EFFECT OF TIME OF SOWING AND WEED MANAGEMENT ON THE PERFORMANCE OF DRY SOWN RAINFED RICE

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Effect of time of sowing and weed management on the performance of dry sown rainfed 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 "Effect of time of sowing and weed management on the performance of dry sown rainfed rice" is a record of research work done independently by Sri. Jacob John, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or a[illegible] to him.

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LIST OF ABBREVIATIONS

@	At the rate of
a.i.	Active ingredient
cm	Centimetre
DAS	Days after sowing
g	Gram
ha	Hectare
kg	Kilogram
$kg.ha^{-1}$	Kilograms per hectare
loc. cit.	Locally cited
m	Metre
m^2	Square metre
mm	Milli metre
ppm	Parts per million
Rs.	Rupees
WSP	Water soluble powder

INTRODUCTION

INTRODUCTION

Indian agriculture is considered a gamble with monsoons and most of the increased production has come from irrigated areas or more favourable ecologies. With limited land reserves for expansion and prohibitively high costs of irrigation, agricultural production will have to be intensified under rainfed farming which constitutes about 70 per cent of the cultivated area in India and contributes more than 42 per cent of the food grain production in the country (Kanwar, 1990). Of the estimated additional production need of over 75 million tonnes of food to attain self sufficiency by 2000 A.D. in India, the share of rice would be not less than 30 million tonnes (about 40 per cent) requiring an annual increase of 3.3 million tonnes (Siddiq, 1990). With nearly 60 per cent of the area under rice exposed to risk prone rainfed ecology and the limited scope for bringing more areas under irrigation, suitable technological options to step up rice production and productivity from these rainfed areas must be given top priority. The highly diverse agro-ecology of rainfed environments requires more precise, location specific production package unlike the fairly homogenous irrigated ecosystem. If the irrigated ecosystem has helped the country to free from the scourge of chronic food deficiency in the last two decades, sustenance of this hard earned self sufficiency in food rice for decades to come depends on how efficiently and speedily the political will that is favourable and committed to the development of rainfed agriculture is translated into a mission oriented production programme (Siddiq, 1990)

In Kerala, majority of rice areas are rainfed and occurrence of water stress during the different stages of growth is common in the first crop season. Crop failure in rainfed areas is often due to inadequate moisture rather than the nonavailability of suitable crop production technology. This aspect which assumes paramount importance in management of rainfed crops and is not always spoken but is tacitly used is timeliness. Proper timing of crop establishment may help reduce the risk of crop failure in rainfed region (Janiya and Moody, 1988). The choice of an appropriate planting date may have considerable effect on water use efficiency by ensuring that the pattern of growth of crop is adjusted to the pattern of precipitation or to available soil moisture (Blum, 1972). Sowing time is crucial not only from the point of view of moisture availability for crop stand establishment and growth of dryland crops, but has a long range effect on productivity.

Another major constraint for dry sown rice production during Virippu (May-september) season is excessive weed growth. Yield losses of upto 100 per cent due to uncontrolled weed growth have been reported in dry-seeded rice (IRRI, 1979). Weeds pose more serious problems in dry-seeded rice than in other rice production systems. A much wider range and intensity of weed problems can be expected in dry sown rice because of differences in land preparation, lack of water at the early stages and simultaneous germination of weed and rice. Weeds share not only plant nutrients but also transpire a good quantity of valuable conserved water from the soil. With effective and timely weed control, dry seeded rice can yield as much as transplanted rice in an environment having adequate and well distributed rainfall. Chemical weed control in dry seeded rice has gained importance because of the intensity of the weed problems coupled with lack of labour for weeding and high cost. Herbicides, although may not control weeds as effectively as hand weeding, frequently offer the most practical, effective and economical means of reducing weed problems, crop losses and production costs. So a suitable weed management practice, which is both effective and economic, for dry sown rainfed rice is highly essential. The present investigation is undertaken to study the effect of time of sowing and weed management on the performance of direct seeded dry sown rainfed rice with the following objectives:

(i) to determine the best time of sowing of rice for better growth and yield under rainfed conditions of south-west monsoon season in Southern Kerala,

(ii) to find out the most effective weed management practice for dry sown rainfed rice and

(iii) to work out the economics of cultivation under these practices.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

As a part of the worldwide efforts to increase agricultural production, rainfed regions occupy an important position. Among the different criteria of crop production under conditions of limiting moisture and nutrient supply, an aspect which assumes paramount importance is adjusting the time of sowing. Besides, weed problems are far more complex and serious in dry seeded rice than in other production systems. Since the dry sown rice is grown under rainfed conditions, the situation is almost similar to upland rice at least during the initial stages. A brief review on the influence of sowing time on rice growth and yield and on the weed problems and its management with special reference to chemical and handweeding in rainfed and upland rice is presented in this chapter.

2.1. Effect of time of sowing

Blum (1972) stated that the choice of an appropriate planting date may have a considerable effect on water use efficiency (in relation to economic yield) by ensuring that the pattern of growth of crop is adjusted to the pattern of precipitation or to available soil moisture.

Singh and Das (1984) stated that time of sowing can make a lot of difference in production and productivity of rainfed crops. Sowing time is crucial not only from the point of view of moisture availability for crop stand establishment and growth of dryland crop, but also has a long range effect on productivity.

The importance of this aspect with respect to rainfed rice has been the topic of research of several workers in the past decade.

2.1.1. Effect of sowing time on rice growth

Ali and Ismail (1982) reported a decrease in the height of the plant with delay in sowing in rainfed rice.

Mandal *et al*. (1984) observed that the leaf area index, crop growth rate and net assimilation rate decreased with increasing delay in planting date which adversely affected the productivity of rainfed rice. Delay in planting date was found to decrease the height of the rice plant in short duration transplanted rainfed rice (Theetharappan and Palaniappan, 1984). According to Reddy and Reddy (1986) the duration of the crop was found to decrease with delay in planting of rainfed rice.

Jiang and Zhou (1987) found a decrease in the number of tillers with delay in sowing in direct sown dryland rice.

Kim *et al*. (1991) found that delayed sowing reduced culm length and the period from sowing to heading in dry sown rainfed rice.

Delaying the sowing date resulted in reduced seedling emergence, leaf area index, photosynthetic potential, specific leaf weight, net assimilation rate and dry matter accumulation per unit area in direct sown rainfed rice (Wang and Liu, 1991). Reddy and Reddy (1992) reported that the number of days required to 50 per cent flowering and crop duration were decreased by delayed planting in rice variety Surekha grown under rainfed conditions.

Hence it may be inferred that there is a significant influence of delayed planting on growth parameters of rice crop and its duration.

2.1.2. Effect of sowing time on yield and yield attributes of rice

Reddy and Narayana (1981) reported that number of panicles, filled grains per panicle, panicle length, grain yield and straw yield decreased with delay in planting in rainfed rice. Panicle length, number of panicles, thousand grain weight and straw yield decreased with delay in sowing in direct sown rainfed rice (Ali and Ismail, 1982). According to Canet *et al*. (1982) grain yields tended to increase with delay in sowing from April to June in rainfed rice. Narayanaswamy et al (1982) observed a decrease in number of panicles, number of grains per panicle, thousand grain weight, straw yield and grain yield with delay in sowing. Production per hectare and harvest index were highest in early sown crop.

Chaudhry (1984) found that, late sowing reduced yields in long duration, medium duration and short duration varieties, in a trial in which cultivars were sown on seven dates from 2 April to 1 June.

Mahapatra and Srivastava (1984) pointed out timely seeding as a practice for increasing the yield of rainfed uplands rice and that in case of late arrival of monsoon dry sowing about ten days before the anticipated date of rainfall is better than late sowing.

Pande and Reddy (1988) suggested early sowing before 15th June as an improved management practice for augmenting production potential of rainfed marginal lands under rice based cropping system in Eastern India.

Ashraf et al. (1989) reported a progressive decline of yield and yield attributes with delay in transplanting. The decrease in yield was partly the result of decrease in productive tillers per hill and in spikelets per panicle.

Joon et al. (1989) in studies on the performance of modern rice varieties under different time of planting found that panicle number, grains per panicle, thousand grain weight and grain yield decreased with delayed planting. Increased spikelet sterility was also observed with delay in planting time.

Padmaja (1990) observed that delay in planting beyond July resulted in reduction in grain yield and was attributed to more number of non productive tillers contributing to more chaff, partially filled, poor and average grade grain.

Dinesh Chandra et al. (1991) reported that in rainfed uplands rice, direct seeding during first fortnight of June (5-15) gave the highest yield. Advanced seeding in May in dry condition did not prove appropriate as the crop stand and yield were adversely affected due to inadequate soil moisture and high temperature whereas, delayed sowing beyond 25th June affected growth of seedlings, yield attributes and yield due to excess soil moisture.

Jha et al. (1991) pointed out the important role of date of seeding on performance of all rainfed lowland rice varieties when sown early. Sowing during 1-7 June gave maximum yield. When sowing was delayed to 14-21 June yield decreased by 29 per cent which further got reduced when delayed to first week of July. Advancing sowing time to 14-21 May improved yield by 36 per cent.

Delay in planting resulted in increased nitrogen and potassium uptake which led to increased grain yield in rainfed rice (Reddy, and Reddy, (1991).

Singh <u>et al</u>. (1991a) found that timely sowing at the onset of monsoon (fourth week of June) caused significant increase in panicle number, panicle length, grains per panicle, percentage of filled grain and thousand grain weight. Timely sowing recorded the highest contribution of 20.1 per cent among all the factors tested.

Thus it is revealed that sowing time has a profound influence on the number of panicles, grain per panicle, thousand grain weight, percentage of filled grains, grain yield and straw yield in rainfed rice.

2.2. Weed spectrum in Dry sown rice

Ali and Sankaran (1984b) reported that <u>Echinochloa colona</u>, <u>Cyperus iria</u> and <u>Eclipta alba</u> were the dominant weeds present in direct seeded rainfed rice at TamilNadu.

In experiments conducted at Tamil Nadu Agricultural University, Coimbatore, Ali <u>et al</u>. (1985) observed that the weed flora in direct seeded lowland rice consisted of

Echinochloa crusgalli and *E. colona* among grasses and *Cyperus difformis*, *Cyperus iria* and *Fimbristylis miliacea* among sedges and *Eclipta alba* among broad-leaved weeds.

In studies conducted at Haryana Agricultural University, Hissar in direct seeded rainfed upland rice Bhan *et al*. (1985) showed that *Echinochloa colonum*, *Cyperus iria*, *Eragrostis nutans*, *Trianthema potulacastrum*, *Digera arvensis*, *Phyllanthus niruri*, *Corchorus acutangulus*, *Amaranthus viridis*, *Vernonia cinerea* and *Pulicaria crispa* were the predominant 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 colonum* 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*.

Weed flora in dry sown rainfed rice at Regional Agricultural Research Station, Pattambi, Kerala consisted chiefly of *Echinochloa crusgalli*, *E. colona*, *Cyperus difformis*, *Cyperus iria*, *Fimbristylis miliacea*, *Monochoria vaginalis* and *Marsilea quadrifolia* (Kamalam Joseph *et al*., 1990).

Moorthy and Rao (1991) in an experiment carried out at CRRI, Cuttack, Orissa in direct seeded rainfed lowland rice found that Echinochloa frumentacea, E. colona var. frumentacea, Leptochloa chinensis were the major grasses, Commelina benghalensis, Alternanthera sessilis and Ludwigia perennis the major broad-leaved weeds and Cyperus iria and Cyperus ésculentus the major sedges. Field experiments carried out at Gumsar Udaygiri, Orissa in rainfed direct seeded upland rice showed that Cyperus rotundus dominated the weed flora in the early stages followed by Echinochloa colonum, Cynadon dactylon, Commelina benghalensis, Dactyloctenінum aegyptium, Eleusine indica and Phyllanthus niruri. Weeds like Synedrella nodiflora, Celosia argentea, Ageratum conyzoides, Achyranthes aspera, Digitaria sangunialis, Acanthospermum hispidum and Stachytarpheta indica emerged at later stages of crop (Padhi et al. 1991).

In field trials conducted at Agricultural Research Station, Mannuthy, Kerala the dominant weeds present in dry sown rainfed rice were Isachne miliacea, Saccoleppis interrupta and Echinochloa colona among grasses, Cyperus iria among sedges and Sphaeranthus indicus, Ludwigia parviflora, Ammania baccifera, Commelina benghalensis among dicots (Suja and Abraham, 1991).

Tewari and Singh (1991) reported that in upland direct seeded rainfed rice at C.S. Azad University of Agriculture and Technology, Kanpur the weed flora consisted of Cyperus rotundus, Echinochloa colona, Phyllanthus niruri, *Trianthema monogyna*, *Digera arvensis*, *Commelina benghalensis* and *Digitaria sanguinalis*.

Thus it is evident that weed spectrum in dry sown rainfed rice is diverse and varies with location. Grasses constitute the major weed flora. Among grasses *Echinochloa colona*, is the most serious one. Among sedges which is second in ortance *Cyperus rotundus* is the dominant one.

2.3. Crop weed competition

2.3.1. Critical period of crop weed competition

Direct sown rainfed rice gave highest yield when kept weed free upto 30 days after sowing. Increasing the duration of weed free period upto 45-60 DAS gave no significant further increase (Bhan *et al*., 1980).

Singh and Ram (1982) reported that the period of the first 45 DAS was most crucial for weed removal for obtaining higher yields in direct seeded rainfed rice. The weed free period required for increased yields in rainfed rice was 60 DAS (Ali & Sankaran, 1984b).

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 removal of weeds during early stages (30 DAS) is imperative for higher yields in upland rainfed rice. (Bhan et al., 1985). Govindra Singh et al. (1985) observed that there was significant increase in yield with increase in duration of the weed free period upto 45 DAS in drill sown rainfed rice.

Azevedo et al. (1986) reported that grain yields in dry season upland rice was significantly reduced where weeds competed between 30-60 days after emergence.

Weed competition studies in rainfed upland rice revealed that the critical period for crop weed competition was from 16 to 45 DAS (Prusty et al., 1990).

Weed free period from 0-90 days after sowing improved growth and yield attributes of rainfed rice significantly (Arya et al., 1991).

The weed free requirement for direct seeded upland rice was upto 45 DAS (Singh et al., 1991 b). Tewari and Singh (1991) identified the competitive period as four weeks after sowing in upland direct seeded rainfed rice.

According to Varshney (1991), 20-40 DAS was the most critical time for weed removal in upland rainfed rice.

Hence it can be concluded that the critical period of weed competition in rice is between 0-45 days after sowing. However, in dry sown rice this period may extend to 60-90 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.

2.3.2. Competition for Nutrients

Sharma and Singh (1981) found that a significantly low yield was given by direct sown rainfed rice owing to corresponding increases in weed dry matter, more depletion of nutrients by weeds and less uptake by the crop. Maximum nitrogen depletion was recorded in unweeded plots. Chaurasia et al. (1983) reported removal of considerable amounts of nitrogen and potassium by weeds but phosphorus uptake was low in direct sown upland rice.

Ali and Sankaran (1984a) estimated maximum removal of nitrogen (26.74 $kg.ha^{-1}$), phosphorus (2.18 $kg.ha^{-1}$) and potassium (22.0 $kg.ha^{-1}$) by weeds in unweeded check in direct sown rainfed rice.

Singh and Reddy (1985) noted that the nitrogen depletion by weeds was maximum at 70 days after sowing and thereafter remained constant till 100 DAS in direct sown rice.

John and Sadanandan (1989) reported that nitrogen loss through weeds was 16.2 kg.ha^{-1} in unweeded control compared to 2.2 kg.ha^{-1} in hand weeded plot in direct sown rainfed rice.

The weeds when allowed to compete with crop depleted 25.8, 3.65 and 21.3 of N, P_2O_5 and K_2O kg-ha^{-1} and uptake by crop was 14.3, 1.1 and 12.7 of N, P_2O_5 K_2O kg.ha^{-1} (Ramamoorthy, 1989).

Biswas and Sattar (1991) reported that as weed density increased, the weeds took up more nitrogen and rice less and nitrogen use efficiency in rice will be low when weeds compete.

Suja and Abraham (1991) estimated that in unweeded control, weeds removed 69.28, 5.77 and 60.62 kg.ha^{-1} N, P_2O_5 and K_2O while the crop uptake was 24.20, 4.86 and 49.98 kg ha^{-1} of N, P_2O_5 and K_2O in dry sown rainfed rice.

Nutrient removal in weedy check was 57.7, 1.64 and 39.6 kg.ha^{-1} N, P_2O_5 and K_2O by monocot weeds and 120.3, 28.3 and 110.7 kg.ha^{-1} N, P_2O_5 and K_2O by dicot weeds in rainfed upland rice (Varshney, 1991).

Thus it may be inferred that crop competition under high weed density exerts an adverse effect on the uptake and utilisation of nutrients by crop which resulted in a severe yield reduction.

2.3.3. Influence of weeds on rice growth

Bhan *et al*. (1985) reported a decrease in the crop dry matter production as weed growth increased in drilled rainfed upland rice. Patel *et al*. (1985) observed that crop dry matter production was negatively correlated with weed dry weight. Highest crop dry matter yield (45 $g \cdot m^{-1}$) was obtained when weed dry weight was the lowest (6 $g.m^{-1}$.

Azevedo *et al*. (1986) found that plant height was not significantly affected by competition although it tended to decrease with increase in duration of competition in dryland rice.

According to Singh and Das (1989) weed dry weight was inversely proportional to crop dry weight and leaf area index in direct seeded rainfed rice.

Suja and Abraham (1991) reported that high weed density and severe weed competition reduced the height and crop dry matter production in dry sown rainfed rice.

Hence it may be understood that significant negative correlation exists between weed and crop dry matter production. Height of plant was also affected by weed competition.

2.3.4. Effect of weeds on yield attributes and yield

Bhan *et al*. (1985) reported a decrease in the number of panicles per metre row, number of fertile spikelets per panicle and grain yield due to weed competition in drilled rainfed upland rice. Jayasree (1987) found a reduction in the number of grains per panicle due to unrestricted weed growth. The lowest grain yield (12.1 q ha^{-1}) was obtained in the unweeded check, which was 73 per cent lesser than the yield in weed free plots.

Singh and Das (1989) observed that weed dry weight was inversely proportional to number of panicles per metre row, number of fertile grains per panicle and grain yield in direct seeded rainfed rice.

Arya *et al*. (1991) reported that panicle weight, thousand grain weight, grain and straw yield were significantly reduced by weed competition in rainfed rice.

Tewari and Singh (1991) in studies on crop weed competition in upland direct seeded rainfed rice found that season long competition gave a decrease of 44.9 per cent in grain yield.

According to Varshney (1991) weed competition in upland rainfed rice reduced panicle number, length of panicle, thousand grain weight, grain and straw yield.

Samantaray *et al*. (1992) reported a significant decrease in panicle number, number of grains per panicle, number of fertile spikelets per panicle, thousand grain weight and grain-straw ratio due to weed competition in direct seeded rainfed rice.

