TIME OF APPLICATION OF PRE-EMERGENCE HERBICIDES IN DRY-SOWN RICE

By

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THESIS

Submitted in partial fulfilment of the

requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture

Kerala Agricultural University

Department of Agronomy

COLLEGE OF HORTICULTURE

Vellanikkara - Trichur

Kerala

1989

DECLARATION

I hereby declare that this thesis entitled "Time of Application of Pre-emergence Herbicides in Dry-sown Rice" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "Time of Application of Pre-emergence Herbicides in Dry-sown Rice" is a record of research work done independently by Smt.G. SUJA, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to her.

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ACKNOWLEDGEMENT

I have no words to express my deep, heartfelt gratitude to Dr.C.T. Abraham, Associate Professor, Department of Agronomy, College of Horticulture and Chairman of my Advisory Committee for his expert guidance, technical advice, timely help and constant encouragement throughout the course of investigation and preparation of the thesis.

My sincere thanks are due to Professor T.F. Kuriakose, Project Co-ordinator (Rice) whose constructive criticisms and critical suggestions has made it possible for me to complete this dissertation in time.

I wish to place on record my extreme gratitude to Dr.C. Sreedharan, Dean, Faculty of Agriculture and Sri.V.K.G. Unnithan, Associate Professor of statistics for all the valuable assistance and suggestions rendered by them.

I am obliged to Sri.P.A.Joseph, Assistant Professor of Agronomy and Smt.K.E. Savithri, Associate Professor of Agronomy for helping me during the planning and layout stage of the experiment. I am deeply indebted to all members of the staff of the Department of Agronomy, College of Horticulture, Vellanikkara and Agricultural Research Station, Mannuthy for extending all possible help in the proper conduct of research work.

I would like to acknowledge the very great help I received from Miss.Mini Thomas, Post-graduate student in Agronomy and Sri.C.George Thomas, Junior Assistant Professor of Agronomy during the preparation of the manuscript.

I owe my gratitude to all my friends and colleagues for their valuable help. My special thanks to Miss.Sherine George and Miss.Mini Jose whose constant help and support has helped me to complete this venture successfully.

The help offered by staff of the Computer Centre, KAU for the statistical analysis of the data is also acknowledged.

A word of thanks to Sri.Joy for the neat typing and prompt service.

But for the inspiration, love and moral support of my husband this venture would only have remained a dream. Mere gratitude is not enough to express the constant encouragement and affection rendered by my parents and sister at all stages of the investigation.

The award of Junior Fellowship by the Indian Council of Agricultural Research is gratefully acknowledged.

Vellanikkara,
2-6-1989.

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INTRODUCTION

Rice is the major food crop of Kerala, occupying an area of 6.63 lakh hectares. According to Farm Information Bureau (FIB, 1989) out of this area 2.86 lakh hectares are cultivated during the virippu season. Almost 87 per cent of the virippu rice is grown under semi-dry conditions. Excessive weed growth is one of the major constraints for rice production under this system of cultivation.

In direct-seeded rice due to the simultaneous germination of seeds of rice and weeds, crop-weed competition is very severe. The intermittent rains leading to alternate wetting and drying of soils, result in the emergence of a number of new flushes of weeds. Generally, the weed spectrum in dry-sown rice is dominated by grassy weeds, which compete with rice for light, space and nutrients and result in heavy yield reduction. Pillai and Rao (1974) have estimated the extent of yield reduction due to weed competition as high as 50 to 60 per cent in direct-sown upland rice.

A much wider range and intensity of weed problem can be expected in dry-seeded than in puddled wet-seeded or transplanted rice because of differences in land preparation, the lack of standing water at the early stage of crop growth and simultaneous germination of rice and weeds. Hand weeding is labour intensive and requires repeated operations for successful weed control. Moreover, the grass seedlings are not easily distinguishable from rice seedlings in the early stages to be removed mannually. With labour becoming more scarce and costly now-a-days, herbicides offer a greater potential.

There are a number of herbicides recommended for wet-sown and transplanted rice. However, in dry-sown rice the range of herbicides that could be effectively used without causing injury to rice seedlings is limited.

Herbicides like butachlor and thiobencarb are found to be effective for pre-emergence application in dry-sown rice (KAU, 1984; Sankaran and De Datta, 1985 and KAU, 1986a). Various reports indicate that these herbicides may cause toxicity to rice seedlings. However, there are evidences that herbicide selectivity can be improved by adjusting the application time. This seems to be a more practical approach and has a greater chance of being adopted by rice farmers. In different trials, these herbicides have been reported to be effective in rice when applied from two to three days before sowing to 12 days after sowing. However, detailed studies in this line are yet to be taken up to develop a recommendation on the time of application of butachlor and thiobencarb, the two most popular pre-emergence herbicides available in the market.

Weed-free condition upto 60 days is essential for getting good yields in dry-sown rice (Sankaran and De Datta, 1985). Several reports show that the residual activity of butachlor and thiobencarb will last only for about three weeks and there is every chance of weed emergence from about one month after sowing.

Single herbicide treatments with pre-emergence herbicides like butachlor or thiobencarb alone, is unsatisfactory for effective weed control throughout the period of crop growth (IRRI, 1980). It has been found necessary to supplement the pre-emergence application of these herbicides with hand weeding at 30 to 45 days after sowing or post-emergence application of propanil. However, propanil is comparatively costlier and is not freely available in market always. Hand weeding too is not economical, as the labour charges are very high.

One of the recent studies conducted in KAU (Palaikudy, 1989) indicated that a second application of the pre-emergence herbicide at a stage when the activity of the first application is over, may help to prolong the weed-free condition to cover the entire critical period of the crop and would also bring down the cost of weed control. In this study attempts were made to confirm these results also.

The present investigation was therefore conducted with the following objectives:

1) To find out the optimum time of application of pre-emergence herbicides, butachlor and thiobencarb for dry-sown rice, so as to have maximum weed control efficiency and crop selectivity.

2) To evaluate the efficiency of the second application of pre-emergence herbicides for prolonging the effect of the herbicides for the entire crop duration.

3) To develop an economical and effective weed control schedule for dry-sown rice.

4) To compare the weed control efficiency and crop selectivity of the two most widely used pre-emergence herbicides, butachlor and thiobencarb.

Review of Literature

2. REVIEW OF LITERATURE

The crop safety and weed control efficiency of pre-emergence herbicides in any crop can be improved by adjusting the time of application. Weed problems are far more complex and serious in dry-seeded rice than in other rice production systems. Several herbicides have been reported to be suitable for pre-emergence weed control in dry-sown rice. A brief review on the weed problems and the use of pre-emergence herbicides, with special reference to butachlor and thiobencarb in dry-sown rice is given in this chapter. Since the semi-dry rice is grown under rainfed condition, the situation is almost similar to upland rice, at least during the initial period. Hence the literature on upland rice also is included. The literature on the time of application of these herbicides in other systems of rice culture are also reviewed, as the studies on this aspect is limited.

2.1. Weed Spectrum in Dry-sown Rice

Pande <u>et al</u>. (1966) and Bhan <u>et al</u>. (1980) reported that grasses were the predominant weed group in upland rice. Misra and Roy (1971) in their studies at the Research Station of the OUAT, Bhubaneswar observed that 80 to 90 per cent of the weeds in upland rice belonged to the families Commelinaceae, Gramineae and Cyperaceae, whereas the major nine families of dicots represented only 10 to 12 per cent of weed population. In the trials carried out at CRRI, Cuttack in direct-seeded upland rice, Mukhopadhyay *et al*. (1972) noted that out of the 19 to 21 weed species present, grasses comprised 85 to 91 per cent of the total weed population and accounted for 91 to 96 per cent of the total weed dry weight. The results of the field experiment conducted at Indian Agricultural Research Institute, New Delhi by Bhol and Singh (1987) revealed that grasses constituted 76 to 90 per cent of weed dry matter, while broad leaved weeds and sedges produced 6 to 17 per cent and 1 to 17 per cent weed dry matter, respectively. In dry drilling *Echinochloa colona* was the predominant grassy weed, *Eclipta alba* and *Alternanthera sessilis*, the dominant broad leaved weeds and *Cyperus rotundus*, the common sedge.

Mukhopadhyay *et al*. (1972) reported that *Echinochloa colona* was the predominant species among the grasses. The other important weeds observed were *Echinochloa crusgalli*, Cynodon dactylon, Eleusine indica, Ipomoea sp., Fimbristylis sp., Commelina benghalensis, Phyllanthus niruri and Amaranthus spp. Field experiments in direct-seeded upland rice at Himachal Pradesh Agricultural University, Palampur by Biswas and Thakur (1983) showed that weed population in upland rice comprised 14 per cent Echinochloa spp., 22 per cent other grasses, 23 per cent Cyperus spp. and 41 per cent broad leaved weeds.

Sankaran and De Datta (1985) while reviewing the weed flora of upland rice in Asia, concluded that Cyperus rotundus was the most noxious weed in upland rice. The next serious one was Echinochloa colona. In the order of importance, other problem weeds are Eleusine indica, Cynodon dactylon, Echinochloa crusgalli, Ageratum conyzoides, Rottboellia exaltata, Commelina benghalensis, Portulaca oleracea and Cyperus iria.

Pandey and Rao (1965) observed Echinochloa colona, Dactyloctenium aegyptium, Eleusine indica, Digitaria sanguinalis and Setaria glauca in the upland rice fields of West Bengal. In drilled sown rice in West Bengal Srinivasan et al. (1985) reported that Echinochloa colona, E. crusgalli, Cyperus iria, Fimbristylis miliacea, Eclipta alba and Amaranthus spp. were of great concern. Cynodon dactylon, Eleusine indica, Digitaria sanguinalis and Cyperus iria were the predominant weeds in upland rice at Jorhat (Assam) (Kakati and Pradhani, 1980).

Weed flora in direct-sown rice at IGFRI, Jhansi consisted chiefly of Echinochloa colona, Setaria glauca, Brachiaria ramosa and Panicum sp. (Dutta et al., 1977) Echinochloa crusgalli, E. colona, Digera arvensis and Cyperus iria were the principal weeds of rice noted under dry condition at Hissar, Haryana (Balyan, 1982) whereas Echinochloa colona, E. crusgalli, Cyperus rotundus, Eragrostis spp., Commelina benghalensis, Eclipta alba and Xanthium strumarium were the predominant weeds at Jabalpur (Madhya Pradesh) (Mishra et al., 1988).

Field experiments conducted at the Headquarters of the All India Co-ordinated Rice Improvement Project at Hyderabad by Pillai et al. (1976) under upland conditions showed that perennial sedges like Cyperus rotundus and grasses like Cynodon dactylon were posing major problems.

In Tamil Nadu the dominant weeds present in direct-seeded rainfed rice were Echinochloa colona, Cyperus iria and Eclipta alba (Ali and Sankaran, 1984b).

In the studies conducted in Kerala at Rice Research Stations, Mannuthy (Sreedevi, 1979) and Pattambi (Pillai et al., 1980), the main grassy weeds were Echinochloa colona, Cynodon dactylon and Ischaemum rugosum, whereas among sedges, Cyperus rotundus and Cyperus difformis were the prominent ones. Amaranthus viridis, Phyllanthus niruri, Ageratum conyzoides and Ludwigia parviflora were the important broad leaved weeds. In the studies by Jayasree (1987) and Palaikudy (1989) in dry-sown rice at Agricultural Research Station, Mannuthy, Kerala the weeds which appeared in large numbers were the grasses, Isachne miliacea, Echinochloa colona and Saccoleppis interrupta and the sedge, Cyperus iria. Dicots were very few in number and the main species present were Alternanthera sessilis and Ludwigia parviflora.

The above review shows that weed spectrum in dry-sown rice is diverse and varies with location. Grasses constitute the major weed flora in both upland as well as semi-dry conditions. Among grasses Echinochloa colona is the most serious one. But in semi-dry condition Echinochloa crusgalli also is reported. Among sedges, which is second in importance, Cyperus rotundus is serious in uplands, while Cyperus iria is more common in semi-dry conditions.

2.2. Crop-Weed Competition in Rice

2.2.1. Critical Period of Crop-Weed Competition

Weed competition in upland rainfed rice was more critical during the early stages of the crop (Nair *et al*., 1976). Dubey *et al*. (1977) reported that maximum weed competition occurred during the first three weeks, in direct-seeded rice. According to Ghosh *et al*. (1977) and Sharma *et al*. (1977), critical crop-weed competition occurred 10 to 20 days after crop emergence.

Bhan *et al*. (1980) and Kohle and Mittra (1981) reported that the first 30 days after seeding was the most critical period for crop-weed competition in direct-sown rice, whereas Singh and Ram (1982) concluded that the period of the first 45 days after seeding was most crucial for weed removal for obtaining higher yields. Singh *et al*. (1987) reported that grain yield of rice increased significantly with increase in duration of weed-free period upto 45 days after sowing. The period upto 30 days after sowing of the crop was observed to be the most critical period for controlling weeds in upland rice (AICRPWC, 1989). Weeding upto 30 days after sowing resulted in yield comparable to the treatment where weed-free condition was maintained throughout the crop growth period.

The weed-free requirement for upland rice varied from 30 to 60 days after sowing, depending on edaphic and climatic conditions and weed flora (Schiller and Indhaphun, 1979; Wells and Cabradilla, 1981 and Singh et al., 1987). Based on grain yield, Ali and Sankaran (1984b) concluded that a weed-free period of 60 days in monsoon and 70 days in summer was needed to get high yields in direct-seeded rainfed rice.

Ghosh et al. (1977) observed that weed infestation during the first 10 days after germination did not affect crop growth and yield. But weed infestation for 20 days or more after germination reduced the yield significantly. According to Schiller and Indhaphun (1979), Wells and Cabradilla (1981) and Singh et al. (1987) the first 15 days after seeding rice seems to be the maximum period during which weeds can be tolerated without affecting the final crop yield. Based on grain yield, Naidu and Bhan (1980) and Sahai et al. (1983) concluded that the critical period of weed competition was between 15 and 45 days after sowing. A study conducted in Kerala (KAU, 1984) revealed that critical period of weed infestation in direct-sown rice under semi-dry condition was 21 to 40 days after sowing.

The works reviewed above shows that the critical period of weed competition in rice is between 15 days to 30-40 days after sowing. However, in dry-sown rice this period may extend to 50 to 60 days after sowing. The maximum period to which weeds can be tolerated in the early stages is upto 15 days after sowing, wherein the competition is not very severe.

2.2.2. Effect of Weeds on Rice Growth

(a) Drymatter production: Severe weed infestation in upland rice was found to depress the total drymatter production of rice (Chakraborthy, 1973). Nanjappa (1975) in a study conducted at the University of Agricultural Sciences, Bangalore concluded that the dry matter production of rice crop was inversely proportional to the dry matter production of weeds. In their studies on crop-weed competition, Wells and Cabradilla (1981) observed that in upland rice, crop growth was suppressed by weed growth and that removal of weeds during the critical period of crop-weed competition increased crop dry matter production. Patel et al. (1985) reported that crop dry matter yield was negatively correlated with weed dry weight. Highest crop dry matter yield (45 g m^{-2}) was obtained when weed dry weight was the lowest (6 g m^{-2}). According to Jayasree

(1987) the least dry matter production by crop was recorded in the unweeded control.

(b) Plant height: Sreedevi (1979), based on a study conducted in direct-sown rice in Kerala, reported that severe weed infestation resulted in reduction in height of rice. Wells and Cabradilla (1981) also reported that in dry-sown rice severe infestation depressed the plant height.

On the other hand, increase in plant height due to weed competition has been reported by Noda et al. (1968), Zimdahl (1980), AICRPWC (1986) and Jayasree (1987).

The above review of literature shows that there is a significant negative correlation between weed and crop dry matter production. However, the influence of weed competition on plant height is controversial.

2.2.3. Effect of Weeds on Yield Attributes

Okafor and De Datta (1974), Sharma et al. (1977) and Kohle and Mittra (1981) noted that severe weed infestation in upland rice depressed the tiller and panicle production. Singlachar et al. (1978) and Kakati and

Pradhani (1980) ascribed the higher grain yield with increase in weed-free duration to greater panicle production. Merlier (1978) and Gupta (1984) observed that increasing the duration of grass weed competition progressively reduced panicle number.

Sreedevi (1979) from Kerala, reported that weeds reduced the production of total and fertile tillers. She observed that the unweeded control plots recorded the least number of productive tillers (193.7 m^{-2}). Similar results was reported by Jayasree (1987) also. The maximum number of productive tillers per hill (8.04) was noticed in the hand weeded plots.

In direct-sown rice under semi-dry conditions in Kerala, Sreedevi (1979) reported that the number of fertile spikelets per panicle was reduced by 58.8 per cent due to weed competition. Sahai et al. (1983) recorded more number of filled grains per panicle by maintaining weed-free condition upto 45 days after sowing. According to Gupta (1984) the percentage of mature grains per panicle was adversely affected by grassy weeds. Jayasree (1987) also reported reduction in the number of grains per panicle due to unrestricted weed growth.

Increasing the duration of grass weed competition progressively reduced the panicle weight (Merlier, 1978). Sreedevi (1979) and Jayasree (1987) reported that in direct-sown rice under semi-dry conditions uncontrolled weed growth reduced 1000 grain weight. Sahai et al. (1983) reported that weed-free condition upto 45 days after sowing resulted in greater weight of grains per panicle than under weedy condition.

The above review points out that severe weed competition in dry-sown rice reduces the total and fertile tillers, number of filled grains per panicle and 1000 grain weight.

2.2.4. Yield Reduction due to Weed Competition

In direct-seeded rice under upland conditions, due to the simultaneous germination of crop and weeds, competition for soil moisture may begin early particularly in low rainfall areas. Weed seedlings grow more rapidly than rice seedlings, due to their greater competitive ability. The intermittent rains obtained early in the season results in the emergence of a number of new flushes of weeds; thus creating severe crop-weed competition and yield reduction (Rao, 1983).

According to Misra and Roy (1970) yield reduction due to unchecked weed growth in upland rice varied from 40 to 85 per cent. Mukhopadhyay et al. (1972) and Okafor and De Datta (1974) reported that severe weed infestation caused 74 to 98 per cent yield loss in direct-seeded upland rice.

Pillai and Rao (1974) estimated the extent of yield reduction due to weeds to be over 50 per cent in direct-sown upland rice, 30 to 35 per cent in direct-sown rice under puddled conditions and around 15 to 20 per cent in transplanted rice. Similarly one estimate at IRRI showed that weed growth in unweeded plots reduced yield by 34 per cent in transplanted rice, 45 per cent in direct-seeded rainfed lowland rice, and 67 per cent in upland rice (De Datta, 1981).

In field experiments conducted in Eastern Uttar Pradesh in direct-seeded upland rice, yield reduction due to weed competition ranged from 42 to 65 per cent (Sharma et al., 1977). In Kerala, in direct-sown rice, weedy condition reduced the grain yield by 87 per cent compared to weed-free plot (Sreedevi, 1979). Jayasree (1987) also obtained, the lowest grain yield (12.1 q ha^{-1}) in the unweeded check, which was 73 per cent lesser than the yield in weed-free plots.

Marlier (1978) observed that weed dry weight and yield of rice were negatively correlated. Zimdahl (1980) and Singh _et al_. (1987) concluded that increase in weed density resulted in severe weed competition and decreased crop yield. Wells and Cabradilla (1981) found that grain yield decreased as weed growth duration increased. Devi and George (1979) and Pillai and Ghosh (1980) reported inverse relationship between weed dry matter production and rice yield.

It is evident from the review that yield reduction due to crop-weed competition is more severe in dry-sown rice than in wet-sown or transplanted crop.

2.2.5. Nutrient Uptake by Rice and Weeds

Nanjappa (1975) and Sahai and Bhan (1982) noted significant negative correlation between nutrient uptake by crop and weeds. Weeds accumulated more nitrogen, in direct-sown rice than the crop indicating severe competition for nitrogen throughout the upland rice growing season (Chakraborthy, 1973 and Singh and Sharma, 1984).

According to Mukhopadhyay *et al.* (1972), grasses absorbed 90 to 94 per cent of the total nitrogen uptake by weeds. Mandal *et al.* (1986) also reported similar results. Severe infestation of *Echinochloa colona* removed 30.4 to 37.1 kg N ha^{-1} from soil, reducing the rice yield by 74 to 98 per cent.

Maiti (1974) reported nitrogen removal as high as 30.78 kg ha^{-1} due to unhampered weed growth. Kakati and Mani (1977) reported that nitrogen loss as high as 24 kg ha^{-1} in the weedy control was reduced to 3 kg ha^{-1} in the herbicide treated plots. Similar results were observed by Nanjappa and Krishnamoorthy (1980), where the weeds in weedy check removed 42 kg N ha^{-1} compared with only 10.45 kg N ha^{-1} in weed-free plots. They observed maximum N uptake by crop in weed-free plot (98.4 kg ha^{-1}). Kaushik and Mani (1980) reported that weeds in unweeded plots of direct-sown rice under unpuddled conditions depleted 24.7 kg N ha^{-1}. According to Chakraborthy (1981) nitrogen removal by weeds in unweeded control was 30.4 kg N ha^{-1}, whereas it was 19.3 kg ha^{-1} in another study conducted by Tosh *et al.* (1981).

Sreedevi (1979) reported maximum N removal by weeds in unweeded control (33.5 kg N ha^{-1}), while in hand weeded check it was only 2.58 kg ha^{-1}. Jayasree (1987) also concluded that unweeded check recorded highest nitrogen removal by weeds (99.2 kg ha^{-1}) at harvest stage of the crop. N uptake by the crop showed a reverse trend.

Sreedevi (1979) estimated maximum removal of phosphorus by weeds in weedy plot (5.13 kg ha^{-1}), whereas in weed-free plot it was only 0.19 kg ha^{-1}. Nanjappa and Krishnamoorthy (1980) also reported that unweeded check recorded 22.15 kg ha^{-1} P_2O_5 uptake by weeds in weedy plot, while in weed-free check it was only 4.27 kg ha^{-1}. Crop removal of 63.15 kg P_2O_5 ha^{-1} was reported in the weed-free plot, showing a reverse trend. Kaushik and Mani (1980) reported that weeds depleted the soil of 5.8 kg ha^{-1} of phosphorus, in the unweeded plots of direct-sown rice under unpuddled condition. According to Chakraborthy (1981) unchecked weed growth removed 19.2 kg P_2O_5 ha^{-1}, whereas Tosh et al. (1981) reported a phosphorus uptake of 11.6 kg ha^{-1} by weeds in unweeded control. Another study by Jayasree (1987) in dry-sown rice revealed that, unweeded treatment recorded the maximum P removal (8.71 kg ha^{-1}) at harvest stage of the crop, while it was reduced considerably by weed control treatments.

