INTEGRATED WEED MANAGEMENT IN UPLAND RICE

By

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2001

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I hereby declare that this thesis entitled "**Integrated weed management in upland 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 of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

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LIST OF ABBREVIATIONS

@	At the rate of
^0C	Degree Celsius
2,4-D	2,4 dichloro phenoxy acetic acid
ai	Active ingredient
cm	Centimeter
DAS	Days after sowing
EC	Emulsifiable concentrate
Fig.	Figure
ha	Hectare
K	Potassium
kg	Kilogram
m	Meter
N	Nitrogen
NS	Not significant
P	Phosphorus
SL	Soluble liquid

Introduction

1. INTRODUCTION

Rice, one of the leading food crops of the world, has been so intensively exposed to adaptive and selection pressures by man to expand it's range, that it now occupies an ecological continuum consisting of upland, low land and deep water rice. Among these various rice growing systems upland rice assumes considerable importance in India as it occupies about one third of the rice growing area of India (Singh and Singh, 1998).

Upland rice culture is the rice cultivation in aerobic soils, whether bunded or not, rainfed or irrigated, which may have no standing water on the soil surface 48 hours after cessation of rain or irrigation. Weed competition is an important constraint in upland rice production and it poses serious threats for the efforts to increase productivity of upland rice by using high yielding, short statured and fertilizer responsive varieties and good irrigation systems.

Weed competition and corresponding yield loss are greater in upland rice compared to other rice growing systems. This is because of the fact that the optimum temperature, aeration and moisture content present at the time of sowing enables weed seeds to germinate earlier than the rice crop. The failure of crop seeds to germinate and poor crop stand, which may arise due to moisture stress, invariably provides better conditions for profuse weed growth. As there is no standing water to suppress weed growth, weeds often smother the rice crop and may even lead to total crop loss if not controlled properly. So weed management assumes considerable importance in upland rice.

Weeds compete with upland rice for nutrients, moisture, light and space. Further, weed infestation deteriorates the quality of rice and increases the cost of operations such as harvesting and cleaning. They may also lead to pest and disease out breaks by altering the micro-climate and acting as alternate hosts. Weed competition in upland rice is reported to cause 50 per cent yield reduction to complete crop loss (Ali and Sankaran, 1984; Singh, 1988). The extent of damage depends on the interaction of factors such as cultivars, row spacing, vigour of crop, weed species, weed population, weed density, time of emergence of weeds, soil fertility and duration of competition (Chisaka, 1977).

Several weed management strategies are adopted for effective weed control in upland rice. Among them, hand weeding is the most common weed control method, but it is a very laborious process demanding 300-800 labour hours per ha for a single hand weeding. In most cases several such hand weedings are necessary to keep the field reasonably free of weeds (Ray, 1973). More over the escalating wage rates combined with low labour efficiency, non availability of labours during peak period of weeding and unworkable soil conditions necessitate the use of improved management strategies to increase upland rice production.

Chemical weed control can be considered as a better alternative to hand weeding because larger area can be effectively covered in a short time with limited labour. Experimental evidences show that the use of herbicides singly does not give satisfactory weed control in direct seeded upland rice unless supplemented with manual weeding or sequential use of herbicides (IRRI, 1980).

If sequential use of herbicide is done in high rainfall areas like Kerala, the intermittent and heavy rainfall may result in leaching and run off of chemicals to the water bodies and other fields causing environmental pollution. So there is a need for an integrated weed management strategy that makes use of herbicides and hand weeding in combination with agronomic strategies like increasing crop competition, which is one of the cheapest but useful weed control method available for the farmer.

In this background the present investigation was undertaken with the following objectives.

1. To evolve a suitable integrated weed management strategy for upland rice.
2. To study the effect of weed management practices on the dominance and persistence of weed flora.
3. To assess the extent of yield loss to weeds in upland rice.
4. To study the effect of spacing on weed population and crop yield.
5. To assess the efficiency and economic feasibility of different weed management strategies in upland rice.

Review of Literature

2. REVIEW OF LITERATURE

Weed competition is a very serious problem in upland rice cultivation compared to other systems of rice culture. The failure of crop seeds to germinate, uneven crop stand and poor growth of rice, which may arise due to moisture stress, often provides better opportunities for the weeds to grow profusely and more vigorously than the crop. Weed growth is more intense in upland rice fields as it does not have standing water to suppress weed growth. Moreover some weeds withstand drought better than rice. Weeds germinate throughout the crop season in upland rice fields and dense weed growth can reoccur even after hand weeding or herbicide application (Thomas and Abraham, 1998). Thus the weed problem and its management are unique in upland rice culture. Earlier investigations on weeds and their management in upland rice are reviewed in this chapter.

2.1 Weed flora in upland rice

The prominent weed species in upland rice fields are much different from those seen in low land rice fields. The weeds, which can grow in comparatively low moisture condition, are problematic weeds of upland rice irrespective of edaphic differences. Chakravarty (1957) observed that 87 species belonging to 28 families were present in rice fields of West Bengal, whereas Sahu and Bhattacharya (1964) reported that 19 annual and 3 perennial weeds were present in paddy fields of Bhubaneshwar.

Several researchers have pointed out that some weeds like *Echinochloa colona* (L.) Link., *Echinochloa crus-galli* (L) P. Beauv., *Cynodon dactylon* (L) Pers., *Ipomoea triloba* L., *Fimbristylis* sp., *Commelina benghalensis* L., *Phyllanthus niruri* L. and *Amaranthus* sp. are most common weeds in upland rice irrespective of edaphic differences (Misra and Roy, 1971; Mukhopadhyay *et al.*, 1972 and Rathi and Tiwari, 1979).

Holm and Herberger (1969) and Okafor (1978) opined that *Cyperus rotundus* L. was a problematic weed wherever rice is grown.

Annual grasses and sedges form 80-90 per cent of the total weed flora in upland rice while broadleaved weeds represent only 10-12 per cent (Misra and Roy, 1971). The greater relative importance of grasses in terms of population and biomass accumulation in direct sown upland rice was recognized by Mukhopadhyay *et al.* (1971) and Zaheruddeen and Rao (1983). Sahai *et al.* (1983) and Singh *et al.* (1986) pointed out that *Echinochloa colona* (L.) Link. Contributed more than 80 per cent of the total weed population in upland rice. Various weed surveys carried out in upland rice (Bhole and Singh, 1987 and Pande and Tiwari, 1996) showed that *Echinochloa colona* (L) Link. is the most common and widely distributed weed in upland rice.

Sugha and Shukla (1977) observed that the weed flora of rice fields in Kangra district of Himachal Pradesh have a total of 56 weed species belonging to 39 genera. The survey showed that 3 families viz. Cyperaceae, Poaceae and Scrophulariaceae together represent 55.3 per cent of the total weed population. Moody and Mian (1979) indicated that a shift in weed flora occurred in upland rice fields due to tillage practices adopted. He reported that less number of perennial weeds such as *Cyperus rotundus* L. and *Cynodon dactylon* (L) Pers. and significantly more number of annual weeds like *Echinochloa colona* (L) Link. were observed in plots which were maintained weed free by off season tillage than in plots which were kept as weedy fallow during the dry season.

Echinochloa colona (L) Link., *Rottboellia exaltata* L.f., *Eleusine indica* (L) Gaertn., *Cleome rutidosperma* D.C. and *Cyperus rotundus* L. were identified as the major weeds of upland rice in the Philippines (IRRI, 1980). Ahmed and Hoque (1981) opined that *Echinochloa colona* (L) Link., *Eleusine indica* (L) Gaertn., *Cyperus iria* L. and *Fimbristylis littoralis* Gaudich. were the prominent weeds of upland rice in Bangladesh. Manipon *et al.* (1981) observed *Echinochloa colona* (L) Link. and *Cynodon dactylon* (L) Pers. as the most dominant weeds of upland rice in the Philippines, whereas Singh *et al.* (1982) reported that *Echinochloa colona* (L.) Link, *Cyperus rotundus* L., *Phyllanthus niruri* L., *Eclipta erecta* (L.) Harsk and *Ammania baccifera* L. were the major weeds of upland rice in Uttar Pradesh.

Mabbayad *et al.* (1983) observed a change in dominance of weed species with respect to planting time. They found out that *Digitaria* sp. and *Echinochloa colona* (L.) Link were dominant under early planting and *Paspalum distichum* L. was dominant under late planting. Moody (1983) reviewed 23 papers dealing with weed control in upland rice to identify major upland rice weed species in the Philippines and reported 50 weed species representing 21 families as upland rice weeds. The most important weeds mentioned by him were *Celosia argentea* L. *Commelina benghalensis* L., *Cyperus rotundus* L., *Dactyloctenium aegyptium* (L) Willd., *Digitaria ciliaris* (Retz.) Koel., *Digitaria sanguinealis* (L.) Scop., *Digitaria setigera.* Roth.ex Roem. Schult., *Echinochloa colona* (L.) Link., *Eleusine indica* (L.) Gaertn., *Ipomoea triloba* L., *Portulaca oleracea* L. and *Rottboellia exaltata* L.F.

