is the adjustment factor which is 0.67 at seedling stage and harvest and 0.75 at other stages

Leaf area per hill = Total area of the middle tiller x total number of tillers

$$\text{LAI} = \frac{\text{Sum of leaf area per hill of the 6 sample hills in cm}^2}{\text{Land area covered by the 6 hills in cm}^2}$$

3.6.1.3.2.1.4. Dry Weight of Plant

From the 0.5 m^2 observational area all plant samples were cut at ground level on 20th, 35th and 60th day after transplanting and at harvest. They were dried in the shade and later oven-dried till it recorded constant weight. The dry weight of the plants were found out and expressed in kg/ha.

3.6.1.3.2.2. Yield Attributing Characters

3.6.1.3.2.2.1. Number of Productive Tillers

At harvest the total number of productive tillers in 0.5 m^2 area was noted and expressed as number of productive tillers per m^2.

3.6.1.3.2.2.2 Weight of Panicle

From the sampling area, 12 sample hills were selected and all the panicles in these hills were weighed and weight per panicle worked out.

3.6.1.3.2.2.3. Number of Spikelets per Panicle

The entire spikelets including filled and unfilled grains were counted from which the mean number of spikelets per panicle was worked out.

3.6.1.3.2.2.4. Number of Filled Grains per Panicle

From each sample hill, the central or middle panicle (based on height) was separated from the rest of the panicles. The grains from the central panicles from all sample hills were threshed and bulked. The filled grains were separated from the unfilled grains. The number of filled grains (f) and the unfilled grains (u) were counted and the weight of filled grains (w) was recorded. The grains from the rest of the panicles of all sample hills were threshed and filled grains were separated from the unfilled grains. The number of unfilled grains (U) were counted and weight of the filled grains (W) was recorded. From this, the number of filled grains per panicle was calculated by the following formula suggested by Gomez (1972).

No. of filled grains per panicle = $\frac{f}{w} \times \frac{W + w}{P}$

Where P is the total number of panicles from all sample hills.

3.6.1.3.2.2.4. 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 per cent moisture by the following formula suggested by Gomez (1972).

$$\text{Thousand grain weight} = \frac{100-M}{86} \times \frac{w}{P} \times 100$$

Where M is the moisture content of grains

3.6.1.3.2.3. Grain Yield

The remaining plots were harvested individually after removing the border rows all round, threshed, dried, winnowed and dry weight recorded. The dry weight was adjusted to 14 per cent moisture and expressed in kg/ha.

3.6.1.3.2.4. Straw Yield

The straw obtained from the net plots excluding weeds was dried in the sun, weighed and expressed in kg/ha.

3.6.1.3.2.5. Harvest Index

From the grain yield and straw yield calculated as mentioned above, the harvest index was worked out.

$$\text{Harvest index} = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3.6.1.3.2.6. Weed Index

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

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

Where WI = Weed Index

x = Yield from weedfree plot or the treatment which recorded the minimum number of weeds

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

3.6.1.4. Chemical Analysis.

3.6.1.4.1. Soil analysis

Composite soil sample collected before the start of the experiment was analysed to determine the physical composition, total nitrogen, available P_2O_5 and available K_2O content. The pH of the soil was determined using a pH meter in a 1:2:5 soil solution.

Soil samples collected from the individual plots after the main experiment, were analysed for total N by Microkjeldahl method, available P_2O_5 by Bray's method and exchangeable K_2O by ammonium acetate method.

3.6.1.4.2. Plant analysis

The crop and weed samples collected on the 20th, 35th and 60th day after transplanting and at harvest were analysed for total N, P and K.

3.6.1.4.2.1. Total nitrogen

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

3.6.1.4.2.2. Total phosphorus

The total phosphorus content was estimated by using Vanadomolybdophosphoric yellow colour method after extraction with triple acid. The yellow colour was read in a Klett Summerson Photoelectric colorimeter at 660 nm (Jackson, 1967).

3.6.1.4.2.3. Total potassium

The same extract used for phosphorus estimation was used for estimation of total potassium using the Flame Photometer method (Jackson, 1967).

3.6.1.4.3. Protein content of grains

The protein content of grains was calculated by multiplying the N content of grain by a factor 6.25 (Simpson et al.1965).

3.6.1.4.4. Uptake studies

The values of total uptake of N, P and K by the crop and weeds, were obtained as the product of the content of these nutrients and the dry weight of crop and weeds and expressed in kg per hectare, respectively.

3.6.2. <u>Experiment No.2</u>.

After the harvest of rice crop the plots were dug and made into beds of 10 cm height without altering the layout. Rhizobium treated cowpea seeds (var. Krishnamony) were dibbled at a spacing of 25 x 15 cm. Fertilizers were applied according to the Package of Practices Recommendations of Kerala Agricultural University (Anon.1982). No weeding operation was carried out. The crop was irrigated according to the requirement. One prophylactic spray with sevin was carried out. The stand of the crop was good.

At two days interval dry pods were picked from 70th day after sowing. There were 7 picking, the plants were cut and removed from the field.

3.6.2.1. Observations

3.6.2.1.1. Germination count

Counts of the number of cowpea seeds germinated was taken from an area of 0.5 m^2 from the third day to the tenth day after sowing and expressed the germination count.

3.6.2.1.2. Grain Yield

The dry pods were harvested from net plot after leaving two rows alround as border and the grains were separated from the pods, dried and weighed. The yield was expressed in kg per hectare.

3.6.2.1.3. Bhusa Yield

The bhusa harvested from the net plot was dried plot-wise and the dry weight of bhusa was expressed in kg per hectare.

3.6.3. Statistical Analysis

The data were subjected to statistical analysis by the Analysis of variance method and significant results were compared by working out critical difference. Data on weed counts were analysed after necessary transformation ($\sqrt{x + 1}$)

Important correlations were also worked out.

RESULTS

Table 1. List of weeds present in the experimental field

	Scientific Name	Family
I. Grasses.		
	Echinochloa colonum (Linn) Link	Graminae
	Panicum repens Linn	Graminae
	Brachiaria ramosa (Griseb) Stapf	Graminae
II. SEDGES.		
	Cyperus iria Linn	Cyperaceae
	Cyperus rotundus Linn	Cyperaceae
	Fimbristylis miliacea (Lin)Vahl	Cyperaceae
	Scirpus articulatus Linn	Cyperaceae
III. BROAD-LEAVED WEEDS.		
	Monechoria vaginalis (Burmf)Prest	Pontederiaceae
	Ludwigia parviflora (Linn) Roxb.	Onagraceae
	Ammania baccifera Linn.	Lytheraceae
	Marsilea quadrifoliata Linn	Marsileaceae

4. RESULTS

The results obtained were analysed statistically and the Analysis of variance tables are presented in Appendices II to XVIII. The mean values corresponding to various characters under study are given in Tables 2 to 18.

4.1. Experiment No.1

4.1.1. Observation on Weeds.

4.1.1.1. Weed Species

The different weed species from the experimental field were collected before and during the experiment and identified. They were grouped into grasses, sedges and broad leaved weeds and are presented in Table 1. The predominant weeds in the experimental field were *Echinochloa* spp, *Brachiaria ramosa*, *Cyperus* spp, *Fimbristylis miliacea*, *Salvinia molesta* and *Monochoria vaginalis*.

4.1.1.2. Weed Count

Observations on the count of monocot, dicot and total number of weeds were recorded before the experiment and also at 20,35 and 60 days after transplanting

Table 1. List of weeds present in the experimental field

	Scientific Name	Family
I. Grasses.		
	Echinochloa colonum (Linn) Link	Graminae
	Panicum repens Linn	Graminae
	Brachiaria ramosa (Gr.seb) Stapf	Graminae
II. SEDGES.		
	Cyperus iria Linn	Cyperaceae
	Cyperus rotundus Linn	Cyperaceae
	Fimbristylis miliacea (Lin)Vahl	Cyperaceae
	Scirpus articulatus Linn	Cyperaceae
III. BROAD-LEAVED WEEDS.		
	Monochoria vaginalis (Burmf)Prest	Pontederiaceae
	Ludwigia parviflora (Linn) Roxb.	Onagraceae
	Ammania baccifera Linn.	Lytheraceae
	Marsilea quadrifoliata Linn	Marsileaceae

and at harvest. Weed count before the experiment was made from an area of 0.5 m^2 each and the mean count expressed per sq. m were as follows.

Monocots	239
Dicots	171
Total	410

The data on weed count at 20,35 and 60 days after transplanting and at harvest were analysed statistically after square root transformation ($\sqrt{X + 1}$) and presented in Appendix II and the mean counts of monocot, dicot and total weeds in Tables 2(a), 2(b) and 2(c) respectively.

4.1.1.2.1. Monocot Weed Population

Since the completely weed free treatment T_{14} was superior to all the other treatments it is not mentioned in the following results.

4.1.1.2.1.a. 20 Days After Transplanting

Lowest count of monocot weeds was recorded by T_1 which was on par with T_2, T_8, T_7, T_6, T_{10}, T_5 and T_9 and superior to T_3, T_{12}, T_4, T_{11}, T_{13} and T_{15}; while T_{15} recorded the highest count which was on par with T_{13}, and T_{13} in turn was on par with T_{11}, T_4 and T_{12}. There was

Table 2(a). Monocot weed population /m^2 at different days after transplanting (After $\sqrt{x+1}$ transformation)

Treatments	20	35	60	Harvest
T_1	3.54 (11.51)	3.76 (13.14)	4.61 (20.30)	7.06 (48.87)
T_2	3.91 (14.33)	4.85 (22.55)	6.54 (41.78)	9.25 (84.48)
T_3	5.68 (31.28)	5.58 (30.17)	7.44(54.35)	9.54 (89.95)
T_4	6.62 (42.77)	4.71 (21.21)	7.87 (60.93)	8.73 (75.29)
T_5	5.08 (24.85)	4.90 (23.02)	7.72 (58.66)	6.93 (46.99)
T_6	4.79 (21.97)	3.91 (14.26)	8.44 (70.24)	8.34 (68.63)
T_7	4.67 (20.85)	5.57 (29.98)	7.88 (61.11)	10.12 (101.51)
T_8	4.31 (17.56)	5.54 (29.65)	8.32 (68.26)	9.55 (90.13)
T_9	5.19 (25.93)	5.41 (28.28)	8.88 (77.77)	9.13 (82.40)
T_{10}	4.91 (23.13)	4.57 (19.88)	10.05 (99.99)	10.79 (115.53)
T_{11}	7.01 (48.11)	6.00 (35.03)	7.55 (55.99)	8.38 (69.27)
T_{12}	5.96 (34.48)	5.51 (29.34)	7.58 (56.46)	9.24 (84.46)
T_{13}	7.62 (57.05)	7.16 (50.22)	10.25 (104.09)	10.34 (105.84)
T_{14}	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
T_{15}	9.27 (84.93)	9.13 (82.33)	13.29 (175.53)	15.26 (231.91)
CD (0.05)	1.719	1.554	2.524	2.377
SE	0.594	0.536	0.871	0.821

Note: Figures in paranthesis are the original weed count/m^2

no significant difference between T_3, T_{12}, T_4 and T_{11}.

4.1.1.2.1.b. 35 Days After Transplanting

T_1 continued to record minimum number of monocot weeds which was on par with T_6, T_{10}, T_4, T_2 and T_5 while T_{15} continued to produce maximum weeds and significantly inferior to all treatments. Next highest number was recorded by T_{13} which was on par with T_{11}. T_{11} in turn was on par with all tho other treatments except T_6 and T_1.

4.1.1.2.1.c. 60 Days After Transplanting

At 60 days after transplanting, T_1 showed its superiority in recording minimum weed count to all other treatments except T_2,while T_2 was found to be on par with T_3, T_{11}, T_{12}, T_5, T_4, T_7, T_8, T_6 and T_9. T_{15} recorded the highest monocot weed count and significantly inferior to all other treatments. T_{15} was closely followed by T_{13} which was on par with T_{10}, T_9, T_6, T_8, T_7 and T_4.

4.1.1.2.1.d. Harvest

At harvest T_5 recorded minimum weed count but it was on par with T_1, T_6, T_{11}, T_4, T_9, T_{12} and T_2; while T_{15} recorded the highest count which was significantly inferior to all treatments. Next highest count was recorded by T_{10} which was on par with all the other treatments except T_{11}, T_6, T_1, T_5 and T_{14}.

4.1.1.2.2. Dicot Weed Population

4.1.1.2.2.a. 20 Days After Transplanting

Completely weed free treatment T_{14} was on par with T_1, T_{12}, T_2, T_8, T_{10}, T_3, T_9 and T_5. T_1 was on par with all the treatments except T_6, T_{13} and T_{15}. T_{15} recorded the highest number of dicot weeds which was on par with T_{13} which in turn was on par with T_6.

4.1.1.2.2.b. 35 Days After Transplanting

Treatments T_8, T_{10}, T_1, T_9, T_7 and T_2 were as good as completely weed free treatment T_{14} while T_8 was on par with all treatments except T_6, T_4, T_{15} and T_{13}. T_{13} and T_{15} did not record any significant difference in the count.

4.1.1.2.2.c. 60 Days After Transplanting

T_{14} was on par with T_{11}, T_2, T_6 and T_8. T_{11} in turn was on par with most of the treatments and significantly superior to T_9, T_4, T_{13}, T_3 and T_{15}. T_{15} recorded highest dicot weed population and was on par with T_3 and T_{13} only.

Table 2(b). Dicot weed population /m^2 at different days after transplanting (After $\sqrt{x+1}$ transformation)

Treatments	20	35	60	Harvest
T_1	1.24 (0.55)	1.66 (1.74)	2.56 (5.56)	3.96 (14.66)
T_2	1.66 (1.74)	1.79 (2.21)	3.04 (8.22)	3.33 (10.12)
T_3	2.34 (4.48)	2.07 (2.27)	4.43 (18.59)	4.13 (16.03)
T_4	2.76 (6.64)	2.63 (5.90)	3.65 (12.35)	2.99 (7.92)
T_5	2.69 (6.25)	2.24 (4.00)	2.95 (7.69)	4.33 (17.77)
T_6	3.34 (10.18)	2.32 (4.39)	2.20 (3.86)	2.83 (7.00)
T_7	2.87 (7.23)	1.73 (2.00)	3.11 (8.64)	3.19 (9.17)
T_8	1.90 (2.61)	1.24 (0.55)	2.49 (5.29)	3.11 (8.64)
T_9	2.49 (5.20)	1.66 (1.74)	3.38 (10.42)	3.97 (14.79)
T_{10}	2.04 (3.15)	1.48 (1.21)	3.08 (8.48)	4.82 (22.20)
T_{11}	2.76 (6.64)	2.07 (3.29)	1.67 (1.79)	4.40 (18.35)
T_{12}	1.66 (1.74)	2.11 (3.46)	2.20 (3.86)	3.21 (9.31)
T_{13}	4.93 (23.32)	5.86 (33.58)	4.26 (17.14)	5.16 (25.68)
T_{14}	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
T_{15}	5.12 (25.17)	5.31 (27.23)	5.58 (31.02)	7.86 (60.72)
CD (0.05)	1.719	1.003	1.558	1.217
SE	0.594	0.346	0.538	0.420

Note: Figures in paranthesis are the original weed count/m^2

4.1.1.2.2.d. Harvest

T_{14} was significantly superior to all treatments. Next minimum number was recorded by T_6 which was on par with T_4, T_8, T_7, T_{12}, T_2, T_1 and T_9. T_{15} continued to record the highest weed population and significantly inferior to all treatments. Next higher number was recorded by T_{13} which was on par with T_{10}, T_{11}, T_5, T_3, T_9 and T_1.

4.1.1.2.3. Total Weed Population

Since the completely weed free treatment T_{14} had no weed population and significantly superior to all other treatments at all stages of growth, it is not referred hereunder.

4.1.1.2.3.a. 20 Days After Transplanting

T_1 recorded a low total weed population which showed no significant difference with T_2 and T_8, while T_2 was on par with T_8, T_{10}, T_7, T_9 and T_5. In the case of T_8, it equalled statistically with T_{10}, T_7, T_9, T_5, T_6, T_3 and T_{12}. Maximum number was recorded by T_{15} and was on par with T_{13} which in turn was on par with T_{11}. There was no significant difference in the total weed count noted between T_{11}, T_4, T_{12} and T_3.

Table 2(c). Total weed population/m^2 at different days after transplanting (After $\sqrt{x+1}$ transformation)

Treatments	Days after transplanting			Harvest
	20	35	60	
T_1	3.63 (12.15)	4.00 (15.02)	5.18 (25.79)	8.06 (64.03)
T_2	4.20 (16.68)	5.09 (24.90)	7.19 (50.71)	9.72 (93.49)
T_3	6.07 (35.87)	5.87 (33.43)	8.62 (73.36)	10.37 (106.60)
T_4	7.11 (49.54)	5.32 (27.28)	8.68 (74.35)	9.21 (83.86)
T_5	5.74 (31.89)	5.30 (27.07)	8.18 (65.93)	8.11 (64.81)
T_6	5.83 (33.02)	4.43 (18.64)	8.64 (73.73)	8.76 (75.59)
T_7	5.43 (28.44)	5.74 (31.98)	8.44 (70.17)	10.61 (111.50)
T_8	4.62 (20.37)	5.59 (30.25)	8.63 (73.50)	9.99 (98.78)
T_9	5.67 (31.11)	5.65 (30.87)	9.46 (88.43)	9.94 (97.83)
T_{10}	5.24 (26.41)	4.72 (21.24)	10.49 (109.03)	11.80 (138.15)
T_{11}	7.47 (54.87)	6.28 (38.38)	7.72 (58.55)	9.28 (85.06)
T_{12}	6.13 (36.58)	5.90 (33.79)	7.83 (60.29)	9.74 (93.92)
T_{13}	9.04 (80.72)	9.24 (84.43)	11.07 (121.48)	11.53 (131.99)
T_{14}	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)
T_{15}	10.54 (110.18)	10.53 (109.84)	14.45 (207.68)	17.16 (293.41)
CD (0.05)	1.603	1.613	2.680	2.344
SE	0.553	0.557	0.925	0.809

Note: Figures in paranthesis are the original weed count/m^2

4.1.1.2.3.b. 35 Days After Transplanting

All the treatments except T_{13} were effective. T_1 recorded the lowest number of total weeds and was on par with T_6, T_{10}, T_2, T_5, T_4 and T_8. T_6 was on par with all the treatments except T_{11}, T_{13} and T_{15}, while T_{10} was on par with all treatments except T_{13} and T_{15}. Maximum count was recorded by T_{15} and it did not differ with T_{13}.

4.1.1.2.3.c. 60 Days After Transplanting

T_1 continued to show minimum number of weeds. T_1, T_2, T_{11} and T_{12} were equally effective but significantly superior to the other treatments. T_2 was on par with most of the treatments and significantly superior to T_{10}, T_{13} and T_{15}. T_{15} was significantly inferior to all treatments while T_{13} recorded next higher number and was on par with T_{10}, T_9, T_4, T_6, T_8, T_3 and T_7.