According to Sreedevi (1979) unweeded control resulted in maximum K removal by weeds. Kaushik and Mani (1980) reported that potassium depletion by weed growth in the unweeded check amounted to 63.4 kg ha^{-1}. Nanjappa and Krishnamoorthy (1980) reported maximum K_2O removal by weeds in unweeded plots (56.04 kg ha^{-1}), while in hand-weeded check it was only 10.16 kg K_2O ha^{-1}. The K uptake by the crop showed a reverse trend and the uptake in unweeded control was reduced by 26 per cent. According to Jayasree (1987) also weedy plot recorded maximum K removal by weeds (103.31 kg ha^{-1}) and least K removal by crop (68.3 kg ha^{-1}) at harvest stage of the crop.

The above review points out that crop-weed competition under high weed intensity exerts adverse effect on the uptake and utilization of nutrients by crop which results in a severe yield reduction.

2.3 Butachlor - A Pre-emergence Herbicide for Dry-sown Rice

Butachlor is a selective pre-as well as post emergence herbicide principally used for the control of most annual grasses, broad leaved weeds and sedges associated with direct-seeded and transplanted rice (De Datta and Bernasor, 1971 and De Datta, 1981).

Several workers have found butachlor an effective pre-emergence herbicide in direct-sown upland rice with good weed control efficiency that gave rice yields comparable to those of hand-weeded plots (Bhagat et al., 1977; Schiller and Indhaphun, 1979; Borgohain and Upadhaya, 1980; Tasic et al., 1980; Singh and Biswas, 1981; Singh and Singh, 1983; Kumar and Singh, 1984; De Detta and Llagas, 1984 and AICRPWC, 1989).

Butachlor as a pre-emergence herbicide had shown considerable promise in direct-seeded rice in Srilanka (Gunasena and Arceo, 1981). Cadang and Mercado (1983), Patel et al. (1985) and Palaikudy (1989) reported that butachlor gave good control of sedges and broad leaved weeds in direct-seeded rice.

In trials with rice grown under semi-dry conditions in Kerala, butachlor was found to be most effective in decreasing population and dry weight of both monocot and dicot weeds (Nair et al., 1979; Sreedevi, 1979; KAU, 1984 and KAU, 1986a).

2.4 Thiobencarb - A Pre-emergence Herbicide for Dry-sown rice

Thiobencarb is a pre-emergence and early post-emerbroad leaved weeds and sedges. It can also control aquatic weeds in rice and has remarkable selectivity against Echinochloa spp. It is an excellent herbicide for dry-sown, wet-sown and transplanted rice (De Datta, 1981 and Rao, 1983).

Pre-emergence thiobencarb at rates ranging from 1.5 to 2.5 kg ha^{-1} gave effective weed control and resulted in high yield in direct-sown upland rice (AICARP, 1978; Manna and Moorthy, 1980; Balyan, 1982; Sharma and Bisen, 1983; KAU, 1984; Bhan et al., 1985; KAU, 1986a; Jayasree, 1987 and Mishra et al., 1988).

Bhan et al. (1986) and Ali et al. (1986) reported that thiobencarb recorded lower population and dry weight of grassy weeds in dry-sown rice and showed selectivity against Echinochloa colona. Jayasree (1987) and Palaikudy (1989) also noted similar result in dry-sown rice in Kerala.

The foregoing review indicates that butachlor and thiobencarb are pre-emergence herbicides that can control weeds effectively in dry-sown rice. It appears that butachlor is more effective against sedges whereas thiobencarb is so against the grasses.

2.5 Time of Application of Pre-emergence Herbicides in Rice

2.5.1 Butachlor

(a) Dry-sown rice: In a trial conducted by Paul and Jacob (1977) at Allahabad University to find out the effectiveness of butachlor at different times in upland rice, butachlor applied five days after sowing gave effective control of weeds.

Gunasena and Arceo (1981) noted that butachlor applied two days before sowing provided better crop tolerance than six days after sowing. However, weed control and yield at six days after sowing application were slightly better than two days before sowing application. Cadang and Mercado (1983) also observed that butachlor applied two days before sowing gave good control of sedges and broad leaved weeds. In field experiments conducted in the Philippines by Henrichs et al. (1987) butachlor applied before sowing was more effective than when applied after sowing in controlling weeds.

Good selective weed control was obtained at IRRI, Philippines (IRRI, 1981) in dry-seeded wetland rice when butachlor was applied eight days after rice emergence.

Lim & Man (1985) observed that butachlor gave effective control of weeds when applied early at seven days before sowing or 14 days after sowing.

(b) Wet-sown rice: De Datta and Bernasor (1971) reported that in direct-seeded flooded rice, butachlor applied six days after sowing gave excellent control of weeds. When applied six to seven days after sowing, butachlor could provide satisfactory weed control in wet-seeded rice (Arceo and Mercado, 1981). Trials conducted by Ali and Sankaran (1984a) at TNAU, Coimbatore indicated that butachlor application at eight days after sowing was more selective and efficient in terms of weed control when compared to application at five days after sowing. Similarly, butachlor application eight days after sowing was superior to its application at 12 days after sowing (Ali *et al*., 1986). However, Srinivasan *et al*. (1985) observed that butachlor applications made zero to two days after sowing provided excellent weed control, while Mabbayad and Moody (1984) and IRRI (1986) found its application three days before sowing was more effective.

(c) Transplanted rice: In transplanted rice, butachlor applied six days after transplanting resulted in effective weed control (Chang and De Datta, 1972; Auma and Gunasena, 1972 and Pillai, 1982). Parthasarathi and Negi (1977), Bajwa et al. (1985) and Kerni et al. (1985) showed that butachlor application at four days after planting, gave effective weed control and high grain yields.

Studies conducted in transplanted rice in Punjab by Chela and Gill (1980, 1981) showed that butachlor applied three days after transplanting controlled weeds effectively and gave paddy yields on par with weed-free plots.

Trials in different regions of India conducted under the All India Co-ordinated Rice Improvement Project, Hyderabad showed that application of butachlor five to six days after transplanting gave excellent control of weeds (Pillai et al., 1983). In another study carried out at Rice Research Station, Moncompu, Kerala (KAU, 1984) it was found that butachlor @ 1.5 kg ha^{-1} applied five days after transplanting controlled weeds effectively.

2.5.2 Thiobencarb

(a) Dry-sown rice: Under Tirupathi conditions, among the different herbicides tried, application of thiobencarb at 1.5 kg ha^{-1} six days after sowing recorded excellent weed control and high grain yield (Sridhar et al., 1976). Pillai

(1977) reported that among the different herbicides tried, application of thiobencarb at four to six days after sowing resulted in effective weed control. Trials conducted under the All India Co-ordinated Agronomic Research Project revealed that, thiobencarb applied at three days after germination was superior to all other pre-emergence herbicides applied at the same time (AICARP, 1978).

Trials conducted by Ali and Sankaran (1981) at TNAU, Coimbatore indicated that application of thiobencarb 12 days after sowing gave good weed control and high yield in direct-sown rice under nonpuddled conditions. In KAU, studies on time of application of thiobencarb in dry-sown rice showed that the optimum time of application was six days after sowing (Jayasree, 1987).

(b) Wet-sown rice: According to De Datta and Bernasor (1971) thiobencarb @ 1.5 kg ha^{-1} applied six days after sowing controlled weeds effectively in direct-seeded flooded rice. Selectivity of rice seedlings in nursery was more when thiobencarb was applied seven days after sowing (Pande, 1982). Gill et al. (1982) observed that thiobencarb applied three days after sowing gave promising control of barnyard grass in rice nursery. In wet-seeded rice, the effect of different time of application of thiobencarb was tested by Ali and Sankaran (1984a). Selectivity of rice seedlings was more when thiobencarb was applied at eight days after sowing compared to application at five days after sowing.

(c) Transplanted rice: Thiobencarb applied six days after transplanting resulted in effective weed control (Cheng and De Datta, 1972 and Pillai, 1982). Mehta (1975), Pandey and Sharma (1980) and Bajwa *et al*. (1985) reported that thiobencarb applied four days after transplanting controlled weeds effectively and recorded grain yields on par with hand weeding. Field experiments conducted at Punjab Agricultrual University by Chela and Gill (1980, 1981) revealed that thiobencarb applied three days after transplanting gave efficient weed control. Gill and Kolar (1980) indicated that under the agroclimatic conditions of Punjab, where grasses were of major concern thiobencarb applied at three to four days after transplanting gave excellent control of *Echinochloa crusgalli*.

The above review of literature projects the importance of the time of application of butachlor and thiobencarb, in relation to the type of rice culture. In dry-sown rice, application three to six days after sowing showed better results whereas in wet-seeded rice, application few days before seeding and after a week showed promise. In transplanted rice these herbicides could be applied within a few days after transplanting as crop toxicity is not a problem.

2.6 Time of Application and Crop Safety

Eventhough the herbicides butachlor and thiobencarb are recommended for dry-sown rice there are many reports that they may cause phytotoxicity to rice seedlings, mainly due to the differences in the time of application. The usually observed phytotoxic symptoms are characteristic drooping and yellowing of leaves and height reduction (Arceo and Mercado, 1981).

Gunasena _et al_. (1981) observed that crop injury by butachlor varied according to location, time of application and rate of application. According to Arceo and Mercado (1981), Mercado and Cadang (1983) and Mabbayad and Moody (1984) crop safety of butachlor in wet and dry-seeded rice, could be improved by adjusting its application time.

Thiobencarb and butachlor showed high degree of selectivity between rice and weed seedlings when applied six days after sowing (De Datta and Bernasor, 1971). According to Chang and De Datta (1972) there was no evidence of rice toxicity in post-emergence application of thiobencarb and butachlor @ 2.0 kg ha^{-1}.

In a study on the tolerance of rice to butachlor applied at different growth stages Ahmed and Moody (1978) found that application at three days after crop emergence caused no serious injury to rice. In a related study by Arceo and Mercado (1981) crop safety of butachlor could be improved when application was done at two days before sowing. According to Pande (1982) thiobencarb @ 1.5 kg ha^{-1} applied seven days after sowing in rice nursery did not cause any phytotoxicity to rice. Ali and Gururajan (1985) based on a trial conducted at TNAU, Coimbatore concluded that application of butachlor and thiobencarb in lowland nursery at eight days after sowing was selective to rice but not at five days after sowing. In Kerala, Jayasree (1987), did not observe any phytotoxic symptoms on the crop when thiobencarb was applied at different dates from zero to 12 days after sowing.

Nako (1977) observed crop injury on seedlings in thiobencarb treatments at germination and 0.8 to 1 leaf stage. Chang and De Datta (1972) noted that rice plants were slightly injured in pre-emergence application of granular thiobencarb and butachlor at rates higher than 2 kg ha^{-1}. Ahmed and Moody (1978) found that application immediately after seeding and four days after seeding induced the highest crop injury to rice. Yamada (1984) noted that thiobencarb was toxic to rice plants when applied at the germinating stage.

The other factors that can modify the crop safety of herbicides are the use of seed safeners, seeding depth, soil moisture status and occurrence of rainfall.

Napthalic anhydride was found to reduce rice injury when applied with butachlor (Mabbayad and Moody, 1985). In a seeding depth study, it was established that butachlor did not cause any visible injury to any cultivar located 5 cm below the sprayed surface (Madrid et al., 1980). Noriel and Mercado (1981) reported that butachlor was phytotoxic to the lowland IR 36 rice when applied at field capacity of the soil and at saturation. It was concluded by Chandraka and Manna (1981) that some phytotoxicity of butachlor to germinating rice seeds was unavoidable if heavy rainfall occurred four to five days after sowing.

There is a limit to which these factors can be manipulated for getting selectivity in rice. Adjusting the time of application that would result in least injury appears to be a more practical approach and to have a greater chance of being adopted by farmers (Arceo and Mercado, 1981). However, studies on this aspect are rare especially in dry-sown conditions.

2.7 Second Application of Pre-emergence Herbicides

A weed-free condition upto 60 days is essential for getting good yields in dry-sown rice. Trials in the Philippines had shown that single pre-emergence treatment of thiobencarb or butachlor alone was not sufficient for effective weed control throughout the period (IRRI, 1980). It was found necessary to supplement the pre-emergence application of these herbicides with a hand weeding 30 to 45 days after sowing (Rathi and Tewari, 1979; KAU, 1984; De Datta _et al_., 1986; Sudhakara and Nair, 1986; KAU, 1986a and KAU, 1987) or post-emergence application of propanil (Singh _et al_., 1973) or 2,4-D (Sudhakara and Nair, 1986 and KAU, 1987).

Trials under the All India Co-ordinated Agronomic Research Project (AICARP, 1977) has showed that application of thiobencarb in two splits @ 1.5 kg ha^{-1} each, after three and 20 days of germination, was as efficient as weed-free check. One of the recent studies at Kerala Agricultural University (Palaikudy, 1989) indicated that a second application of butachlor or thiobencarb 20 to 30 days after the initial pre-emergence application could extend the herbicidal effect for the entire crop duration. However such studies are rare.

The works reviewed above shows that the application of pre-emergence herbicide alone is not sufficient to give satisfactory weed control throughout the crop season, and it has to be supplemented with chemical or manual weeding. Recent works also indicate that even the same pre-emergence herbicide could be repeated three to four weeks later to extend the duration of weed control.

Materials and Methods

3. MATERIALS AND METHODS

A field experiment was conducted during the first crop season of 1988 to find out the optimum time of application of pre-emergence herbicides, butachlor and thiobencarb, and to assess the scope of second application of these herbicides, for efficient weed control in dry-sown rice. The materials used and the methods followed are described in this chapter.

3.1. Site, Climate and Soil

The investigation was conducted at the Agricultural Research Station, Mannuthy under the Kerala Agricultural University, Vellanikkara, Trichur. The station is located at 12° 32' N latitude, 74° 20' E longitude and at an altitude of 22.25 m above MSL. Typical humid tropical climate is experienced by the area.

The study was carried out during May to September, 1988. The details of meteorological observations recorded during the crop season are presented in Appendix I.

The soil of the experimental field was sandy clay loam in texture. The physical and chemical nature of soil in the field are given in Table 1.

Table 1. Physical and chemical nature of soil in the experimental field

Particulars	Value	Method employed
A. <u>Mechanical composition</u>		
Coarse sand (%)	27.2	Robinson's international Pipette method (Piper, 1942)
Fine sand (%)	23.8	
Silt (%)	22.6	
Clay (%)	26.4	
Bulk density	1.52	Core sampler method (Piper, 1942)
B. <u>Chemical composition</u>		
Organic Carbon (%)	0.661	Walkley and Black method (Soil Survey Staff, 1967)
Total N (%)	0.138	Semi micro-kjeldahl method (Soil Survey Staff, 1967)
Available P (kg ha^{-1})	32.06	Bray I extractant, molybdophosphoric acid method (Jackson, 1958)
Available K (kg ha^{-1})	172.08	Neutral normal ammonium acetate extract, flame photometry (Jackson, 1958)
pH	5.84	1:2.5 Soil-water suspension, using a pH meter

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

3.2. Treatments

The treatments consisted of different time of application of the pre-emergence herbicides, butachlor and thiobencarb, which were applied at zero, three, six or nine days after sowing only or repeated at 25 days after sowing also. In addition, an unweeded control and a weed-free control (three hand weedings) were also included for comparison. Thus there were 18 treatments as shown below.

Treatments	Notation
1. Butachlor at sowing (0 days after sowing)	B_0
2. Butachlor 3 days after sowing	B_3
3. Butachlor 6 days after sowing	B_6
4. Butachlor 9 days after sowing	B_9
5. Butachlor 0 days after sowing + 25 days after sowing	B_0 + 25
6. Butachlor 3 days after sowing + 25 days after sowing	B_3 + 25
7. Butachlor 6 days after sowing + 25 days after sowing	B_6 + 25
8. Butachlor 9 days after sowing + 25 days after sowing	B_9 + 25

9. Thiobencarb at sowing (0 days after sowing)	T_0
10. Thiobencarb 3 days after sowing	T_3
11. Thiobencarb 6 days after sowing	T_6
12. Thiobencarb 9 days after sowing	T_9
13. Thiobencarb 0 days after sowing + 25 days after sowing	T_0 + 25
14. Thiobencarb 3 days after sowing + 25 days after sowing	T_3 + 25
15. Thiobencarb 6 days after sowing + 25 days after sowing	T_6 + 25
16. Thiobencarb 9 days after sowing + 25 days after sowing	T_9 + 25
17. Hand weeded control (3 hand weedings at 20, 40 and 60 days after sowing)	H.W.
18. Unweeded Control	U.W.

3.3. Herbicides

The pre-emergence herbicides, thiobencarb, available in the trade name Saturn 50 EC ®, containing 50 per cent a.i., supplied by M/s. Pesticides India Ltd. and butachlor commercially available as Butachlor 50 EC ® containing 50 per cent a.i., marketed by National Organic Chemicals Industries Ltd. were used in the trial. Details of the herbicides are presented in Appendix II.

3.4. Herbicide Application

The herbicides were sprayed at the rate of 1.5 kg a.i. ha^{-1} on the days as per treatments, using a knapsack sprayer fitted with a flat fan nozzle. Measured quantity of herbicides were mixed with required quantity of water, the volume of which was determined by running a blank, and sprayed uniformly.

3.5. Variety

Rice variety Jyothi with a duration of 110 to 125 days was used for the experiment. This variety evolved at the Rice Research Station, Pattambi, has red kernel, long and bold grains. This is moderately tolerant to brown plant hopper and blast and is susceptible to sheath blight (KAU, 1986b).

3.6. Field Culture

The cultural practices recommended by the Kerala Agricultural University (KAU, 1986b) were followed during the course of the experiment, except the weed control operations, which varied as per the treatments.

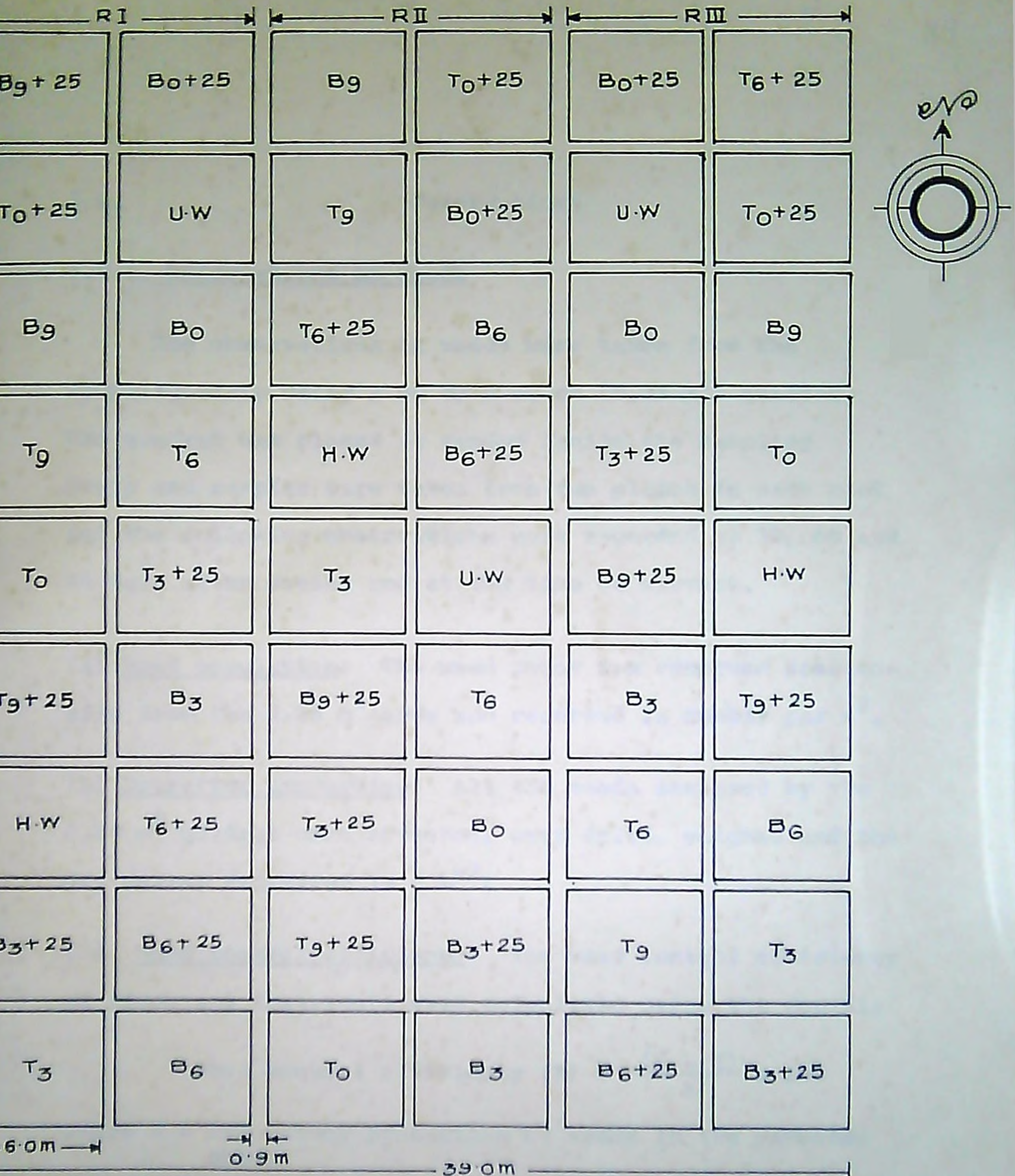
The land was ploughed twice, clods broken and all weeds and stubbles removed. The seeds were dibbled on

28th May 1988 with the receipt of one soaking rain. There was a serious attack of gall fly at the active tillering stage. Dimecron 0.1 per cent and carbaryl 0.4 per cent were sprayed to control the attack of gall fly. Malathion 0.1 per cent was sprayed to control rice bug attack, which occurred at the milk stage. Hinosan 0.1 per cent was also sprayed against sheath blight and brown leaf spot. At maturity, the crop was harvested on 22nd September 1988.

3.7. Design and Layout

The experiment was laid out in randomized block design with three replications. The layout plan is given in Fig. 1.

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



. PLAN OF LAY-OUT

TACHLOR AT 0 DAYS AFTER SOWING. T0 THIOBENCARB AT 0 DAYS AFTER SOWING.

