

EFFECT OF HERBICIDES ON WEED CONTROL IN DRILL SOWN RICE (*Oryza sativa* L.)

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EFFECT OF HERBICIDES ON WEED CONTROL IN DRILL SOWN RICE (*Oryza sativa* L.)

M. MAHADEVASWAMY, B.Sc., (Agri.)

Thesis submitted to the
University of Agricultural Sciences, Bangalore
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for the award of the degree of

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IN
AGRONOMY

BANGALORE

NOVEMBER 1986

Affectionately Dedicated
To My Parents

Department of Agronomy
UNIVERSITY OF AGRICULTURAL SCIENCES
Bangalore

CERTIFICATE

This is to certify that the thesis entitled "EFFECT OF HERBICIDES ON WEED CONTROL IN DRILL SOWN RICE (Oryza sativa L.)" submitted by Mr.M. MAHADEVASWAMY for the degree of MASTER OF SCIENCE (AGRICULTURE) in AGRONOMY of the University of Agricultural Sciences, Bangalore, is a record of research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles.

BANGALORE

November 5, 1986

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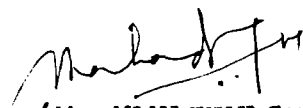
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INTRODUCTION

I. INTRODUCTION

Rice is the staple food of more than 60 per cent of the world's population. It is the world's leading food crop cultivated over an area of about 145 million ha with a production of about 380 million tonnes. In terms of area and production, it is second to wheat. It provides about 22 per cent of the world's supply of calories and 17 per cent of proteins. Maximum area under rice is in Asia. Among the rice growing countries, India has the largest area of 40.2 million ha with a production of 69 million tonnes. In Karnataka it occupies 1.12 million ha area with 3.3 million tonnes of production.

'In upland rice cultivation, weeds are a major problem.' Unlike the flooded direct seed cultivation where flooding alone controls many weeds, in the non-flooded direct seeded upland rice culture, 'the seeds of weeds germinate along with rice causing greater reduction in the yield. The germinated weeds not only compete for nutrients, light and space but also transpire lot of valuable conserved water from the soil.' They increase the cost of labour, reduce the quantity and

quality of rice, harbour insects and diseases, reduce the efficiency of mechanical production and harvest. Thorough weed control during initial stages thus become essential to get optimum yield from the crop.'

'Control of weeds, is one of the most expensive items in production of paddy. The hand weeding which is a common practice is expensive and accounts for 20 to 25 per cent of the total cost of production (Sahu and Battacharya, 1964). Weeding has to be carried out expeditiously with^ain short period of time, the labour supply during which period is normally inadequate. The delayed weeding is not only less effective but also becomes more expensive. In areas where labour is costly and in cases where timely weeding could not be done due to labour scarcity, herbicides offer an excellent alternative to control weeds. In some instances herbicides offer the most practical, effective and economical means of reducing weed competition, crop losses and production losses.'

'The final choice of any weed control measure will depend largely on its effectiveness and economics.' The cost of weed control must be compared with the resultant increased value of the crop. With labour becoming scarce and costly, the herbicides no doubt, offer a great

potential in minimising the cost of weed control. The majority of the farmers in India are reluctant to use herbicides mainly due to prohibitive cost, lack of knowledge about rate, time and method of application and unavailability of suitable herbicides.

Best results on weed control with herbicides are obtained when they are used in conjunction with tillage and other agronomic practices. The choice of the best specific treatment varies with agronomic, ecological and economic factors. Use of pre-emergence herbicides to keep the crop weed free in early stages followed by hand weeding may be helpful in minimising the cost of weeding as well as managing the weeds below the damaging level. Since such studies are scanty on drill sown rice, an experiment was laid out to investigate with the following objectives:

1. To find out the relative effectiveness of some new herbicides at different doses and hand weeding on the control of weeds in drill sown rice.
2. To study the weed flora in drill sown rice.
3. To compare the economics of weed control through chemicals, cultural practices and integrated weed control methods.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Weeds are unwanted and undesirable plants which interfere with the utilization of land and water resources and thus adversely affect human welfare. Weeds compete with crop plants for nutrients, soil moisture and sunlight. Reduction in crop yield has a direct correlation with weed competition.

In direct seeded rice under upland conditions, weeds often emerge along with the crop and competition for soil moisture may begin early particularly in low rainfall areas. Weed seedlings due to their greater competitive ability, grow more rapidly than rice seedlings. In the transplanted rice, flooding and puddling reduces the existing weed growth before the seedlings are planted. Further more, new flush of weeds establishes only after two to three weeks of transplantation, thus enabling the rice seedlings to establish well and withstand subsequent weed competition better. Pillai and Rao (1974) estimated the extent of yield reduction due to weeds around 15 to 20 per cent in transplanted rice, 30 to 35 per cent in direct sown under puddled conditions and over 50 per cent in direct sown upland rice.

In this chapter the literature pertaining to the direct sown rainfed rice culture is reviewed under these aspects.

1. Weed flora in direct sown rice
2. Crop-weed competition
3. Methods of weed control
4. Economics of weed control

2.1 Weed flora in direct sown rice

The degree of damage caused by weeds is related to the type, species and density of weeds growing in a crop community.

Pande and Sankara Rao (1965) and Pande et al. (1966) reported that predominant weeds of upland rice were Panicum humilae, Dactyloctenium aegyptium, Digitaria sanguinalis, Paspalum scrobiculatum, Setaria glauca, Eleusine indica, Echinochloa colanum, Panicum crusgalli and Panicum capillare.

Mukopadhyay et al. (1972) reported that in direct sown IR-8 rice, out of the 19 to 21 weed species identified, grasses comprised 85 - 90 per cent of the total population and 91 - 96 per cent of the total dry matter and absorbed 90 - 94 per cent of the total amount of nitrogen taken up by weeds. Echinochloa colanum was the predominant species

Nair et al. (1974) observed that Echinochloa crusgalli, Fimbristylis miliacea, and Cyperus sp, were the prominent weeds in direct sown rice crop.

Field experiments conducted at the Headquarters of the All India Co-ordinated Rice Improvement Project at Hyderabad and at the co-operative centres all over the country have shown that predominant weed species under upland conditions ^{were} perennial sedges like Cyperus rotundus and grasses like Cynodon dactylon (Gopalakrishna Pillai et al., 1976)

Bhagat et al. (1977) reported that among the annual weeds, Digitaria longiflora and Echinochloa crusgalli accounted for 36 to 48 per cent of the total weed population. Dhiman and Awasthi (1977) reported that the grasses infested to the extent of 86.45 per cent of the total weed population. With in the Graminae family percentage of weeds belonging to Echinochloa species comprising of Echinochloa colanum and Echinochloa crusgalli were pre-dominantly ^{no} growing.

Mohamed Ali and Sankaran (1979) reported that among grass weeds Echinochloa colanum, among sedges Cyperus iria and among dicot weeds Eclipta alba were predominant and competition was severe in early stages under non-puddled conditions in direct sown rice.

Field studies conducted on drilled rice (var. Jaya) have shown that grassy weeds dominated over broad leaved weeds. The intensity of grassy weeds was more in plots maintained weed free for initial 15 to 30 days (Bhan et al., 1980a). Further, Kakati and Pradhani (1980) observed in upland rice Cynodon dactylon, Digitaria sanguinalis, and Eleusine indica of grasses, Cyperus iria and Cyperus pilosus of sedges and Ageratum conyzoides and Borreria hispida of dicot weeds.

Bisen and Tiwari (1985) reported that complex weed system in rice consisted of Cyperus iria, Cyperus rotundus, Echinochloa crusgalli, Phyllanthus niruri, P. simplex, Commelina spp., Alysicarpus spp., Ageratum conyzoides, Cynodon dactylon, Eragrostis spp., Saccharum spontaneum, Seheina nervosum and Ludwigia parviflora.

Babu and Singh (1985) reported that Cyperus rotundus and Echinochloa colanum^o were the most dominant weed species in the drilled rice and together^{they} constituted 79.8 per cent of the total weed population. The common weeds observed in upland drilled paddy were Cyperus iria L., Cyperus rotundus L., Phyllanthus niruri, Trianthema monogyna, Echinochloa crusgalli Beauv., Digitaria adscendense Heur., Cynodon dactylon pers., Physalis minima L., Eclipta alba Hasak. and Commelina commuⁿⁱns L. (Trivedi et al., 1985).

2.2 Crop-weed competition

Competition between plants is maximum when available resources for crop growth becomes limiting. The plants that germinate fast and grow fast tend to suppress the other plants. Competition between crops and weeds is most severe when the competing plants have similar vegetative habits and demands upon resources. An annual grass Monochoria vaginalis is a more severe competitor than another annual grass barnyard grass (Echinochloa crusgalli var. Oryzicola) in rice culture (Chiska, 1977).

2.2.1 Critical stages of competition

Weed competition is maximum during the early stages of crop growth.

Ghosh et al. (1975) reported that the weeds could be permitted to grow in the upland rice at most for 10 days after seeding. Any further competition is likely to reduce the yield significantly. Keeping the rice crop weed free from 10 days after seeding upto maturity could make maximum possible yield. The period between 10 days to 40 days after seeding appeared the most critical when serious reduction in yield occurred in unweeded plots.

The yield reduction in direct seeded upland rice ranged from 42 to 65 per cent. The most critical period,

when crop losses due to weed competition were most severe, ranged from three to four weeks after emergence, yields generally continued to increase, as the length of the weed-free period increased (Dubey et al., 1977, Sharma et al., 1977 and Bhan et al., 1980b).

2.2.2 Effect of crop-weed competition on growth and yield in rice

Reduction in crop yield has a direct correlation with weed competition. In drought situation, weeds thrive better than crop plants. When left uncontrolled weeds can grow taller than crop plants and inhibit tillering.

Delayed weeding for about three weeks in case of direct seeded rice in puddled condition at ^{Cuttack} CRRI resulted in yield loss by 378 kg/ha. Similarly no weeding operation in direct seeded rice on dry soil resulted in total loss (Dubey et al., 1976).

At Bhubaneswar in upland direct sown rice, ^{the} yield reduction due to weed competition was about 69 per cent (Tosh, 1977). Moorthy and Dubey (1978) reported that maximum yield of 4.7 tonnes per ha was obtained with thorough hand weeding compared to 1.4 tonnes per ha under unweeded plots. The yield reduction was 42 per cent.

In direct seeded puddled rice the weed problem was very severe amounting to more than 35 per cent yield reduction (Pillai and Bhaskar Choudhary, 1978). Unweeded check produced the lowest yield of 2894 kg/ha compared to 4945 kg/ha obtained from the weed free plots. The reduction in yield was due to weed competition, which reduced the number of spikelets per panicle and 1000 seed weight (Kenchiah et al., 1980).

Babu and Singh (1985) reported that weedy condition caused 85.8 per cent reduction in grain yield as compared to weed free treatment. Uncontrolled weeds reduced the yield of rice by 80.97 per cent (Bhan et al., 1985).

2.2.3 Competition for nutrients

The weeds grow faster than crop plants and absorb nutrients earlier, with the result there may be a deficit of nutrients for the crop plants. Mukhopadhyay et al. (1972) reported that severe weed infestation removed upto 30.4-37.1 kg N/ha from the soil reducing the rice yield by 74-78 per cent. A very large share of plant nutrients in direct sown rice was taken up by weeds (Shetty and Gill, 1975).

Kaushik and Mani (1977) reported that the nutrient depletion by weed growth in the unweeded check amounted to 24:7, 5.8 and 63.4 kg/ha of N, P and K respectively.

Govindra Singh et al. (1983) reported that in drilled rice under upland conditions uncontrolled weeds during the entire crop season removed 107.5 kg N, 66.8 kg P_2O_5 and 58.8 kg K_2O per hectare. Echinochloa colanum was the dominating weed which removed 50 kg N/ha at 60 days stage. The total uptake of N, P and K by the crop in weedy and weed free condition was 13.5 and 8.8, 4.7 and 125.2, 45.7 and 99.5 kg/ha respectively.

Mahatim Singh et al. (1983) reported that in upland rice increasing levels of nitrogen (0, 40, 80 and 120 kg N/ha) increased weed population and their dry matter production with stipulated depletion of nitrogen by weeds.

2.2.4 Competition for moisture

Weeds which generally sprout in the field cause a heavy loss of moisture. Each plant could be considered as a pump which would pump out the otherwise unaffected and deep seated moisture into the surrounding atmosphere which goes as a waste. Weed competition for water is more serious for upland and rainfed rice than for irrigated rice because moisture is often a limiting factor.

Nijhawan (1944) reported that it was possible to save 300 to 500 tonnes of water by eliminating weed competition which is equivalent to 8.5 cm to 12.5 cm of

rainfall and this could be sufficient to produce about 500 to 1000 lb. of a crop. It is worth mentioning at this stage that weed competition for moisture is normally seen only under water scarcity conditions or rainfed conditions.

Robbins et al. (1958) reported that the water requirement of Amaranthus sp., was three times more than that of millets. Arakeri et al. (1962) inferred that moisture lost by transpiration of weeds is often much greater than that lost by transpiration through crop.

Thus, the weeds on account of their competitive ability, owing to evolution of several morphological characters like deep root system, are able to draw moisture from the soils and utilize the same for their growth at the expense of the crop plants. This phenomenon results in a considerable loss of the much needed water, a vital element for the growth and survival of plant species.

2.2.5 Competition for light

Competition for light could be visualised under those situations, where moisture and nutrients are available in plenty (Stahler, 1941). Under these situations crops and weeds would be growing simultaneously, but weeds owing to their faster development rate, would outgrow the crop

plants in a short span of time and thus shade the crop plants depriving them of the much needed solar energy.

A study at the International Rice Research Institute, Philippines (Anon., 1967) have indicated that compared to pure stand of rice the plots with rice plus Echinochloa crusgalli had 40 per cent lower light transmission ratio.

Okafor and De Datta (1976) reported that purple nut sedge competition reduced the light transmission ratio in upland rice. This reduction was proportional to the increase in purple nut sedge population density and reductions were greater at higher nitrogen levels.

2.3 Methods of weed control

There are various methods to control weeds in drilled rice but none can be said as the best because each has its own merits and demerits. The final choice of any weed control method will depend largely on effectiveness and economics.

2.3.1 Mechanical methods

Mechanical or physical methods of weed control are being employed ever since man began to grow crops. Many agricultural practices are dictated by the need for weed

control. Although herbicides are fast replacing the traditional methods of weed control, mechanical methods are very much needed to make weed control more effective and economical. The mechanical methods include tillage, hoeing, hand weeding, digging, cheeling, sickling, mowing, burning, flooding etc.

Pande and Bhan (1964) concluded that ploughing with a mould board rather than a country plow resulted in better control of weeds and that plowing once with a mould board plough, followed by harrowing was the minimum cultivation necessary for efficient production of upland paddy. The local practice of one hoeing and weeding could give 65 per cent control (Misra and Roy, 1971).

Rotary weeding and dichloromate did not show encouraging effects on weed control and gave significantly lower yield as compared to hand weeding (Dubey, 1976).

Rangaiah et al. (1976) reported that hand weeding and employing rotary weeder recorded the maximum yield when compared to the herbicides , butachlor, propanil and 2,4-D which were in turn better than unweeded check. Hand weeding proved to be the most effective method in controlling weeds when compared to chemical and mechanical methods during kharif (Ghosh et al., 1977).

Kaushik and Mani (1978) found that hand weeding treatments gave most effective weed control followed by propanil. Among the weed control treatments, manual weeding was the best to increase the fertilizer use efficiency. Dry weight of weeds was only 3.2 q/ha in hand weeded treatment as against 20.3 q/ha in no weeding. Manual weeding resulted in 44 per cent increase in rice yield compared with no weeding (Rami Reddy et al., 1980).

Unchecked competition between weeds and rice throughout the growing period caused maximum reduction in grain yield. Two hand weedings^{at} 20 and 40 days after sowing had the maximum grain yield followed by pre-emergence application of butachlor (Singh and Gopal Reddy, 1980). Biswas and Thakur (1983) reported that in direct seeded upland rice, hand weeding controlled weeds best followed by 2,4-D, propanil and butachlor which were sprayed 6 days after sowing.

Grain yields were increased as number of hand weedings increased. The best yield (4.1 t/ha) was obtained from three to four weedings carried out at 15, 30, 45 and 60 days after rice emergence (George and Ghobrial, 1981).

Hand weeding twice recorded the lowest^w dry weight with highest weed control efficiency and highest grain yield (96.34 q/ha). However, the use of herbicides butachlor

and thiobencarb at the rate of 2 kg a.i./ha were found better over their lower doses (Chandrashekar et al., 1985).

Govindra Singh et al. (1985) reported that single weeding done either at 15, 30, 45 or 60 days after sowing could not provide desired level of weed control. Three weedings (15, 30 and 45 DAS) or four weedings (15, 30, 45 and 60 DAS) could minimize the crop weed competition and produce grain yields at par with that of weed free conditions

2.3.2 Chemical method

The potential use of herbicide would be to delay weed growth or to check its growth during cropping season (Ogborn, 1969). Because of the high labour requirement for hand weeding, high wages and unfavourable weather conditions at weeding, herbicides in dry seeded rice are gaining importance in areas where they have not previously been used.

Results of the recent experiments at IRRI, however indicated that chemical weed control in upland rice is not only a possibility but is effective and economical (De Datta et al., 1974). The herbicides looked promising were butachlor, flurodifen, benthocarb, butralin, Oxadiazon, AC 92555, dinitramine and the combination herbicide C-288.

These herbicides were effective when used at the rate of 2 kg/ha active ingredient and sprayed before the weeds emerged (De Datta and Bernasor, 1975). As the total labour requirement for a single hand weeding range from 300 to 700 man hours/day, the use of herbicides could result in considerable savings to the farmer (Sharma et al., 1977).

2.3.2.1 2,4-D and related compounds

2,4-D and MCPA have been tried, but the chemicals did not prove effective because most of the upland rice in India are mainly infested by grasses which are resistant to 2,4-D group of herbicides (Mukhopadhyay and Baig, 1967).

The post-emergence application of sodium MCPA and sodium 2,4-D at both the rates (1.25 and 2.5 kg/ha) brought significant reduction in dry matter production of weeds. Cyperus iria constituted the major weed population and it proved highly susceptible to the toxic effect of herbicides. The grassy weeds like Panicum sp., Paspalum sanguinalis and Dactyloctenium aegyptium showed resistance to the effect of the chemicals (Pande et al., 1966).

Kaushik and Mani (1980) reported that MCPB and butachlor proved superior to unweeded check plus 3 per cent urea but these herbicides did not control weeds as effectively as hand weeding. A low dose of MCPB (0.4 kg/ha)

combined with 3 per cent urea proved as effective as a higher dose of 1.00 kg/ha so far as productivity is concerned.

Singh and Singh (1983) reported that in direct seeded rice, the maximum dry matter accumulation by weeds (142.92 g/m^2) was obtained in unweeded control and minimum (25.16 g/m^2) under hand weeded plot followed by 2,4-D (EE) as pre-emergence and propanil as post-emergence (38.22 g/m^2).

2.3.2.2 Butachlor

Butachlor controls annual grasses and some broad leaved weeds in transplant and direct seeded rice. It is applied as pre-emergence in EC formulations and as post-emergence in the form of granules.

Ghosh et al. (1977) reported that alachlor and butachlor at 2.5 kg/ha pre-emergence proved equally effective and were superior to propanil (2.5 l/ha) post-emergence.

The experimental results shown that use of herbicides was convenient, handy and more speedy and effective. Machete (5% granules) has been recommended for control of weeds in rice (Gill and Brar, 1975). Gopalakrishna Pillai (1977a) opined that choice of herbicides limited to butachlor and propanil and they were not completely effective

in controlling the entire weed flora under heavily weed infested conditions.

Babu and Sankaran (1977) reported that maximum yield was obtained in Penoxalin (5370 kg/ha) followed by butachlor 5307 kg/ha). The unweeded check gave the lowest yield (2210 kg/ha). Singh et al. (1983) reported that in rainfed direct seeded rice yield reduction due to weed competition ranged from 47 to 60 per cent under dry land conditions of Varanasi. The most effective herbicide evaluated was a pre-emergence application of butachlor 2.5 kg a.i./ha.

2.3.2.3 Pendimethalin

Stomp (Pendimethalin) was found to be effective in controlling grasses, sedges and broad leaved weeds as compared to butachlor, benthocarb, C-288 and propanil (Mohamed Ali and Sankaran, 1975) and further, Ali and Sankaran (1984) reported that application of Pendimethalin (0.75 kg/ha) 8 days after seeding produced better yields than other herbicides for rainfed bunded rice in summer.

2.3.2.4 Oxyflurofen

Gidnavar (1981) reported that oxyflurofen was effective on perennial weed Cyperus iria at 0.4 kg a.i./ha. The grain

yield of paddy was highest (2275 kg/ha) in oxyflurofen which was followed by weed free check (2255 kg/ha).