Zaheruddeen and Rao (1983) revealed the presence of 52 weed species belonging to 15 families in different Agro-ecosystems of Orissa. De Datta and Llagas (1984) indicated that *Echinochloa crus-galli* (L.) P. Beauv., *Brachiaria ramosa* L., *Cynodon dactylon* (L) Pers., *Fimbristylis littoralis* Gaudich. and *Melochia corchorifolia* L. were the important weeds of upland rice. Moody (1984) conducted a review of rice weeds in the Philippines and recorded 454 weed species belonging to 223 genera and 65 families. He reported that four families viz., Poaceae, Cyperaceae, Papilionaceae and Asteraceae accounted for 54 per cent of the weed species and the most commonly occurring weed species was *Monochoria vaginalis* (Burm. f.) Presl. According to Timsina *et al.* (1984) *Ipomoea triloba* L., *Portulaca oleracea* L., *Amaranthus viridis* L., *Echinochloa colona* (L) Link. and *Cyperus rotundus* L. were prominent weed species in upland rice.

Babu and Singh (1985) found out that *Cyperus iria* L., *Cyperus rotundus* L. and *Echinochloa colona* (L.) Link. were the most dominant rice weed species in Pant Nagar. Bisen and Tiwari (1985) stated that *Cyperus iria* L., *Cyperus rotundus* L., *Echinochloa crus-galli* (L.) P. Beauv and *Erograstis* sp. were the major weeds of upland rice weeds in Jabalpur. Sankaran and De Datta (1985) listed out 25 most commonly mentioned weeds in the upland areas of different continents, wherein *Cyperus rotundus* L. was found to be the most noxious one. Trivedi *et al.* (1986) pointed out that *Cyperus iria* L. *Cyperus rotundus* L., *Digitaria* sp., *Echinochloa crus-galli* (L) P. Beauv., *Cynodon dactylon* (L.) Pers., *Phyllanthus niruri* L. and *Physalis minima* L. were the major weeds of upland rice.

According to Jania and Moody (1988) *Echinochloa colona* (L) Link and *Melochia concantinata* L. were the dominant weeds in dry land rice. Bhanumurthy and Subramanian (1990) also stated that *Echinochloa colona* (L.) Link. was the predominant weed in upland rice. Dutta and Gogoi (1994b) were of the opinion that *Ageratum conyzoides*, L., *Borreria articularis* (L.F) Will., *Cynodon dactylon* (L) Pers. and *Digitaria ciliaris* (Retz) Koel. were the dominant weeds in upland rice. Pande and Pande (1994) stated that *Cyperus rotundus* L. *Cynodon dactylon* (L) Pers., *Echinochloa colona* (L) Link., *Echinochloa crus-galli* (L) P. Beauv and *Eclipta alba* (L) Hassk. were dominant upland rice weeds in Rewa District of Madhya Pradesh. Pande and Tiwari (1994) reported that *Echinochloa colona* (L) Link was the most dominant weed in upland rice followed by *Cynodon dactylon* (L) Pers. *Echinochloa crus-galli* (L.) P. Beauv. and *Setaria glauca* .(L.) Beauv. *Echinochloa colona* (L) Link. and *Cyperus iria* L. were reported to be the major weeds in direct seeded puddled rice (Nandal and Singh 1994, 1995).

Paradkar (1994) conducted a survey on weed flora of upland rice in Damoh district of Madhya Pradesh and identified 57 weed species. Among them monocot weeds accounted for 79 per cent of the population and *Echinochloa crus-galli* (L) P. Beauv. was the most dominant weed species. According to Singh and Sharma (1994) *Cynodon dactylon* (L.) Pers., *Echinochloa colona* (L) Link., *Echinochloa crus-galli* (L) P. Beauv., *Cyperus rotundus* L., *Cyperus iria* L. *Fimbristylis miliacea* Gaudich., *Commelina benghalensis* L. and *Euphorbia hirta* L. were the dominant weeds of upland rice in Varanashi, Uttar Pradesh. Thakur and Bassi (1994) revealed that *Echinochloa colona* (L) Link., *Cyperus iria* L., *Panicum* spp, *Phyllanthus niruri* L., *Cynodon dactylon* (L) Pers. and *Setaria glauca* (L) Beauv. were the dominant weed species in upland rice.

Ramamoorthy and Balasubramanian (1995) opined that *Echinochloa colona* (L) Link, *Eclipta prostrata* (L.) L. and *Cyperus rotundus* L. were the major weeds in upland direct seeded rice. They reported that 80 per cent of the weed population was contributed by grasses, 13 per cent by broadleaved weeds and 7 per cent by sedges. Sharma and Gogoi (1995) identified *Borreria articularis* (L.F.) Will. and *Digitaria ciliaris* (Retz.) Koel. as the major weeds of upland rice. Bisht *et al.* (1996) pointed out that *Echinochloa colona* (L) Link., *Panicum* sp., *Digitaria* sp. *Cyperus iria* L., *Cyperus defformis* L., *Ischaemum rugosum* Salisb., *Commelina benghalensis* L. and *Eclipta Prostrata* (L.) L. were the common weeds found is upland rice fields. According to Mutanal *et al.* (1997), *Echinochloa crus-galli* (L) P. Beauv., *Echinochloa colona* (L) Link, *Cyperus iria* L., *Fimbristylis* sp., *Monochoria vaginalis* (Burm. F.) Prest., *Eclipta alba* (L) Hassk., *Paspalum distichum* L. *Panicum* sp, and *Commelina benghalensis* L. were the important weeds of upland rice. Pande *et al.* (1997) indicated that majority of weed flora in drilled upland rice is contributed by *Echinochloa crus-galli* (L) P. Beauv., *Cynodon dactylon* (L) Pers., *Commelina communis* L., *Eclipta alba* (L) Hassk., *Ageratum conyzoides* L., *Alternanthra sessilis* L., *Cyperus rotundus* L. and *Cyperus iria* L.

2.2 Crop - Weed Competition

Crop plants vary greatly in their ability to compete with associated weeds. Crop weed competition in the field depends mainly on the relative merits of weed species and crop varieties in relation to seasonal and annual cycles, tillage practices and rotational practices adopted. Weeds compete with crop plants for nutrients, light, moisture, space, oxygen and carbon dioxide and thus seriously affect yield and quality of rice plants (Moolani and Sachhan, 1966).

Weed competition largely governs the development of upland rice. Among the various limiting factors in upland rice production, inadequate weed control is next only to poor water supply and is the most difficult constraint in increasing upland rice production (De Datta, 1972). Sweet *et al.* (1974) concluded that those plants, which got off to a quick start and established a good canopy early, effectively suppresses the weed growth. On the other hand, slower growing plants tended to become infested with weeds. Initial plant growth is slow in upland rice due to the possible moisture stress. This leads to greater weed competition and corresponding yield loss in upland rice than any other rice production system (Moody, 1983). Sankaran and De Datta (1985) indicated that most of the weed species in upland rice could withstand drought better than the crop as they have deeper root system and higher root density to tap moisture from the deeper layers. So weed problem occurs to a much greater intensity in upland rice. Jania and Moody (1988) also reported that weed competition was greater in dry seeded rice than in low land submerged rice fields.

2.2.1 Nature of Competition

Nutrients, light and moisture are the three most important resources for which weeds compete with crop plants and ultimately reduces the yield (Moolani and Sachhan, 1966).

2.2.1.1 Competition for Nutrients

Severe weed competition depletes 30.4 to 37.0 kg N ha^{-1} in upland rice (Mukhopadhyay *et al.*, 1971). According to Mukhopadhyay *et al.* (1972) amount of nitrogen taken up by rice in the weeded plot was on an average 1.9 times higher than that in the unweeded plots. Nitrogen content of the weed species at vegetative, flowering and post flowering stage was higher (Chakraborty, 1973) indicating severe competition for nitrogen throughout the upland rice-growing season. Mallappa (1973) reported that nitrogen removal by weeds in unweeded control was 28 kg ha^{-1} in drilled rice. Shetty (1973), opined that weeds removed 65 per cent of total nitrogen, 62 per cent of total phosphorus and 65 per cent of total potassium in direct sown rice.

A significant negative correlation between *Cyperus rotundus* L. dry weight and rice grain yield was established by De Datta (1974). Sankaran *et al.* (1974) showed that the uptake of nutrients by weeds in unweeded plot were nearly nine times higher than that from plots weeded manually or using herbicides. Makhopadhyay (1974) also reported that weeds in upland rice depletes considerable amount of nutrients affecting growth and yield. Okafor and De Datta (1976) observed that the total nitrogen uptake of both purple nutsedge and rice increased significantly with added nitrogen. With increase in purple nutsedge population, total nitrogen uptake of purple nutsedge increased and that of rice decreased.

Pillai *et al.* (1976) from their investigations found out that the major loss due to weed competition was that of nitrogen, which is the most essential nutrient element in rice production. The extent of nitrogen loss from unweeded plots ranged from 11 kg ha^{-1} in transplanted crop to 92 kg ha^{-1} in direct sown upland rice. Kakati and Mani (1977) also indicated that rice crop could remove only 24 kg nitrogen ha^{-1} under unweeded conditions. Chakraborty (1981) pointed out that competition for nutrients, especially nitrogen is the major factor responsible for yield reduction in rice. Among the various weed species present in drilled rice, *Echinochloa* spp. were the most competent weed species for nutrients (Sahai and Bhan, 1982).