TACHLOR AT 3 DAYS AFTER SOWING. T3 THIOBENCARB AT 3 DAYS AFTER SOWING.

TACHLOR AT 6 DAYS AFTER SOWING. T6 THIOBENCARB AT 6 DAYS AFTER SOWING.

TACHLOR AT 9 DAYS AFTER SOWING. T9 THIOBENCARB AT 9 DAYS AFTER SOWING.

TACHLOR AT 0 AND 25 DAYS AFTER SOWING. T0 + 25 - THIOBENCARB AT 0 AND 25 DAYS AFTER SOWING

3.8. Observations

3.8.1. Observations on Weeds

The observations on weeds were taken from the sampling strip using a 50 cm x 50 cm (0.25 m^2) quadrat. The quadrat was placed at random inside the sampling strip and samples were taken from two places in each plot and the following observations were recorded at 30, 60 and 90 days after sowing and at the time of harvest.

(a) Weed population: The weed count was recorded species-wise from the 0.25 m^2 area and reported in number per m^2.

(b) Drymatter production: All the weeds enclosed by the 0.25 m^2 quadrat were uprooted, oven dried, weighed and the dry matter expressed in $g\ m^{-2}$.

(c) Weed control efficiency: The weed control efficiency of different treatments were calculated using the formula

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

where X = Dry matter production of weeds in the unweeded check

Y = Dry matter production of weeds in the treatment

3.8.2. Observations on the Crop

(a) Phytotoxicity

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

(b) Crop Growth Characters

(i) Drymatter production: The crop samples were also taken from the 0.25 m^2 area from where weed samples were taken, dried in a hot air oven to constant weight and the dry matter production was recorded in g m^{-2}. The observations were taken at 30, 60 and 90 days after sowing and at harvest.

(ii) Plant height at harvest: The height of the plants were measured on the day of harvest, from the soil surface to the tip of earhead and the mean of such observations expressed as height of plants in cm.

(c) Yield Characters

(i) Productive tillers: The number of productive tillers were counted from ten hills and their average expressed as number of productive tillers per hill.

(ii) Panicle length: The length of ten panicles from the neck to the tip of the panicle was measured and the average length recorded in centimetres.

(iii) Number of spikelets per panicle: The total number of grains in each panicle was recorded.

(iv) Weight of thousand grains: One thousand grains were counted from the cleaned produce from each plot and the weight recorded in grams.

(v) Grain yield: The grains harvested from each net plot were dried to 14 per cent moisture, cleaned, winnowed, weighed and expressed in kg ha^{-1}.

(vi) Straw yield: The straw from each net plot was sundried and the weight recorded in kg ha^{-1}.

(vii) Weed index: Weed index values of different treatments were calculated using the equation given by Gill and Vijaykumar (1969) as follows:

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

where X = Yield obtained from the hand weeded plot

Y = Yield obtained from the treatment

3.9. Chemical Analysis

The weeds and crop plants collected from the sampling area were separately oven dried to constant weight, ground in a wiley mill and analysed for nitrogen, phosphorus and potassium.

The following methods were used for analyses:

1. Nitrogen : Colorimetric determination using Nessler's Reagent (AOAC, 1960)
2. Phosphorus : Vanadomolybdo phosphoric yellow colour method, using Spectronic 20 (Jackson, 1958)
3. Potassium : Triple acid extract method, using flame photometer (Jackson, 1958)

The analyses of weed and crop samples taken at 30, 60 and 90 days after sowing and at the time of rice harvest were done. At harvest stage, the analysis of crop was done separately for grain and straw.

The nitrogen, phosphorus and potassium removed by crop and weeds were calculated by multiplying the dry matter of the crop and weeds with the respective nutrient content and expressed in kg ha^{-1}.

3.10. Statistical Analysis

The data recorded for different characters were compiled and tabulated in proper form and were subjected to analysis of variance (Panse and Sukhatme, 1978). Subsequently standard errors were worked out and wherever the 'F' tests were significant, appropriate critical differences (CD) were calculated to test the significance of the treatment differences. Correlation between the important characters were also worked out.

Analysis of variance for the data on weed population and weed dry matter production were carried out after transforming the data to $\sqrt{x + 1}$ for those with zero values and to $\sqrt{x}$ for those without zero values.

3.11. Economics of Weed Control Operations

The relative economics of different weed control operations were compared by calculating the additional cost for the operation over and above the unweeded control and working out the return per rupee invested on weed control.

Results and Discussion

4. RESULTS AND DISCUSSION

The results of the experiment conducted to find out the optimum time of application of pre-emergence herbicides, butachlor and thiobencarb and to assess the scope of second application of these herbicides in dry-sown rice are presented and discussed in this chapter. The data on different observations were subjected to analysis of variance, the abstract of which is present in Appendix XI. Results are discussed under the following heads:

4.1. Studies on weeds

- 4.1.1. Weed spectrum
- 4.1.2. Weed population
- 4.1.3. Dry matter production
- 4.1.4. Weed control efficiency

4.2. Studies on crop

- 4.2.1. Phytotoxicity
- 4.2.2. Growth characters
- 4.2.3. Yield attributes
- 4.2.4. Yield
- 4.2.5. Weed index

4.3. Studies on nutrient uptake

4.3.1. Uptake by weeds

4.3.2. Uptake by crop

4.4. Economics of weed control operations

4.1. Studies on Weeds

4.1.1. Weed Spectrum

The weed flora found in the experimental field are presented in Appendix III. Grasses and sedges constituted major part of the weed flora. Among the grasses, *Isachne miliacea*, *Saccoleppis interrupta* and *Echinochloa colona* and among sedges, *Cyperus iria* were the prominent ones. Dicots were very few in number, *Sphaeranthus indicus*, *Ludwigia parviflora*, *Ammannia baccifera*, *Commelina benghalensis* and *Cyanotis* sp. being the main ones.

A critical analysis of the relative proportion of grasses and sedges to the total weed population indicates that at all stages, the proportion of grasses was much higher than that of the sedges. In the weedy check, at 30 days, grasses comprised 87 per cent of the total weed population, while the sedges accounted for only less than two per cent. At 60 days, the share of grasses and sedges in the unweeded plots were 98 per cent and one per cent respectively. But towards harvest, the population of sedges declined drastically to zero per cent resulting in increased proportion of grasses (100 per cent) (Tables 5 and 6). This might be due to the fact that sedges had completed their life cycle by 70 to 80 days. Similar observations have been reported by Trivedi et al. (1985) also.

Only very few dicot weeds were present in the unweeded check, probably due to the dominance of grass weeds. In the plots where the grasses were controlled, relatively more number of dicot weeds were present. These weeds emerged late and were mainly aquatic or semiaquatic types. Even though the seeding of the crop was done under dry conditions, during the latter half of the crop season, the field remained flooded and resembled a wet-sown rice field. Moist conditions would have favoured the establishment of the dicot weeds, Ludwigia parviflora, Sphaeranthus indicus, Ammannia baccifera, Commelina benghalensis and Cyanotis sp.

The observation that grassy weeds constitute the major weed problem in dry-sown rice is supported by the observations of Pande et al. (1966), Mukhopadhyay et al. (1972), Bhan et al. (1980) and Bhol and Singh (1987). The predominance of *Echinochloa colona* and *Cyperus iria* in dry-sown rice has also been observed by Ali and Sankaran (1981), Srinivasan *et al.* (1985) and Jayasree (1987).

4.1.2. Weed Population

4.1.2.1. Grasses

(a) *Isachne miliacea*: The data on the population of *Isachne miliacea* at various stages are presented in Table 2.

At 30 days, all the herbicide treatments except butachlor application at 6 DAS and 9 DAS and thiobencarb at 9 DAS (whether or not repeated at 25 DAS) were found to be equal to hand weeded control and were statistically superior to unweeded control.

The data indicates that weed control treatments involving thiobencarb applications at 0, 3 and 6 DAS and repeated at 25 DAS controlled the weed very effectively and were statistically on par with hand weeding at almost all stages. Among the butachlor treatments, B_0 + 25 was the best treatment and was on par with handweeding at 30 and 60 days.

At 90 days and harvest stages hand weeding recorded least count of this weed. Thiobencarb 0+25 alone showed

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

Treatments	30 DAS		60 DAS		90 DAS		Harvest	
	T	O	T	O	T*	O	T	O
B_0	24.76	612.34	29.76	884.67	36.35	1321.47	13.83	190.47
B_3	18.85	354.41	25.98	674.16	33.87	1147.40	27.79	771.31
B_6	37.75	1424.54	40.87	1669.84	34.51	1191.05	18.66	347.49
B_9	31.96	1020.75	32.56	1059.51	24.15	583.58	28.83	830.43
B_0 + 25	20.98	439.51	18.85	354.48	24.31	591.08	30.08	904.09
B_3 + 25	23.18	536.41	22.62	510.99	35.79	1281.34	27.08	732.41
B_6 + 25	41.65	1734.00	38.65	1493.41	31.89	1017.13	30.61	936.06
B_9 + 25	33.01	1089.00	38.33	1468.26	32.15	1033.95	20.51	419.92
T_0	13.19	173.03	23.69	560.56	35.06	1229.83	25.53	650.89
T_3	19.31	372.09	15.86	250.55	34.69	1204.02	29.89	892.50
T_6	23.93	571.75	28.53	813.38	34.27	1174.56	29.24	854.11
T_9	30.71	942.35	35.95	1291.48	32.37	1048.14	21.23	450.11
T_0 + 25	5.09	24.97	6.13	36.63	12.56	157.82	11.09	122.10
T_3 + 25	10.37	106.63	6.61	42.73	18.75	351.77	21.74	471.72
T_6 + 25	17.29	298.08	10.45	108.35	14.45	208.98	28.12	789.97
T_9 + 25	29.82	888.64	29.41	864.13	29.13	848.65	19.41	375.85
H.W.	14.85	219.52	6.40	40.01	2.82	8.00	3.77	13.25
U.W.	46.38	2150.86	39.02	1521.86	33.36	1112.91	28.68	821.73
SEm±	5.98		4.56		3.25		4.27	
CD (0.05)	17.20		13.12		9.35		12.29	

T - transformed value ($\sqrt{x+1}$) T* - transformed value ($\sqrt{x}$) O - original value (retransformed) control of this weed on par with hand weeding at harvest stage. All other herbicide treatments recorded poor control of the weed at the later stages of the crop.

The result shows that thiobencarb was very efficient in controlling *Isachne*. However, a single application was not generally sufficient to give satisfactory control of this weed. In the repeated application of thiobencarb at 25 DAS secondary germination of weeds were also controlled thereby resulting in weed control on par with hand weeded plot. In general, butachlor was not very efficient in controlling this weed.

(b) *Saccoleppis interrupta*: Effect of treatments on the population of *Saccoleppis interrupta* at different stages is presented in Table 3.

The unweeded check recorded the maximum count of this weed at all stages of crop growth. Among the thiobencarb treatments, T_6+25 recorded lower *Saccoleppis* population at all stages. The treatments where thiobencarb was applied at 3 DAS alone, repeated at 0 and 25 DAS or at 3 and 25 DAS were on par with this treatment at 30 and 60 days. At 90 days also all these treatments except T_3+25 showed their superior weed control effect. However towards

Table 3. Effect of treatments on the population of *Saccoleppis interrupta* (plants/m^2)

Treatments	30 DAS		60 DAS		90 DAS		Harvest	
	T	O	T	O	T	O	T	O
B_0	7.51	55.45	10.92	118.26	14.53	210.37	14.22	201.25
B_3	13.39	178.46	10.49	109.06	13.20	173.32	14.05	196.44
B_6	12.94	166.60	11.51	131.61	12.36	151.90	13.16	172.19
B_9	11.09	122.13	22.43	502.36	17.71	312.75	17.44	303.29
B_0 + 25	5.99	34.98	7.24	51.47	8.76	75.73	11.68	135.63
B_3 + 25	7.67	57.93	9.04	80.79	9.99	98.80	10.83	116.27
B_6 + 25	10.45	108.32	11.81	138.53	12.01	143.32	9.86	96.31
B_9 + 25	10.53	110.04	15.97	254.07	17.09	291.12	12.89	165.35
T_0	8.08	64.36	11.84	139.26	14.05	196.40	14.98	223.48
T_3	7.08	49.21	9.90	97.10	9.37	86.90	11.73	136.80
T_6	9.52	89.72	9.53	89.99	14.38	205.79	12.56	156.98
T_9	9.45	88.45	13.91	192.64	12.61	158.16	14.34	204.64
T_0 + 25	7.44	54.47	8.98	79.67	9.22	84.02	9.22	84.15
T_3 + 25	7.60	56.69	10.50	109.38	11.17	123.77	11.93	141.45
T_6 + 25	1.41	0.99	6.28	38.52	7.70	58.36	14.48	208.69
T_9 + 25	7.67	57.95	14.82	219.63	17.56	307.35	14.45	207.91
H.W.	6.71	44.01	5.23	26.40	1.41	0.99	2.91	7.46
U.W.	27.12	734.62	24.48	598.30	24.70	609.23	20.10	403.36
SEm±	2.39		2.24		2.81		2.65	
CD (0.05)	6.87		6.46		8.08		NS	

T - transformed value ($\sqrt{x+1}$) O - original value (retransformed)

harvest stage the difference between treatments narrowed down and there was no statistical difference between the different treatments.

Butachlor treatments recorded poor control of this weed and among them only B_0+25 and B_6+25 recorded comparable control of Saccoleppis to that of thiobencarb treatments, at most of the stages. B_9 and B_9+25 recorded higher weed counts, which was significantly higher than the other butachlor treatments.

(c) Echinochloa colona: The data on the population of Echinochloa colona under different weed control treatments at various stages of the crop are presented in Table 4.

At 30 days and 60 days most of the herbicide treatments were on par with hand weeded control and statistically superior to the weedy check. At 90 days and harvest stages, the differences in the Echinochloa colona population in different treatments were not significant.

Butachlor treatments were less efficient in controlling this weed, and only B_0+25 and B_3+25 could effect consistent control of this weed at almost all stages.

Table 4. Effect of treatments on the population of *Echinochloa colona* (plants/m^2)

Treatments	30 DAS		60 DAS		90 DAS		Harvest	
	T	O	T	O	T	O	T	O
B_0	9.43	87.93	8.27	67.42	4.61	20.25	3.66	12.44
B_3	6.36	39.53	4.52	19.47	3.06	8.38	1.00	0.00
B_6	11.81	138.63	5.82	32.91	3.40	10.58	1.41	0.99
B_9	6.17	37.17	9.78	94.77	2.58	5.66	1.00	0.00
B_0 + 25	6.97	47.58	5.40	28.23	1.00	0.00	1.00	0.00
B_3 + 25	5.23	26.40	4.02	15.22	2.28	4.20	1.00	0.00
B_6 + 25	9.79	94.97	6.35	39.40	4.60	20.17	3.84	13.76
B_9 + 25	10.70	113.50	10.31	105.32	3.93	14.49	1.00	0.00
T_0	6.39	39.89	6.80	45.27	4.54	19.64	4.05	15.41
T_3	4.07	15.56	2.07	3.32	1.00	0.00	1.00	0.00
T_6	5.72	31.71	3.79	13.40	1.86	2.49	1.00	0.00
T_9	7.51	55.41	6.65	43.21	2.28	4.20	1.00	0.00
T_0 + 25	3.00	8.00	1.00	0.00	1.00	0.00	1.00	0.00
T_3 + 25	1.86	2.49	1.66	1.77	1.00	0.00	1.00	0.00
T_6 + 25	3.93	14.49	1.86	2.49	1.86	2.49	1.41	0.99
T_9 + 25	8.01	63.26	6.04	35.55	2.91	7.46	1.82	2.32
H.M.	5.03	24.36	3.27	9.71	2.07	3.32	2.53	5.42
U.M.	18.94	357.85	12.42	153.46	4.38	18.20	1.00	0.00
SEm±	2.16		1.39		0.99		0.89	
CD (0.05)	6.22		4.02		NS		NS	

T - transformed value ($\sqrt{x+1}$)   O - original value (retransformed)

The result clearly shows the effectiveness of thiobencarb for controlling Echinochloa colona, the most troublesome grass weed in rice fields. These results are in accordance to the observations of Bhan et al. (1986), Ali et al. (1986), Jayasree (1987) and Palaikudy (1989) who have found thiobencarb very effective for controlling this weed.

Studies conducted by Jayasree (1987) and Palaikudy (1989) also showed excellent control of Echinochloa upto 60 days, when thiobencarb was applied immediately after sowing (T_0). Palaikudy (1989) also noted that this effect could be extended throughout the crop growth period when thiobencarb was applied at 0 DAS and again repeated at 20 DAS. This suggests that the effect of this pre-emergence herbicide is lasting only for a few weeks and requires follow up application one month later for getting good control of the weed.

(d) Total grass weed population: Effect of treatments on the population of grass weeds at different stages of observation are presented in Table 5.

Unweeded control recorded maximum count of grass weeds at all stages of crop growth.

Table 5. Effect of treatments on the total grass weed population (plants/m^2)

Treatments	30 DAS		60 DAS		90 DAS		Harvest	
	T*	0	T*	0	T*	0	T	0
B_0	27.85	775.80	33.67	1183.90	39.59	1567.36	21.76	472.84
B_3	27.19	739.80	30.03	902.17	36.67	1345.21	31.48	989.99
B_6	41.78	1745.72	43.00	1848.96	37.06	1373.85	25.69	659.44
B_9	34.53	1192.80	41.21	1698.49	31.03	963.32	35.62	1268.32
B_0 + 25	23.39	547.30	20.92	437.72	26.31	692.54	32.96	1085.58
B_3 + 25	24.92	621.37	25.42	646.64	37.33	1393.94	28.67	821.18
B_6 + 25	44.05	1939.96	41.15	1693.99	35.32	1247.68	32.72	1069.80
B_9 + 25	36.55	1336.23	43.92	1929.31	37.28	1390.08	28.44	807.97
T_0	17.33	300.57	29.99	899.49	38.19	1458.73	34.92	1218.53
T_3	21.05	443.40	20.33	413.29	35.99	1295.48	35.33	1247.34
T_6	26.36	695.01	30.33	920.13	37.32	1392.76	32.13	1031.31
T_9	33.64	1132.17	39.71	1577.61	35.32	1248.02	26.29	690.46
T_0 + 25	9.92	98.49	12.43	154.71	16.10	259.36	15.75	247.06
T_3 + 25	13.00	169.13	13.83	191.51	22.79	519.60	26.33	692.49
T_6 + 25	17.76	315.64	13.40	179.69	17.04	290.49	32.05	1026.51
T_9 + 25	32.26	1041.10	33.64	1131.61	35.33	1248.63	28.67	821.48
H.W.	17.47	305.37	8.82	77.94	3.58	12.87	6.56	42.11
U.W.	57.45	3301.06	47.86	2290.64	41.87	1753.44	35.89	1287.37
SEm±	5.75		3.87		2.93		3.59	
CD (0.05)	16.54		11.12		8.43		10.33	

T - transformed value ($\sqrt{x+1}$) T* - transformed value ($\sqrt{x}$) 0 - original value (retransformed)

At 30 days, all the treatments except B_6 and B_6+25 recorded significantly lower grass counts than the unweeded check. All the thiobencarb treatments where the application was given upto 6 DAS were on par with hand weeding. Among butachlor treatments only B_0+25 and B_3+25 were on par with these thiobencarb treatments.

At 60 days, only the treatments where thiobencarb was repeated at 25 DAS, excepting T_9+25, were equally effective as hand weeding. Thiobencarb at 3 DAS (T_3) and B_0+25 were the other two better treatments which were on par with the above thiobencarb treatments. However, these treatments were significantly inferior to the hand weeded control.

At 90 days also, repeated application of thiobencarb (T_0+25, T_3+25 and T_6+25) showed its superiority over the other herbicide treatments, though they were not as effective as hand weeding. All other treatments except B_0+25 and B_9 gave very poor grass control and were on par with unweeded check. At harvest stage, all the treatments other than T_0+25 were statistically inferior to hand weeding in the grass control and were in general on par with unweeded control.

The results clearly establish the relative superiority of thiobencarb in grass weed control in rice. The efficiency of thiobencarb in reducing grass weed population has been reported earlier by De Datta and Bernasor (1971), Bhan *et al*. (1986), Ali *et al*. (1986) and Jayasree (1987). In a trial involving both thiobencarb and butachlor Palaikudy (1989) also observed that thiobencarb was more efficient in grass weed control. Observations on the individual grasses in this trial also showed this effect and hence the same result is reflected in the total grass weed population.

The result also indicates that eventhough thiobencarb is efficient in grass control the effect lasts for few weeks only and that is why the observation from 60 days onwards showed the superiority of the treatments where the herbicides was repeated.

4.1.2.2. Sedges

Effect of treatments on the population of sedges at 30, 60 and 90 days are presented in Table 6. At harvest stage there was no sedge in most of the treatments as they have completed their life cycle and hence the data are not given. Among the sedges, *Cyperus iria* was the most prominent one present in the field.

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

Treatments	30 DAS		60 DAS		90 DAS	
	T	O	T	O	T	O
B_0	2.07	3.32	1.41	0.99	1.41	0.99
B_3	1.86	2.49	1.00	0.00	1.86	2.49
B_6	1.00	0.00	1.00	0.00	1.00	0.00
B_9	1.00	0.00	1.00	0.00	1.00	0.00
B_0 + 25	1.00	0.00	1.00	0.00	1.00	0.00
B_3 + 25	1.00	0.00	1.00	0.00	1.00	0.00
B_6 + 25	1.00	0.00	1.00	0.00	1.00	0.00
B_9 + 25	2.94	7.68	1.00	0.00	1.86	2.49
T_0	5.17	25.78	5.62	30.61	1.00	0.00
T_3	5.77	32.30	4.56	19.87	1.00	0.00
T_6	3.41	10.64	2.07	3.32	1.66	1.77
T_9	10.75	114.57	7.43	54.21	1.00	0.00
T_0 + 25	2.86	7.18	2.07	3.32	1.00	0.00
T_3 + 25	4.02	15.22	1.66	1.77	1.41	0.99
T_6 + 25	2.60	5.79	1.00	0.00	1.00	0.00
T_9 + 25	7.70	58.38	5.93	34.23	1.41	0.99
H.W.	7.76	59.25	1.86	2.49	2.74	6.53
U.W.	7.42	54.13	5.42	28.41	1.00	0.00
SEm±	2.17		1.12		0.43	
CD (0.05)	NS		3.23		NS	

T - transformed value ($\sqrt{x+1}$) O - original value (retransformed)

In general, all the butachlor treatments except its application at 0 and 3 DAS and 9+25 DAS gave complete control of sedges at all stages. On the contrary all the thiobencarb treatments, except T_6+25, recorded higher sedge count at all stages, though this effect was not significant at 30 and 90 days. However, T_6+25 gave total control of sedges at almost all stages.