The results of the experiment at Ranchi, showed that pre-emergence application of Oxyflurofen (0.1 kg a.i./ha) one day after sowing effectively controlled the weeds in upland rice fields and it recorded the lowest dry weight of weeds, highest number of panicles per meter square and finally produced highest grain yield among other chemicals and cultural treatments (Ghosh and Singh, 1985).

2.3.2.5 Oxadiazon

Oxadiazon at 1 kg, AC-92553 (Penoxalin) 2 kg, and USB-3854 (dinicramine) 2 kg/ha were highly selective in controlling the grasses, sedges and broad leaved weeds with no adverse effect on germination and no sustained injury to the crop (Tosh, 1975).

Tosh and Nanda (1985) reported that maximum mortality of weeds and maximum grain yield was obtained in treatment where herbicide (Oxadiazon @ 0.75 kg/ha - 3 DAS) was supplemented with bushening operation in time (30 DAS). Bisen and Tiwari (1985) found that none of the herbicide controlled all the weed species of rice fields. Two hand weedings can be substituted by pre-emergence application of oxadiazon plus one hand weeding 35 days after sowing.

2.3.2.6 Thiobencarb (Benthocarb)

Similar to butachlor, thiobencarb is highly effective against most annual grasses, broad leaved weeds and sedges.

At Bhubaneswar, application of benthocarb (liquid) in two splits at the rate of 1.5 kg a.i./ha each after three and 20 days of rice germination proved to be as efficient as weed free check (Anon., 1975).

Dubey (1975) reported that butachlor (1.5 kg/ha) gave significantly higher yield (3928 kg/ha) than hand weeded plot (3282 kg/ha) while benthocarb (1.5 kg/ha) and C-288 (1.00 kg/ha) gave yields at par with hand weeded plots.

Experiments conducted on upland rice crop at ICAR Research Complex Farm, Barapani (Meghalaya), benthocarb at the rate of 1.5 kg a.i./ha as pre-emergence controlled the weeds quite effectively over hand weeding (Jay Varsheny, 1985).

Singh and Singh (1985) reported that pre-emergence application of thiobencarb 1.5 kg a.i./ha with post-emergence application of propanil 1.5 kg a.i./ha resulted in maximum nitrogen uptake^{by crop} and minimum nitrogen drain by weeds throughout the crop growth stages. Amongst the herbicides,

thiobencarb 1.5 kg a.i./ha as pre-emergence was found most effective in minimising the depletion by weeds and maximizing the uptake of nitrogen by plant. Post-emergence application of thiobencarb was not as effective as its pre-emergence applications.

2.3.2.7 Limitation of herbicides

(Due to toxic nature of the herbicides, correct dosage and time of application is necessary. At times herbicides can cause phytotoxic effects on the desired vegetation. Some times herbicides may not give desired level of weed control due to their activity which is only for short duration/

Rao et al. (1976) observed severe toxicity to rice seedlings on the 14th day in herbicide sprayed plots. The extent of toxicity to rice was 86 - 90 per cent with dinitramine at 1.5 - 2 kg, 87-88 per cent with butachlor (2-3 kg), 79-91 per cent with C-288 (1.5-2 kg), 66-89 per cent with thiobencarb 2-3 kg and 39-62 per cent with fluchloralin at 1.5-2.5 kg/ha.

(Results of the experiment showed that oxadiazon and butachlor effectively controlled the annual weeds but they caused about five per cent mortality to the rice seedlings) (Mohamad Ali et al., 1977). Pillai et al. (1980)

reported that application of oxyflurofen caused some toxicity on leaves but after a week the crop recovered.

Application of butachlor and oxadiazon increased significantly the grain yield of rice over weedy check but was significantly less than that obtained under weed free check. The gap between weed free (obtained by mechanical weeding) check and weed control by herbicide is very wide (Bhan et al., 1980). This clearly demonstrated the limitation of herbicides, especially the pre-emergence group, which had activity only for a short duration.

(Benthiocarb plus 2,4-D isopropyl ester (1.0 + 0.5 kg/ha) butachlor 1.00 kg/ha and 2,4-D alone 0.5 kg/ha applied 10 days after sowing significantly reduced the plant population and plant height in the initial stages due to phytotoxicity (Pillai and Ghosh, 1980).

Moorthy and Dubey (1981) reported that in upland rainfed rice majority of pre-emergence herbicides showed phytotoxicity on crop due to rainfall-herbicide interactions. Highest phytotoxicity was shown by oxadiazon at 1 kg a.i./ha.)

2.3.3 Integrated methods of weed control

(It is opined that at present, we may have to resort mainly to an integrated approach of weed control in rice, involving cultural practices in combination with some

chemicals. A sudden switch over from hand weeding to chemical weed control may not be the answer to alleviate the weed problem in rice culture.'

(Since herbicides are costly and not easily available weed control may be a possibility only in those areas where cost-benefit ratio is in favour of herbicide. Management of weeds^{by} adopting suitable cropping patterns, cultural practices, and herbicides application to the extent possible, should be a better approach to meet the future challenges in weed control for rice)(Gopalakrishna Pillai, 1977b).

Gurmel Singh and Chauhan (1977) found that weeds could be effectively controlled in upland rice with the application of butachlor granules at 2 kg/ha plus one hand weeding (3155 kg/ha) and propanil at 1.4 kg/ha plus one hand weeding (2852 kg/ha) as compared to control (1014 kg/ha). Net returns obtained with the help of chemicals were comparable with hand weeding. ✓

Bhan et al. (1983) reported that in direct seeded upland rice, pre-emergence application of thiobencarb and Pendimethalin with one hand weeding 30 days after sowing, reduced density and dry matter production of weeds and increased grain yields significantly higher than when the herbicides were used alone. ✓

The transplanted crop significantly out yielded (41.0 q/ha) the direct seeded one (4.5 q/ha) but when the weeds were controlled either through repeated hand weedings or spraying butachlor at 1 kg/ha as pre-emergence supplemented with one hand weeding at 20-25 days after seeding, the wet land direct seeded crop either broadcast or drilled registered the grain yield on par with the transplanted crop (Singh et al., 1985).

2.4 Economics of weed control

(The final choice of any weed control method depends to a greater extent on the cost of the herbicides and their relative efficacy)

(Singh and Khan (1972) reported that 2,4-D sodium salt 1 kg/ha one week before sowing followed by one hoeing four weeks after sowing gave the highest grain and straw yields and net returns) Sankaran (1977) reported that in rice var. IR-20 butachlor at 2 kg/ha gave an additional income of Rs. 420 per hectare over conventional method.

A net return of Rs. 3100 per hectare was desired from the application of machete alone, followed by machete supplemented by a hand weeding (Rs. 2975 per ha.)(Rajaram et al., 1978).

Nanja Reddy and Ramanna (1978) reported that the use of the chemical (combined with some hand weeding) was Rs.195

per hectare while the cost of weeding purely by manual labour was Rs. 253 per hectare. Besides there was an increase in the yield of rice of 117 kg per hectare, in the plots where weedicides were used. The analysis indicated that there was a net benefit of Rs. 321 per hectare due to the use of herbicides.)

(From this brief review it can be concluded that weeds pose greater problem under direct seeded upland rice. The yield loss in direct seeded rice is very large and it varies to a greater extent depending on the type of weed flora, intensity of weeds and management level. The available information also indicate that weed competition during the first four to six weeks of sowing is critical. / Although chemical weed control seems to be cheaper and effective, the overall economics of this practice does not justify its general adoption by farmers, except in areas where the labour is costly and scarce during peak periods of farm operation. At present, management of weeds by adopting suitable cropping patterns, cultural practices and herbicide application to the extent possible, may be a better approach in managing weed problem under dry seeded rice cultivation.)

With this background, a field study was conducted to find out the relative effectiveness of some herbicides, cultural practices and integrated weed management in drill sown rice.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

The materials used and techniques adopted during the course of this investigations are described in detail in this chapter.

3.1 General description

3.1.1 Location

The experiment was conducted at the wet land, Main Research Station, University of Agricultural Sciences, Hebbal, Bangalore, during the kharif season of 1985.

3.1.2 Soil

Composite samples of soil collected from 0-15 cm depth were analysed for textural classification and chemical properties (Table 1). The soil of the experimental site was sandy clay and neutral in reaction (pH 6.69). The soil was low in available nitrogen (219.73 kg/ha), medium in available phosphorus (21.93 kg/ha) and high in available potassium (340.96 kg/ha). The electrical conductivity (0.21 mmhos/cm) was normal. The top soil had 22.10 per cent of coarse sand, 34.20 per cent of fine sand, 8.19 per cent of silt and 34.35 per cent of clay.

Table 1. The physical and chemical properties of the soil at the experimental site.

Particulars	Values	Remarks	Methods followed
<u>Physical properties</u>			
<u>Mechanical composition</u>			
i) Coarse sand (%)	22.10	Sandy clay	International pipette method (Piper, 1966)
ii) Fine sand (%)	34.20		
iii) Silt (%)	8.19		
iv) Clay (%)	34.35		
<u>Physics - chemical properties</u>			
i) Redox potential (Eh) mv	-195	Reduced	Potentiometry (Jackson, 1973)
ii) Soil reaction (pH)	6.69	Neutral	Potentiometry (Jackson, 1973)
iii) Electrical conductivity (EC) (mmhos/cm)	0.21	Normal	Conductometry (Jackson, 1973)
<u>Chemical properties</u>			
i) Cation exchange capacity (m.eq/100g soil)	11.00	Low	Jackson (1973)
ii) Organic carbon (%)	0.52	Medium	Walkley and Black's method (Piper, 1966)
iii) Available nitrogen (kg/ha)	219.73	Low	Alkaline permanganate method (Jackson, 1973)
iv) Available phosphorus (kg/ha)	21.93	Medium	Olsen's method (Jackson, 1973)
v) Available potassium (kg/ha)	340.90	High	Flame photometry (Jackson, 1973)

3.2 Climatic conditions

The normal as well as actual weather data on total rainfall, temperature (maximum and minimum), relative humidity, daily bright sun shine hours and open pan evaporation per day that prevailed during the period of crop growth (June 1985 to November, 1985) are presented in Table 2 and 2a (Fig.1).

The Main Research Station, Hebbal is situated at a latitude of 12°58' North, longitude of 77°35' East and an altitude of 899 meters above the mean sea level. The average total rainfall of this station is 890.4 mm.

The total rainfall during the crop growth period was 469.6 mm and it was less by 175.5 mm from the normal for the period. The rainfall during the crop growth period was more than the normal in the months of July (+1.5 mm) and September (+11.1 mm), while it was less than the normal in the months of June (-31.74 mm), August (-93.7 mm), October (-58.7 mm) and November (-4.3 mm). The maximum temperatures were more than the normal in the months of August (+0.9°C), September (+1.0°C), October (+0.3°C) and November (+0.2°C) and were less in the month of June (-0.4°C) and July (-0.1°C). The minimum temperatures

Table 2. Meteorological data indicating mean monthly normal (1953-1984) and Actual (1985) for the crop growth period at the Main Research Station, Hebbal, Bangalore-24.

Months	Total rainfall (mm)			Temperature °C (Mean Max.)			Temperature °C (Mean Min.)		
	Normal	Actual	Deviation	Normal	Actual	Deviation	Normal	Actual	Deviation
June	61.4	30.0	-31.74	29.8	29.4	-0.4	19.9	20.0	+0.1
July	90.6	92.1	+ 1.5	28.5	28.4	-0.1	19.0	19.4	+0.4
August	112.7	19.0	-93.7	27.9	28.8	+0.9	18.9	19.6	+0.7
September	166.9	178.0	+11.1	28.0	29.0	+1.0	18.8	19.7	+0.9
October	151.8	93.1	-58.7	27.5	27.8	+0.3	18.5	18.0	-0.5
November	61.6	57.3	- 4.3	26.0	26.2	+0.2	15.7	15.2	-0.5
Total seasonal Rainfall	645.0	469.5	-175.5						
Months	Mean relative humidity (%)			Daily sunshine hours(hr)			Open pan evaporation (mm/day)		
	Normal	Actual	Deviation	Normal	Actual	Deviation	Normal	Actual	Deviation
June	70.7	70.5	- 0.2	6.2	5.8	- 0.4	6.7	5.6	- 1.1
July	74.9	76.0	+ 1.1	4.8	4.8	- 0.0	5.7	4.7	- 1.0
August	75.9	73.5	- 2.4	5.4	6.1	+ 0.7	5.2	4.7	- 0.5
September	74.9	75.0	- 0.1	6.0	6.9	+ 0.9	4.9	4.4	- 0.5
October	73.6	72.0	- 1.6	6.9	6.5	- 0.4	4.3	4.4	- 0.1
November	70.7	70.3	- 0.4	7.5	6.4	- 1.1	4.2	3.5	- 0.7

Table 2a. Daily rainfall during crop season for 1985 at Hebbal, Bangalore.

Month and date	Rainfall (mm)	Month and date	Rainfall (mm)	Month and date	Rainfall (mm)
June 1	0.2	August 1	3.0	September 24	3.7
3	0.3	6	0.5	26	3.2
5	14.5	10	2.4	27	1.8
7	7.5	11	1.0	28	0.3
23	1.8	12	3.4	29	26.0
27	3.7	14	1.8	30	34.0
28	2.0	15	1.8	Total	178.0
Total	30.0	16	1.1		
		17	1.9	October 1	3.1
July 5	6.0	18	0.5	3	5.0
6	3.0	22	1.6	5	11.2
10	0.5	Total	19.0	6	0.3
14	28.0			7	6.6
22	4.0	September 3	0.2	10	34.5
23	1.0	5	7.0	11	8.1
24	7.2	6	8.5	14	9.1
25	12.5	7	6.2	19	15.2
27	12.0	10	36.0	Total	93.1
28	12.0	12	0.6		
30	0.4	16	6.5	November 5	27.8
Total	92.1	19	44.0	6	0.8
				7	4.0
				8	6.5
				9	18.2
				Total	57.3

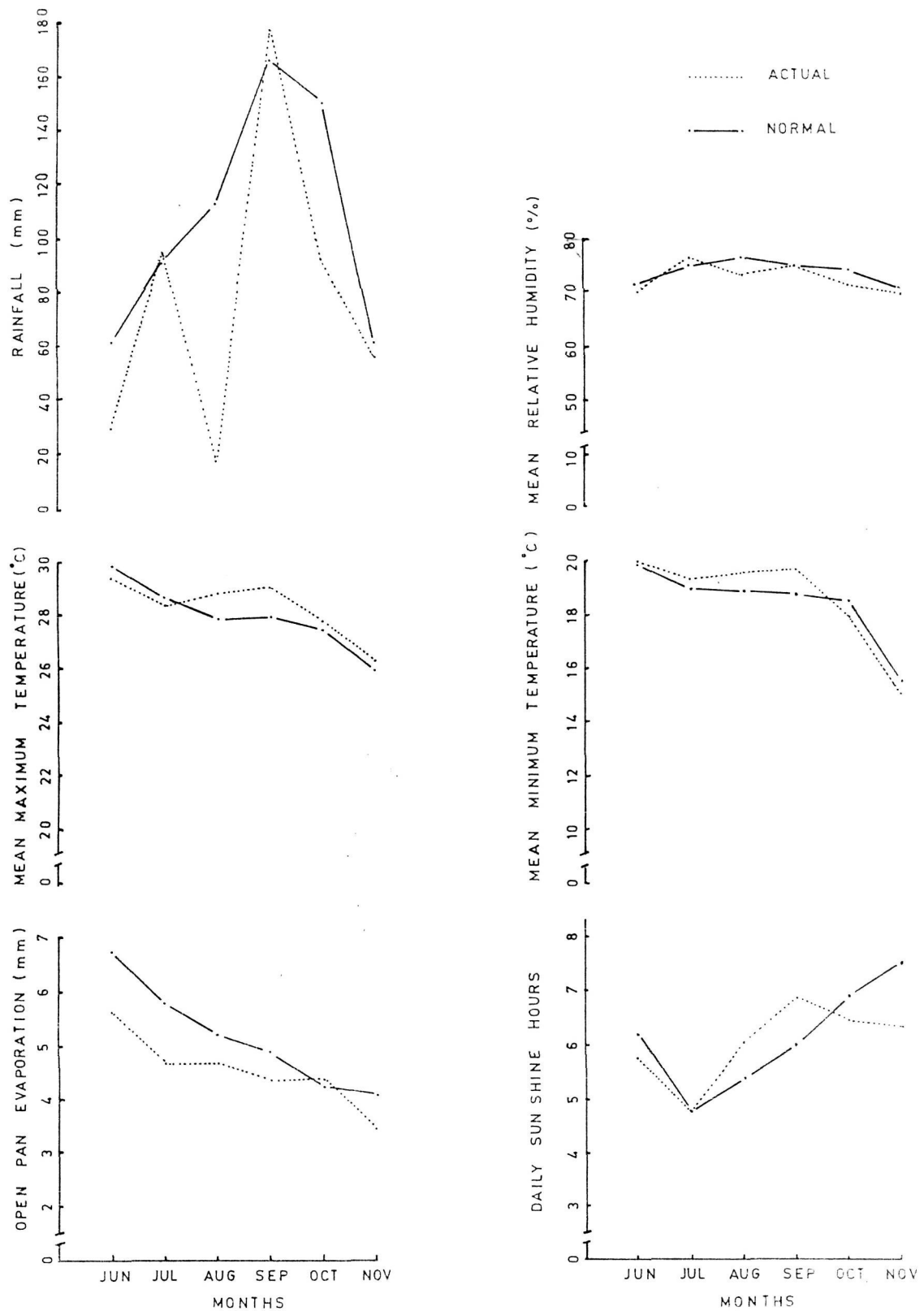


FIG.1. NORMAL (1953 - 84) AND ACTUAL (1985) MEAN MONTHLY METEOROLOGICAL DATA FOR THE CROP GROWTH PERIOD AT THE MAIN RESEARCH STATION, HEBBAL.

were more than the normal in the months of June (+0.1°C), July (+0.4°C), August (+0.7°C) and September (+0.9°C) and were less in October and November (-0.5°C). Mean relative humidity was less than the normal in all the months by 0.1 to 2.4 per cent except in July (+1.1 per cent). The daily sunshine hours were more in August (0.7 hours) and September (+0.9 hours) and it varied from 4.8 to 6.9 hours/day. Open pan evaporation was less in all the months by 0.1 mm/day in October to 1.1 mm/day in July and it varied from 3.5 to 5.6 mm/day during the crop growth period.

3.3 Cropping history of the experimental site

The crop grown during kharif 1983 was paddy and in 1984 was also paddy.

3.4 Experimental details

3.4.1 Treatments

Five pre-emergence and one post emergence herbicides at two doses were used. The lower dose of herbicide was 75 per cent of higher dose in four chemicals and 50 per cent of higher dose in one chemical. In case of lower dose treatment, one hand weeding was given 45 days after sowing. These herbicidal and integrated treatments were compared with two hand weedings and unweeded control.

Treatment details

- T₁ : 2,4-D 1.00 kg a.i./ha as post-emergence spray
25 days after sowing.
- T₂ : 2,4-D 0.75 kg a.i./ha as post-emergence spray 25
days after sowing followed by one hand weeding
45 days after sowing.
- T₃ : Butachlor 1.00 kg a.i./ha as pre-emergence spray.
- T₄ : Butachlor 0.75 kg a.i./ha as pre-emergence spray
followed by one hand weeding 45 days after sowing.
- T₅ : Pendimethalin 1.00 kg a.i./ha as pre-emergence spray.
- T₆ : Pendimethalin 0.75 kg a.i./ha as pre-emergence spray
followed by one hand weeding 45 days after sowing.
- T₇ : Oxyflurofen 0.5 kg a.i./ha as pre-emergence spray.
- T₈ : Oxyflurofen 0.25 kg a.i./ha as pre-emergence spray
followed by one hand weeding 45 days after sowing.
- T₉ : Oxadiazon 1.00 kg a.i./ha as pre-emergence spray.
- T₁₀ : Oxadiazon 0.75 kg a.i./ha as pre-emergence spray
followed by one hand weeding 45 days after sowing.
- T₁₁ : Benthocarb 1.00 kg a.i./ha as pre-emergence spray.
- T₁₂ : Benthocarb 0.75 kg a.i./ha as pre-emergence followed
by one hand weeding 45 days after sowing.
- T₁₃ : Hand weeding once at 45 days after sowing.
- T₁₄ : Hand weeding twice at 20 and 45 days after sowing.
- T₁₅ : Unweeded control.

3.4.2 Design and Layout

The experiment was laidout in Randomised Complete

Block Design with three replications. The plan of layout of the experiment is given in Fig.2.

3.4.3 Plot size

Gross plot size : 5.00 m x 2.50m = 12.5 m²

Net plot size : 4.90m x 1.80m = 8.82 m²

3.4.4 Variety

Jaya rice variety (155 days) was used.