Weeds are the major competitors for nitrogen in upland rice (Rao and Agrawal, 1984; Chandrakar and Chandrakar, 1992). Ali and Sankaran (1984) reported that NPK removal was 2.4, 0.22 and 2.1 kg ha^{-1} by weeds and 10.0, 1.0 and 15.1 kg ha^{-1} by rice at 40 days after sowing. A significant negative relationship was observed between nitrogen uptake of upland rice and that of weeds by Singh and Dash (1988). Ramamoorthy (1991) also opined that weeds in unweeded check removed more nutrients from the soil during crop season resulting in lower grain yield of upland rice. Nitrogen uptake of the crop is reported to increase as the weed control efficiency increases in direct seeded upland rice (Gogoi and Kalita, 1990; Ramamoorthy and Balasubramanian, 1995). Nandal and Singh (1995) showed that weed infestation reduced the NPK uptake by upland rice.

2.2.1.2 Competition for Light

Smith (1968) reported that hemp sesbania (*Sesbania exaltala* (Rab.) Cory.) and northern joint vetch (*Aeschynomene virginica* (L) B.S.P.) decreased the yield of paddy in late season by reducing available light and decreasing the number of florets per panicle. According to Okafor and De Datta (1976) increase in dry weight of purple nutsedge population increased competition for light and reduced the light transmission ratio. Utomo (1981) indicated that the top portion of rice plants and weeds competes for light and the root zone competes for nitrogen and moisture.

2.2.1.3 Competition for Moisture

Bodade (1965) calculated that every tonne of weeds removed moisture equivalent to 7.6 cm of rainfall, which is sufficient to starve the crop for want of moisture. Weeds in upland rice compete severely for moisture. The fact that weed competition depletes soil moisture is well established (De Datta and Beachell, 1972; Okafor and De Datta, 1976).

2.2.2 Effect of Competition

Weed competition reduces crop yield by competing for nutrients, light and moisture. Weed infestation has direct effect on different yield attributes, which ultimately leads to yield reduction. According to Okafor (1978) yield loss due to weed competition is a resultant of reduction in plant height, LAI, tillering capacity and number of panicles.

Chang (1973) opined that weed infestation leads to reduction in plant height and hastens maturity.

Okafor and De Datta (1974) reported that weed competition reduces the number of tillers, number of panicles and Leaf Area Index (LAI). According to Ramamoorthy *et al.* (1974) severe weed infestation reduces the number of productive tillers and number of spikelets per panicle. Several other workers also have reported that weed infestation reduced the number of tillers and number of panicles (Sharma *et al.*, 1977; Kohle and Mitra, 1981). Weed competition reduced the number of panicles by 37 per cent, number of filled grains per panicle by 13 per cent and thousand grain weight by 4 per cent (Ghobrial, 1981). Severe weed infestation in upland rice is reported to depress the crop dry matter production considerably (Sahai *et al.*, 1983).

Wells and Cabradilla (1981) reported that severe weed infestation reduced plant height. Sharanappa *et al.* (1994) showed that weed competition reduced number of filled grains per panicle; whereas Pande and Tiwari (1996) reported that weed competition significantly reduced the weight of panicle.

2.2.3 Critical Period of Competition

Critical period of weed competition is the period between early growth during which weeds can grow without affecting crop yield and the point after which weed growth does not affect yield. Weed competition during the critical period of competition drastically reduces the yield (Kalwatai and Koto, 1959). For upland rice the first 15 days after sowing seems to be maximum period during which weeds can be tolerated without substantial reduction in crop yield (Wells and Cabradilla 1981; Sahai *et al.*, 1983). The weed free requirements after this period vary from 30-60 DAS depending on the edaphic and climate conditions and the existing weed flora.

Vega *et al.* (1967a) found out that weed free condition between 20 and 40 DAS was essential for direct sown upland rice of 120 days duration. Mukhopadhyay *et al.* (1971) opined that a weed free period of 55 days resulted in maximum yield. Linear increase in yield was established by Panchal and Sastry (1974) with increase in weed free period from 10-30 DAS. According to Dubey *et al.* (1977) maximum competition occurs during the first 3 weeks after sowing and the loss gradually declines till 9 weeks after sowing.

Bhan *et al.* (1980) observed that weed free condition upto 30 days after sowing resulted in highest grain yield in direct seeded rice. Kohle and Mitra (1981) stated that weed free period for 30-40 DAS gave the highest grain yield in direct seeded upland rice. Wells and Cabradilla (1981) were of the opinion that critical period of weed competition was from 2-9 weeks after sowing in upland rice. Alkantara *et al.* (1982) revealed that 30-40 days after emergence is most critical for weed competition in upland rice in Brazil, but Olivera and Almeida (1982) opined that the critical period of weed competition was between 45-60 DAS. Sahai *et al.* (1983) reported that upland rice required weed free maintenance during the first 45 days after sowing. Ali and Sankaran (1984) reported that 60 weed free days were essential for maximum yield in upland rice. Shelke *et al.* (1985) indicated that the first 30-45 days after sowing upland rice is critical for weed competition; whereas Varshney (1985) reported that the period from 20-40 days after sowing is critical.

2.2.4 Yield loss due to weeds

The fact that the grain yield and weed dry weight are negatively correlated is well established (Bhurer *et al.*, 1989).

Different scientists have estimated the yield loss due to weed competition in upland rice. These estimates vary very much because of the differences in weed flora present, climatic conditions, edaphic conditions and competence of the cultivar used. The occurrence of complete crop loss as a result of severe weed infestation in upland rice was reported by several workers (Moody and Mian, 1979; Moody, 1982).

Vega *et al.* (1967 b) pointed out that the yield loss due to weeds in upland rice is as high as 79-83 per cent. The investigations carried out by Mani *et al.* (1968) revealed that weeds causes 9.1 to 51.4 per cent yield loss in rice. Chang (1973) showed that weeds causes 49.1 to 90.2 per cent yield loss. Shetty (1973) stated that weeds causes 10-70 per cent yield reduction in upland rice.

Cyperus rotundus L. alone causes 43 per cent yield reduction is drilled rice (Okafor and De Datta, 1974). Pillai and Rao (1974) indicated that weeds caused more than 50 percent yield reduction in upland rice. Ghosh *et al.* (1977) opined that severe weed competition in upland rice reduced yield to the extent of 50-90 per cent. Pillai (1977) pointed out that weeds caused 71-81 per cent yield reduction to complete crop failure in upland rice. Tosh (1977) indicated that 6.9 per cent yield reduction occurs due to weed competition in upland rice; whereas Schiller and Indhaphun (1980) showed the yield reduction to be 75 per cent. Ghobrial (1981) observed only 50 per cent yield loss due to weeds in irrigated dry seeded rice.

Singh and Mani (1981) reported that weeds caused 50-90 per cent yield reduction, while Poonia (1983) observed 50-60 per cent yield reduction in upland rice. Sahai *et al.* (1983) revealed that season long weed free condition enhances rice grain yield 16 fold by comparison with unweeded control. Ali and Sankaran (1984) opined that weeds are quiet troublesome in upland direct seeded rice and they may cause up to 91 per cent yield reduction.

De Datta and Llagas (1984) estimated that annual weeds reduce the yield by 67 per cent and *Cyperus rotundus* alone by 51 per cent in upland rice. Shelke *et al.* (1985) indicated 48-78 per cent yield reduction by weed competition in upland rice while IRRI (1986) showed the yield reduction to be 61-65 per cent. Singh (1988) observed 43-84 per cent yield reduction in rainfed upland rice. *Cyperus rotundus* is a problematic weed of upland rice and it alone can reduce yield by 40.71 per cent (Saha and Srivastava, 1992).

2.3 Methods of Weed Management

Effective weed management in upland rice can be achieved by using different methods of weed control. Cultural methods, physical methods, chemical methods and integrated weed management are the commonly adopted strategies in weed management of upland rice.

2.3.1 Cultural Weed Management

Good cultural practices are effective in managing weeds as it directly induces healthy growth of the crop and indirectly maintains a crop environment as detrimental to the weeds as possible. De Datta (1978) reported that crop weed competition varies with method of planting, cultivar used, and cultural practices adopted. Moody and Mian (1979) indicated that delaying planting time of dry seeded rice resulted in an increase in weed growth as compared to early planting. Lopez *et al.* (1980) revealed that type of cultivar used did not affect weed dry weight. The effect of seed rate and method of seeding on weed growth is evident from the report of Tosh *et al.* (1981). He pointed out that high seed rate of 110 kg ha^{-1} gives significantly higher yield compared to lower seed rates of 50 or 70 kg ha^{-1}. He also showed that row seeding produced higher plant population, low weed dry matter accumulation, low nutrient uptake by weeds and higher yield compared to broadcasting.

Pablico and Moody (1983) opined that the use of stale seed bed technique does not significantly reduce total weed weight compared to conventional tillage practice in upland rice, but Moorthy and Manna (1988) showed that under stale seed bed method the level of weed infestation in unweeded check was reduced by 27.1 per cent compared to that of conventional method.

Mabbayad *et al.* (1983) indicated that earlier planting (May) of dry seeded rice resulted in greater weed growth than late planting (August).