4.1.1.2.3.d. Harvest

T_1 which recorded the minimum weed population was significantly superior to T_7, T_{13}, T_{10} and T_{15} only. T_{15} continued to record the highest number of weeds and was inferior to all the treatments while T_{10} was on par with T_{13}, T_7, T_3, T_8, T_9, T_{12} and T_2.

4.1.1.3. Weed Dry Matter Production

The data on weed dry matter at 20, 35 and 60 days after transplanting and at harvest were analysed statistically and the analysis of variance table is presented in Appendix III and the mean values in Table 3(a).

4.1.1.3.a. 20 Days After Transplanting

T_1, T_8, T_2, T_6, T_5 and T_{10} recorded minimum dry matter production which was as good as a weed free situation (T_{14}). T_1 recorded the lowest dry matter production of weeds and it was on par with T_8, T_2, T_6, T_5, T_{10}, T_7 and T_9. T_{15} recorded the highest dry weight of weeds and was significantly inferior to all other treatments. It was followed by T_{13}in this aspect. T_{11} recorded the next highest dry matter production and was on par with all other treatments and significantly inferior to T_1 and T_{14}.

4.1.1.3.b. 35 Days After Transplanting

T_1, T_6, T_{10}, T_5 and T_2 recording low dry matter production of weeds were on par with T_{14}. T_1 which recorded the lowest weed dry matter production was on par

Table 3(a). Dry matter production of weeds at different days after transplanting (g/m^2)

Treatments	Days after transplanting			Harvest
	20	35	60	
T_1	1.86	2.53	14.35	32.88
T_2	3.61	6.50	23.27	43.35
T_3	6.81	10.33	36.48	46.23
T_4	6.70	9.70	35.92	41.02
T_5	4.24	6.31	17.83	20.60
T_6	3.95	4.18	24.76	33.29
T_7	4.90	9.59	34.67	44.48
T_8	3.49	7.98	26.47	38.19
T_9	5.27	9.48	29.68	37.94
T_{10}	4.25	6.06	39.17	57.82
T_{11}	7.07	12.19	20.36	31.07
T_{12}	6.77	9.11	16.50	35.21
T_{13}	14.61	20.85	51.23	67.75
T_{14}	0	0	0	0
T_{15}	20.29	30.72	76.44	108.62
CD (0.05)	4.802	7.231	22.380	25.909
SE	1.658	2.531	7.727	8.946

with T_6, T_{10}, T_5, T_2, T_8, T_{12}, T_9, T_7 and T_4. T_{15} recorded the highest dry matter production of weeds and significantly inferior to all treatments. It was closely followed by T_{13} which was also significantly inferior to other treatments. T_{11} recording the next highest dry matter production, showed no significant difference from T_3, T_4, T_7, T_9, T_{12}, T_8, T_2, T_5 and T_{10}, while it was significantly inferior to T_6, T_1 and T_{14}.

4.1.1.3.c. 60 Days After Transplanting

T_1, T_{12}, T_5 and T_{11} were on par with the completely weed free treatment(T_{14}) and significantly superior to the rest of the treatments. T_1 continued to record the lowest dry weight and it was on par with all other treatments except T_{10}, T_{13} and T_{15}. T_{15} recorded the maximum dry matter production and it was statistically inferior to the rest of the treatments. Next highest weed dry matter production was recorded by T_{13} which was on par with T_{10}, T_3, T_4, T_7 and T_9.

4.1.1.3.d. harvest

T_5 produced the lowest dry matter which was on par with T_{14} on one hand and with T_{11}, T_1, T_6, T_{12},

T_9, T_8, T_4, T_2, T_7 and T_3 on the other hand. T_{15} recorded the highest dry matter and it was inferior to the other treatments. T_{13} recorded the next highest dry matter production which showed no significant difference from T_{10}, T_3, T_7 and T_2.

4.1.1.4. Weed Control Efficiency

The data was analysed after angular transformation and the analysis of variance table is presented in Appendix IV and the mean values in Table 3(b).

T_{14} recorded the highest weed control efficiency (100%) and it was significantly superior to all other treatments. T_5 was the next efficient in controlling weeds and it was on par with T_1, T_{11}, T_4, T_6, T_{12}, T_2, T_9, T_8 and T_3. T_{13} recorded the lowest weed control efficiency which was on par with T_{10}, T_7, T_3, T_8, T_9, T_2 and T_{12}.

4.1.2. <u>Observations on Crop.</u>

4.1.2.1. Crop Growth Characters

4.1.2.1.1. Height of Plant

The height of plants was recorded at 20, 35 and 60 days after transplanting and at harvest. These data were analysed and the analysis of variance given in Appendix V. The mean values are presented in Table 4.

Table 3(b). Weed control efficiency (per cent)
(After angular transformation)

Treatments	Weed control efficiency (per cent)
T_1	60.62 (75.90)
T_2	54.56 (66.40)
T_3	52.32 (62.60)
T_4	56.58 (69.70)
T_5	61.88 (77.80)
T_6	56.57 (69.60)
T_7	51.48 (61.20)
T_8	54.22 (65.80)
T_9	54.27 (65.90)
T_{10}	46.15 (52.00)
T_{11}	57.18 (70.60)
T_{12}	54.99 (67.10)
T_{13}	45.90 (51.60)
T_{14}	90.00 (100.00)
T_{15}	0 (0)
CD (0.05)	9.709
SE	3.352

Note: The figures in paranthesis are the original values.

4.1.2.1.1.a. 20 Days After Transplanting

There was no significant effect of the treatments on the height of plants at 20 days after transplanting.

4.1.2.1.1.b. 35 Days After Transplanting

There was no significant difference in plant height between the various treatments at 35 days after transplanting.

4.1.2.1.1.c. 60 Days After Transplanting

At this stage also there was no significant difference among the treatments, regarding the plant height.

4.1.2.1.1.d. Harvest

At harvest, significant difference was observed among the treatments in the plant height. Plant height was the highest in completely weed free treatment. No significant difference in height was observed between T_{14}, T_{11}, T_{10}, T_9, T_6, T_8, T_5, T_{13} and T_{12}. Height was significantly low for plants grown in unweeded plots and it was inferior to all the other treatments. T_3 recorded the next lower height and was on par with T_1, T_4, T_2, T_7, T_{12}, T_{13}, T_5 and T_8.

Table 4. Height of plants at different days after transplanting (cm)

Treatments	Days after transplanting			Harvest
	20	35	60	
T_1	34.9	54.9	70.0	78.0
T_2	35.3	58.6	72.9	79.6
T_3	35.0	57.3	71.8	77.8
T_4	35.2	58.2	70.2	79.6
T_5	34.3	57.1	72.7	81.3
T_6	34.5	57.5	72.2	82.2
T_7	35.0	57.2	73.3	80.1
T_8	34.2	56.5	71.3	82.0
T_9	35.3	57.4	73.6	82.8
T_{10}	35.5	56.4	72.6	83.0
T_{11}	33.9	57.2	70.5	83.3
T_{12}	35.8	57.2	70.7	80.1
T_{13}	35.6	56.8	71.7	80.8
T_{14}	35.7	57.1	74.3	84.5
T_{15}	34.3	53.0	69.1	72.6
CD (0.05)	-	-	-	4.416
SE	0.525	1.319	1.331	1.525

4.1.2.1.2. Number of Tillers/m^2

The number of tillers were counted at 20, 35 and 60 days after transplanting. The data were analysed statistically and the analysis of variance is presented in Appendix VI and the mean values in Table 5.

4.1.2.1.2.a. 20 Days After Transplanting

T_{14} recorded the highest tiller number which was on par with T_{10}, T_8 and T_6 and superior to all other treatments. Next highest count was recorded by T_{10} which was superior only to T_{11}, T_5 and T_{15}. T_{15} was on par with T_5 and T_{11}.

4.1.2.1.2.b. 35 Days After Transplanting

The highest number of tillers was produced by T_{14} which was superior to all other treatments. T_{15} produced minimum number of tillers and it was inferior to all treatments. There was no significant difference in tiller number among other treatments (T_1 to T_{13}).

4.1.2.1.2.c. 60 Days After Transplanting

At 60 days after transplanting there was no significant difference in the number of tillers among all the treatments.

Table 5. Number of tillers/m^2

Treatments	Days after transplanting		
	20	35	60
T_1	258.0	338.0	310.0
T_2	252.7	333.3	334.7
T_3	250.0	336.7	336.0
T_4	248.0	325.3	310.7
T_5	238.0	330.7	327.3
T_6	267.3	349.3	340.0
T_7	242.7	325.3	316.0
T_8	272.7	342.0	348.7
T_9	254.7	334.0	338.0
T_{10}	272.7	356.7	334.0
T_{11}	238.7	335.3	322.7
T_{12}	241.3	340.7	321.3
T_{13}	252.0	322.0	340.7
T_{14}	298.0	438.7	382.0
T_{15}	207.3	276.0	308.7
CD(0.05)	32.648	37.496	-
SE	11.272	12.946	16.803

4.1.2.1.3. Leaf Area Index

The leaf area indices were estimated at flowering stage of the crop and the analysis of variance is presented in Appendix VII and the mean values in Table 6.

Plants in T_2 produced the highest LAI which was on par with T_{14}, T_4, T_1 and T_{12} and superior to all other treatments. T_{14} in turn was on par with T_4, T_1, T_{12} and T_5 and superior to all other treatments. There was no significant difference in LAI among T_4, T_1, T_{12}, T_5, T_{11} and T_8. T_{15} recorded the lowest LAI which was inferior to all other treatments except T_{13} with which it was on par. T_{13}, T_6, T_7, T_3, T_{10}, T_9 and T_8 did not differ statistically among themselves on this aspect.

4.1.2.1.4. Dry Matter Production

The dry matter production of crop was recorded at 20, 35 and 60 days after transplanting and at harvest. Their analysis of variance is presented in Appendix VIII and the mean values in Table 7.

4.1.2.1.4.a. 20 Days After Transplanting

Maximum dry matter production was recorded by T_{14} which was superior to all other treatments. T_{10} produced

Table 6. Leaf area index at flowering

Treatments	Leaf Area Index
T_1	5.64
T_2	6.02
T_3	4.84
T_4	5.66
T_5	5.35
T_6	4.80
T_7	4.81
T_8	5.08
T_9	4.99
T_{10}	4.95
T_{11}	5.27
T_{12}	5.56
T_{13}	4.58
T_{14}	5.95
T_{15}	4.05
CD (0.05)	0.614
SE	0.212

more dry matter than the rest of the treatments except T_9 with which it was on par. There was no difference statistically between T_9, T_8, T_5 and T_1. Minimum dry matter accumulation was noticed in T_{15} which was on par with T_{12}, T_4, T_{11}, T_7, T_3, T_6, T_{13} and T_2 and inferior to other treatments.

4.1.2.1.4.b. 35 Days After Transplanting

T_{14} recorded the highest dry matter production and it was superior to all treatments except T_6 and T_8 with which it was on par. Next highest dry matter production was noticed in T_6 and it was statistically equal to T_8, T_{10}, T_{11}, T_5, T_{12}, T_9 and T_{13}. T_{15} recorded the lowest dry matter production and it did not differ significantly from T_3, T_4, T_7 and T_2. T_1 was inferior to T_{13} and superior to T_2.

4.1.2.1.4.c. 60 Days After Transplanting

Highest dry matter accumulation was recorded by T_{14} which was on par with T_8 and superior to the other treatments. T_8 was superior to T_2, T_4 and T_3 and T_{15} only and on par with the rest. T_{15} recorded the lowest dry matter yield and it was on par with T_3 and T_4 while it was inferior to the other treatments.

Table 7. Dry matter production of crop at different days after transplanting (kg/ha)

Treatments	Days after transplanting			Harvest
	20	35	60	
T_1	846.7	3023.3	4901.7	7163.3
T_2	800.0	2969.3	4736.7	7155.7
T_3	766.7	2730.0	4235.7	6686.3
T_4	720.0	2866.7	4450.7	7267.7
T_5	883.3	3275.3	4818.7	7141.0
T_6	781.7	3800.0	5266.7	7646.3
T_7	763.3	2940.7	4851.3	6967.0
T_8	893.3	3743.3	5740.0	7775.3
T_9	966.7	3190.3	5073.0	7128.3
T_{10}	1049.3	3343.3	5267.3	6650.3
T_{11}	740.0	3286.7	5121.7	7232.0
T_{12}	666.7	3233.3	4750.0	6756.3
T_{13}	785.7	3135.0	5156.7	6427.0
T_{14}	1200.0	4405.3	6568.3	10653.3
T_{15}	666.7	2271.7	3723.0	5681.3
CD(0.05)	146.403	706.978	993.418	631.706
SE	50.548	244.103	342.995	218.107

4.1.2.1.4.d. Harvest

T_{14} continued to accumulate significantly more dry matter at this stage also, compared to all other treatments. T_8 had the next highest dry matter accumulation which was on par with T_6, T_4, T_{11}, T_1 and T_2. T_6 showed no significant difference from T_4, T_{11}, T_1, T_2, T_5 and T_9 but was superior to T_7, T_{12}, T_3, T_{10}, T_{13} and T_{15}. T_{15} recorded the lowest dry matter accumulation and was inferior to all treatments. T_{13} recorded the next lower dry matter production and was on par with T_{10}, T_3, T_{12} and T_7.

4.1.2.2. Yield Attributing Characters

The analysis of variance tables for the various yield attributing characters are presented in Appendix IX and their mean values in Table 8.

4.1.2.2.1. Productive Tillers/m^2

Complete weed free plot recorded the highest number of productive tillers and it was superior to the rest. The next highest count was produced by T_3 which was on par with T_8 and T_9 but superior to the rest. T_8 in turn was on par with all other treatments except T_{12}, T_3, T_{10}, T_{11}, T_4 and T_{15}. T_{15} recorded the lowest

Table 8. Yield attributing characters

Treat- monts	No.of pro- ductive tillers/ m^2	Weight of paniclo (g)	No. of spike- lets/ panicle	No. of filled grains/ panicle	Thousand grain weight (g)
T_1	226.7	2.27	96.4	68.9	24.95
T_2	224.0	2.24	98.9	62.4	25.00
T_3	257.3	1.86	96.4	59.7	24.27
T_4	208.7	1.86	106.3	75.5	24.67
T_5	223.3	1.62	93.3	58.7	24.77
T_6	224.7	2.49	114.1	83.2	25.16
T_7	230.7	1.64	101.1	72.3	24.99
T_8	247.3	2.51	106.7	80.2	24.97
T_9	236.0	1.80	104.6	74.6	25.47
T_{10}	219.3	1.90	97.5	72.3	23.42
T_{11}	218.0	2.37	91.5	62.3	24.96
T_{12}	220.0	2.37	111.7	81.9	25.03
T_{13}	219.3	1.79	103.1	69.4	24.87
T_{14}	311.3	2.57	118.5	86.7	26.97
T_{15}	195.3	1.62	87.3	63.9	22.83
CD(0.05)	26.503	0.362	14.169	14.846	1.256
SE	9.151	0.125	4.892	5.126	0.434

number of productive tillers and was inferior to all treatments except T_4, T_{11}, T_{10}, T_3 and T_{12}, with which it was on par.

4.1.2.2.2. Weight of Panicle

Maximum weight was recorded by T_{14} which was on par with T_8, T_6, T_{12}, T_{11}, T_1 and T_2. There was no significant difference between T_2 and T_{10}. The lowest weight was recorded by T_{15} and T_5 and both were on par with T_7, T_{13}, T_9, T_4, T_3 and T_{10}.

4.1.2.2.3. Number of Spikelets/ Panicle

Highest number of spikelets per panicle was recorded in T_{14} which was superior to all treatments except T_6, T_{12}, T_8, T_4 and T_9. T_6 was on par with T_{12}, T_8, T_4, T_9, T_{13} and T_7. T_{15} recorded the lowest count of spikelets and was on par with T_{11}, T_5, T_3, T_1, T_{10}, T_2 and T_7.

4.1.2.2.4. Number of Filled Grains/Panicle

T_{14} exhibited its superiority with regard to the number of filled grain also, and was on par with T_6, T_{12}, T_8, T_4, T_9, T_{10} and T_7. There was no difference statis-stically between T_6, T_{12}, T_8, T_4, T_9, T_{10}, T_7, T_{13} and T_1.

T_5 recorded the lowest number of filled grains and was on par with T_3, T_{11}, T_2, T_{15}, T_1, T_{13}, T_7 and T_{10}.

4.1.2.2.5. Thousand Grain Weight

Thousand grain weight was significantly high for plants grown in completely weed free plots and it was superior to all treatments. T_9 recorded the next highest grain weight and it was on par with all treatments except T_{10} and T_{15}. The lowest weight was observed in T_{15} which was on par with T_{10} and inferior to all the other treatments.

4.1.2.3. Grain Yield/ha

The analysis of variance table is presented in Appendix X and the mean values in Table 9.

The grain yield was significantly high in completely weed free plots. Though the yield from T_6 was significantly lower than that of T_{14} it was superior to other treatments. T_8 recorded the next highest yield and was on par with T_5, T_2, T_{11}, T_7, T_9, T_1, T_{12} and T_{13} but superior to T_4, T_3, T_{10} and T_{15}. T_{15} recorded the lowest grain yield and was inferior to all treatments except T_{10} which in turn was on par with T_3 and T_4.