3.4.5 Herbicides used

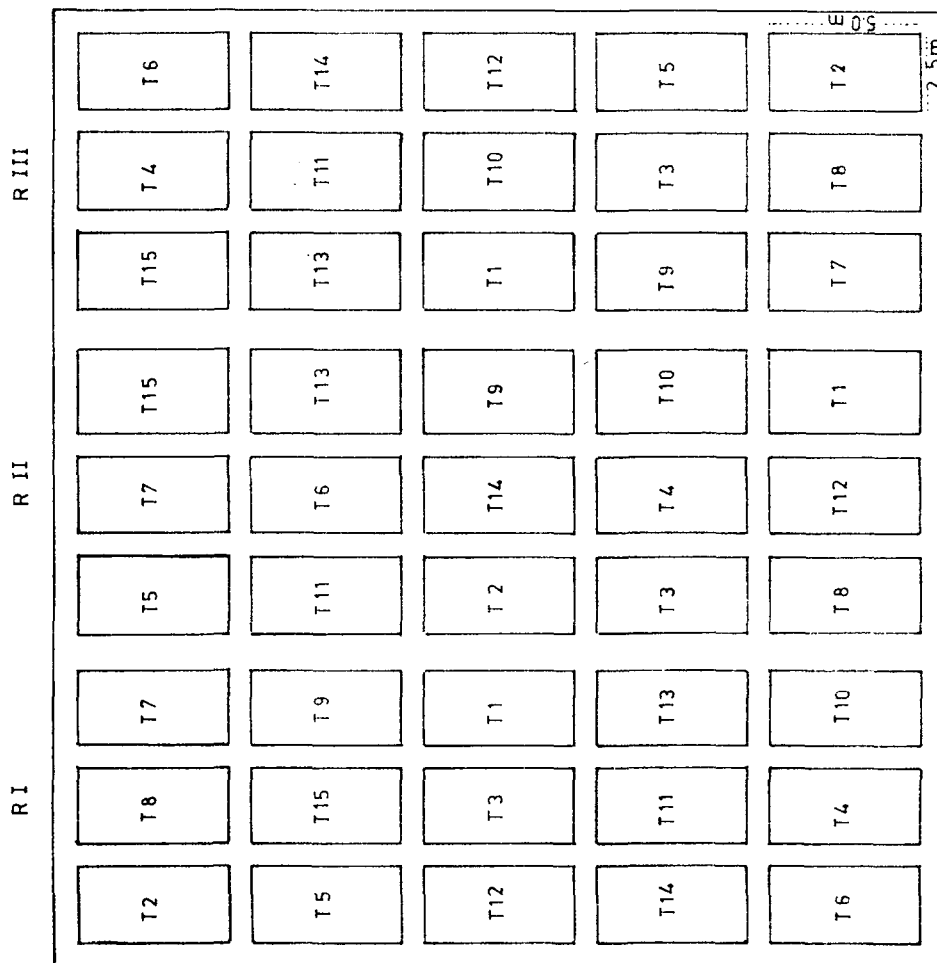
3.4.5.1 2,4-D sodium salt (80%)

This is a salt of 2,4-dichlorophenoxy acetic acid and belongs to phenoxy acid groups. This is used as post-emergence herbicide against sedges and broad leaf weeds in wheat, maize, rice, sorghum and other cereals and sugarcane.

3.4.5.2 Butachlor (Machete) 50% EC

It belongs to acetamide group. The chemical name is N-(butoxymethyl)-2-chloro-2',6'-diethylacetanilide. It controls most annual grasses and some broad leaf weed in transplanted and direct sown rice. It is applied as pre-emergence spray can also be applied as post-emergence in the form of granule.

N ←



LEGEND

- T1 - 2,4-D 1.00 Kg ai./ ha 25 DAS
- T2 - 2,4-D 0.75 Kg ai./ ha 25 DAS + 1 HW 45 DAS
- T3 - BUTACHLOR 1.0 Kg ai./ ha pre-em.
- T4 - BUTACHLOR 0.75 Kg ai./ ha pre-em + 1 HW 45 DAS
- T5 - PENDIMETHALIN 1.00 Kg ai./ ha pre-em
- T6 - PENDIMETHALIN 0.75 Kg ai./ ha pre-em + 1 HW 45 DAS
- T7 - OXYFLUROFEN 0.50 Kg ai./ ha pre-em
- T8 - OXYFLUROFEN 0.25 Kg ai./ ha pre-em + 1 HW 45 DAS
- T9 - OXADIAZON 1.00 Kg ai./ ha pre-em
- T10 - OXADIAZON 0.75 Kg ai./ ha pre-em + 1 HW 45 DAS
- T11 - BENTHIOCARB 1.00 Kg ai./ ha pre-em
- T12 - BENTHIOCARB 0.75 Kg ai./ ha pre-em + 1 HW 45 DAS
- T13 - HAND WEEDING ONCE AT 45 DAYS AFTER SOWING
- T14 - HAND WEEDING TWICE AT 20 AND 45 DAYS AFTER SOWING
- T15 - UNWEEDDED CONTROL

FIG. 2. PLAN OF LAYOUT

3.4.5.3 Pendimethalin (Stomp) 30% EC

It belongs to dinitroaniline group. The chemical formula is N-(1-ethyl propyl)-3, 4-dimethyl-2, 6-dinitro-benzenamine. It is used mainly for the control of annual grasses and broad-leaf weeds in corn, cotton, soybean, tobacco, and rice. It is used as pre-emergence and also applied as a pre-plant soil incorporation treatment.

3.4.5.4 Oxyfluorfen (Goal) 24% EC

This chemical belongs to diphenyl ether group. The chemical name of this herbicide is 2-chloro-1-(3 ethoxy-4-nitrophenoxy)-4-(trifluoromethyl) benzene. It is used in soybean, groundnut, rice, tea, rubber and oil-palm as a selective pre-emergence herbicide.

3.4.5.5 Oxadiazon (Ronstar) 25% EC

The chemical name of this herbicide is 2-tert-butyl-4-(2,4-dichloro-5-isopropoxy phenyl)-1,3,4-oxadiazolin-5-one. It is primarily a pre-emergence herbicide, although it shows some post-emergence activity. It is used for the control of weeds in rice, cotton, sugarcane, soybean and groundnut.

3.4.5.6 Thiobencarb (Saturn) 50% EC

It belongs to thiocarbamate group. The chemical name is S-(4-chlorobenzyl) N, N-diethyl-thiocarbamate. Benthiocarb is a pre-emergence and early post-emergence herbicide

used in rice for control of many annual and broad leaf weeds. It can also control aquatic weeds in rice and very safe to rice.

3.5 Cultural practices

3.5.1 Land preparation

The land was ploughed with bullock drawn mould board plough and brought to good tilth condition by passing cultivator. The experimental area was laid out as per the plan with **bunds** on four sides of each plot. The plots were dug manually, weeds were removed and finally plots were levelled.

3.5.2 Fertilizer application

At the time of sowing 50 kg N, 50 kg P_2O_5 and 50 kg K_2O per hectare were broadcasted and mixed well before sowing. Top dressing with remaining 50 kg N in the form of urea was done when the crop was 40 days old. N, P_2O_5 and K_2O were applied in the form of urea, super phosphate and muriate of potash respectively.

3.5.3 Seeds and sowing

Certified seeds of Jaya variety were used at the rate of 120 kg/ha. The furrows were opened manually with the help of Guddali. The seeds were dropped in furrows manually

and seed rows were covered with the soil. The crop was sown on 9th June 1985.

3.5.4 Pre-emergence spraying of herbicides

One day after the sowing, the herbicides were sprayed with the help of hand operated Knap sac sprayer. Spray volume used was 1000 l/ha.

3.5.5 Post-emergence spraying of herbicide

Post-emergence spraying of herbicides was done 25 days after sowing (5th July 1985). Here also ^a spray volume of 1000 litres per hectare was used.

3.5.6 Irrigation

For the first two months, the crop was irrigated whenever there was deficit of moisture in the soil. After two months the soil was maintained at saturated condition. Subsequently flooding was done.

3.5.7 After care

In treatments T₂, T₄, T₆, T₈, T₁₀, T₁₂ and T₁₃ hand weeding was done 45 days after sowing. In treatment T₁₄ where two hand weedings were included, weeding was done at 20 and 45 days after sowing.

When the crop was 38 days old, Hinoson 50 per cent W/W was sprayed for the control of blast disease. Metasystox, a syscamic insecticide spraying was taken when the crop was 50 days old for the control of Hispa and other sucking insects.

3.5.8 Harvesting

The crop was harvested on 21st November 1985. All the border rows were harvested first. In the net plot the crop was harvested separately, and threshed separately. Grains were sun dried for five days and weight was recorded separately for each plot. Straw from net plot was also sun dried for five days and dry weight was recorded.

3.6 Biometric observations

In the net plot one square meter area was fixed and observations on weed count were recorded at different growth stages. For dry matter studies of both crop and weeds, destructive sampling area was utilized. Three spots of 0.5 meter row length were fixed in the net plot and they were used for tiller count during different growth stages. At the time of harvest, in the net plot, grain yield, and straw yield, yield component observations and dry weight of weeds were recorded.

3.6.1 Observations on crop growth

3.6.1.1 Total number of shoots in 0.5 meter row length

Total number of shoots in fixed 0.5 meter row length was recorded at 30, 60 and 90 days after sowing and at harvest.

3.6.1.2 Dry matter production

Dry matter production of crop in 0.25 m^2 area was recorded at 30, 60 and 90 days after sowing and at harvest.

3.6.1.3 Plant height

Plant height(cm) was recorded at 60 and 90 days after sowing and at harvest.

3.6.2 Observations on weed growth

3.6.2.1 Weed control and crop toxicity ratings

Visual ratings were made at 30, 40 and 90 days after sowing and at harvest to determine the extent of weed control and at 30, 40 and 50 days after sowing to know the extent of toxicity caused by different herbicides on crop employing EWRC ratings.

The crop toxicity ratings (EWRC system) made from 0 to 10 point scale as follows:

<u>Score</u>	<u>Phytotoxicity symptoms</u>
1	No symptoms/healthy plants.
2	Very mild symptoms, slight stunting.
3	Mild but clearly recognizable symptoms.
4	More severe symptoms (e.g. chlorosis) not necessarily with negative effect on yield.
5	Thinning out, heavy chlorosis or stunting reduction in the yield to be expected.
6	Heavy damage to total kill.
7	
8	
9	
10	

The weed control ratings were made from 0 to 10 point scale as follows:

<u>Score</u>	<u>Per cent activity</u>
1	100
2	99.9 - 98.0
3	97.9 - 95.0
4	94.9 - 90.0
5	89.9 - 82.0
6	81.9 - 70.0
7	69.5 - 55.0
8	54.9 - 30.0
9	29.9 - 0.00
10	0.00

3.6.2.2 Weed count

Observations on monocot, dicot and total weed population were recorded from permanently fixed one square meter area in the net plot at 30, 45, 60 and 90 days after sowing and at harvest.

3.6.2.3 Dry matter production of weeds

Dry matter production of weeds was recorded from 0.25 m² area at 30, 60 and 90 days after sowing and at harvest. In the destructive sampling area weeds were removed from 0.25 m² area, oven dried at 80°C and dry weight was recorded.

At the time of harvest, dry matter production of weeds per plot was recorded. From the net plot weeds were removed, sun dried for eight days and dry weight was recorded and it was converted to hectare basis.

3.6.2.4 Weed Index

Weed index was worked out by following the procedure given by Gill and Vijayakumar (1969).

3.6.3 Observations on yield and yield components

3.6.3.1 Grain yield

Leaving the border rows, the crop from the net plot was harvested and threshed. The grains were cleaned, dried

in sun for five days and weight was recorded in q/ha.

3.6.3.2 Straw yield

After threshing the crop from the net plot, the straw was dried in sun for seven days and dry weight was recorded in q/ha.

3.6.3.3 Total number of productive shoots in 0.5 meter row length

Total number of productive shoots in 0.5 meter row length was recorded at the harvest of crop. From three different spots of 0.5 meter row length in the net plot the total number of productive shoots were recorded.

3.6.3.4 Total number of unproductive shoots in 0.5 meter row length

From the three spots of 0.5 meter row length, where productive shoots were recorded, the total number of unproductive shoots were also recorded.

3.6.3.5 Panicle length

At harvest, 10 panicles were randomly selected from net plot and average length was recorded in cm.

3.6.3.6 Total number of grains per panicle

At harvest, 10 panicles were randomly selected from the net plot and average total number of grains were counted.

3.6.3.7 Total number of developed grains per panicle

From the 10 panicles where average total number of grains were counted, average number of developed and undeveloped grains were also counted.

3.6.3.8 Sterility percentage

After counting the total number of grains and total number of undeveloped grains, the sterility percentage was worked out.

$$\text{Sterility percentage} = \frac{\text{Total number of undeveloped grains}}{\text{Total number of grains}} \times 100$$

3.6.3.9 Thousand grain weight

A sample was drawn from net plot yield, thousand grains were counted and weight was recorded in g.

3.7 Economics of weed control treatments

To study the economics of different weed control treatments, observations on market prices of herbicides, time taken for herbicidal spray and labour units required

for spraying and hand weeding were recorded. Cost of labour was calculated taking into account the prevailing labour wages at the time of investigation at Rs. 7=50 per Woman and Rs. 8=50 per Man. Gross return from grain and straw yield was calculated. Net returns were calculated by using the following formulae:

$$\text{Net returns} = \text{Gross returns} - \text{Cost of production}$$

3.8 Statistical analysis of data

Data were subjected to the statistical analysis. The analysis of variance was used wherever the nature of the data permitted its usage of the same directly. However, wherever the data showed high variation, they were transformed ($\sqrt{x + 0.5}$) and later the analysis of variance was used (Panse and Sukhatme, 1967). The results are presented with the level of significance of 0.05.

The correlation coefficients were also worked out for grain yield verses weed weight at harvest, number of productive tillers, number of unproductive tillers, length of the panicle, test weight and sterility percentage and have been tested at 5 per cent level of significance.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The results of the field experiment conducted during kharif season of 1985 are presented in this chapter.

4.1 Weeds observed in the experimental field

The important weed species observed in the experimental field were Echinochloa crusgalli (L.) Beauv., Echinochloa colanum (L) Link., Dinebra retroflexa (Vahl) Panz., Panicum repens L., Paspalum conjugatum Berg., Digitaria longiflora (Retz.) Pers. and Cynodon dactylon(L.) Pers., among the monocots. Among sedges Cyperus iria and among dicots Eclipta alba L. Hassk, Portulaca oleracea L., and Spilanthes calva DC. were the predominant weeds. These weeds are described below.

4.1.1 Echinochloa crusgalli (L.) Beauv.

Family : Poaceae

It is a major weed in rice and many field and horticultural crops. It emerges before or along with the crops and during the first several weeks it usually outgrows crop plants rapidly. It grows to a height of 30 to 120 cm with thick, coarse, mostly erect, smooth, and branching at the base (Plate 1). The plant has sessile leaf blades attached to a smooth sheath which

Plate 1. Echinochloa crusgalli (L.) Beauv.

Plate 2. Echinochloa colanum (L.) Link.



Plate 1



Plate 2

encircles the stem in the absence of a ligule. The sheath is pale green, flattened, and splits with hyaline margins. The leaf blade is 10 to 30 cm long and 5 to 20 mm wide. The stem is stout, glabrous, with a diameter of 6 mm. The culm branches at the base and produces tillers. The stem ends in 10 to 20 cm long inflorescence with a slender spike like panicle, green or purplish in colour. The lower branches of the panicle are far apart from each other while the upper ones are more or less aggregated into a terminal lump. The spikelets are densely crowded in 2 to 4 rows on each side of the stem. The spikelet is about 6 mm long and oval in shape with unequal pointed glumes. The seeds are strongly convex on one side and flat on the other. They are light orange yellow in colour and 2.5 to 3.5 mm long. The plant propagates mainly through seeds.

4.1.2 Echinochloa colanum⁰ (L.) Link

Family : Poaceae

It is a slender annual grass growing to a height of 60 to 90 cm (Plate 2). The stem is creeping below and erect above, with rooting at lower nodes. Stem is tufted, 12.5 to 37.5 cm long, leaves flaccid as long as the stem; bracts 2-3, 5 to 20 cm long; spikelets many

densely grouped into congested globose heads, glumes obovate, apex rounded; nut sub-equally trigonous, yellow or pale brown. It is a very common weed in both low land and upland rice fields. It propagates mainly through seeds which have a dormancy period of about two months. It can also propagates vegetatively, with nodes striking roots when in contact with soil and the new shoots, when seperated, can give independent plants.

4.1.3 Dinebra retroflexa (Vahl) Panz.

Family : Poaceae

It is a tufted leafy annual; culms erect or decumbent at base, upto 60 cm high; leaves linear, sparingly hairy; inflorescence a narrow, pyramidal panicle of alternate or fascioled, 0.8-3.5 cm long, spreading or deflexed, pale green to purple racemes; Spikelets dense, 2-3 flowered, 5mm long, alternate and sessile on the dorsally flattened rachis; glumes about twice as long as the lemma. A weed of damp and cultivated fields (Plate 3).

4.1.4 Panicum repens L.

Family : Poaceae

It is an aggressive perennial grass (Plate 4). It is a creeping perennial which propagates vegetatively through rhizomes. The rhizomes are knoty and swollen in appearance and send out errect culms from the rather distant nodes.

Plate 3. Dinebra retroflexa (Vahl) Panz.

Plate 4. Panicum repens L.



Plate 3



Plate 4

The leaves are 15 to 25 cm long and 1.5 cm wide or less, linear, flat or folded with a round base. The panicles are 6 to 18 cm long, some what loose and open and erect or ascending. The spikelets are two flowered, pale green or pale yellow. It occurs under both irrigated and rainfed conditions. It spreads very rapidly and becomes very persistent.

4.1.5 Paspalum conjugatum Berg.

Family : Poaceae

It is a creeping, stoloniferous perennial grass. The culms are 20 to 40 cm long, erect with smooth nodes. The leaves are 5 to 20 cm long, 5 to 15 mm wide, lanceolate, smooth, flat and sparingly hairy, with a rough or stiffy hairy margins. The spikelets are flattened, pale green, the margin fringed with long white silky hairs. It reproduces by runners and seeds.

4.1.6 Digitaria longiflora (Retz.) Pers.

Family : Poaceae

Clums creeping and rooting at nodes; leaves lanceolate, racemes 2-3, 4-5 cm long; spikeletes in pairs, monomorphic, elliptic-acute, 2 mm long, pubescent; upper glume as long as the prominently nerved lower lemma (Plate 5)

Plate 5. Digitaria longiflora (Retz.) Pers.

Plate 6. Cynodon dactylon (L.) Pers.



Plate 5



Plate 6

4.1.7 Cynodon dactylon (L.) Pers.

Family : Poaceae

It is a perennial grass with long runners which strike root at the nodes, and extensive underground rhizomes (Plate 6). The leaves vary greatly in length from 3 to 20 cm. There is no membranous ligule where the leaf blade joins the sheath. The flowering stems normally 15 to 50 cm long. The inflorescence consists of 4 to 5 slender purplish spikes of 10 cm long. It propagates vegetatively more than by seeds.

4.1.8 Cyperus iria Linn.

Family : Cyperaceae

A widely distributed species in all marshy situations and also occurs as a very common weed in paddy field. Stem 15 to 50 cm tall, trigonous, leaves upto 42.5 cm long; bracts 3-5, 5 to 25 cm long; spike consists of 5-15 spikelets; spikelets linear, oblong, yellow or pale brown; glumes plicate; nut trigonous, obovoid, black (Plate 7).

4.1.9 Eclipta alba (L.) Hassk.

Family : Asteraceae

Errect or prostrate, much branched annual, often rooting at nodes. Stem and branches strigose with appressed white hairs. Leaves opposite, sessile, oblong lanceolate or linear-lanceolate, sometimes ovate-lanceolate. Heads 5-8 mm

Plate 7. Cyperus iria L.

Plate 8. Spilanthes calva DC.



Plate 7



plate 8

across, white, peduncled, one to three or some times more in leaf axils. Achenes cuncate, 2 mm long, compressed, common weed of cultivated fields.

4.1.10 Portulaca oleracea L.

Family : Portulacaceae

A prostrate succulent herb, with erect main stem and prostrate lateral branches, leaves oblong to linear, alternate at base and opposite towards the tip; the leaf apex round and margin tapering towards the base; flowers. Yellow in clusters; fruit a dry capsule, opening transversly by a lid, seeds minute, blackish brown; propagation by seeds.

4.1.11 Spilanthes calva DC.

Family : Asteraceae

Creeping ascending herb upto 30 cm, leaves ovate, acute, subserenate; heads solitary, homogamous, ovoid; bract ovate, acute, sometimes elliptical, glabrous; corolla yellow, 4-5 lobed, stamen 5; fruit is achene and it is propagated by seeds (Plate 8).

4.2 Weed population counts

Observations on monocot, dicot and total weed population were recorded from one square meter area at 30, 45, 60 and 90 days after sowing and at harvest.

4.2.1 Monocot weed population

Observations on monocot weed count at different crop growth stages are presented in Table 3. At all the crop growth stages monocot weed counts differed significantly among weed control treatments.