At almost all stages it was the hand weeded control that gave maximum count of sedges. This may be due to the lack of competition from grass weeds, which were effectively controlled manually. Also subsequent germination of the sedge from the dormant seed, after the hand weeding resulted in a higher sedge count in these plots.

From the above observations it can be concluded that pre-emergence application of butachlor was more efficient in controlling sedges throughout the crop growth period. The efficiency of butachlor in controlling the sedge population in rice has been reported earlier by Cadang and Mercado (1983), Patel et al. (1985) and Palaikudy (1989). Relatively poor control of Cyperus iria with thiobencarb has also been reported by Jayasree (1987). The observation that the thiobencarb treatment, T_6+25 gave total control of sedges at almost all stages is supported by the observation of Jayasree (1987) who reported that among the different time of application of thiobencarb, 6 DAS gave the least Cyperus count.

The result suggests that in a field where sedges are of major concern, butachlor should be preferred to thiobencarb.

4.1.2.3. Broad leaved Weeds

The data on the total broad leaved weed population in the experimental field as affected by the different treatments are presented in Table 7.

At 30 days, there was no significant difference between treatments on the broad leaved weed count. Throughout the crop growth period the unweeded control, B_6+25 and B_9+25 recorded relatively lower count of broad leaved weeds. Among thiobencarb treatments, T_9 recorded the lowest broad leaved weed population. This may be due to the high population of tall sedges and grasses in these treatments which have resulted in severe competition for light and thus prevented the emergence of other weeds. On the other hand, the weed-free check and the herbicide treatments where the grasses were controlled better, recorded higher broad leaved weed count. These results are in

Table 7. Effect of treatments on the population of broad leaved weeds (plants/m^2)

Treatments	30 DAS		60 DAS		90 DAS		Harvest	
	T	O	T	O	T	O	T	O
B_0	6.85	46.01	6.26	38.20	3.54	11.53	1.41	0.99
B_3	4.08	15.66	13.23	174.28	4.51	19.40	4.33	17.77
B_6	4.64	20.60	5.00	24.00	1.41	0.99	1.00	0.00
B_9	2.53	5.42	2.46	5.06	2.73	6.49	3.23	9.46
B_0 + 25	2.53	5.42	5.12	25.30	3.00	8.00	2.33	4.44
B_3 + 25	4.21	16.72	13.79	189.38	7.39	53.70	6.81	45.49
B_6 + 25	4.04	15.33	2.33	4.44	1.41	0.99	1.00	0.00
B_9 + 25	2.53	5.42	1.00	0.00	1.41	0.99	2.58	5.66
T_0	7.13	49.86	8.87	77.74	4.04	15.33	5.00	24.00
T_3	11.43	129.77	16.84	282.85	6.27	38.40	4.70	21.12
T_6	3.93	14.45	6.90	46.73	2.19	3.81	1.86	2.49
T_9	6.51	41.45	4.48	19.10	2.04	3.16	1.00	0.00
T_0 + 25	11.12	122.86	11.32	127.21	12.30	150.40	14.60	212.25
T_3 + 25	7.44	54.46	14.10	197.99	13.29	175.67	4.04	15.33
T_6 + 25	4.05	15.44	9.55	90.26	9.62	91.58	2.80	6.84
T_9 + 25	3.00	8.00	7.29	52.21	3.68	12.55	3.67	12.46
M.W.	4.81	22.19	9.72	93.62	6.88	46.46	16.68	277.22
U.W.	5.40	28.18	1.41	0.99	1.41	0.99	1.00	0.00
SEm±	2.26		2.75		2.07		2.39	
CD (0.05)	NS		7.91		5.97		6.87	

T - transformed value ($\sqrt{x+1}$) O - original value (retransformed)

accordance to the earlier observation of Palaikudy (1989) who noted low broad leaved weed count in the weedy check.

Among the butachlor treatments, application at 6 DAS (whether or not repeated at 25 DAS) recorded lower broad leaved weed count at almost all stages of crop growth. Thiobencarb was found to be inferior in controlling this group of weeds. However, T_6 and T_9 gave satisfactory control on par with the best butachlor treatments. Another fact to be noted in this context is that thiobencarb treatments (T_0+25, T_3+25 and T_6+25) that gave superior control of other major weeds gave a very poor control of broad leaved weeds and recorded higher counts as in the hand weeded plots. This may be due to the shift in the flora towards broad leaved weeds in these plots when the more competitive grasses were controlled effectively. Akobundu and Fagade (1978) also reported such shift to dicots, especially compositae and commelinaceae, in fields where other dominant weeds have been controlled by pre-emergence herbicides. In this study the major dicot weeds were <u>Sphaeranthus indicus</u> (Compositae), <u>Ludwigia parviflora</u> (Onagraceae), <u>Ammannia baccifera</u> (Lythraceae), <u>Commelina benghalensis</u> and <u>Cyanotis</u> sp. (Commelinaceae). However, such a shift favouring the slow-growing broad leaved weeds over fast growing annual grasses is desirable considering the relative easiness in controlling these dicot weeds in rice.

4.1.2.4. Total Weed Population

The data on the total weed population at different stages are presented in Table 8.

At almost all stages except at 30 days, the hand weeded check recorded the least count of weeds. Throughout the crop season the weedy check recorded maximum weed count.

At 30 days, all the thiobencarb treatments except T_9 gave weed control on par with hand weeding. Thiobencarb application at 0 DAS (whether or not repeated at 25 DAS) and at 3 DAS and 6 DAS (both repeated at 25 DAS) recorded even lower weed counts than hand weeded plots, eventhough the differences were not statistically significant. Among the butachlor treatments, the repeated application at 0+25 DAS and 3+25 DAS could result in effective weed control on par with hand weeding. All the other treatments recorded higher weed counts, eventhough superior to the weedy check, which was found to be statistically inferior to all other treatments.

Table 8. Effect of treatments on the total weed population (plants/m^2)

Treatments	30 DAS		60 DAS		90 DAS		Harvest	
	T*	O	T*	O	T*	O	T*	O
B_0	29.07	845.55	31.10	967.39	39.77	1581.75	21.78	474.38
B_3	28.05	786.99	31.61	999.54	37.08	1375.04	32.16	1034.45
B_6	42.06	1769.77	44.53	1982.94	37.08	1375.38	25.67	659.30
B_9	38.20	1459.45	41.33	1708.13	31.11	968.24	35.79	1281.15
B_0 + 25	23.50	552.37	21.64	468.31	26.70	713.17	33.06	1093.30
B_3 + 25	25.41	645.83	30.32	919.79	38.20	1459.78	30.87	953.43
B_6 + 25	44.24	1957.88	41.25	1702.33	35.33	1248.81	33.07	1094.13
B_9 + 25	36.75	1350.93	43.92	1929.31	37.35	1395.05	28.62	819.18
T_0	19.93	397.29	32.35	1046.74	38.54	1485.65	35.46	1257.71
T_3	24.69	609.58	27.41	751.55	36.57	1338.01	35.71	1275.65
T_6	27.01	729.96	31.35	983.04	37.43	1401.19	32.16	1034.62
T_9	37.36	1396.23	41.50	1722.38	35.71	1275.49	26.27	690.46
T_0 + 25	16.08	258.81	18.47	341.14	21.46	460.90	25.01	625.70
T_3 + 25	15.90	252.97	20.33	413.44	27.42	752.13	26.66	710.90
T_6 + 25	18.64	347.61	16.53	273.32	21.67	469.97	32.26	1040.80
T_9 + 25	33.57	1127.05	36.06	1300.83	35.68	1273.14	28.96	839.13
H.W.	20.11	404.76	13.47	181.54	9.42	88.91	21.49	462.08
U.W.	61.44	3775.62	48.18	2321.96	41.88	1754.70	35.87	1287.29
SEm±	5.66		4.44		2.77		3.33	
CD (0.05)	16.28		12.77		7.98		9.58	

T* - transformed value ($\sqrt{x}$)   O - original value (retransformed)

At 60 days, the hand weeded plot recorded the least count of weeds and only the treatment, T_6+25 was on par with it. T_0+25, T_3 (whether or not repeated at 25 DAS) and B_0+25 were on par with the best thiobencarb treatment (T_6+25) though inferior to hand weeding. Thiobencarb application at 9 DAS and butachlor treatments at 6 and 9 DAS (whether or not repeated at 25 DAS) were less effective in controlling weeds and recorded weed counts equal to weedy check.

At 90 days, hand weeding was found to be statistically superior recording least count of weeds. Among the herbicide treatments, T_0+25, T_3+25, T_6+25 and B_0+25 were on par and gave effective control of weeds. All the other treatments gave poor control of weeds at this stage with weed counts and mostly on par with weedy check.

At harvest stage all the treatments except T_0+25, T_9, B_0 and B_6 were on par with weedy check. The least total weed count was noticed in hand weeded plots.

The major part of the total weed population was constituted by grasses. So the trend in total weed population was greatly influenced by the grass weeds. As in the case of grass weeds the repeated application of thiobencarb at 0, 3 or 6 DAS and at 25 DAS and butachlor 0+25 was the best for reducing total weed count in dry-sown rice for the major part of the crop season. This result is supported by the earlier report of Palaikudy (1989). According to her observations T_0+20 and B_0+20 recorded weed counts on par with hand weeding at almost all stages of dry-sown rice, proving the almost equal effect of thiobencarb and butachlor on total weed population, due to their differential effect on grasses and sedges.

Many workers have reported that a weed-free duration upto 45 to 60 days was essential for getting good crop growth and optimum yield in dry-sown rice (Wells and Cabradilla, 1981; Ali and Sankaran, 1984b; Sankaran and De Datta, 1985 and Singh et al., 1987). Hence any weed control treatment which can effectively check the weed competition during this period will have a favourable influence on crop yield. It is seen that single application of thiobencarb or butachlor is not enough to give satisfactory weed control for the entire critical period, whereas their repeated application at 25 DAS is necessary to prolong the weed-free condition to cover the entire critical period of the crop.

4.1.3. Dry matter production by Weeds

The data on the weed dry matter production under different treatments, at different stages of the crop are presented in Table 9 and illustrated in Fig.2a and 2b.

Table 9. Effect of treatments on the dry matter production by weeds (g m^{-2})

Treatments	30 DAS		60 DAS		90 DAS		Harvest	
	T*	O	T*	O	T*	O	T*	O
B_0	5.47	29.95	14.85	220.73	27.85	775.95	21.50	462.38
B_3	3.85	14.87	12.17	148.14	23.18	537.72	21.66	469.14
B_6	7.47	55.80	17.56	308.44	22.84	522.05	22.55	508.71
B_9	5.95	35.40	20.13	405.30	24.06	579.11	24.52	601.59
B_0 + 25	4.16	17.35	9.15	83.85	17.09	292.39	21.75	473.12
B_3 + 25	4.15	17.28	14.14	199.97	21.67	469.70	22.21	493.63
B_6 + 25	7.61	57.99	18.28	354.48	26.37	695.42	17.72	314.07
B_9 + 25	7.52	56.55	22.54	508.14	26.39	696.46	18.61	346.55
T_0	4.33	18.82	13.64	186.04	25.72	661.53	21.43	459.58
T_3	3.34	11.18	11.32	128.17	22.28	496.68	26.65	710.44
T_6	5.17	26.82	12.65	160.23	24.27	589.25	22.47	505.06
T_9	7.22	52.24	17.40	302.95	26.60	707.96	18.64	347.77
T_0 + 25	2.08	4.33	7.19	51.77	12.62	159.36	16.35	267.38
T_3 + 25	2.76	7.64	6.80	46.29	13.36	178.57	20.10	404.01
T_6 + 25	3.87	15.02	6.41	41.16	10.96	120.16	23.44	549.54
T_9 + 25	5.73	32.90	12.91	166.71	22.64	512.91	20.31	412.64
H.W.	2.42	5.88	3.50	12.27	2.74	7.54	9.10	82.90
U.W.	10.00	100.18	16.84	283.08	28.14	792.24	22.86	522.68
SEm±	1.03		1.62		1.79		2.52	
CD (0.05)	2.98		4.68		5.16		7.26	

T* - transformed value ($\sqrt{x}$) O - original value (retransformed)

FIG.2a TREND IN WEED DRYMATTER PRODUCTION AS INFLUENCED BY BUTACHLOR TREATMENTS

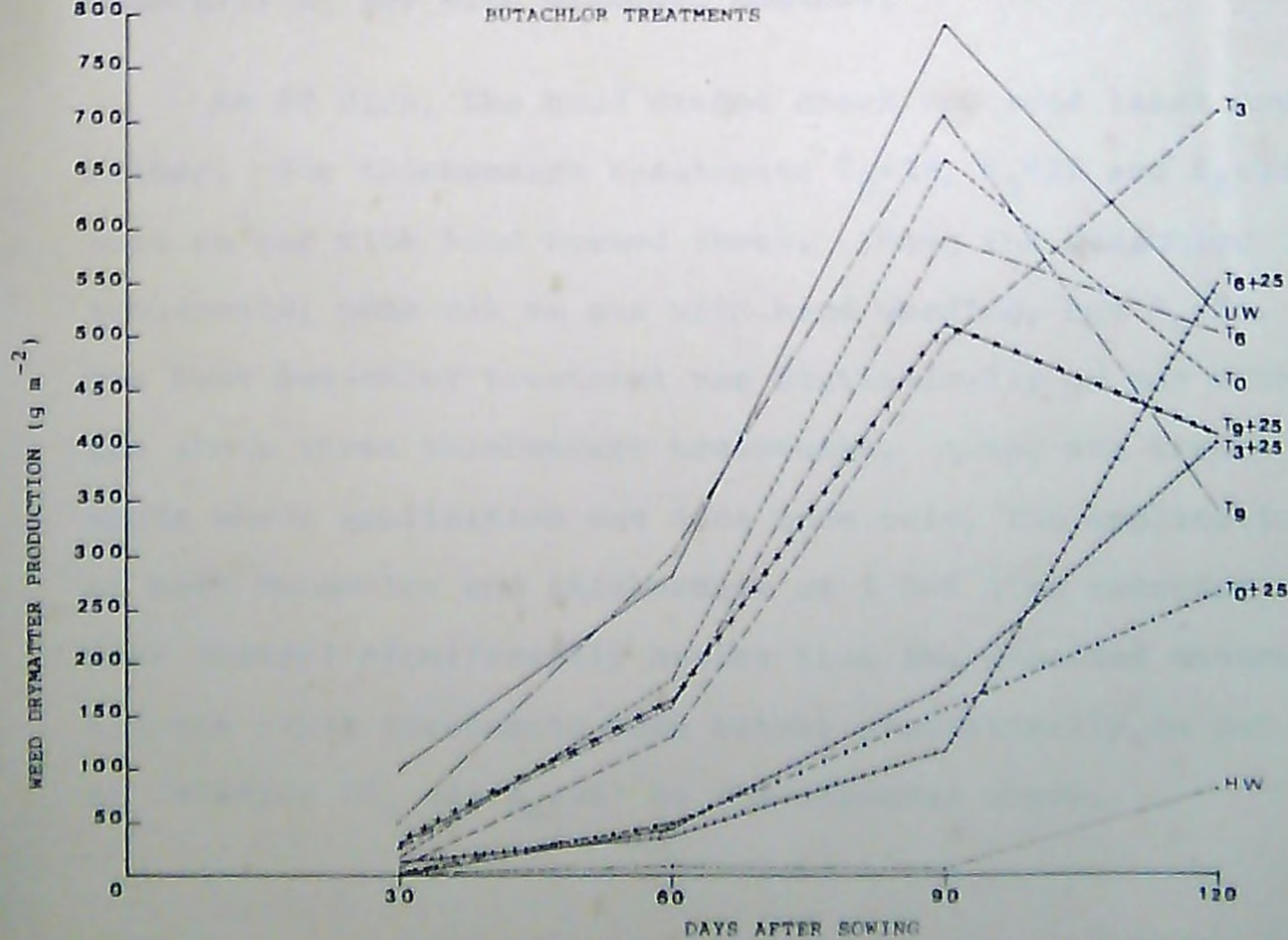
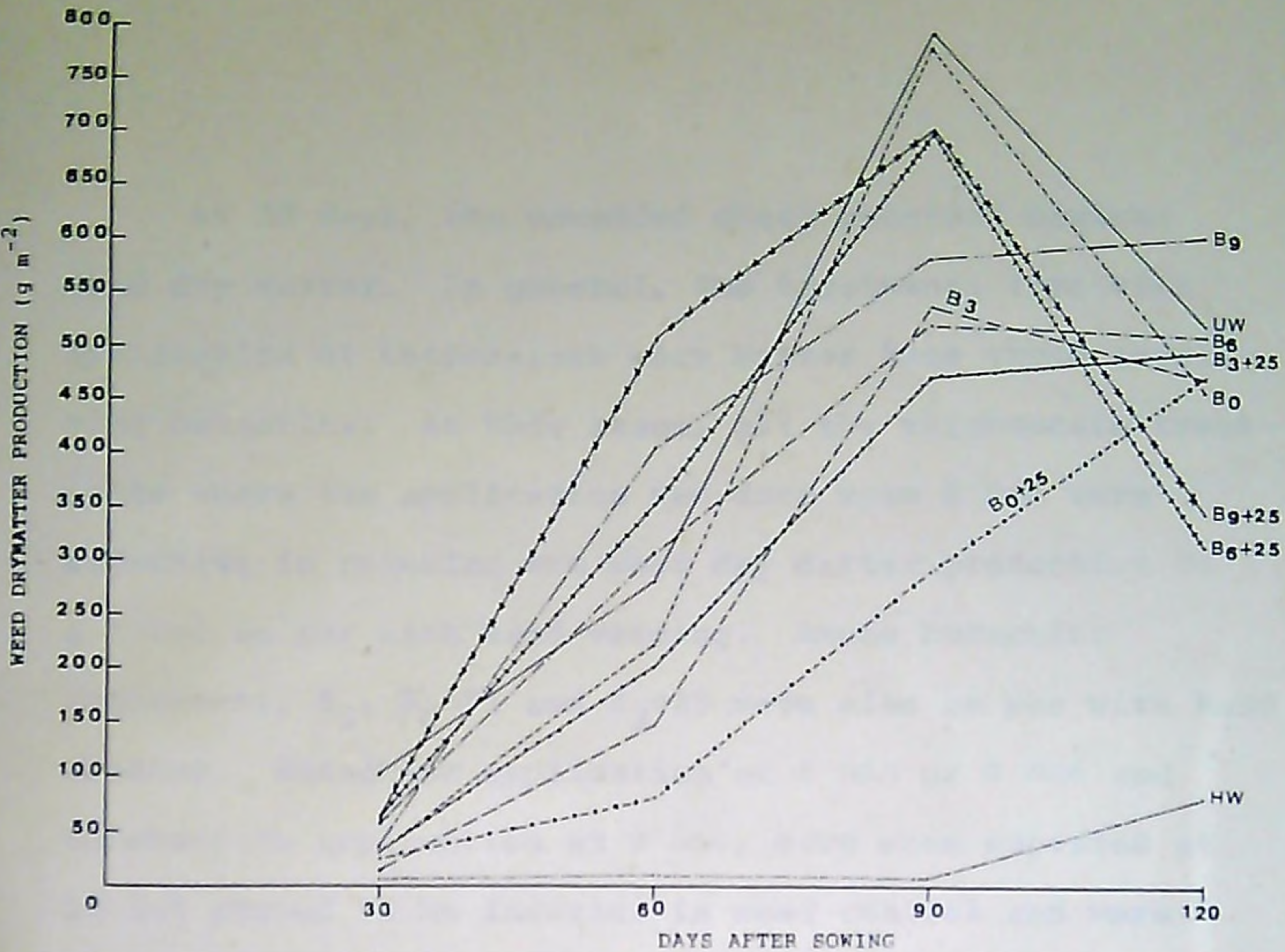


FIG.2b TREND IN WEED DRYMATTER PRODUCTION AS INFLUENCED BY THIOBENCARB TREATMENTS



800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
WEED DRYMATTER PRODUCTION (g m^{-2})
30
60
90
120
DAYS AFTER SOWING
B9
B3
UW
B6
B3+25
B0
B0+25
B9+25
B6+25
HW

At 30 days, the unweeded check recorded maximum weed dry matter. In general, the treatments involving application of thiobencarb were better than those involving butachlor. At this stage, all the thiobencarb treatments where the application was done upto 6 DAS were effective in reducing the weed dry matter production to a level on par with hand weeding. Among butachlor treatments, B_3, B_0+25 and B_3+25 were also on par with hand weeding. Butachlor application at 6 DAS or 9 DAS and thiobencarb application at 9 DAS, even when repeated at 25 DAS proved to be inferior in weed control and were generally on par with unweeded control.

At 60 days, the hand weeded check recorded least dry matter. The thiobencarb treatments T_0+25, T_3+25 and T_6+25 were on par with hand weeded check. Among the butachlor treatments, none was on par with hand weeding, but B_0+25, the best butachlor treatment was statistically on par with the above three thiobencarb treatments. Among the treatments where application was done once only, the application of both butachlor and thiobencarb at 3 DAS also recorded weed control significantly better than the unweeded control. All the other treatments were either statistically on par or inferior (B_9 and B_9+25) to the unweeded check.

At 90 days, the least dry matter was recorded by hand weeded plots which was statistically superior to all other treatments. However, all the repeated application treatments of butachlor and thiobencarb (B_0+25, T_0+25, T_3+25 and T_6+25) that were superior at 60 days continued to be so at this stage also. At this stage treatments involving single applications of thiobencarb or butachlor at 0, 3, 6 and 9 DAS were not promising. As in other stages, the treatments wherein pre-emergence application of thiobencarb or butachlor at 9 DAS was repeated at 25 DAS were also not effective.

At harvest stage also hand weeding recorded the least dry matter production. All the herbicide treatments were either on par or inferior to unweeded check indicating that the activity of herbicides applied was no more existing. The subsequent germination of weeds after 90 days in the treatments where weeds were controlled effectively resulted in an increase in the weed dry matter towards harvest stage. However, in those treatments where weed control was very poor, the weeds got dried off towards harvest stage and the stubbles prevented fresh germination of weeds. So the difference in the weed dry matter production got narrowed down and there was no significant difference between most of the herbicide treatments and unweeded check at harvest stage of the crop.