O'Brien and Price (1983) suggested that the amount of nitrogen applied to rice influence competition for nutrients and application of less fertilizers than what is needed to produce maximum yield is better when weed control is inadequate. Kehinde (1985) found out that the sowing rate and crop establishment techniques did not influence weed growth; where as Pande and Pande (1994) reported that Lehi method of sowing (Sowing sprouted seeds in puddled soil) gave maximum weed control compared to broadcasting or dibbling.

Intercrops are also effective in reducing the weed growth in upland rice. According to Dutta and Gogoi (1994 a) cowpea grown as an inter crop reduced weed population and dry matter production of weeds in upland rice. Jayachandran and Veerabadran (1996) advocated *Sesbania rostrata* as intercrop in semidry rice to reduce weed population.

2.3.2 Physical Methods of Weed Management

In this method weeds are removed manually or by mechanical force.

2.3.2.1 Hand Weeding

Several workers have studied the efficiency of hand weeding compared to other weed control methods. Schiller and Indhaphun (1979) reported that 2 hand weedings at 30 and 50 days after sowing is adequate to manage weeds in upland rice. Upadhyaya and Choudhary (1979) found two hand weedings three and six weeks after sowing is ideal for maximum yield. Borghohain and Upadhyaya (1980) and Biswas and Thakur (1983) also recognized that hand weeding was highly effective for weed control in upland rice.

Pablico and Moody (1983) found out that average yield from plots which were hand weeded thrice was comparable to that from weed free check. Sharma *et al.* (1986) and Elliot and Moody (1987) also advocated three hand weedings for effective weed control in upland rice. Estornios and Moody (1988) opined that a single hand weeding forty days after emergence lead to significant yield increase, whereas Dutta and Gogoi (1994a) stated that three hand weedings at 15, 25 and 35 days after sowing provided good weed control and high yield. Singh and Sharma (1994) recommended that hand weedings at three and six weeks after sowing for high yield in upland rice. Many other workers also have reported the effectiveness of two hand weedings to produce high yield in upland rice (Nandal and Singh, 1995; Pande and Tiwari, 1996; Pande *et al.* ,1997; Ramamoorthy *et al.*, 1998).

Eventhough hand weeding is effective, it is time consuming and laborious. A single hand wedding requires 300 to 700 labour hours per hectare (Ray, 1973; De Datta, 1977).

2.3.2.2 Mechanical Weed Management

Mechanical weeding is much faster and less laborious compared to hand weeding. Lopez *et al.* (1980) revealed that two rotavations using rotavators lead to a good seed bed and provided optimum weed control and high yield in upland rice. This also helped to reduce the time required for next hand weeding by 29 per cent. Singh *et al.* (1985) opined that two inter row cultivation with hand hoe or a high wheel cultivator was very effective. Moorthy (1990) observed that mechanical weeding with finger type weeder between the crop rows during early growth period supplemented with hand weeding was the best weed control practice for upland rice. Dutta and Gogoi (1994 b) reported IITWAM-82, a weeder cum herbicide applicator to be effective in weed management of upland rice. Sharma and Gogoi (1995) observed that peg type dry land weeder, thin wheel hoe and IITWAM -82 operated twice at 20 and 35 days after sowing controlled the weeds effectively.

2.3.3 Chemical Management

Chemical weed management is the weed control method using herbicides, which are chemicals capable of killing or suppressing plant growth. Because of high labour requirements for hand weeding, high wages and unfavourable weather conditions during weeding time, herbicides are getting importance for weed control in upland rice (Moody, 1982). Several workers have reported that herbicide based weed management system for upland rice cultivation was very effective in controlling weed flora of upland rice (Ramamoorthy, 1985; Ali and Sankaran, 1986; Moorthy and Manna, 1988).

Among various herbicides used in upland rice butachlor is an extensively tested pre -emergent herbicides. Butachlor is extensively used for controlling upland rice weeds effectively (IRRI, 1976).

Butachlor at the rate of 2.0 kg ha^{-1} was recommended for pre-emergent weed control in upland rice by Pillai (1977), Okafor (1978) and Schiller and Indhaphun (1979). According to Singh and Singh (1986) a higher dose of 3.6 kg ha^{-1} was required for effective weed control. Saha and

Srivastava (1992) revealed that butachlor @ 2 kg ha^{-1} was effective in controlling *Cyperus rotundus*, which is one of the troublesome weeds in upland rice. Mutanal *et al.* (1997) reported that the use of butachlor at the rate of 1.5 kg ha^{-1} was effective for controlling weeds in upland rice.

Sequential application of butachlor and propanil was found to be very effective for weed control in upland rice (Pathak and Hazarika, 1985; Estorninos and Moody, 1988).

Several workers have pointed out that pendimethalin was very effective for weed management in upland rice (Ramamoorthy, 1991; Ramamoorthy *et al.*, 1998). Tosh, (1975) reported that pendimethalin was selective in direct seeded upland rice and @ 1 to 2 kg ha^{-1} controlled most of the annual grasses and several small seeded broadleaved weeds. Singlachar *et al.* (1978) and Pablico *et al.* (1982) recommended pendimethalin @ 2 kg ha^{-1}, but Abud (1982) pointed out that a higher dose of 2.5 to 3.5 kg ha^{-1} was most effective to control *Echinochloa* spp. and *Cyperus* spp. in upland rice. Sharanappa *et al.* (1994) indicated that Pendimethalin @ 1.5-2 kg ha^{-1} is effective in upland rice, while Pande and Tiwari (1994) and Behara and Jena (1998) opined that sequential application of Pendimethalin and 2,4- D was more advantageous.

Fluchloralin is a pre-planting soil incorporated herbicide used commonly in upland crops. Bhan and Singh (1979) reported that fluchloralin is effective in controlling weeds of irrigated rice. Sankaran and Balasubramanian (1981) indicated that fluchloralin @ 0.2 to 1.25 kg ha^{-1} is effective in managing weeds of pulses. Patel *et al.* (1981) advocated the use of fluchloralin @ 1.5 kg ha^{-1} for weed control in green gram. Lal and Singh (1984) and Ali and Sankaran (1984) recommended fluchloralin for weed management in green gram at the rate of 1.0 and 0.5-0.75 kg ha^{-1} respectively. Singh and Singh (1993) observed that fluchloralin at the rate of 1 kg ha^{-1} was effective in upland rice.

Several other herbicides like propanil (Singh and Singh, 1985), Oxyfluorfen (Ghosh and Singh 1985), thiobencarb + propanil (Pathak and Hazarika, 1985), molinate + propanil (Bhanumurthy and Subramanian, 1990), thiobencarb (Dwivedi *et al.*, 1991; Sharanappa *et al.*, 1994) and 2,4-D (Singh and Singh, 1998) were also recommended for weed management in upland rice.

2.3.4 Integrated Weed Management

Integrated weed management is a system approach which uses different methods of weed prevention and control in right proportion and at appropriate time against target weeds without damaging environment. Integrated weed management was found essential not only for satisfactory weed control but also for minimising spread of weeds (Moody, 1982).

The application of butachlor as a pre-emergent spray followed by one hand weeding three weeks after sowing is a recommended practice in upland rice (Munroe *et al.*, 1982; Singh and Sharma, 1994).

Moody and Mukhopadhyay (1982) suggested combination of hand weeding with other weed control methods for effective weed control in upland rice. Pre-emergent application of pendimethalin followed by one hand weeding 30-35 DAS also is an established practice for weed management in upland rice (Ramamoorthy and Balasubramanian, 1995; Ramamoorthy *et al.*, 1997).

Elliot *et al.* (1984) reported that pre-emergent application of butachlor followed by one hand weeding three weeks after sowing effectively controlled weeds in upland rice, when *Echinochloa colona* (L) Link. was the dominant weed, but not when *Cyperus rotundus* L. was the dominant one. Singh and Singh (1985) advocated pre-emergent application of fluchloralin followed by one hand weeding for effective weed management in upland rice. Dwivedi *et al.* (1991) suggested pre-emergent application of thiobenecarb followed by one hand weeding 30 DAS for better weed management in upland rice. Ramamoorthy (1991) showed that pre emergent application of Pendimethalin and hand weeding or hoeing thrice produces yield comparable to that from weed free check. Thakur and Bassi (1994) opined that pre-emergent application of thiobenecarb, butachlor or pendimethalin followed by one hand weeding three weeks after sowing controlled weeds effectively in upland rice. Angiras and Sharma (1998) revealed that high seed rate of 150 kg ha^{-1} and application of 0.2 kg Oxyfluorfen per ha provided good weed control in upland rice. Ramamoorthy *et al.* (1998) observed that pre-emergent application of Pendimethalin or Fluchloralin followed by one hand weeding 35 days after sowing provided good weed control and generated more income.

2.4 Economics of Weed Control

Weed management of upland rice by application of a pre-emergent herbicide followed by hand weeding; mechanical weeding or application of a post emergent herbicide is the economically viable option considering the high cost of labour. Ghosh *et al.* (1977) reported that pre-emergent application of butachlor at 2.5 kg ha^{-1} generated higher net income inspite of it being more expensive than mechanical weeding. Rathi and Tiwari (1979) observed that pre-emergent application of butachlor 2 kg ha^{-1} + one hand weeding 25 DAS reduced labour requirement from 105 to 38 men/ha and total cost from Rs. 577 to Rs. 429 ha^{-1}. Tasic *et al.* (1980) also indicated that plots treated with butachlor 2 kg ha^{-1} as a pre-emergent spray gave higher net returns.