At 30 days after sowing all herbicidal treatments recorded lower weed counts (6.33 to 17.00/m²) except 2,4-D. The maximum number of weeds were in unweeded ^{control} ~~counts~~ (27.3/m²). Application of oxyflurofen (0.25 kg a.i. per ha) recorded the lowest weed count (6.3/m²) while 2,4-D (1.00 kg a.i. per ha) recorded the highest weed count (31.3/m²).

At 45 days after sowing all herbicidal treatments recorded lower weed counts as compared to unweeded control (29.6/m²) excepting 2,4-D sodium salt (1.00 kg a.i./ha), which recorded 41.6/m². All the treatments which received hand weeding during this period recorded zero weed count. Among the herbicides alone pendimethalin (1.00 kg a.i. per ha) recorded the lowest weed count (6.0/m²) while 2,4-D sodium salt recorded the highest weed count (41.6/m²). Pendimethalin (1.00 kg a.i per ha) recorded significantly lower weed count (6.0/m²) compared to benthocarb (1.00 kg a.i. per ha) which recorded 18.6/m².

Table 3. Effect of different weed control treatments on monocooc weed (No./square meter area) at different crop growth stages in drill sown Jaya rice.

Treatments	Days after sowing				At harvest
	30	45	60	90	
2,4-D 1.00 kg a.i./ha 25 DAS	5.63(31.33)	6.48(41.66)	8.74(54.66)	6.61(43.33)	6.45(45.33)
2,4-D 0.75 kg a.i./ha 25 DAS + 1HW	5.38(29.33)	0.70(0.00)	2.26(4.66)	4.36(19.00)	5.81(36.33)
Butachlor 1.00 kg a.i./ha pre-en.	3.64(13.66)	2.66(7.66)	4.39(25.00)	5.34(28.33)	3.12(9.33)
Butachlor 0.75 kg a.i./ha pre-en. + 1 HW	4.14(17.00)	0.70(0.00)	2.17(4.33)	3.51(12.00)	2.78(7.66)
Pendimethalin 1.00 kg a.i./ha pre-en.	2.92(8.66)	2.45(6.00)	3.09(9.66)	4.41(19.33)	2.80(7.66)
Pendimethalin 0.75 kg a.i./ha pre-en. + 1 HW	3.46(12.00)	0.70(0.00)	1.43(1.66)	2.64(6.63)	2.19(14.33)
oxyflurofen 0.50 kg a.i./ha pre-en.	2.96(8.33)	3.07(9.00)	3.69(13.33)	4.46(19.66)	4.55(20.33)
oxyflurofen 0.25 kg a.i./ha pre-en. + 1 HW	2.51(6.33)	0.70(0.00)	1.46(2.00)	2.62(8.33)	2.85(7.66)
Oxadiazon 1.00 kg a.i./ha pre-en.	3.43(11.66)	3.50(12.33)	4.16(17.66)	6.16(37.66)	3.55(12.66)
Oxadiazon 0.75 kg a.i./ha pre-en. + 1 HW	3.72(14.66)	0.70(0.00)	1.73(3.33)	2.88(8.00)	3.21(10.00)
Benthiocarb 1.00 kg a.i./ha pre-en.	3.52(12.66)	4.26(18.66)	5.12(28.00)	5.94(35.00)	3.84(14.33)
Benthiocarb 0.75 kg a.i./ha pre-en. + 1 HW	4.11(16.66)	0.70(0.00)	1.84(3.33)	3.40(11.66)	2.17(4.33)
Hand weeding once at 45 DAS	5.02(26.66)	0.70(0.00)	1.85(3.33)	3.50(12.00)	2.66(6.66)
Hand weeding twice at 20 and 45 DAS	2.16(4.66)	0.70(0.00)	1.64(2.33)	2.93(8.66)	1.93(3.33)
Unweeded control	5.21(27.33)	5.33(29.66)	6.71(46.33)	7.98(65.33)	10.69(114.33)
F - test	*	*	*	*	*
S.E.m _t	0.54	0.61	0.60	0.45	0.49
C.D. at 5%	1.55	1.77	1.74	1.31	1.43

Figures in the parentheses refers to original values

1 HW indicates one hand weeding 45 days after sowing.

DAS indicates days after sowing

At 60 days after sowing all weed control treatments recorded significantly lower weed counts (2.3 to 25.0/m²) as compared to unweeded control (46.33/m²), excepting 2,4-D sodium salt (1.00 kg a.i. per ha) and benthocarb (1.00 kg a.i. per ha) which recorded 64.66 and 28.0 per m² respectively. Pendimethalin 0.75 kg a.i. per ha plus one hand weeding recorded the lowest weed count (1.66/m²), followed by oxyflurofen 0.25 kg a.i. per ha plus one hand weeding (2.0/m²), hand weeded twice (2.33/m²), oxadiazon 0.75 kg a.i. per ha plus one hand weeding (3.33/m²), benthocarb 0.75 kg a.i. per ha plus one hand weeding (3.33/m²) and hand weeded once (3.33/m²). Benthocarb (1.00 kg a.i. per ha), 2,4-D sodium salt (1.00 kg a.i. per ha) were on par with unweeded control.

At 90 days after sowing all weed control treatments differed significantly from unweeded control (65.33/m²). Oxyflurofen (0.25 kg a.i. per ha) plus one hand weeding recorded the lowest weed count (8.33/m²), which was on par with pendimethalin 0.75 kg a.i. per ha plus one hand weeding (6.63/m²), oxadiazon 0.75 kg a.i. per ha plus one hand weeding (8.00/m²), hand weeded twice (8.66/m²), benthocarb 0.75 kg a.i. per ha plus one hand weeding (11.66/m²), hand weeded once (12.0/m²), and butachlor 0.75 kg a.i. per ha plus one hand weeding (12.0/m²).

At harvest also all weed control treatments recorded significantly lower weed population (3.33 to 46.33/m²) than unweeded control which had the highest weed count (114.33/m²). All herbicidal treatments in combination with one hand weeding reduced the weed population as compared to herbicides alone. Hand weeded twice recorded the lowest weed population (3.33/m²) which was on par with pendimethalin 0.75 kg a.i. per ha plus one hand weeding and benthocarb 0.75 kg a.i. per ha plus one hand weeding (4.33/m²). Among the weed control treatments 2,4-D sodium salt (1.00 kg a.i. per ha) recorded the highest weed count (46.33/m²).

4.2.2 Dicot weed population

Observations on dicot weed count at different crop growth stages are presented in Table 4. At all crop growth stages dicot weed counts differed significantly among the different weed control treatments.

At 30 days after sowing all weed control treatments recorded lower dicot weed population than unweeded control (21.66/m²). oxyflurofen 0.50kg a.i. per ha recorded no dicot weed followed by oxyflurofen 0.25 kg a.i. per ha plus one hand weeding (1.00), oxadiazon 0.75 kg a.i. per ha plus one hand weeding (2.00), oxadiazon 1.00 kg a.i. per ha (2.33), pendimethalin 0.75 kg a.i. per ha plus one hand

Table 4. Effect of different weed control treatments on dicot weeds (No./square meter area) at different crop growth stages in drill sown Jaya Rice.

Treatments	Days after sowing				At harvest
	30	45	60	90	
2,4-D 1.00 kg a.i./ha 25 DAS	2.88(9.66)	2.48(6.33)	3.11(11.33)	3.40(11.66)	15.41(238.66)
2,4-D 0.75 kg a.i./ha 25 DAS + 1 HW	4.50(20.33)	0.70(0.00)	4.39(19.33)	7.70(60.66)	14.10(201.66)
Bucachlor 1.00 kg a.i./ha pre-em.	2.75(11.66)	2.91(9.00)	4.24(20.66)	5.59(36.66)	16.93(286.33)
Bucachlor 0.75 kg a.i./ha pre-em. + 1 HW	2.54(7.66)	0.70(0.00)	3.51(13.66)	5.26(29.33)	15.72(247.00)
Pendimethalin 1.00 kg a.i./ha pre-em.	2.32(5.33)	5.87(35.00)	7.91(63.66)	3.10(66.00)	19.23(396.66)
Pendimethalin 0.75 kg a.i./ha pre-em. + 1 HW	2.15(4.33)	0.70(0.00)	6.22(38.66)	8.24(67.66)	17.82(317.66)
oxyflurofen 0.50 kg a.i./ha pre-em.	0.70(0.00)	2.27(5.00)	2.62(7.66)	2.79(7.66)	9.01(82.33)
oxyflurofen 0.25 kg a.i./ha pre-em. + 1 HW	1.09(1.00)	0.70(0.00)	2.58(7.33)	3.24(10.33)	9.14(84.33)
Oxadiazon 1.00 kg a.i./ha pre-em.	1.54(2.23)	4.00(17.66)	5.05(27.33)	4.23(18.00)	15.05(226.33)
Oxadiazon 0.75 kg a.i./ha pre-em. + 1 HW	1.58(2.00)	0.70(0.00)	3.02(11.00)	4.03(17.00)	15.33(235.00)
Benchiocarb 1.00 kg a.i./ha pre-em.	2.90(9.66)	5.95(49.00)	9.02(83.00)	8.98(83.33)	18.52(345.66)
Benchiocarb 0.75 kg a.i./ha pre-em. + 1 HW	3.64(13.00)	0.70(0.00)	6.73(46.33)	8.28(68.66)	16.39(268.66)
Hand weeding once at 45 DAS	4.19(18.00)	0.70(0.00)	6.66(48.00)	7.54(60.00)	16.38(268.33)
Hand weeding twice at 20 and 45 DAS	3.47(13.00)	0.70(0.00)	6.94(39.00)	7.47(55.66)	15.37(236.33)
Unweeded control	4.60(21.66)	7.71(61.33)	8.67(77.66)	8.96(80.00)	10.39(109.66)
F - test	*	*	*	*	*
S.E.m±	0.66	0.53	0.73	0.77	0.51
C.D. at 5%	1.91	1.54	2.28	2.24	1.49

Figures in the parantheses indicate original data 1 HW indicates one hand weeding

45 days after sowing

DAS indicated days after sowing

weeding (4.33), and pendimethalin 1.00 kg a.i. per ha (5.33), which recorded significantly lower weed population than unweeded control.

At 45 days after sowing all weed control treatments significantly reduced weed population (0.0 to 35.0/m²) over unweeded control which recorded the highest (61.33/m²), except benthocarb 1.00 kg a.i. per ha (49.00/m²). All weed control treatments, which received hand weeding 45 days after sowing recorded new weed count. Among the herbicides alonge, oxyflurofen recorded the lowest weed count (5.00/m²), followed by 2,4-D 1.00 kg a.i. per ha (6.33) and butachlor 1.00 kg a.i. per ha (9.00/m²) which were on par. Pendmethalin 1.00 kg a.i. per ha (35.0/m²), benthocarb 1.00 kg a.i. per ha (49.0/m²), and unweeded control (16.33/m²) recorded higher weed count than other weed control treatments.

At 60 days after sowing all weed control treatments significantly reduced the weed population (7.33 to 38.66/m²) over unweeded control (77.66/m²), excepting pendimethalin 1.00 kg a.i. per ha (63.66/m²), benthocarb 0.75 kg a.i. per ha plus one hand weeding (46.33/m²), hand weeded once (46.00/m²), which recorded lower weed population than unweeded control and benthocarb (83.0/m²) which recorded

higher weed population than unweeded control. Oxyflurofen 0.25 kg a.i. per ha plus one hand weeding recorded the lowest weed population ($7.33/\text{m}^2$), followed by oxyflurofen 0.50 kg a.i. per ha ($7.66/\text{m}^2$), oxadiazon 0.75 kg a.i. per ha plus one hand weeding ($11.00/\text{m}^2$), 2,4-D 1.00 kg a.i. per ha ($11.33/\text{m}^2$), butachlor 0.75 kg a.i. per ha plus one hand weeding ($13.66/\text{m}^2$) and 2,4-D 0.75 kg a.i. per ha plus one hand weeding ($19.33/\text{m}^2$), which were on par. Hand weeded twice recorded lower weed population ($39.0/\text{m}^2$) as compared to hand weeded once ($48.0/\text{m}^2$) which was on par with unweeded control.

At 90 days after sowing, all weed control treatments recorded lower weed population (7.66 to $68.66/\text{m}^2$) as compared to unweeded control ($80.00/\text{m}^2$), except benthocarb 1.00 kg a.i. per ha which recorded higher weed population ($83.33/\text{m}^2$) than unweeded control. Oxyflurofen 0.50 kg a.i. per ha recorded the lowest weed population ($7.66/\text{m}^2$) than any other weed control treatments, followed by oxyflurofen 0.25 kg a.i. per ha plus one hand weeding ($10.33/\text{m}^2$), 2,4-D sodium salt 1.00 kg a.i. per ha ($11.66/\text{m}^2$), oxadiazon 1.00 kg a.i. per ha ($18.0/\text{m}^2$) and butachlor 0.75 kg a.i. per ha plus one hand weeding ($29.33/\text{m}^2$), which recorded significantly lower weed population than unweeded control. Among the hand weeded

treatments, hand weeded twice recorded lower weed population ($55.66/\text{m}^2$) than hand weeded one ($60.0/\text{m}^2$), but the difference was not significant.

At harvest, all the weed control treatments recorded significantly higher weed population (201.66 to $396.6/\text{m}^2$) than unweeded control ($109.66/\text{m}^2$) except oxyflurofen. Oxyflurofen at both the rates 0.50 kg a.i. per ha ($82.33/\text{m}^2$) and 0.25 kg a.i. per ha plus one hand weeding ($84.53/\text{m}^2$) recorded lower weed population, than unweeded control. Pendimethalin 1.00 kg a.i. per ha ($396.66/\text{m}^2$) recorded the highest dicot weed population followed by benthocarb 1.00 kg a.i. per ha ($345.66/\text{m}^2$) and pendimethalin 0.75 kg a.i. per ha plus one hand weeding ($317.66/\text{m}^2$).

4.2.3 Total weed population

Observations on total weed count at different crop growth stages are presented in Table 5. At all growth stages, total weed count differed significantly among the weed control treatments.

At 30 days after sowing all weed control treatments had minimum total weed count as compared to unweeded control ($49.00/\text{m}^2$), except 2,4-D sodium salt 0.75 kg a.i. per ha, which recorded the maximum total weed count ($49.66/\text{m}^2$).

Table 5. Effect of different weed control treatments on total weed (No./square meter area) at different crop growth stages in drill sown Jaya rice.

Treatments	Days after sowing				At harvest
	30	45	60	90	
2,4-D 1.00 kg a.i./ha 25 DAS	6.41(41.00)	6.95(48.00)	8.62(76.00)	7.42(55.00)	16.86(285.00)
2,4-D 0.75 kg a.i./ha 25 DAS + 1 HW	7.20(49.66)	0.70(0.00)	4.90(24.00)	8.84(79.66)	15.35(238.00)
Butachlor 1.00 kg a.i./ha pre-em.	4.65(25.33)	3.73(14.00)	6.17(45.66)	7.87(65.00)	17.20(295.66)
Butachlor 0.75 kg a.i./ha pre-em. + 1 HW	4.11(24.66)	0.70(0.00)	4.12(18.00)	6.33(41.33)	15.97(254.66)
Pendimethalin 1.00 kg a.i./ha pre-em.	3.67(14.00)	6.36(41.00)	8.51(73.33)	9.22(85.33)	19.43(377.33)
Pendimethalin 0.75 kg a.i./ha pre-em. + 1 HW	4.02(16.33)	0.70(0.00)	6.35(40.33)	8.64(74.33)	17.94(322.00)
Oxyflurofen 0.50 kg a.i./ha pre-em.	2.96(8.33)	3.79(14.00)	4.52(21.00)	5.27(27.33)	10.09(102.66)
Oxyflurofen 0.25 kg a.i./ha pre-em. + 1 HW	2.66(7.33)	0.70(0.00)	2.86(9.33)	4.26(18.66)	9.56(92.00)
Oxadiazon 1.00 kg a.i./ha pre-em.	3.75(14.00)	5.29(30.00)	6.51(45.00)	7.59(55.66)	15.46(239.00)
Oxadiazon 0.75 kg a.i./ha pre-em. + 1 HW	4.01(16.66)	0.70(0.00)	3.44(14.33)	4.91(25.00)	15.65(245.00)
Benthiocarb 1.00 kg a.i./ha pre-em.	4.55(22.33)	8.16(67.66)	10.44(110.00)	10.78(118.33)	18.96(360.00)
Benthiocarb 0.75 kg a.i./ha pre-em. + 1 HW	5.48(29.66)	0.70(0.00)	6.95(49.66)	8.97(80.32)	16.52(273.00)
Hand weeding once at 45 DAS	6.51(44.66)	0.70(0.00)	6.90(51.00)	8.30(72.00)	16.58(275.00)
Hand weeding twice at 20 and 45 DAS	4.03(17.66)	0.70(0.00)	6.23(41.33)	8.03(64.33)	15.49(239.66)
Unweeded control	6.94(49.00)	9.37(91.00)	10.97(124.00)	12.02(145.33)	14.96(224.00)
F - test	*	*	*	*	*
S.E.m _t	0.68	0.62	0.87	0.76	0.47
C.D. at 5%	1.97	1.81	2.51	2.20	1.37

Figures in the parantheses indicates original data

1 HW indicates one hand weeding
45 days after sowing.

DAS indicates days after sowing.

Oxyflurofen 0.25 kg a.i. per ha recorded the lowest weed count ($7.33/\text{m}^2$) followed by oxyflurofen 0.50 kg a.i. per ha ($8.33/\text{m}^2$), pendimethalin and oxadiazon 1.00 kg a.i. per ha ($14.0/\text{m}^2$), pendimethalin 0.75 kg a.i. per ha ($16.33/\text{m}^2$) and oxadiazon 0.75 kg a.i. per ha ($16.66/\text{m}^2$). Among the hand weeded treatments, the treatment which received hand weeding 20 days after sowing recorded significantly lower weed count ($17.66/\text{m}^2$) as compared to treatment which received no hand weeding at 20 days after sowing ($44.66/\text{m}^2$), which was on par with unweeded control.

At 45 days after sowing, the total weed count was significantly lower in all weed control treatments (0.0 to $48.0/\text{m}^2$) as compared to unweeded control ($91.0/\text{m}^2$), except benthicarb. Benthicarb 1.00 kg a.i. per ha recorded lower weed count ($67.66/\text{m}^2$) than unweeded control ($91.00/\text{m}^2$), but the difference was not significant. All the weed control treatments which received one hand weeding at this stage recorded zero weed count. Among the herbicides alone, butachlor 1.00 kg a.i. per ha and oxyflurofen 0.50 kg a.i. per ha recorded the lowest total weed count ($14.00/\text{m}^2$), while benthicarb 1.00 kg a.i. per ha recorded the highest ($67.66/\text{m}^2$) followed by 2,4-D 1.00 kg a.i. per ha ($48.00/\text{m}^2$) and pendimethalin 1.00 kg a.i. per ha ($41.00/\text{m}^2$) which were on par.

At 60 days after sowing all weed control treatments recorded significantly lower weed counts (9.33 to 45.66/m²) as compared to unweeded control (124.0/m²) except pendimethalin 1.00 kg a.i. per ha (73.3/m²), 2,4-D sodium salt 1.00 kg a.i. ha (76.0/m²) and benthocarb 1.00 kg a.i. per ha (111.00/m²), which were on par with unweeded control. All herbicidal treatments in combination with one hand weeding reduced weed population (9.33 to 40.33/m²) than herbicides alone (21.0 to 110.0/m²). Among the herbicides alone oxyfluorfen 0.50 kg a.i. per ha recorded the lowest weed count (21.0/m²), followed by butachlor 1.00 kg a.i. per ha (45.66/m²), which were on par. Among the hand weeded treatments, hand weeded once (51.0/m²) and hand weeded twice (41.33/m²) significantly controlled the weeds as compared to unweeded control (124.0/m²).

At 90 days after sowing, all weed control treatments recorded significantly lower total weed counts (18.66 to 85.33/m²) as compared to unweeded control (145.33/m²) except benthocarb 1.00 kg a.i. per ha (118.33/m²) which was on par with unweeded control. All herbicidal treatments in combination with one hand weeding had lower weed counts (18.66 to 80.33/m²) as compared to herbicides alone (27.33 to 118.33/m²) except 2,4-D sodium salt. 2,4-D sodium salt 0.75 kg a.i. per ha plus one hand weeding

recorded higher weed counts ($79.66/\text{m}^2$) as compared to 2,4-D 1.00 kg a.i. per ha ($55.0/\text{m}^2$). Oxyflurofen 0.25 kg a.i. per ha plus one hand weeding recorded the lowest weed count ($18.66/\text{m}^2$) as compared to any other treatments, followed by oxadiazon 0.75 kg a.i. per ha plus one hand weeding ($25.0/\text{m}^2$), oxyflurofen 0.50 kg a.i. per ha ($27.33/\text{m}^2$), and butachlor 0.75 kg a.i. per ha plus one hand weeding ($41.33/\text{m}^2$), which were on par. Hand weeded twice ($64.33/\text{m}^2$) and hand weeded once ($72.0/\text{m}^2$) recorded significantly lower weed population compared to unweeded control.