The observation on weed dry matter production at different stages shows that thiobencarb is better than butachlor in reducing weed dry matter production. This is because of the fact that thiobencarb could more effectively control the grass weed which accounted for the major part of the weed flora in the field, as it is clear from the data on the population of grass weeds (Table 5). Earlier reports by many scientists (Chang and De Datta, 1972; Sridhar et al., 1976; Jayasree, 1987 and Palaikudy, 1989) have proved the efficiency of thiobencarb in reducing dry matter production of weeds.

The results of this trial clearly shows that even though single application of thiobencarb or butachlor at 0 DAS or 3 DAS could control the weeds effectively upto 30 days, there was gradual increase in the weed competition thereafter and only the repeated application treatments were effective as hand weeding from 60 days onwards. Kulshrestha et al. (1981) and Klingman and Ashton (1982) in their studies on the residual life of butachlor and thiobencarb have reported that the effect of these herbicides will last only for a few weeks. So a second application of thiobencarb or butachlor at 25 days can extend their activity in the soil, thereby giving an effect equivalent to hand weeding. Similar result has been reported by Palaikudy (1989) from her works conducted in dry-sown rice in Kerala. She noted that the effect of a second application of the same pre-emergence herbicide (at 20 or 30 days) was equal to that of a hand weeding given around 40 days.

A correlation study between the total weed population and dry matter production by weeds at different stages of crop growth (Table 10) showed that there was significant positive correlation between these two parameters at all stages of observation.

Table 10. Correlation between total weed count and weed dry matter at different stages

Stages	Correlation coefficient
30 DAS	0.9358*
60 DAS	0.7825*
90 DAS	0.8086*
Harvest	0.5499*
Critical values (16 df)	0.4680

4.1.4. Weed control Efficiency

The effect of different treatments on weed control efficiency is presented in Table 11.

Table 11. Effect of treatments on weed control efficiency (%)

Treatments	30 DAS	60 DAS	90 DAS	Harvest
B_0	70.27	0.06	-2.09	10.47
B_3	79.90	41.45	30.20	10.10
B_6	21.84	-15.69	32.20	1.77
B_9	64.16	-63.07	25.71	-17.87
B_0 + 25	76.89	70.12	57.45	8.37
B_3 + 25	83.61	10.12	38.13	1.20
B_6 + 25	3.56	-46.03	8.32	38.58
B_9 + 25	28.88	-97.82	10.27	33.94
T_0	82.31	20.68	7.84	-3.28
T_3	85.55	42.25	33.99	-38.30
T_6	75.46	55.86	22.32	2.68
T_9	40.83	-18.10	10.60	33.71
T_0 + 25	95.32	79.70	78.61	39.17
T_3 + 25	91.38	78.47	72.22	19.34
T_6 + 25	76.20	85.71	84.63	-6.68
T_9 + 25	66.85	39.07	26.02	19.81
H.W.	90.78	94.66	98.69	82.45
SEm±	18.73	25.47	11.13	18.66
CD (0.05)	53.93	73.36	32.05	53.73

At 30 days, all the thiobencarb treatments where the application was done upto 6 DAS (whether repeated at 25 DAS or not) recorded higher weed control efficiency on par with the hand weeded plot. In the case of butachlor this effect was seen only for the application at 0 or 3 DAS. This indicates that when the herbicide application was delayed, some weeds germinated and resulted in low weed control efficiency in B_6, B_9 and T_9.

At 60 days, hand weeding recorded the highest weed control efficiency (94.66%) and most of the thiobencarb treatments excepting T_0 and T_9 were statistically on par with it. Among butachlor treatments, B_3 and B_0+25 showed weed control efficiency on par with these treatments. However, most of the butachlor treatments (B_6, B_6+25, B_9 and B_9+25) recorded even negative values for weed control efficiency as they had higher dry matter production of weeds than the unweeded control. Among thiobencarb treatments the delayed application at 9 DAS (T_9) also showed similar results. It can be seen that the grass weed population in all these treatments were higher than the other better treatments, but they had relatively lower population of sedges and other weeds. This would have favoured the better growth of grasses to produce higher dry matter production than even the unweeded control.

At 90 days, the repeated application of thiobencarb at 0+25, 3+25 and 6+25 recorded weed control efficiency above 70% and were on par with the hand weeded plot which had the maximum weed control efficiency (98.69%). Among the butachlor treatments, B_0+25 had the highest efficiency (57.45%) which was statistically on par with the other three thiobencarb treatments but inferior to hand weeding. However, at harvest stage, this trend of better performance of thiobencarb treatments was not seen, probably due to the fact that many of the earlier germinated weeds had died and new flushes had germinated. This is likely because the pre-emergence herbicides applied would have degraded by this time to show their effect on weed growth. This effect is also reflected in the performance of repeated application treatments. When some of the single application treatments were as effective as the repeated application treatments upto 60 days, only the repeated application treatments showed better efficiency at 90 days.

4.2. Observations on the Crop

4.2.1. Phytotoxicity

Some phytotoxic symptoms were observed on rice seedlings in plots where thiobencarb was applied at 0 DAS.

The main symptoms noticed were stunting of plants, yellowing and drying of leaf tips and margins. In severely affected seedlings leaves did not emerge from coleoptile. If they did, the emerging leaves did not unroll completely, trapping the tip of next developing leaf and causing it to form a loop. Similar phytotoxic symptoms have been reported for chloroacetamide and carbamate herbicides by other workers also (Fuerst, 1987). Chang and De Datta (1972), Nako (1977), Yamada (1984) and Palaikudy (1989) have also reported toxic effect of thiobencarb to germinating rice seedlings. The symptoms persisted for two to three weeks but subsequently the crop recovered. However, several workers noted no phytotoxicity for thiobencarb (Sridhar *et al*., 1976; Pande, 1982; Sudhakara and Nair, 1986 and Jayasree, 1987).

Chandraka and Manna (1981) have pointed out that some phytotoxicity of butachlor to germinating rice seeds is likely to occur due to heavy rainfall four to five days after sowing. In this trial there was rainfall immediately after the application of thiobencarb at zero days which might be responsible for the expression of phytotoxicity. Application of thiobencarb was taken up first and immediately after its spraying there was a very heavy downpour.

Hence the application of butachlor was withheld for few hours till the soil came to condition and there was no rain for few hours after the application of butachlor.

Hence it has to be presumed that in the case of thiobencarb, herbicide did not get any chance to be adsorbed on the soil before the rainfall and it had leached down along with rain water to the seeds, resulting in expression of toxic symptoms. On the other hand, butachlor got a chance to be adsorbed on the clays before the rains and thus the herbicide remained on the soil surface itself. Had there been a rain immediately after the application of butachlor, it also would have resulted in crop toxicity as observed by Palaikudy (1989) in a previous trial in the same station, wherein there was crop toxicity when there was a rainfall after the application of both these herbicides. This assumption is also supported by the observations of Jayasree (1987) that there was no phytotoxicity for rice when there was a rain-free period for few days after the application of thiobencarb at 0 DAS. In their studies on the influence of soil moisture on crop phytotoxicity by chloroacetamide herbicides, Ketchersia et al. (1981) also found that these herbicides were very selective to grain sorghum when the surface soil remained

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4.2.2. Crop Growth Characters

(a) Plant height at harvest

The data on the mean height of the crop plants at harvest under different treatments are presented in Table 12.

All the herbicide treatments were statistically superior to unweeded check and resulted in taller plants. The maximum height of 84.50 cm was recorded in the butachlor treatment, B_3+25 which was even significantly taller than the hand weeded treatment. The unweeded check resulted in the shortest rice plants (50.24 cm). All herbicide treatments, except B_9+25 were on par with hand weeded check.

Due to the high weed density in the unweeded check there was severe crop-weed competition for nutrients (Tables 18, 19 and 20) and crop growth was affected.

Similar observation of reduction in plant height due to weed competition was also reported by Sreedevi (1979), Wells and Cabradilla (1981) and Palaikudy (1989).

Table 12. Effect of treatments on the height of rice

Treatments	Height of plant (cm)
B_0	77.53
B_3	83.01
B_6	81.20
B_9	68.30
B_0 + 25	78.93
B_3 + 25	84.50
B_6 + 25	74.12
B_9 + 25	59.98
T_0	77.76
T_3	81.99
T_6	80.89
T_9	72.05
T_0 + 25	82.72
T_3 + 25	76.34
T_6 + 25	74.77
T_9 + 25	74.77
H.W.	74.81
U.W.	50.24
SEm±	3.17
CD (0.05)	9.12

(b) Drymatter production by crop

The data on the dry matter production by the crop at different stages are given in Table 13 and illustrated in Fig. 3a and 3b.

In general at 30 days all the herbicide treatments recorded dry matter production on par with hand weeding. Most of them even recorded higher dry matter production and this effect was even significant in the case of treatments, T_3+25 and B_3. This may be because the first hand weeding in the hand weeded plot was given only after weeds had grown to some size for effective hand weeding (20 days) by which time competition occurred between rice and weeds as in unweeded plot. In the herbicide treated plots this early competition was avoided and resulted in better crop growth. At 60 days, there was no significant difference between the different treatments in crop dry matter production.

As is very clear from the figure, from 90 days onwards the hand weeded check recorded maximum crop dry matter production. Among the herbicide treatments, T_0+25, T_3+25, T_6+25, T_3 and B_0+25 were on par and recorded higher dry matter production than the other herbicide treatments. Thiobencarb and butachlor application at 9 DAS (whether

Table 13. Effect of treatments on the dry matter production by crop (g m^{-2})

Treatments	30 DAS	60 DAS	90 DAS	Harvest
B_0	47.33	1[illegible]9.33	432.00	495.00
B_3	106.66	336.66	430.66	512.66
B_6	64.00	299.33	408.66	502.00
B_9	67.33	212.00	293.33	332.33
B_0 + 25	66.00	279.33	560.66	686.00
B_3 + 25	68.00	197.33	370.66	493.66
B_6 + 25	66.00	276.66	380.66	458.66
B_9 + 25	56.00	134.00	233.33	261.66
T_0	45.33	328.66	412.00	456.00
T_3	65.33	372.00	532.00	603.00
T_6	74.66	250.66	310.00	408.00
T_9	48.00	217.33	289.33	347.00
T_0 + 25	73.33	350.66	585.33	695.00
T_3 + 25	106.66	313.33	466.66	651.00
T_6 + 25	80.00	326.66	493.33	713.00
T_9 + 25	51.33	235.33	327.33	379.00
H.W.	53.33	289.33	714.66	996.33
U.W.	26.67	182.66	211.33	229.33
SEm±	14.24	64.97	60.06	59.07
CD (0.05)	40.92	NS	172.43	169.75

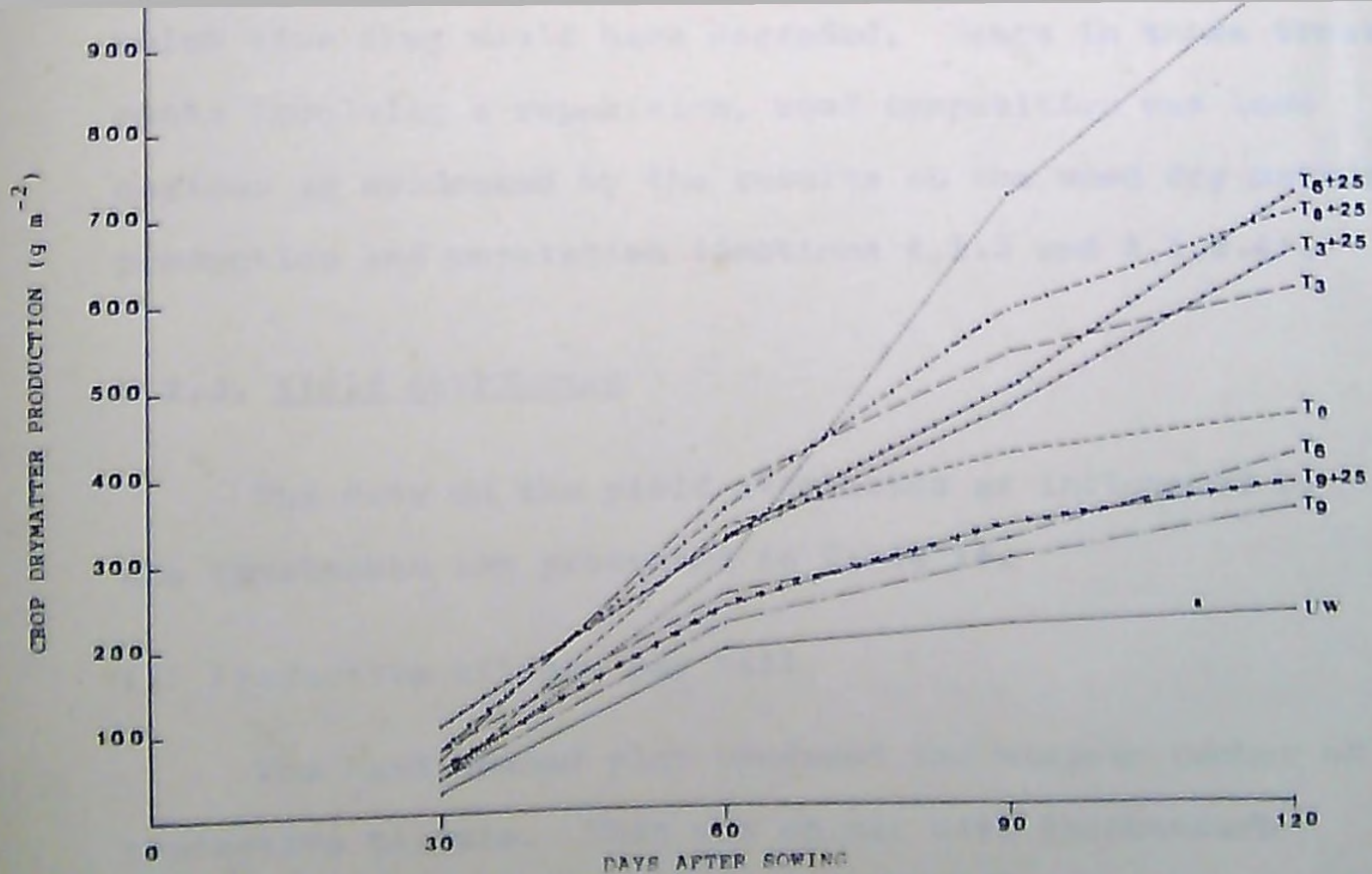

FIG.3b TREND IN CROP DRYMATTER PRODUCTION AS INFLUENCED BY THIOBENCARB TREATMENTS

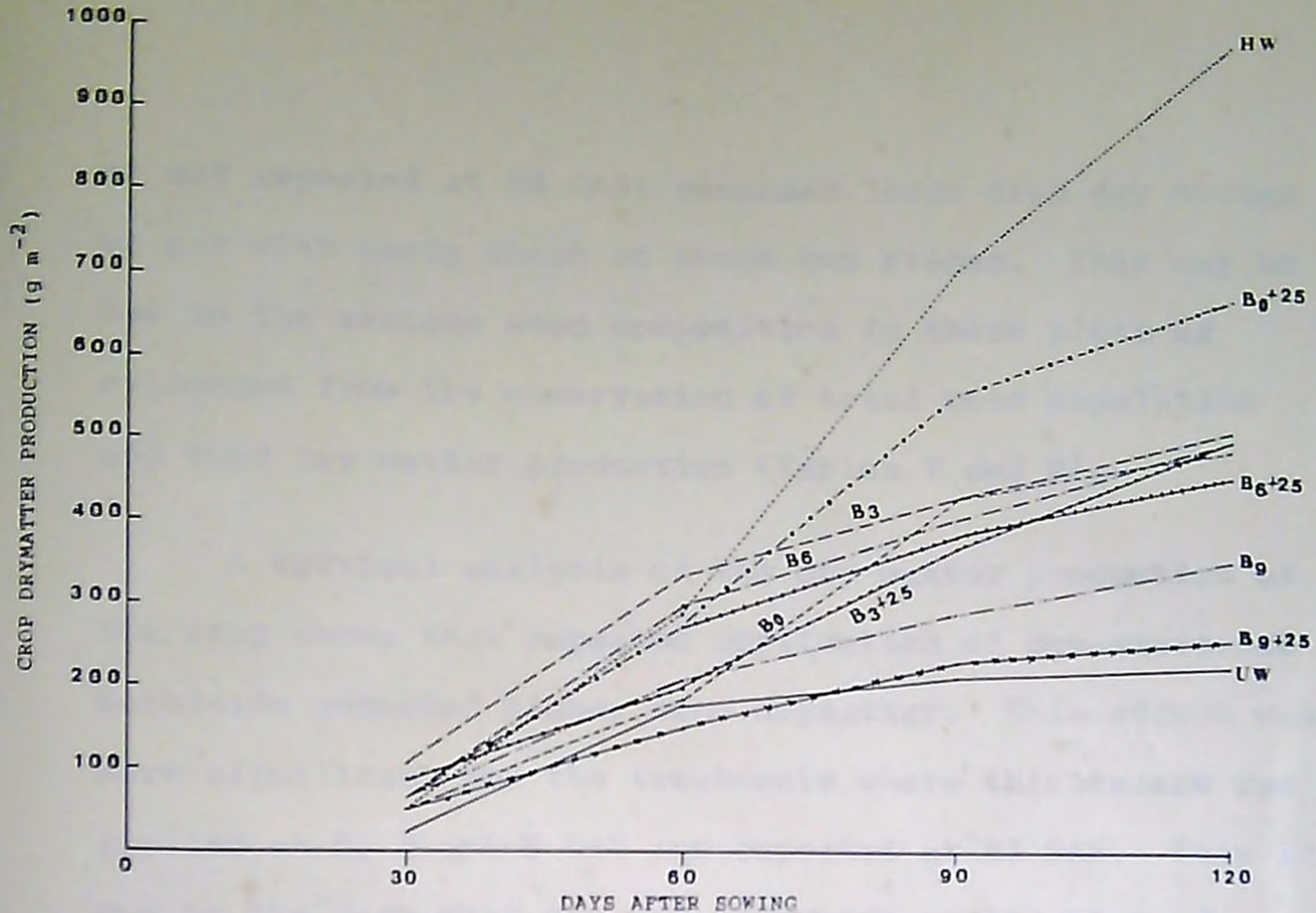

FIG.3a TREND IN CROP DRYMATTER PRODUCTION AS INFLUENCED BY BUTACHLOR TREATMENTS

or not repeated at 25 DAS) recorded lower crop dry matter on par with weedy check at these two stages. This may be due to the serious weed competition in these plots as evidenced from the observation of total weed population and weed dry matter production (Tables 8 and 9).

A critical analysis of the dry matter production of the crop shows that repeated application of pre-emergence herbicide recorded higher crop drymatter. This effect was more significant for the treatments where thiobencarb was applied at 0, 3 and 6 DAS and repeated at 25 DAS. This is due to the fact that the pre-emergence application of herbicides would check the weeds only for about a month, by which time they would have degraded. Hence in those treatments involving a repetition, weed competition was less serious as evidenced by the results on the weed dry matter production and population (Sections 4.1.3 and 4.1.2.4).

4.2.3. Yield Attributes

The data on the yield attributes as influenced by the treatments are presented in Table 14.

(a) Productive tillers per hill

The hand weeded plot produced the maximum number of productive tillers. This was on par with thiobencarb

Table 14. Effect of treatments on yield attributes

Treatments	Productive tiller (No./hill)	Length of panicle (cm)	Total No. of spikelets/ panicle	Thousand grain weight (g)
B_0	5.20	17.76	56.26	24.96
B_3	5.08	17.35	54.20	27.73
B_6	6.43	17.08	50.41	27.33
B_9	3.13	15.17	29.37	24.26
B_0 + 25	5.00	18.21	60.33	25.83
B_3 + 25	5.83	19.10	55.20	27.86
B_6 + 25	3.36	15.87	41.73	27.33
B_9 + 25	4.13	14.41	39.66	22.90
T_0	3.60	16.44	42.63	25.86
T_3	5.96	16.37	46.53	27.06
T_6	5.16	17.70	57.80	25.86
T_9	4.40	16.76	37.79	23.96
T_0 + 25	5.90	17.42	50.00	24.60
T_3 + 25	7.00	17.66	56.00	25.50
T_6 + 25	5.83	17.67	56.73	27.06
T_9 + 25	4.63	16.55	49.24	26.50
H.W.	7.76	17.76	59.80	27.56
U.W.	4.26	13.86	31.20	25.90
SEm±	0.70	0.67	5.28	1.31
CD (0.05)	2.03	1.93	15.20	NS

applications at 0, 3 and 6 DAS and repeated at 25 DAS, single application of thiobencarb at 3 DAS, butachlor application at 3 DAS and repeated at 25 DAS and its single application at 6 DAS. All other treatments recorded significantly lower number of productive tillers and were on par with unweeded control.

(b) Panicle length

All the herbicide treatments except butachlor application at 9 DAS (whether or not repeated at 25 DAS) produced significantly longer panicles than the unweeded control, which recorded the lowest panicle length.

(c) Total number of spikelets per panicle

In general, all the herbicide treatments except their application at 9 DAS recorded higher number of spikelets per panicle than unweeded control and were on par with hand weeded plot.

(d) Weight of thousand grains

There was no significant difference between the treatments with respect to weight of thousand grains.

Among the yield attributes discussed above, all components except thousand grain weight were adversely affected by severe weed competition. With increase in weed density, the number of productive tillers per hill, panicle length and total number of spikelets per panicle showed reduction in their values as reported by Sreedevi (1979), Kohle and Mittra (1981), Jayasree (1987) and Palaikudy (1989).

4.2.4. Yield

The data on the grain and straw yield as influenced by different treatments are presented in Table 15 and illustrated in Fig. 4a and 4b.