Munroe *et al.* (1982) reported that butachlor 2 kg ha^{-1} followed by one hand weeding produced the highest yield and net return. According to Sing *et al.* (1992) sequential application of butachlor and 2,4-D or pendimethalin and 2,4-D resulted in high net return of Rs. 5169 and Rs. 5162 ha^{-1} respectively. Pande and Tiwari (1994) showed that pendimethalin @ 1.0 kg ha^{-1} followed by 2,4-D 0.6 kg ha^{-1} generated the highest net return of Rs. 3438 ha^{-1} whereas, unweeded control provided only Rs. 915.42 ha^{-1}. Dutta and Gogoi (1994 a) reported that intercropping fodder cowpea in upland rice and harvesting it 45 DAS showed superiority in earning the maximum net return of Rs. 3951 ha^{-1}.

Ramamoorthy and Balasubramaniam (1995) revealed that pendimethalin 1.25 kg ha^{-1} + one hand weeding 30 DAS gave the highest net return of Rs. 3935 ha^{-1} which was higher by Rs. 2505 ha^{1} to conventional hand weeding. Pande *et al.* (1997) obtained a net profit of Rs. 5208 to 6704 ha^{-1} from herbicide treated plot and a net loss of Rs. 877 ha^{-1} under unweeded check. Ramamoorthy *et al.* (1998) reported that pre-emergent application of pendimethalin 1.25 kg ha^{-1} followed by one hand weeding produced a net return of Rs. 12709 and benefit :

cost ratio of 2.94 while unweeded check recorded a net return of Rs. 3443 and benefit : cost ratio of Rs. 0.43.

2.5 Crop toxicity due to herbicides

Some herbicides may produce phytotoxic effect on the crop at varying degrees based on the time and rate of application. Symptoms of injury like stunted growth, shortened internodes and lack of lateral roots were observed in peanut plants at higher concentration of trifluralin (Ketchersid, 1967). Some reports on the effect of butachlor on rice culture showed that phytotoxicity was observed even at rates lower than 2 kg ha^{-1}, the recommended and widely used rate for rice (Manipon *et al.*, 1981 ; Olofintoye and Mabbayad, 1983). Marcado *et al.* (1974) pointed out that pendimethalin did not reduce rice germination. Tosh (1977) observed phytotoxicity on rice with butachlor applied at eight DAS. Lopez *et al.* (1980) found out that there was visible injury and root weight reduction in rice when dinitramine was incorporated before planting.

Manipon *et al.* (1981) opinion that pre-emergent application of butachlor, pendimethalin and thiobenecarb @ 2 kg ha^{-1} caused slight injury to IR-38 rice variety but phytotoxicity was severe @ 4 kg ha^{-1}. Pablico *et al.* (1982) noticed no stand reduction in rice due to butachlor application. Olofintoye *et al.* (1983) reported that butachlor had no pronounced inhibitory effect on rice germination and seedling emergence at normal dose of 2 kg ha^{-1} but seedling establishment was adversely affected by increasing rates of butachlor.

A stand reduction upto 57 per cent occurs in rice depending on the herbicide applied, time and rate of application (Pablico *et al.*, 1982). He also revealed that dinitramine and pendimethalin caused stand reduction when applied immediately after sowing but not when applied four days after emergence. According to Ghosh and Singh (1985) oxyfluorfen 0.2 kg ha^{-1} adversely affects germination of rice resulting in poor crop stand and very low yield. Durgesha and Lekshminarayanam (1989) showed that root and shoot growth and nodulation in groundnut were reduced when treated with high rate of fluchloralin.

2.6 Effect of spacing (plant density) in weed control and yield

Plant density is determined by the number of hills m^{-2} area. Yamada *et al.* (1961) reported that final dry weight of rice per unit area was approximately constant irrespective of different plant densities. Takeda and Hirota (1971) observed that grain yield was nearly constant for plant densities ranging from 10 to 100 hills m^{-2}. Yoshida (1972) opined that variation in spacing resulted in an alteration of leaf area index, which has a direct impact on grain yield.

Plant density also affects weed growth. Various workers (Ghosh and Sarkar, 1975; Manuel *et al.*, 1979; Kim and Moody, 1980) have shown that as the distance between hills of transplanted rice is reduced the crop becomes more competitive and weed population reduces.

Mehrothra *et al.* (1975) indicated that uptake of nitrogen was more at closer spacing because of high total dry matter production. The yield of semi-dwarf cultivars can be increased and weed competing ability can be improved by decreasing the spacing from 25 x 25 cm to 15 x 15 cm (IRRI, 1976).

Yamaguchi *et al.* (1978) reported that the competitiveness of rice against *Echinochloa crus-galli* did not increase as plant density increased. Estorninos and Moody (1983) also showed that weed dry weight was lowest at closer spacing and under identical management practices, closer spacing of 15 x 15 cm gave highest yield.

Pathak and Hazarika (1985) reported that there was no significant difference in yield of upland rice grown in rows 15, 18 and 21 cm apart. Villanueva *et al.* (1988) revealed that plant spacings of 10 x 10 cm, 15 x 15 cm, 20 x 20 cm, 25 x 25 cm and 30 x 30 cm did not had any influence on grain yield of rice. Sharma and Singh (1992) observed that 20 cm uniform row seeding of upland rice produced more dry matter and increased grain and straw yield compared to 25 and 40 cm uniform row and 10/40 cm paired row.

Materials and Methods

3. MATERIALS AND METHODS

A field experiment was carried out at the Instructional Farm, College of Agriculture, Vellayani to evolve a suitable integrated weed management practice for upland rice. Details of the materials used and methods adopted for the study are presented in this chapter.

3.1 Experimental site

The experiment was conducted at the Instructional Farm attached to the College of Agriculture, Vellayani, situated at 8^0 5' N latitude and 76^0 9' E longitude. It lies at an attitude of 29 m above mean sea level.

3.1.1 Climate

A humid tropical climate prevails in the area of the experimental site. The weekly averages of weather parameters viz., temperature, relative humidity and rainfall during the cropping period were collected from the meteorological observatory of the College of Agriculture, Vellayani. Details of these weather parameters are given in Appendix I.

3.1.2 Season

The experiment was conducted during the virippu season of 1999.

3.1.3 Soil

The soil of the experimental site was lateritic red loam belonging to the order oxisols of Vellayani series. The important physico-chemical properties of the soil and the methods adopted for soil analysis are presented in Table 1.

Fig. 1 Data on weather parameters during cropping period (July 4 to October 10)