FIG. 3 GRAIN YIELD, STRAW YIELD AND WEED DRY MATTER PRODUCTION AT HARVEST (kg/ha)

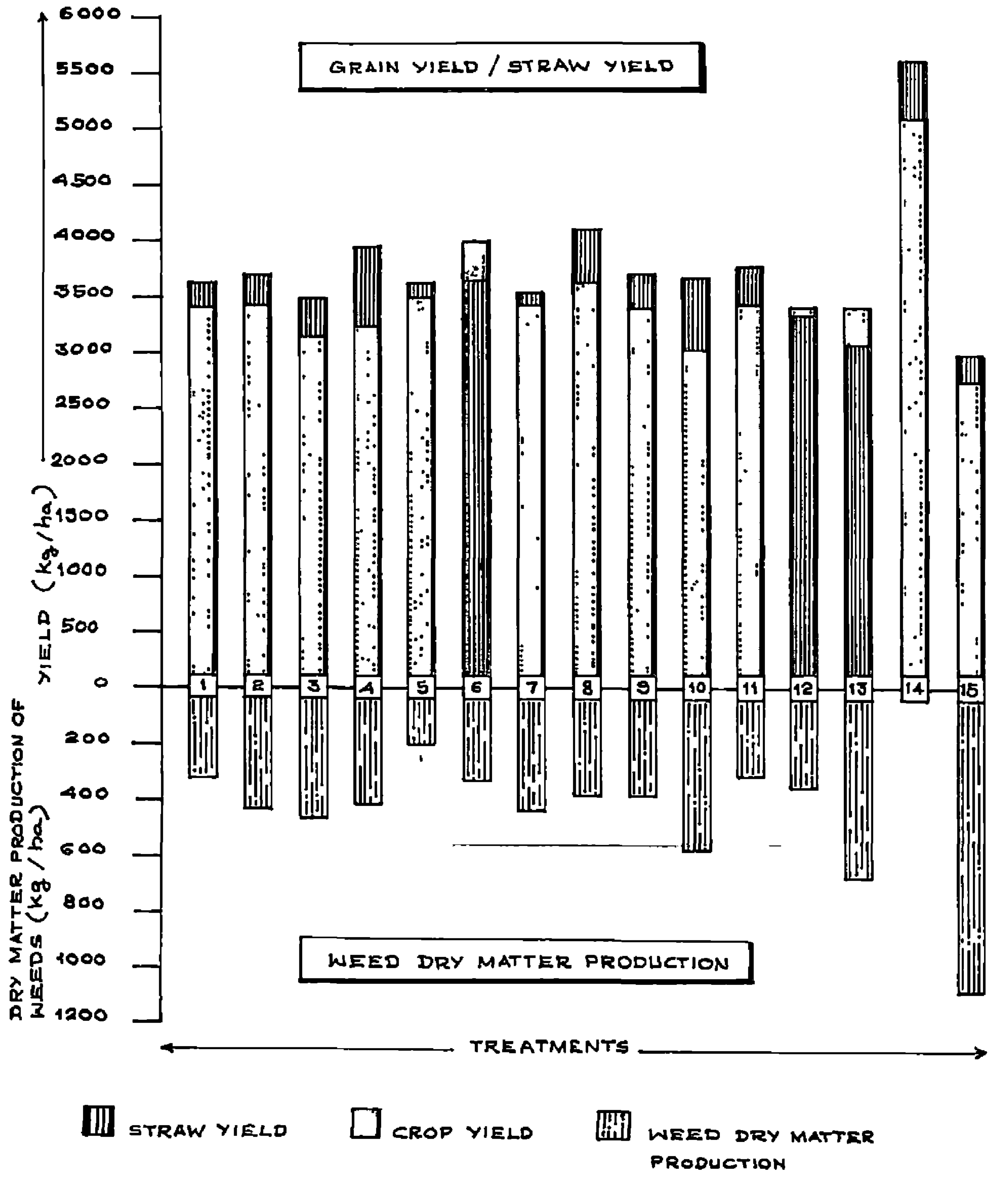


Table 9. Grain and straw yield (kg/ha) and Harvest Index

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index
T_1	3428.7	3734.7	0.48
T_2	3443.3	3712.3	0.48
T_3	3168.3	3518.0	0.47
T_4	3308.7	3959.0	0.45
T_5	3501.0	3640.0	0.49
T_6	3993.0	3653.3	0.52
T_7	3429.0	3538.0	0.49
T_8	3660.3	4115.0	0.47
T_9	3428.7	3699.7	0.48
T_{10}	3003.3	3647.0	0.45
T_{11}	3433.0	3799.0	0.47
T_{12}	3414.3	3342.0	0.51
T_{13}	3375.0	3052.0	0.52
T_{14}	5063.7	5589.7	0.48
T_{15}	2731.7	2949.7	0.48
CD (0.05)	320.741	614.793	-
SE	110.741	212.268	0.016

4.1.2.4. Straw Yield/ha

The analysis of variance table is presented in Appendix X and their mean values in Table 9.

T_{14} exhibited its superiority by recording the highest straw yield and it was followed by T_8 which did not differ significantly from T_4, T_{11}, T_1, T_2, T_9 T_6, T_{10}, T_5, T_7 and T_3. The lowest straw yield was noticed in T_{15} which was inferior to all treatments except T_{13}, T_{12}, T_3 and T_7.

4.1.2.5. Harvest Index

The analysis of variance table is presented in Appendix X and the mean values in Table 9.

There was no significant difference in harvest index between the different treatments.

4.1.2.6. Weed Index

The analysis of variance is given in Appendix XI and the mean values in Table 10.

The treatments showed significant variation in this aspect. T_{14} which recorded the highest yield was taken as the basis for calculation of weed index. The values were subjected to angular transformation and

Table 10. Weed Index (after angular transformation)

Treatments	Weed index
T_1	31.93 (27.97)
T_2	34.19 (31.60)
T_3	37.60 (37.20)
T_4	35.75 (34.10)
T_5	33.53 (30.50)
T_6	26.52 (19.90)
T_7	34.40 (31.90)
T_8	31.83 (27.80)
T_9	32.55 (28.90)
T_{10}	39.55 (40.60)
T_{11}	34.27 (31.70)
T_{12}	34.53 (32.10)
T_{13}	35.03 (32.90)
T_{14}	0 (0)
T_{15}	42.65 (45.90)
CD (0.05)	4.754
SE	1.641

Note: Figures in paranthesis are the original values.

analysed. T_6 recorded the lowest weed index and was superior to all treatments. This was followed by T_8 which was superior only to T_3, T_{10} and T_{15}. T_{15} recorded the highest weed index and was inferior to all treatments except T_{10}.

4.1.3. Chemical Analysis.

4.1.3.1. Nutrient Uptake of Rice

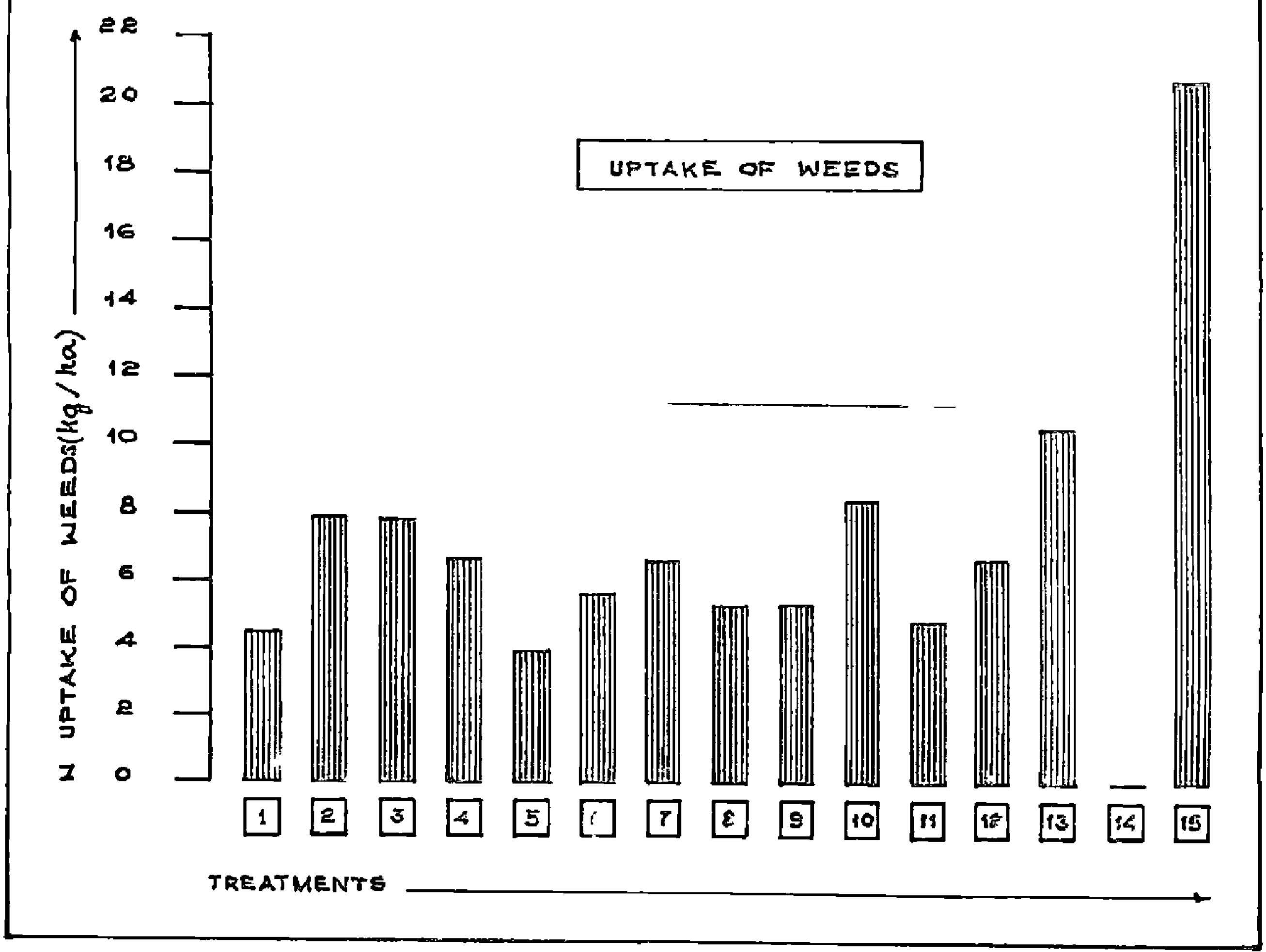
Nutrient uptake of rice was worked out on the 20th, 35th and 60th day after transplanting and also at harvest. The data were statistically analysed and the analysis of variance is given in Appendix XII and the mean values in Tables 11(a), 11(b) and 11 (c).

4.1.3.1.1. Nitrogen

The analysis of variance is presented in Appendix XII and the mean values in Table 11(a).

4.1.3.1.1.a. 20th Day After Transplanting

T_{14} recorded the highest uptake of nitrogen by crop and it was superior to the other treatments. T_8 recorded the next highest uptake which was on par with T_{10}, T_9 and T_{13}. The lowest uptake was noted in the weedy check which was inferior to all treatments except



UPTAKE OF WEEDS
N UPTAKE OF WEEDS(kg/ha)
22
20
18
16
14
12
10
8
6
4
2
0
1
2
3
4
5
7
9
10
11
13
14
15
TREATMENTS

FIG 4 NITROGEN UPTAKE OF CROP AND WEEDS AT HARVEST (kg/ha)

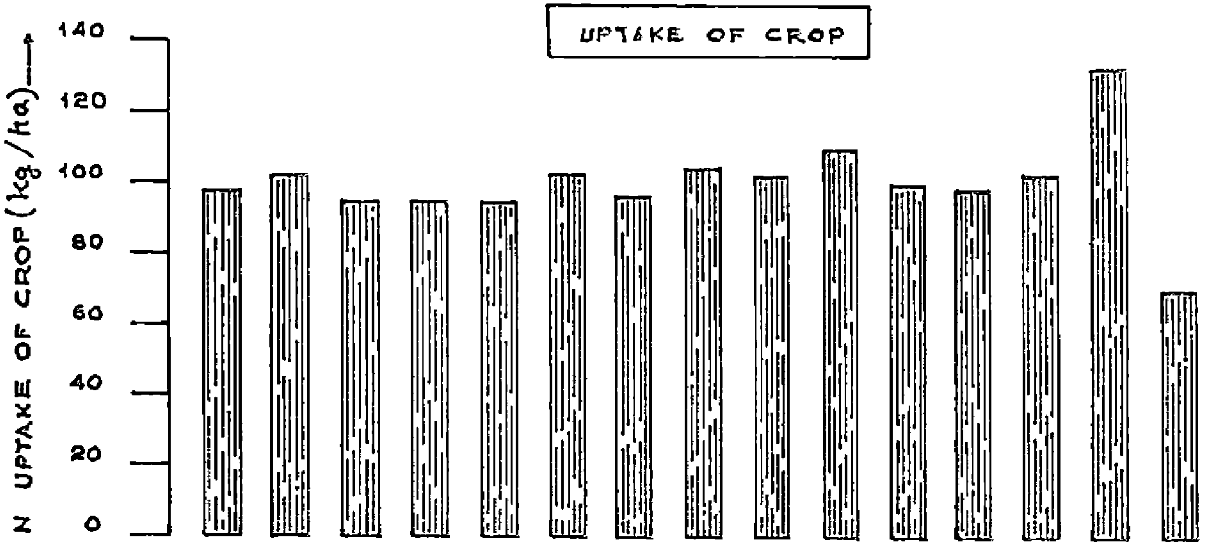


Table 11(a). Nitrogen uptake of rice at different days after transplanting (kg/ha)

Treatments	Days after transplanting			Harvest
	20	35	60	
T_1	13.28	53.85	89.25	93.07
T_2	11.15	55.39	91.82	103.49
T_3	10.76	37.43	83.01	94.62
T_4	12.72	37.71	86.61	95.09
T_5	13.40	45.02	80.58	94.69
T_6	12.65	49.33	90.75	102.47
T_7	12.28	44.41	91.40	97.53
T_8	17.68	52.15	96.77	103.91
T_9	15.58	42.63	84.34	101.97
T_{10}	16.93	49.79	101.93	108.92
T_{11}	12.00	46.97	82.70	98.46
T_{12}	10.66	44.69	80.16	98.20
T_{13}	14.03	44.99	93.85	102.17
T_{14}	22.44	69.17	109.20	132.72
T_{15}	8.68	28.46	65.58	80.28
CD (0.05)	3.888	13.753	18.241	11.896
SE	1.342	4.748	6.298	4.107

T_{12}, T_3, T_2, T_{11} and T_7. There was no significant difference between T_{12}, T_3, T_2, T_{11}, T_7, T_6, T_4, T_1, T_5 and T_{13}.

4.1.3.1.1.b. 35th Day After Transplanting

Maximum uptake was shown by T_{14} and it was superior to the other treatments. It was followed by T_2 which was on par with all treatments except T_4, T_3 and T_{15}. T_{15} recorded the lowest uptake which was on par with T_3 and T_4 and inferior to the rest.

4.1.3.1.1.c. 60th Day After Transplanting

T_{14} continued to record the highest uptake of nitrogen but was on par with T_{10}, T_8, T_{13}, T_2 and T_7. The lowest uptake was obtained in T_{15} which was inferior to all treatments except T_{12}, T_5, T_{11} and T_3 while T_{12} was inferior only to T_{10} and T_{14}.

4.1.3.1.1.d. Harvest

T_{14} still recorded the highest uptake which was superior to all treatments. T_{10} which recorded the next highest uptake was on par with all treatments except T_4, T_5, T_3 and T_{15}. T_{15} recorded the lowest uptake and it was inferior to all treatments while T_3 having the next lowest uptake was inferior only to T_{10} and T_{14}.

4.1.3.1.2. Phosphorus

The analysis of variance is presented in Appendix XII and the mean values in Table 11(b).

4.1.3.1.2.a. 20th Day After Transplanting

Highest uptake was noted in T_{14} which was superior to all treatments and it was followed by T_{10} which was on par with T_3, T_9, T_8, T_5, T_1, T_6, T_{12} and T_4. T_{15} recorded the lowest uptake and no significant difference was observed among T_{15}, T_{11}, T_7, T_2, T_{13}, T_4, T_{12}, T_6, T_1 and T_5.

4.1.3.1.2.b. 35th Day After Transplanting

T_{14} continued to exhibit its superiority over the other treatments and it was followed by T_6 which was superior only to T_{13} and T_{15}. T_{15} which recorded the lowest uptake was on par with T_{13}, T_9 and T_{10} and inferior to the rest.

4.1.3.1.2.c. 60th Day After Transplanting

At this stage also T_{14} recorded the highest uptake of phosphorus which was on par with T_8, T_6, T_{10}, T_{11} and T_{13}. T_8 was superior only to T_{15}. T_{15} which had the lowest uptake was on par with T_9, T_4 and T_1.

FIG 5 PHOSPHORUS UPTAKE OF CROP AND WEEDS AT HARVEST (kg/ha)

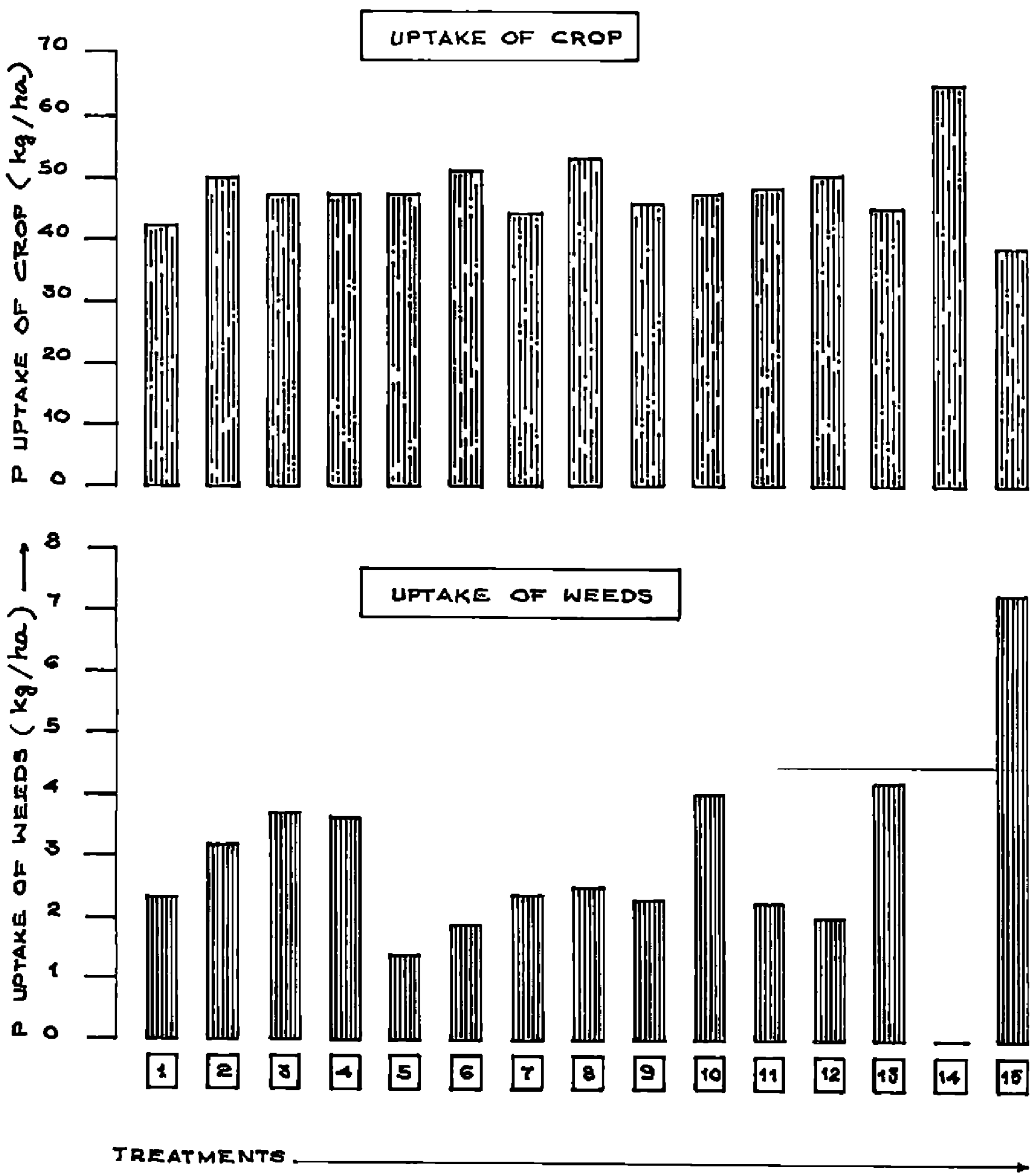


Table 11(b). Phosphorus uptake of rice at different days after transplanting (kg/ha)

Treatments	Days after transplanting			Harvest
	20	35	60	
T_1	6.31	20.56	34.94	42.34
T_2	5.69	20.77	38.61	49.47
T_3	6.89	19.90	37.74	46.67
T_4	6.18	19.29	34.42	46.90
T_5	6.39	19.19	35.90	46.96
T_6	6.29	21.23	40.43	51.23
T_7	5.27	19.17	37.10	44.29
T_8	6.79	20.69	40.62	52.49
T_9	6.85	18.57	33.78	45.69
T_{10}	7.60	18.94	40.23	47.00
T_{11}	5.16	19.65	39.80	48.37
T_{12}	6.19	19.72	38.05	49.50
T_{13}	5.73	17.00	38.97	44.74
T_{14}	11.25	26.53	45.93	64.76
T_{15}	4.85	15.17	28.65	38.06
CD (0.05)	1.708	3.843	7.169	7.235
SE	0.590	1.327	2.475	2.498

4.1.3.1.2.d. Harvest

T_{14} continued to record the highest uptake and it was superior to the other treatments. T_8 recording the next highest uptake was on par with all treatments except T_{13}, T_7, T_1 and T_{15}. Lowest uptake of phosphorus was noted in T_{15} and it was on par with T_1, T_7 and T_{13}.