(a) Grain yield

Highest grain yield (2564.44 kg ha^{-1}) was recorded by hand weeded plot. Among the herbicide treatments, T_0+25 recorded the maximum grain yield which was statistically superior to all other treatments but inferior to hand weeding. The other two better treatments were the repeated application of thiobencarb at 25 DAS following their initial application at 3 or 6 DAS (T_3+25 and T_6+25). Among the butachlor treatments, B_0+25 was the best and was the only

Table 15. Effect of treatments on the yield of rice ($kg\ ha^{-1}$)

Treatments	Grain yield	Straw yield
B_0	193.01	524.00
B_3	355.90	664.67
B_6	249.99	383.16
B_9	113.88	252.10
B_0 + 25	1055.00	2805.55
B_3 + 25	787.22	1423.61
B_6 + 25	452.57	1026.96
B_9 + 25	244.44	498.05
T_0	291.66	666.66
T_3	704.16	1083.33
T_6	402.77	1077.77
T_9	105.55	306.94
T_0 + 25	1980.55	3280.55
T_3 + 25	1357.00	2585.42
T_6 + 25	1305.55	3187.49
T_9 + 25	497.22	1037.49
H.W.	2564.44	3807.11
U.W.	47.36	149.84
SEm±	148.91	249.77
CD (0.05)	427.92	717.76

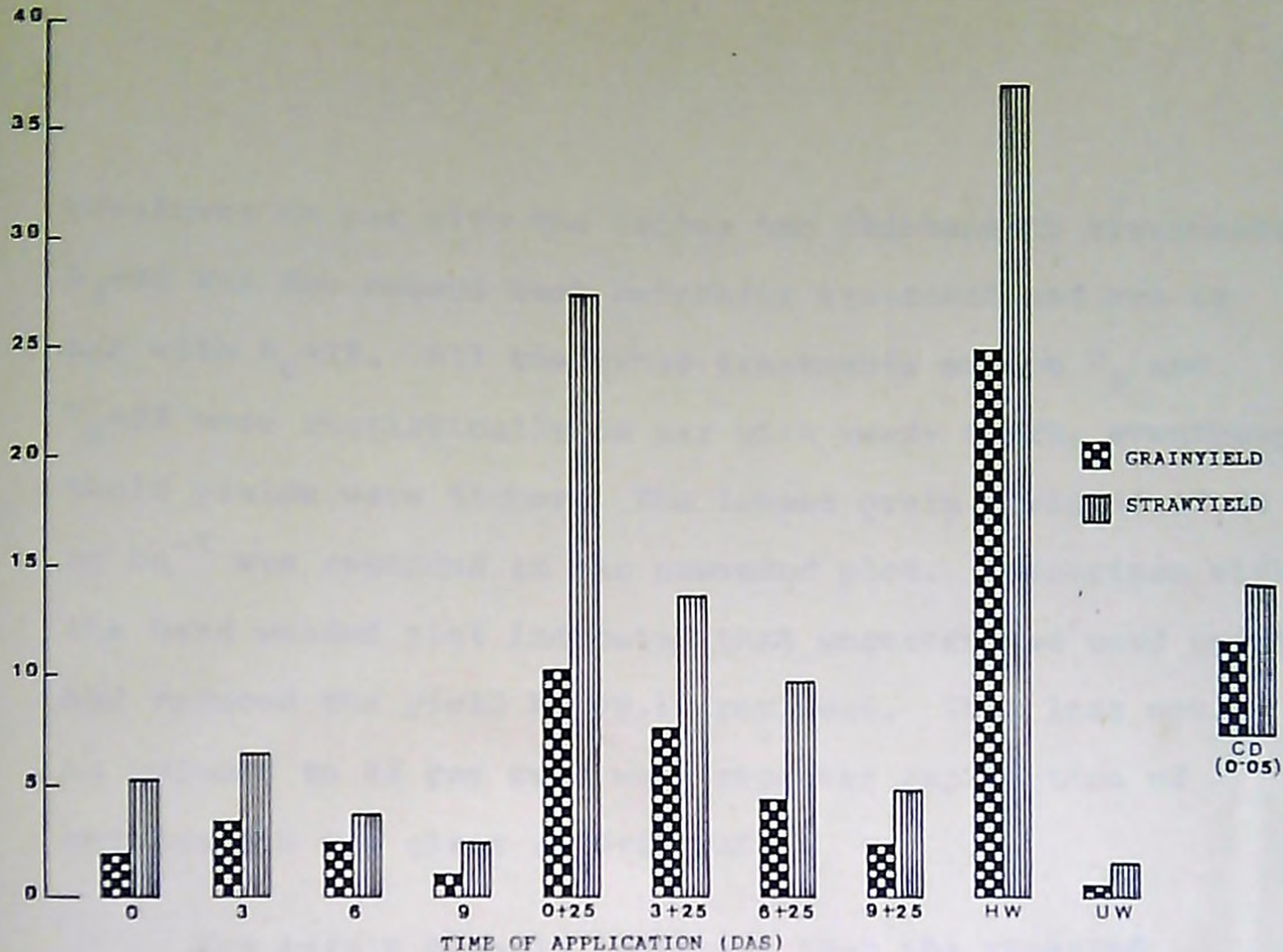

FIG.4a EFFECT OF BUTACHLOR TREATMENTS ON THE YIELD OF RICE

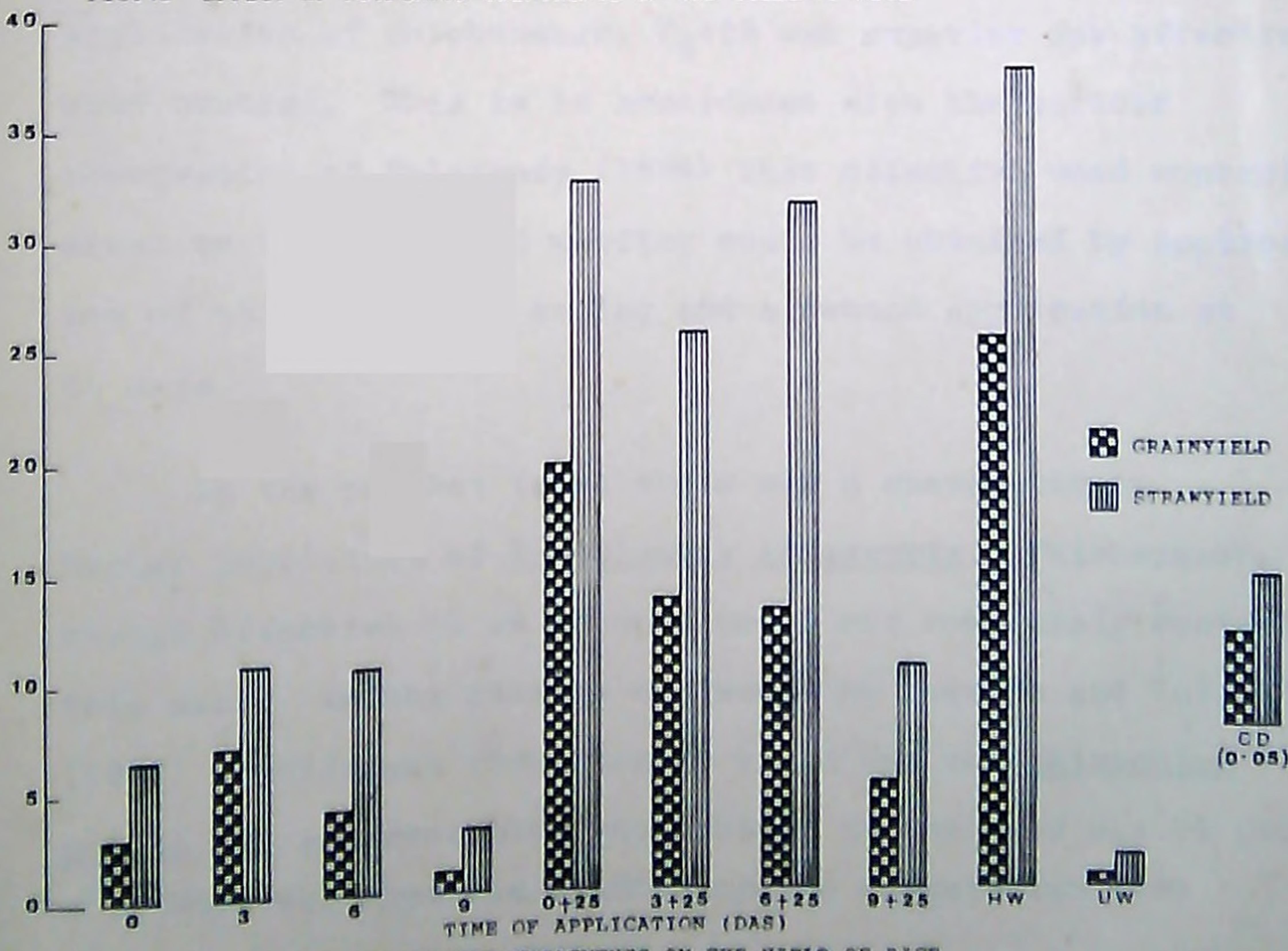

FIG.4b EFFECT OF THIOBENCARB TREATMENTS ON THE YIELD OF RICE

treatment on par with the latter two thiobencarb treatments. B_3+25 was the second best butachlor treatment and was on par with B_0+25. All the other treatments except T_3 and T_9+25 were statistically on par with weedy check, eventhough their yields were higher. The lowest grain yield of 47.36 kg ha^{-1} was recorded in the unweeded plot. Comparison with the hand weeded plot indicates that uncontrolled weed growth had reduced the yield by 98.15 per cent. This loss could be reduced to 23 per cent when repeated application of thiobencarb was given at 0+25 DAS.

The result clearly indicates that the repeated application of thiobencarb, T_0+25 was superior for effective weed control. This is in accordance with the earlier observation of Palaikudy (1989) that effective weed control equal to frequent hand weeding could be obtained by application of thiobencarb at sowing and a second application at 20 days.

In the present trial there was a comparatively higher population of Saccoleppis interrupta. Thiobencarb, though effective to an extent, could not completely control this weed. In the studies conducted by Mercado and Talatala (1977) significant reduction in yield due to Echinochloa colona was apparent when the density of the weed was 80 per m^2. However, specific studies on the competition from

Saccoleppis interrupta, the most trouble-some weed noted in this trial, have not been undertaken so far. Judging from the similarities in morphology between Echinochloa colona and Saccoleppis interrupta, at least the same amounts of competition as that of E. colona for nutrients, water and light can be expected. In this trial throughout the crop growth period the density of Saccoleppis interrupta was much higher - about three times more than the critical density of 80 per m^2 for E. colona, that can be allowed to grow with rice. This has adversely affected the major yield attribute viz., number of ear bearing tillers leading to reduced yield even in herbicide treated plots. This might be the reason for a lower yield in T_0+25 than the hand weeded plot.

The trial has shown that reasonably good yields can be obtained by the application of thiobencarb at 0, 3 or 6 DAS and repeated at 25 DAS or by butachlor application at 0 and 25 DAS. The higher yields in these treatments has resulted from the cumulative contribution of yield attributes namely number of productive tillers, panicle length and number of grains per panicle (Table 14) due to the relatively weed-free conditions during the critical stages of the crop (Table 8). Considering the observations (as discussed in

Section 4.2.1) that crop phytotoxicity may occur from the herbicide applied soon after sowing, when rainfall is received within few days, it is advisable to delay the herbicide application to 3 or 6 DAS.

In the trial butachlor proved to be inferior to thiobencarb probably due to the fact that grass weeds accounted for major portion of the weed population on which thiobencarb was effective. Similar result has also been reported by Palaikudy (1989).

The trial also revealed that a single pre-emergence application of butachlor or thiobencarb could not bring out satisfactory control of the weeds. The probable reason might be the disintegration of the applied herbicide and its becoming ineffective to check the subsequent germination of weed seeds. Kulshrestha et al. (1981) and Klingman and Ashton (1982) has also reported that the half life of these herbicides is only 2 to 3 weeks under aerobic conditions in soil. The rate of degradation of thiobencarb under warm humid tropical condition is very high especially under aerobic condition due to photochemical and microbial degradation, volatilization, leaching and run-off (Yaron et al., 1987). Intermittent rains and warm condition during the experimental period would have resulted in degradation of pre-emergence herbicide at a very fast rate. So the higher grain yield in the repeated application treatments can be attributed to the better control of weeds throughout the critical stages of the crop.

It has to be mentioned here that the grain yield of different treatments in this trial was lower than the normal due to the serious attack of gall fly at the active tillering stage causing a serious reduction in the number of productive tillers.

(b) Straw yield

The maximum straw yield (3807.11 kg ha^{-1}) was recorded in the hand weeded plots. Among the herbicide treatments, only T_0+25 and T_6+25 were on par with hand weeding. However, B_0+25 and T_3+25 were equally effective as the above thiobencarb treatments. All other treatments were statistically inferior to these treatments. The other treatments which recorded comparatively higher straw yields were B_3+25, B_6+25, T_3, T_6 and T_9+25. All these treatments were on par and significantly superior to unweeded control. All other treatments did not show any significant difference to the unweeded control, which recorded the lowest straw yield.

It can be seen that the treatments which gave effective weed control resulted in better crop growth, leading to higherstraw yield, as already discussed for grain yield and dry matter production of crop.

From Fig. 4a and 4b it is clear that straw yield and grain yield is highest in hand weeded plot and is closely followed by T_0+25. The repeated application of herbicides, always yielded higher than their single applications. Between thiobencarb and butachlor, thiobencarb treatments (T_0+25, T_3+25, T_6+25 and T_9+25) yielded higher than the corresponding butachlor treatments (B_0+25, B_3+25, B_6+25 and B_9+25), showing the superior weed control effect of thiobencarb.

(c) Grain-straw ratio and harvest index

The data on grain-straw ratio and harvest index under the different treatments are presented in Table 16.

The grain-straw ratio and harvest index were significantly influenced by the different treatments.

Hand weeded control recorded the maximum grain-straw ratio and unweeded control the lowest. Among the herbicide treatments, butachlor application at 6 DAS (B_6) and

Table 16. Effect of treatments on the grain-straw ratio and harvest index

Treatments	Grain-straw ratio	Harvest index
B_0	0.363	0.263
B_3	0.537	0.349
B_6	0.658	0.396
B_9	0.480	0.322
B_0 + 25	0.375	0.272
B_3 + 25	0.544	0.350
B_6 + 25	0.449	0.309
B_9 + 25	0.487	0.327
T_0	0.424	0.296
T_3	0.643	0.392
T_6	0.384	0.275
T_9	0.354	0.261
T_0 + 25	0.594	0.370
T_3 + 25	0.525	0.342
T_6 + 25	0.414	0.293
T_9 + 25	0.448	0.303
H.W.	0.672	0.405
U.W.	0.311	0.238
SEm±	0.04	0.02
CD (0.05)	0.13	0.06

3 DAS (whether or not repeated at 25 DAS) and thiobencarb application at 3 DAS (whether or not repeated at 25 DAS) and 0+25 DAS were on par with hand weeding. Almost the same trend was observed in case of harvest index also.

It can be seen that, in general in the treatments where weed control was effective the grain-straw ratio and harvest index were higher.

4.2.5. Weed Index

The data on the weed index values pertaining to the different treatments are presented in Table 17 and illustrated in Fig. 5a and 5b.

The minimum weed index value (21.48) was noticed in the thiobencarb repeated application at 0 and 25 DAS which was significantly better than all other treatments. This was followed by the treatments, T_3+25, T_6+25 and B_0+25, the differences between them being not significant. All other treatments except B_3+25, T_3 and T_9+25 were statistically on par with unweeded control which recorded the highest weed index (98.15).

Weed index is a measure of the relative decrease in crop yield due to weed competition compared to hand weeded plot. Greater the grain yield reduction, higher

Table 17. Effect of treatments on the weed index

Treatments	Weed index
B_0	92.34
B_3	86.04
B_6	90.31
B_9	95.52
B_0 + 25	57.97
B_3 + 25	68.84
B_6 + 25	82.41
B_9 + 25	90.42
T_0	88.59
T_3	71.95
T_6	84.01
T_9	95.77
T_0 + 25	21.48
T_3 + 25	45.10
T_6 + 25	49.56
T_9 + 25	79.48
U.W.	98.15
SEm$\pm$	6.23
CD (0.05)	17.94

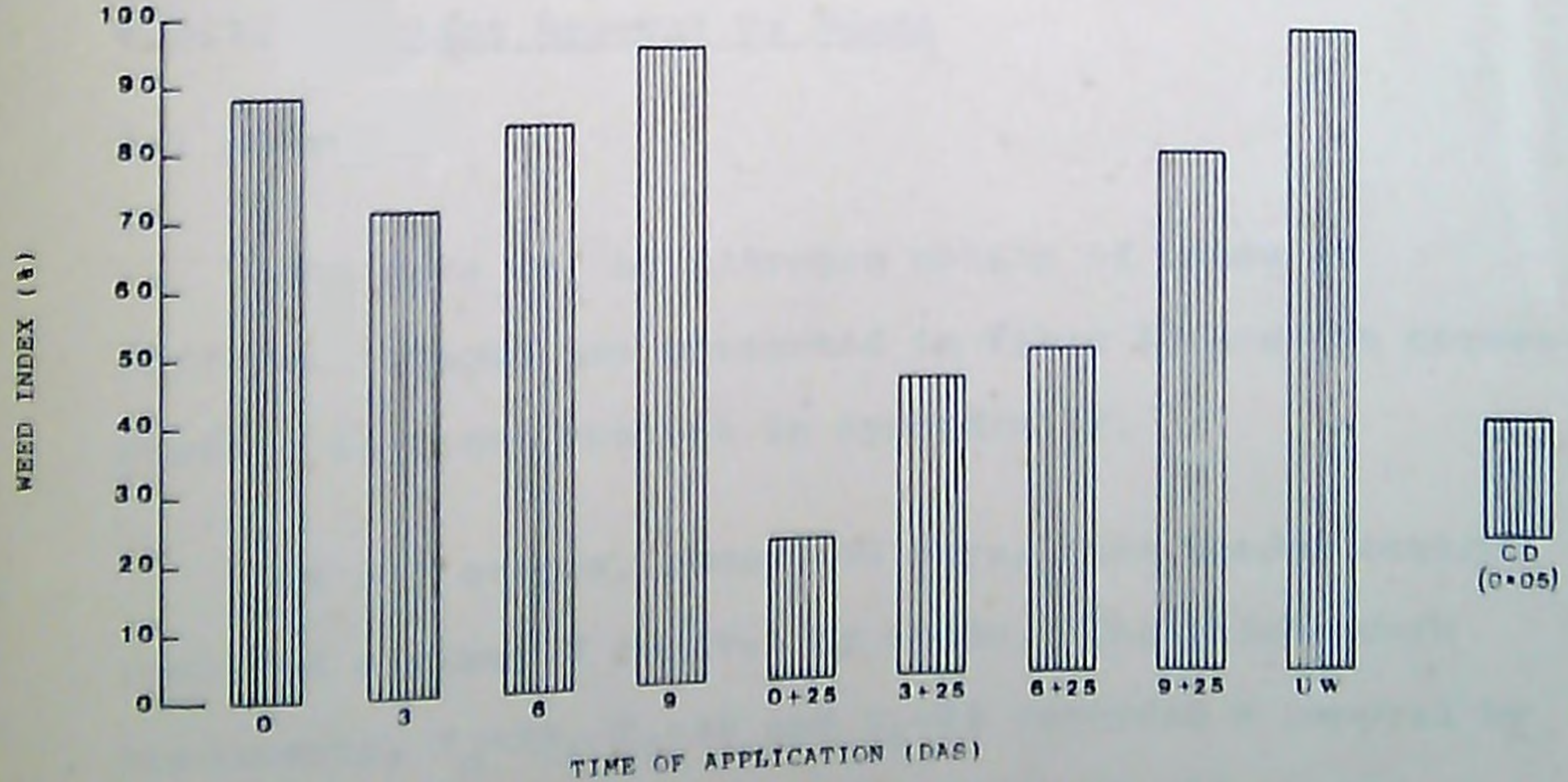

FIG.5b EFFECT OF THIOBENCARB TREATMENTS ON WEED INDEX

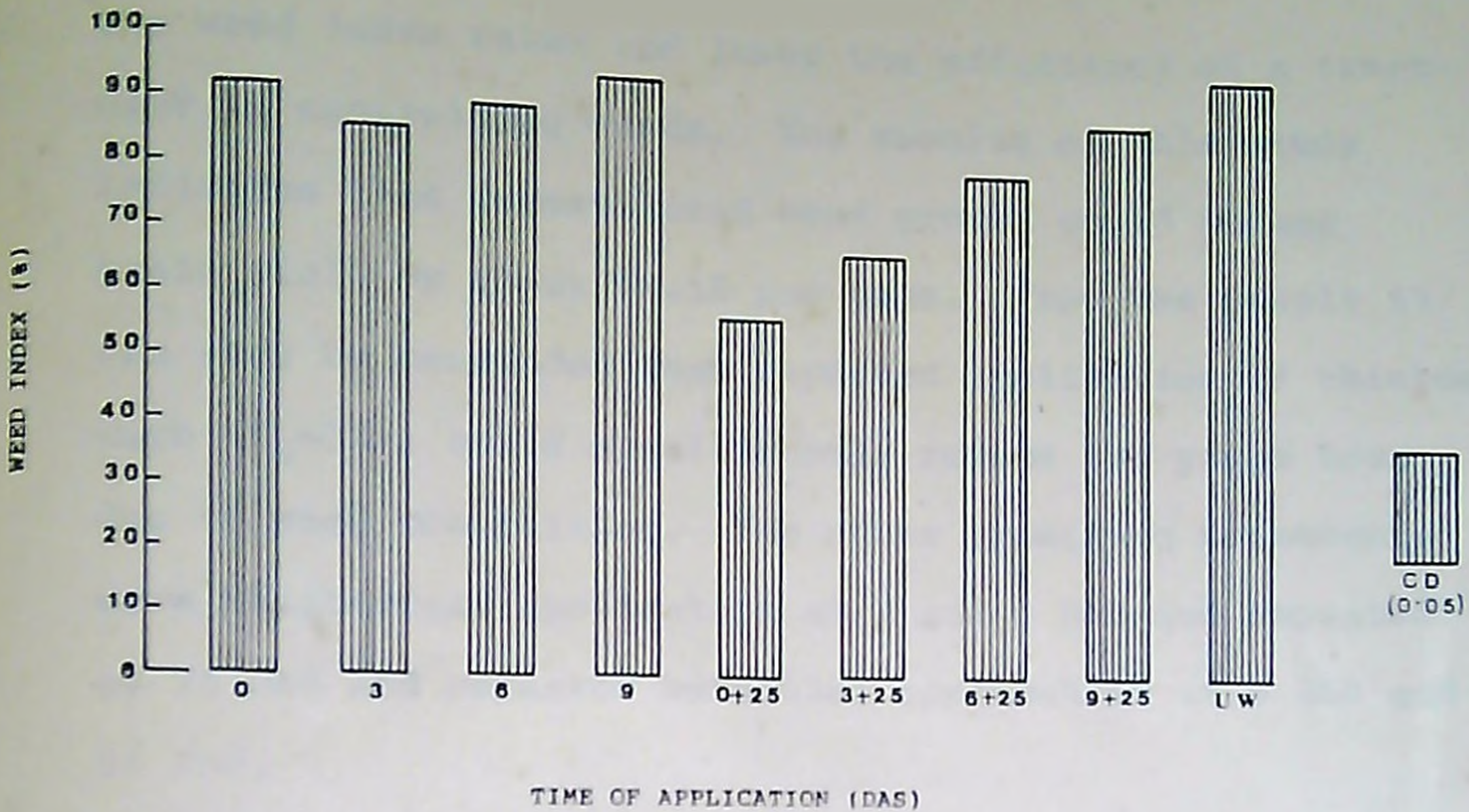

FIG.5a EFFECT OF BUTACHLOR TREATMENTS ON WEED INDEX

the weed index value and lower the efficiency of a treatment in controlling weeds. The results of this study indicates that unrestricted weed growth could reduce grain yield by about 98.15 per cent. From the result it can also be concluded that repeated application of thiobencarb (T_0+25), could significantly reduce the yield loss due to weed competition. The other promising treatments were thiobencarb application at 3 and 6 DAS and repeated at 25 DAS and repeated butachlor application at 0 DAS and 25 DAS.