At harvest, all the weed control treatments recorded ^{higher} ~~lower~~ total weed count (238 to $377.33/\text{m}^2$) as compared to unweeded control ($224/\text{m}^2$), except oxyflurofen. Oxyflurofen 0.25 kg a.i. per ha plus one hand weeding ($92/\text{m}^2$) and oxyflurofen 0.50 kg a.i. per ha ($102.66/\text{m}^2$) recorded significantly lower weed count as compared to unweeded control. Pendimethalin 1.00 kg a.i. per ha recorded the highest weed count ($377.33/\text{m}^2$) followed by benthocarb 1.00 kg a.i. per ha ($360.0/\text{m}^2$), pendimethalin 0.75 kg a.i. per ha plus one hand weeding ($322.0/\text{m}^2$), butachlor 1.00 kg a.i. per ha ($295.66/\text{m}^2$) and 2,4-D sodium salt 1.00 kg a.i. per ha ($285.0/\text{m}^2$). All herbicidal treatments in combination with one hand weeding reduced weed population (92 to $238/\text{m}^2$) as compared to herbicides alone (102.66 to $377.33/\text{m}^2$).

Among the hand weeded treatments, hand weeded twice recorded lower weed count ($239.66/\text{m}^2$) as compared to hand weeded once ($275.0/\text{m}^2$), but the difference was not significant.

4.3 Total dry matter production of weeds

Observations on dry matter production of weeds sampled in 0.25 m^2 area at 30, 60 and 90 days after sowing and at harvest are presented in Table 6 and Fig.3.

(a) At 30 days after sowing

Dry matter production of weeds differed significantly among the weed control treatments. All weed control treatments recorded significantly lower weed dry weight (0.46 to $10.96 \text{ g}/0.25 \text{ m}^2$) than unweeded control ($13.7 \text{ g}/0.25 \text{ m}^2$) excepting 2,4-D sodium salt $0.75 \text{ kg a.i. per ha}$ and hand weeded once which recorded 21.53 and $12.63 \text{ g}/0.25 \text{ m}^2$ respectively. Application of oxyflurofen $0.25 \text{ kg a.i. per ha}$ recorded the lowest weed dry weight ($0.46 \text{ g}/0.25 \text{ m}^2$) followed by hand weeded twice ($1.53 \text{ g}/0.25 \text{ m}^2$). However, hand weeding twice and pendimethalin $1.00 \text{ kg a.i. per ha}$ were on par.

(b) At 60 days after sowing

Dry matter production of weeds differed significantly among the weed control treatments. All weed control

Table 6. Effect of different weed control treatments on dry matter production of weeds (g/0.25 m² area) at different crop growth stages in drill sown Jaya rice.

Treatments	Days after sowing				At harvest
	30	60	90		
2,4-D 1.00 kg a.i./ha 25 DAS	10.13	53.96	98.70		131.83
2,4-D 0.75 kg a.i./ha 25 DAS + 1 HW	21.53	5.73	31.80		58.16
Butachlor 1.00 kg a.i./ha pre-em.	5.16	10.96	46.60		47.33
Butachlor 0.75 kg a.i./ha pre-em. + 1 HW	3.40	4.60	23.40		30.16
Pendimethalin 1.00 kg a.i./ha pre-em.	2.70	17.23	48.33		67.80
Pendimethalin 0.75 kg a.i./ha pre-em. + 1 HW	4.16	4.20	21.46		55.00
Oxyflurofen 0.50kg a.i./ha pre-em.	6.06	5.86	34.73		55.00
Oxyflurofen 0.25 kg a.i./ha pre-em. + 1 HW	0.46	2.60	9.86		18.46
Oxadiazon 1.00 kg a.i./ha pre-em.	10.96	39.40	50.16		50.50
Oxadiazon 0.75 kg a.i./ha pre-em. + 1 HW	10.78	12.50	20.23		38.16
Benthiocarb 1.00 kg a.i./ha pre-em.	9.40	46.13	57.00		118.33
Benthiocarb 0.75 kg a.i./ha pre-em. + 1 HW	4.40	4.76	19.70		40.33
Hand weeding once at 45 DAS	12.63	9.93	23.30		59.83
Hand weeding twice at 20 and 45 DAS	1.53	5.40	19.63		50.00
Unweeded control	13.70	48.00	91.08		150.90
F - test	*	*	*	*	*
SEM±	0.69	2.01	2.35		8.14
C.D. at 5%	1.99	5.81	6.80		23.57

DAS indicates days after sowing.

1 HW indicates one hand weeding
45 days after sowing.

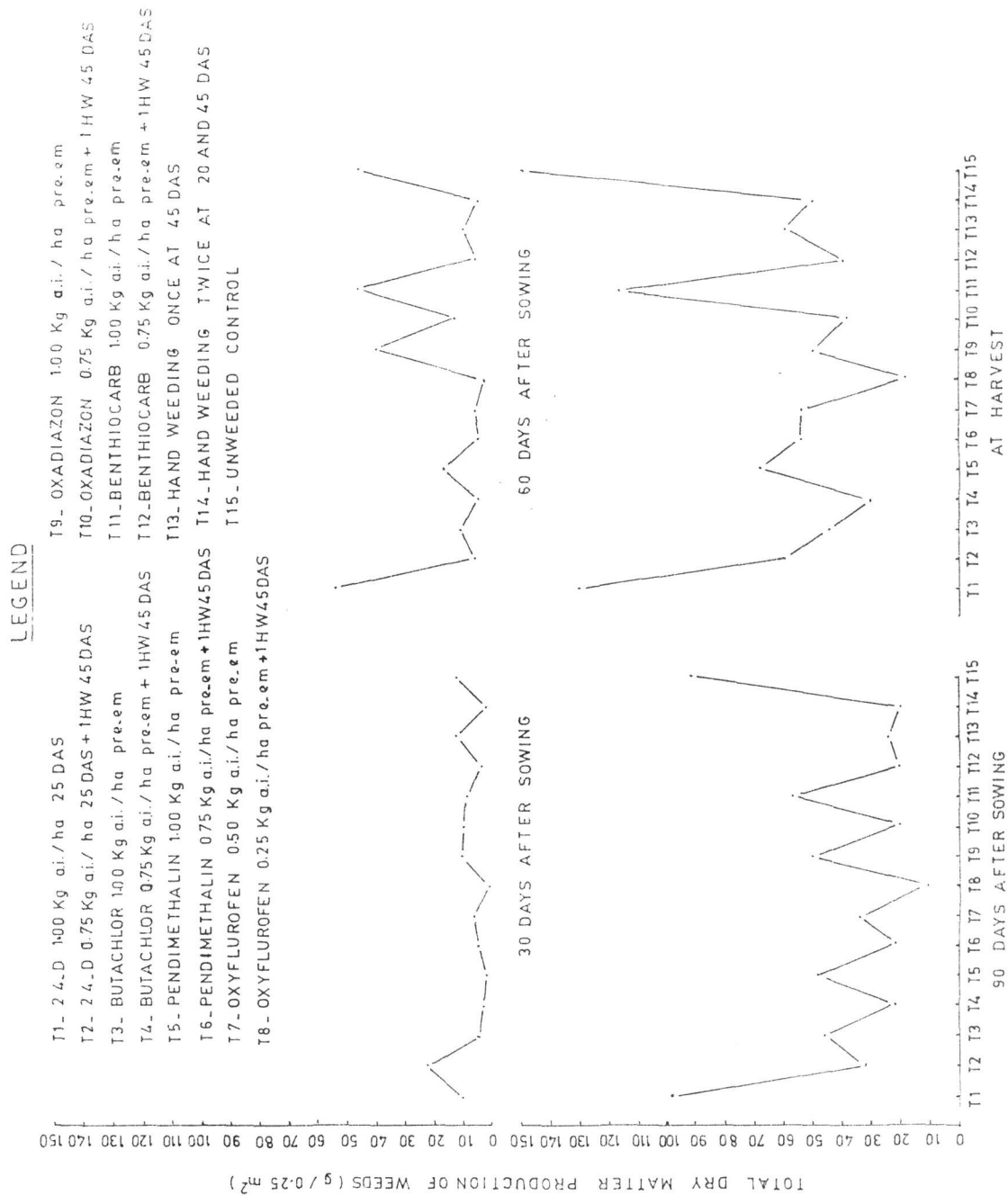


FIG.3. TOTAL DRY MATTER PRODUCTION OF WEEDS AT DIFFERENT CROP GROWTH STAGES AS AFFECTED BY DIFFERENT WEED CONTROL TREATMENTS IN DRILL SOWN JAYA RICE.

treatments recorded significantly lower weed dry weight (2.6 to 39.4 g/0.25 m²) as compared to unweeded control (48.0 g/0.25 m²), excepting 2,4-D sodium salt (1.00 kg a.i. per ha) and benthocarb (1.00 kg a.i. per ha) which recorded 53.96 and 46.13 g/0.25 m² ^{respectively} area. All herbicidal treatments in combination with one hand weeding 45 days after sowing recorded significantly lower weed dry weight (2.6 to 12.50 g/0.25 m²) as compared herbicides alone (5.86 to 53.96 g/0.25 m²) excepting oxyflurofen 0.50 kg a.i. per ha (5.86 g/0.25 m²) and oxyflurofen 0.25 kg a.i. per ha plus one hand weeding (2.60 g/0.25 m²) which were on par. Pendimethalin 0.75 kg a.i. per ha plus one hand weeding (4.20 g/0.25 m²) was on par with butachlor 0.75 kg a.i. per ha plus one hand weeding (4.60 g/0.25 m²), benthocarb 0.75 kg a.i. per ha plus one hand weeding (4.76 g/0.25 m²) and 2,4-D sodium salt 0.75 kg a.i. per ha plus one hand weeding (5.73 g/0.25 m²). In the hand weeded treatments, there was no significant difference in weed dry weight between hand weeded once at 45 days after sowing (9.93 g/0.25 m²) and hand ^{weeded} twice at 20 and 45 days after sowing (5.40 g/0.25 m²).

(c) At 90 days after sowing

Dry matter production of weeds differed significantly among the weed control treatments. All weed control treatments recorded significantly lower weed dry matter

(9.86 to 57.0 g/0.25 m²) as compared to unweeded control (91.08 g/0.25 m²), excepting 2,4-D sodium salt 1.00 kg a.i. per ha which recorded 98.70 g per 0.25 m² area. All herbicidal treatments in combination with one hand weeding recorded significantly lower weed dry weight (9.86 to 31.80 g/0.25 m²) as compared to herbicides alone (34.73 to 98.7 g/0.25 m²). Oxyflurofen 0.25 kg a.i. per ha plus one hand weeding recorded significantly lower weed dry weight (9.86 g/0.25 m²) as compared to any other treatments, which is followed by hand weeded twice (19.63 g/0.25 m²), benthiocarb 0.75 kg a.i. per ha plus one hand weeding (19.70 g/0.25 m²), oxadiazon 0.75 kg a.i. per ha plus one hand weeding (20.23 g/0.25 m²), pendimethalin 0.75 kg a.i. per ha plus one hand weeding (21.46 g/0.25 m²), hand 2 weeded once (23.30 g/0.25 m²) and butachlor 0.75 kg a.i. per ha plus one hand weeding (23.40 g/0.25 m²) which were on par with each other. Among herbicides alone oxyflurofen 0.50 kg a.i. per ha recorded significantly lowest weed dry weight (34.73 g/0.25 m²) as compared to other treatments. There was no significant difference between hand weeded once (23.30 g/0.25 m²) and hand weeded twice (19.63 g/0.25 m²).

(d) At harvest

Total weed dry weight differed significantly among the weed control treatments. All weed control treatments

recorded significantly lower weed dry weight (18.46 to 118.3 g/0.25 m²) as compared to unweeded control (150.90 g/0.25 m²), excepting 2,4-D sodium salt (1.00 kg a.i. per ha) which recorded 131.83 g per 0.25 m² area. The herbicidal treatments in combination with one hand weeding recorded significantly lower weed dry weight (18.46 to 58.16 g/0.25 m²) as compared to herbicides alone (55.0 to 131.83 g/0.25 m²) in case of oxyfluorfen, benthocarb and 2,4-D sodium salt. Oxyfluorfen 0.25 kg a.i. per ha plus one hand weeding recorded significantly lowest weed dry weight (18.46 g/0.25 m²) compared to all other treatments except butachlor 0.75 kg a.i. per ha plus one hand weeding (30.16 g/0.25 m²), oxadiazon 0.75 kg a.i. per ha plus one hand weeding (38.16 g/0.25 m²) and benthocarb 0.75 kg a.i. per ha plus one hand weeding (40.33 g/0.25 m²), which were on par with hand weeded twice (50.0 g/0.25 m²). Among herbicides alone butachlor (1.00 kg a.i. per ha) recorded lowest weed dry weight (47.3 g/0.25 m²), which was on par with oxadiazon 1.00 kg a.i. per ha (50.5 g/0.25 m²) and oxyfluorfen 0.50 kg a.i. per ha (55.0 g/0.25 m²). There was no significant difference between hand weeded once (59.83 g/0.25 m²) and hand weeded twice (50.0 g/0.25 m²).

In general at all crop growth stages different weed control treatments recorded lower weed dry weight as compared

to unweeded control, except 2,4-D sodium salt (1.00 kg a.i. per ha). Compared to herbicides alone, herbicides in combination with one hand weeding was better.

4.4 Studies on weed control and crop toxicity ratings

Visual observations recorded on weed control ratings at 30, 40 and 90 days after sowing and at harvest are presented in Table 7 and crop toxicity ratings recorded at 30, 40 and 50 days after sowing are presented in Table 8.

4.4.1 Weed control ratings

(a) At 30 days after sowing

Marked differences in weed control ratings were noticed among the weed control treatments. The application of oxyflurofen at both the doses 0.50 kg a.i. and 0.25 kg a.i. per ha gave good control of weeds which was comparable to hand weeded twice (3.33). Oxadiazon 1.00 kg a.i. per ha gave moderate control of weeds (4.66), while butachlor at both the doses (1.00 kg and 0.75 kg a.i. per ha) gave deficient to moderate control of weeds (5.33).

(b) At 40 days after sowing

Hand weeded twice gave good control of weeds in the field (3.33) which was comparable to oxyflurofen

Table 7. Weed control ratings as influenced by different weed control treatments at different crop growth stages in drill sown Jaya rice.

Treatments	Days after sowing			At harvest
	30	40	90	
2,4-D 1.00 kg a.i./ha 25 DAS	8.66	9.33	9.33	9.00
2,4-D 0.75 kg a.i./ha 25 DAS + 1 HW	7.66	9.00	5.66	8.66
Butachlor 1.00 kg a.i./ha pre-em.	5.33	6.00	7.33	8.00
Butachlor 0.75 kg a.i./ha pre-em. + 1 HW	5.33	6.66	5.00	6.33
Pendimethalin 1.00 kg a.i./ha pre-em.	6.00	5.66	6.33	9.33
Pendimethalin 0.75 kg a.i./ha pre-em. + 1 HW	5.33	5.66	5.33	8.33
Oxyflurofen 0.50 kg a.i./ha pre-em.	3.33	3.66	5.00	5.33
Oxyflurofen 0.25 kg a.i./ha pre-em. + 1 HW	3.33	4.00	3.66	4.66
Oxadiazon 1.00 kg a.i./ha pre-em.	4.66	6.66	6.66	6.33
Oxadiazon 0.75 kg a.i./ha pre-em. + 1 HW	6.00	7.33	4.33	5.33
Benthiocarb 1.00 kg a.i./ha pre-em.	7.33	6.66	8.33	9.00
Benthiocarb 0.75 kg a.i./ha pre-em. + 1 HW	7.66	7.66	5.00	8.00
Hand weeding once at 45 DAS	7.66	9.00	6.00	6.33
Hand weeding twice at 20 and 45 DAS	3.33	3.33	5.00	7.33
Unweeded control	9.33	10.00	10.00	10.00

DAS indicates days after sowing

1 HW indicates one hand weeding 45 days after sowing

0.50 kg a.i. per ha (3.66). Oxyflurofen 0.25 kg a.i. per ha (4.00) and pendimethalin 1.00 kg a.i. per ha (5.66) gave deficient to moderate control of weeds, while all other treatments gave very poor control of weeds.

(c) At 90 days after sowing

Oxyflurofen 0.25 kg a.i. per ha plus one hand weeding gave good control of weeds (3.66), while oxadiazon 0.75 kg a.i. per ha plus one hand weeding (4.33) and benthocarb 0.75 kg a.i. per ha plus one hand weeding (5.00) gave deficient to moderate control of weeds.

(d) At harvest

At harvest, none of the treatments gave good control of weeds. Oxyflurofen 0.50 kg a.i. per ha (5.33) and oxyflurofen 0.25 kg a.i. per ha plus one hand weeding (4.66) gave deficient to moderate control of weeds, while all other treatments gave poor control of weeds.

4.4.2 Crop toxicity ratings

(a) At 30 days after sowing

At 30 days after sowing there was^a marked difference in the crop toxicity ratings. Moderate injury to the crop (3.33) was noticed in the treatment, oxyflurofen 0.50 kg

Table 8. Crop toxicity ratings as influenced by different weed control treatments at different crop growth stages in drill sown Jaya rice.

Treatments	Days after sowing		
	30	40	50
2,4-D 1.00 kg a.i/ha 25 DAS	2.00	2.00	1.33
2,4-D 0.75 kg a.i/ha 25 DAS + 1 HW	2.66	2.33	1.66
Butachlor 1.00 kg a.i/ha pre-em.	2.66	2.66	1.66
Butachlor 0.75 kg a.i/ha pre-em. + 1 HW	1.33	2.33	1.66
Pendimethalin 1.00 kg a.i/ha pre-em.	1.66	1.66	1.33
Pendimethalin 0.75 kg a.i/ha pre-em. + 1 HW	2.00	2.00	1.66
Oxyflurofen 0.50 kg a.i/ha pre-em.	3.33	2.66	2.00
Oxyflurofen 0.25 kg a.i/ha pre-em. + 1 HW	2.66	2.00	1.66
Oxadiazon 1.00 kg a.i/ha pre-em.	2.00	2.00	1.33
Oxadiazon 0.75 kg a.i/ha pre-em. + 1 HW	2.00	2.00	1.33
Benchiocarb 1.00 kg a.i/ha pre-em.	2.33	1.66	1.33
Benchiocarb 0.75 kg a.i/ha pre-em. + 1 HW	2.33	2.33	1.00
Hand weeding once at 45 DAS	1.33	1.00	1.00
Hand weeding twice at 20 and 45 DAS	1.00	1.00	1.00
Unweeded control	1.00	1.00	1.00

DAS indicates days after sowing

1 HW indicates one hand weeding 45 days after sowing

a.i. per ha while mild injury (2.66) was noticed in the treatments, butachlor 1.00 kg a.i. per ha, oxyflurofen 0.25 kg a.i. per ha and 2,4-D 0.75 kg a.i. per ha. Benthocarb at both the doses 1.00 kg and 0.75 kg a.i. per ha resulted in slight stunting of the crop (2.33).

(b) At 40 days after sowing

On 40th days after sowing, mild injury (2.66) was seen in oxyflurofen 0.50 kg a.i. per ha and butachlor 1.00 kg a.i. per ha. Application of 2,4-D 0.75 kg a.i. per ha, butachlor 0.75 kg a.i. per ha and benthocarb 0.75 kg a.i. per ha resulted in slight injury to the crop (2.33).

(c) At 50 days after sowing

Oxyflurofen 0.50 kg a.i. per ha showed only a slight injury (2.00) while all other treatments did not show any injury to the crop.

4.5 Studies on crop growth

4.5.1 Plant height

The observations on plant height recorded on 60 and 90 days after sowing and at harvest are presented in Table 9. No significant differences in the plant height was noticed at any stage of the crop growth. However hand weeded twice at 20 and 45 days after sowing recorded taller plants.

Table 9. Effect of different weed control treatments on plant height(cm) at different crop growth stages in drill sown Jaya rice.

Treatments	Days after sowing		At harvest
	30	90	
2,4-D 1.00 kg a.i./ha 25 DAS	11.09	32.10	48.90
2,4-D 0.75 kg a.i./ha 25 DAS + 1 HW	10.03	25.35	51.37
Bucachlor 1.00 kg a.i./ha pre-em.	10.65	29.38	52.05
Bucachlor 0.75 kg a.i./ha pre-em. + 1 HW	10.52	28.20	53.54
Pendimethalin 1.00 kg a.i./ha pre-em.	10.45	29.20	56.96
Pendimethalin 0.75 kg a.i./ha pre-em. + 1 HW	10.95	28.40	55.26
Oxyflurofen 0.50 kg a.i./ha pre-em.	11.82	27.53	52.51
Oxyflurofen 0.25 kg a.i./ha pre-em. + 1 HW	10.56	27.26	53.44
Oxadiazon 1.00 kg a.i./ha pre-em.	10.29	27.53	52.16
Oxadiazon 0.75 kg a.i./ha pre-em. + 1 HW	10.49	28.70	54.21
Benthiocarb 1.00 kg a.i./ha pre-em.	11.14	31.33	51.83
Benthiocarb 0.75 kg a.i./ha pre-em. + 1 HW	10.40	27.10	56.52
Hand weeding once at 45 DAS	10.54	27.16	52.52
Hand weeding twice at 20 and 45 DAS	10.92	28.56	57.10
Unweeded control	11.66	32.06	49.51
F - test	NS	NS	NS
S.E.m±	0.51	1.55	1.84
DAS indicates days after sowing 1 HW indicates one hand weeding			
NS indicates not significant at P=0.05 45 days after sowing			

4.5.2 Total number of shoots in 0.5 meter row length

Total number of shoots in 0.5 meter row length recorded at 30, 60 and 90 days after sowing and at harvest are presented in Table 10.