2.4. Weed management

Freedom from weeds during the critical period of weed crop competition can be achieved by removing the weeds mechanically or chemically. Among the different methods of weed control being adopted, important ones are handweeding and chemical weed control or a combination of both.

2.4.1. Handweeding

Kaushik and Mani (1980) reported that handweeding alone was most efficient in bringing down the weed population and dry matter accumulation by weeds. Nutrient depletion was reduced from 23.8, 5.9 and 64.8 kg.ha^{-1} in unweeded control to 5.4, 1.5 and 16.9 kg.ha^{-1} N, P_2O_5 and K_2O respectively in direct seeded rainfed rice.

Chaurasia *et al*. (1983) found that rice yields of direct sown upland rice were 1.85-4.07 t.ha^{-1} in plots given three handweedings and was reduced to 0.82-2.03 t.ha^{-1} by one handweeding only.

Ali and Sankaran (1984a) reported that handweeding twice brought about a low nitrogen uptake of 4.2 $kg.ha^{-1}$ by weeds when compared to 26.7 $kg.ha^{-1}$ in unweeded check.

Bhan et al. (1985) reported that handweeding at 15 and 30 days after sowing (DAS), at 15 and 45 DAS and at 30 and 45 DAS, and thrice at 15, 30 and 45 DAS resulted in significant decrease in population and dry matter of weeds at subsequent stages of crop growth in drill sown upland rice. It also facilitated production of more panicles, more fertile spikelets and higher grain and straw yields in rice crop.

Chandrakar et al. (1985) observed that in dry sown rainfed rice, two handweedings gave lowest dry weight of weeds with highest weed control efficiency and the highest yield.

Reddy and Bhargavi (1989) observed weed dry weights and highest grain yields with handweeding twice 20 and 40 DAS in direct seeded rainfed lowland rice.

Patel (1990) found that lowest weed dry weight and highest yields and weed control efficiencies were obtained with handweeding at 20, 40, 60 and 80 DAS followed by handweedings at 20,40 and 60 DAS and handweeding twice 20 and 40 DAS in direct sown upland rice.

Bhagat *et al*. (1991) reported highest grain yields from handweeding 15, 30 and 45 DAS when compared to other herbicides in direct seeded upland rainfed rice.

Ramamoorthy (1991) found handweeding at 20 and 35 DAS to be the least effective treatment which resulted in highest nutrient uptake by weeds in upland rainfed rice.

Samantaray *et al*. (1992) observed that handweeding twice 20 and 40 DAS controlled weeds to a significant extent and lowered weed dry weight by 84.5 per cent and nitrogen uptake of weed by 87.5 per cent.

Singh (1992) reported that handweeding at 20 and 40 DAS in comparison with other herbicide treatments recorded 80 per cent weed control efficiency.

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

2.4.2. Chemical weed control

2.4.2.1. Butachlor

Moorthy and Dubey (1981) observed that pre-emergence application of butachlor gave yields comparable to handweeding but showed crop phytotoxicity due to rainfall herbicide interaction.

Sharma and Singh (1981) reported that butachlor at 1-2.0 $kg.ha^{-1}$, pre-emergent was the most effective herbicide in checking weed growth and nutrient depletion and produced yields comparable to the handweeded plot in rainfed rice.

Studies on the response of rainfed upland rice to butachlor revealed that there was no pronounced inhibitory effect on rice germination and seedling emergence. Seedling establishment was adversely affected by increasing rates of butachlor. Occurrence of leaf deformation, stunted growth and limited development of emerged seedlings increased with increase in herbicide rates (Olifintoye et al., 1983).

Elliot et al. (1984) reported that upto 80 to 90 per cent control of the major weed especially Echinochloa colona was obtained in plots treated with 1.5 kg ha^{-1} butachlor in dry seeded rainfed rice.

Olifintoye and Mabbayad (1984) suggested that post-emergence application of butachlor was superior to pre-emergence treatment with respect to stand and establishment. Rainfall distribution during herbicide application had significant influence on growth and yield of rice. Tolerance of dry seeded rice to butachlor can be improved by reducing herbicide rate below 1.5 kg ha^{-1} or applying post-emergence when moisture is not limiting.

Senthong (1984) found that butachlor at 2.0 kg ha^{-1} gave good control of Cyperus procerus, Fimbristylis miliacea and Monochoria vaginalis in direct sown lowland rainfed rice. Ali et al. (1985) observed that butachlor 1.0 kg.ha^{-1} applied eight DAS was effective in controlling Echinochloa crus-galli and Cyperus difformis but showed phytotoxicity on rice seedlings and hence reduced the grain yields considerably, more so in the monsoon season.

Pathak and Hazarika (1985) found that from the economic point of view pre-emergence application of butachlor 2.0 kg ha^{-1} was the best with a net profit of Rs. 1123.20 per hectare.

Shad and De Datta (1985) reported an increase in grain yield and tiller number with 0.8 kg butachlor per hectare applied six DAS in rainfed rice.

Studies on the dissipation of butachlor in silty clay loam and loamy soils revealed that at 21 days after treatment only about one ppm herbicide could be detected. By 70 days after treatment, no herbicide was present. Faster dissipation occurred at higher soil moistures and higher temperatures (Maxima et al., 1986).

Raju and Reddy (1986) found that butachlor possessed strong selectivity against Echinochloa spp. and controlled most annual grasses, sedges and broadleaved weeds.

Heinrich et al. (1987) reported that butachlor 1.0 kg ha^{-1} applied before sowing was more effective than when applied after sowing, in direct seeded rainfed rice in terms of weed density, weed weight, gross profit and net gain.

Bhagwan Singh (1988) observed a significant reduction in weed number and weed dry weight due to application of butachlor 2.0 kg ha^{-1} in upland rainfed rice.

Choudhary and Pradhan (1988) recorded the highest weed control efficiency of 89.4 per cent with butachlor 1.5-2.0 kg. ha^{-1} in direct sown rainfed upland rice.

Pablico et al. (1988) found that flooding increased butachlor toxicity. As little as one cm water caused a 73 per cent reduction in stand. Reducing the application rate from 1.0 to 0.375 kg. a.i. ha^{-1} and changing the time of application from three days before sowing to three DAS reduced herbicide toxicity.

Singh (1988) observed that butachlor alone gave poor control of broadleaved weeds and Cynadon dactylon under upland rainfed conditions.

Singh and Singh (1989) recorded an increase in the growth, yield attributes and yield of upland rice by pre-emergent application of 2 $kg.ha^{-1}$ butachlor.

Singh and Ram (1990) found an increase in the number of panicles per row, grain per panicle, thousand grain weight, straw yield and grain yield, by the application of butachlor at the rate of 1.25-2.0 $kg.ha^{-1}$.

Budhar et al. (1991) reported that pre-emergent herbicide butachlor could be used for effective weed control against grasses and sedges and reducing the labour cost in direct sown rainfed rice.

According to Moorthy and Rao (1991) pre-emergence application of butachlor could not completely control sedges in rainfed lowland rice.

Padhi et al. (1991) observed an increase in rice height, panicle density, production of filled grains per panicle, thousand grain weight, straw yield and grain yield with application of 1.5 $kg.ha^{-1}$ butachlor in rainfed direct seeded upland rice.

Suja and Abraham (1991) reported that butachlor application at 0 and 25 DAS reduced weed dry matter production and nutrient removal by weeds, and increased nutrient uptake by crop in dry sown rice.

Zhang and Tang (1991) found germinating rice seeds to be most sensitive to butachlor with phytotoxicity decreasing with time before or after germination.

Bajpai and Singh (1992) observed that the highest weed control efficiency (70.8 per cent) was obtained due to application of butachlor on the day of sowing and thereafter it decreased gradually and resulted in lowest weed control efficiency (4.7 per cent) at 30 DAS. The net income and cost : benefit ratio were maximum due to application of butachlor @ 1.5 kg.ha^{-1} at 10 DAS.

Saha and Srivastava (1992) reported that in suppressing population and biomass of nutgrass *Cyperus rotundus*, butachlor @ 2 kg.ha^{-1} proved to be most effective. On the other hand it caused maximum injury (as high as 40.7 per cent) to rice plant in rainfed upland rice.

Samantaray *et al*. (1992) reported that butachlor @ 1.5 kg.a.i.per hectare although recorded the lowest weed dry weight and nitrogen uptake by weeds, obtained significantly less grain yield.

Thus it can be understood that butachlor is an effective pre-emergence herbicide in direct seeded rainfed rice. It has been found to increase growth and yield of rice owing to its high weed control efficiency. However, rates above 1.5 kg a.i ha^{-1} has been found to cause phytotoxicity to rice seedlings.

2.4.2.2. 2,4-D

Mukhopadhyay (1971) reported that in a situation where grass weeds were predominant, 2,4-D resulted in a very negligible reduction in weed infestation (12.5 per cent mortality) and as a result the yield was almost the same as no weeding.

Elisa (1980) observed moderate phytotoxicity when butachlor was applied in combination with 2,4-D at the rate of 0.75 + 0.50 kg.ha^{-1} during the initial stages of crop growth in direct seeded rice.

Munroe et al. (1982) found that replacing handweeding with post-emergence application of 2,4-D at 29-39 DAS did not provide complete control of broad leaf species nor did it provide control of those grass species which escaped the pre-emergence herbicide application in rainfed upland rice.

Singh et al. (1982) reported that yields in plots treated with 2,4-D alone four to five weeks after sowing gave lower yields than handweeded plots in dryland rice.

Keisers and Paidin (1986) recorded good control of weeds without damaging the rice with post-emergence application of 2,4-D in direct seeded rice. Kumar and Gautam (1986) observed an increase in the number of panicles per m^2, filled grains per panicle and grain yield with application of 0.8 kg 2,4-D ethyl ester per hectare in direct seeded rice.

Raju and Reddy (1986) reported that crop injury may occur if nitrogen fertilizer is applied 10-15 days before or after application of 2, 4-D (0.5-1.0 kg·ha^{-1}).

John and Sadanandan (1989) reported that Fernoxone, a 2,4-D sodium salt (a.i 80% w/w) applied at 1.25 kg ha^{-1} 20 DAS was effective in reducing weed population, weed dry weight and nutrient removal by weeds and resulted in higher number of productive tillers per hill, thousand grain weight, grain and straw yield and weed control efficiency. The weed indices were also lower in Fernoxone treated plot in lowland direct sown rice.

Package of Practices for KAU (1989) recommended butachlor @ 1.25 kg.a.i per hectare to be applied on six to nine DAS followed by 2,4-D sodium salt at 0.8 a.i per hectare 20 DAS for weed control in direct sown rice under puddled condition.

Fatemi (1990) reported that application of 2,4-D @ 1.0 kg·ha^{-1} at 25 DAS in combination with thiobencarb gave effective control of <u>Echinochloa crus-galli</u>, Ammania multiflorum, Cyperus difformis, Polygonum persicana and Alisma lanceolata in direct sown rice.

In studies on the effect of 2,4-D on seed germination and seedling growth of rice. Emmanuvel et al. (1991) found that pre or early post-emergent application is injurious to crop emergence in direct sown rice.

Singh and Ram (1991) observed that 2,4-D at the rate of 1.0 $kg.ha^{-1}$ applied 20 DAS was best for controlling sedges and broadleaved weeds and weed control efficiency varied from 30 to 58.2 per cent in direct seeded upland rice.

The All India Co-ordinated Research Project on Weed Control (1992) recommended pre-emergence application of butachlor followed by post-emergence application of 2,4-D sodium salt 0.5 $kg.ha^{-1}$ in direct seeded puddled rice.

Thus the past experimental evidences reveal that 2,4-D is an effective post-emergent herbicide and in combination with other pre-emergent herbicides controls weeds effectively in rainfed rice..

2.4.3. Combination of chemical and Handweeding

2.4.3.1. Butachlor followed by hand weeding

Munroe et al. (1982) reported that butachlor applied zero to four DAS at 2.0 $kg.a.i.ha^{-1}$ followed by handweeding

29-39 DAS gave the highest yield and net return in direct seeded upland rice.

Elliot et al. (1984) found that butachlor applied one DAS followed by handweeding 21 DAS performed well when Echinochloa colona was dominant but not when Cyperus rotundus dominated in dry seeded rice. Kumar and Singh (1986) observed that butachlor at 1.0 kg.a.i ha^{-1} pre-emergence plus one handweeding gave most effective weed control and increased rice yields and water use efficiency in direct seeded rainfed rice.

Bhagwan Singh (1988) reported that application of butachlor at the rate of 1.0 kg.ha^{-1} with one supplementary handweeding 30 DAS reduced the weed density and dry weight and nutrient removal significantly, over 2.0 kg.ha^{-1} butachlor alone in upland rainfed rice.

Singh and Prakash (1990) recorded that butachlor 1.5 kg.ha^{-1} followed by one handweeding at 25-30 DAS gave weed control efficiency of 84.4 per cent in rainfed upland rice.

Mahadevaswamy and Nanjappa (1991) suggested that butachlor 0.7 kg.ha^{-1} pre-emergence followed by one handweeding 45 DAS resulted in timely and effective control of weeds by the herbicide at initial stages and later by handweeding leading to increased number of tillers, number of panicles, length of panicle, panicle weight, thousand grain weight and decreased sterility percentage in drill sown rainfed rice.

Padhi et al. (1991) reported that highest grain yield, straw yield, net returns and lowest weed dry weight were obtained with butachlor followed by handweeding in direct seeded upland rice. Thus it is pointed out that butachlor followed by handweeding is more effective than butachlor alone and also gives higher net returns in rainfed rice.

2.5. Interaction between sowing time and weed management

Janiya and Moody (1988) reported that the dominance of weed species varied with time of planting. Monochoria concatenata was a major weed in the April and May plantings in dry seeded rice. In wet seeded rice Cynadon dactylon, Echinochloa colona, Cyperus difformis and Cyperus iria were the dominant weeds in plots planted in July. M. vaginalis was dominant in August planting. In September planting E. colona, C. dactylon, Fimbristylis miliacea and C. difformis were the major weeds. They suggested that efficiency of weed control method varied with time of planting. Hand weeding reduced weed growth when rice was planted in April and May but herbicides failed to control weeds. Herbicides reduced growth when rice was planted in June, July and August because of favourable soil moisture. The highest yield was obtained in the July planting because of adequate water supply and weed control. Butachlor failed to increase rice yield at all planting dates because it did not control weeds in dry seeded rice and it caused crop stand reduction in wet seeded rice.

Kim et al. (1991) observed that in dry seeded rice infested predominantly with *Echinochloa* spp., delaying the sowing date significantly reduced weed growth.

The sowing time has a profound influence on the weed species and the efficiency of weed control methods adopted in both dry and wet seeded rainfed rice.

The above review reveals that sowing time has a profound influence on the growth, yield and yield attributes in rainfed rice. Besides, a wide range and intensity of weed problems are observed in dry sown rainfed rice. This highlights the need for a suitable weed management practice, which is both effective and economic.

Unfortunately, these problems have received very little attention in research, especially in rainfed rice, in Kerala, resulting in stagnant and uneconomic rice yield. With the aim of filling this void, the present trial is undertaken.

MATERIALS AND METHODS

MATERIALS AND METHODS

An investigation was carried out with the objective of assessing the effect of time of sowing and weed management on the performance of dry sown rainfed rice.

The experiment was done during the period from May to September in the year 1992. The details of the materials used and methods adopted for the study are presented below.

3.1. Materials

3.1.1. Experimental site

The experiment was conducted in the rice fields of the Instructional Farm, College of Agriculture, Vellayani. The farm is located at 8.5°N latitude and 76.9°E longitude at an altitude of 29 m above mean sea level.

3.1.2. Soil

The soil of the experimental site was sandy clay loam in texture. The Physico-chemical properties of the soil of the experimental site are given in Table 3.1.2a, 2b and 2c.

Table 3.1.2a. Mechanical Analysis of the soil of the experimental site

Constituent	Content in soil (%)	Method used
A. Mechanical Composition		
Coarse sand	48.75	International Pipette method (Piper, 1950)
Fine sand	12.25	
Silt	3.44	
Clay	33.68	
Textural class	Sandy clay loam	

Table 3.1.2b. Physical constants of the soil of the experimental site

Particulars	Depth of soil layer (0-30 cm)	Methods
B. Physical constants		
Field capacity (%)	19.9	
Permanent wilting point (%)	8.9	Pressure membrane apparatus
Bulk density ($g.cm^{-3}$)	1.4	Core sampler (Misra and Ahmed, 1993)

Table 3.1.2c. Chemical properties of the soil of the experimental site

Constituent	Content	Rating	Method used
C. Chemical Composition			
Available nitrogen ($kg \cdot ha^{-1}$)	311.0	Medium	Alkaline potassium permanganate method (Subbiah and Asija, (1956)
Available phosphorus ($kg \cdot ha^{-1}$)	55.0	High	Bray colorimetric method (Jackson, 1973)
Available Potassium ($kg \cdot ha^{-1}$)	88.2	Low	Ammonium acetate method (Jackson, 1973)
Organic carbon (%)	0.24	Low	Walkley and Black rapid titration method (Jackson, 1973)
pH	5.2	Acidic	1:2.5 soil solution ratio using pH meter with glass electrode (Jackson, 1973)

3.1.3. Cropping history of the field

The experimental site selected was under bulk crop of rice and was lying fallow for one month just before the commencement of this experiment.

3.1.4. Season

The experiment was conducted during the first crop season from May to September 1992.