4.1.3.1.3. Potassium

The analysis of variance is presented in Appendix XII and the mean values in Table 11(c).

4.1.3.1.3.a. 20th Day After Transplanting

The highest uptake of potassium occurred in T_{14} which was superior to other treatments. It was followed by T_9 which was on par with T_8, T_1 and T_{10}. T_8 was superior only to T_{11}, T_7, T_3 and T_{15}. T_{15} recorded the lowest uptake which did not differ significantly from T_3, T_7, T_{11}, T_{12}, T_{13} and T_5.

4.1.3.1.3.b. 35th Day After Transplanting

T_{14} recorded the highest potassium uptake and was superior to all treatments except T_{13}, T_5, T_{12}, T_7 and T_8 with which it was on par. T_{13} which recorded the next highest uptake did not differ significantly

FIG. 6 POTASSIUM UPTAKE OF CROP AND WEEDS AT HARVEST (kg/ha)

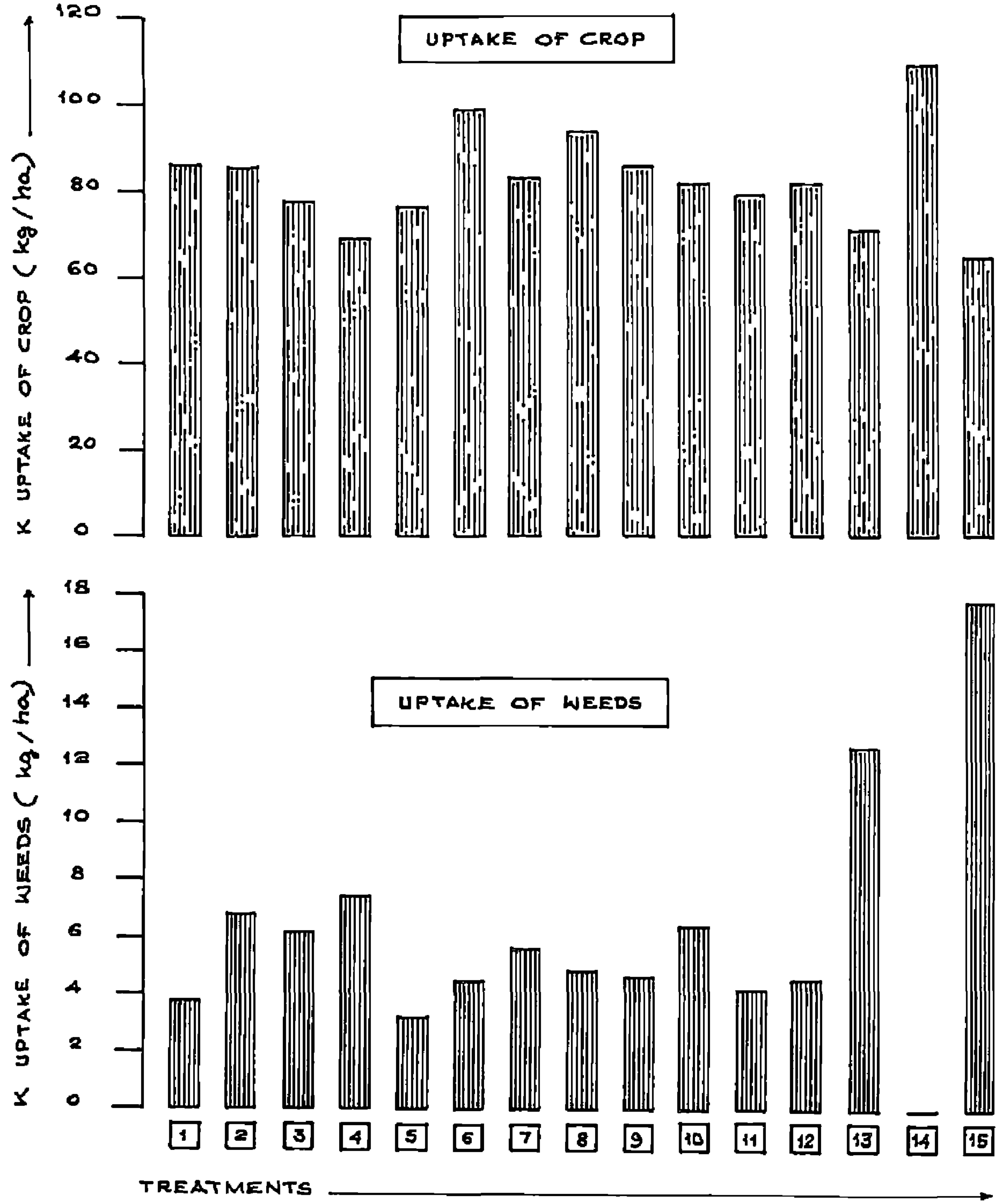


Table 11(c). Potassium uptake of rice at different days after transplanting (kg/ha)

Treatments	Days after transplanting			Harvest
	20	35	60	
T_1	19.91	51.00	82.50	86.03
T_2	17.90	48.69	82.56	85.87
T_3	13.00	39.59	63.04	77.68
T_4	18.17	38.90	58.00	68.71
T_5	17.05	57.50	73.07	76.15
T_6	17.92	50.97	85.85	98.89
T_7	14.71	54.43	71.61	82.92
T_8	20.68	53.79	86.20	93.52
T_9	24.32	35.45	71.62	85.57
T_{10}	19.53	46.46	70.34	81.39
T_{11}	15.03	42.88	73.91	79.11
T_{12}	16.27	55.73	75.32	81.42
T_{13}	16.90	58.46	73.82	71.41
T_{14}	30.23	66.14	100.79	109.07
T_{15}	12.35	33.81	55.59	63.65
CD (0.05)	4.863	13.913	17.626	14.288
SE	1.679	4.804	6.086	4.933

from T_5, T_{12}, T_7, T_8, T_1, T_6, T_2 and T_{10}. The lowest uptake occurred in T_{15} which was on par with T_9, T_4, T_3 and T_{11} while T_9 did not differ significantly from T_4, T_3, T_{11}, T_{10} and T_2.

4.1.3.1.3.c. 60th Day After Transplanting

T_{14} continued to record the highest uptake and it was superior to all treatments except T_8 and T_6 with which it was on par. T_8 was superior only to T_3, T_4 and T_{15}. T_{15} recorded the lowest uptake and it was on par with T_4, T_3, T_{10}, T_7, T_9 and T_5.

4.1.3.1.3.d. Harvest

Maximum potassium uptake was obtained in the completely weed free plot (T_{14}) and it was on par with T_6 which in turn did not differ significantly from T_8, T_1, T_2 and T_9. No significant difference was observed between the treatments T_8, T_1, T_2, T_9, T_7, T_{12} and T_{10}. The lowest potash uptake was noticed in T_{15} but it was on par with T_4, T_{13}, T_5 and T_3 and inferior to the rest. T_4 was on par with T_{13}, T_5, T_3, T_{11}, T_{10}, T_{12} and T_7.

4.1.3.1.4. Grain Protein Content

The analysis of variance table is presented in Appendix XIII and the mean values in Table 12.

The highest protein content was recorded by T_1 and it was on par with T_{14}, T_{12}, T_4 and T_2 but superior to all other treatments. T_{14} did not differ significantly from T_{12}, T_4, T_2, T_{13} and T_7. T_{15} which recorded the lowest protein content was inferior only to T_2, T_4, T_{12}, T_{14} and T_1.

4.1.3.2. Nutrient Uptake of Weeds

Nutrient uptake of weeds was estimated on 20th, 35th and 60th day after transplanting and also at harvest. The data was analysed statistically and the analysis of variance is given in Appendix XIV and the mean values in Tables 13(a), 13(b) and 13(c). T_{14} was the best treatment in this aspect since it was completely weed free.

4.1.3.2.1. Nitrogen

The analysis of variance table is presented in Appendix XIV and the mean values in Table 13(a).

Table 12. Grain protein content (per cent)

Treatments	Protein content (per cent)
T_1	8.58
T_2	7.72
T_3	7.23
T_4	7.72
T_5	6.86
T_6	6.98
T_7	7.47
T_8	7.11
T_9	7.35
T_{10}	6.98
T_{11}	6.98
T_{12}	7.84
T_{13}	7.47
T_{14}	8.45
T_{15}	6.50
CD (0.05)	1.081
SE	0.373

4.1.3.2.1.a. 20th Day After Transplanting

T_{14} was on par with T_1, T_8, T_6, T_2, T_5, T_{10} and T_7 and superior to the other treatments. T_{15} recorded the highest N uptake followed by T_{13}. T_{12} recorded the next highest uptake and it was inferior only to T_1 and T_{14} but on par with other treatments.

4.1.3.2.1.b. 35th Day After Transplanting

T_{14} did not show any significant difference from T_1, T_6, T_2, T_{10} and T_5 but it was superior to the rest. T_{15} recorded the highest uptake followed by T_{13}. T_9 recorded the next highest uptake and it was on par with all other treatments, but inferior to T_1 and T_{14}.

4.1.3.2.1.c. 60th Day After Transplanting

T_{14} was on par with T_1, T_5, T_{12}, and T_2, but superior to the other treatments. However, T_1 was superior only to T_7, T_4, T_{10}, T_{13} and T_{15}. The highest uptake continued to occur in T_{15}. In T_{13} the uptake was low compared to T_{15} and it was on par with T_{10}, T_4 and T_7.

Table 13(a). Nitrogen uptake of weeds at different days after transplanting (kg/ha)

Treatments	Days after transplanting			Harvest
	20	35	60	
T_1	0.32	0.39	2.46	4.58
T_2	0.64	0.76	3.61	7.88
T_3	1.15	1.65	5.13	7.86
T_4	1.04	1.45	6.95	6.62
T_5	0.75	1.01	2.71	3.99
T_6	0.62	0.73	5.04	5.60
T_7	0.80	1.39	6.54	6.46
T_8	0.57	1.18	5.44	5.38
T_9	0.82	1.78	5.29	5.34
T_{10}	0.76	0.86	8.92	8.33
T_{11}	1.10	1.62	3.97	4.67
T_{12}	1.29	1.32	2.80	6.66
T_{13}	2.75	3.71	9.79	10.40
T_{14}	0	0	0	0
T_{15}	3.65	5.59	16.39	20.61
CD (0.05)	0.804	1.147	3.777	5.488
SE	0.277	0.396	1.304	1.895

4.1.3.2.1.d. Harvest

T_{14} did not differ significantly from T_5, T_1, T_{11}, T_9 and T_8. T_{15} recorded the highest uptake and it was inferior to all treatments. T_{13} which recorded the next highest uptake was on par with all other treatments except T_{11}, T_1, T_5 and T_{14} with which it was inferior.

4.1.3.2.2. Phosphorus

The analysis of variance table is presented in Appendix XIV and the mean values in Table 13(b).

4.1.3.2.2.a. 20th Day After Transplanting

T_{14} did not differ significantly from T_1, T_2, T_6, T_8, T_5, T_9, T_7 and T_{10} with respect to the weed uptake of phosphorus. The highest uptake occurred in the unweeded check (T_{15}) compared to the other treatments. It was closely followed by T_{13}. T_{11} which recorded the next highest uptake was inferior to T_1 and T_{14} while it was on par with the other treatments.

4.1.3.2.2.b. 35th Day After Transplanting

T_{14} was on par with T_1, T_6, T_{10}, T_5 and T_8 and T_2 while other treatments were significantly inferior to it. The highest uptake occurred in T_{15} followed by

Table 13(b). Phosphorus uptake of weeds at different days after transplanting (kg/ha)

Treatments	Days after transplanting			Harvest
	20	35	60	
T_1	0.10	0.21	1.13	2.34
T_2	0.18	0.55	1.36	3.26
T_3	0.49	0.83	2.40	3.72
T_4	0.44	0.77	2.31	3.62
T_5	0.22	0.47	1.22	1.38
T_6	0.19	0.31	1.62	1.95
T_7	0.28	0.74	2.16	2.39
T_8	0.20	0.55	2.12	2.53
T_9	0.24	0.58	1.77	2.29
T_{10}	0.31	0.45	2.52	4.02
T_{11}	0.51	0.88	1.39	2.25
T_{12}	0.43	0.56	1.31	2.02
T_{13}	1.05	1.76	3.05	4.22
T_{14}	0	0	0	0
T_{15}	1.72	2.57	4.43	7.29
CD (0.05)	0.400	0.558	1.175	1.588
SE	0.138	0.193	0.406	0.548

T_{13}. T_{11} having the next highest uptake did not differ significantly from T_3, T_4, T_7, T_9, T_{12}, T_2, T_8, T_5 and T_{10} while it was inferior to T_6, T_1 and T_{14}.

4.1.3.2.2.c. 60th Day After Transplanting

T_{14} was on par with T_1 which in turn did not show significant difference from T_5, T_{12}, T_2, T_{11}, T_6, T_9, T_8 and T_7. T_{15} was inferior to all treatments and it was followed by T_{13} which was on par with T_{10}, T_3, T_4 T_7 and T_8.

4.1.3.2.2.d. Harvest

T_{14} and T_5 were on par and T_5 was on par with all other treatments but superior to T_2, T_4, T_3, T_{10}, T_{13} and T_{15}. T_{15} continued to record the highest uptake followed by T_{13} which was on par with T_{10}, T_3, T_4 and T_2.

4.1.3.2.3. Potassium

The analysis of variance table is presented in Appendix XIV and the mean values in Table 13(c).

4.1.3.2.3.a. 20th Day After Transplanting

The treatments T_{14}, T_1, T_6, T_2, T_8, T_5, T_{10}, T_7, T_9 and T_4 did not show any significant difference among

Table 13(c). Potassium uptake of weeds at different days after transplanting (kg/ha)

Treatments	Days after transplanting			
	20	35	60	Harvest
T_1	0.26	0.60	2.19	3.75
T_2	0.55	1.45	3.06	6.82
T_3	1.10	2.48	4.34	6.21
T_4	0.90	2.61	5.14	7.56
T_5	0.65	1.58	2.23	3.17
T_6	0.50	1.04	3.30	4.47
T_7	0.83	1.70	4.58	5.68
T_8	0.58	1.84	3.57	4.79
T_9	0.84	2.12	3.68	4.68
T_{10}	0.80	1.32	5.03	6.45
T_{11}	1.18	3.21	2.67	4.21
T_{12}	1.28	2.10	2.50	4.45
T_{13}	2.53	6.46	7.05	12.74
T_{14}	0	0	0	0
T_{15}	3.85	7.57	8.90	17.90
CD (0.05)	0.949	1.870	2.918	4.979
SE	0.328	0.646	1.007	1.719

themselves with respect to the potassium uptake of weeds, while they were superior to T_3, T_{11}, T_{12}, T_{13} and T_{15} following the same trend as in N and P. T_{15} recorded the highest uptake followed by T_{13}. T_{12} which recorded the next highest uptake was superior to T_1 and T_{14} while it was on par with other treatments.

4.1.3.2.3.b. 35th Day After Transplanting

T_{14} was on par with T_1, T_6, T_{10}, T_2, T_5, T_7 and T_8 and superior to the rest. The uptake was highest in T_{15} compared to the other treatments except T_{13} with which it was on par. T_{11} which recorded the highest uptake next to T_{15} and T_{13}, was on par with T_4, T_3, T_9, T_{12}, T_8, T_7, T_5 and T_2.

4.1.3.2.3.c. 60th Day After Transplanting

T_{14} was superior to all other treatments except T_1, T_5, T_{12} and T_{11} with which it was on par. T_1 was superior to T_4, T_{13} and T_{15} only. Although T_{15} recorded the highest uptake it was on par with T_{13} which in turn was on par with T_4, T_{10}, T_7 and T_3.

4.1.3.2.3.d. Harvest

T_{14} did not differ significantly from T_5, T_1, T_{11}, T_{12}, T_6, T_9 and T_8 while it was superior to the rest. However, T_5 was superior only to T_{13} and T_{15}. The uptake in all treatments was less compared to T_{13}. However, T_{13} recorded a lesser uptake compared to the unweeded check T_{15}.

4.1.3.3. Soil Analysis

The soil samples were collected from the individual plots after the experiment and were analysed for total N, available P_2O_5 and exchangeable K_2O. The analysis of variance is given in Appendix XV and the mean values in Table 14.

4.1.3.3.1. Total Nitrogen

There was no significant difference between the treatments with respect to the total nitrogen content of soil.

4.1.3.3.2. Available Phosphorus

The available P_2O_5 content of the soil also did not show any significant difference among the treatments.

4.1.3.3.3. Exchangeable Potassium

The treatments showed variation in this aspect.