(a) At 30 days after sowing

The total number of shoots differed significantly among the weed control treatments. Pendimethalin 0.75 kg a.i. per ha recorded the highest number (78.99) while unweeded control recorded the lowest number (38.33). All the weed control treatments recorded significantly higher number of shoots (56.88 to 78.99) as compared to unweeded control (38.33), excepting 2,4-D 1.00 kg a.i. per ha (42.33), 2,4-D 0.75 kg a.i. per ha (45.94), butachlor 1.00 kg a.i. per ha (53.88) and oxyflurofen 0.5 kg a.i. per ha which were on par. There was significant difference between hand weeding once (56.88) and hand weeded twice (73.99), which was on par with pendimethalin 0.75 kg a.i. per ha (71.77), butachlor 0.75 kg a.i. per ha (66.8), benchiocarb 1.00 kg a.i. per ha (65.33), oxadiazon 1.00 kg a.i. per ha (64.22) and oxadiazon 0.75 kg a.i. per ha (62.88).

Table 10. Effect of different weed control treatments on total number of shoots (No./0.5m row length) at different crop growth stages in drill sown Jaya rice.

Treatments	Days after sowing			At harvest
	30	60	90	
2,4-D 1.00 kg a.i./ha 25 DAS	42.33	38.21	34.66	39.55
2,4-D 0.75 kg a.i./ha 25 DAS + 1 HW	45.94	76.22	62.66	58.66
Butachlor 1.00 kg a.i./ha pre-em.	53.88	80.77	39.55	52.76
Butachlor 0.75 kg a.i./ha pre-em. + 1 HW	66.88	105.10	77.08	65.43
Pendimethalin 1.00 kg a.i./ha pre-em.	61.99	100.55	64.88	52.10
Pendimethalin 0.75 kg a.i./ha pre-em. + 1 HW	78.99	101.55	72.33	58.32
Oxyfluorfen 0.50 kg a.i./ha pre-em.	49.55	84.33	57.99	60.55
Oxyfluorfen 0.25 kg a.i./ha pre-em. + 1 HW	58.10	97.44	73.44	66.10
Oxadiazon 1.00 kg a.i./ha pre-em.	64.22	92.44	66.16	57.99
Oxadiazon 0.75 kg a.i./ha pre-em. + 1 HW	62.88	99.00	80.19	67.53
Benchiocarb 1.00 kg a.i./ha pre-em.	65.33	82.10	49.66	42.54
Benchiocarb 0.75 kg a.i./ha pre-em. + 1 HW	71.77	99.22	67.55	58.99
Hand weeding once at 45 DAS	56.88	93.22	72.20	63.88
Hand weeding twice at 20 and 45 DAS	73.99	96.77	74.31	72.44
Unweeded control	38.33	45.99	29.66	35.88
F - test	*	*	*	*
S.E.m±	5.66	7.72	5.51	3.53
C.D. at 5%	16.34	22.31	15.90	10.21

DAS indicates days after sowing

1 HW indicates one hand weeding
45 days after sowing

(b) At 60 days after sowing

The total number of shoots differed significantly among the weed control treatments. All weed control treatments recorded significantly higher number of shoots (76.22 to 105.10) as compared to unweeded control (45.99), excepting 2,4-D sodium salt 1.00 kg a.i. per ha which recorded the lowest number of shoots (38.21). The herbicidal treatments in combination with one hand weeding did not differ significantly from the herbicides alone except 2,4-D sodium salt 0.75 kg a.i. per ha plus one hand weeding (76.22) and butachlor 0.75 kg a.i. per ha plus one hand weeding (105.10) which recorded significantly higher number of shoots as compared to 2,4-D sodium salt alone 1.00 kg a.i. per ha (38.21) and butachlor alone 1.00 kg a.i. per ha (80.77) respectively. Among the herbicides alone, pendimethalin 1.00 kg a.i. per ha recorded the highest number of shoots (100.55) followed by oxadiazon 1.00 kg a.i. per ha (92.44), oxyfluorfen 0.50 kg a.i. per ha (84.33), benthiocarb 1.00 kg a.i. per ha (82.10), and butachlor 1.00 kg a.i. per ha (80.77) which were on par with hand weeded twice (96.77).

(c) At 90 days after sowing

The total number of shoots differed significantly among the weed control treatments. All weed control

treatments recorded significantly higher number of shoots (49.66 to 80.19) as compared to unweeded control (29.66) excepting 2,4-D sodium salt 1.00 kg a.i. per ha (34.66) and butachlor 1.00 kg a.i. per ha (39.55). All herbicidal treatments in combination with one hand weeding recorded significantly higher number of shoots (62.66 to 77.08) compared to herbicides alone (34.66 to 64.88) except oxyflurofen 0.25 kg a.i. per ha plus one hand weeding (73.44) and oxadiazon 0.75 kg a.i. per ha plus one hand weeding (80.19), which recorded higher number of shoots than herbicides alone 57.99 and 66.16 respectively. Oxadiazon 0.75 kg a.i. per ha plus one hand weeding recorded the highest number of shoots (80.19), which was on par with hand weeded twice (74.31) and hand weeded once (74.31) while unweeded control recorded the lowest number of shoots (29.66). Among the herbicides alone, oxadiazon 1.00 kg a.i. per ha recorded the highest number of shoots (66.16) while 2,4-D sodium salt 1.00 kg a.i. per ha recorded the lowest number of shoots (34.66). There was no significant difference between hand weeded once (72.20) and hand weeded twice (74.31) which were on par.

(d) At harvest

The total number of shoots differed significantly among the weed control treatments. All weed control treatments recorded significantly higher number of shoots (52.10 to 72.44) as compared to unweeded control (35.88), excepting 2,4-D sodium salt 1.00 kg a.i. per ha (39.55) and benthocarb 1.00 kg a.i. per ha (42.54). The herbicidal treatments in combination with one hand weeding showed significant difference from herbicides alone in case of 2,4-D 0.75 kg a.i. per ha plus one hand weeding (58.66), butachlor 0.75 kg a.i. per ha plus one hand weeding (65.43) and benthocarb 0.75 kg a.i. per ha plus one hand weeding (58.99) which recorded higher number of shoots than 2,4-D 1.00 kg a.i. per ha (39.55), butachlor 1.00 kg a.i. per ha (52.76) and benthocarb 1.00 kg a.i. per ha (42.54) respectively. Hand weeded twice recorded the highest number of shoots (72.44), which was on par with oxadiazon 0.75 kg a.i. per ha plus one hand weeding (67.53), butachlor 0.75 kg a.i. per ha plus one hand weeding (65.43), oxyflurofen 0.25 kg a.i. per ha plus one hand weeding (66.10) and hand weeded once (63.88). Among the herbicides alone oxyflurofen 0.50 kg a.i. per ha recorded the highest number of shoots, while 2,4-D sodium salt 1.00 kg a.i. per ha recorded the lowest number of shoots, which was on par

with benthocarb 1.00 kg a.i. per ha (42.54) and unweeded control (36.88). There was no significant difference between hand weeded once (63.88) and hand weeded twice (72.44).

In general, the total number of shoots increased from 30th day after sowing upto 60th day after sowing and there after slightly decreased upto harvest in different weed control treatments. The herbicidal treatments in combination with one hand weeding increased the number of shoots.

4.5.3 Total dry matter production of crop

Observations on dry matter production of crop sampled in 0.25 m^2 area at 30, 60 and 90 days after sowing and at harvest are presented in Table 11.

(a) At 30 days after sowing

Dry matter production of crop differed significantly among the weed control treatments. Hand weeded twice recorded the highest dry weight of the crop ($10.86 \text{ g}/0.25 \text{ m}^2$) while oxadiazon 0.75 kg a.i. per ha recorded the lowest dry weight ($6.20 \text{ g}/0.25 \text{ m}^2$). Hand weeded twice ($10.86 \text{ g}/0.25 \text{ m}^2$), oxyflurofen 0.50 kg a.i. per ha ($10.73 \text{ g}/0.25 \text{ m}^2$), benthocarb 1.00 kg a.i. per ha ($9.80 \text{ g}/0.25 \text{ m}^2$) and

Table 11. Effect of different weed control treatments on dry matter production of plants (g/0.25 m² area) at different crop growth stages in drill sown Jaya rice.

Treatments	Days after sowing			At harvest
	30	60	90	
2,4-D 1.00 kg a.i./ha 25 DAS	7.33	23.86	57.60	127.66
2,4-D 0.75 kg a.i./ha 25 DAS + 1 HW	7.20	23.93	101.30	248.66
Bucachlor 1.00 kg a.i./ha pre-em.	8.56	38.86	92.00	260.66
Bucachlor 0.75 kg a.i./ha pre-em. + 1 HW	6.90	39.86	110.93	283.33
Pendimethalin 1.00 kg a.i./ha pre-em.	7.66	43.20	100.20	223.33
Pendimethalin 0.75 kg a.i./ha pre-em. + 1 HW	4.66	45.86	106.33	237.00
Oxyflurofen 0.50 kg a.i./ha pre-em.	10.73	56.66	119.13	276.00
Oxyflurofen 0.25 kg a.i./ha pre-em. + 1 HW	9.06	63.50	126.33	321.00
Oxadiazon 1.00 kg a.i./ha pre-em.	6.43	32.20	102.33	302.00
Oxadiazon 0.75 kg a.i./ha pre-em. + 1 HW	6.20	40.36	103.50	264.66
Benthiocarb 1.00 kg a.i./ha pre-em.	9.80	29.80	65.35	214.33
Benthiocarb 0.75 kg a.i./ha pre-em. + 1 HW	8.73	28.33	101.73	228.00
Hand weeding once at 45 DAS	7.16	25.06	66.33	236.00
Hand weeding twice at 20 and 45 DAS	10.86	39.13	102.60	277.66
Unweeded control	6.33	22.20	56.60	101.66
F - test	*	*	*	*
S.E.m _t	0.92	4.72	14.89	20.03
C.D. at 5%	2.66	13.65	43.10	57.84

DAS indicates days after sowing

1 HW indicates one hand weeding
45 days after sowing

oxyflurofen 0.25 kg a.i. per ha ($9.06 \text{ g}/0.25 \text{ m}^2$) differed significantly from the unweeded control which recorded 6.33 g per 0.25 m^2 area, while all the other treatments showed no significant difference with unweeded control.

(b) At 60 days after sowing

Dry matter production of crop differed significantly among the weed control treatments. All herbicidal treatments in combination with one hand weeding recorded higher dry weight of the crop (23.93 to $63.50 \text{ g}/0.25 \text{ m}^2$) as compared to herbicides alone (23.86 to $56.66 \text{ g}/0.25 \text{ m}^2$) excepting benthocarb 0.75 kg a.i. per ha plus one hand weeding which recorded lesser dry weight of the crop ($28.33 \text{ g}/0.25 \text{ m}^2$) than benthocarb 1.00 kg a.i. per ha alone ($29.80 \text{ g}/0.25 \text{ m}^2$). Oxyflurofen 0.25 kg a.i. per ha plus one hand weeding recorded the highest dry weight ($63.50 \text{ g}/0.25 \text{ m}^2$) while unweeded control recorded the lowest dry weight of the crop ($22.28 \text{ g}/0.25 \text{ m}^2$). Among herbicides alone, oxyflurofen 0.50 kg a.i. per ha recorded the highest dry weight ($56.66 \text{ g}/0.25 \text{ m}^2$) followed by pendimethalin 1.00 kg a.i. per ha ($43.20 \text{ g}/0.25 \text{ m}^2$). Hand weeded once recorded significantly lower crop dry weight ($25.06 \text{ g}/0.25 \text{ m}^2$) as compared to hand weeded twice ($39.13 \text{ g}/0.25 \text{ m}^2$), which was on par with butachlor 0.75 kg a.i. per ha plus one hand weeding ($39.86 \text{ g}/0.25 \text{ m}^2$), oxadiazon 0.75 kg a.i. per ha plus one hand

weeding (40.36 g/0.25 m²), pendimethalin 1.00 kg a.i. per ha (42.30 g/0.25 m²) and pendimethalin 0.75 kg a.i. per ha plus one hand weeding (45.86 g/0.25 m²).

(c) At 90 days after sowing

Dry matter production of crop differed significantly among the weed control treatments. All herbicidal treatments in combination with one hand weeding recorded higher dry weight of crop (101.73 to 126.33 g/0.25 m²) as compared to herbicides alone (65.35 to 119.13 g/0.25 m²) excepting 2,4-D. 2,4-D sodium salt 0.75 kg a.i. per ha plus one hand weeding recorded significantly higher dry weight of crop (101.30 g/0.25 m²) as compared to 2,4-D sodium salt alone at the rate of 1.00 kg a.i. per ha (57.6 g/0.25 m²). oxyflurofen 0.25 kg a.i. per ha plus one hand weeding recorded the highest dry weight of crop (126.33 g/0.25 m²) followed by oxyflurofen 0.50 kg a.i. per ha (119.13 g/0.25 m²) which were on par. All the weed control treatments recorded significantly higher dry weight of the crop (100.20 to 126.33 g/0.25 m²) as compared to unweeded control (56.60 g/0.25 m²) excepting 2,4-D sodium salt 1.00 kg a.i. per ha (57.6 g/0.25 m²), benthocarb 1.00 kg a.i. per ha (65.35 g/0.25 m²), hand weeded once (66.33 g/0.25 m²) and butachlor 1.00 kg a.i. per ha (92.0 g/0.25 m²) which were on par.

(d) At harvest

Dry matter production of crop differed significantly among the weed control treatments. All weed control treatments recorded significantly higher dry weight of the crop (214.33 to 321.0 g/0.25 m²) as compared to unweeded control (101.66 g/0.25 m²) except 2,4-D sodium salt 1.00 kg a.i. per ha which recorded 127.66 g per 0.25 m² area. 2,4-D 0.75 kg a.i. per ha plus one hand weeding recorded significantly higher dry weight (248.6 g/0.25 m²) as compared to 2,4-D alone at the rate of 1.00 kg a.i. per ha (127.66 g/0.25 m²), while all other herbicidal treatments in combination with one hand weeding recorded higher dry weight of the crop (228.0 to 321.0 g/0.24 m²) as compared to herbicides alone (214.33 to 276.0 g/0.24 m²), excepting oxadiazon. Oxadiazon alone at the rate of 1.00 kg a.i. per ha recorded higher dry weight of crop (302.0 g/0.25 m²) compared to oxadiazon 0.75 kg a.i. per ha plus one hand weeding (264.66 g/0.25 m²). Highest dry weight of the crop (321.0 g/0.25 m²) was recorded by oxyflurofen 0.26 kg a.i. per ha plus one hand weeding followed by oxadiazon 1.00 kg a.i. per ha (302.0 g/0.25 m²), butachlor 0.75 kg a.i. per ha plus one hand weeding (283.33 g/0.25 m²), hand weeded twice (277.66 g/0.25 m²) and oxyflurofen 0.50 kg a.i. per ha (276.0 g/0.25 m²) which were on par. Hand weeded once at 45 days

after sowing recorded 236.0 g per 0.25 m² area which was on par with hand weeding twice at 20 and 45 days after sowing (277.66 g/0.25 m²).

4.6 Studies on crop yield

Data on grain yield (q/ha), straw yield (q/ha), weed index (%) and dry weight of weeds at harvest (q/ha) are presented in Table 12 and Fig.4.

4.6.1 Grain yield

Grain yield differed significantly among the weed control treatments. Application of herbicides in combination with one hand weeding 45 days after sowing gave significantly higher grain yield (29.15 to 59.67 q/ha) as compared to herbicides alone (8.91 to 41.69 q/ha) except benthocarb. Benthocarb 0.75 kg a.i. per ha plus one hand weeding recorded higher grain yield (15.18 q/ha) as compared to benthocarb 1.00 kg a.i. per ha (14.27 q/ha), but the difference was not significant. All the weed control treatments recorded significantly higher grain yield (8.91 to 59.67 q/ha) as compared to unweeded control (Plate 9). Oxyflurofen 0.25 kg a.i. per ha plus one hand weeding recorded significantly higher grain yield

Table 12. Effect of different weed control treatments on grain and straw yield of drill sown Jaya rice and weed dry matter production at harvest.

Treatments	Grain yield (q/ha)	Straw yield (q/ha)	Weed weight (q/ha)	Weed index (%)
2,4-D 1.00 kg a.i./ha 25 DAS	8.91	22.40	56.40	79.35
2,4-D 0.75 kg a.i./ha 25 DAS + 1 HW	29.15	75.40	31.70	32.46
Butachlor 1.00 kg a.i./ha pre-em.	26.81	57.10	40.30	37.88
Butachlor 0.75 kg a.i./ha pre-em. + 1 HW	39.57	78.10	14.90	8.31
Pendimethalin 1.00 kg a.i./ha pre-em.	17.52	48.10	36.80	59.40
Pendimethalin 0.75 kg a.i./ha pre-em. + 1 HW	31.95	76.30	20.40	25.97
Oxyflurofen 0.50 kg a.i./ha pre-em.	41.69	60.80	37.20	3.40
Oxyflurofen 0.25 kg a.i./ha pre-em. + 1 HW	59.67	85.30	8.30	-38.25
Oxadiazon 1.00 kg a.i./ha pre-em.	31.11	59.10	38.90	27.91
Oxadiazon 0.75 kg a.i./ha pre-em. + 1 HW	48.64	79.90	13.20	-12.69
Benchiocarb 1.00 kg a.i./ha pre-em.	14.27	32.40	49.10	66.93
Benchiocarb 0.75 kg a.i./ha pre-em. + 1 HW	15.18	54.30	35.50	64.82
Hand weeding once at 45 DAS	23.98	59.80	39.80	44.43
Hand weeding twice at 20 and 45 DAS	43.16	72.90	26.80	0.00
Unweeded control	00.44	18.20	83.60	98.98
F - test	*	*	*	-
S.E.m	2.82	7.26	6.17	-
C.D. at 5%	8.15	20.98	17.80	-
DAS indicates days after sowing	1 HW indicates one hand weeding 45 days after sowing			

LEGEND

T1. 2,4-D 1.00 Kg ai./ha 25 DAS	T10. OXADIAZON 0.75 Kg ai./ha pre-em + 1 HW 45 DAS
T2. 2,4-D 0.75 Kg ai./ha 25 DAS + 1 HW 45 DAS	T11. BENTHIOCARB 1.00 Kg ai./ha pre-em
T3. BUTACHLOR 1.00 Kg ai./ha pre-em	T12. BENTHIOCARB 0.75 Kg ai./ha pre-em + 1 HW 45 DAS
T4. BUTACHLOR 0.75 Kg ai./ha pre-em + 1 HW 45 DAS	T13. HAND WEEDING ONCE AT 45 DAS
T5. PENDIMETHALIN 1.00 Kg ai./ha pre-em	T14. HAND WEEDING TWICE AT 20 AND 45 DAS
T6. PENDIMETHALIN 0.75 Kg ai./ha pre-em + 1 HW 45 DAS	T15. UNWEEDED CONTROL
T7. OXYFLUROFEN 0.50 Kg ai./ha pre-em	□ - GRAIN YIELD
T8. OXYFLUROFEN 0.25 Kg ai./ha pre-em 1 HW 45 DAS	▨ - STRAW YIELD
T9. OXADIAZON 1.00 Kg ai./ha pre-em	▩ - WEED WEIGHT

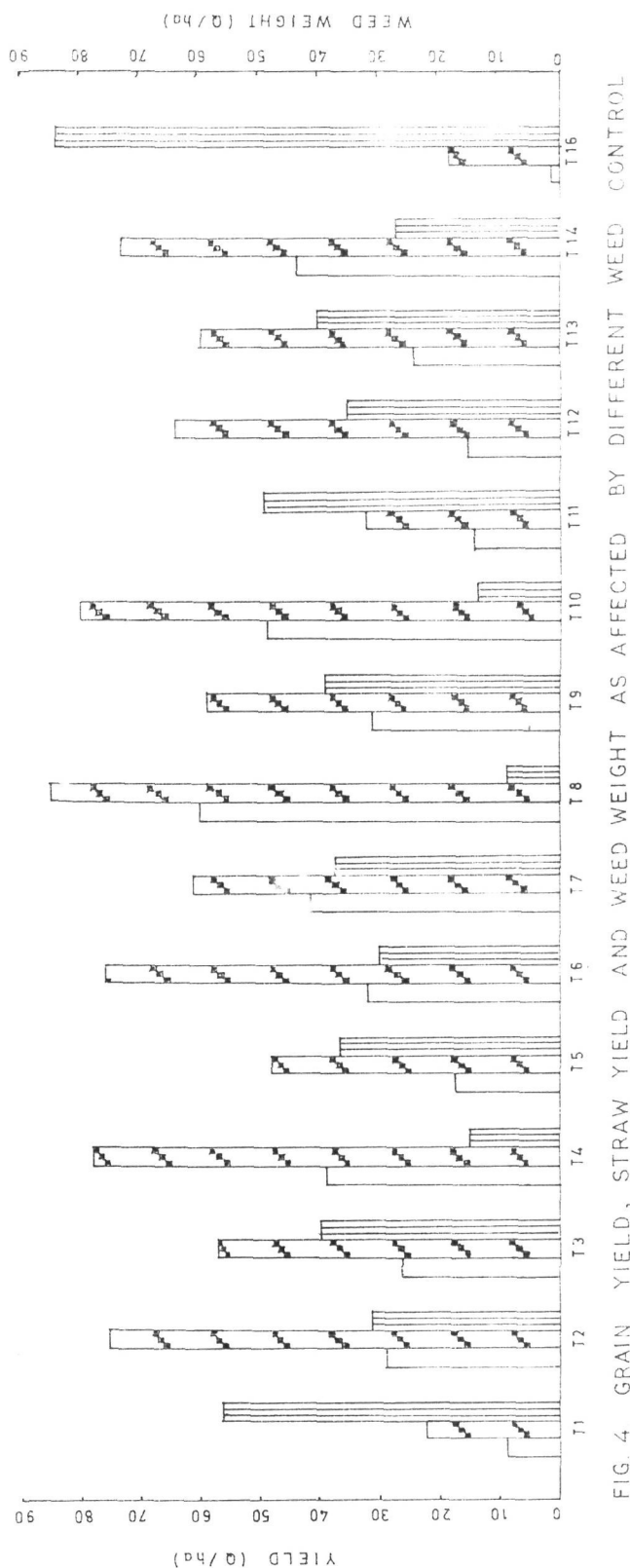


FIG. 4 GRAIN YIELD, STRAW YIELD AND WEED WEIGHT AS AFFECTED BY DIFFERENT WEED TREATMENTS IN DRILL SOWN JAYA RICE.