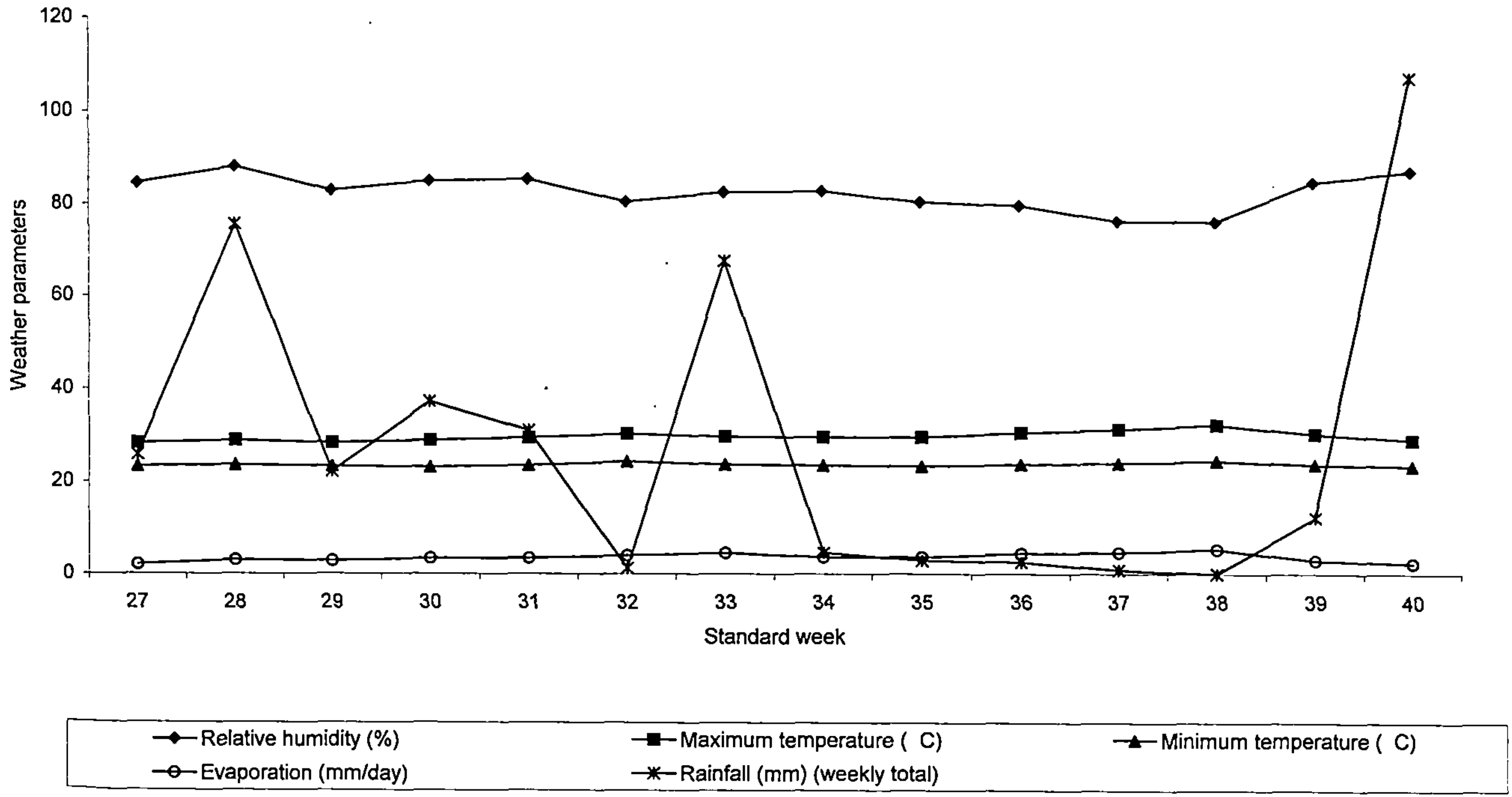


Table 1 Soil characteristics of the experimental site

Sl. No.	Fractions	Content in soil	Methods used
A.	Mechanical composition		
1.	Coarse sand (%)	36.35	International pipette method (Piper, 1966)
2.	Fine sand (%)	15.20	
3.	Silt (%)	17.30	
4.	Clay (%)	30.00	
5.	Textural class : Sandy clay loam		
B.	Chemical properties		
1.	Available Nitrogen (Kg ha^{-1})	294.82	Alkaline Permanganate Method (Subbiah and Asija, 1956)
2.	Available P_2O_5 (Kg ha^{-1})	46.36	Bray colorimetric Method (Jackson, 1967)
3.	Available K_2O (Kg ha^{-1})	124.68	Ammonium acetate Method (Jackson, 1967)
5.	Soil reaction (pH)	4.9	1 : 2 : 5 soil solution ratio using pH meter with glass electrode (Jackson, 1967)

3.2 Materials

3.2.1 Seed material

The rice variety used for the experiment was Matta Triveni. It is a red kernelled variety from Regional Agricultural Research Station, Pattambi, Kerala. This variety has a duration of 100-105 days and has bold grains with medium length. It is a photoinsensitive non lodging variety with medium grain shattering. This variety is susceptible to blast and sheath blight and it is recommended for both upland conditions and dry sowing.

3.2.1.1 Source of seed material

The seed material was collected from Regional Agricultural Research Station, Pattambi, Kerala.

3.2.2 Manures and Fertilizers

Cowdung containing 0.4 per cent Nitrogen, 0.3 per cent P_2O_5 and 0.2 per cent K_2O was used for the experiment. Chemical fertilizers viz., urea analysing to 46 per cent N, Mussuriephose analysing to 20 per cent P_2O_5 and Muriate of potash containing 60 per cent K_2O were used to supply NPK at the rate of 60 : 30 : 30 kg ha^{-1}.

3.2.3 Herbicides

The herbicides Pendimethalin, fluchloralin and butachlor were applied according to the treatments.

1. Pendimethalin : N-(ethylpropyl)-3,4-diemethyl-2,6 dinitrobenzamine

   Formulation : 50 per cent EC

   Trade name : Stomp

   Produced by : Cynamide India Ltd.

   Price : Rs. 540 per litre

2. Fluchloralin : N-(2-chloroethyl)-2,6-dinitro-N-propyl-4 (trifluromethyl) aniline

   Formulation : 45 per cent EC

   Trade name : Basalin

   Produced by : BASF India Ltd

   Price : Rs. 530 per litre

3. Butachlor : N-(butoxymethyl)-2-chloro-2,6-diethyl-acetanilide

Formulation : 50 per cent EC

Trade name : Butachlor

Produced by : Hoechst India Ltd

Price : Rs. 240 per litre

3.2.4 Cucumber seeds

Cucumber seeds used for herbicide residue test was collected from the Instructional Farm, College of Agriculture, Vellayani.

3.3 Methods

3.3.1 *Design and Layout*

The detailed layout plan of the experiment is given in Fig.2.

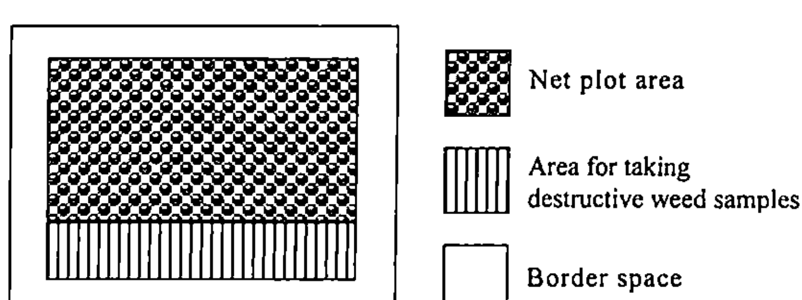
Design	: Split plot design
Number of main plot treatments	: 3
Number of sub plot treatments	: 6
Number of replications	: 3
Gross plot size	: 5 x 4.5 m^2
Net plot size	: 4 x 2.5 m^2
Total number of plots	: 54

A border space of 50 cm was left on all sides of all the plots. An area of 1 x 4.5 m was left for taking destructive weed samples on the same side of all the plots and the observations were taken from the net plot area.

N

Fig. 2 Layout plan of the experiment

	s_1w_6	S_1w_1	s_1w_4	s_1w_2	s_1w_3	s_1w_5
R_1	s_3w_4	S_3w_1	s_3w_2	s_3w_3	s_3w_5	s_3w_6
	s_2w_2	S_2w_1	s_2w_6	s_2w_4	s_2w_3	s_2w_5
	s_1w_2	S_1w_6	s_1w_1	s_1w_4	s_1w_5	s_1w_3
R_2	s_2w_3	S_2w_1	s_2w_2	s_2w_6	s_2w_4	s_2w_5
	s_3w_5	S_3w_6	s_3w_1	s_3w_3	s_3w_2	s_3w_4
	s_2w_6	S_2w_2	s_2w_4	s_2w_3	s_2w_5	s_2w_1
R_3	s_3w_3	S_3w_1	s_3w_2	s_3w_6	s_3w_4	s_3w_5
	s_1w_6	S_1w_5	s_1w_1	s_1w_2	s_1w_3	s_1w_4



3.3.2 Treatments

There were 3 main plot treatments and 6 subplot treatments and so the experiment altogether comprised of 18 treatment combinations replicated 3 times.

3.3.2.1 Main plot treatments

Three different spacings or plant densities were used as main plot treatments (S).

s_1 = Spacing of 15x10 cm (67 hills m^{-2})

s_2 = Spacing of 20x10 cm (50 hills m^{-2})

s_3 = Spacing of 20x15 cm (33 hills m^{-2})

3.3.2.2 Sub plot treatments

Four different weed management practices, an unweeded check and a weed free check were the subplot treatments (W).

w_1 = Pre-emergent application of Pendimethalin @ 1.5 kg a.i. ha^{-1} + One hand weeding three weeks after sowing.

w_2 = Pre-planting incorporation of Fluchloralin @ 1.0 kg a.i. ha^{-1} + One hand weeding three weeks after sowing.

w_3 = Pre-emergent application of Butachlor @ 1.25 kg a.i. ha^{-1}+ One hand weeding three weeks after sowing.

w_4 = Two hand weedings at 20th and 40th days after sowing.

w_5 = Unweeded check.

w_6 = Weed free check.

3.3.4 Cultural practices

3.3.4.1 Field Preparation

The experimental area was dug well, weeds and stubbles removed and clods broken. Plots of size 5 x 4.5m were laid out with 18 plots in each block. The plots were separated with bunds of 30 cm thickness and blocks with bunds of 50 cm thickness. Individual plot were again dug and perfectly levelled.

3.3.4.2 Fertilizer application

Cowdung was applied to all plots @ 5 t ha^{-1} urea, mussusiephose and muriate of potash were applied to supply N, P_2O_5 and K_2O at the rate of 60, 30 and 30 Kg ha^{-1} respectively (KAU, 1996).

3.3.4.3 Seeds and Sowing

Two to three pre-germinated seeds were dibbled at three different spacings according to the treatments. Sowing was done on 6th of July 1999.

3.3.4.4 Weed Management

3.3.4.4.1 Application of herbicides

Herbicidal spray solution was prepared as per the treatment and sprayed uniformly in the respective time of application.

3.3.4.4.2 Hand weeding

First hand weeding was done on 20 days after sowing (DAS) and the second on 40 DAS in the respective plots. Complete weed free condition was maintained by hand weeding, as and when weeds appeared in complete weed free treatment plots. A weedy check was also maintained.

3.3.4.5 Plant protection

One spray of methyl parathion (0.05 per cent) was given against rice bug with a knapsak sprayer at milky stage of the crop.