Table 14. N, P_2O_5 and K_2O content of soil after experiment

Treatments	Total N (per cent)	Available P_2O_5 (kg/ha)	Exchangeable K_2O (kg/ha)
T_1	0.15	16.83	198.40
T_2	0.16	14.33	185.60
T_3	0.13	14.50	211.20
T_4	0.11	16.17	172.80
T_5	0.17	16.50	217.60
T_6	0.15	15.67	188.80
T_7	0.16	14.00	204.80
T_8	0.16	15.67	268.80
T_9	0.12	13.67	169.60
T_{10}	0.17	14.50	227.20
T_{11}	0.15	15.67	284.90
T_{12}	0.14	14.33	201.93
T_{13}	0.14	17.50	224.00
T_{14}	0.16	19.00	262.40
T_{15}	0.10	13.50	192.00
CD(0.05)	-	-	46.527
SE	0.024	1.179	16.064

The highest content of exchangeable K_2O was obtained in T_{11} which was on par with T_8 and T_{14} and superior to the other treatments. T_8 did not differ significantly from T_{14}, T_{10} and T_{13}. T_{14}, T_{10}, T_{13} and T_5 were on par. The lowest content was noted in T_9 which did not differ significantly from T_4, T_2, T_6, T_{15}, T_1, T_{12}, T_7 and T_3 and inferior to the other treatments. T_4 was inferior to T_{13}, T_{10}, T_{14}, T_8 and T_{11} while it was on par with other treatments.

4.1.5. Correlation Studies.

The values of simple correlation coefficients are presented in Table 15.

The weed count at harvest was negatively correlated with grain yield. Similarly, a significant negative correlation existed between the dry matter production of weeds at harvest and the grain yield.

The grain yield was negatively correlated with N, P and K uptake of weeds at harvest. But the crop uptake of N, P and K at harvest, showed significant positive correlation with grain yield.

The N, P and K uptake of crop and weed at harvest were negatively correlated.

Table 15. Value of simple correlation co-efficients

Sl. No.	Characters correlated	Correlation coefficient
1	Grain yield x Weed count at harvest	-0.6723
2	Grain yield x Dry matter production of weeds at harvest	-0.5399
3	Grain yield x N uptake of weeds at harvest	-0.5517
4	Grain yield x P uptake of weeds at harvest	-0.6596
5	Grain yield x K uptake of weeds at harvest	-0.5224
6	Grain yield x N uptake of the crop at harvest	0.6970
7	Grain yield x P uptake of the crop at harvest	0.7843
8	Grain yield x K uptake of the crop at harvest	0.6859
9	Dry matter production of crop at harvest x Dry matter production of weeds at harvest	-0.5615
10	N uptake of crop at harvest x N uptake of weeds at harvest	-0.5087
11	P uptake of crop at harvest x P uptake of weeds at harvest	-0.5508
12	K uptake of crop at harvest x K uptake of weeds at harvest	-0.5828

Table 16. Economics of Crop production

Treat-ments	Normal expendi-ture (Rs/ha)	Additional expendi-ture (Rs./ha)	Total Expendi-ture (Rs./ha)	Total income (Rs./ha)	Net income (Rs./ha)	Cost-benefit ratio
T_1	7662.35	584.50	8246.85	9471.60	1224.75	1.15
T_2	7662.35	661.75	8324.10	9485.30	1161.20	1.14
T_3	7662.35	575.50	8237.85	8799.27	561.42	1.07
T_4	7662.35	501.25	8163.60	9388.63	1225.03	1.15
T_5	7662.35	875.50	8537.85	9550.00	1012.15	1.12
T_6	7662.35	901.25	8563.60	10543.33	1979.73	1.23
T_7	7662.35	569.50	8331.85	9137.93	806.08	1.10
T_8	7662.35	646.75	8309.10	10192.50	1883.40	1.23
T_9	7662.35	465.50	8127.85	9247.10	1119.25	1.14
T_{10}	7662.35	491.25	8153.60	8559.57	405.97	1.05
T_{11}	7662.35	865.50	8527.85	9525.30	997.45	1.12
T_{12}	7662.35	891.25	8553.60	9168.07	614.47	1.07
T_{13}	7662.35	1200.00	8862.35	8886.40	24.05	1.00
T_{14}	7662.35	5000.00	12662.35	14040.10	1377.75	1.11
T_{15}	7662.35	-	7662.35	7528.10	-134.25	0.98
C.D					727.664	0.033
SE					251.238	0.011

Cost of 1 kg grain = Rs.2.00
Cost of 1 kg straw = 70 ps.

Wages for men = Rs.25.00
Wages for women = Rs.20.00

4.1.6. Economics of Crop Production.

4.1.6.1. Net Income

T_6 gave the highest net profit and was on par with T_8 and T_{14}. T_8 was statistically similar to T_{14}, T_4 and T_1. The lowest net profit was obtained from the weedy check (T_{15}) and did not differ significantly from T_{13}, T_{10} and T_3. T_3 in turn showed no significant difference from other treatments except T_{14}, T_8 and T_6.

4.1.6.2. Cost-benefit ratio

T_6 recorded the highest ratio and was on par with T_8. T_4 registered the next highest value and it did not differ significantly from T_1, T_9, T_2 and T_5. The lowest ratio was recorded by the weedy check and it was statistically equal to T_{13}.

4.2. Experiment No.2

4.2.1. Observations on Cowpea.

4.2.1.1. Germination count

The data on germination count of cowpea from an area of 0.5 m^2 was analysed and the analysis of variance is given in Appendix XVII and the mean values in Table 17.

Table 17. Germination count of cowpea/0.5 m^2 on the 10th day after sowing

Treatments	Germination count
T_1	36.99
T_2	30.96
T_3	35.31
T_4	34.22
T_5	33.65
T_6	33.65
T_7	35.30
T_8	33.62
T_9	33.26
T_{10}	33.12
T_{11}	32.17
T_{12}	34.31
T_{13}	30.21
T_{14}	31.51
T_{15}	29.96
CD (0.05)	-
SE	0.185

No significant difference in germination count between the different treatments was noticed.

4.2.1.2. Grain Yield

The analysis of variance table is presented in Appendix XVIII and the mean values in Table 18.

The treatments showed variation in this aspect. T_3 recorded the highest grain yield and it was superior to all treatments except T_{14} and T_8 with which it was on par. T_{14}, T_8, T_1, T_{13}, T_{15}, T_2, T_4, T_9, T_5 and T_{12} showed no significant difference among themselves. Lowest yield was recorded by T_{11} and it was inferior to T_8, T_{14} and T_3 only.

4.2.1.3. Bhusa Yield

The analysis of variance table is presented in Appendix XVIII and the mean values in Table 18.

The results indicated that there was no significant difference in bhusa yield between the treatments.

Table 18. Grain and bhusa yield of cowpea (kg/ha)

Treatments	Grain yield	Bhusa yield
T_1	958.00	2025.67
T_2	868.00	2083.00
T_3	1274.67	1591.67
T_4	868.00	1909.67
T_5	852.33	1967.67
T_6	790.00	1880.67
T_7	759.67	1620.67
T_8	1031.67	1967.67
T_9	866.67	1852.00
T_{10}	777.00	1794.00
T_{11}	745.00	1620.33
T_{12}	829.00	2517.33
T_{13}	903.00	1909.67
T_{14}	1092.67	2170.00
T_{15}	881.00	1938.67
CD (0.05)	266.904	-
SE	92.153	333.032

DISCUSSION

5. DISCUSSION

An experiment was conducted in the Instructional Farm attached to the College of Agriculture, Vellayani, during the Mundakan (Second crop) season of 1985-1986 to evolve a suitable method to control weeds in a medium duration rice. The residual effect of the herbicides was studied by raising a successive crop of cowpea during the Punja(third crop) season of 1985-1986. The results of the experiments are discussed hereunder.

5.1. Experiment No.1

5.1.1. Observations on Weeds.

5.1.1.1. Weed Species

The weeds present in the experimental field before and during the experiment were identified and classified into grasses, sedges and broad-leaved weeds. The predominant grasses were *Echinochloa* spp and *Brachiaria ramosa*. *Cyperus* spp and *Fimbristylis miliacea* were the important sedges. Among the broad-leaved weeds *Monochoria vaginalis* and *Ludwigia parviflora* were the predominant ones.

5.1.1.2. Weed Count

Weed population was recorded on the 20th, 35th and 60th day after transplanting and at harvest. Monocot and dicot weed population were estimated separately. It was found that monocot weeds predominated throughout the crop growth. The monocot weeds have similar morphological characters as that of rice crop, which made them to compete with rice crop and persist throughout the crop growth. Similar results were reported by Nair and Sadanandan (1975), Ravindran (1976), Abraham Varughese (1978), Ahmed and Hoque (1981) and Sukumari (1982).

5.1.1.2.1. Monocot Weed Population

At all stages the completely weed free treatment was superior to herbicide treatments and the practice of handweeding twice. The weedy check recorded the highest count of monocot weeds and all the treatments were found to be superior to the weedy check.

Among the herbicide treatments it was found that application of thiobencarb @ 1.0 and 1.5 kg a.i/ha could give better control of weeds than butachlor at same rates. Spray or granular method of application had the same effect. Also the integrated method of weed control could not significantly reduce the weed population.

Ravindran (1976) obtained good control of monocot weeds by thiobencarb (G) in the early stages of crop growth and thiobencarb (E.C) at harvest. Mandal (1977) reported that thiobencarb at 1.0 kg a.i/ha was effective in controlling monocot weeds. Gill and Kolar (1980) found that thiobencarb granules and E.C. formulation at 1.5 kg a.i/ha effectively controlled Echinochloa crus-galli. Lakshmi (1983) reported good control of monocot weeds throughout the crop growth by thiobencarb @ 1.5 kg a.i/ha.

5.1.1.2.2. Dicot Weed Population

As in the case of monocot weed count, application of thiobencarb or butachlor @ 1.0-1.5 kg a.i/ha in the spray or granule form had the same effect on the dicot weed population at different stages of crop growth. However, herbicide application was found to be better than the local practice of handweeding twice in suppressing the dicot weeds. The weedy check recorded the highest weed count at all stages of crop growth.

5.1.1.2.3. Total Weed Population

The total weed population also showed the same trend as in the case of monocot and dicot weeds separately. Thiobencarb 1.5 kg a.i/ha as spray or granule was more effective in suppressing the total weed population throughout the growth period compared to the lower rates as well as butachlor at high and low rates. In general both the herbicides were more effective in controlling weed growth throughout the growth of the crop compared to hand weeding at early stages of growth.

Eventhough the herbicide at different rates and in different methods of application were effective in suppres sing the weed growth, as compared to the local practice, among the herbicide treatments lower rate of 1.0 kg a.i/ha can be cheaper than 1.5 kg a.i/ha. Application of herbicide in granular form will be easier and cheaper compared to spraying. The integrated method also could not substantially reduce the weed population in the later stages of growth.

Mehta (1975), Ravindran (1976), Sridhar et al.(1976), Ravindran et al.(1978), Pandey and Sharma (1980), Gill and Mehra (1981), Balyan (1982) and Lakshmi (1983) also obtained promising results with thiobencarb and this corroborates with the present findings.

Correlation studies revealed that significant negative correlation existed between the grain yield and weed count ($r = -0.6723$).

5.1.1.3. Dry Matter Production of Weeds

The weedy check record the highest dry matter production of weeds at all stages of crop growth. The uncontrolled weed growth has absorbed nutrients in greater amounts and thereby recorded the highest dry matter production.

Application of thiobencarb at 1.5 kg a.i/ha as spray or granules could suppress dry matter accumulation and are comparable to that of a weed free situation in the early stages of growth. On the 60th day, thiobencarb 1.5 kg a.i/ha as spray, thiobencarb 1.0 kg a.i/ha spray + handweeding, butachlor 1.0 kg a.i/ha as spray or granules + handweeding were as good as weed free situation.

Taking all the herbicide treatments into consideration, thiobencarb 1.5 kg a.i/ha as spray or granules was comparable with thiobencarb at lower rates + handweeding, butachlor 1.5 kg a.i/ha as spray or granules and butachlor 1.0 kg a.i/ha + handweeding in reducing the dry matter accumulation by the weeds in the early stages of growth, while in the later stages of growth thiobencarb 1.5 kg a.i/ha spray, thiobencarb 1.0 kg a.i/ha spray + handweeding, butachlor 1.0 kg a.i/ha spray or granules + handweeding were effective. According to Abraham Varughese (1978) and Sukumari (1982) weed growth beyond 45 days has no significant influence on the rice yield. Therefore the suppression of weeds in the early stages is important which could be achieved by the application of thiobencarb

1.5 kg a.i/ha or 1.0 kg a.i/ha either as spray or granules or it's integrated method closely followed by butachlor at the same rates and method of application.

As in the case of total weed population referred early, dry matter accumulation can be substantially reduced by herbicide treatment. Lower rates of heribicide in the granular form will be cheaper than spraying. Butachlor at lower rate applied in combination with hand-weeding is more beneficial in preventing dry matter accumulation compared to higher rate. Correlation studies indicated that significant negative correlation exists between dry matter production of weeds and grain yield ($r = -0.5399$).

Ravindran (1976) and Balu and Sankaran (1977) reported reduction in dry weight of weeds by the use of chemicals. Lakshmi (1983) and Ali and Sankaran (1985) found that thiobencarb spray @ 1.5 kg a.i/ha was efficient in reducing the dry matter accumulation by weeds throughout the crop growth.

5.1.1.4. Weed Control Efficiency

In the case of thiobencarb, the efficiency ranged from 62.6 to 77.8 per cent while in the case of butachlor the variation was from 52.0 to 70.6 per cent. Thus it is evident that thiobencarb is more efficient in controlling the weeds than butachlor at the rates tested. This result is in conformity with the findings of Ravindran (1976). Balyan (1982) obtained a weed control efficiency of 93.2 per cent with thiobencarb 2.0 kg a.i/ha pre-emergence while Lakshmi (1983) obtained a weed control efficiency of more than 76.0 per cent with thiobencarb 2.0 kg a.i/ha and 66 to 70 per cent efficiency with thiobencarb 1.5 kg a.i/ha.

Highest value of weed control efficiency, next to the completely weed free treatment, was obtained by the application of thiobencarb @ 1.0 kg a.i/ha in the spray form followed by one handweeding on the 35th day after transplanting. Similarly butachlor spray @ 1.0 kg a.i/ha, followed by one handweeding, recorded greater weed control efficiency (70.6 per cent) than butachlor 1.5 kg a.i/ha (61.2 per cent).

The lowest weed control efficiency (51.6 per cent) was recorded by the handweeded plot. Thus the two handweedings done on the 20th and 35th day after transplanting were not sufficient to suppress the weed population till the harvest of crop. Moreover the soil disturbance caused by these two weedings might have encouraged rapid growth of the dormant weed seeds which were below the soil surface. This is in agreement with the findings of Gupta et al.(1975).

Thus it is evident that chemical control of weeds is more efficient than handweeding twice. This is in agreement with the findings of Mukhopadhyay (1967) and Sreedevi (1979). The efficiency of weed control further increased by giving one handweeding at 35th day, following the application of a reduced dose of the herbicide. Rangiah et al. (1976) reported that the weed control efficiency increased to 77 per cent when butachlor 2.5 kg a.i/ha was combined with one handweeding compared to 67 per cent with butachlor 2.5 kg a.i/ha applied alone.

5.1.2. Observations on Crop.

5.1.2.1. Crop Growth Characters

5.1.2.1.1. Plant Height

The height of the plants measured on the 20th, 35th and 60th day after transplanting, revealed no significant difference between the treatments. In general, the completely weed free treatment recorded the highest plant height throughout the crop growth. The absence of weeds in those plots reduced the competition enabling the crop to utilize the nutrients and space for its normal growth. The weedy check on the other hand recorded the lowest plant height due to the severe competition for space and nutrients by the weed population.

At the harvest stage of the crop, significant difference was observed in plant height with respect to the various treatments. Plant height was higher in plots treated with butachlor @ 1.0 kg a.i/ha applied alone in the spray or granule form or butachlor @ 1.0 kg a.i/ha as spray or granules followed by a handweeding, butachlor granules @ 1.5 kg a.i/ha, thiobencarb @ 1.0 kg a.i/ha applied in the spray or granule form + handweeding and the local practice of two handweedings. The dwarfing effect of higher rates of thiobencarb on rice plant as reported by Koyama et al.(1979) was obtained in this study also.

Rethinam et al.(1974) and Gill and Kolar (1980) reported the beneficial effects of weed control treatments on the height of rice plants. Contrary to the present findings, Rethinam and Sankaran (1974) found that at harvest the height of plants was not significantly influenced by the different weed control treatments.

5.1.2.1.2. Tiller Count

The tiller count observed on the 20th and 35th day after transplanting showed significant difference between the various weed control treatments. The total tiller count per sq.m was highest (298.0, 438.7 and 382.0 /m^2) in the completely weed free plot and lowest in the weedy check (207.3, 276.0, 308.7 /m^2) respectively on the 20th, 35th and 60th DAT. Upto 60th day of transplanting the tiller count was minimum in the weedy check compared to other plots. In weedy check the weeds competed for nutrients and space with the rice crop which reduced the rice from putting forth higher number of tillers. On the 35th day after transplanting no significant difference in tiller count was seen between the plots which were treated with herbicides and those handweeded twice. Sundaru (1971) and Ravindran (1976) also obtained similar results. On the 60th day, the difference between the treatments was nullified indicating that some of the tillers produced were dried out which may be due to translocation of photosynthates to the other tillers for the production of panicle.

Chang and De Datta (1972), Sridhar et al.(1976), Ravindran et al.(1978), Sukumari (1982) and Lakshmi (1983) have reported a reduction in tiller production in rice due to weed competition. The findings in the present experiment is in agreement with the above findings.

5.1.2.1.3. Leaf Area Index at Flowering

The leaf area index recorded at the flowering stage of the crop showed significant difference among the treatments.

The weedy check recorded the lowest leaf area index (4.05) which may be attributed to the severe competition between the crop and the weeds. Handweeding twice also recorded reduced leaf area index which was on par with the weedy check indicating that this treatment was also not efficient in controlling the weeds compared to the herbicide treatments. Sreedevi (1979) and Iruthayaraj and Morachan (1980) have reported such a decrease in leaf area index due to weed competition.

Highest leaf area index (6.02) was recorded by the application of thiobencarb @ 1.5 kg a.i/ha in the granule form which was on par with the completely weed free treatment, thiobencarb granules @ 1.0 kg a.i/ha, thiobencarb spray @ 1.5 kg a.i/ha and butachlor 1.0 kg a.i/ha granule + handweeding. Lakshmi (1983) has reported an increase in leaf area index by the application of thiobencarb @ 1.5 to 2.0 kg a.i/ha.

5.1.2.1.4. Dry Matter Production of Crop

The dry matter production of crop was recorded on the 20th, 35th and 60th day after transplanting and at harvest and significant difference was observed between the treatments. The highest dry matter production was recorded by the completely weed free treatment and the weedy check recorded the minimum dry matter.