Plate 9. Plot showing heavy infestation of
weeds in unweeded control treatment.

Plate 10. Plot treated with oxyflurofen 0.25 kg
a.i. per ha plus one hand weeding
45 days after sowing.



plate 9



plate 10

Plate 11. Plot treated with oxadiazon 0.75 kg
a.i. per ha plus one hand weeding
45 days after sowing.

Plate 12. Plot hand weeded twice at 20 and
45 days after sowing.



Plate 11



Plate 12

(59.67 q/ha) as compared to all other treatments (Plate 10) whereas oxadiazon 0.75 kg a.i. per ha plus one hand weeding (48.64 q/ha), hand weeded twice (43.16 q/ha) were on par (Plate 11 and 12) while oxyflurofen 0.50 kg a.i. per ha (41.69 q/ha) and butachlor 0.75 kg a.i. per ha plus one hand weeding (39.57 q/ha) were on par. Among herbicides alone, oxyflurofen 0.50 kg a.i. per ha recorded significantly higher grain yield (41.69 q/ha), followed by oxadiazon 1.00 kg a.i. per ha (31.11 q/ha) and butachlor 1.00 kg a.i. per ha (26.81 q/ha), which were on par. Hand weeded twice recorded significantly higher grain yield (43.16 q/ha) as compared to hand weeded once (23.98 q/ha).

4.6.2 Straw yield

Straw yield also differed significantly among the weed control treatments. Application of herbicides in combination with one hand weeding 45 days after sowing gave significantly higher straw yield (64.3 to 85.3 q/ha) as compared to herbicides alone (22.4 to 60.8 q/ha). All weed control treatments recorded significantly higher straw yield (48.1 to 85.3 q/ha) as compared to unweeded control (18.2 q/ha), excepting 2,4-D sodium salt 1.00 kg a.i. per ha (22.4 q/ha) and benthocarb 1.00 kg a.i. per ha (32.4 q/ha), which were on par. Oxyflurofen 0.25 kg

a.i. per ha plus one hand weeding recorded the highest straw yield (85.3 q/ha), followed by oxadiazon 0.75 kg a.i. per ha plus one hand weeding (79.9 q/ha), butachlor 0.75 kg a.i. per ha plus one hand weeding (78.1 q/ha), pendimethalin 0.75 kg a.i. per ha plus one hand weeding (76.3 q/ha), 2,4-D sodium salt 0.75 kg a.i. per ha plus one hand weeding (75.4 q/ha), and hand weeded twice (72.9 q/ha), which were on par. Among the herbicides alone oxyflurofen 0.50 kg a.i. per ha recorded the highest straw yield (60.8 q/ha), while 2,4-D sodium salt 1.00 kg a.i. per ha recorded the lowest (22.4 q/ha) followed by benthocarb 1.00 kg a.i. per ha (32.4 q/ha) which were on par with the unweeded control (18.2 q/ha). There was no significant difference between hand weeded once (59.8 q/ha) and hand weeded twice (72.9 q/ha).

4.6.3 Weed Index (%)

Weed index expresses the competition offered by weeds as measured by percentage reduction in yield owing to their presence in the field. It was computed taking hand weeding twice at 20 and 45 days after sowing as weed free plot.

All herbicidal treatments in combination with one hand weeding 45 days after sowing showed lower reduction

in grain yield (-38.25 to 64.82 per cent) as compared to herbicides alone (3.40 to 79.35 per cent). Yield reduction due to weed competition was the highest in the unweeded control (98.98 per cent) followed by 2,4-D 1.00 kg a.i. per ha (79.35 per cent), benchiocarb 1.00 kg a.i. per ha (66.93 per cent), benchiocarb 0.75 kg a.i. per ha plus one hand weeding (64.82 per cent), pendimethalin 1.00 kg a.i. per ha (59.40 per cent), and hand weeded once (44.43 per cent). Oxyflurofen 0.25 kg a.i. per ha plus one hand weeding (-38.25 per cent) and oxadiazon 0.75 kg a.i. per ha plus one hand weeding (-12.69) recorded the negative weed index, due to more grain yield 59.67 and 48.64 q/ha respectively as compared to weed free treatment (43.16 q/ha).

4.6.4 Weed dry weight

At harvest of the crop, the dry weight of weeds in net plot was recorded and expressed in quintal per ha.

Weed dry weight differed significantly among the weed control treatments. All weed control treatments recorded significantly lower weed dry weight (8.3 to 56.4 q/ha) as compared to unweeded control (83.6 q/ha). All the herbicidal treatments in combination with one hand weeding recorded lower weed dry weight (8.3 to

35.5 q/ha) as compared to herbicides alone (36.8 to 56.4 q/ha). Application of oxyflurofen 0.25 kg a.i. per ha plus one hand weeding recorded the lowest weed dry weight (8.3 q/ha) followed by oxadiazon 0.75 kg a.i. per ha plus one hand weeding (13.2 q/ha), butachlor 0.75 kg a.i. per ha plus one hand weeding (14.9 q/ha), and hand weeded twice (26.8 q/ha). There was no significant difference between hand weeded once (39.8 q/ha) and hand weeded twice (26.8 q/ha). The unweeded control (83.6 q/ha) and 2,4-D 1.00 kg a.i. per ha (56.4 q/ha) recorded higher weed dry weight as compared to other treatments.

4.7 Studies on yield components

Observations on yield components like the number of productive shoots per 0.50 meter row length, the number of unproductive shoots per 0.50 meter row length, panicle length (cm), sterility percentage (%) and 1000 grain weight (g) are presented in Table 13.

4.7.1 Number of productive shoots per 0.5 meter row length

The number of productive shoots at harvest differed significantly among the weed control treatments. All herbicidal treatments in combination with one hand weeding recorded significantly higher number of productive

Table 13. Effect of different weed control treatments on yield components in drill sown Jaya rice.

Treatments	No. of productive shoots/ 0.5m row length	No. of unproductive shoots/ 0.5m row length	Panicle length (cm)	Sterility (%)	1000 grain weight (g)
2,4-D 1.00 kg a.i./ha 25 DAS	22.55	16.99	16.01	62.08	26.33
2,4-D 0.75 kg a.i./ha 25 DAS + 1 HW	55.66	3.00	15.59	33.99	27.33
Butachlor 1.00 kg a.i./ha pre-em.	45.32	7.44	15.45	44.83	27.16
Butachlor 0.75 kg a.i./ha pre-em. + 1 HW	61.88	3.55	15.78	33.50	28.06
Pendimethalin 1.00 kg a.i./ha pre-em.	45.55	6.55	15.43	39.94	26.66
Pendimethalin 0.75 kg a.i./ha pre-em. + 1 HW	55.22	3.10	15.65	40.18	27.33
Oxyflurofen 0.50 kg a.i./ha pre-em.	57.20	3.33	16.10	28.34	28.33
Oxyflurofen 0.25 kg a.i./ha pre-em. + 1 HW	63.33	2.77	16.10	22.34	28.46
Oxadiazon 1.00 kg a.i./ha pre-em.	53.88	4.10	15.79	30.61	25.96
Oxadiazon 0.75 kg a.i./ha pre-em. + 1 HW	64.55	2.97	16.00	24.41	28.20
Benthiocarb 1.00 kg a.i./ha pre-em.	34.33	8.21	15.66	38.57	26.83
Benthiocarb 0.75 kg a.i./ha pre-em. + 1 HW	54.99	3.99	15.96	57.90	26.48
Hand weeding once at 45 DAS	55.44	8.44	15.33	38.58	27.00
Hand weeding twice at 20 and 45 DAS	61.11	4.66	15.76	35.25	27.66
Unweeded control	16.55	19.33	15.23	81.00	25.96
F - test	*	*	NS	*	NS
S.E.m±	3.66	1.64	0.37	5.06	0.69
C.D. at 5%	10.58	4.76	-	17.52	-

DAS indicates days after sowing 1 HW indicates one hand weeding

45 days after sowing

NS indicates not significant at P=0.05

shoots (55.22 to 64.55/0.5m) as compared to herbicides alone (22.5 to 57.20/0.5m), except oxyflurofen.

Oxyflurofen 0.25 kg a.i. per ha plus one hand weeding recorded higher number of productive shoots (63.33/0.5m) as compared to oxyflurofen (0.50 kg a.i. per ha) alone (57.20/0.5m), but the difference was not significant.

All weed control treatments recorded significantly higher number of productive shoots (34.33 to 64.55) as compared to unweeded control (16.55/0.5m), except 2,4-D sodium salt 1.00 kg a.i. per ha (22.55/0.5m). Oxadiazon 1.00 kg a.i. per ha plus one hand weeding recorded the highest number of shoots (64.55/0.5m) followed by oxyflurofen 0.25 kg a.i. per ha plus one hand weeding (63.33/0.5m), hand weeded twice (61.11/0.5m), oxyflurofen 0.50 kg a.i. per ha (57.20/0.5m), 2,4-D 0.75 kg a.i. per ha plus one hand weeding (55.6/0.5m), hand weeded once (55.44/0.5m), and pendimethalin 0.75 kg a.i. per ha plus one hand weeding (55.22/0.5m), which were on par. There was no significant difference between hand weeded once (55.44/0.5m) and hand weeded twice (61.11/0.5m).

4.7.2 Number of unproductive shoots per 0.5 meter row length

The number of unproductive shoots at harvest differed significantly among the weed control treatments.

All weed control treatments recorded significantly lower number of unproductive shoots (2.77 to 8.44/0.5m), as compared to unweeded control (19.33/0.5m), except 2,4-D sodium salt 1.00 kg a.i. per ha (16.99/0.5m). Oxyflurofen 0.25 kg a.i. per ha plus one hand weeding recorded the lowest number of unproductive shoots (2.77/0.5m), followed by oxadiazon 0.75 kg a.i. per ha plus one hand weeding (2.97/0.5m), 2,4-D 0.75 kg a.i. per ha plus one hand weeding (3.0/0.5m), pendimethalin 0.75 kg a.i. per ha plus one hand weeding (3.10/0.5m), oxyflurofen 0.50 kg a.i. per ha (3.33/0.5m), butachlor 0.75 kg a.i. per ha plus one hand weeding (3.55/0.5m) benthocarb 0.75 kg a.i. per ha plus one hand weeding (3.99/0.5m), and oxadiazon 1.00 kg a.i. per ha (4.10/0.5m). Hand weeded twice recorded the lower number of unproductive shoots (4.66/0.5m) as compared to hand weeded once (8.44/0.5m).

4.7.3 Panicle length

Panicle length did not differ significantly among the weed control treatments. Panicle length was maximum in oxyflurofen 0.50 kg a.i. per ha and oxyflurofen 0.25 kg a.i. per ha plus one hand weeding (16.0 cm) as compared to other weed control treatments. The unweeded control recorded the minimum panicle length (15.23 cm).

4.7.4 Sterility percentage

Sterility percentage also differed significantly among the weed control treatments. All weed control treatments recorded significantly lower sterility percentage (22.34 to 62.08) as compared to unweeded control, which recorded the highest sterility percentage (81.00). All herbicidal treatments in combination with one hand weeding reduced the sterility percentage (22.34 to 57.90) as compared to herbicides alone (28.34 to 62.08). Oxyflurofen 0.25 kg a.i. per ha plus one hand weeding recorded the lowest sterility percentage (22.34), followed by oxyflurofen 0.50 kg a.i. per ha (28.34), oxadiazon 1.00 kg a.i. per ha (30.61) and butachlor 0.75 kg a.i. per ha plus one hand weeding (33.50). Benthocarb 0.75 kg. a.i. per ha plus one hand weeding (57.90), 2,4-D 1.00 kg a.i. per ha (62.08) and unweeded control (81.00) recorded higher sterility percentage compared to other treatments. There was no significant difference between hand weeded once (38.58) and hand weeded twice (35.25).

4.7.5 Thousand grain weight

Thousand grain weight did not differ significantly among the weed control treatments. Thousand grain weight was maximum in the treatment oxyflurofen 0.25 kg a.i. per

ha plus one hand weeding (28.46 g) followed by oxyfluorfen 0.50 kg a.i. per ha (28.33 g), while unweeded control recorded the minimum (25.96 g).

4.8 Correlation studies

The correlation co-efficient values ('r') were worked out for grain yield versus weed weight, number of productive tillers, number of unproductive tillers, panicle length, test weight and sterility percentage, and also for straw yield versus weed weight. The 'r' values are presented in Table 14.

Grain yield had the positive significant correlation with number of productive shoots ($r=0.85$), panicle length ($r=0.78$), test weight ($r=0.84$), and straw yield ($r=0.86$). Grain yield had the negative significant correlation with weed weight ($r= -0.87$), number of unproductive shoots ($r= -0.76$), and sterility percentage ($r= -0.85$). Straw yield had a negative correlation with weed weight ($r = -0.91$) which was significant.

4.9 Economics of different weed control treatments

Economics of different weed control treatments in drill sown rice is presented in Table 15. Cost of weed control, total cost of cultivation and net returns could not be worked out in pendimethalin, oxadiazon and

Table 14. Correlation co-efficient values ('r') for grain yield with weed weight and yield components

	Grain yield	Weed weight	No. of productive tillers/0.5m row length	No. of unproductive tillers/0.5m row length	Panicle length	Test weight	Sterility	Straw yield
Grain yield		-0.878*	0.851*	-0.763*	0.780*	0.848*	-0.857*	0.860*
Weed weight			-0.913*	0.867*	-0.775*	-0.750*	0.845*	-0.917*
Number of productive tillers/0.5m row length				-0.932*	0.789*	0.675*	-0.828*	0.959*
Number of unproductive tillers/0.5m row length					-0.823*	-0.640*	+0.843*	-0.896*
Panicle length						0.656*	-0.822*	0.732*
Test weight							-0.801*	0.668*
Sterility percentage								-0.759*

* Significant at 5%

Table 15. Economics of weed control treatments in drill sown Jaya rice.

Treatments	Cost of cultivation excluding weed control (Rs/ha)	Cost of weed control (Rs/ha)	Total cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)
2,4-D 1.00 kg a.i./ha 25 DAS	2705=00	141=00	2846=00	2163=80	-682=20
2,4-D 0.75 kg a.i./ha 25 DAS + 1 HW	2705=00	524=00	3229=00	7132=00	3903=00
Bucachlor 1.00 kg a.i./ha pre-em.	2705=00	269=00	2974=00	6253=30	3279=30
Butachlor 0.75 kg a.i./ha + 1 HW	2705=00	622=00	3327=00	9075=10	5748=10
Pendimethalin 1.00 kg a.i./ha	2705=00	-	-	4356=10	-
Pendimethalin 0.75 kg a.i./ha + 1 HW	2705=00	-	-	7658=50	-
Oxyflurofen 0.50 kg a.i./ha	2705=00	913=00	3618=00	9024=20	5406=20
Oxyflurofen 0.25 kg a.i./ha + 1 HW	2705=00	807=00	3602=00	12873=10	9271=10
Oxadiazon 1.00 kg a.i./ha	2705=00	-	-	7077=30	-
Oxadiazon 0.75 kg a.i./ha + 1 HW	2705=00	-	-	10752=70	-
Benchiocarb 1.00 kg a.i./ha	2705=00	-	-	3378=60	-
Benchiocarb 0.75 kg a.i./ha + 1 HW	2705=00	-	-	4339=90	-
Hand weeding once at 45 DAS	2705=00	593=75	3298=75	5811=40	2512=65
Hand weeding twice at 20 and 45 DAS	2705=00	800=00	3505=00	9591=30	6086=30
Unweeded control	2705=00	-	2705=00	534=20	-2170=80

Oxyflurofen (24% EC) 1 lit = Rs. 400=00 DAS indicates days after sowing
 Bucachlor (50% EC) 1 lit = Rs. 94=00 1 HW indicates one hand weeding
 2,4-D Na salt WP 1 kg = Rs. 48=00 45 days after sowing

Rice grain Rs. 180/q. Rice straw Rs. 250/tonn

Labour cost : Man Rs. 8-50/day , Woman Rs. 7-50/day

benthiocarb treatments because these herbicides are not available in the market and hence their prices could not be known.

Gross returns were higher in all the herbicidal treatments in combination with one hand weeding (Rs. 4339=90 to 12873=10/ha) as compared to herbicides alone (Rs. 2163=80 to 9024=20/ha). The highest gross return was realised in the treatment oxyflurofen 0.25 kg a.i. per ha plus one hand weeding (Rs. 12873/ha) followed by oxadiazon 0.75 kg a.i. per ha plus one hand weeding (Rs. 10752=70/ha) hand weeding twice at 20 and 45 days after sowing (Rs. 9591=30/ha) and butachlor 0.75 kg a.i. per ha plus one hand weeding (Rs. 9075=10/ha). Unweeded control (Rs. 534=20/ha) and 2,4-D sodium salt 1.00 kg a.i. per ha (Rs. 2163=80/ha) gave lower gross return as compared to other treatments.

The cost of weed control was maximum in the treatment oxyflurofen 0.50 kg a.i. per ha (Rs. 913/ha) followed by oxyflurofen 0.25 kg a.i. per ha plus one hand weeding (Rs. 897/ha), hand weeding twice at 20 and 45 days after sowing (Rs. 800/ha) and butachlor 0.75 kg a.i. per ha plus one hand weeding (Rs. 622/ha). The lower cost of

weed control was recorded in the treatment 2,4-D sodium salt 1.00 kg a.i. per ha (Rs. 141=00/ha) and butachlor 1.00 kg a.i. per ha (Rs. 269/ha).

Highest net return was obtained in oxyflurofen 0.25 kg a.i. per ha plus one hand weeding (Rs. 9271/ha) followed by hand weeding twice at 20 and 45 days after sowing (Rs. 6086/ha), butachlor 0.75 kg a.i. per ha plus one hand weeding (Rs. 5748/ha) and oxyflurofen 0.50 kg a.i. per ha (Rs. 5406=20/ha). The lower net return was obtained in hand weeding once at 45 days after sowing (Rs. 2512=65/ha) and butachlor 1.00 kg a.i. per ha (Rs. 3279=30/ha). The unweeded control recorded a net loss of Rs. 2170 per ha. While 2,4-D sodium salt 0.75 kg a.i. per ha plus one hand weeding recorded a net profit of Rs. 3903 per ha, 2,4-D sodium salt alone at the rate of 1.00 kg a.i. per ha recorded a net loss of Rs. 682 per ha.

DISCUSSION

V. DISCUSSION

The present investigation was undertaken to find out the efficacy of some herbicides singly and in combination with one hand weeding to minimise weed infestation and to obtain better yields in drill sown rice. The results obtained from this investigation are discussed under the following heads:

1. Influence of different weed control treatments on crop yield and yield components.
2. Effect of different weed control treatments on crop growth.
3. Effect of different weed control treatments on weed growth.
4. Economics of different weed control treatments in drill sown rice.