4.3. Studies on Nutrient Uptake

4.3.1. <u>Nutrient Removal by Weeds</u>

(a) Nitrogen:

The data on the nitrogen uptake of weeds at different stages are presented in Table 18 and the corresponding nitrogen content in Appendix IV.

At all stages, except 30 days, hand weeded control recorded minimum N removal by weeds. The thiobencarb treatments, T_0+25, T_3+25 and T_6+25 recorded N removal by weeds on par with hand weeding at almost all stages. However, at harvest stage there was no significant difference between treatments. At 30 days, the unweeded check

Table 18. Effect of treatments on the nitrogen removal by weeds (kg ha^{-1})

Treatments	30 DAS	60 DAS	90 DAS	Harvest
B_0	10.88	48.13	93.12	65.42
B_3	4.66	35.88	86.08	67.57
B_6	16.24	76.30	75.32	66.21
B_9	8.82	96.60	93.12	66.29
B_0 + 25	3.78	16.08	66.29	71.20
B_3 + 25	4.40	31.36	65.89	94.74
B_6 + 25	12.88	51.89	83.52	50.34
B_9 + 25	6.96	128.66	195.62	57.28
T_0	4.18	40.40	113.78	91.09
T_3	2.49	26.47	59.68	99.86
T_6	9.33	47.97	94.29	63.20
T_9	13.18	58.14	109.10	75.32
T_0 + 25	1.35	13.33	33.88	64.22
T_3 + 25	1.28	15.49	20.82	62.00
T_6 + 25	3.42	12.50	18.85	60.72
T_9 + 25	7.84	36.40	57.86	57.77
H.W.	1.68	3.06	1.21	12.13
U.W.	27.66	69.28	112.18	84.05
SEm±	3.50	10.63	12.08	14.66
CD (0.05)	10.05	30.56	34.73	NS

recorded maximum N removal by weeds which was statistically higher than all other treatments. At this stage all the other treatments except B_6, B_6+25 and T_9 were on par with hand weeding.

At 60 and 90 days, repeated application of thiobencarb, where the first application was done upto 6 DAS (0+25, 3+25 and 6+25) recorded lower N removal on par with that of hand weeding, which recorded the least removal. Butachlor treatments, B_0+25 and B_3+25 also showed lower N removal on par with hand weeding at 60 DAS. B_9+25 recorded maximum N removal by weeds, which was even significantly higher than the removal in unweeded plot, at 60 and 90 DAS.

(b) Phosphorus:

The phosphorus removal by weeds at different stages is presented in Table 19 and the corresponding phosphorus content is given in Appendix V.

At almost all stages of crop growth, except at 30 days, the hand weeded check recorded the minimum removal of P by weeds. The treatments, T_0+25, T_3+25 and B_0+25 recorded lower P removal by weeds throughout the crop period and were statistically on par with hand weeding at most of the stages.

Table 19. Effect of treatment on the phosphorus removal by weeds (kg ha^{-1})

Treatments	30 DAS	60 DAS	90 DAS	Harvest
B_0	1.17	6.58	15.52	12.14
B_3	0.51	4.42	13.98	8.68
B_6	1.28	7.83	10.76	10.18
B_9	1.09	10.92	8.73	13.66
B_0 + 25	0.46	2.79	6.02	4.74
B_3 + 25	0.51	6.26	8.46	4.98
B_6 + 25	1.59	10.37	13.92	6.29
B_9 + 25	1.16	11.82	13.97	4.65
T_0	0.57	5.65	13.38	11.38
T_3	0.29	3.62	11.43	14.26
T_6	0.76	5.31	7.65	6.84
T_9	1.77	9.48	20.36	8.24
T_0 + 25	0.12	1.06	3.21	6.08
T_3 + 25	0.24	1.45	1.89	7.43
T_6 + 25	0.41	1.25	3.49	14.34
T_9 + 25	0.85	5.71	6.83	6.19
H.W.	0.15	0.30	0.13	1.73
U.W.	2.87	5.77	16.02	7.88
SEm±	0.38	1.40	1.67	1.67
CD (0.05)	1.10	4.03	4.80	4.80

At 30 days, the maximum P removal by weeds was recorded by the unweeded check and all the other treatments except T_9 were statistically superior to it. However, at subsequent stages treatments like B_6, B_9, B_6+25, B_9+25, T_9 and T_9+25 recorded higher removal of P by weeds than even the unweeded control.

(c) Potassium:

The data on the potassium removal by weeds are presented in Table 20 and the corresponding potassium content in Appendix VI.

At 30 days, maximum removal of potassium was observed in the unweeded check which differed significantly from all other treatments. At this stage, all other treatments except T_9, B_6 and B_6+25 recorded potassium removal on par with T_0+25, which recorded the least K removal. At 60 and 90 days, hand weeded plot showed least removal of K followed by T_6+25 and T_0+25 which were on par. At 60 days, T_3, T_3+25 and B_0+25 were also equally effective as hand weeding. At 90 days, B_0+25 and T_3+25 were statistically on par with T_0+25. However the better performance (low K uptake) of these treatments was not consistent at the harvest level and many of them were on par with the unweeded

Table 20. Effect of treatments on the potassium removal by weeds (kg ha^{-1})

Treatments	30 DAS	60 DAS	90 DAS	Harvest
B_0	10.20	73.46	170.72	98.14
B_3	4.41	57.72	118.36	101.36
B_6	11.20	106.53	112.98	112.05
B_9	9.24	123.90	101.85	126.56
B_0 + 25	4.23	24.97	90.40	85.44
B_3 + 25	4.40	69.44	122.37	122.17
B_6 + 25	11.96	127.88	118.32	81.81
B_9 + 25	9.86	154.41	157.20	87.71
T_0	6.16	75.75	143.90	153.72
T_3	2.38	43.89	94.49	156.93
T_6	7.66	59.96	106.08	131.66
T_9	12.04	97.92	152.74	75.32
T_0 + 25	1.12	20.26	43.56	101.40
T_3 + 25	1.68	25.45	50.17	101.26
T_6 + 25	2.97	12.06	28.28	115.92
T_9 + 25	7.46	52.00	99.94	90.78
H.W.	1.23	3.53	1.56	18.63
U.W.	26.56	60.62	128.21	105.06
SEm±	3.28	16.01	16.67	23.68
CD (0.05)	9.43	46.00	47.91	68.06

control. At harvest stage also, hand weeding recorded minimum removal of K.

The pattern of N, P and K removal by weeds was more or less the same as that of dry matter production by weeds. This may be due to the fact that there was not much variation in the respective nutrient contents of the weeds at a particular stage. Hence in those treatments where weeds were controlled better, the removal of nutrients by weeds was the least. The lesser competition for nutrients in the plots with low nutrient removal during critical stages might be the reason for the higher yields obtained from them. Similar increase in yield due to less competition for nutrients by weeds have been reported earlier by Sreedevi (1979), Nanjappa and Krishnamoorthy (1980), Kumar and Singh (1984), Jayasree (1987) and Palaikudy (1989).

The results also show that thiobencarb was better than butachlor in reducing nutrient uptake by weeds. This is supported by the observation of Palaikudy (1989) who also noted the efficiency of thiobencarb in reducing nutrient uptake by weeds.

Another fact to be mentioned in this context is that the repeated application of the pre-emergence herbicides resulted in lesser nutrient uptake by weeds than the single application due to the effective weed control possible in these plots. This effect is more pronounced in the case of T_0+25 which could control weeds effectively and so the yield recorded by T_0+25 was also the highest among herbicide treatments.

4.3.2. Nutrient Uptake by Crop

(a) Nitrogen:

Nitrogen uptake by crop at different stages are presented in Table 21 and Appendix VII presents the corresponding nitrogen content (%) in the plant samples.

At 30 days, T_3+25 recorded maximum N uptake by crop followed by T_6+25 which were statistically on par and significantly higher than hand weeding. All the other treatments were found to be statistically equal to hand weeding in the N removal at this stage. At 60 days, there was no significant difference between the different treatments. Towards the latter half of the crop season, hand weeding recorded the maximum N removal by the crop and was statistically superior to all the other treatments. At 90 days, hand weeding was followed by T_0+25, B_0+25 and T_6+25 and the difference between these were not significant.

Table 21. Effect of treatments on the nitrogen uptake by crop (kg ha^{-1})

Treatments	30 DAS	60 DAS	90 DAS	Harvest
B_0	7.57	37.86	69.12	72.47
B_3	14.93	67.33	68.90	77.56
B_6	13.44	59.86	73.56	77.48
B_9	9.42	38.16	46.93	50.48
B_0 + 25	11.88	78.21	89.70	93.91
B_3 + 25	10.20	43.41	51.89	69.50
B_6 + 25	15.18	44.26	45.68	65.24
B_9 + 25	11.20	26.80	28.00	32.92
T_0	12.69	65.73	65.92	66.90
T_3	15.02	59.52	63.84	70.74
T_6	18.66	35.09	37.20	54.48
T_9	8.64	36.94	37.61	43.77
T_0 + 25	11.00	70.13	105.36	108.26
T_3 + 25	30.93	50.13	74.66	88.76
T_6 + 25	22.40	71.86	83.86	103.32
T_9 + 25	12.83	37.65	39.28	42.15
H.W.	13.33	66.54	150.08	160.42
U.W.	4.80	32.88	33.81	24.20
SEm±	3.03	13.43	9.55	7.89
CD (0.05)	8.73	NS	27.47	22.67

At harvest, the N uptake in hand weeded plot was followed by the treatments, T_0+25, T_6+25, B_0+25 and T_3+25, differences between which were not significant. At all stages, unweeded control recorded least removal of N, except at 60 and 90 days, where B_9+25 recorded lowest values.

(b) Phosphorus:

The data on the P uptake by crop at different stages (Table 22 and Appendix VIII) show that the unweeded check recorded the minimum uptake of phosphorus at almost all stages.

At 30 days, there was no significant difference between hand weeding and most of the treatments. Only T_3+25 and B_3 recorded significantly higher P uptake then the hand weeding. However, most of the herbicide treatments were significantly better than unweeded control. At 60 days, there was no significant difference between the treatments in the removal of P by the crop. During latter half of the crop season, hand weeding recorded significantly higher P uptake. At 90 days, hand weeding was followed by T_0+25, B_0+25, T_3, T_6+25 and T_3+25 differences between which were not significant. At harvest stage hand weeding was followed by B_0+25, T_0+25, T_3+25, T_6+25, T_3 and B_3+25, which were statistically on par.

Table 22. Effect of treatments on the phosphorus uptake by crop (kg ha^{-1})

Treatments	30 DAS	60 DAS	90 DAS	Harvest
B_0	1.46	5.86	9.93	10.24
B_3	2.77	8.75	9.90	10.87
B_6	1.66	7.77	9.39	10.56
B_9	1.75	5.51	6.74	6.86
B_0 + 25	2.17	8.65	14.57	15.90
B_3 + 25	2.10	6.11	9.63	12.14
B_6 + 25	2.04	7.19	8.75	9.17
B_9 + 25	1.73	3.48	5.36	5.71
T_0	1.17	8.54	9.47	10.58
T_3	2.35	9.66	13.83	14.05
T_6	2.31	7.76	8.05	8.16
T_9	1.48	5.64	7.52	7.55
T_0 + 25	1.90	9.81	15.21	15.68
T_3 + 25	2.98	8.76	12.13	14.43
T_6 + 25	2.23	10.12	13.81	14.24
T_9 + 25	1.43	5.40	7.52	7.86
H.W.	1.38	6.65	20.00	26.42
U.W.	0.53	4.74	4.85	4.86
SEm±	0.41	1.84	1.51	1.32
CD (0.05)	1.18	NS	4.34	3.80

(c) Potassium:

The potassium uptake by crop and the corresponding potassium content at different stages of the crop are presented in Table 23 and Appendix IX respectively.

At 30 days, B_3 recorded maximum K uptake by crop and the treatments T_3+25, B_3+25, T_6 and T_0+25 were on par with it. All the treatments except B_3 and T_3+25 were on par with hand weeding. At 60 days, there was no significant difference between the different treatments. During the latter half of the crop season, hand weeding recorded maximum removal of K. At 90 days, hand weeding was on par with T_0+25 and T_3. However, at harvest stage hand weeding was found to be superior to all other treatments. Among the herbicide treatments, B_0+25, T_0+25, T_3+25, T_6+25 and T_3 were statistically on par and recorded higher K removal by crop. The unweeded control recorded least removal of K at all stages.

The results on the nutrient uptake by the crop at different stages shows that nutrient uptake by crop was higher in those treatments where nutrient uptake by weeds was less (Table 18, 19 and 20). This is in accordance to the observation of Nanjappa (1975) and Sahai and Bhan (1982)

Table 23. Effect of treatments on the potassium uptake by crop (kg ha^{-1})

Treatments	30 DAS	60 DAS	90 DAS	Harvest
B_0	13.25	60.58	99.33	105.08
B_3	32.53	79.78	94.74	106.13
B_6	20.80	89.62	93.99	100.10
B_9	14.14	60.42	70.40	70.92
B_0 + 25	19.47	83.80	112.13	140.82
B_3 + 25	22.44	59.20	87.10	96.78
B_6 + 25	18.48	71.93	79.94	95.49
B_9 + 25	15.68	46.90	53.66	56.35
T_0	11.78	108.46	94.76	99.78
T_3	19.60	92.02	122.36	123.90
T_6	22.40	75.20	75.95	77.06
T_9	13.92	65.20	66.54	68.55
T_0 + 25	22.00	119.22	128.77	139.14
T_3 + 25	30.93	106.53	114.33	118.74
T_6 + 25	17.60	98.01	113.46	132.72
T_9 + 25	12.23	65.89	72.01	80.21
M.W.	13.33	95.48	157.22	198.03
U.W.	7.46	47.49	47.55	49.98
SEm±	4.06	22.37	13.65	13.40
CD (0.05)	11.67	NS	39.24	38.53

who observed significant negative correlation between nutrient uptake by crop and weeds. This may be because of the better growth and dry matter production of crop (Table 13) due to the absence of competition from weeds for the major nutrients N, P and K. This is supported by the observation of Jayasree (1987) and Palaikudy (1989) who have reported higher nutrient uptake in hand weeded plot compared to unweeded control.

It is to be noted that hand weeding recorded lower uptake of N, P and K by the crop on par with unweeded check at 30 days, whereas most of the herbicide treatments showed higher uptake of these nutrients. This indicates that by the time the first hand weeding was given at 20 days weeds have already competed with the crop for the available nutrients. In the herbicide treated plots this competition was avoided and thus resulted in higher nutrient uptake by the crop.

4.4. Economics of Weed Control Operations

The data on the economics of different treatments are presented in Table 24 and the details in Appendix X.

The total returns was highest in hand weeded plot (Rs.10358.30/ha) followed by T_0+25 (Rs.8238.05/ha). The

Table 24. Economics of weed control treatments

Treatments	Total return (Rs./ha)	Cost of the Weed control operation (Rs./ha)	Additional return from the weed control (Rs./ha)	Return per Rupee invested on weed control (Rs.)	Expenditure for chemical weed control as percentage of Handweeding
B_0	945.80	474.00	698.80	1.47	16.59
B_3	1532.95	474.00	1285.95	2.71	16.59
B_6	1018.20	474.00	771.20	1.62	16.59
B_9	518.15	474.00	271.15	0.57	16.59
B_0 + 25	5129.00	948.00	4882.00	5.14	33.19
B_3 + 25	3358.15	948.00	3111.15	3.28	33.19
B_6 + 25	2076.70	948.00	1829.70	1.93	33.19
B_9 + 25	1081.90	948.00	834.90	0.88	33.19
T_0	1341.65	477.00	1094.65	2.29	16.70
T_3	2870.80	477.00	2623.80	5.50	16.70
T_6	1962.70	477.00	1715.70	3.59	16.70
T_9	531.50	477.00	284.50	0.59	16.70
T_0 + 25	8238.05	954.00	7991.05	8.37	33.40
T_3 + 25	5880.80	954.00	5633.80	5.90	33.40
T_6 + 25	6147.90	954.00	5900.90	6.18	33.40
T_9 + 25	2217.90	954.00	1970.90	2.06	33.40
H.W.	10358.30	2856.00	10111.30	3.54	100.00
U.W.	247.00	-	-	-	-

highest return per rupee invested on weed control was obtained in T_0+25 (Rs.8.37) followed by T_6+25 (Rs.6.18) and T_3+25 (Rs.5.90). Among the butachlor treatments, B_0+25 recorded the highest return per rupee invested (Rs.5.14) on weed control.

Eventhough the total returns from hand weeded plot was higher, the high cost of labour involved in hand weeding has lead to lower return per rupee (Rs.3.54) invested on weed control. Thus the treatments, T_0+25, T_3+25, T_6+25 and B_0+25 where the repeated application of the herbicides was done gave higher returns for the investment on weed control, than that for hand weeding. However, since the grain yield in the single application of herbicides was generally lower, only T_3 and T_6 resulted in benefit-cost ratio higher than hand weeding.

A comparison of the return per rupee invested and the expenditure on chemical weeding as percentage of hand weeding leads to a conclusion very much in favour of herbicidal weed control. The best herbicide treatment, T_0+25 which costed only one third of the cost for hand weeding resulted in more than twice the return per rupee invested for the hand weeding. Similarly T_3 which accounted for only 16 per cent of the cost of hand weeding gave a return of Rs.5.5 per rupee invested compared to Rs.3.54 for hand weeding.

Summary

5. SUMMARY

A field experiment was conducted at the Agricultural Research Station, Mannuthy under the Kerala Agricultural University, during the first crop season of 1988 to find out the optimum time of application of pre-emergence herbicides, butachlor and thiobencarb and to assess the scope of second application of these herbicides, for efficient weed control in dry-sown rice. The experiment was laid out in randomized block design, with three replications. Treatments consisted of different time of application of pre-emergence herbicides, butachlor and thiobencarb, which were applied at zero, three, six or nine days after sowing only or repeated at 25 days after sowing also. Efficiency of these treatments were compared with two controls viz., hand weeded check and unweeded check. The salient findings of the experiment are summarized below:

Major part of the weed flora of the experimental field was constituted by grasses and sedges. Among the grasses, Isachne miliacea, Sacciolepis interrupta and Echinochloa colona and among sedges Cyperus iria were the prominent weeds. A few broad leaved weeds were also present from 60 days onwards; Sphaeranthus indicus, Ludwigia parviflora, Ammannia baccifera, Commelina benghalensis and Cyanotis sp. being the main ones.

The grass weeds were very effectively controlled with thiobencarb application. Repeated application of thiobencarb at 0+25, 3+25 and 6+25 DAS showed its superiority over the other herbicide treatments. Almost the same trend was followed in the case of individual grass species, particularly Isachne miliacea and Echinochloa colona. Thiobencarb, though effective to an extent could not give satisfactory control of Saccoleppis interrupta. All the butachlor treatments except its application at 0 and 3 DAS and 9+25 DAS gave complete control of sedges at all stages. The repeated application of thiobencarb at 0, 3 or 6 DAS and at 25 DAS and butachlor 0+25 DAS were the better treatments for reducing total weed count during the major part of the crop season.

Thiobencarb was better than butachlor in reducing dry matter production by weeds. A second application at 25 days stage extended the weed control effect of butachlor applied at 0 DAS and thiobencarb applied at 0, 3 or 6 DAS and thus giving an effect equivalent to hand weeding during critical stages (upto 60 days). A significant positive correlation was found to exist between total weed population and weed dry matter production during all the stages. The highest weed control efficiency at almost all stages was observed in hand weeded plots and the repeated application of thiobencarb upto 6 DAS (T_0+25, T_3+25 and T_6+25) and the butachlor repeated application, B_0+25 were on par with it.

Some phytotoxic symptoms were observed in rice seedlings due to heavy rainfall after the application of thiobencarb at 0 DAS. High weed density and severe weed competition affected the crop growth and reduced the height and crop dry matter production. The repeated herbicide application, T_0+25, T_3+25, T_6+25 and B_0+25 recorded significantly higher crop dry matter.

The hand weeded plot produced the maximum number of productive tillers per hill and the repeated applications of thiobencarb, T_0+25, T_3+25 and T_6+25 were on par with it. Hand weeding and the herbicide treatments where weed control was effective produced longer panicles and higher number of spikelets per panicle. There was no significant difference between the treatments with respect to weight of thousand grains. Highest grain yield was recorded by hand weeded plot followed by T_0+25. Maximum straw yield was produced by hand weeded control which was on par with T_0+25 and T_6+25. In general, in the treatments where weed control was effective the grain-straw ratio and harvest index were higher

The minimum weed index values was noticed in the thiobencarb repeated application at 0 and 25 DAS, which was significantly superior to all other treatments.

Nutrient uptake by weeds and crop showed almost opposite trend. The N, P and K removal by weeds were lower in the repeated application of thiobencarb T_0+25, T_3+25 and T_6+25 and the butachlor application, B_0+25, while the corresponding uptake by crop were high in these treatments.

The total return was highest in hand weeded plot. However, the highest return per rupee invested on weed control was obtained in T_0+25 due to the lower cost of weed control.

Thus the repeated application of thiobencarb at 0 and 25 days after sowing was the most efficient treatment in controlling weeds, and thereby increasing the yield of dry-sown rice. The repeated application of thiobencarb, T_3+25 and T_6+25 and butachlor application, B_0+25 also could give good weed control.