On 20th day after transplanting, lowest dry weight was recorded by the weedy check (666.7 kg/ha) which was on par with the dry weight obtained by the application of thiobencarb granule @ 1.5 kg a.i/ha thiobencarb spray or granules @ 1.0 kg a.i/ha, butachlor spray @ 1.5 kg a.i/ha, butachlor spray or granules @ 1.0 kg a.i/ha and handweeded treatment. On the 35th day after transplanting highest dry matter production was recorded by the completely weed free plot (4405.3 kg/ha) and it was on par with application of thiobencarb granules @ 1.0 kg a.i/ha and butachlor granules @ 1.5 kg a.i/ha. There was no significant difference among other herbicide treatments.

On the 60th day after transplanting the dry matter production of crop in plots treated with butachlor granules

@ 1.5 kg a.i/ha was highest (5740.0 kg/ha) compared to other herbicide treatments. Thiobencarb application @ 1.0 kg a.i/ha as spray or granules recorded low dry weight which was on par with the weedy check with the lowest value of 3723.0 kg/ha. The higher weed growth in these plots might have suppressed the crop growth and thus resulted in lessor dry weight. Handweeding twice was on par with other herbicide treatments.

At the harvest stage, butachlor granules applied @ 1.5 kg a.i/ha recorded the greatest dry weight(7775.3 kg/ha) next to the completely weed free treatment(10653.3 kg/ha) and on par with thiobencarb applied @ 1.5 kg a.i/ha as spray or granules, thiobencarb granules @ 1.0 kg a.i/ha applied alone or with one handweeding and butachlor spray @ 1.0 kg a.i/ha + handweeding. The unweeded control was inferior to other treatments (5681.3 kg/ha).

Thus during the early stages of growth butachlor 1.0 kg a.i/ha granule or spray, 1.5 kg a.i/ha granule and thiobencarb applied @ 1.0-1.5 kg a.i/ha as spray helped in increasing the dry matter accumulation by the crop. As the growth advanced both the herbicides at 1.5 kg a.i/ha as spray or granule could increase the dry matter accumulation compared to the unweeded check. The handweeding given on 20th day and 35th day of transplanting helped the crop to increase the dry matter accumulation only from 35th day of transplanting. The present results are in agreement with the findings of Rethinam and Sankaran (1974) who obtained significantly higher dry matter production of crop due to the control of weeds by butachlor granules applied @ 2.0 kg a.i/ha.

The dry matter accumulation by the crop in weedy check was only 50 to 56 per cent of the total dry matter accumulation by the crop in the completely weed free plot during all tho stages of growth (Table 19). This indicates the severe competition between the crop and weeds in the weedy check plot. On the 20th, 35th and 60th day after transplanting and at harvest the dry matter accumulation by the crop in the weedy check was 55.6, 51.6, 56.7 and 53.3 per cent of that of the crop from the weed free plot. Even the total dry matter accumulation by the weed and crop together in the weedy check was much less than that by the crop alone in the weed free plot. This shows tho antagonistic effect of crop and weed on the dry matter accumulation. Similar trend was seen in various herbicide treated plots where the dry matter accumulation of weeds was significantly low and

Table 19. Dry matter production of crop in the completely weed free plot and weedy check compared

Days after trans-planting	Weedy check			Completely weed free plot			%
	Weed	Crop	Total	Weed	Crop	Total	
20	202.9	666.7	869.6	-	1200.0	1200.0	55.6
35	307.2	2271.7	2578.9	-	4405.3	4405.3	51.1
60	764.4	3723.0	4487.4	-	6568.3	6568.3	56.7
Harvest	1086.2	5681.3	5767.5	-	10653.3	10653.3	53.3

the dry matter production of crop was substantially high.

5.1.2.2. Yield Attributing Characters

5.1.2.2.1. Number of Productive Tillers /m^2

There was significant influence of the herbicide treatments on the number of productive tillers per sq.m. Among the different treatments the completely weed free treatment recorded the highest number of productive tillers (311.3/m^2) which was superior to all others. The absence of weed competition in this plot has enabled the crop to utilise nutrients to a maximum for its growth and tiller production. The weedy check on the other hand recorded the lowest number of productive tillers (195.3/m^2) which was only 62.7 per cent of completely weed free plot.

Comparing the different herbicide treatments, thiobencarb spray @ 1.0 kg a.i/ha, butachlor spray @ 1.0 kg a.i/ha and butachlor granules @ 1.5 kg a.i/ha recorded higher number of productive tillers. But thiobencarb granules @ 1.0 kg a.i/ha, butachlor @ 1.0 kg a.i/ha in the spray or granule form + handweeding and the local practice of handweeding twice recorded lower number of productive tillers and were on par with the weedy check.

Rethinam and Sankaran (1974) obtained maximum number of productive tillers with butachlor granules @ 1.0 kg a.i/ha while Gill and Kolar (1980) obtained maximum number with thiobencarb granules @ 2.0 kg a.i/ha Chang and De Datta (1972), Ali and Sankaran (1975), Ravindran (1976) Abraham Varughese (1978), Sukumari (1982) and Lakshmi(1983) have reported a reduction in productive tillers due to weed competition. In general the findings of this study is in full agreement with the findings of other scientists.

5.1.2.2.2. Weight of Panicle

The weight of panicle was significantly influenced by the herbicides. Completely weed free plot recorded the maximum weight of 2.57 g and the weedy check recorded the minimum weight of 1.62 g. Application of butachlor @ 1.5 kg a.i/ha in the granule form, butachlor @ 1.0 kg a.i/ha as spray or granules + handweeding, thiobencarb @ 1.5 kg a.i/ha in the spray or granule form and thiobencarb granules @ 1.0 kg a.i/ha + handweeding recorded higher weights and were as good as completely weed free condition. The reduced weed competition in these plots during panicle initiation might have enabled greater uptake of nutrients and greater photosynthesis by the crop resulting in higher panicle weight. Dubey and Harbans Singh (1986) reported maximum panicle weight in plots treated with delchlor 1.5 kg a.i/ha.

Handweeding twice has resulted in a lesser weight of the panicle and was on par with the weedy check. The reduced dose of both the herbicides when applied as spray or granules recorded lower weight of panicle and equalled with that of the weedy check. In general herbicide treatment gave a higher panicle weight compared to handweeding twice. Sreedevi (1979), Sukumari (1982) and Shashidhar (1983) have reported reduction in panicle weight due to weed competition. Lakshmi (1983) found that chemical weed control favoured greater weight of panicle compared to handweeding. The present findings is in agreement with the findings of other scientists.

5.1.2.2.3. Number of Spikelets per Panicle

There was significant influence of the weed control treatments on the number of spikelets per panicle. The plot which was kept weed free throughout the crop growth recorded the highest number of spikelets(118.5) per panicle. Application of thiobencarb @ 1.0 kg a.i/ha as granules alone and with one handweeding, butachlor granules @ 1.0 kg a.i/ha alone and with one handweeding and butachlor spray @ 1.0 kg a.i/ha produced greater number of spikelets which did not significantly differ from the completely weed free treatment. It was observed that the granular formulations in general favoured the production of more number of spikelets, compared to spray method of application and the lower rate of 1.0 kg a.i/ha was sufficient for production of more number of spikelets.

5.1.2.2.4. Number of Filled Grains per Panicle

Number of filled grains per panicle was also influenced by the herbicide treatment. The highest number of filled grains (86.67) was recorded from the completely weed free plot. The absence of competition by weeds for nutrients and light might have enabled the crop to produce more photosynthate thereby resulting in the maximum number of filled grains.

Thiobencarb granules @ 1.0 kg a.i/ha + handweeding, butachlor granules @ 1.0 kg a.i/ha + handweeding, butachlor granules or spray @ 1.5 kg a.i/ha and thiobencarb granules @ 1.0 kg a.i/ha recorded a higher number of filled grains and was on par with the completely weed free treatments. Thus at the lower doses of both the herbicides, granular formulations were found to be more efficient. This might have resulted due to the greater persistence of the herbicide in the soil when applied in the granular form compared to spray. Yogoswara Rao and Padmanabhan (1972), Sreedevi (1979), Sukumari (1982) and Lakshmi (1983) have reported significant influence of weed growth on the number of filled grains per panicle. Ravindran et al.(1978) obtained highest percentage of filled grains by the application of thiobencarb E.C. formulation. In contrast, Rethinam and Sankaran (1974) obtained no significant effect due to different weed control treatments on the number of grains per earhead.

5.1.2.2.5. Thousand Grain Weight

The completely weed free treatment recorded the highest thousand grain weight (26.97 g) and was superior to all other treatments. The lowest value of thousand grain weight (22.83 g) was recorded by the weedy check which was on par with butachlor granule application @ 1.0 kg a.i/ha. Thiobencarb @ 1.0 kg a.i/ha applied alone in the spray or granule form also recorded a lower thousand grain weight. There was no significant difference between the other herbicide treatments and handweeding treatment in respect of this character.

Maharudrappa et al.(1975) found that butachlor @ 1.5 kg a.i/ha reduced the thousand grain weight. Rethinam and Sankaran (1974), Ravindran et al. (1978), Mukhopadhyay and De (1980) and Gill and Mehra (1981) have reported that there was no significant difference in the thousand grain weight between different weed control treatments in rice.

5.1.2.3. Grain Yield

The effect of herbicides on grain yield was significant. Highest grain yield (5064 kg/ha) was recorded by the completely weed free plot. This was followed by thiobencarb application @ 1.0 kg a.i/ha in the granule form + handweeding (3993 kg/ha). The other treatments were inferior to it. It may be noted that this herbicide treatment recorded higher number of spikelets, number of filled grains and thousand grain weight. Application of butachlor granules @ 1.5 kg a.i/ha recorded the next highest grain yield which was on par with the other treatments except thiobencarb application @ 1.0 kg a.i/ha in the spray or granule form, butachlor granules @ 1.0 kg a.i/ha and the weedy check. The weedy check registered the lowest grain yield and it did not differ significantly from the yield obtained with the application of butachlor granules @ 1.0 kg a.i/ha. Chang and De Datta (1972), Gomez and De Datta (1975), Gill et al.(1977), Shahi et al.(1978), Pillai et al. (1983) and Patel and Patel (1984) have reported increase in grain yield by weed control.

Correlation studies showed a significant negative correlation between grain yield and weed count and weed dry matter production.

5.1.2.4. Straw Yield

The highest straw yield was recorded from the completely weed free plot (5590 kg/ha) and it was superior to the other treatments. Among the herbicide treatments, butachlor granules applied @ 1.5 kg a.i/ha recorded the highest straw yield which was on par with butachlor application in the spray form @ 1.5 kg a.i/ha, thiobencarb @ 1.0 to 1.5 kg a.i/ha in the spray or granule form, butachlor spray or granules @ 1.0 kg a.i/ha, thiobencarb spray or granules @ 1.0 kg a.i/ha + hand-weeding and butachlor spray @ 1.0 kg a.i/ha + handweeding. The reduced weed growth in these treatments might have influenced the crop for a greater vegetative growth.

The weedy check recorded the lowest straw yield (2950 kg/ha). The severe weed competition in these plots has resulted in lesser plant height and reduced tiller production which might have resulted in a reduction of straw yield. Handweeding twice recorded a higher yield over the weedy check.

Ravindran (1976) reported highest straw yield by thiobencarb EC formulation @ 2.0 kg a.i/ha which was on par with penoxalin (G), handweeding and butachlor (G) application. Lakshmi (1983) also obtained highest straw yield by the application of thiobencarb (E.C) formulation @ 2.0 kg a.i/ha.

5.1.2.5. Harvest Index

Although there was significant effect of herbicides on the grain and straw yield, the harvest index in general was unaffected. The values ranged from 0.45 to 0.52, the highest being recorded by handweeding twice and thiobencarb granules applied @ 1.0 kg a.i/ha + handweeding.

Hussain and Khan (1976) reported no significant difference in the grain straw ratio among the different weed control treatments, which corroborates with the present finding.

5.1.2.6. Weed Index

Weed Index explains the reduction in yield due to weeds when compared with the yield from the completely weed free treatment. Herbicides had significant effect on the weed index.

Thiobencarb granules @ 1.0 kg a.i/ha + hand-weeding recorded the lowest weed index (19.90 per cent) and it was superior to the rest. This makes clear that this treatment did not suffer from greater yield reduction, due to less severe weed competition. Butachlor granules applied @ 1.5 kg a.i/ha recorded the next lowest value (27.80 per cent) which was on par with hand-weeding twice and other herbicide treatments except thiobencarb spray @ 1.0 kg a.i/ha, butachlor granules @ 1.0 kg a.i/ha and the weedy check. The weedy check suffered greater reduction in yield compared to the weed free treatment and hence recorded the highest weed index (45.90 per cent).

Similar reduction in weed index by weed control treatments have been reported by Rangiah et al.(1976), Ravindran (1976), Abraham Varughese (1978), Sukumari (1982) and Lakshmi (1983) in rice crop.

5.1.3. <u>Chemical Analysis</u>.

5.1.3.1. Nutrient Uptake of Crop

5.1.3.1.1. Nitrogen

The highest nitrogen uptake at all stages of crop growth (22.44, 69.17, 109.20 and 132.72 kg/ha on the 20th, 35th and 60th day after transplanting and at harvest respectively) was recorded by the completely weed free treatment and the lowest uptake by the weedy check (8.68, 28.46, 65.58 and 80.28 kg/ha respectively on the 20th, 35th and 60th day after transplanting and at harvest).

On the 20th day after transplanting, maximum uptake of nitrogen (17.68 kg/ha) among the herbicide treatments was recorded by butachlor granules @ 1.5 kg a.i/ha which was on par with butachlor @ 1.0 kg a.i/ha as spray or granules and the practice of handweeding twice.

Uptake studies on the 35th day after transplanting showed that lowest uptake of nitrogen among the herbicide treatments was recorded by thiobencarb application @ 1.0 kg a.i/ha as spray or granules which was on par with the weedy check. The lower dose of the herbicide was not sufficient to control the weed growth which resulted in lesser dry matter production of crop and lesser absorption of nutrients. There was no significant difference between the other herbicide treatments and handweeding twice.

On the 60th day after transplanting highest uptake of nitrogen was obtained with the compltely weed free treatment (45.93 kg/ha) which was on par with the application of butachlor spray or granules @ 1.5 kg a.i/ha, butachlor granules @ 1.0 kg a.i/ha, thiobencarb granules @ 1.5 kg a.i/ha and the plots given two handweedings.

At harvest no significant difference was observed among the herbicide treatments regarding the uptake of nitrogen by the crop.

Thus in general, application of butachlor granules @ 1.0 -1.5 kg a.i/ha enhanced the dry matter production and thereby the uptake of nitrogen by the crop throughout the growth period.

It was also observed that the uptake of nitrogen by the crop alone in the completely weed free plot was substantially higher than the total uptake of nitrogen by the crop and weeds in the weedy check. Highly positive correlation was noticed between the nitrogen uptake of crop and grain yield ($r = + 0.6970$). Similar results were obtained by Ravindran (1976) and Lakshmi (1983) and Singh and Singh (1985). The nitrogen uptake by the crop and weeds showed significant negative correlation.

5.1.3.1.2. Phosphorus

The phosphorus uptake of crop on the 20th, 35th and 60th day after transplanting and at harvest revealed significant effect of herbicides. The highest uptake was recorded by the plots kept weedfree throughout crop growth.

On the 20th day after transplanting there was no significant difference between the herbicide treatments except thiobencarb granules @ 1.0 - 1.5 kg a.i/ha, butachlor spray @ 1.5 kg a.i/ha and handweeding twice which recorded lower uptake by the crop. The weedy check recorded the lowest uptake (4.85 kg/ha).

The weedy check recorded the lowest uptake (15.17 kg/ha) on the 35th day after transplanting which was on par with handweeded plot and butachlor application @ 1.0 kg a.i/ha as spray or granules. The crop dry matter production was lesser in these treatments resulting in lesser uptake.

On the 60th day after transplanting also the weedy check recorded the lowest uptake of 28.65 kg/ha. Handweeding twice and herbicide treatments showed no significant difference.

At harvest also weedy check registered the lowest uptake which was on par with handweeding twice and butachlor or thiobencarb spray @ 1.5 kg a.i/ha. There was no significant difference between the other herbicide treatments.

Thus in the weedy check the uptake was the lowest during all the stages of growth. In the case of handweeded plot there was wide fluctuation in the uptake pattern which was due to greater variation in the dry matter production. The uptake was more on the 60th day of transplanting and at harvest and it was more or less same as the weedy check during the early stages. Among the herbicides tried there was a constant and significant increase in the uptake with regard to butachlor applied @ 1.5 kg a.i/ha as granules. It is closely followed by thiobencarb applied @ 1.0 kg a.i/ha as granules + handweeding especially during the later stages.

The uptake of phosphorus by the crop and weeds together in the weedy check was far less than the uptake by the crop alone in the completely weed free plot. Nanjappa and Krishnamurthy (1980) have reported similar results.

There was significant positive correlation between the phosphorus uptake by the crop and grain yield ($r = +0.7843$) which was corroborated by the findings of Rangiah et al.(1975) and Okafor and De Datta (1976).

5.1.3.1.3. Potassium

The potassium uptake of the crop showed a steep increase till the 60th day after transplanting after which the increase was very less. The lowest uptake was noticed in the unweeded control and the highest uptake was recorded by the completely weed free plot.

Lesser uptake of potassium on par with the weedy check was recorded by the application of thiobencarb spray @ 1.0 kg a.i/ha, butachlor spray @ 1.5 kg a.i/ha, butachlor spray or granules @ 1.0 kg a.i/ha and hand-weeded plot on the 20th day after transplanting.

On the 35th day after transplanting, lowest uptake was recorded by the weedy check (33.81 kg/ha) which was on par with butachlor spray @ 1.0 kg a.i/ha and thiobencarb spray or granules @ 1.0 kg a.i/ha. There was no significant difference between other herbicide treatments and handweeded plot.

Highest uptake of potassium on the 60th day after transplanting, on par with the completely weedfree plot, was obtained by the application of butachlor granules @ 1.5 kg a.i/ha and thiobencarb granules @ 1.0 kg a.i/ha + handweeding. The lowest uptake of potassium on par with the weedy check, was noticed in plots treated with thiobencarb @ 1.0 kg a.i/ha as spray or granules, butachlor @ 1.0 kg a.i/ha as spray or granules, butachlor spray @ 1.5 kg a.i/ha and thiobencarb spray @ 1.0 kg a.i/ha + handweeding.

At harvest, the highest uptake was recorded by thiobencarb granular application @ 1.0 kg a.i/ha + handweeding (98.89 kg/ha) which did not significantly differ from completely weed free plot. Lowest uptake was recorded by the unweeded control (63.65 kg/ha) which was on par with thiobencarb application @ 1.0 kg a.i/ha as spray or granules, thiobencarb spray @ 1.0 kg a.i/ha + handweeding and handweeding twice. There was significant positive correlation between grain yield and potassium uptake of crop at harvest ($r = +0.6859$).