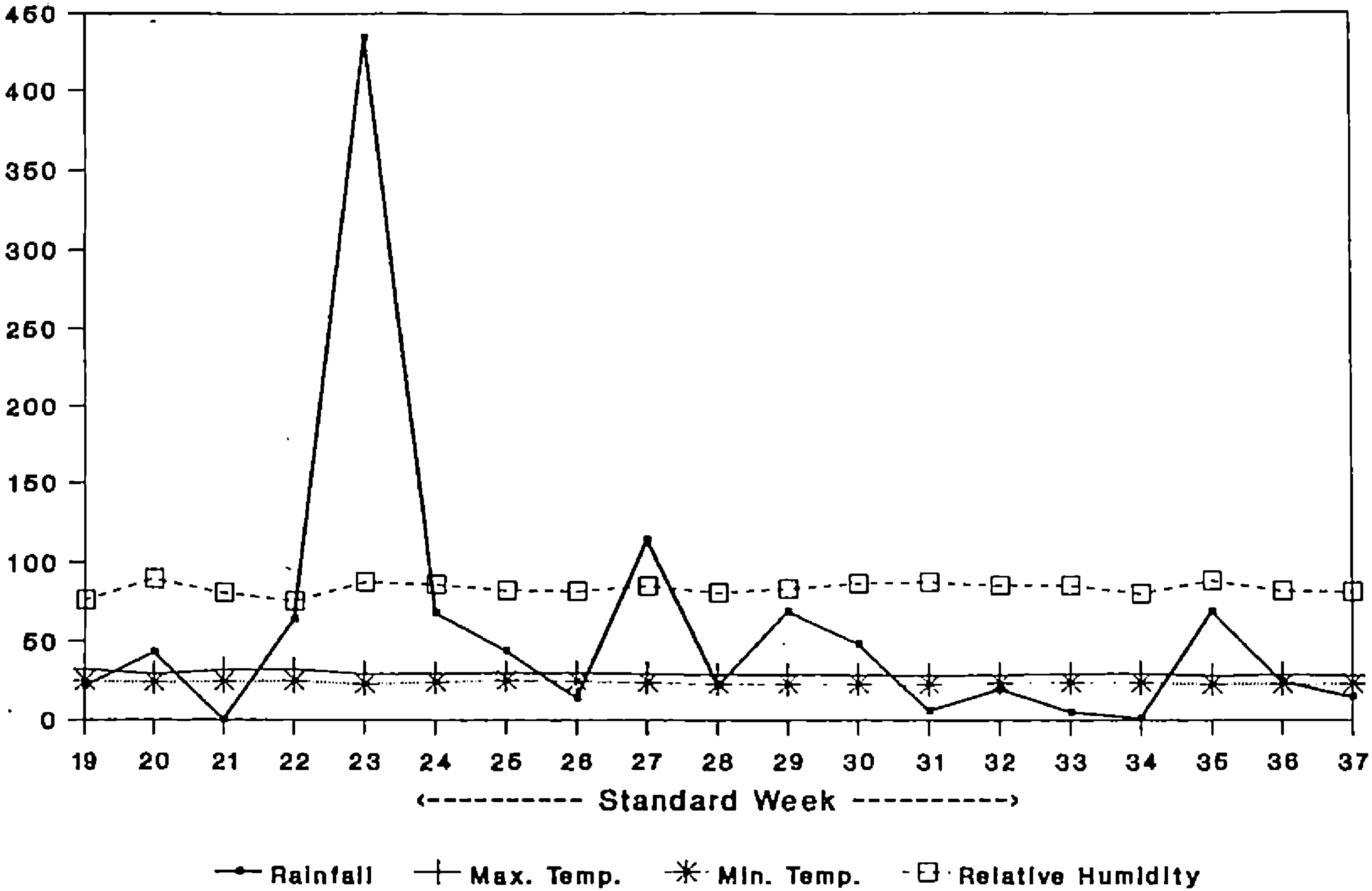
3.1.5. Weather conditions

The experimental site enjoys a humid tropical climate. The data on various weather parameters (rainfall, mean maximum temperature, mean minimum temperature and relative humidity) during the cropping period are given in Appendix I and graphically represented in Fig. 3.1.5. The mean maximum and minimum temperatures during the cropping period ranged from 28.22°c to 32.02°c and 22.45°c to 25.25°c respectively. The mean relative humidity ranged from 75.14 to 89.71 per cent. The total rainfall received during the crop period was 1044.10 mm.

3.1.6. Seed material

The rice variety selected for the experiment was Onam, the progeny of a cross between (Kochuvithu x TN-1) and Triveni. It was released from Rice Research Station, Kayamkulam, Kerala. Onam is a short duration variety (95

Fig. 3.1.5. Weather Data during the Cropping Period



days) which shows early drought resistance and is recommended for cultivation in the first crop season in Kerala.

3.1.7. Manures

Cattle manure containing 0.95 per cent N, 0.54 per cent P_2O_5 and 0.36 per cent K_2O were used for the experiment.

Urea, Mussoriephos and Muriate of Potash analysing 46 per cent N, 20 per cent P_2O_5 and 60 per cent K_2O respectively were applied to rice.

3.1.8. Herbicides

3.1.8.1. Butachlor 50 E.C

Butachlor 50 E.C is the proprietory product of Hoechst (pvt.) Limited. It is a pre-emergence herbicide with good efficiency for controlling annual grasses and broad-leaved weeds.

3.1.8.2. 2, 4-D Sodium salt (Fernoxone)

Fernoxone is a product of ICI India Ltd. and is available as 80 per cent WSP. It is used as a post-emergence herbicide for efficiently controlling broad-leaved weeds.

3.2. Methods

3.2.1. Design and layout

Split plot experiment in Randomised Block Design as suggested by Snedecor and Cochran (1967) was adopted. The experiment comprised of 15 treatments with date of sowing in the main plots and weed management in subplots. The treatments were replicated thrice The layout plan of the experiment is given in Fig. 3.2.1. The details of the layout are given below.

Number of treatment combinations	=	15
Number of blocks	=	3
Number of replications	=	3
Gross plot size	=	6.0 x 4.0 m
Weed observation area in each plot	=	1.0 x 4.0 m
Net plot size	=	4.2 x 3.6 m
Total number of plots	=	45

3.2.2. Treatments

Three dates of sowing and five weed management practices were fixed as the main plot and sub plot treatments respectively.

Date of sowing

S_1 - With receipt of first rain of the onset of monsoon (May 16)

S_2 - Seven days after first sowing (May 23)

S_3 - Fourteen days after first sowing (May 30)

Weed management

W_1 - Butachlor @ 1.25 kg. a.i/ha applied six to nine DAS followed by 2,4-D sodium salt @ 0.8 kg a.i/ha 20 DAS using high volume spray (500 litres/ha)

W_2 - Butachlor @ 1.00 kg. a.i/ha on the date of sowing followed by handweeding 40 DAS

W_3 - Handweeding on 20 and 40 DAS

W_4 - Completely weed free

W_5 - Unweeded control

3.2.3. Treatment combinations

The treatment combinations are as follows:

$T_1:S_1W_1$	$T_6:S_2W_1$	$T_{11}:S_3W_1$
$T_2:S_1W_2$	$T_7:S_2W_2$	$T_{12}:S_3W_2$
$T_3:S_1W_3$	$T_8:S_2W_3$	$T_{13}:S_3W_3$
$T_4:S_1W_4$	$T_9:S_2W_4$	$T_{14}:S_3W_4$
$T_5:S_1W_5$	$T_{10}:S_2W_5$	$T_{15}:S_3W_5$

Fig. 3.2.1. LAYOUT PLAN - Split plot experiment in Randomised Block Design

Replication I					Replication II					Replication III				
S_2W_3	S_2W_5	S_2W_2	S_2W_4	S_2W_1	S_3W_2	S_3W_1	S_3W_5	S_3W_3	S_3W_4	S_3W_3	S_3W_4	S_3W_1	S_3W_2	S_3W_5
S_1W_2	S_1W_1	S_1W_4	S_1W_3	S_1W_5	S_2W_5	S_2W_2	S_2W_3	S_2W_1	S_2W_4	S_1W_1	S_1W_3	S_1W_4	S_1W_5	S_1W_2
S_3W_3	S_3W_2	S_3W_5	S_3W_4	S_3W_1	S_1W_5	S_1W_1	S_1W_3	S_1W_4	S_1W_2	S_2W_4	S_2W_3	S_2W_2	S_2W_1	S_2W_5

Treatments

Date of sowing

S_1 - May 16

S_2 - May 23

S_3 - May 30

Weed management practices

W_1 - Butachlor + 2, 4-D

W_2 - Butachlor + handweeding

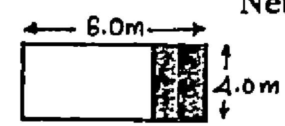
W_3 - Handweeding twice

W_4 - Complete weed free

W_5 - Unweeded control

Gross plot size : 6.0 x 4.0 m

Net plot size : 4.2 x 3.6 m




Weed observation area in each plot : 1.0 x 4.0 m

3.2.4. Field culture

3.2.4.1. Land preparatior

The experimental area was ploughed twice, weed and stubbles removed and clods broken. Plots of size 6 x 4 m were laid out with 15 plots in each block. The plots were separated with bunds of 30 cm thickness and blocks with bunds of 50 cm thickness. Individual plots were again dug and perfectly levelled.

3.2.4.2. Fertilizer application

Urea, Mussoriephos and Muriate of potash were applied to each plot so as to supply nutrients at the rate of 70 kg N, 35 kg. P_2O_5 and 35 kg. K_2O/ha respectively as per the Package of Practices for Kerala for short duration high yielding varieties Farm yard manure was applied @ 5 t. ha^{-1} to all plots.

3.2.4.3. Seeds and sowing

Dry sowing of the seeds by dibbling at a spacing of 20 x 10 cm with two to three seeds per hill was done on three different dates. 16th May, 23rd May and 30th May were the first second and third dates of sowing respectively.

3.2.4.4. Weed management

3.2.4.4.1. Pre-emergence application of herbicides

The liquid formulation of Butachlor was made into an emulsion with water at the required dose. The herbicide solutions were sprayed uniformly at the rate of 500 l ha^{-1} on the date of sowing and seven days after sowing in the respective treatment plots.

3.2.4.4.2. Post-emergence application of herbicides

2,4-D sodium salt at the required dose was applied 21 DAS using high volume spray.

3.2.4.4.3. Handweeding

Handweeding was done first on the 20th day after sowing and the second on the 40th day after sowing in the respective treatment plot. Completely weed free condition was maintained by handweeding, as and when weeds appeared, in completely weed free treatment plots.

3.2.4.5. Plant protection

No pests and diseases were observed in the crop. Hence no plant protection operations were carried out.

3.2.4.6. Harvest

The crop sown on the first date (16-5-1992) was harvested 98 DAS, that on the second date (23-5-1992) was harvested 96 DAS and that sown on the third date (30-5-1992) was harvested 97 DAS. In the case of all the treatments, the crop in the weed observation area and the two border rows were harvested separately and thereafter the crop in the net area of the individual plots was harvested and threshed individually. Weight of grain and straw of individual plots were recorded.

Observations

3.2.5. <u>Observations on weeds</u>

3.2.5.1. Weed species

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

3.2.5.2. Weed count

Weed samples were collected from an area of 1.0m^2 in the weed observation area on 20th, 40th, 60th and 80th day after sowing. Weeds were separated into monocots and dicots and their counts were taken. The weeds were pulled out carefully, washed and dried under shade and later it was oven dried to a constant weight.

3.2.5.3. Weed dry weight

Dry weight of weeds collected on 20th, 40th, 60th and 80th day after sowing were recorded in whole units.

3.2.5.4. Weed control efficiency

Weed control efficiency was worked out on the basis of total weed population. The following formula was used for the calculation of weed control efficiency (Upadhyay and Sivanand, 1985).

$$WCE = \frac{(WPC - WPT) \times 100}{WPC} \text{ where}$$

WCE = Weed control efficiency

WPC = Weed population in the control plot

WPT = Weed population in the treated plot

3.2.6. <u>Observation on crop</u>

3.2.6.1. Growth characters of rice

3.2.6.1.1. Height of plants

The height of the plants (in centimetres) was recorded on 20th, 40th, 60th and 80th day after sowing and at harvest. Four hills were randomly selected within the net plot. Height was measured from the base of the plant to the tip of the longest leaf or to the tip of the longest earhead, whichever was taller.

3.2.6.1.2. Total number of tillers per square metre

Total number of tillers per square metre was recorded on the 40th, 60th and 80th day after sowing and at harvest. Tiller number was taken from four randomly selected hills and expressed as number of tillers per square metre.

3.2.6.2. Yield and Yield attributes of rice

3.2.6.2.1. Productive tillers per square metre

Productive tillers were recorded from the four randomly selected hills on the 80th day after sowing and at harvest and expressed as productive tillers per square metre.

3.2.6.2.2. Panicle weight

All the panicles in the sample hills were weighed and weight per panicle was worked out.

3.2.6.2.3. Thousand grain weight

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

3.2.6.2.4. Grain yield of rice

The grains harvested from each net plot was dried, cleaned and weighed and expressed as $kg.ha^{-1}$ at 14 per cent moisture.

3.2.6.2.5. Straw yield of rice

The straw harvested from each net plot was dried under sun, weighed and the weight was expressed as $kg.ha^{-1}$

3.2.6.2.6. Harvest index

Harvest index was calculated by dividing the weight of grains with the total weight of grain and straw of each plot (Sinha and Swaminathan, 1984).

$$HI = \frac{\text{Economic Yield}}{\text{Biological Yield}} \quad \text{where}$$

HI - Harvest index

..2.6.2.7. Weed index

Weed index was computed by using the formula suggested by Gill and Vijayakumar (1969).

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

WI = Weed index

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

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

3.2.7. <u>Soil moisture estimations</u>

Soil moisture was estimated using the gravimetric method, twice before monsoon had set in (Appendix II). Field capacity was attained during the remaining period of crop growth.

3.2.8. <u>Rainfall observations</u>

Rainfall observations during the entire crop growth period was obtained from Agro-Meteorological Observatory, College of Agriculture, Vellayani.

3.2.9. <u>Chemical Analysis</u>

3.2.9.1. Soil analysis

Composite soil sample collected before the start of the experiment was analysed to determine the available nitrogen, available phosphorus and available potassium. The physical composition and pH were determined for this composite soil sample. After the harvest of the rice crop,soil samples were taken from each plot separately and analysed for available N, available P_2O_5 and available K_2O.

3.2.9.2. Plant analysis

The whole plants of rice collected at harvest and the weed samples collected on 20th, 40th, 60th and 80th day after sowing were analysed for nitrogen, phosphorus and potassium. In the case of rice, the grains were analysed separately. The samples were dried to constant weight in an electric hot air oven at 70^{o}C, ground and passed through a 0.5 mm mesh in a Willey mill. The required quantity of samples were then weighed out accurately in an electronic balance, subjected to acid extraction and the nutrient contents were determined and expressed as percentage on dry weight basis.

3.2.9.2.1. Total nitrogen content

Total nitrogen content was estimated by modified microkjeldahl method as given by Jackson (1973).

3.2.9.2.2. Total phosphorus content

Total phosphorus content was estimated by using Vanado-molybdo-phosphoric yellow color method (Jackson, 1973) and read in Spectronic 20.

3.2.9.2.3. Total potassium content

Total potassium content in plant was estimated by flame photometry. K_2O content was read in EEL Flame photometer (Jackson, 1973).

3.2.9.3. Uptake of nutrients

The total uptake of nitrogen, phosphorus and potassium by weed at 20, 40, 60,and 80 days after sowing and by rice crop at harvest were calculated as the product of the content of these nutrients in the plant sample and the respective dry weight and expressed as kg ha $^{-1}$.

3.2.9.4. Protein content of rice (Crude protein)

The protein content of the grains was computed by multiplying the percentage of nitrogen in grains by the factor 6.25 (Simpson et al., 1965).

3.2.10. Estimation of Herbicide Residue

The rice grains were analysed for weedicide residues of Butachlor and 2,4-D at the Agricultural Chemicals Laboratory of the Indian Agricultural Research Institute, New Delhi.

3.2.11. Economics of cultivation

The economics of cultivation was worked out based on various input costs.

Net income (Rs./ha) : Gross income - Cost of cultivation

Benefit-cost ratio : $\dfrac{\text{Gross income}}{\text{Cost of cultivation}}$

3.2.12. Statistical analysis

The data generated through split-plot design were subjected to analysis of variance (Gomez and Gomez, 1976). Whenever the results were significant, the Critical Difference (CD) was worked out at five and one per cent probability.

ANOVA

Source	Degrees of freedom
Replication	2
Date of sowing (S)	2
Error 1	4
Weed management (W)	4
S x W	8
Error 2	24
Total	44

RESULTS

RESULTS

The results of the field experiment conducted to determine the effect of the time of sowing and weed management on the performance of dry sown rainfed rice are presented below after suitable statistical analysis.

4.1. Observations on crop

4.1.1. Crop growth characters

4.1.1.1. Height of plant

Among the different dates of sowing the plants at S_2 recorded a significantly greater height than those at S_1 or S_3, the minimum height being recorded at S_3. This is noticed throughout the growth period. However, at 60 DAS an interaction was seen between time of sowing and weed management practices. Within S_1 and S_2, plant height was more or less same in treated and weed free plots but at S_3, treated and control plots were at par.

Height differences in plants due to weed management treatments were observed from 60 DAS onwards. Treatments W_1, W_2, W_3 and W_4 were at par. However, plant height in these plots were significantly higher than those in control plots. This trend was maintained till the completion of the crop growth.

Table 4.1.1.1a. Effect of sowing time on plant height under different weed management practices

Treatments	Height of the plants (cm)				
	20 DAS	40 DAS	60 DAS	80 DAS	Harvest
S_1W_1	24.12	46.01	65.46	74.60	75.49
S_1W_2	25.04	45.03	66.83	76.89	77.65
S_1W_3	23.76	46.69	67.78	77.07	77.87
S_1W_4	25.88	43.42	66.20	75.38	76.51
S_1W_5	24.03	45.46	53.39	62.69	63.72
Mean (S_1)	25.57	45.32	63.93	73.32	74.25
S_2W_1	39.99	48.89	77.40	85.47	85.65
S_2W_2	37.47	49.51	76.68	84.07	84.40
S_2W_3	40.28	50.52	77.22	84.08	84.54
S_2W_4	38.68	48.70	75.70	84.78	85.19
S_2W_5	37.02	48.18	70.28	79.49	79.62
Mean (S_2)	38.69	49.16	75.45	83.58	83.88
S_3W_1	23.92	40.41	60.73	68.19	68.91
S_3W_2	23.40	41.28	62.49	69.30	69.98
S_3W_3	23.24	41.19	58.91	66.59	67.34
S_3W_4	22.40	41.62	60.18	66.87	67.29
S_3W_5	25.02	38.70	56.91	63.89	64.61
Mean (S_3)	23.79	40.64	59.84	66.97	67.63
$F_{2,4}$ S	47.22**	24.59**	47.42**	32.94**	32.22**
$F_{8,24}$ SW	1.37	0.73	2.99*	2.26	2.33
CD S	4.78	3.37	4.61	5.73	5.65
CD SW	NS	NS	4.08	NS	NS
SE S	1.22	0.86	1.17	1.46	1.43
SE SW	1.17	1.15	1.39	1.66	1.61

NS not significant

Table 4.1.1.1b. Average effect of weed management on plant height

Treatment	Plant height (cm)				
	20 DAS	40 DAS	60 DAS	80 DAS	Harvest
W_1	29.34	45.10	67.87	76.08	76.68
W_2	28.97	45.27	68.67	76.75	77.34
W_3	29.09	46.13	67.97	75.91	76.58
W_4	28.99	44.58	67.36	75.67	76.33
W_5	28.69	44.11	60.19	68.69	69.32
$F_{4, 24}$ W	0.12	1.31	18.85**	12.01**	12.83**
CD W	N'	-	2.35	2.81	2.71
SE W	0.67	0.66	0.81	0.96	0.93

4.1.1.2. Tiller number per square metre

Tiller number per m^2 was not significantly different when the crop was sown at different dates. But the weed management practices influenced the tiller number . Maximum tiller number was recorded from weed free plots. Tiller number in the handweeded and weed free plots was not significantly different at later stages of crop growth. At 40DAS no significant difference was observed among treated plots and control except in handweeded plots. From 60 DAS onwards tiller number was significantly higher in handweeded plots than control and was at par with weed free plots. But W_1 and W_2 were not superior to control plots.