3.3.4.6 Harvest

The net plot area was harvested separately, threshed, winnowed and weight of grains and straw from individual plots were recorded.

3.4 Observations

3.4.1 Observation on weeds

3.4.1.1 Weed flora

Weeds from the experimental area during the experiment were identified and recorded.

3.4.1.2 Absolute density (Ad)

Absolute weed density was recorded by placing 25 x 25 cm quadrate at random in four sites in each plot and calculating the average. The weeds were categorized into grasses, broadleaved weeds and sedges and the absolute density was recorded at 20, 40, 60th days after sowing (DAS) using the formula suggested by Philips (1959).

Ad = Total number of weeds of a given species m^{-2}.

3.4.1.3 Relative density (Rd)

Relative density (Rd) of grasses, broadleaved weeds and sedges were worked out separately at 20, 40, 60 DAS using the formula put forward by Philips (1959).

$$Rd = \frac{\text{Absolute density of a species}}{\text{Total absolute density of all species}} \times 100$$

3.4.1.4 Absolute frequency (Af)

Absolute frequency was computed 20, 40, 60 DAS according to the equation developed by Philips (1959). Absolute weed frequency of grasses, broadleaved weeds and sedges were recorded separately.

$$Af = \frac{\text{Number of quadrates in which a given species occurred}}{\text{Total Number of quadrates used}} \times 100$$

3.4.1.5 Relative frequency (Rf)

The computation of Relative weed density was done 20, 40 and 60 DAS separately for grasses, broad leaved weeds and sedges using the relationship developed by Philips (1959).

$$Rf = \frac{\text{Absolute frequency of a species}}{\text{Total of absolute frequencies of all species}} \times 100$$

3.4.1.6 Summed Dominance Ratio (SDR)

Summed Dominance Ratio (SDR) was found out at 20, 40 and 60 DAS according to the equation developed by Sen (1981). Summed Dominance Ratio of grasses broad leaved weeds and sedges were worked out separately.

$$SDR = \frac{\text{Relative density} + \text{Relative frequency}}{2}$$

3.4.1.7 Weed dry matter

Weed samples for taking dry weight were collected from the 1 x 4.5 m area left aside for taking destructive weed samples. Weeds coming inside the quadrate were pulled out carefully with roots intact, washed, dried under shade and then oven dried to a constant weight. The dry weight was expressed in g m^{-2}. Weed dry weight was recorded 20, 40 and 60 DAS.

3.4.1.8 Weed Control Efficiency (WCE)

Weed control efficiency was calculated by adopting the formula suggested by Mani *et al.* (1973).

$$WCE = \frac{WDWC - WDWT}{WDWC} \times 100$$ where,

WCE = Weed control efficiency

WDWC = Weed dry weight in unweeded (control) plot

WDWT = Weed dry weight in treated plot

3.4.2 Observation on Crop

3.4.2.1 Crop Growth Characters

3.4.2.1.1 Height of the plant

The height of the plant was recorded on 30 and 60 DAS and at harvest. Height of 5 randomly selected plants from the net plot area was measured from the base of the plant to the tip of the longest leaf or the tip of the longest ear head, whichever was taller and the average was recorded in centimetres.

3.4.2.1.2 Number of tillers hill^{-1}

The number of tillers per hill was worked out from 5 randomly selected hills at 30 and 60 DAS and at harvest.

3.4.2.1.3 Leaf Area Index (LAI)

Leaf area index was determined at harvest. Five sample hills were selected and the maximum width (w) and length (l) of all the leaves of the middle most tiller of each hill was measured and leaf area index was calculated according to the method developed by Gomez (1972). Leaf area of a single leaf was worked out using the relationship : Leaf Area = K x l x w were K is the adjustment factor which is 0.6 at harvest.

Leaf area hill^{-1} = Total leaf area of middle most tiller x Total number of tillers.

$$LAI = \frac{\text{Sum of leaf area/ hill of 5 sample hills } (cm^2)}{\text{Area of land covered by that hills } (cm^2)}$$

3.4.2.1.4 Dry Matter Production

From each plot 5 hills were uprooted at harvest. They were washed, dried in shade and latter in a hot air oven till a constant weight is attained. Dry weight of the plants were found out and dry matter production was expressed in kg ha^{-1}.

3.4.2.2 Yield attributes

3.4.2.2.1 Number of productive tillers m^{-2}

At harvest, the number of productive tillers was obtained from 5 randomly selected hills in the net plot area and was expressed as number of productive tillers m^{-2}.

3.4..2.2.2 Length of panicle

Ten panicles were taken randomly from the net plot area and average panicle length was measured and expressed in cm.

3.4.2.2.3 Weight of panicle

Weight of panicle was obtained from 10 randomly selected panicles and expressed in grams.

3.4.2.2.4 Number of spikelets per panicle

Number of spikelets per panicle was found out by counting the grains from 10 randomly selected panicles in each plot.

3.4.2.2.5 Number of filled grains per panicle

Number of filled grains per panicle was obtained by counting the number of filled grains from ten panicles randomly taken from each plot and taking the mean number of grains per panicle.

3.4.2.2.6 Chaff percentage

Total number of spikelets per panicle and number of unfilled grains per panicle were obtained from 10 randomly selected panicles and chaff percentage was worked out using the following relationship.

$$\text{Chaff percentage} = \frac{\text{Number of unfilled grains per panicle}}{\text{Number of filled grains per panicle}} \times 100$$

3.4.2.2.7 Thousand grain weight

One thousand grains were counted from the cleaned and dried produce from net plot area of each plot and the weight of the grains was recorded in grams.

3.4.2.2.8 Grain yield

The net plot area was harvested individually, threshed, cleaned, dried and weight was recorded and expressed in kg ha^{-1}.

3.4.2.2.9 Straw yield

The straw obtained from net plot area was dried in sun, weighed and expressed in kg ha^{-1}.

3.4.2.2.10 Harvest Index (HI)

Harvest Index was worked out using the following formula suggested by Donald and Hamblin (1976).

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

3.4.2.2.11 Weed Index (WI)

Weed index was calculated according to the equation suggested by Gill and Vijayakumar (1969).

$$WI = \frac{X-Y}{X} \times 100 \text{ where}$$

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

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

3.5 Chemical Analysis

3.5.1 Soil Analysis

Composite soil samples collected before the start of the experiment was analysed to determine the available N, available P_2O_5 and available K_2O. The physical composition and pH were also determined. After the harvest of the crop, soil samples were taken from each plot separately and analysed for available N, P and K.

3.5.1.1 Physical composition of soil

Percentage of course sand, fine sand, silt and clay were determined by international pipette method (Piper, 1966).

3.5.1.2 Available Nitrogen

Available nitrogen content of the soil was estimated by alkaline permanganate method (Subbiah and Asija, 1956).

3.5.1.3 Available P_2O_5

Available P_2O_5 content was determined by Dickman and Brays molybdenum blue method. Bray No.1 reagent was used for extraction (Jackson, 1967).

3.5.1.4 Available K_2O

Available K_2O was determined using neutral normal ammonium acetate extract and estimated using EEL Flame photometer (Jackson, 1967).

3.5.1.5 Soil Reaction

pH of the soil was estimated using 1 : 25 soil water suspension using Perkin Elmer pH meter (Jackson, 1967).

3.5.2 Plant Analysis

The weed samples uprooted 20, 40 and 60 DAS and the rice plants uprooted at harvest were analysed for total N, P and K. After harvest, the grains were analysed separately for total Nitrogen content. The samples were dried in an electric hot air oven to constant weight, ground and passed through a 0.5 mm sieve. The required quantity of samples was weighed out accurately in an electronic balance, subjected to acid extraction and used for analysis.

3.5.2.1 Total nitrogen content

Total Nitrogen content was estimated by modified microkjeldal method (Jackson, 1967).

3.5.2.2 Total phosphorus content

Total phosphorus content was found out using Vanadomolybdo-phosphoric yellow colour method (Jackson, 1967).

3.5.2.3 Total potassium content

Total potassium content in plant was determined using EEL flame photometer (Jackson, 1967).

3.6 Uptake of Nutrients

The uptake of N, P and K by weeds at 20, 40 and 60 DAS and by the crop at harvest were calculated as the product of the content of these nutrients and the respective plant dry weight and expressed as kg ha^{-1}.

3.7 Protein content of rice grains

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

3.8 Observation on residual effect of herbicides

Hundred cucumber seeds were sown in $1 m^2$ area in each plot treated with herbicides and also in completely weed free plot. Germination count was taken 10 days after sowing and recorded.

3.9 Economics of cultivation

For analyzing the economics of cultivation, net income and benefit cost ratio were determined using the following equation based on cost of cultivation and prevailing price of the crop produce.

Net income (Rs ha^{-1}) = Gross income – total expenditure

$$\text{Benefit cost ratio (B.C.R.)} = \frac{\text{Gross Income}}{\text{Cost of cultivation}}$$

3.10 Statistical Analysis

The data generated were subjected to analysis of variance (Panse and Sukhatme, 1985). The data, which do not satisfy the basic assumptions of ANOVA, were transformed using square root transformation ($\sqrt{x + 1}$) and the transformed values were used for analysis of variance. Whenever the result was significant the critical difference was worked out at 5 per cent probability.