The uptake of potassium by the crop was influenced to the maximum in a completely weed free situation during all the stages of growth. In the handweeded plot, the first weeding given on the 20th day temporarily encouraged the crop for a higher uptake upto 35th day of transplanting after which the uptake was on par with many herbicide treatments. Among the herbicide treatments in general butachlor @ 1.5 kg a.i/ha as granule was helpful in increasing the potassium uptake by the crop in the early stages, while thiobencarb @ 1.0 kg a.i/ha + handweeding on the 35th day assisted the crop in increasing the uptake during the later stages.

Taking the three major nutrients into consideration, herbicide application was found to supress the weed growth and encourage crop growth and nutrient uptake compared to the local practice of handweeding.

The importance of weed removal from rice fields can be understood by comparing the weedy check containing undisturbed weed growth along with the crop and the completely weed free plot. The data on the uptake of nitrogen, phosphorus and potassium by the weeds and crop under these two situations are presented in Table 20.

It is seen from the table that on the 20th day after transplanting the nitrogen uptake in the weedy check was only 39 per cent of the uptake by the crop in the completely weed free treatment. During the later stages of growth (60 days after transplanting and at harvest) the percentage of increase recorded was 60-61 per cent compared to 39-41 per cent which indicate that weed competition was not severe during these stages.

In the case of phosphorus, the crop in the weedy check could absorb only 43 per cent of the phosphorus uptake by the crop in the weed free situation on the 20th day after transplanting and it increase to 59 per cent at harvest.

Considering the uptake of potassium, the uptake by the crop in the weedy check was around 41 per cent of the uptake

Table 20. N, P, K Uptake in the completely weed free treatment and woody check compared (kg/ha)

Days after transplanting	Weedy check		Total	Completely weed free plot			% Uptake
	Weed	Crop		Weed	Crop	Total	
N Uptake							
20	3.65	8.68	12.33	-	22.44	22.44	38.68
35	5.59	28.46	34.05	-	69.17	69.17	41.15
60	16.39	65.58	81.97	-	109.20	109.20	60.05
Harvest	20.61	80.28	100.89	-	132.72	132.72	60.49
P Uptake							
20	1.72	4.85	6.57	-	11.25	11.25	43.11
35	2.57	15.17	17.74	-	26.53	26.53	57.18
60	4.43	28.65	33.08	-	45.93	45.93	62.38
Harvest	7.29	38.06	45.35	-	64.76	64.76	58.77
K Uptake							
20	3.85	12.35	16.20	-	30.23	30.23	40.85
35	7.57	33.81	41.38	-	66.14	66.14	51.12
60	8.90	55.59	64.49	-	100.79	100.79	55.15
Harvest	17.90	63.65	81.55	-	109.07	109.07	58.36

of the crop in the completely weed free plot. During the later stages (60 days after transplanting and at harvest) the percentage of uptake was 55 to 58 per cent compared to 41 to 51 per cent during initial stages (20 and 35 days after transplanting).

Thus in general, the uptake of the nutrients by the crop in the weedy check was only 50 per cent of the uptake by the crop in the completely weed free treatment. This indicates the antagonistic influence of the weeds on the crop uptake of nutrients.

5.1.3.2. Protein Content of Grain

The highest protein content (8.58 per cent) was obtained in plots treated with thiobencarb @ 1.5 kg a.i/ha in the spray form which was on par with completely weed free treatment, butachlor application @ 1.0 kg a.i/ha in the granule form + 1 handweeding and thiobencarb granules applied @ 1.0 to 1.5 kg a.i/ha.

The lowest protein content (6.50 per cent) was observed in the unweeded control which showed no significant difference from other herbicide treatments tried.

The higher protein content in plots, where weed population was less might be due to greater uptake of nitrogen by the crop between panicle initiation and harvest (Table 13).

Ramamoorthy et al.(1974), Gomez and De Datta(1975), Ravindran (1976), Abraham Varughese (1978) and Sukumari (1982) obtained higher protein content in the weeded plots than the weedy check. Lakshmi (1983) reported that the grain protein content was the highest in the completely weed free treatment which was on par with thiobencarb treated plot. The present finding is in full agreement with the above findings.

5.1.3.3. Nutrient Uptake of Weeds

5.1.3.3.1. Nitrogen

The effect due to herbicides was significant in this aspect.

At all stages of crop growth, the highest nitrogen uptake was observed in the weedy check. On the 20th day after transplanting the herbicide treatments recorded lesser uptake compared to handweeding twice.

On the 35th day after transplanting, thiobencarb application @ 1.0-1.5 kg a.i/ha in the spray or granule form and butachlor granules @ 1.0 kg a.i/ha recorded least uptake by weeds. It may be noted that the weed dry matter production was least in these plots at this stage. At this stage also the weeds of handweeded plot recorded higher uptake of nitrogen than the herbicide treated plots.

On the 60th day after transplanting, a lower uptake was recorded by thiobencarb application @ 1.5 kg a.i/ha in the spray or granule form, thiobencarb @ 1.0 kg a.i/ha in the spray form + 1 handweeding on the 35th day after transplanting and butachlor granules @ 1.0 kg a.i/ha + handweeding. Thus the one additional handweeding given was sufficient to control the regeneration of weeds and thus reduce the uptake in these plots. The uptake of nitrogen in plots handweeded twice recorded uptake which did not significantly differ from that of plots treated with butachlor spray @ 1.5 kg a.i/ha, butachlor granules @ 1.0 kg a.i/ha and thiobencarb granules @ 1.0 kg a.i/ha.

At harvest a lower uptake of nitrogen was recorded by thiobencarb spray @ 1.0 kg a.i/ha + handweeding, thiobencarb spray @ 1.5 kg a.i/ha, butachlor spray @ 1.0 kg a.i/ha applied alone and with one handweeding or butachlor granules @ 1.5 kg a.i/ha. Handweeding twice recorded higher uptake (10.40 kg/ha) next to the weedy check.

Thus, in general thiobencarb spray @ 1.5 kg a.i/ha recorded the lowest uptake at all stage of growth while during the later stages, thiobencarb spray @ 1.0 kg a.i/ha + handweeding recorded lesser uptake. Correlation studies indicated that nitrogen uptake by weeds at harvest was negatively correlated with grain yield ($r = -0.5517$).

Rangiah et al.(1975), Okafor and De Datta (1976), Ravindran (1976) and Lakshmi (1983) have reported similar negative correlation between grain yield and nitrogen uptake by weeds.

5.1.3.3.2. Phosphorus

The herbicides significantly influenced the uptake of phosphorus by weeds. The highest uptake was recorded by the unweeded control plot at all stages of growth and was inferior to handweeding and herbicide treatments.

On the 20th day after transplanting, no significant difference was observed in the uptake of phosphorus among plots treated with thiobencarb or butachlor @ 1.0 - 1.5 kg a.i/ha applied in the spray or granule form. Handweeded plot recorded a higher uptake (1.05 kg/ha) compared to herbicide treated plots.

Thiobencarb application 1.0 - 1.5 kg a.i/ha in the spray or granule form and butachlor application @ 1.0 -1.5 kg a.i/ha in the granule form recorded the lowest uptake on the 35th day after transplanting. Handweeding twice recorded a higher uptake compared to herbicide treatments.

On the 60th day after transplanting, the lowest uptake was recorded by thiobencarb application @ 1.5 kg a.i/ha in the spray form. The lesser dry matter production of weeds in this plot may be the reason for this. Handweeding twice recorded higher uptake which was on par with application of butachlor granules @ 1.0 kg a.i/ha thiobencarb @ 1.0 kg a.i/ha in the spray or granule form and butachlor @ 1.5 kg a.i/ha in the spray or granule form.

Lowest uptake of 1.38 kg phosphorus/ha at harvest was recorded by thiobencarb application @ 1.0 kg a.i/ha as spray followed by one handweeding on the 35th day after transplanting. The highest uptake, next to the unweeded control, was recorded by plots handweeded twice which was on par with butachlor application @ 1.0 kg a.i/ha as granules, thiobencarb @ 1.0 kg a.i/ha as spray or granules and thiobencarb granules @ 1.5 kg a.i/ha. There was no significant difference between the other herbicide treatments.

Taking all the stages into consideration, phosphorus uptake by weeds was least in plots treated with thiobencarb spray @ 1.5 kg a.i/ha, thiobencarb spray or granules @ 1.0 kg a.i/ha + 1 handweeding which might be due to the lesser dry matter accumulation by weeds in these plots. There was significant negative correlation between the grain yield and phosphorus uptake by the weeds (r = -0.6596). Similar results were obtained by Ravindran (1976) and Lakshmi (1983).

5.1.3.3.3. Potassium

The effect due to herbicides was significant on the uptake of potassium. The highest uptake was noticed in the weedy check. Handweeding twice recorded more uptake than the herbicide treated plots. Among the herbicide treatments, butachlor 1.0 kg a.i/ha as granules recorded the highest uptake of 1.28 kg/ha which was on par with all the herbicide treatments except thiobencarb applied @ 1.5 kg a.i/ha as spray.

On the 35th day after transplanting there was no significant difference in potassium uptake among the different herbicide treatments. Evenafter giving one handweeding on 20th day after transplanting, handweeded plot recorded potassium uptake which was statistically on par to weedy check. The disturbance of soil caused by the handweeding given on the 20th day might have encouraged the germination of weed seeds and thereby increased the weed population which in turn has increased the uptake (Table 2c.).

Lowest uptake on the 60th day after transplanting was recorded by application of thiobencarb spray @ 1.5 kg a.i/ha, thiobencarb spray @ 1.0 kg a.i/ha + handweeding and butachlor @ 1.0 kg a.i/ha in the spray or granule form + handweeding. Thus the dose of both the herbicides could be reduced to 1.0 kg a.i/ha if it is supplemented by one late handweeding. Plots that received two handweedings on the 20th and 35th day after transplanting, recorded higher uptake and was on par with the application of thiobencarb @ 1.0 kg a.i/ha as spray or granules, butachlor spray @ 1.5 kg a.i/ha and butachlor granules @ 1.0 kg a.i/ha.

At harvest, there was no significant difference in potassium uptake between the herbicide treatments. However, the local practice of handweeding twice recorded higher uptake (12.74 kg/ha) next to the weedy check. There was significant negative correlation between the potassium uptake of weeds at harvest and the grain yield (r = -0.5224).

Taking into consideration all the stages of growth it was revealed from the data that the potassium uptake in plot treated with thiobencarb @ 1.5 kg a.i/ha as spray was less (0.26, 0.60, 2.19 and 3.75 kg/ha respectively on 20th, 35th and 60th DAT and at harvest) compared to all other herbicide treatments. With regard to the uptake of this nutrient by the weed, it can be considered negligible since it was as good as a completely weed free situation.

Ramamoorthy et al.(1974), Ravindran (1976), Kakati and Mani (1977) and Lakshmi (1983) have reported lesser nutrient uptake by weeds in herbicide treated plots than the control plots.

5.1.3.4. N, P and K content of the soil after the experiment

The nitrogen, phosphorus and potassium content of the soil was analysed after the experiment. There was no significant difference in the N and P_2O_5 content of soil. But the K_2O content of the soil showed significant difference between the treatments. The highest content was observed in plots treated with butachlor @ 1.0 kg a.i/ha in the spray form + 1 handweeding (284.90 kg/ha) and was on par with butachlor application @ 1.5 kg a.i/ha as granules and completely weed free treatment. The better weed control in these plots reduced the uptake by weeds and thus more nutrients were left in the soil.

5.1.4. Economics of Crop Production.

5.1.4.1. Net Income

There was significant difference in tho net income obtained from the different treatments. Application of thiobencarb granules @ 1.0 kg a.i/ha + 1 handweeding gave the highest net income (Rs.1979.73) and it was on par with application of butachlor granules @ 1.5 kg a.i/ha and the completely weed free treatment. The unweeded control recorded a loss of Rs.134.25 and it was statistically similar to handweeding twice, butachlor granules at 1.0 kg a.i/ha and thiobencarb spray @ 1.0 kg a.i/ha.

Thus in general application of granules was cheaper, except butachlor granules at 1.0 kg a.i/ha. This is due to the higher yield obtained from these treatments in spite of the greater labour requirement. Also herbicide application was more economical than manual weed control.

The results of the study are in agreement with the findings of Rangiah et al. (1974), Rangiah et al.(1976), Ravindran (1976), Nanja Reddy and Ramanna (1978), Versteeg and Maldonado (1978) and Lakshmi (1983).

5.1.4.2. Cost-benefit ratio

The various weed control treatments significantly influenced the cost-benefit ratio. The highest ratio (1.23)

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5.1.4.2. Cost-benefit ratio

The various weed control treatments significantly influenced the cost-benefit ratio. The highest ratio (1.23) was recorded by the application of thiobencarb granules at 1.0 kg a.i/ha + 1 handweeding and it did not differ significantly from the application of butachlor granules @ 1.5 kg a.i/ha. Application of thiobencarb granules @ 1.0 kg a.i/ha recorded the next highest ratio and it was on par with thiobencarb spray and granules @ 1.5 kg a.i/ha, butachlor spray @ 1.0 kg a.i/ha and thiobencarb granules at 1.0 kg a.i/ha + handweeding. The unweeded control worked out the lowest ratio (0.98) and it was on par with the local practice of two handweedings.

5.2. Experiment No.2

5.2.1. Observations on Cowpea.

5.2.1.1. Germination Count

The germination count of cowpea taken at ten days after sowing revealed that there was no significant difference between the treatments. This indicates that there was no residual effect of the herbicide which could affect the germination of the succeeding crop.

Vijayaraghavan (1974) observed no significant effect of butachlor on the stand of green gram raised after paddy. Ravindran (1976), Balu and Sankaran (1978) and Patro and Prusty (1978) also found out that thiobencarb and butachlor did not affect the germination percentage of crops raised after the harvest of rice.

5.2.1.2. Grain Yield

There was significant differenco among the treatments with respect to this character.

The highest grain yield (1274.7 kg/ha) was recorded in plots where thiobencarb was applied @ 1.0 kg a.i/ha in the spray form which was on par with completely weed free treatment and application of butachlor granules @ 1.5 kg a.i/ha. The lowest yield (745.0 kg/ha) was recorded by butachlor spray @ 1.0 kg a.i/ha + handweeding treatment which did not significantly differ from other treatments, except butachlor application @ 1.5 kg a.i/ha as granules, thiobencarb spray @ 1.0 kg a.i/ha and the completely weed free treatment.

Reports from AICARP have indicated that application of thiobencarb liquid in two splits @ 1.5 kg a.i/ha each after 3 days and 20 days germination gave maximum yield of succeeding rabi crop of cowpea (Anon.1974-75). But Rajaram et al. (1978) obtained no significant difference in yield of black gram by the application of butachlor granules to previous rice crop. Also Vijayaraghavan (1974) and Jayakumar et al.(1986) obtained no significant difference in the seed yield of green gram due to butachlor applied to previous rice crop.

5.2.1.3. Bhusa Yield

The effect due to herbicides was not significant on the bhusa yield of the succeeding crop of cowpea. Thus the vegetative growth of cowpea was not adversely affected by the herbicide applied to the previous crop indicating that there was no residual effect of the herbicides. This is against the findings of Balu and Sankaran (1978) who reported that butachlor applied to previous crop resulted in greater dry matter production of subsequent crop of green gram.

SUMMARY

6. SUMMARY

An experiment was conducted in the Instructional farm attached to the College of Agriculture, Vellayani to develop a suitable weed control method for medium duration transplanted crop of rice during the second crop season (*Mundakan*) of 1985-86. Also a succeeding crop of cowpea was raised during the third crop (*Punja*) season to evaluate the residual effect of the herbicides. The results of the study are summarised below.

1. Grasses like *Echinochloa* spp., *Brachiaria ramosa*, sedges like *Cyperus* spp., *Fimbristylis miliacea* and broad-leaved weeds like *Monochoria vaginalis*, *Ludwigia parviflora* were the predominant weeds in the rice fields of Vellayani.

2. Monocot weeds constituted the major portion of the weed population throughout the crop growth period.

3. Thiobencarb @ 1.0 - 1.5 kg.a.i/ha either as spray or as granules controlled monocot weeds better than butachlor at the same rates. The use of herbicides was effective than handweeding twice.

4. Herbicide application was better than the cultural method in suppressing the dicot weed population throughout crop growth. Thiobencarb or butachlor

@ 1.0-1.5 kg a.i/ha either as spray or granules had the same effect on the dicot weed population.

5. Thiobencarb 1.5 kg a.i/ha as spray or granules was the most effective treatment in suppressing the total weed population compared to other herbicide treatments and handweeding.

6. The suppression of dry matter accumulation of weeds in the early stages is important which could be achieved by the application of thiobencarb @ 1.5 kg a.i/ha as spray or granules, thiobencarb @ 1.0 kg a.i/ha spray or granules alone or in combination with one handweeding at 35 DAT.

7. The weed control efficiency ranged from 62.6 to 77.8 per cent in the case of thiobencarb and 52.0 to 70.6 per cent in the case of butachlor. Thiobencarb spray @ 1.0 kg a.i/ha + hand weeding at 35DAT recorded the highest weed control efficiency (77.8) next to the completely weed free treatment.

8. The plant height at 20th, 35th and 60th day after transplanting showed no significant difference among the treatments, while at harvest the plant height was higher in plots treated with butachlor granules @

1.5 kg a.i/ha, butachlor spray or granules @ 1.0 kg a.i/ha either alone or followed by a handweeding, thiobencarb spray or granules @ 1.0 kg a.i/ha + handweeding at 35 DAT and twice handweeded plots.

9. The various weed control treatments influenced the tiller count taken at 20th and 35th day after transplanting, but the effect was nullified at 60th day after transplanting.

10. Highest leaf area index on par with the completely weed free treatment was achieved by the application of thiobencarb (spray) @ 1.0 kg a.i/ha and followed by one handweeding at 35 DAT.

11. Butachlor @ 1.0 kg a.i/ha as granule or spray, butachlor 1.5 kg a.i/ha granule and thiobencarb @ 1.0-1.5 kg a.i/ha applied as spray helped in increasing the dry matter accumulation of crop in the early stages of growth while during the later stages both butachlor and thiobencarb @ 1.5 kg a.i/ha as spray or granule increased the dry matter accumulation. Handweeding given on 20th and 35th day after transplanting increased the dry matter accumulation only from 35th day after transplanting.

12. Thiobencarb spray @ 1.0 kg a.i/ha, butachlor spray @ 1.0 kg a.i/ha and butachlor granules @ 1.5 kg a.i/ha recorded higher number of productive tillers.