4.1.2. Yield components

4.1.2.1. Productive tiller number per square metre

Time of sowing had no significant effect on the number of productive tillers per m^2, but the weed management practices influenced it. Significantly higher productive tiller number was recorded from weed free plots than other treatments. At 80 DAS, W_3 produced more number of productive tillers than W_1 and W_2 which were at par. At harvest no significant difference was seen between W_1, W_2 and W_3. The result of weed management practices remained consistent over the different dates of sowing.

Treatments	40 DAS	60 DAS	80 DAS	Harvest
S_1W_1	536	744	570	525
S_1W_2	463	664	609	530
S_1W_3	486	754	609	542
S_1W_4	676	765	620	586
S_1W_5	436	648	554	503
Mean (S_1)	519	715	592	537
S_2W_1	558	664	631	564
S_2W_2	519	664	637	569
S_2W_3	659	715	676	581
S_2W_4	664	720	676	592
S_2W_5	503	508	497	525
Mean (S_2)	581	654	623	566
S_3W_1	395	562	546	478
S_3W_2	416	566	554	495
S_3W_3	467	707	602	560
S_3W_4	582	868	710	628
S_3W_5	398	555	522	467
Mean (S_3)	452	652	587	525
$F_{2,\ 4}$ S	NS	NS	NS	NS
$F_{8,\ 24}$ SW	NS	NS	NS	NS
SE S	28.35	43.61	24.07	26.87
SE SW	50.49	63.72	42.26	36.66

NS not significant

Table 4.1.1.2b. Average effect of weed management on tiller number

Treatment	Tiller number (per squaremetre)			
	40 DAS	60 DAS	80 DAS	Harvest
W_1	496	657	582	522
W_2	466	632	600	532
W_3	537	725	629	561
W_4	641	784	668	602
W_5	445	570	524	498
$F_{4,\ 24}$ W	7.02**	5.10**	4.85**	3.54**
CD W	85.09	107.39	71.23	61.78
SE W	29.15	36.79	24.40	21.16

Table 4.1.2.1a. Effect of time of sowing on productive tiller number under different weed management practices

Treatments	Productive tiller number (Per squaremetre) 80 DAS	Harvest
S_1W_1	279	270
S_1W_2	320	311
S_1W_3	312	269
S_1W_4	376	372
S_1W_5	217	194
Mean (S_1)	301	283
S_2W_1	293	275
S_2W_2	333	321
S_2W_3	337	327
S_2W_4	97	380
S_2W_5	40	221
Mean (S_2)	20	305
S_3W_1	41	221
S_3W_2	33	221
S_3W_3	70	262
S_3W_4	27	310
S_3W_5	93	181
Mean (S_3)	253	239
$F_{2, 4}$ S	NS	NS
$F_{8, 24}$ SW	NS	NS
SE S	16.37	17.74
SE SW	16.87	19.59

NS not significant

Table 4.1.2.1b. Average effect of weed management on productive tiller number

Treatment	Productive tiller number (per squaremetre)	
	80 DAS	Harvest
W_1	271	255
W_2	295	284
W_3	306	286
W_4	367	354
W_5	217	199
$F_{4, 24}$ W	31.25**	24.45**
CD W	28.44	33.02
SE W	9.74	11.31

4.1.2.2. Panicle weight

Panicle weight was significant for different planting dates. S_2 resulted in significant panicle weight while S_3 had the least.

Weed control treatments also significantly influenced panicle weight. Significant panicle weight was recorded from weed free plots. From the treated plots panicle weight was found to be higher than that of control with handweeded treatment being better than W_1 and W_2. Significant interaction between sowing time and weed management practices was observed with a divergent result of significant difference between handweeded and weed free plots in S_1 and S_2, whereas in S_3 they were at par.

4.1.2.3. Thousand grain weight

Difference in the date of sowing did not influence thousand grain weight and also no interaction was observed between sowing time and weed control.

Thousand grain weight was maximum in weed free plot. Handweeded plot recorded significant thousand grain weight than herbicide (butachlor + 2, 4-D) and herbicide followed by handweeding (butachlor + handweeding) treatments.

Table 4.1.2.2. Effect of sowing time and weed management on panicle weight (in grams)

Treatments	W_1	W_2	W_3	W_4	W_5	mean(S)
S_1	1.51	1.42	1.89	2.15	1.17	1.63
S_2	1.62	1.64	1.95	2.34	1.34	1.78
S_3	1.54	1.49	1.75	1.85	1.07	1.54
Mean (W)	1.55	1.51	1.86	2.11	1.19	

$F_{2,4}$ S	35.56**	CD S	0.079	SE S	0.020
$F_{4,24}$ W	208.64**	CD W	0.071	SE W	0.024
$F_{8,24}$ SW	4.86**	CD SW	0.120	SE SW	0.042

Table 4.1.2.3. Effect of sowing time and weed management on thousand grain weight (in grams)

Treatments	W_1	W_2	W_3	W_4	W_5	mean(S)
S_1	26.28	26.69	27.84	28.54	25.02	26.87
S_2	28.51	28.59	29.49	30.41	27.50	28.90
S_3	27.02	26.72	28.06	29.90	25.61	27.46
Mean (W)	27.27	27.33	28.46	29.61	26.04	

$F_{2,4}$ S	NS	CD S	-	SE S	0.73
$F_{4,24}$ W	36.17**	CD W	0.65	SE W	0.22
$F_{8,24}$ SW	NS	CD SW	-	SE SW	0.38

NS not significant

4.1.2.4. Grain yield

Maximum grain yield was obtained from plots of S_2 and was at par with that of S_1. Grain yield was significantly lower at S_3 in comparison with S_2.

All the weed treatment plots produced more grain yield than control plot. Significant grain yield was recorded from weed free plot. Handweeded plot produced better yield than herbicide followed by handweeding treatment and herbicide alone applied plots. Also W_2 gave higher yield than W_1. No interaction was observed between sowing date and weed management.

4.1.2.5. Straw yield

Maximum straw yield was recorded from S_2 which was at par with S_1 but significantly different from S_3.

Straw yield was significantly higher in weed free plots. Handweeded plots performed better than W_1 and W_2 which were at par.

4.1.2.6. Harvest index

The effects of time of sowing, weed management and their interaction on harvest index were not significant.

Table 4.1.2.4. Effect of time of sowing and weed management on grain yield ($kg \cdot ha^{-1}$)

Treatments	W_1	W_2	W_3	W_4	W_5	mean(S)
S_1	1190.48	1355.83	1807.77	2127.44	881.84	1472.67
S_2	1565.26	2017.21	2281.76	2678.58	1124.34	1933.43
S_3	925.93	970.02	1300.71	1785.72	540.12	1104.12
Mean (W)	1227.22	1447.68	1796.74	2197.25	848.77	

$F_{2, 4}$ S	4.46**	CD S	771.53	SE S	196.52
$F_{4, 24}$ W	108.73**	CD W	145.14	SE W	49.72
$F_{8, 24}$ SW	NS	CD SW	-	SE SW	86.12

NS - Not Significant

Table 4.1.2.5. Effect of time of sowing and weed management on straw yield ($kg.ha^{-1}$)

Treatments	W_1	W_2	W_3	W_4	W_5	mean(S)
S_1	1477.08	1609.35	1851.86	2391.98	1058.20	1677.69
S_2	2006.18	2204.60	2403.01	2711.66	1388.90	2142.87
S_3	992.11	1146.39	1565.26	2160.51	727.52	1318.36
Mean (W)	191.79	1653.44	1940.04	2421.38	1058.20	

$F_{2, 4}$ S	4.44*	CD S	769.48	SE S	196.00
$F_{4, 24}$ W	48.94**	CD W	212.18	SE W	72.69
$F_{8, 24}$ SW	NS	CD SW	-	SE SW	125.90

Table 4.1.2.6. Effect of sowing time and weed management on harvest index

Treatments	W_1	W_2	W_3	W_4	W_5	mean(S)
S_1	0.45	0.44	0.49	0.47	0.44	0.46
S_2	0.43	0.48	0.48	0.49	0:44	0.46
S_3	0.46	0.43	0.45	0.44	0.38	0.43
Mean (W)	0.44	0.45	0.47	0.47	0.42	
$F_{2,\ 4}$ S	NS	CD S	-	SE S	0.017	
$F_{4,\ 24}$ W	NS	CD W	-	SE W	0.013	
$F_{8,\ 24}$ SW	NS	CD SW	-	SE SW	0.023	

Table 4.1.2.7. Effect of sowing time and weed management on weed index

Treatments	W_1	W_2	W_3	W_4	W_5	mean(S)
S_1	41.70	34.38	18.55	0	59.46	30.82
S_2	33.67	21.80	13.18	0	53.42	24.41
S_3	54.06	49.45	29.07	0	69.68	40.45
Mean (W)	43.14	35.21	20.26	0	60.85	
$F_{2,\ 4}$ S	NS	CD S	-	SE S	4.16	
$F_{4,\ 24}$ W	199.74**	CD W	16.14	SE W	2.10	
$F_{8,\ 24}$ SW	NS	CD SW	-	SE SW	3.65	

NS not significant

4.1.2.7. Weed index

Weed index did not vary with difference in time of sowing nor with its interaction with weed management practices.

There was a significant difference between treated and control plots. Handweeded plot recorded the lowest weed index and was significantly different from all other treatments. W_2 was found to be superior to W_1 plots.

4.2. Observations on weeds

4.2.1. Weed species

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

The predominant weeds were *Echinochloa colona*, *E. crus-galli*, *Brachiaria ramosa*, *Cyperus iria*, *Fimbristylis miliaceae*, *Ludwigia parviflora*, *Marsilia quadrifoliata*, *Monochoria vaginalis* and *Panicum repens*.

4.2.2. Monocot weed count

Different dates of sowing did not produce any significant effect on monocot weed count. With respect to

Table 4.2.1. List of weeds found in the experimental field

No.		Scientific name	Family
I		Grasses	
	1.	*Brachiaria ramosa* (Griseb) stapf	Graminae
	2.	*Dactyloctenium aegyptium* (L) Beauv	Graminae
	3.	*Echinochloa colona* (L) Link	Graminae
	4.	*Echinochloa crus-galli* (L) Beauv	Graminae
	5.	*Ischaemum rugosum* Salish	Graminae
	6.	*Oryza sativa* var. fatua (L)	Graminae
	7.	*Panicum repens* (L)	Graminae
II		Sedges	
	1.	*Cyperus difformis* (L)	Cyperaceae
	2.	*Cyperus iria* (L)	Cyperaceae
	3.	*Cyperus rotundus* (L)	Cyperaceae
	4.	*Fimbristylis miliaceae* (L) Vahl	Cyperaceae
	5.	*Scirpus articulatus* (L)	Cyperaceae
III		Broad-leaved weeds	
	1.	*Alternanthera sessilis* (L) R. Br. Roth	Amaranthaceae
	2.	*Ammania multiflora* (L)	Lythraceae
	3.	*Ludwigia parviflora* (L) Roxb	Onagraceae
	4.	*Marsilia quadrifoliata* (L)	Marsileaceae
	5.	*Monochoria vaginalis* (Burm) Prest	Pontiederiaceae

Table 4.2.2a. Effect of time of sowing on monocot weed population under different weed management practices

Treatments	Monocot weed population (Per squaremetre)			
	20 DAS	40 DAS	60 DAS	80 DAS
S_1W_1	54(7.40)	79(8.92)	104(10.22)	115(10.76)
S_1W_2	27(5.27)	50(7.11)	49(7.09)	72(8.55)
S_1W_3	55(7.51)	23(4.85)	19(4.46)	39(6.29)
S_1W_4	0(1.00)	0(1.00)	0(1.00)	0(1.00)
S_1W_5	60(7.84)	61(7.86)	180(13.46)	203(14.28)
Mean (S_1)	5.80	5.95	7.24	8.18
S_2W_1	39(6.31)	67(8.22)	135(11.64)	140(11.86)
S_2W_2	30(5.56)	80(9.00)	48(7.01)	70(8.40)
S_2W_3	24(5.02)	46(6.84)	41(6.49)	58(7.69)
S_2W_4	0(1.00)	0(1.00)	0(1.00)	0(1.00)
S_2W_5	49(7.08)	119(10.93)	273(16.56)	276(16.63)
Mean (S_2)	4.99	7.20	8.54	9.12
S_3W_1	57(7.60)	119(10.91)	128(11.37)	156(12.54)
S_3W_2	64(8.08)	109(10.48)	90(9.52)	102(10.14)
S_3W_3	51(7.21)	48(7.00)	51(7.20)	60(7.83)
S_3W_4	0(1.00)	0(1.00)	0(1.00)	0(1.00)
S_3W_5	55(7.48)	156(12.52)	188(13.74)	214(14.65)
Mean (S_3)	6.28	8.38	8.56	9.23
$F_{2,\ 4}$ S	NS	NS	NS	NS
$F_{8,\ 24}$ SW	NS	NS	NS	NS
SE S	0.41	0.66	0.65	0.47
SE SW	1.08	1.19	1.03	0.94

NS- Not Significant

Figures in paranthesis represent values obtained after square root transformation.

Table 4.2.2b. Average effect of weed management on Monocot weed population

Treatment	Weed count (per m^2)			
	20 DAS	40 DAS	60 DAS	80 DAS
W_1	7.11	9.35	11.08	11.72
W_2	6.30	8.86	7.87	9.03
W_3	6.58	6.23	6.05	7.27
W_4	1.00	1.00	1.00	1.00
W_5	7.47	10.44	14.59	15.19
$F_{4, 24}$ W	17.95**	30.22**	74.60**	93.73**
CD W	1.83	2.00	1.73	1.59
SE W	0.62	0.68	0.59	0.54

weed control, none of the treatments were found to be effective on 20 DAS. At 40 DAS, handweeded plots alone recorded low weed counts. At 60 DAS in handweeded plots weed population was the least. However, W_1 and W_2 were also found to control the weed population. Herbicide followed by handweeding was found to be better than combination of butachlor with 2, 4-D. At 80 DAS the results were similar to that at 60 DAS. The effects of the weed control treatments were consistent over different sowing dates.

4.2.3. Dicot weed count

Different dates of sowing had no significant effect on dicot weed counts at any stage of crop growth.

At 20 DAS, the weed control treatments produced no significant response in controlling the dicot weeds. At 40, 60 and 80 DAS, herbicide treated plots and handweeded plots recorded more or less the same weed population but at later stages herbicide application alone was effective though handweeding was also helpful in reducing the weed population. From 40 DAS, the effect of weed management treatments was not consistent. At S_1, W_1 and W_3 which were on par was found to be effective. Herbicide applied plots recorded the same weed population as that of W_4 at all dates of sowing. In plots sown at S_2 the weed population was less

Table 4.2.3a. Effect of time of sowing on Dicot weed population under different weed management practices

Treatments	Dicot population (Per squaremetre)			
	20 DAS	40 DAS	60 DAS	80 DAS
S_1W_1	3(1.90)	2(1.74)	3(1.89)	3(2.09)
S_1W_2	4(2.19)	47(6.92)	39(6.35)	40(6.37)
S_1W_3	5(2.44)	9(3.11)	26(5.16)	26(5.23)
S_1W_4	0(1.00)	0(1.00)	0(1.00)	0(1.00)
S_1W_5	2(1.85)	47(6.95)	87(9.35)	67(8.22)
Mean (S_1)	1.89	3.94	4.75	4.58
S_2W_1	8(2.97)	3(1.89)	3(2.00)	8(3.00)
S_2W_2	4(2.12)	6(2.67)	16(4.06)	14(3.89)
S_2W_3	1(1.47)	5(2.52)	17(4.19)	14(3.86)
S_2W_4	0(1.00)	0(1.00)	0(1.00)	0(1.00)
S_2W_5	5(2.40)	17(4.25)	26(5.20)	32(5.74)
Mean (S_2)	1.99	2.47	3.29	3.50
S_3W_1	5(2.53)	1(1.24)	1(1.57)	3(1.98)
S_3W_2	17(4.27)	25(5.08)	25(5.04)	25(5.08)
S_3W_3	3(1.91)	3(2.05)	3(3.19)	5(2.34)
S_3W_4	0(1.00)	0(1.00)	0(1.00)	0(1.00)
S_3W_5	4(2.24)	8(2.95)	12(3.62)	15(3.94)
Mean (S_3)	2.39	2.46	2.66	2.87
$F_{2,\ 4}$ S	NS	NS	NS	NS
$F_{8,\ 24}$ SW	NS	2.30*	2.66*	2.96*
CD S	–	–	–	–
CD SW	–	2.23	2.34	1.85
SE S	0.40	0.58	0.70	0.60
SE SW	0.60	0.76	0.80	0.63

NS- Not Significant

Figures in paranthesis represent values obtained after square root transformation.

Table 4.2.3b. Average effect of weed management on Dicot weed population

Treatment	Dicot weed count (per m^2)			
	20 DAS	40 DAS	60 DAS	80 DAS
W_1	2.49	1.62	1.82	2.36
W_2	2.86	4.89	5.15	5.11
W_3	1.94	2.56	3.80	3.81
W_4	1.00	1.00	1.00	1.00
W_5	2.16	4.72	6.06	5.96
$F_{4, 24}$ W	4.07**	16.08**	21.34**	30.04**
CD W	1.01	1.29	1.35	1.07
SE W	0.34	0.44	0.46	0.36

in all the plots but only the herbicide alone applied plots recorded significant reduction in comparison with control. At this date of sowing all the treated plots recorded weed population at par with weed free plot. At S_3, in W_1, W_3 and W_5 the results were at par. However, the weed population in W_2 was significantly higher compared to other plots.

At 60 DAS, in S_1 treatments were found to be effective. The W_1 plots were at par with weed free plots. At the second and third dates of sowing the population was low in all the plots. At S_2, W_1 was at par with W_4 and at S_3, W_1 and W_3 were at par.

At 80 DAS, for S_1 date of sowing W_1 was on par with W_4. At S_3 also W_1 was found to be the best and was at par with W_3. At S_2, though the dicot population was a bit high, the treatments were found to be effective.

4.2.4. Weed Dry Weight

Different dates of sowing produced no variation in the dry weight of weeds and also no interaction was observed between sowing date and weed management practices.