5.1 Influence of different weed control treatments on crop yield and yield components

Heavy infestation of plots with both monocot and dicot weeds was observed. All herbicidal treatments in combination with one hand weeding 45 days after sowing gave significantly higher grain yield (15.18 to 59.67 q/ha) as compared to herbicides alone (8.91 to 41.69 q/ha). The higher grain yield can be attributed

to timely and effective control of weeds by herbicides at initial stages and later by hand weeding 45 days after sowing, which resulted in better availability of nutrients and light to the crop as evidenced from the beneficial effects on the crop growth reflected through increased number of productive shoots, length of panicle and decreased sterility percentage. Similar increase in grain yield of rice due to better weed control were reported by Misra and Roy (1970), Vijayaraghavan (1974), Gurmeh Singh and Chauhan (1978) and Rathi and Tewari (1979). Application of oxyflurofen 0.25 kg a.i. per ha plus one hand weeding recorded the highest grain yield (59.67 q/ha) followed by oxadiazon 0.75 kg a.i. per ha plus one hand weeding (48.64 q/ha) and hand weeding twice at 20 and 45 days after sowing (43.16 q/ha) as compared to any other treatments. Ghosh and Singh (1985) reported that pre-emergence application of oxyflurofen (0.1 kg a.i. /ha) effectively controlled the weeds of upland rice and produced highest grain yield.

Tosh and Nanda (1985) reported that oxadiazon (0.75 kg a.i./ha 3 days after sowing) supplemented by bushening operation (30 days after sowing) was effective in increasing the grain yield of direct seeded rice. Shetty and Gill (1975) reported that in direct sown rice two

hand weeding 22 and 55 days after sowing were insufficient for maximum yields.

Weed index which indicates the yield reduction due to weed competition was worked out. Maximum yield reduction of 98.98 per cent was observed in unweeded control followed by 2,4-D sodium salt 1.00 kg a.i. per ha 25 days after sowing (79.35 per cent) as compared to hand weeded treatment. Similar reduction in grain yield due to weed competition have been reported by Vega (1954), Tosh (1977) and Mohamed Ali and Sankaran (1984). This reduction in grain yield can be attributed to higher relative density of monocot weeds, higher dry matter production of weeds, lower total number of shoots, less number of productive shoots and shorter panicles. Okafor and DeDatta (1974) reported that grain yield reduction was due to reduced tiller and panicle number.

Straw yield was also high in all the herbicidal treatments in combination with one hand weeding (75.40 to 85.30 g/ha) as compared to herbicides alone (22.40 to 60.80 g/ha). Straw yield was highest in oxyflurofen 0.25 kg a.i. per ha plus one hand weeding treatment followed by oxadiazon 0.75 kg a.i. per ha plus one hand weeding. This increased straw yield may be attributed

to better weed control and there by better environment for plant growth as evidenced by increased number of total shoots and dry matter production of crop. The lowest straw yield of 18.20 q per ha was observed in unweeded control. Luxurious growth of weeds, especially monocots in unweeded control competed with the crop to maximum extent and suppressed the growth of crop and thus resulted in lower straw yield. Singh and Tandon (1982) reported that grain and straw yield without weed control was significantly lower than in the weed free check.

The difference in grain and straw yield was the consequence of differences in yield components as well as growth components. Among the yield components the number of productive shoots per 0.5 meter row length was higher in all herbicidal treatments in combination with one hand weeding (54.99 to 64.55/0.5m) as compared to herbicides alone (22.55 to 57.20/0.5m). Number of productive shoots per 0.5 meter row was the highest in oxadiazon 0.75 kg a.i. per ha plus one hand weeding (64.55/0.5m) followed by oxyflurofen 0.25 kg a.i. per ha plus one hand weeding (63.33/0.5m). Swain (1967) reported that weed competition reduced the tiller number by 45 per cent. The number of productive shoots was the main

contributing factor for grain yield. Thus grain yield was higher in those treatments where the number of productive shoots was also high. Application of 2,4-D sodium salt 1.00 kg a.i. per ha 25 days after sowing resulted in lower number of productive shoots (22.55/0.5m) followed by benthocarb 1.00 kg a.i. per ha (34.33/0.5m) among the weed control treatments, while unweeded control recorded the lowest (16.55/0.5m). 2,4-D 1.00 kg a.i. per ha even though controlled broad leaved weeds effectively, could not control the monocots effectively and thus resulted in lower productive shoots.

The number of unproductive shoots per 0.5 meter row length was less in all herbicidal treatments in combination with one hand weeding (2.77 to 3.99/0.5m) as compared to herbicides alone (3.33 to 16.92/0.5m). Oxyflurofen 0.25 kg a.i. per ha plus one hand weeding recorded the lowest number of unproductive shoots (2.77/0.5m) followed by oxadiazon 0.75 kg a.i. per ha plus one hand weeding (2.97/0.5m). The decrease in the number of unproductive shoots can be attributed to the better availability of nutrients and sunlight as evidenced by increase in the number of productive shoots.

Sterility percentage which indicates number of unfilled grains per panicle to the total number of grains per panicle, was worked out. All herbicidal treatments in combination with one hand weeding recorded the lower sterility percentage (24.41 to 57.90) as compared to herbicides alone (28.34 to 62.08). Oxyflurofen 0.25 kg a.i. per ha plus one hand weeding recorded the lowest sterility percentage (22.34), followed by oxadiazon 0.75 kg a.i. per ha plus one hand weeding (24.41), and oxyflurofen 0.5 kg a.i. per ha (28.34). Unweeded control recorded the highest sterility percentage (81.00). Smith (1968) and Kleinig and Nible (1968) reported that the number of filled grains per panicle decreased with the increase in weed population in rice field. This can be attributed to higher weed competition for nutrients, light and moisture with crop. Shading of earheads by tall weeds at developing and grain filling stage resulted in fewer number of filled grains per panicle (Basak and Chakraborty, 1963).

The panicle length and thousand grain weight did not differ significantly among the weed control treatments. However, oxyflurofen 0.25 kg a.i. per ha plus one hand weeding recorded the highest grain weight (31.28 g) followed by oxadiazon 0.75 kg a.i. per ha plus one hand weeding (30.66 g). Kenchaiah et al. (1980) reported that

the reduction in grain yield of rice was due to weed competition which reduced the number of spikelets per panicle and 1000 seed weight.

5.2 Effect of different weed control treatments on crop growth

Visual observations recorded on crop toxicity ratings on 30th day after sowing showed phytotoxicity in all pre and post-emergence herbicide sprayed plots. Oxyflurofen at the rate of 0.50 kg a.i. per ha showed moderate injury to the crop (3.33), while oxyflurofen at the rate of 0.25 kg a.i. per ha, butachlor 1.00 kg a.i. per ha and 2,4-D sodium salt 0.75 kg a.i. per ha showed slight injury to the crop (2.66). The injury was characterized by mild chlorosis and stunted growth in the beginning. However, the crop recovered from the toxicity 50 days after sowing. Rao et al. (1976) observed severe toxicity to rice seedlings on the 14th day in the pre-emergence herbicide sprayed plots due to the herbicide-moisture interaction. Mohamed Ali et al. (1977) observed 5 per cent mortality to rice seedlings due to the pre-emergence application of oxadiazon (1.25 kg a.i./ha) and butachlor (1.00 kg a.i./ha). Moorthy and Dubey (1981) reported that in upland rainfed rice oxadiazon at the

rate of 1.00 kg a.i. per ha caused phytotoxicity. Pillai et al. (1980) reported that application of oxyflurofen caused some toxicity on leaves but after a week, the crop recovered. In case of post-emergence application, 2,4-D sodium salt caused slight injury to the crop. In support of this Sunduru (1971) has reported that 2,4-D caused slight toxic symptoms to the rice seedlings.

Observations on total number of shoots per 0.5 meter row length recorded at 30, 60 and 90 days after sowing and at harvest differed significantly among the different weed control treatments, while plant height recorded at 60 and 90 days after sowing and at harvest did not differ significantly.

At 30 days after sowing, all pre-emergence herbicides sprayed treatments recorded higher number of shoots as compared to post-emergence herbicide. This is because the post-emergence application of 2,4-D was done at 25 days after sowing by the time the weeds, both monocots and dicots reduced the shoot number. At 60 days after sowing all herbicidal treatments in combination with one hand weeding recorded higher number of shoots as compared to herbicides alone. At later stages also the same trend followed with oxadiazon 0.75 kg a.i. per ha plus one hand weeding recording the highest number of shoots (67.53).

This can be attributed to less weed competition as compared to unweeded control, which recorded the lowest number of shoots. It was due to more weed competition for nutrients and light with the crop.

Dry matter production of crop observed at 30, 60 and 90 days after sowing and at harvest recorded significant differences among the weed control treatments. At 30 days after sowing oxyflurofen 0.50 kg a.i. per ha recorded the higher dry weight of the crop due to better control of weeds at the initial stages, among the herbicide sprayed treatments. Unweeded control recorded the lowest dry weight of the crop. Hand weeded twice at 20 and 45 days after sowing recorded the highest dry weight at this stage and at later stages due to weed competition it recorded slightly less crop dry weight. From 60 days after sowing till harvest all herbicidal treatments in combination with one hand weeding recorded higher crop dry weight as compared to herbicides alone. At harvest oxyflurofen 0.25 kg a.i. per ha plus one hand weeding recorded the highest crop dry matter. The unweeded control recorded the lowest dry weight of the crop. This can be attributed to more weed competition which suppressed the crop growth resulting in reduction of dry weight of the crop.

5.3 Effect of different weed control treatments on weed growth

Visual observations recorded on weed control ratings showed marked differences among the different herbicides. At initial stages, oxyflurofen gave moderate control of weeds, while benchiocarb and 2,4-D gave no control of weeds. At later stages none of the herbicides were effective in controlling the weeds, while the herbicidal treatments in combination with one hand weeding gave better control of weed than the herbicides alone. 2,4-D sodium salt gave good control of dicot weed, but was ineffective in controlling dicots. Mukhopadhyay and Baig (1967) reported that 2,4-D and MCPA did not prove effective because most of the upland rice in India are mainly infested by grasses which are resistant to 2,4-D group of herbicides.

Observations on weed count of monocot and dicot weeds ^{were} ~~was~~ recorded at 30, 45, 60 and 90 days after sowing and at harvest. At all crop growth stages different weed control treatments recorded lower total weed count as compared to unweeded control except at harvest. Oxyflurofen 0.25 kg a.i. per ha recorded the lowest total weed count. This is because at harvest the unweeded control recorded lower dicot weed count. Application of 2,4-D sodium salt

gave good control of dicots and poor control of monocots, whereas pendimethalin and benthocarb gave moderate control of monocots and poor control of dicots. Bharadwaj and Verma (1959) reported that most broad leaf weeds can be controlled by post-emergence spray of 2,4-D. Oxyflurofen gave good control of both monocots and dicots as compared to other herbicides, while oxadiazon and butachlor gave only moderate control of both dicots and monocots. Hand weeding once at 45 days after sowing and hand weeding twice at 20 and 45 days after sowing could not reduce the weed population. It was due to heavy infestation of weeds especially dicots at later stages of the crop growth. Application of herbicides in combination with one hand weeding reduced the weed population as compared to herbicides alone. It was due to hand weeding operation at 45 days after sowing which reduced the weed population.

Dry matter production of weeds at 30, 60 and 90 days after sowing and at harvest recorded significant differences among the weed control treatments. At all crop growth stages 2,4-D sodium salt and unweeded control recorded higher dry weight of weed as compared to other weed control treatments except at 30 days after sowing. Higher number of monocot weeds contributed for increase

in dry weight of weeds in case of 2,4-D sodium salt. Singh and Singh (1983) reported that in direct seeded rice, the maximum dry matter accumulation by weeds was obtained in unweeded control. All herbicidal treatments in combination with one hand weeding reduced the weed dry weight as compared to herbicides alone since the weeds were removed manually at 45 days after sowing. Thus, the weed did not put forth growth continuously and finally recorded the lower weed dry weight. Oxyfluorfen 0.25 kg a.i. per ha plus one hand weeding and butachlor 0.75 kg a.i. per ha plus one hand weeding recorded lower weed dry weight. Pande et al. (1966) reported that application of herbicides significantly reduced the dry weight of weeds. The reduced weed population per unit area resulted in the reduction of dry weight of weeds. The reduction in dry weight may also be due to the rapid depletion of carbohydrate reserve due to rapid respiration and restricted moisture and nutrient uptake as stated by Dakshindas (1962) and also due to the inhibition of photosynthetic activity (Helton et al., 1963). 2,4-D sodium salt 1.00 kg a.i. per ha recorded the maximum dry weight of weeds among the different weed control treatments. This was due to less effectiveness of herbicide in controlling weeds, especially monocots, at later stages.

Weed dry weight per ha was the highest in unweeded control while other weed control treatments recorded the lower weed dry weight. Among the herbicidal treatments oxyflurofen 0.25 kg a.i. per ha plus one hand weeding recorded the lowest weed dry weight due to effectiveness of this herbicide against both monocot and dicot weeds. Ghosh and Singh (1985) reported that pre-emergence application of oxyflurofen 0.1 kg a.i. per ha one day after sowing effectively controlled the weeds in upland rice and it recorded the lowest dry weight of weeds. All herbicidal treatments in combination with one hand weeding reduced weed dry weight as compared to herbicides alone. Hand weeded twice 20 and 45 days after sowing reduced the weed dry weight as compared to hand weeded once 45 days after sowing. This reduced the weed competition with crop and resulted in improvement of crop yield.

5.4 Economics of different weed control treatments

Highest net return was obtained in oxyflurofen 0.25 kg a.i. per ha plus one hand weeding (Rs. 9271) followed by hand weeded twice at 20 and 45 days after sowing (Rs. 6086) and butachlor 0.75 kg a.i. per ha plus one hand weeding (Rs. 5748). Nanja Reddy and Ramanna(1978)

reported that the use of the chemical (combined with some hand weeding) was Rs. 195.29 per ha while the cost of weeding purely by manual labour was Rs. 253.05 per ha. While 2,4-D sodium salt 0.75 kg a.i. per ha plus one hand weeding recorded a net profit of Rs. 3903, 2,4-D sodium salt alone at the rate of 1.00 kg a.i. per ha recorded a net loss of Rs. 682. This was due to poor weed control which resulted in low yield of crop.

5.5 Practical application of the results

From this study, it could be concluded that use of pre-emergence herbicides to keep the crop weed free in early stages followed by one hand weeding 45 days after sowing is better as compared to herbicides alone. Among integrated approaches pre-emergence application of oxyflurofen 0.25 kg a.i. per ha plus one hand weeding at 45 days after sowing proved effective in producing higher grain yields as well as in controlling weeds. Oxadiazon at the rate of 0.75 kg a.i. per ha plus one hand weeding also proved effective.

5.6 Future line of work

- (a) The type of weed flora controlled by different herbicides needs to be studied in greater detail to improve the efficacy of herbicide in controlling weeds.

- (b) These pre-emergence herbicides should be continued further to find out appropriate dose for drill sown rice.
- (c) The use of both pre-emergence and post-emergence herbicide for effective control of monocots as well as dicot weeds in drill sown rice needs to be studied in greater detail.

SUMMARY

VI. SUMMARY

A field experiment to find out the efficacy of some herbicides singly and in combination with one hand weeding in drill sown rice was conducted during kharif 1985, at the wet land, Main Research Station, University of Agricultural Sciences, Hebbal, Bangalore. The herbicides (pre-emergence) included were butachlor (1.00 kg a.i./ha), pendimethalin (1.00 kg a.i./ha), oxyflurofen (0.50 kg a.i./ha), oxadiazon (1.00 kg a.i./ha), benthocarb (1.00 kg a.i./ha) and post-emergence herbicide 2,4-D sodium salt (1.00 kg a.i./ha). Integrated treatments were 75 per cent of these herbicides plus one hand weeding 45 days after sowing except oxyflurofen, where in 50 per cent of the herbicide was used in combination with one hand weeding 45 days after sowing.

The important weed species observed in the experimental field were Echinochloa crusgalli (L.) Beauv., Echinochloa colanum (L.) Link., Dinebra retroflexa (Vahl) Panz., Panicum repens L., Paspalum conjugatum Berg., Digitaria longiflora (Retz.) Pers. and Cynodon dactylon (L.) Pers., among the monocots. Among sedges Cyperus iria L. and among dicots Eclipta alba (L.) Hassak., Portulaca oleracea L. and Spilanthus calva DC. were the predominant weeds.

At initial stages crop was infested with equal density of both dicot and monocot weeds. As the age of the crop advanced the density of monocot weed reduced and dicot density increased. Application of herbicides in combination with one hand weeding recorded the lower weed count as compared to herbicides alone. At all crop growth stages different weed control treatments recorded lower weed count as compared to unweeded control except at harvest. Application of 2,4-D sodium salt resulted in good control of dicots but poor control of monocots, whereas pendimethalin and butachlor gave moderate control of monocots and poor control of dicots. Oxyflurofen gave good control of both monocots and dicots and all other herbicides gave only moderate control of both monocots and dicots.

At all crop growth stages 2,4-D sodium salt and unweeded control recorded the higher dry weight of weeds as compared to other weed control treatments. All herbicidal treatments in combination with one hand weeding reduced the weed dry weight as compared to herbicides alone. Oxyflurofen 0.25 kg a.i. per ha plus one hand weeding and butachlor 0.75 kg a.i. per ha plus one hand weeding recorded lower weed dry weight. 2,4-D sodium salt 1.00 kg per ha and benthocarb 1.00 kg a.i. per ha recorded the higher weed dry weight among the different weed control treatments.

Moderate phytotoxic injury was noticed in oxyflurofen, 2,4-D and butachlor while oxyflurofen at higher dosage showed severe symptoms of injury. The injury was characterised by chlorotic leaves and stunted growth in the beginning. However, the crop recovered from the toxicity 50 days after sowing. At 30 days after sowing all pre-emergence herbicide sprayed treatments recorded higher number of shoots as compared to post-emergence herbicide. At 60 days after sowing all herbicidal treatments in combination with one hand weeding recorded higher number of shoots as compared to herbicides alone. The plant height did not differ significantly among the weed control treatments.

All the weed control treatments recorded higher crop dry weight (from 0.25 m² area) as compared to unweeded control, at all the stages of crop growth. Hand weeded twice at 20 and 45 days after sowing recorded the highest crop dry weight at 30 days after sowing, and at later stages due to weed competition it recorded slightly less crop dry weight. From 60 days after sowing till harvest all herbicidal treatments in combination with one hand weeding recorded higher crop dry weight as compared to herbicides alone. Oxyflurofen 0.25 kg a.i. per ha plus one hand weeding recorded the maximum crop dry weight at harvest.

All herbicidal treatments in combination with one hand weeding gave significantly higher grain yield as compared to herbicides alone, except benthocarb. Application of oxyflurofen 0.25 kg a.i. per ha plus one hand weeding gave highest grain yield followed by oxadiazon 0.75 kg a.i. per ha plus one hand weeding and hand weeded twice at 20 and 45 days after sowing, as compared to any other treatments. Yield reduction of 98.98 per cent was noticed in unweeded control followed by 2,4-D sodium salt 1.00 kg a.i. per ha (79.35 per cent) as compared to hand weeded treatment.

Straw yield was also high in all the herbicidal treatments in combination with one hand weeding as compared to herbicides alone. Straw yield was the highest in the treatment oxyflurofen 0.25 kg a.i. per ha plus one hand weeding while unweeded control recorded the lowest straw yield.

The number of productive shoots per 0.5 meter row length was higher in all herbicidal treatments in combination with one hand weeding as compared to herbicides alone. Oxadiazon 0.75 kg a.i. per ha plus one hand weeding recorded the highest shoot number followed by oxyflurofen 0.25 kg a.i. per ha plus one hand weeding.

The unweeded control gave the lowest number of productive shoots followed by 2,4-D sodium salt 1.00 kg a.i. per ha. The number of unproductive shoots per 0.5 meter row length were lower in all herbicidal treatments in combination with one hand weeding. Oxyflurofen 0.25 kg a.i. per ha plus one hand weeding recorded the lowest number of unproductive shoots, while the unweeded control recorded the highest.

All herbicidal treatments in combination with one hand weeding recorded lower sterility percentage as compared to herbicides alone. Oxyflurofen 0.25 kg a.i. per ha plus one hand weeding recorded the lowest sterility percentage followed by oxadiazon 0.75 kg a.i. per ha plus one hand weeding. The unweeded control recorded the highest sterility percentage. The panicle length and thousand grain weight did not differ significantly among the weed control treatments.

Highest net return was obtained in oxyflurofen 0.25 kg a.i. per ha plus one hand weeding followed by hand weeding twice at 20 and 45 days after sowing and butachlor 0.75 kg a.i. per ha plus one hand weeding. 2,4-D sodium salt alone at the rate of 1.00 kg a.i. per ha recorded a net loss of Rs. 682=20, while unweeded control recorded a net loss of Rs. 2170=80.

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