13. Application of butachlor @ 1.5 kg a.i/ha in the granule form, butachlor 1.0 kg a.i/ha as spray or granules + handweeding and thiobencarb granules @ 1.0 kg a.i/ha + handweeding recorded higher weight of panicle and were as good as completely weed free treatment.

14. Application of thiobencarb @ 1.0 kg a.i/ha as granules alone and with one handweeding, butachlor granules @ 1.0 kg a.i/ha alone and with one handweeding and butachlor spray @ 1.0 kg a.i/ha recorded greater number of spikelets. Thus granule formulations in general favoured the production of more number of spikelets and the lower rate of 1.0 kg a.i/ha was sufficient.

15. At lower doses of both the herbicides, granular formulations were found to be more efficient in recording greater number of filled grains.

16. Butachlor granules @ 1.0 kg a.i/ha and thiobencarb @ 1.0 kg a.i/ha as spray or granules recorded lower values of thousand grain weight while there was no significant difference between other herbicide treatments

and handweeding twice. Completely weed free treatment recorded the highest thousand grain weight.

17. Yield of grain was significantly influenced by the herbicides and thiobencarb application @ 1.0 kg a.i/ha in the granule form + handweeding recorded higher grain yield which was on par with completely weed free condition.

18. Among the herbicide treatments, butachlor granules or spray @ 1.5 kg a.i/ha, thiobencarb @ 1.0 - 1.5 kg a.i/ha in the spray or granule form, butachlor spray or granules @ 1.0 kg a.i/ha, thiobencarb spray or granules @ 1.0 kg a.i/ha + handweeding and butachlor spray @ 1.0 kg a.i/ha + handweeding recorded higher straw yields. Handweeding twice recorded lower yields next to the weedy check .

19. The harvest index was unaffected by the weed control treatments in general.

20. The lowest value of weed index (19.90 per cent) was recorded by the application of thiobencarb granules @ 1.0 kg a.i/ha + handweeding and the highest value (45.90 per cent) by the weedy check.

21. Thiobencarb spray @ 1.5 kg a.i/ha recorded the lowest nitrogen uptake by weeds during the early stages

while during later stages, thiobencarb spray @ 1.0 kg a.i/ha + handweeding also recorded lesser uptake.

22. Phosphorus uptake of weeds, in general was least in plots treated with thiobencarb spray @ 1.5 kg a.i/ha and thiobencarb spray or granules @ 1.0 kg a.i/ha + handweeding.

23. Potassium uptake of weeds was less in plots treated with thiobencarb @ 1.5 kg a.i/ha as spray, compared to other herbicide treatments.

24. Application of butachlor granules @ 1.0-1.5 kg a.i/ha enhanced the crop uptake of nitrogen throughout the crop growth period.

25. There was a constant and significant increase in the phosphorus uptake of crop, with regard to butachlor applied @ 1.5 kg a.i/ha as granules.

26. Butachlor granules @ 1.5 kg a.i/ha increased the potassium uptake of crop in the early stages while thiobencarb granules @ 1.0 kg a.i/ha + handweeding increased the uptake during the later stages.

27. The highest protein content was recorded by application of thiobencarb @ 1.5 kg a.i/ha as spray which

was on par with completely weed free treatment, butachlor granules @ 1.0 kg a.i/ha + one handweeding and thiobencarb granules @ 1.0 - 1.5 kg a.i/ha.

28. There was no significant difference in the N and P_2O_5 content of the soil after the experiment, while K_2O content significantly differed. The highest content was observed in plots treated with butachlor @ 1.0 kg a.i/ha as spray + one handweeding and was on par with application of butachlor granules @ 1.5 kg a.i/ha and completely weed free treatment.

29. Application of thiobencarb granules @ 1.0 kg a.i/ha + one handweeding gave the highest net income(Rs.1979.73) which was on par with completely weedfree treatment and butachlor granules @ 1.5 kg a.i/ha.

30. Application of thiobencarb granules @ 1.0 kg a.i/ha + handweeding recorded the highest cost-benefit ratio and it was on par with application of butachlor granules @ 1.5 kg a.i/ha.

31. There was no residual effect of the herbicides on the germination of succeeding crop of cowpea.

32. There was significant difference between the treatments regarding the grain yield of cowpea. The highest grain yield was recorded by thiobencarb spray @ 1.0 kg a.i/ha which was on par with completely weed free treatment and butachlor granules @ 1.5 kg a.i/ha.

33. There was no significant difference in the <u>bhusa</u> yield of cowpea.

Thus in general higher grain yields can be obtained by the application of thiobencarb granules @ 1.0 kg a.i/ha and followed by one handweeding at 35 DAT which also gave highest net profit and cost-benefit ratio.

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APPENDICES

APPENDIX I

Weather data during the crop period (10-9-1985 to 29-4-1986) and its variation from the past five years

Sl. No.	Standard week No.	Periods	Temperature (°C) Maximum cp	Temperature (°C) Maximum V	Temperature (°C) Minimum cp	Temperature (°C) Minimum V	Humidity (per cent) Forenoon cp	Humidity (per cent) Forenoon V	Humidity (per cent) Afternoon cp	Humidity (per cent) Afternoon V	Total rainfall (mm) Cp	Total rainfall (mm) V
1	37	10/9-16/9	30.4	+0.23	23.2	-0.17	93.3	+6.63	73.3	-1.70	-	-17.50
2	38	17/9-23/9	30.4	-0.33	23.5	+0.03	93.3	+10.47	75.6	+4.40	-	-23.77
3	39	24/9-30/9	29.9	-0.73	23.4	+0.20	90.7	+5.57	75.6	+1.00	-	-29.47
4	40	1/10-7/10	30.3	+0.17	22.5	-0.23	89.7	+1.23	78.1	+2.97	-	-61.77
5	41	8/10-14/10	30.4	-0.18	22.9	+0.42	86.0	-0.30	74.6	+7.07	-	-29.15
6	42	15/10-21/10	29.5	-1.35	22.4	+0.07	85.0	+3.37	73.0	+10.30	128.0	+116.00
7	43	22/10-28/10	29.6	-1.28	23.1	+0.32	90.9	+11.30	74.1	+1.57	155.0	+133.87
8	44	29/10-4/11	29.2	-1.60	22.6	-0.83	90.0	+3.00	72.9	-8.67	311.0	+283.00
9	45	5/11-11/11	30.1	-1.60	23.9	+0.97	89.0	+8.80	71.6	+3.50	34.8	+ 12.60
10	46	12/11-18/11	29.6	-1.35	23.3	+0.17	87.1	+4.40	74.3	-2.77	152.2	+115.97
11	47	19/11-25/11	29.7	-1.00	22.8	-0.40	82.7	-4.00	71.3	-2.50	45.8	+ 27.40
12	48	26/11-2/12	30.0	-0.60	21.2	-1.83	88.9	+0.01	65.1	-7.47	-	- 21.15
13	49	3/12-9/12	30.4	-1.18	23.4	+0.77	86.9	+1.97	74.4	+9.63	45.6	+ 42.27
14	50	10/12-16/12	31.0	+0.05	24.1	+1.57	88.0	+5.03	91.4	+26.60	39.7	+ 26.72
15	51	17/12-23/12	31.1	+0.63	22.4	-0.13	92.5	+9.35	57.7	-20.65	8.1	- 4.63
16	52	24/12-31/12	31.5	+0.80	23.5	+0.93	78.9	-7.15	57.8	-15.75	9.4	- 16.17
17	1	1/1-7/1	32.2	+1.49	20.7	-1.18	77.9	-2.09	55.3	-10.27	-	- 17.73
18	2	8/1-14/1	31.9	+0.82	22.7	+1.00	85.9	+4.80	74.3	+ 9.00	13.2	+ 13.20
19	3	15/1-21/1	32.8	+1.85	20.9	-0.68	86.6	+2.80	67.4	- 1.10	-	- 16.25
20	4	22/1-28/1	32.5	+1.37	23.1	+1.52	89.9	+7.23	68.7	+ 7.83	-	-

(contd.)

APPENDIX I (contd.)

Sl. No.	Standard week No.	Periods	Temperature (°C) Maximum CP	Maximum V	Minimum CP	Minimum V	Humidity (per cent) Forenoon CP	Forenoon V	Afternoon CP	Afternoon V	Total rainfall (mm) CP	V
21	5	29/1– 4/2	32.1	+0.70	21.6	–0.01	86.6	–1.00	74.9	+7.03	8.4	+2.65
22	6	5/2–11/2	32.0	+0.7	20.6	–2.25	87.1	–0.47	64.7	–2.90	–	–2.98
23	7	12/2–18/2	31.9	+0.40	20.5	–2.08	93.1	+6.60	66.4	–4.67	–	–20.20
24	8	19/2–25/2	32.0	+0.12	20.6	–2.25	85.3	–1.40	65.1	–5.07	69.6	+66.17
25	9	26/2–4/3	31.1	–0.80	21.4	–2.75	86.9	+0.57	77.7	+8.07	16.4	+14.65
26	10	5/3 –11/3	31.7	–0.43	20.8	–3.68	86.6	+1.23	68.4	–4.23	8.2	– 0.70
27	11	12/3–18/3	31.6	–0.83	20.7	–3.50	87.0	+1.57	62.1	–6.47	0.4	– 0.30
28	12	19/3–25/3	31.9	–0.78	20.2	–4.60	84.1	–1.37	61.1	–6.10	–	– 0.45
29	13	26/3– 1/4	32.5	–0.83	21.3	–3.35	87.9	+1.03	57.0	–10.03	–	– 6.08
30	14	2/4 – 8/4	33.8	+0.80	24.1	+0.73	87.3	+0.20	58.3	–11.17	8.3	–22.90
31	15	9/4 –15/4	33.9	+1.32	22.9	–0.10	89.4	+5.87	60.1	– 7.73	42.2	–28.40
32	16	16/4–22/4	34.0	+1.05	23.4	+0.42	86.0	+2.87	62.0	– 4.30	18.2	+ 7.05
33	17	23/4–29/4	34.4	+1.27	24.1	+1.72	86.7	+4.37	59.3	– 9.53	25.2	+ 9.15

CP = during the crop period

V = variation from the past five years

\+ more than 5 years mean

– less than 5 years mean

APPENDIX II

Summary of the analysis of variance tables for the weed population/m^2 at different days after transplanting

Source	df	Mean Squares											
		Monocot weed population				Dicot weed population				Total weed population			
		20	35	60	Harvest	20	35	60	Harvest	20	35	60	Harves
Total	44												
Replication	2	2.08	0.32	0.91	0.81	0.29	0.09	0.59	1.03	2.41	0.30	0.55	0.80
Treatments	14	11.08**	9.14**	21.69**	25.50**	4.18**	5.78**	4.02**	6.62**	14.97*	13.81**	25.09**	31.50**
Error	28	1.06	0.96	2.28	2.02	0.31	0.36	0.87	0.53	0.92	0.93	2.57	1.97

* Significant at 0.05 level

** Significant at 0.01 level

Note: Data analysed after $\sqrt{x + 1}$ transformation

APPENDIX III

Summary of the analysis of variance tables for dry weight of weeds/m^2 at different days after transplanting

Source	df	Mean squares			Harvest
		20	35	60	
Total	44				
Replication	2	6.77	30.86	469.41	1057.01
Treatment	14	76.62**	168.63**	952.00**	1703.76**
Error	28	6.25	19.22	179.13	240.08

** Significant at 0.01 level

APPENDIX IV

Summary of the analysis of variance table for weed control efficiency

Source	df	Mean squares
Total	44	
Replication	2	324.63
Treatment	14	957.28**
Error	28	33.71

** Significant at 0.01 level

APPENDIX V

Summary of the analysis of variance tables for the height of plants at different days after transplanting.

Source	df	Mean squares			
		20	35	60	Harvest
Total	44				
Replication	2	1.99	3.89	7.32	53.31
Treatments	14	1.07	5.36	6.66	25.62**
Error	28	0.82	5.22	5.31	6.97

** Significant at 0.01 level

APPENDIX VI

Summary of the analysis of variance table for the tiller count/m^2 at 20,35 and 60 days after transplanting

Source	df	Mean squares		
		20	35	60
Total	44			
Replication	2	243.25	2062.00	3936.25
Treatments	14	1248.36**	3244.75**	1057.79
Error	28	381.20	502.80	847.03

** Significant at 0.01 level

APPENDIX VII

Summary of the Analysis of variance table for the Leaf Area Index at flowering

Source	df	Mean square
Total	44	
Replication	2	0.04
Treatments	14	0.87**
Error	28	0.13

** Significant at 0.01 level

APPENDIX VIII

Summary of the analysis of variance tables for the dry matter production of crop at different days after transplanting

Source	df	Mean Squares			
		20	35	60	Harvest
Total	44				
Replication	2	31.82	899.02	2249.80	23846.02
Treatments	14	63.77**	747.74**	12615.80**	3468629.45**
Error	28	7.67	178.76	3529.40	142712.40

** Significant at 0.01 level

APPENDIX IX

Summary of the analysis of variance tables for the yield components

Source	df	Mean Squares				
		Number of productive tillers/m^2	Number of spikelets per panicle.	Number of filled grains per panicle	Weight of panicle	Thousand grain weight
Total	44					
Replication	2	169.88	18.75	53.33	0.15	4.27
Treatments	14	2129.57**	226.46**	239.06**	0.37**	2.49**
Error	28	251.20	71.79	78.82	0.05	0.56

** Significant at 0.01 level

APPENDIX X

Summary of the analysis of variance tables for grain yield, straw yield and harvest index

Source	df	Grain yield	Straw yield	Harvest index
Total	44			
Replication	2	91776.00	147712.00	0.002
Treatments	14	801938.30**	1068613.00**	0.001
Error	28	36790.86	135172.60	0.001

** Significant at 0.01 level

APPENDIX XI

Summary of the analysis of variance table for Weed Index

Source	df	Mean Squares
Total	44	
Replication	2	125.64
Treatment	14	279.11**
Error	28	8.08

** Significant at 0.01 level

APPENDIX XII

Summary of the analysis of variance table for the nutrient uptake by the crop at different days after transplanting

Source	df	Mean Squares											
		Nitrogen uptake				Phosphorus uptake				Potassium uptake			
		20	35	60	Harvest	20	35	60	Harvest	20	35	60	Harvest
Total	44												
Replication	2	16.04	103.02	71.48	90.86	4.04	6.99	11.27	22.86	24.98	284.76	54.12	17.95
Treatments	14	34.92**	258.97**	315.66*	357.29**	6.80**	17.63**	46.38*	103.23**	60.73**	259.26**	403.20**	401.63**
Error	28	5.41	67.64	118.99	50.61	1.04	5.28	18.38	18.72	8.46	69.23	111.10	73.01

* Significant at 0.05 level

** Significant at 0.01 level

APPLNDIX XIII

Summary of the analysis of variance table for the protein content of grain.

Source	df	Mean Squares
Total	44	
Replication	2	0.45
Treatments	14	0.10*
Lrror	28	C.42

* Signıficant at 0.05 level

APPENDIX XIV

Summary of the analysis of variance tables for the nutrient uptake of weeds at different days after transplanting

Source	df	Mean squares											
		Nitrogen				Phosphorus				Potassium			
		20	35	60	Harvest	20	35	60	Harvest	20	35	60	Harvest
Total	44												
Replication	2	0.54	1.26	16.69	11.46	0.08	0.17	0.78	4.62	0.39	2.81	8.06	28.76
Treatments	14	2.61**	5.80**	45.48**	59.42**	0.56**	1.23**	3.07**	8.02**	2.77**	12.53**	16.06**	53.59**
Error	28	0.23	0.47	5.10	10.77	0.06	0.11	0.49	0.90	0.32	1.25	3.04	8.87

** Significant at 0.01 level

APPENDIX XV

Summary of the analysis of variance tables for the Nitrogen, Phosphorus and Potassium content of soil after the experiment

Source	df	Mean Squares		
		Total N	Available P_2O_5	Exchangeable K_2O
Total	44			
Replication	2	0.0017	0.51	353.25
Treatments	14	0.0015	7.26	3583.14**
Error	28	0.0012	4.17	774.19

** Significant at 0.01 level

APPENDIX XVI

Summary of the analysis of variance tables for net income and cost-benefit ratio

Source	df	Mean squares	
		Net income	Cost-benefit ratio
Total	44		
Replication	2	234001.84	0.003
Treatment	14	1064949.33	0.02**
Error	28	189362.18	0.0004

** Significant at 0.01 level

APPENDIX XVII

Summary of the analysis of variance table for the germination count of cowpea/ 0.5 sq m

Source	df	Mean Squares
Total	44	
Replication	2	0.0352
Treatments	14	0.0859
Error	28	0.1031

APPENDIX XVIII

Summary of the analysis of variance tables for grain yield and bhusa yield of cowpea

Source	df	Mean Squares	
		Grain yield	Bhusa yield
Total	44		
Replication	2	46078.00	2381592.00
Treatments	14	59996.57*	165265.14
Error	28	25476.57	332730.86

* Significant at 0.05 level

INTEGRATED WEED MANAGEMENT IN TRANSPLANTED MEDIUM DURATION RICE

BY

BEENA MAHESWARI, S. K.

ABSTRACT OF A THESIS
SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR
THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURE (AGRONOMY)
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DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
VELLAYANI, TRIVANDRUM

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ABSTRACT

An experiment was conducted in the Instructional Farm attached to the College of Agriculture, Vellayani during the second crop (Mundakan) season of 1985-86 to develop a suitable weed control method for medium duration transplanted crop of rice in randomised block design with 15 treatments and 3 replications. During the third crop (Punja) season a succeeding crop of cowpea was raised to assess the residual effect of the herbicides.

Monocot weeds predominated throughout the crop growth. Herbicide application controlled the weed population better than handweeding twice. Thiobencarb @ 1.0 kg a.i/ha as spray plus one handweeding at 35 DAT gave the highest weed control efficiency next to the completely weed free treatment. Lower dose of thiobencarb or butachlor (1.0 kg a.i/ha) were sufficient to increase the dry matter accumulation of crop in the earlier stages, while higher dose (1.5 kg a.i/ha) was required during later stages. Plant height, tiller count and LAI were higher in the herbicide treatments compared to the weedy check.

Granular formulation of both the herbicides improved the yield attributing characters in general and thiobencarb granules @ 1.0 kg a.i/ha plus one handweeding at 35 DAT gave the highest grain yield which was on par with completely weed free situation. The herbicide treatments gave better straw yields when compared to handweeding twice. However, the harvest index was unaffected by the treatments. The uptake of nutrients by the weeds was reduced by the weed control treatments which in turn enhanced the uptake by the crop. Chemical analysis of the soil after the experiment revealed that K_2O content only differed significantly. Application of Thiobencarb granules @ 1.0 kg a.i/ha plus one handweeding at 35 DAT gave the highest net income and cost-benefit ratio.

There was no residual effect of the herbicides on the germination of cowpea seeds. Grain yield of cowpea differed significantly while the bhusa yield was unaffected.