Weed dry weight was not significantly different in the treated and control plots on 20 DAS. At 40 DAS handweeded plots recorded the minimum dry weight which was at par with herbicide followed by handweeding. The weed dry

4.2.4a. Effect of time of sowing on weed dry weight under different weed management practices

Treatments	Weed dry weight ($g \cdot m^{-1}$)			
	20 DAS	40 DAS	60 DAS	80 DAS
S_1W_1	13.07	43.38	92.09	96.46
S_1W_2	7.75	40.94	61.28	75.69
S_1W_3	11.10	8.99	25.46	52.45
S_1W_4	0	0	0	0
S_1W_5	19.58	48.66	138.54	134.02
Mean (S_1)	10.30	28.39	63.47	71.72
S_2W_1	13.74	39.20	176.67	178.28
S_2W_2	7.03	40.91	33.07	60.01
S_2W_3	6.91	17.52	31.98	58.17
S_2W_4	0	0	0	0
S_2W_5	16.71	83.25	194.51	240.93
Mean (S_2)	8.81	36.17	87.24	107.47
S_3W_1	15.78	80.42	101.30	114.21
S_3W_2	27.27	62.49	53.79	67.81
S_3W_3	24.10	27.10	40.52	53.56
S_3W_4	0	0	0	0
S_3W_5	16.16	111.82	123.86	144.33
Mean (S_3)	16.64	56.36	63.89	75.98
$F_{2, 4}$ S	NS	NS	NS	NS
$F_{8, 24}$ SW	NS	NS	NS	NS
SE S	3.791	9.555	12.973	11.798
SE SW	5.903	18.717	25.361	22.893

NS not significant

Table 4.2.4b. Average effect of weed management on weed dry weight

Treatment	Weed dry weight (per m^2)			
	20 DAS	40 DAS	60 DAS	80 DAS
W_1	14.20	54.33	123.35	129.63
W_2	14.01	48.11	49.38	67.84
W_3	14.04	17.87	32.65	54.73
W_4	0	0	0	0
W_5	17.48	81.24	152.30	173.09
$F_{4, 24}$ W	4.02**	8.69**	19.03**	26.02**
CD W	9.948	31.544	42.740	38.581
SE W	3.408	10.806	14.642	13.230

Table 4.2.5a. Effect of time of sowing on weed control efficiency under different weed control treatments

Treatments	Weed control efficiency (%)		
	40 DAS	60 DAS	80 DAS
S_1W_1	(34.18)31.59	(53.27)64.27	(48.64)56.38
S_1W_2	(40.15)41.61	(59.10)73.67	(52.16))62.41
S_1W_3	(44.94)49.92	(63.25)79.78	(57.08)70.50
S_1W_4	(90.00)99.99	(90.00)99.99	(90.00)99.99
S_1W_5	(0) 0	(0) 0	(0) 0
Mean (S_1)	41.85	53.12	49.58
S_2W_1	(44.36)48.92	(45.03)50.08	(40.00)41.36
S_2W_2	(38.41)38.64	(61.46)77.21	(58.38)72.55
S_2W_3	(52.85)63.56	(62.35)78.51	(59.49)74.27
S_1W_4	(90.00)99.99	(90.00)99.99	(90.00)99.99
S_1W_5	(0) 0	(0) 0	(0) 0
Mean (S_2)	45.12	53.12	49.57
S_3W_1	(32.24)28.48	(36.46)35.34	(34.24)30.06
S_3W_2	(36.32)35.60	(46.97)53.47	(46.86)53.28
S_3W_3	(47.92)55.12	(51.59)61.44	(52.06)62.23
S_1W_4	(90.00)99.99	(90.00)99.99	(90.00)99.99
S_1W_5	(0) 0	(0) 0	(0) 0
Mean (S_3)	41.29	45.00	44.43
$F_{2,\ 4}$ S	NS	NS	NS
$F_{8,\ 24}$ SW	NS	NS	NS
CD S	–	–	–
CD SW	–	–	–
SE (plot)	1.79	1.10	1.32

NS- Not Significant

Figures in paranthesis represent values obtained after angular transformation and weighted analysis.

Table 4.2.5b. Average effect of weed management on weed control efficiency

Treatment	Weed control efficiency (%)		
	40 DAS	60 DAS	80 DAS
W_1	36.79	46.03	41.01
W_2	38.15	57.06	53.08
W_3	48.64	60.08	56.60
W_4	90.00	90.00	90.00
W_5	0	0	0
$F_{4, 24}$ W	64.36**	174.87**	120.50**
CD W	11.721	7.207	8.633
SE W	4.016	2.469	2.958

weight from herbicide applied plot was at par with that of control. The same trend was seen at 60 DAS also. At 80 DAS, W_3 and W_2 plots recorded no significant difference in dry weight, whereas in W_1 dry weight was significantly less than that of control.

4.2.5. Weed control efficiency

Weed control efficiency was not influenced by the difference in sowing date nor by its interaction with weed control treatments.

There was a significant difference between treated and control plots. Weed free plot recorded the highest efficiency in weed control. At 40 DAS, handweeded plot was at par with herbicide followed by handweeding plot, but superior to herbicide treated plot. W_1 and W_2 were at par. At 60 and 80 DAS, handweeded treatment was at par with W_2 but both were superior to W_1.

4.3. Chemical Analysis

4.3.1. Nutrient uptake by crop

4.3.1.1. Nitrogen

N uptake was high in plants sown on S_2 and was significantly superior to those recorded from S_3 but S_1 and S_3 were at par.

Among the weed treatments, in handweeded plots the uptake was high and no significant difference was observed between W_1 and W_2. Uptake was maximum in weed free plots and significantly very low in control plots. This trend of result was consistent in S_2 and S_3 but in S_1, N uptake in handweeded and weed free plots was not significantly different.

4.3.1.2. Phosphorus

P uptake was not significantly different when crop was sown at S_1 and S_2 but was significantly low at S_3.

Among the treated plots. handweeded plots recorded maximum P uptake and herbicide alone applied plots the minimum. However, this result differed with change of sowing date. Though maximum P uptake was in weed free plots at different sowing dates, for S_3 no significant difference was seen between weed free and handweeded plots. Also W_2 and W_1 were at par, W_1 being at par with W_5. P uptake from W_1 and W_5 were at par at S_1 also but they differed significantly at S_2.

4.3.1.3. Potassium

K uptake was high in S_2 which was at par with S_1 but differed significantly from S_3. S_1 and S_3 recorded no significant difference in K uptake.

Table 4.3.1a. Effect of sowing time on Nutrient uptake by crop under different weed management treatments

Treatment	Uptake of nutrients ($kg.ha^{-1}$)		
	N	P_2O_5	K_2O
S_1W_1	22.82	14.34	22.63
S_1W_2	23.93	18.43	32.34
S_1W_3	41.64	19.92	30.36
S_1W_4	45.26	27.91	38.37
S_1W_5	14.96	11.91	18.26
Mean (S_1)	29.72	18.50	28.39
S_2W_1	31.23	11.27	33.76
S_2W_2	34.93	18.35	37.82
S_2W_3	52.08	23.81	42.23
S_2W_4	61.25	28.79	51.92
S_2W_5	19.01	8.01	28.56
Mean (S_2)	39.70	18.05	38.85
S_3W_1	15.43	6.73	14.48
S_3W_2	16.30	8.68	16.61
S_3W_3	26.77	11.77	32.32
S_3W_4	36.26	12.76	34.74
S_3W_5	9.90	5.60	10.77
Mean (S_3)	20.93	9.10	21.78
$F_{2,\ 4}$ S	8.19**	10.95**	6.68**
$F_{8,\ 24}$ SW	4.70	19.75	2.96
CD S	12.87	6.28	13.06
CD SW	4.86	2.76	5.78
SE S	3.27	1.60	3.32
SE SW	1.66	0.94	1.98

Table 4.3.1b. Average effect of weed management on nutrient uptake by crop

Treatment	Uptake of nutrients (kg. ha^{-1})		
	N	P	K
W_1	23.16	10.78	23.62
W_2	25.05	15.15	28.92
W_3	40.16	18.50	34.97
W_4	47.59	23.15	41.68
W_5	14.62	18.50	19.20
$F_{4, 24}$ W	194.71**	116.04**	61.00**
CD W	2.80	1.59	3.33
SE W	0.96	0.54	1.14

Maximum K uptake was from weed free plot followed by handweeded plot and the minimum in control plots.

Whatever be the time of sowing, herbicide alone treated plot and control did not produce any significant difference in K uptake. Maximum K uptake was recorded from weed free plots but it was at par with handweeded plot in S_3. Among the weed management practices handweeding was found to result in higher K uptake in S_2 and S_3 but in S_1 it was at par with herbicide followed by handweeding treatment. In S_1, K uptake was significantly low in W_1 compared to other treated plots. But in S_2 and S_3, W_1 and W_2 were at par.

4.3.2. Grain protein

Grain Protein was higher from plots sown at S_2 followed by S_1 and S_3. With respect to weed management grain protein from W_4 and W_3 were same and higher than that recorded from other treated plots. The lowest was recorded from control plots. Grain protein from herbicide alone treated plot was higher than that from herbicide followed by handweeded plots. But this result was not consistent in all plots when the sowing date differed.

From S_1 plots maximum grain protein was recorded from herbicide alone treated plots followed by handweeded plot and the minimum from herbicide followed by handweeding

Table 4.3.2. Effect of sowing time and weed management on grain protein (in per cent)

Treatments	W_1	W_2	W_3	W_4	W_5	mean(S)
S_1	7.90	5.40	7.30	6.60	5.90	6.62
S_2	6.60	7.43	8.00	7.30	6.30	7.12
S_3	5.80	7.00	6.30	7.70	5.50	6.46
Mean (W)	6.76	6.61	7.20	7.20	5.90	

$F_{2, 4}$ S	205.30**	CD S	0.095	SE S	0.024
$F_{4, 24}$ W	185.84**	CD W	0.181	SE W	0.062
$F_{8, 24}$ SW	223.04**	CD SW	0.104	SE SW	0.036

plot. For S_2 sowing, maximum values were recorded from W_3 followed by W_2 which was at par with W_4 and the minimum from control plot. For S_3, the maximum grain protein was recorded from weed free plot and the minimum from control plot.

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

4.3.3.1. Nitrogen

The N uptake of weed was not significantly influenced by the different dates of sowing nor by its interaction with weed management practices.

N uptake by weeds was at par in treated and control plots at 20 DAS. N uptake was significantly less in W_2 and W_3 in comparison to control at 40 DAS. At 60 and 80 DAS, N uptake in treated plots was significantly less than that of control plots. At all stages of crop growth after 20 DAS, the minimum uptake by weeds was recorded in handweeded plots.

4.3.3.2. Phosphorus

P uptake by weeds was not influenced by sowing time differences or its interaction with weed management treatments except at 40 DAS. At 40 DAS, in S_1 and S_2 the P uptake by weeds was significantly less than that observed

4.3.3.1a. Effect of sowing time on Nitrogen uptake by weeds under different weed management practices

Treatments	Nitrogen uptake ($kg \cdot ha^{-1}$)			
	20 DAS	40 DAS	60 DAS	80 DAS
S_1W_1	1.30	5.81	11.79	9.64
S_1W_2	0.90	3.89	7.53	6.72
S_1W_3	1.61	0.90	2.58	6.13
S_1W_4	0	0	0	0
S_1W_5	2.29	6.19	16.20	15.01
Mean (S_1)	1.22	3.55	7.62	7.50
S_2W_1	1.60	5.01	19.76	19.95
S_2W_2	0.78	4.08	3.13	5.33
S_2W_3	0.92	2.04	3.19	5.18
S_2W_4	0	0	0	0
S_2W_5	1.87	10.64	24.87	28.18
Mean (S_2)	1.03	4.35	10.19	11.85
S_3W_1	1.93	10.28	11.3	11.41
S_3W_2	2.88	6.99	5.37	6.77
S_3W_3	3.07	3.16	4.04	5.08
S_3W_4	0	0	0	0
S_3W_5	1.88	14.28	16.56	17.74
Mean (S_3)	1.95	6.94	7.45	8.20
$F_{2,4}$ S	NS	NS	NS	NS
$F_{8,24}$ SW	NS	NS	NS	NS
CD S	-	-	-	-
CD SW	-	-	-	-
SE S	0.435	1.182	1.532	1.37
SE SW	0.659	2.245	2.902	2.559

NS not significant

Table 4.3.3.1b. Average effect of weed management on Nitrogen uptake by weeds

Treatment	N uptake by weed ($kg \cdot ha^{-1}$)			
	20 DAS	40 DAS	60 DAS	80 DAS
W_1	1.61	7.03	14.28	13.67
W_2	1.52	4.99	5.34	6.27
W_3	1.86	2.03	3.27	5.67
W_4	0	0	0	0
W_5	2.01	10.37	19.21	20.31
$F_{4,\ 24}$ W	4.51**	9.92**	22.95**	28.51**
CD W	1.112	3.784	4.890	4.313
SE W	0.380	1.296	1.675	1.477

4.3.3.2a. Effect of sowing time on Phosphorus uptake by weeds under different weed management practices

Treatments	P uptake by weeds (kg.ha^{-1} P_2O_5)			
	20 DAS	40 DAS	60 DAS	80 DAS
S_1W_1	0.53	2.37	3.77	6.55
S_1W_2	0.35	2.67	3.36	4.16
S_1W_3	0.60	0.60	2.71	4.19
S_1W_4	0	0	0	0
S_1W_5	0.80	1.99	7.61	9.11
Mean (S_1)	0.45	1.52	3.49	4.80
S_2W_1	0.76	1.60	9.55	9.79
S_2W_2	0.47	1.67	2.40	4.08
S_2W_3	0.37	0.80	2.55	4.64
S_2W_4	0	0	0	0
S_2W_5	0.68	2.41	7.97	11.[illegible]
Mean (S_2)	0.45	1.29	4.49	5.9[illegible]
S_3W_1	0.21	6.43	8.09	9.13
S_3W_2	0.37	3.43	4.29	4.94
S_3W_3	0.98	1.84	4.33	4.28
S_3W_4	0	0	0	0
S_3W_5	0.46	8.94	9.90	11.54
Mean (S_3)	0.40	4.12	5.32	5.97
$F_{2,\ 4}$ S	NS	7.88**	NS	NS
$F_{8,\ 24}$ SW	NS	3.19*	NS	NS
CD S	-	2.198	-	-
CD SW	-	2.681	-	-
SE S	0.162	0.560	0.668	0.554
SE SW	0.194	0.918	1.392	1.254

NS not significant

Table 4.3.3.2b. Average effect of weed management on Phosphorus uptake by weeds

Treatment	P uptake by weed (kg.ha^{-1} P_2O_5)			
	20 DAS	40 DAS	60 DAS	80 DAS
W_1	0.50	3.46	7.13	8.49
W_2	0.40	2.59	3.35	4.39
W_3	0.65	1.08	3.20	4.37
W_4	0	0	0	0
W_5	0.64	4.44	8.49	10.57
$F_{4, 24}$ W	5.74**	11.40**	17.85**	32.13**
CD W	0.327	1.548	2.346	2.114
SE W	0.112	0.530	0.803	0.724

from plots sown at S_3. However, with S_1 and S_2 no significant difference in P uptake was seen in treated and control plots but at S_3 the P uptake was significantly less in W_2 and W_3 treated plots. P uptake by weeds was not significantly different in treated and control plots at 20 DAS. At 40 DAS, P uptake was significantly low in handweeded plots which was at par with W_2. In herbicide treated plots the P uptake was found to be at par with control. The same trend was observed at 60 DAS and 80 DAS.

4.3.3.3. Potassium

A significant difference in K uptake by weeds was seen only at 40 DAS with respect to different sowing dates. From plots sown at S_2, K uptake was significantly lower than from plots sown at S_3. However, K uptake by weeds for S_1 and S_2 were at par.

The treated and control plots did not produce any significant difference in K uptake by weeds at 20 DAS. Handweeded plots recorded significantly lower K uptake compared to other treatments and control which were at par at 40 DAS. K uptake was significantly low in W_2 and W_3 plots at 60 DAS. However, W_1 and control recorded higher and similar values. The same trend was recorded at 80 DAS.

4.3.3.3a. Effect of sowing time on Potassium uptake by weeds under different weed management practices

Treatments	K uptake by weeds ($kg.ha^{-1}$ K_2O)			
	20 DAS	40 DAS	60 DAS	80 DAS
S_1W_1	1.97	8.32	14.36	14.85
S_1W_2	1.96	10.27	10.59	12.71
S_1W_3	2.30	2.17	5.29	6.76
S_1W_4	0	0	0	0
S_1W_5	3.22	10.02	22.30	21.84
Mean (S_1)	1.89	6.15	10.50	11.23
S_2W_1	3.15	6.30	31.79	30.84
S_2W_2	1.12	7.85	5.08	8.93
S_2W_3	1.19	2.81	5.14	9.19
S_2W_4	0	0	0	0
S_2W_5	3.61	11.23	23.61	38.78
Mean (S_2)	1.81	5.64	13.12	17.55
S_3W_1	3.05	16.54	17.01	18.61
S_3W_2	4.38	10.18	10.16	11.86
S_3W_3	6.35	5.01	3.11	4.11
S_3W_4	0	0	0	0
S_3W_5	3.90	21.34	18.69	23.52
Mean (S_3)	3.54	10.62	9.79	11.62
$F_{2,4}$ S	NS	4.90*	NS	NS
$F_{8,24}$ SW	NS	NS	NS	NS
CD S	-	4.856	-	-
CD SW	-	-	-	-
SE S	0.761	1.237	2.477	1.937
SE SW	1.128	2.939	4.922	3.924

NS - not significant

Table 4.3.3.3b. Average effect of weed management on Potassium uptake by weeds

Treatment	K uptake by weed (kg.ha^{-1} K_2O)			
	20 DAS	40 DAS	60 DAS	80 DAS
W_1	2.72	10.39	21.05	21.43
W_2	2.48	9.43	8.61	11.17
W_3	3.28	3.33	4.51	6.69
W_4	0	0	0	0
W_5	3.58	14.19	21.53	28.05
$F_{4, 24}$ W	4.73**	11.34**	11.78**	24.77**
CD W	1.902	4.953	8.295	6.613
SE W	0.651	1.697	2.842	2.265

4.3.4. Available nutrient status in soil after the experiment

Difference in time of sowing did not affect the available nitrogen and potassium status of soil after the experiment. However, available phosphorus content of soil was influenced. Maximum available P was observed in S_2 which was superior to S_1 and S_3. S_1 and S_3 were at par.

With respect to weed management treatments, only the available N status of soil was influenced. Maximum available N was recorded from W_2 plots which was at par with control plot. The available N in soil was not significantly different in handweeded and weed free plot and was significantly less than that seen in other treatments. W_1 and W_5 were at par.

The available nutrient status was not significantly different with respect to different treatments at different sowing dates.

4.3.5. Herbicide Residue in Grains

The rice grains did not contain any residue of butachlor and 2,4-D at the time of harvest.