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*Originals not seen

Appendices

Mean weekly weather pa

Month and week		Temperature
		Maximum
1988		
May	21-27	34.0
June	28-3	31.7
	4-10	29.1
	11-17	30.4
	18-24	30.3
	25-1	29.7
July	2-8	30.4
	9-15	29.6
	16-22	28.2
	23-29	27.6
August	30-5	29.9
	6-12	28.9
	13-19	28.2
	20-26	29.7
September	27-2	29.6
	3-9	29.6
	10-16	30.5
	17-23	29.6
	24-30	29.7

Appendix I

rameters for the entire crop period

(°C) Minimum	Mean relative humidity (%)	Total rainfall (mm)	No. of bright sunshine hours
25.4	74.0	9.2	7.8
24.3	83.0	292.6	2.7
23.9	90.5	144.4	1.5
23.9	85.0	58.0	6.3
23.9	85.0	102.7	4.7
22.6	84.5	154.3	3.9
23.1	82.5	19.7	6.6
23.4	86.5	105.4	4.0
22.8	93.0	245.9	0.3
23.3	88.0	134.9	0.5
24.5	86.0	89.9	3.6
23.9	87.5	61.2	2.9
24.3	89.0	177.6	3.2
24.6	83.5	72.1	5.1
23.6	84.0	200.8	3.9
23.6	84.5	153.7	4.9
23.4	85.0	113.7	6.0
23.4	85.5	240.0	4.5
22.4	85.0	123.2	4.3

Appendix II

Details of the Herbicides used in the trial

1. Butachlor

A. **Nomenclature, chemical and physical properties**

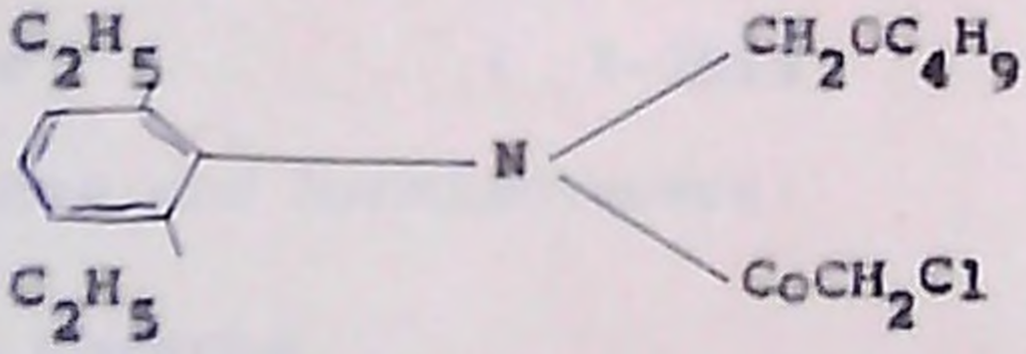
1. Common name : Butachlor (ANSI, BSI, WSSA)
2. Code number : CP-53619
3. Product name and manufacturer:

MACHETE ® - Monsanto

4. Chemical name :

N - (butoxymethyl)-2-Chloro-2', 6' - diethyl acetanilide or (N - (butoxy methyl)-2-chloro-N-(2,6-diethylphenyl) acetamide)

5. Structural formula :



6. Molecular formula : $C_{17}H_{26}ClNo_2$
7. Molecular weight : 311.9
8. Physical state : Slightly sweet aromatic amber liquid
9. Density : 1.070 g/ml at 25°C
10. Boiling point : 156°C at 0.5 mm Hg
11. Vapour pressure : 4.5×10^{-6} mm Hg at 25°C
12. Solubility : Water - 23 ppm at 24°C. Soluble in ether, acetone, benzene, alcohol, ethyl acetate and hexane at room temperature

B. Behaviour in or on soils

1. Adsorption and leaching characteristics in basic soil types: Adsorbed by soil colloids.
2. Microbial break down: Main method of degradation.
3. Loss from photodecomposition and/or volatilization: Low
4. Average persistence at recommended rates: 6 to 10 weeks; varies with soil type and climatic conditions.

2. Thiobencarb

A. Nomenclature, chemical and physical properties

1. Common name : Thiobencarb (WSSA, ANSI, BSI, New Zealand)
2. Code number : B-3015
3. Product names and manufacturers:

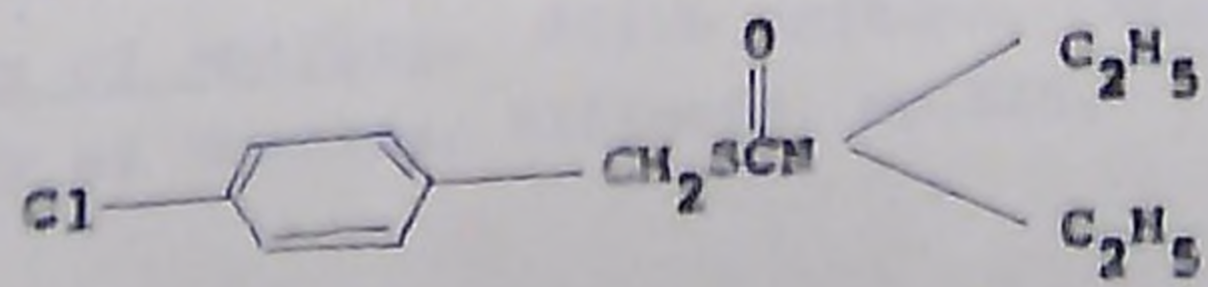
BOLERO® - Chevron

SATURN® - Kumiai

4. Chemical name :

S ((4-chlorophenyl) methyl) diethyl carbamothioate or (S-(4-chlorobenzyl) N, N-diethyl thiolcarbamate)

5. Structural formula :



6. Molecular formula : $C_{12}H_{16}ClNOS$

7. Molecular weight : 257.8

8. Physical state : Light yellow or brownish yellow liquid

9. Specific gravity : d^{20} 1.145 to 1.180

10. Boiling point : 126 to 129°C at 0.008 mm Hg

11. Vapour pressure : 1.476×10^{-6} mm Hg at 20°C

12. Solubility at 20°C : Water - 30 ppm. Readily soluble in acetone, ethyl alcohol and xylene

B. <u>Behaviour in or on soils</u>

1. Adsorption and leaching characteristics: Rapidly adsorbed by soil and not readily leached with water.

2. Microbial break down: Responsible for major portion of degradation.

3. Photodecomposition and volatilization: Can be lost from aqueous solution by volatility and photodegradation. Adsorption on soil minimises loss from volatilization and photodegradation.

4. Average persistence at recommended rates: Laboratory studies gave a half life of 2 to 3 weeks under aerobic conditions and 6 to 8 months under anaerobic conditions.

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

Appendix III

Weed flora of the experimental field

Scientific name	Common name	Family
A. Monocots		
(i) Grasses		
1. Cynodon dactylon (L.) Pers.	Bermuda grass	Poaceae
2. Dactyloctenium aegyptium (L.) Beauv.	Crow foot grass	Poaceae
3. Digitaria sanguinalis (L.) Scop.	Large crab grass	Poaceae
4. Echinochloa colona (L.) Link.	Jungle rice	Poaceae
5. Isachne miliacea Roth.	-	Poaceae
6. Ischaemum rugosum Salib	-	Poaceae
7. Panicum repens L.	Torpedo grass	Poaceae
8. Saccoleppis interrupta L.	-	Poaceae
(ii) Sedges		
1. Cyperus iria L.	Rice flat sedge	Cyperaceae
2. Cyperus difformis L.	Small-flowered umbrella sedge	Cyperaceae
3. Fimbristylis miliacea (L.) Vahl.	Globe fringe brush	Cyperaceae
(iii) Other monocots		
1. Commelina benghalensis L.	Hairy wandering jew	Commelinaceae
2. Cyanotis sp.	-	Commelinaceae
3. Eriocaulon sp.	-	Eriocaulaceae
B. Dicots		
1. Ammannia baccifera L.	Blistering ammannia Nellicheera (M)	Lythraceae
2. Aeschynomene indica L.	-	Leguminosae
3. Lindernia parviflora (Roxb.) Haines	-	Scrophulariaceae
4. Ludwigia parviflora Roxb.	Neergrambu (M)	Onagraceae
5. Mollugo disticha Ser.	-	Aizoaceae
6. Phyllanthus niruri Auct. non. L.	Niruri Kisharnelli (M)	Euphorbiaceae
7. Sphaeranthus indicus L.	Adakkamaniyan (M)	Asteraceae
8. Sphenochlea zeylanica Gaertn.	Goose weed	Campanulaceae
C. Ferns		
1. Marsilea quadrifolia L.	Pepperwort	Marsiliaceae

(M) - Malayalam name

Appendix IV

Nitrogen content of weeds at different stages (%)

Treatments	Stages			
	30 DAS	60 DAS	90 DAS	Harvest
B_0	2.4	1.9	1.2	1.4
B_3	2.8	2.3	1.6	1.4
B_6	2.9	2.4	1.4	1.3
B_9	2.1	2.3	1.6	1.1
B_0 + 25	2.1	1.9	2.2	1.5
B_3 + 25	2.2	1.4	1.4	1.9
B_6 + 25	2.1	1.4	1.2	1.6
B_9 + 25	1.2	2.5	2.3	1.6
T_0	1.9	2.0	1.7	1.6
T_3	2.2	1.9	1.2	1.4
T_6	2.8	2.8	1.6	1.2
T_9	2.3	1.9	1.5	2.1
T_0 + 25	2.9	2.5	2.1	1.9
T_3 + 25	1.6	2.8	1.1	1.5
T_6 + 25	1.9	2.8	1.4	1.1
T_9 + 25	2.1	2.1	1.1	1.4
H.W.	2.8	2.3	1.4	1.4
U.W.	2.5	2.4	1.4	1.6

Appendix V

Phosphorus content of weeds at different stages (%)

Treatments	Stages			
	30 DAS	60 DAS	90 DAS	Harvest
B_0	0.26	0.26	0.20	0.26
B_3	0.31	0.28	0.26	0.18
B_6	0.23	0.26	0.20	0.20
B_9	0.26	0.26	0.15	0.23
B_0 + 25	0.26	0.33	0.20	0.10
B_3 + 25	0.26	0.28	0.18	0.10
B_6 + 25	0.20	0.28	0.20	0.20
B_9 + 25	0.20	0.23	0.20	0.13
T_0	0.26	0.28	0.20	0.20
T_3	0.26	0.26	0.23	0.20
T_6	0.23	0.31	0.13	0.13
T_9	0.31	0.31	0.28	0.23
T_0 + 25	0.28	0.20	0.20	0.20
T_3 + 25	0.31	0.26	0.10	0.18
T_6 + 25	0.23	0.28	0.26	0.26
T_9 + 25	0.23	0.33	0.13	0.15
H.W.	0.26	0.23	0.15	0.20
U.W.	0.26	0.20	0.20	0.15

Appendix VI

Potassium content of weeds at different stages (%)

Treatments	Stages			
	30 DAS	60 DAS	90 DAS	Harvest
B_0	2.2	2.9	2.2	2.1
B_3	2.6	3.7	2.2	2.1
B_6	2.0	3.3	2.1	2.2
B_9	2.2	2.9	1.7	2.1
B_0 + 25	2.3	2.9	3.0	1.8
B_3 + 25	2.2	3.1	2.6	2.4
B_6 + 25	1.9	3.4	1.7	2.6
B_9 + 25	1.7	3.0	2.2	2.4
T_0	2.8	3.7	2.1	2.7
T_3	2.1	3.1	1.9	2.2
T_6	2.3	3.5	1.8	2.5
T_9	2.1	3.2	2.1	2.1
T_0 + 25	2.4	3.8	2.7	3.0
T_3 + 25	2.1	3.6	2.6	2.4
T_6 + 25	1.6	2.7	2.1	2.1
T_9 + 25	2.0	3.0	1.9	2.2
H.W.	2.0	2.6	1.8	2.1
U.W.	2.4	2.1	1.6	2.0

Nitrogen content of crop at different stages (%)

Treatments	Stages				
	30 DAS	60 DAS	90 DAS	Harvest	
				Grain	Straw
B_0	1.6	2.0	1.6	2.7	1.3
B_3	1.4	2.0	1.6	2.7	1.3
B_6	2.1	2.0	1.8	2.7	1.3
B_9	1.4	1.8	1.6	2.5	1.4
B_0 + 25	1.8	2.8	1.6	2.7	1.1
B_3 + 25	1.5	2.2	1.4	2.1	1.2
B_6 + 25	2.3	1.6	1.2	2.7	1.2
B_9 + 25	2.0	2.0	1.2	1.8	1.2
T_0	2.8	2.0	1.6	2.3	1.4
T_3	2.3	1.6	1.2	1.8	1.1
T_6	2.5	1.4	1.2	1.8	1.2
T_9	1.8	1.7	1.3	2.1	1.1
T_0 + 25	1.5	2.0	1.8	2.5	1.4
T_3 + 25	2.9	1.6	1.6	1.8	1.2
T_6 + 25	2.8	2.2	1.7	1.8	1.3
T_9 + 25	2.5	1.6	1.2	1.8	1.1
H.W.	2.5	2.3	2.1	2.2	1.4
U.W.	1.8	1.8	1.6	1.6	1.1

Phosphorus content of crop at

Treatments	30 DAS	60 DAS
B_0	0.31	0.31
B_3	0.26	0.26
B_6	0.26	0.26
B_9	0.26	0.26
B_0 + 25	0.33	0.31
B_3 + 25	0.31	0.31
B_6 + 25	0.31	0.26
B_9 + 25	0.31	0.26
T_0	0.26	0.26
T_3	0.36	0.26
T_6	0.31	0.31
T_9	0.31	0.26
T_0 + 25	0.26	0.28
T_3 + 25	0.28	0.28
T_6 + 25	0.28	0.31
T_9 + 25	0.26	0.23
H.W.	0.26	0.23
U.W.	0.20	0.26

different stages (%)

Stages

90 DAS	Harvest	
	Grain	Straw
0.23	0.26	0.20
0.23	0.28	0.20
0.23	0.26	0.20
0.23	0.26	0.20
0.26	0.30	0.20
0.26	0.20	0.26
0.23	0.20	0.20
0.23	0.30	0.20
0.23	0.26	0.23
0.26	0.26	0.23
0.26	0.20	0.20
0.26	0.31	0.20
0.26	0.20	0.23
0.26	0.20	0.23
0.28	0.20	0.20
0.23	0.26	0.20
0.28	0.28	0.26
0.20	0.30	0.20

Appendix IX

Potassium content of crop at different stages (%)

Treatments	Stages				
	30 DAS	60 DAS	90 DAS	Harvest	
				Grain	Straw
B_0	2.8	3.2	2.3	0.79	2.3
B_3	3.0	3.4	2.2	0.79	2.3
B_6	3.2	3.0	2.3	0.78	2.2
B_9	2.1	2.8	2.4	0.77	2.3
B_0 + 25	2.9	3.0	2.0	0.83	2.3
B_3 + 25	3.3	3.0	2.3	0.83	2.3
B_6 + 25	2.8	2.6	2.1	0.83	2.3
B_9 + 25	2.8	3.5	2.3	0.79	2.3
T_0	2.6	2.8	2.3	0.80	2.3
T_3	3.0	3.0	2.3	0.81	2.2
T_6	3.0	3.0	2.4	0.82	2.2
T_9	2.9	3.0	2.3	0.81	2.2
T_0 + 25	3.0	3.4	2.2	0.82	2.2
T_3 + 25	2.9	3.4	2.4	0.82	2.2
T_6 + 25	2.2	3.0	2.3	0.83	2.3
T_9 + 25	2.4	2.8	2.2	0.81	2.3
H.W.	2.5	3.3	2.2	0.83	2.4
U.W.	2.8	2.6	2.4	0.77	2.2

Treatments	Cost of weed control operation	Return from grain yield	Return from straw yield	Total returns
B_0	474.00	579.00	366.80	945.80
B_3	474.00	1067.70	465.25	1532.95
B_6	474.00	750.00	268.20	1018.20
B_9	474.00	341.65	176.50	518.15
B_0 + 25	948.00	3165.00	1964.00	5129.00
B_3 + 25	948.00	2361.65	996.50	3358.15
B_6 + 25	948.00	1357.70	719.00	2076.70
B_9 + 25	948.00	733.30	348.60	1081.90
T_0	477.00	875.00	466.65	1341.65
T_3	477.00	2112.50	758.30	2870.80
T_6	477.00	1208.30	754.40	1962.70
T_9	477.00	316.65	214.85	531.50
T_0 + 25	954.00	5941.65	2296.40	8238.05
T_3 + 25	954.00	4071.00	1809.80	5880.80
T_6 + 25	954.00	3916.65	2231.25	6147.90
T_9 + 25	954.00	1491.65	726.25	2217.90
H.W.	2856.00	7693.30	2665.00	10358.30
U.W.	-	142.00	105.00	247.00

Price of paddy @ Rs.3/kg Price of straw @ Rs.0.70 ps/kg
Cost of butachlor (Butachlor 50 EC) @ Rs.96.00/litre
Cost of thiobencarb (Saturn 50 EC) @ Rs.97.00/litre
Spray application, 6 men @ Rs.31/man
Hand weeding (3 hand weedings), 102 women @ Rs.28/woman

Abstract

Character	Source
Studies on weeds	
Isachne sp. Count	Treatment
	Error
Saccolepsis sp. Count	Treatment
	Error
Echinochloa sp. Count	Treatment
	Error
Total grass weed count	Treatment
	Error
Sedge count	Treatment
	Error
Broad leaved weed count	Treatment
	Error
Total weed count	Treatment
	Error
Weed dry matter production	Treatment
	Error
Weed control efficiency	Treatment
	Error

Appendix XI

of analyses of variance

	Mean sum of squares			
df	30 DAS	60 DAS	90 DAS	Harvest
17	364.6*	428.0*	280.8*	171.2*
34	107.5	62.6	31.7	54.8
17	80.0*	75.4*	74.4*	38.4
34	17.1	15.1	23.7	21.0
17	46.5*	30.3*	5.1	3.5
34	14.0	5.8	2.9	2.3
17	431.2*	447.8*	312.1*	171.5*
34	99.4	44.9	25.8	38.7
17	25.9	13.9*	0.68	-
34	14.2	3.7	0.57	-
17	21.1	67.4*	41.6*	59.0*
34	15.4	22.7	12.9	17.1
17	413.3*	299.3*	207.6*	66.3*
34	96.3	59.2	23.1	33.3
17	13.7*	81.0*	144.7*	43.3*
34	3.2	7.9	9.6	19.1
16	2147.8*	9427.1*	2740.5*	2203.1*
32	1052.5	1947.6	371.8	1045.0

Contd.

Appendix XI. Continued

Character	Source	df	Mean sum of squares			
			30 DAS	60 DAS	90 DAS	Harvest
Studies on crop						
Crop dry matter production	Treatment	17	1189.0*	13520.1	51180.8*	106522.8*
	Error	34	608.5	12665.2	10802.3	10468.7
Nutrient uptake uptake by weeds						
Nitrogen	Treatment	17	133.0*	3123.8*	5944.0*	1123.3
	Error	34	36.7	339.4	438.3	645.0
Phosphorus	Treatment	17	1.4*	36.9*	91.9*	40.1*
	Error	34	0.44	5.9	8.3	8.3
Potassium	Treatment	17	110.4*	5447.8*	6298.4*	2916.5*
	Error	34	32.3	768.9	834.1	1683.2
Uptake by crop						
Nitrogen	Treatment	17	104.8*	776.7	2723.1*	3049.8*
	Error	34	27.7	541.0	274.1	186.7
Phosphorus	Treatment	17	1.0*	11.0	45.2*	75.9*
	Error	34	0.50	10.1	6.8	5.2
Potassium	Treatment	17	125.0*	1360.3	2348.4*	3857.0*
	Error	34	49.5	1501.9	559.4	539.3

Contd.

Appendix XI. Continued

Character	Source	df	Mean sum of squares
Observations at harvest			
Height of plant	Treatment	17	222.2*
	Error	34	30.2
Productive tillers per hill	Treatment	17	4.6*
	Error	34	1.5
Panicle length	Treatment	17	4.7*
	Error	34	1.3
Number of spikelets per panicle	Treatment	17	275.9*
	Error	34	83.9
Thousand grain weight	Treatment	17	6.1
	Error	34	5.2
Grain yield	Treatment	17	1467004.5*
	Error	34	66525.3
Straw yield	Treatment	17	4259959.2*
	Error	34	187160.4
Grain-straw ratio	Treatment	17	0.036*
	Error	34	0.007
Harvest index	Treatment	17	0.007*
	Error	34	0.001
Weed index	Treatment	16	1375.2*
	Error	32	116.4

TIME OF APPLICATION OF PRE-EMERGENCE HERBICIDES IN DRY-SOWN RICE

By

G. SUJA

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture

Kerala Agricultural University

Department of Agronomy

COLLEGE OF HORTICULTURE

Vellanikkara - Trichur

Kerala

1989

ABSTRACT

A field experiment was conducted at the Agricultural Research Station, Mannuthy under the Kerala Agricultural University during the first crop season of 1988 to find out the optimum time of application of pre-emergence herbicides, butachlor and thiobencarb and to assess the scope of second application of these herbicides, for efficient weed control in dry-sown rice. Sixteen treatments were compared with two controls (hand weeded and unweeded). The experiment was laid out in RBD with three replications.

The dominant weeds were Isachne miliacea, Saccolepis interrupta and Echinochloa colona among grasses, Cyperus iria among sedges and Sphaeranthus indicus, Ludwigia parviflora and Ammannia baccifera among broad leaved weeds. Control of Echinochloa colona and other grasses were very effective in the treatments where thiobencarb was applied at 0, 3 or 6 DAS and repeated at 25 DAS whereas almost all the butachlor treatments gave complete control of sedges. The population and dry matter production of weeds were appreciably reduced by the repeated application of thiobencarb at 0, 3 or 6 DAS and at 25 DAS and butachlor application at 0 and 25 DAS. Weed control efficiency was also higher for these treatments.

The repeated application of thiobencarb where the first application was done upto 6 DAS were also effective in improving the growth, yield attributes and yield of rice and gave higher grain and straw yields. The minimum weed index value was noticed in the thiobencarb application at 0 and 25 DAS.

The benefit-cost ratio for weed control worked out to be maximum for the repeated application of thiobencarb at 0 and 25 DAS proving it to be the most effective and cheapest method of weed control in dry-sown rice.