Table 4.3.4a. Effect of sowing time on available nutrient status of soil after the experiment under different weed management practices

Treatment	Available nutrients ($kg.ha^{-1}$)		
	N	P_2O_5	K_2O
S_1W_1	332.00	53.66	79.33
S_1W_2	334.66	54.33	72.33
S_1W_3	319.33	53.00	80.33
S_1W_4	321.33	53.66	79.66
S_1W_5	333.66	52.33	52.66
Mean (S_1)	328.20	53.40	72.86
S_2W_1	328.66	61.66	53.66
S_2W_2	336.33	60.33	72.00
S_2W_3	319.00	60.66	68.66
S_2W_4	315.00	59.00	67.33
S_2W_5	330.00	61.33	52.00
Mean (S_2)	325.80	60.60	62.73
S_3W_1	327.66	51.66	81.66
S_3W_2	331.66	50.33	86.66
S_3W_3	324.33	49.00	78.33
S_3W_4	320.33	49.66	82.33
S_3W_5	329.33	51.66	83.33
Mean (S_3)	326.66	50.46	82.46
$F_{2,4}$ S	NS	11.00*	NS
$F_{8,24}$ SW	NS	NS	NS
CD S	-	6.17	-
CD SW	-	-	-
SE S	3.32	1.57	5.45
SE SW	2.21	1.18	7.33

NS not significant

Status of soil after the experiment

Treatment	Available nutrients ($kg.ha^{-1}$)		
	N	P_2O_5	K_2O
W_1	329.44	55.66	71.55
W_2	334.22	55.00	77.00
W_3	320.88	54.22	75.77
W_4	318.88	54.11	76.44
W_5	331.00	55.11	62.66
$F_{4, 24}$ W	26.98**	NS	NS
CD W	3.73	-	-
SE W	1.28	0.68	4.23

NS not significant

Table 4.4a. Effect of sowing time on net returns and Benefit-cost ratio under different weed management practices

Treatment	Gross returns (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	Benefit-cost ratio
S_1W_1	9810.46	7455	2355.46	1.31
S_1W_2	11100.16	8795	2305.16	1.25
S_1W_3	14506.25	9815	4691.25	1.47
S_1W_4	17284.06	15815	1469.06	1.09
S_1W_5	7231.08	6815	416.08	1.05
Mean (S_1)			2247.40	1.23
S_2W_1	12693.05	7455	5508.05	1.73
S_2W_2	16325.07	8795	7530.07	1.85
S_2W_3	18375.33	9815	8560.33	1.86
S_2W_4	21461.76	15815	5646.76	1.35
S_2W_5	9259.44	6815	2444.44	1.35
Mean (S_2)			5937.93	1.63
S_3W_1	9319.00	7455	1864.00	1.00
S_3W_2	7936.58	8795	-858.42	0.89
S_3W_3	10670.26	9815	855.26	1.08
S_3W_4	14660.60	15815	-1154.40	0.92
S_3W_5	4508.41	6815	-2306.59	0.65
Mean (S_3)			-689.10	0.91
$F_{2,\ 4}$ S			NS	NS
$F_{8,\ 24}$ SW			NS	NS
CD S			-	-
CD SW			-	-
SE S			1559.40	0.17
SE SW			672.63	0.08

NS - Not Significant

Table 4.4b. Average effect of weed management on net returns and Benefit-cost ratio

Treatment	Gross returns (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	Benefit-cost ratio
W_1	10082.38	7455	2627.38	1.34
W_2	11787.27	8795	2992.27	1.33
W_3	14517.28	9815	4702.28	1.47
W_4	17802.14	15815	1987.14	1.12
W_5	6999.64	6815	184.64	1.02
$F_{4, 24}$ W			17.79**	14.10**
CD W			1133.55	0.14
SE W			338.34	0.04

4.4. Economic Evaluation

The net returns and benefit-cost ratio was not influenced by the different dates of sowing nor by its interaction with weed management practices.

Among the weed management treatments highest returns was obtained with handweeding. W_1, W_2 and W_4 were at par and superior to W_5. With respect to benefit-cost ratio W_1, W_2 and W_3 were at par and superior to complete weed free and unweeded control.

DISCUSSION

DISCUSSION

A field experiment was conducted to determine the best time of sowing and an effective weed management practice for dry sown rainfed rice. The experiment was laid out at the College of Agriculture, Vellayani, during the Virippu season of 1992. Results obtained from the experiment were statistically analysed and are discussed in this chapter.

5.1. Observations on crop

5.1.1. Difference in Growth characters

5.1.1.1. Plant height

The crop sown on May 23 produced the tallest plants at all stages of growth followed by that sown on May 16. The least height was recorded in plants sown on May 30, the third sowing date. The better emergence and establishment of seedlings owing to the prevalance of optimum moisture in the soil due to the rainfall received immediately before sowing with minimum rain during time of sowing resulted in plants of greater height under second sowing. High soil moisture due to excess rainfall following the first and third sowing dates affected seedling emergence and growth. These findings are in agreement with that of Dinesh Chandra et al (1991) All weed control treatments resulted in better height of plants than unweeded control. This was due to the minimisation in competition by adopting weed control measures, and this result is in conformity with that of Padhi et al. (1991) and Suja and Abraham (1991).

An interaction between sowing date and weed control was observed at 60 DAS. The weed control treatments in the crop sown on May 30 resulted in no significant differences. This was due to the excess soil moisture present at sowing time and also, at the time of carrying out the weed control measures. Similar results were obtained by Olifintoye and Mabbayad (1984) and Janiya and Moody (1988).

5.1.1.2. Tiller number

Though the different dates of sowing did not affect the tiller number, it was influenced by the weed control treatments. Maximum tiller number was observed with handweeding at all stages of crop growth. However, at 60 and 80 DAS, handweeded and complete weed free plots recorded the same result because of the effective control of both monocot and dicot weeds. Similar results were reported by Soman (1988). Butachlor + handweeding and Butachlor + 2,4-D had no effect on tiller count and was at par with unweeded control at all stages of growth. This was probably due to the ineffective control of dicot and monocot weeds at the early stages of crop growth by these treatments. This type of high weed competition resulting in reduction of tiller number was reported by Sukumari (1982) and Shahi (1985) also.

5.1.2. Difference in yield attributes and yield

5.1.2.1. Productive tiller number

The productive tiller number was significantly influenced by different weed control treatments. At 80 DAS handweeding and butachlor + handweeding treatments were at par and superior to the combined application of butachlor and 2,4-D. But at harvest time the above three treatments were at par and superior to control. This was in accordance with the findings of Budhar *et al*. (1991) who reported an increase in the number of panicles by handweeding owing to the complete removal of weeds. Similarly, the effect of butachlor in increasing productive tiller number was pointed out by Singh and Singh (1989), Singh and Ram (1990) and Padhi *et al*. (1991) and that of 2,4-D by John and Sadanandan (1989). An increase in panicle number by butachlor + handweeding was reported by Mahadevaswamy and Nanjappa (1991). Bhagwan Singh (1988) reported the advantage of butachlor + handweeding over butachlor alone. The interaction between sowing time and weed control was not significant.

5.1.2.2. Panicle weight

There was significant effect of sowing time on panicle weight. Plants sown on May 23 recorded maximum panicle weight due to better plant growth at early stages owing to optimum soil moisture conditions. However, excess soil moisture affected growth of seedlings and reduced panicle weight at the first and third dates of sowing. This result is in agreement with the findings of Dinesh Chandra et al (1991). All the weed control treatments were effective in increasing panicle weight. Highest panicle weight was recorded from handweeded plots due to better weed control. Similar results were obtained by Budhar et al. (1991). Butachlor + handweeding and the combination of butachlor and 2,4-D were also effective. This is in conformity with the results of Kumar and Gautam (1986), Singh and Singh (1989), Singh and Ram (1990), Mahadevaswamy and Nanjappa (1991) and Padhi et al. (1991). Panicle weight was influenced by the interaction of sowing time and weed control treatments. When sowing was done on May 30, panicle weight in handweeded and weed free plots were at par unlike when sown on May 16 and May 23. This shows the greater efficiency of weed control treatments at the third sowing date where high soil moisture prevailed from sowing time till harvest. Similarly Janiya and Moody (1988) reported that the efficiency of weed control methods varied with the time of sowing.

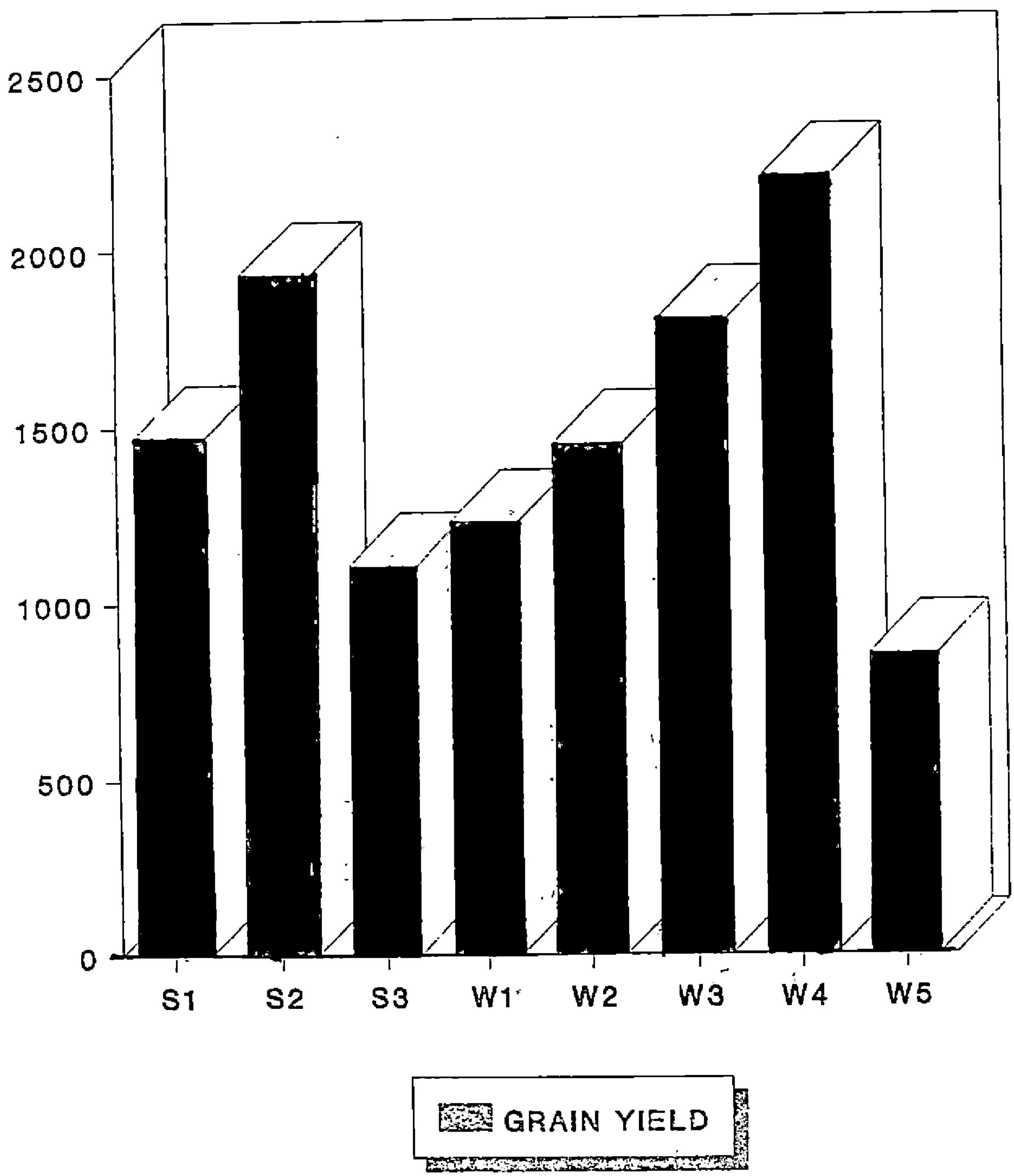
5.1.2.3. Thousand grain weight

Thousand grain weight was influenced neither by date of sowing nor by its interaction with weed management. Thousand grain weight was maximum in weed free plot due to no weed competition. Arya et al. (1991) and Varshney (1991) also reported a decrease in thousand grain weight due to weed competition. Among the treated plots, handweeding gave the best result. Reddy and Bhargavi (1989) and Budhar et al. (1991) reported similar findings. Butachlor + handweeding and butachlor combined with 2,4-D were also effective. This is in agreement with the results of John and Sadanandan (1989), Singh and Ram (1990), Mahadevaswamy and Nanjappa (1991) and Padhi et al. (1991).

5.1.2.4. Grain yield

Grain yield on second sowing was the highest and was at par with the first. Third sowing date produced the lowest yield but was at par with the first. The excess moisture at the time of third sowing resulted in poor seedling emergence, lesser plant height and panicle weight and hence, low yield. Optimum soil moisture during the second sowing enabled better seedling emergence and growth, greater panicle weight and ultimately, higher yield. This

Fig. 5.1.2.4. Effect of sowing time and weed management on grain yield

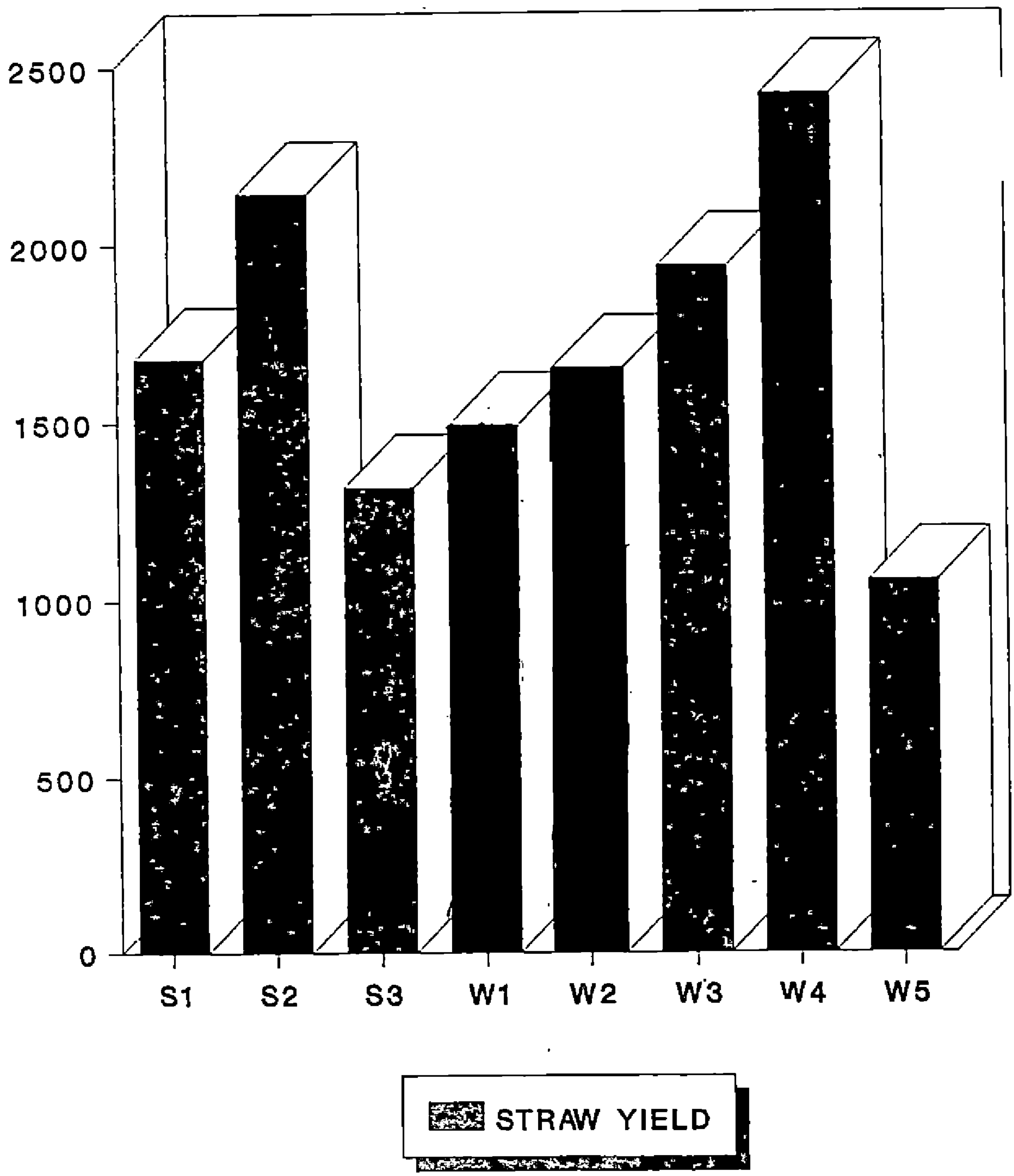


result is in concurrence with the findings of Blum (1972)) and Dinesh Chandra et al (1991) All weed control treatments were effective in increasing grain yield. The best weed control treatment was handweeding. This is due to lesser weed growth, higher productive tiller number, panicle weight and thousand grain weight. Similar findings were obtained by Patel (1990) and Budhar et al. (1991). Butachlor + handweeding was superior to herbicide alone. Munroe et al. (1982), Kumar and Singh (1986) and Bhagwan Singh (1988) reported similarly. Butachlor combined with 2,4-D was also effective and gave higher yield than control. Kumar and Gautam (1986) and Heinrich et al. (1987) also recommended the same.

5.1.2.5. Straw yield

The effect of sowing time on straw yield showed a similar trend of grain yield. Narayanaswamy et al (1982) reported a decrease in straw yield with a delay in sowing. Among the weed control treatments highest straw yields were obtained from complete weed free plots due to no weed competition. Arya et al. (1991) and Varshney (1991) reported a decrease in straw yield due to weed competition. Handweeding was the best among the treated plots. This is in agreement with the findings of Bhan et al. (1985). Butachlor

Fig. 5.1.2.5. Effect of sowing time and weed management on straw yield



+ handweeding and the combined application of butachlor and 2, 4-D were also effective in increasing straw yield over unweeded control. Similar results were recorded by John and Sadanandan (1989), Singh and Ram (1990) and Padhi et al. (1991).

5.1.2.6. Harvest index

Different time of sowing, weed control treatments and their interaction did not influence the harvest index.

5.1.2.7. Weed index

Different dates of sowing did not influence the weed index. The lowest weed index was for handweeding which is an indicator of the superiority of handweeding over the other treatments. The next better treatment was butachlor + handweeding. The combined application of butachlor and 2,4-D was also effective. The unweeded control recorded very high weed index resulting from the very low yields. Lowering of weed index by proper control of weeds was reported by Chandrakar et al. (1985), John and Sadanandan (1989), Singh and Prakash (1990) and Singh and Ram (1990) which is in agreement with the present result. The effect of interaction was not significant.

5.2. Observations on weeds

5.2.1. Weed species

Observation on weed species revealed that grasses, sedges and broad-leaved weeds competed with rice plant. But the competition was mostly by grasses followed by sedges and broad-leaved weeds. Most important grass weeds identified were *Brachiaria ramosa*, *Echinochloa colona*, *E. crus-galli* and *Panicum repens*. *Cyperus iria* and *Fimbristylis miliaceae* dominated among sedges. *Ludwigia parviflora*, *Marsilia quadrifoliata* and *Monochoria vaginalis* were the prominent among broad-leaved weeds. Kamalam Joseph *et al*. (1990) also made similar observations.

5.2.2. Monocot weed count

Different dates of sowing did not affect the monocot weed population. Among the weed control treatments, handweeding was the best at all stages. Similar results were recorded by Kaushik and Mani (1980), Bhan *et al*. (1985) and Samantaray *et al*. (1992). Butachlor application was ineffective at the early stages. This is in accordance with the findings of Singh (1988). However, at later stages butachlor + handweeding treatment and the combination of butachlor and 2,4-D were effective in controlling monocot weeds. Reports of Kumar and Singh (1986) and the findings of AICWCRP (1992) were in concurrence with these results. But butachlor + handweeding was superior to combined application of butachlor and 2,4-D. This is in agreement with the findings of Bhagwan Singh (1988). The interaction of sowing time and weed control did not affect monocot weed populaiion.

5.2.3. Dicot weed count

Dicot weed count was not affected by difference in sowing time. Among the weed control treatments both the treatments with butachlor alone were not effective in controlling the dicot weeds at 20 DAS. This is in agreement with the findings of Singh (1988) regarding the ineffective control of broad-leaved weeds by butachlor alone. However, at later stages the application of 2,4-D in butachlor applied treatment was effective. Similar results were reported by Keisers and Paidin (1986), Singh and Ram (1990) and AICWCRP (1992). Handweeding was also effective in reducing dicot weed population. Bhan et al. (1985) and Samantary et al. (1992) recorded similarly. The interaction effect of sowing time and weed management on dicot weed population was significant. The combined application of butachlor and 2.4-D was effective in reducing dicot weeds at all sowing dates from 40 DAS onwards. This was at par with handweeding for the third sowing date for observation on 60 and 80 DAS. However, for first and second date of sowing the same was at par with complete weed free treatment on 60 and 80 DAS. This is in concurrence with the reports of Janiya and Moody (1988) who observed that efficiency of weed control method varied with time of sowing.

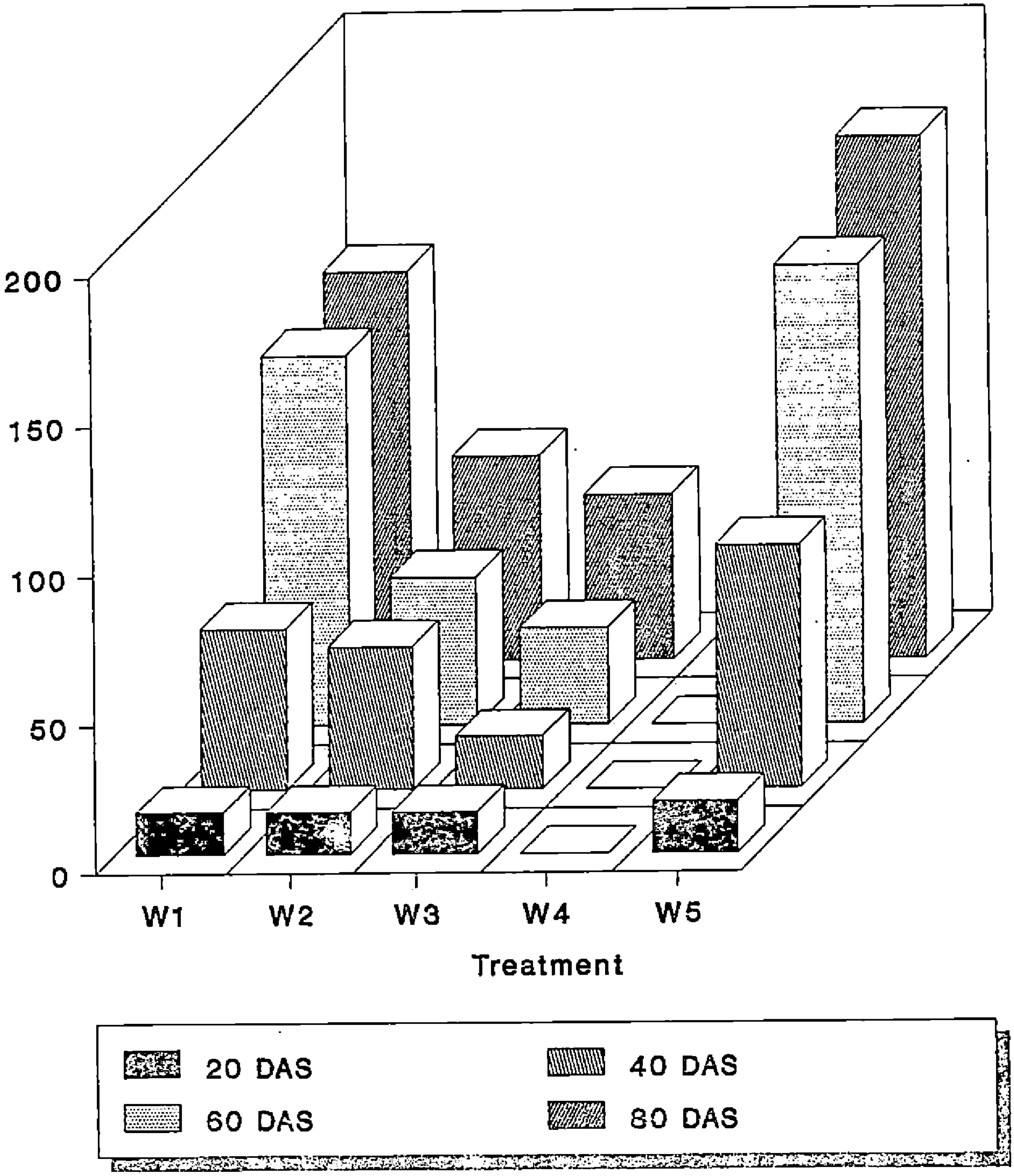
5.2.4. Weed dry weight

Different dates of sowing produced no variation in the dry weight of weeds. Among the weed control treatments, butachlor + 2,4-D combination was ineffective at 20, 40 and 60 DAS. This may be due to the inefficiency of this treatment in controlling the monocot weeds. However, at 80 DAS the weed dry weight was less in this treatment. Handweeding alone was most effective in reducing weed dry weight. Similar results were reported by Kaushik and Mani (1980). Chandrakar *et al*. (1985), Reddy and Bhargavi (1989) and Patel (1990). Butachlor + handweeding treatment was also effective in reducing weed dry weight. This is in accordance with the results of Bhagwan singh (1988) and Padhi *et al*. (1991). Weed dry weight was not affected by the interaction of sowing time and weed management.

5.2.5. Weed control efficiency

The highest weed control efficiency was obtained by handweeding. Butachlor + handweeding was equally effecient. Similar results were reported by Chandrakar *et al*. (1985), Singh and Prakash (1990) and Singh (1992). The combined

Fig. 5.2.4. Effect of weed management on weed dry weight



application of butachlor and 2,4-D was also effective, though less efficient than handweeding and butachlor + handweeding treatments. This is in conformity with the findings of Choudhary and Pradhan (1988) and John and Sadanandan (1989).

5.3. Chemical analysis

5.3.1. Nutrient uptake by crop

5.3.1.1. Nitrogen

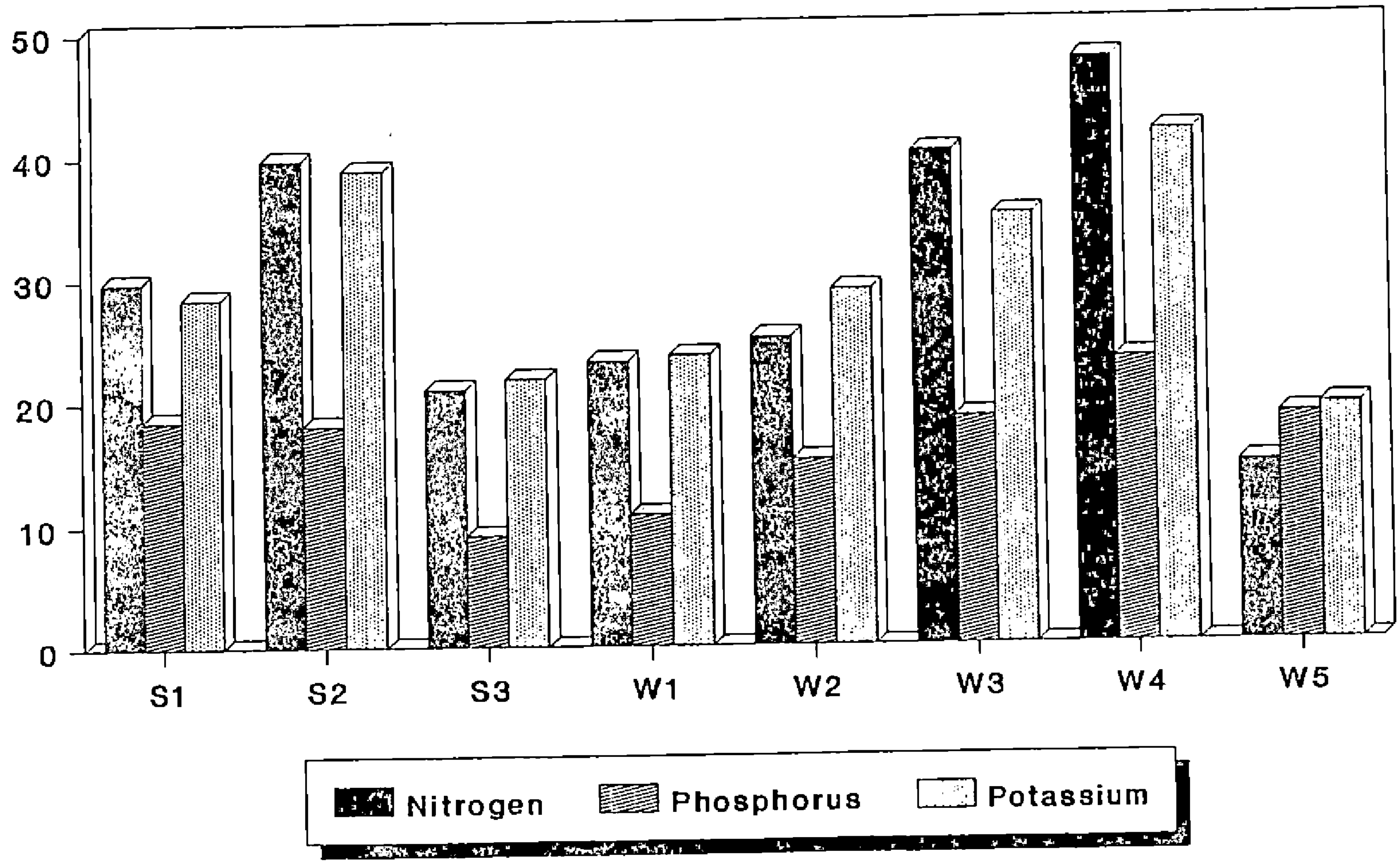
Nitrogen uptake was higher in crop sown on the second date than first and third dates of sowing which were at par. This was due to the optimum moisture conditions prevailing at the time of fertilizer application and sowing which ultimately resulted in better growth and yield due to higher uptake. Similar results were recorded by Reddy and Reddy (1991). N uptake by crop was maximum in complete weed free plot and minimum in unweeded control. Similar results in unweeded crop was reported by Sharma and Singh (1981). Among the treated plots N uptake by the crop was highest in handweeded plot due to less weed competition. Kaushik and Mani (1980) and Samantary et al. (1992) recorded concurrent results. Butachlor + handweeding and butachlor + 2,4-D were also effective in increasing N uptake by crop over unweeded control. This is in accordance with the findings of Sharma and Singh (1981), Bhagwan Singh (1988) and John and Sadanandan (1989).

The interaction of sowing time and weed control affected N uptake of the crop. The handweeded and complete weed free plots recorded similar uptake values only at third sowing date. Similar findings were reported by Janiya and Moody (1988) who mentioned the varying efficiency of weed control treatments over different sowing dates.

5.3.1.2. Phosphorus

The crop sown on the first and second dates recorded similar and higher P uptake values when compared to the third date of sowing. The unfavourable soil moisture conditions that prevailed during the time at which the entire dose of P fertilizer was applied as basal, may be the reason for reduced P uptake by the crop sown on third date. With respect to weed management, among the treated plots maximum P uptake was recorded in the handweeded plot. Kaushik and Mani (1980) also had similar findings and reported that nutrient depletion by weeds was reduced by handweeding. However, combined application of butachlor and 2,4-D was not effective in increasing the P uptake by crop. This was due to poor control of weeds in the initial stages resulting in higher uptake of P by weeds. The interaction of sowing time and

Fig. 5.3.1. Effect of sowing time and weed management on nutrient uptake by crop



weed control on P uptake was significant. Similarly, Janiya and Moody (1988) reported that efficiency of weed control method varied with time of planting.

5.3.1.3. Potassium

The crop sown on second date recorded highest K uptake and third sown crop, the least. This may be due to the optimum soil moisture conditions prevalent at the time of basal fertilizer application leading to better uptake and growth in crop sown on second date.

Among the weed management treatments complete weed free plots recorded highest K uptake by the crop and unweeded control the least. Among the treated plots, handweeding was the best. Similar results were reported by Kaushik and Mani (1980).

The interaction of sowing time and weed management on K uptake by crop was significant. This may be due to varying efficiency of weed control methods over different sowing dates as has been reported by Janiya and Moody (1988).

5.3.2. Grain protein

The grain protein was highest in crop sown on second date and least from the third. This may be due to the higher uptake of nitrogen by crop sown on second date.

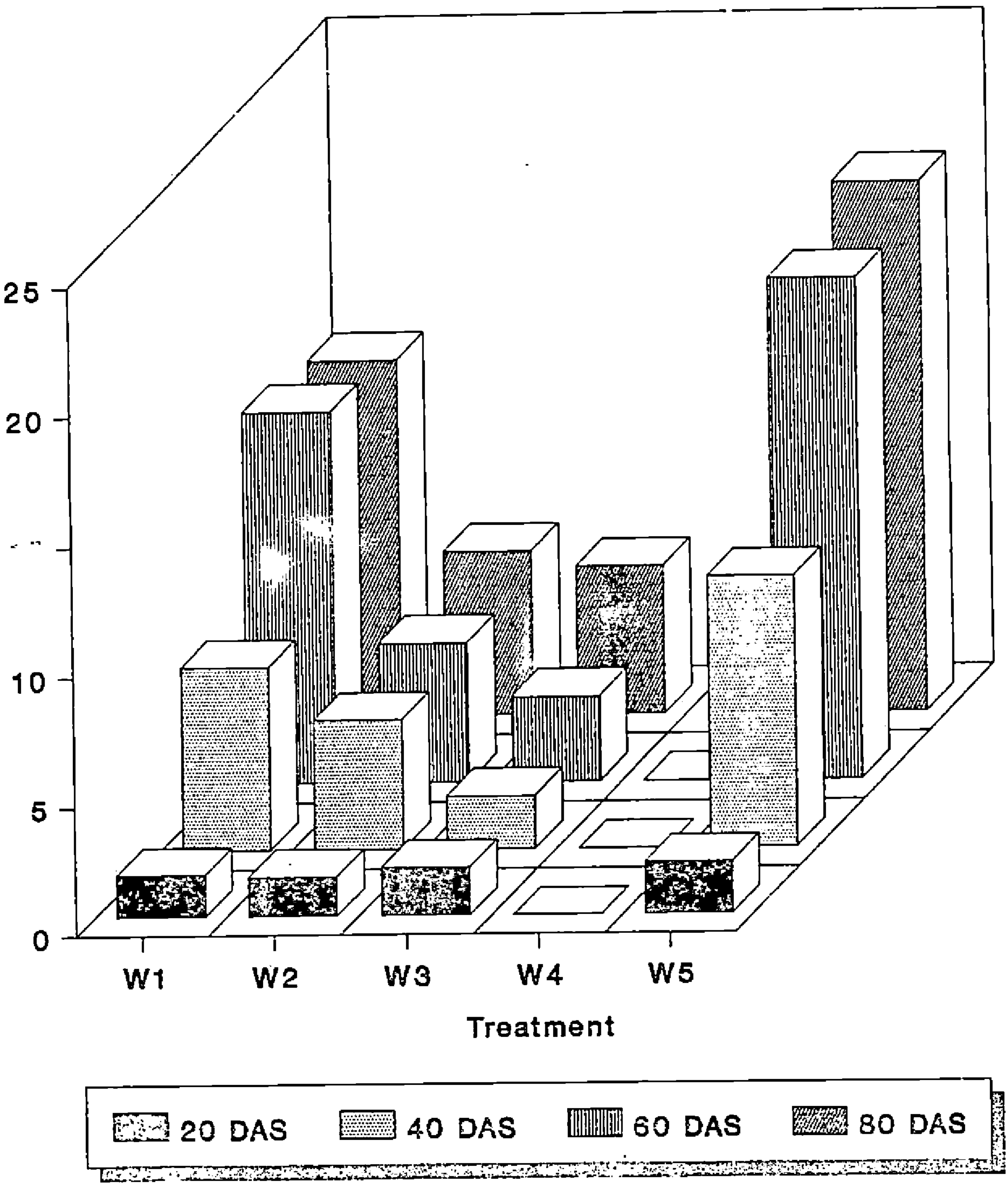
Among the weed control treatments, complete weed free and hand weeded plots recorded higher protein content. Butachlor + handweeding and combined application of Butachlor and 2,4-D were also effective over unweeded control. This may be due to the control of weeds by these treatments which enabled a higher uptake of nitrogen. Similar results of increased protein content of grain in rice by control of weeds was reported by Raveendran (1976) and Sukumari (1982). The interaction of sowing time and weed control method also influenced the grain protein content. For crop sown on first date, maximum value was recorded by Butachlor + 2,4-D followed by handweeding treatment. The minimum was for Butachlor + handweeding treatment. For the second sowing date, maximum value was recorded from handweeded plot folllowed by butachlor + handweeding. For the third sowing date, maximum grain protein was recorded from complete weed free plot and the minimum from unweeded control. This interaction may be due to the varying efficiency of weed control methods over different sowing dates as suggested by Janiya and Moody (1988).

5.3.3. Nutrient uptake by weeds

5.3.3.1. Nitrogen

The N uptake by weeds was not influenced by the different dates of sowing.

Fig. 5.3.3.1. Effect of weed management on Nitrogen uptake by weeds



Among the weed control treatments, handweeded plots recorded the least N uptake by weeds at all stages of growth. This is in concurrence with the results of Kaushik and Mani (1980), Ali and Sankaran (1984a) and Samantaray et al. (1992). Butachlor + handweeding and the combined application of butachlor and 2,4-D was also effective. This is in conformity with the findings of Bhagwan Singh (1988) and Suja and Abraham (1991).

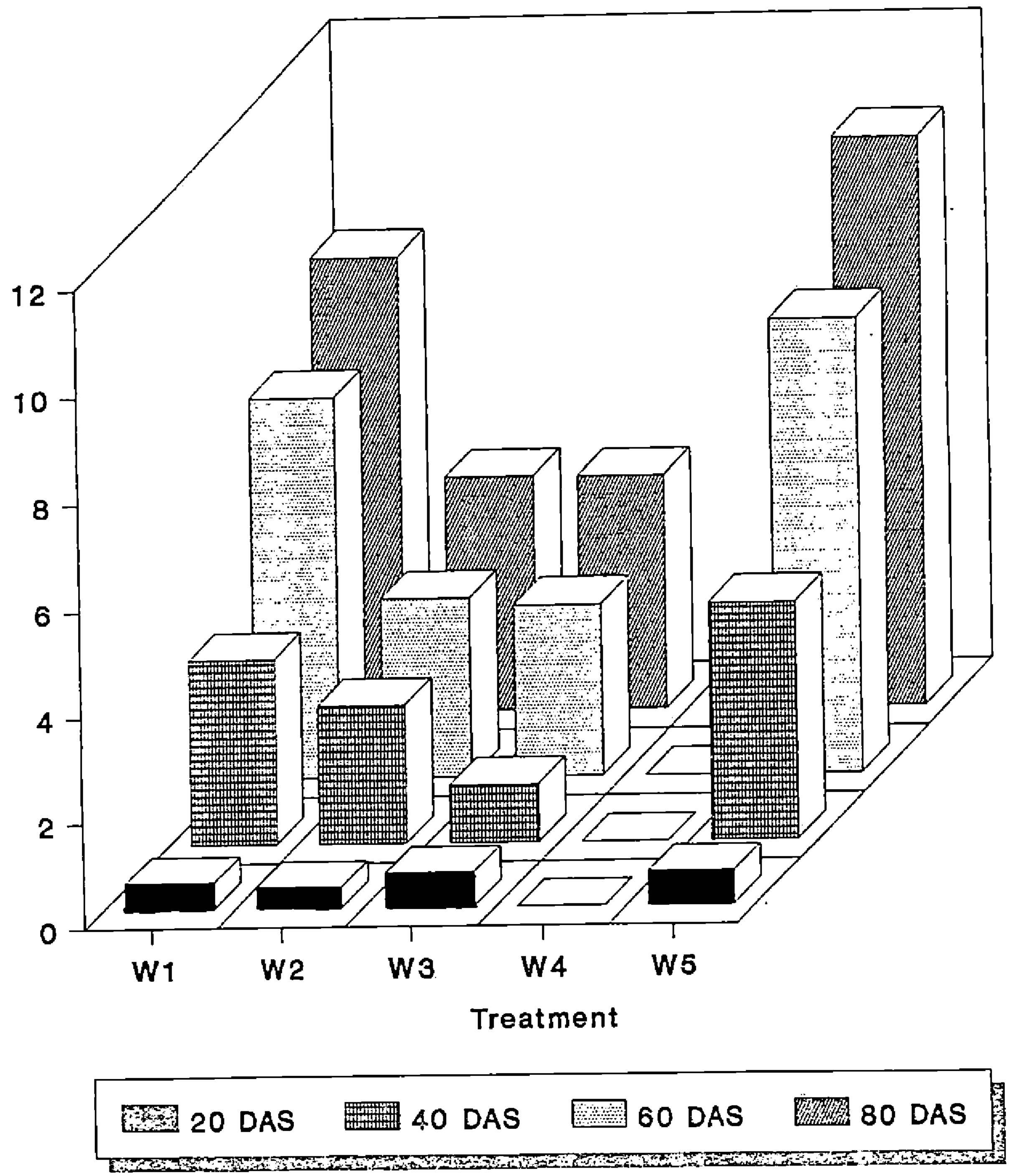
The interaction of sowing time and weed management was not significant.

5.3.3.2. Phosphorus

Phosphorus uptake by weeds in first and second sowing dates was significantly less than that of the third at 40 DAS. This may be due to the better growth and uptake of P by rice under the first and second sowing when compared to the third.

Among the weed control treatments, lowest P uptake by weeds was recorded by handweeding. This is in agreement with the findings of Kaushik and Mani (1980). Butachlor + handweeding was also equally effective in reducing P uptake by weeds. Similar results were reported by Bhagwan Singh (1988). The combined application of butachlor and 2,4-D was on a par with unweeded control. This was due to the

Fig. 5.3.3.2. Effect of weed management on Phosphorus uptake by weeds



ineffective control of weeds in the early stages of the crop.

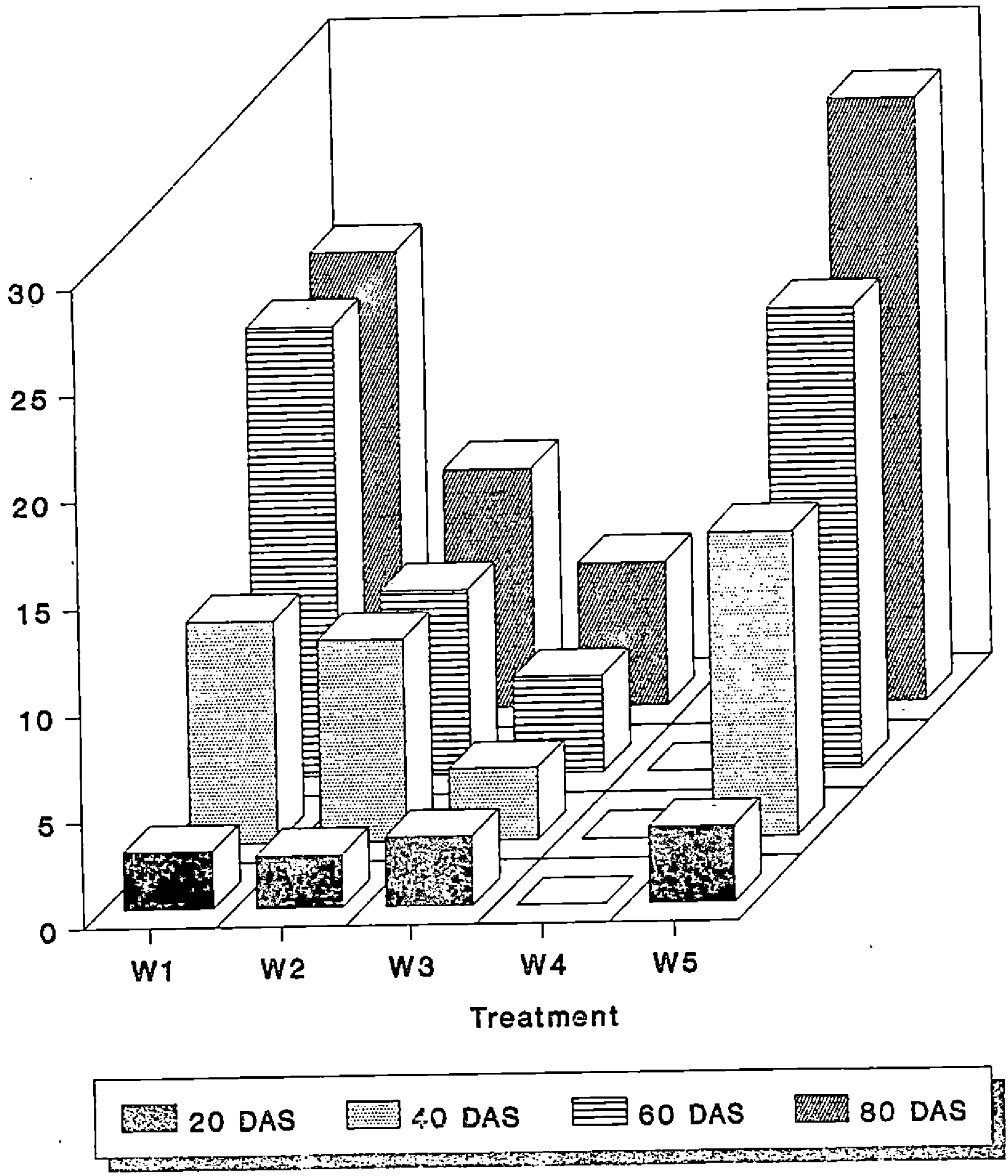
Significant interaction between sowing time and weed control treatments was observed only at 40 DAS. The treated and control plots were at par in the first and second sowing dates. However, with the third sowing date P uptake by weeds in Butachlor + handweeding and handweeding alone was lesser than control.

5.3.3.3. Potassium

Potassium uptake by weeds was least in the second sown crop and highest in third. This was due to the better growth and uptake of K by rice crop sown on second date when compared to the third. This was also due to the optimum soil moisture conditions favouring crop growth and K uptake by crop sown on second date.

Among the weed treatments, handweeded plots recorded lowest K uptake by weeds due to better weed control at 40, 60 and 80 DAS. Similar results were reported by Kaushik and Mani (1980). Butachlor + handweeding treatment was also effective at 60 and 80 DAS. This was because of the reduction in weed population from 40 DAS. This is in accordance with the results of Bhagwan Singh (1988) who found that butachlor + handweeding reduced the nutrient depletion by weeds.

Fig. 5.3.3.3. Effect of weed management on Potassium uptake by weeds



The interaction of sowing time and weed control was not significant.

5.3.4. Available nutrient status in soil after the experiment

Difference in time of sowing did not influence the available N and K but was found to affect available P. Maximum available P was found in plots of crop sown on the second date. This may be because of the optimum soil moisture conditions that prevailed at the time of P application which enabled better retention in the soil. However, at the first and third sowing dates, high rainfall at the time of P application might have led to greater leaching losses and lesser retention. Similar findings were reported by Brady (1984).

With respect to weed management only the available N status was influenced. Lowest available N was recorded from handweeded and weed free plot. This was because of the higher crop uptake from these plots. Reduced crop uptake from butachlor + 2,4-D combination and unweeded control plots might be the reason for higher N status in these plots.

5.3.5. Herbicide residue in grain

The rice grains did not contain any residue of butachlor and 2,4-D.

5.4. Economic evaluation

The highest net returns was obtained with handweeding twice. Butachlor + handweeding, butachlor + 2, 4-D and complete weed free treatments were at par but gave better returns than unweeded control. Similar results were reported by Padhi et al. (1991) who found butachlor + handweeding and handweeding alone to be economic and complete weed free to be most uneconomic. Also Pathak and Hazarika (1985) and Heinrich et al. (1985) found herbicide application to be economic. With respect to benefit-cost ratio the combined application of butachlor and 2,4-D, butachlor + handweeding and handweeding alone were at par and superior to complete weed free and unweeded control. Though complete weed free plots recorded the highest yields, the cost incurred was very high resulting in lesser returns.

SUMMARY

SUMMARY

A field experiment was laid out to study the effect of time of sowing and weed management on the performance of dry sown rainfed rice using Onam variety at the College of Agriculture, Vellayani during the Virippu season of 1992.

Observations on the vegetative and productive aspects of rice and weed population and weed control efficiency were recorded and statistically analysed. The results are summarised below.

1. Optimum soil moisture condition prevailed during the week following second date of sowing (May 23), whereas, in the case of first (May 16) and third (May 30) the soil moisture content exceeded field capacity.

2. The crop sown on May 23 produced the tallest plants at all stages and the least was recorded in the case of third sowing date. All weed control treatments resulted in plants of greater height than unweeded control.

3. Sowing time did not influence tiller number. Among weeding, handweeding alone produced maximum tiller number at all stages. However, combination of butachlor with handweeding and butachlor with 2,4-D were ineffective.

4. Productive tiller number also was not influenced by sowing time. In this case, handweeding and combination of butachlor with handweeding influenced favourably. At harvest alone, combined application of butachlor and 2,4-D was superior to unweeded control.

5. Maximum panicle weight was recorded in the crop sown on the second date and in weed management for handweeding. The combination of butachlor with handweeding and butachlor with 2,4-D were also effective.

6. Sowing dates did not influence the thousand grain weight. Among weed treatments, handweeding gave the best result. The combination of butachlor with 2,4-D and butachlor with handweeding were also effective.

7. Grain yield from the second sowing (1933 $kg.ha^{-1}$) was the the highest and third sowing (1105 $kg.ha^{-1}$) the least. All weed control treatments were effective in increasing grain yield with handweeding being the best (1797 $kg\ ha^{-1}$).

8. The highest straw yield was obtained from second sowing (2143 $kg.ha^{-1}$) and the lowest from the third (1318 $kg.ha^{-1}$). With respect to weed management, handweeding was the best. The combination of butachlor with 2,4-D and butachlor with handweeding were also effective.

9. Harvest index was not influenced by time of sowing and weed control treatments.

10. The lowest weed index was for handweeding. The next better treatment was combination of butachlor and handweeding. Butachlor and 2,4-D together was also effective.

11. In general, complete weed free control recorded the highest values of all growth and yield components and yield while unweeded control the least.

12. The weed flora was dominated by grasses followed by sedges and broad-leaved weeds. *Brachiaria ramosa*, *Echinochloa colona*, *E. crus-galli* and *Panicum repens* dominated among grasses while *Cyperus iria* and *Fimbristylis miliaceae* among sedges. *Ludwigia parviflora*, *Marsilia quadrifoliata* and *Monochoria vaginalis* were prominent among broad-leaved weeds.

13. The monocot weeds outnumbered the dicot weeds throughout the crop period. Among the weed control treatments, handweeding was the best at all stages in controlling monocot weeds. Butachlor application was ineffective at early stages. However, at later stages the combination of butachlor with 2,4-D and butachlor with handweeding were also effective with the latter being superior.

14. Dicot weeds were not effectively controlled by butachlor alone in early stages. However, combination of butachlor with 2,4-D and handweeding alone were effective in reducing dicot weed population at later stages.

15. Weed dry weight was significantly reduced by handweeding alone at all stages. Butachlor with 2,4-D and butachlor with handweeding were effective only in the later stages of crop growth.

16. The highest weed control efficiency was obtained by handweeding which was at par with combination of butachlor and handweeding. The combined application of butachlor and 2,4-D was also effective in comparison with unweeded control.

17. Maximum nutrient uptake by crop was observed in second sowing and the least in the third. Among the weed control treatments, handweeding resulted in the highest nutrient uptake by crop. Butachlor with handweeding was also effective. The combination of butachlor with 2,4-D and butachlor with handweeding were also effective in increasing uptake of N and K but failed to increase P uptake by the crop.

18. Grain protein was maximum for crop sown on May 23 and the least in third sown crop. Handweeding, butachlor

with 2,4-D and butachlor with handweeding were also effective in increasing grain protein, among which handweeding was the best.

19. Nitrogen uptake by weeds was minimum in handweeded plots. Butachlor with 2,4-D and butachlor with handweeding were also found to reduce N uptake by weeds.

20. Phosphorus uptake by weeds in first and second sowing dates was significantly less than the third. Handweeding and butachlor with handweeding were equally effective in reducing P uptake by weeds, However, combined application of butachlor and 2,4-D was ineffective.

21. Potassium uptake by weeds was the least in second sown crop and the highest in third. Handweeding resulted in the lowest K uptake by weeds. The combination of butachlor with handweeding was effective at 60 and 80 DAS.

22. Different dates of sowing influenced available P status of soil after the experiment with the highest values being obtained from second sown area. Weed control treatments influenced available N status only. The lowest values were obtained for handweeding and complete weed free zones.

23. The rice grains contained no applied weedicide residues.

24. The highest net profit was obtained with handweeding. Butachlor with handweeding and butachlor with 2,4-D were also superior to no weeding.

25. Handweeding, butachlor with 2,4-D and butachlor with handweeding gave similar values of benefit-cost ratio and was superior to complete weed free and unweeded control.

Future line of work

As this trial is time and location specific, the same has to be repeated to arrive at viable conclusions for the same location and as a whole for different locations.

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* Originals not seen

APPENDICES

Appendix I

Weather Data During the Cropping Period

Standard Week	Period From	To	Rainfall (mm)	Average Maximum temperature (^oc)	Average Minimum temperature (^oc)	Average Relative Humidity (%)
19	May 7	May 13	21.6	32.37	25.0	76.14
20	May 14	May 20	43.0	29.19	23.92	89.71
21	May 21	May 27	0	31.85	24.45	80.35
22	May 28	Jun 3	64	32.02	24.77	75.14
23	Jun 4	Jun 10	434	29.15	22.96	87.33
24	Jun 11	Jun 17	67.8	29.56	23.98	85.85
25	Jun 18	Jun 24	43.9	29.98	25.25	82.28
26	Jun 15	Jul 1	14.0	29.92	24.53	81.78
27	Jul 2	Jul 8	113.7	29.18	23.74	84.92
28	Jul 9	Jul 15	22.0	28.93	22.92	80.64
29	Jul 16	Jul 22	68.8	29.02	22.74	83.28
30	Jul 23	Jul 29	48.2	28.60	22.84	86.64
31	Jul 30	Aug 5	5.8	28.22	22.45	87.50
32	Aug 6	Aug 12	19.4	28.70	23.40	85.40
33	Aug 13	Aug 19	5.2	29.19	23.88	85.28
34	Aug 20	Aug 26	1.0	29.65	23.80	80.14
35	Aug 27	Sep 2	68.8	28.29	22.84	88.50
36	Sep 3	Sep 9	24.5	28.77	22.95	81.71
37	Sep 10	Sep 16	14.6	28.48	23.27	80.92

Appendix II

Soil moisture estimations

Date	Soil moisture content (%)
May 9	10.6
May 16	Above field capacity
May 23	11.7
May 30 and remaining period	Above field capacity

EFFECT OF TIME OF SOWING AND WEED MANAGEMENT ON THE PERFORMANCE OF DRY SOWN RAINFED RICE

By

JACOB JOHN

ABSTRACT OF THESIS

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ABSTRACT

An experiment was conducted at the College of Agriculture, Vellayani, Kerala Agricultural University, during the first crop season of 1992 to study the effect of time of sowing and weed management on the performance of dry sown rainfed rice using Onam variety.

Split plot experiment in randomised block design with time of sowing as major treatments and weed management as minor treatments was adopted and the treatments replicated thrice. May 16, May 23 and May 30 were the first, second and third dates of sowing respectively. The weed management treatments included combination of butachlor with 2, 4-D, butachlor with handweeding, handweeding twice 20 and 40 DAS, complete weed free and unweeded control.

Sowing on May 23 resulted in greater plant height, panicle weight, grain and straw yield, nutrient uptake, grain protein and lesser uptake of phosphorus and potash by weeds when compared to May 16 and May 30. The second best sowing date was May 16.

When compared to unweeded control, handweeding twice, combination of butachlor with handweeding and butachlor with 2, 4-D gave higher plant height, tiller number, productive tiller number, panicle weight, thousand

grain weight, grain yield, straw yield, nutrient uptake and grain protein out of which handweeding was the best. Handweeding also resulted in the lowest weed population, weed dry weight, nutrient uptake by weeds, weed index and the highest weed control efficiency.

Initially, butachlor alone was ineffective in reducing weed population and its dry weight. However, the combination of butachlor with 2,4-D and butachlor with handweeding was effective in later stages.

The combination of butachlor with handweeding resulted in higher weed control efficiency than butachlor with 2,4-D.

The rice grains contained no applied weedicide residues.

Handweeding, combination of butachlor with handweeding and butachlor with 2,4-D resulted in greater profit and benefit-cost ratio than unweeded control. However, the highest profit was obtained with handweeding twice.