Results

4. RESULTS

A field experiment was conducted at the Instructional farm, College of Agriculture, Vellayani to evolve a suitable integrated weed management practice for upland rice. The results of the experiment are presented in this chapter.

4.1 Observation on crop

Observations on crop growth characters, yield attributes and yield were collected. The treatment w_2 (Pre-emergent application of fluchloralin followed by one hand weeding 3 weeks after sowing) resulted in more than 50% stand reduction of the crop and therefore observations on crop were not taken from these plots. However there was enough crop stand to allow the observation on plant height and tiller number at 30 DAS. So only those observations were collected from the treatment w_2.

4.1.1 Crop growth characters

Observations on crop growth characters like plant height, tiller number per hill, leaf area index and crop dry matter production were collected from five randomly selected hills from the net plot area.

4.1.1.1 Plant height

Plant height was recorded at 30 and 60 DAS and at harvest. The results are presented in Tables 2 and 3.

Table 2 Effect of spacing and weed management treatments on plant height at 30 and 60 DAS and at harvest

Treatment	Plant height (cm)		
	30 DAS	60 DAS	At harvest
s_1	31.54	60.19	70.44
s_2	30.98	65.36	74.31
s_3	30.21	64.99	75.17
F	0.18	2.03	5.08
SE	0.86	0.74	0.82
CD	NS	NS	NS
w_1	35.53	63.69	73.40
w_2	15.38	-	-
w_3	34.27	64.00	72.38
w_4	31.47	62.09	74.07
w_5	32.62	62.11	70.33
w_6	36.20	65.67	76.36
F	48.35**	0.82	2.15
SE	1.26	1.02	1.14
CD	3.24	NS	NS

** significant at 1 per cent level.

Table 3 Effect of treatment combinations on plant height at 30 and 60 DAS and at harvest

Treatment	Plant height (cm)		
	30 DAS	60 DAS	At harvest
s_1w_1	36.67	58.80	67.80
s_1w_2	15.93	-	-
s_1w_3	34.87	61.53	68.67
s_1w_4	34.07	60.20	70.00
s_1w_5	32.73	59.53	69.33
s_1w_6	35.00	60.87	76.40
s_2w_1	36.80	68.60	77.67
s_2w_2	16.00	-	-
s_2w_3	33.80	64.46	75.13
s_2w_4	30.33	62.87	72.93
s_2w_5	30.67	62.87	68.13
s_2w_6	38.27	68.00	77.66
s_3w_1	33.13	63.67	74.73
s_3w_2	40.20	-	-
s_3w_3	34.13	66.00	73.33
s_3w_4	30.00	63.20	79.27
s_3w_5	34.47	63.93	73.53
s_3w_6	35.33	68.13	75.00
F	0.79	0.39	1.36
SE	2.18	1.76	1.97
CD	NS	NS	NS

The different plant densities did not influence the plant height at any of the periods of observation.

The weed control treatments influenced plant height at 30 DAS. Plot receiving completely weed free situation (w_6) recorded the highest plant height of 36.2cm at this period, which was on par with w_1 and w_3. w_2 recorded the lowest plant height (15.38). w_4 recorded a mean plant height of 31.47 cm, which was on par with the unweeded check and w_3 and it was significantly higher than w_2.

No interaction effect was observed between plant density and herbicide treatments.

4.1.1.2 Number of tillers per hill

Number of tiller per hill was recorded at 30 and 60 DAS and at harvest. The results are presented in Tables 4 and 5.

The number of tillers per hill was affected by plant density only at harvest, where the largest spacing of 20 x 15cm (s_3) recorded the highest number of tillers per hill (10.25) and it was on par with s_2 (9.21) and superior to s_1 which recorded the lowest number of tillers per hill (8.01).

The weed management treatments influenced the number of tillers per hill at all periods of observation. w_6 recorded the highest number of tillers per hill (9.16) at 30 DAS, which was on par with w_1, w_3 and w_4. w_2 recorded significantly the lowest number of tiller per hill (5.18).

Table 4 Effect of spacing and weed management treatments on number of tillers per hill at 30 and 60 DAS and at harvest

Treatment	Number of tillers per hill		
	30 DAS	60 DAS	At harvest
s_1	6.58	7.92	8.01
s_2	8.28	9.81	9.21
s_3	8.37	9.96	10.25
F	1.73	5.90	8.22*
SE	0.23	0.36	0.35
CD	NS	NS	1.54
w_1	8.33	9.56	9.74
w_2	5.18	-	-
w_3	8.51	9.29	9.36
w_4	7.98	9.11	8.64
w_5	7.29	8.04	7.89
w_6	9.16	10.16	10.16
F	7.22**	3.15*	4.85**
SE	0.58	0.46	0.43
CD	1.50	1.27	1.19

* significant at 5 per cent level ** significant at 1 per cent level.

Table 5 Effect of treatment combinations on number of tillers per hill at 30 and 60 DAS and at harvest

Treatment	Number of tillers per hill		
	30 DAS	60 DAS	At harvest
s_1w_1	6.93	8.20	9.23
s_1w_2	4.73	-	-
s_1w_3	7.93	8.93	8.13
s_1w_4	6.67	7.40	7.00
s_1w_5	5.87	7.13	6.93
s_1w_6	7.33	7.93	8.73
s_2w_1	8.73	10.00	9.47
s_2w_2	4.73	-	-
s_2w_3	7.80	8.33	7.80
s_2w_4	8.53	10.07	9.27
s_2w_5	9.13	9.60	8.73
s_2w_6	10.73	11.07	10.80
s_3w_1	9.33	10.47	10.53
s_3w_2	6.07	-	-
s_3w_3	9.80	10.60	12.13
s_3w_4	8.73	9.87	9.67
s_3w_5	6.87	7.40	8.00
s_3w_6	9.40	11.47	10.93
F	1.07	1.81	2.18
SE	1.00	2.20	0.76
CD	NS	NS	NS

Weed free plots recorded the highest tiller number per hill at 60 DAS (10.16), which was on par with w_1, w_3 and w_4. However no significant difference was observed between w_4 and w_5.

At harvest the weed free situation (w_6) resulted in the highest number of tillers per hill (10.16), and w_1 and w_3 kept the same trend at harvest also. Weedy check (w_5) recorded the lowest number of tillers per hill (7.89). Here also w_4 and w_5 were on par.

The absence of interaction was observed at all these stages of crop.

4.1.1.3 Leaf area index(LAI)

LAI was worked out at harvest. The results are presented in Tables 6 and 7.

Among different spacings tried, the closest spacing of 15 x 10 cm (s_1) recorded significantly the highest LAI of 5.5 and s_3 recorded the lowest LAI of 2.9. s_2 recorded a LAI of 4.12 which was higher than s_3 but lower than s_1.

Weed management treatments also influenced the LAI significantly. Weed free situation (w_6) recorded significantly the highest LAI of 4.41 and the unweeded check (w_5) recorded significantly the lowest (3.86). LAI was more or less equal at w_1, w_3 and w_4.

The LAI was not influenced by the interaction effect.

Table 6 Effect of spacing and weed management treatments on dry matter production and leaf area index of rice

Treatments	Dry matter production (kg ha^{-1})	Leaf area index
s_1	9395.31	5.50
s_2	11688.52	4.12
s_3	11750.71	2.90
F	32.67**	3386.00**
SE	234.84	0.03
CD	721.96	0.08
w_1	12182.97	4.19
w_3	10447.16	4.20
w_4	11462.25	4.19
w_5	7030.96	3.86
w_6	13600.90	4.41
F	12.40**	55.6**
SE	701.70	0.04
CD	2048.23	0.08

** significant at 1 per cent level

Table 7 Interaction effect of main plot and sub plot treatments on dry matter production and leaf area index of rice

Treatment combination	Dry matter production (kg ha^{-1})	Leaf area index
s_1w_1	11320.49	2.95
s_1w_3	6523.67	2.91
s_1w_4	10375.33	2.90
s_1w_5	6082.85	2.59
s_1w_6	12674.20	3.13
s_2w_1	13323.57	4.16
s_2w_3	13573.40	4.20
s_2w_4	11542.46	4.12
s_2w_5	6375.77	3.86
s_2w_6	1362.26	4.25
s_3w_1	11904.85	5.46
s_3w_3	11244.27	5.50
s_3w_4	12468.94	5.54
s_3w_5	8634.27	5.13
s_3w_6	14501.22	5.84
F	1.50	2.2
SE	1215.39	0.006

4.1.1.4 Dry matter production (DMP)

The results are presented in tables 6 and 7.

Variation in plant density significantly influenced the DMP of rice. s_3 recorded the highest DMP (11750.71 kg ha^{-1}) and was on par with s_2. s_1 recorded the lowest DMP with a mean value of 9395.31 kg ha^{-1}.

Weed management treatments also influenced the DMP significantly. Completely weed free situation (w_6) recorded the highest DMP (13600.90 kg/ha), which was on par with w_1. Unweeded check resulted in significantly the lowest DMP of 7030.96 kg ha^{-1}. However, the treatments w_3, w_4 and w_1 were on par with respect to DMP of rice.

The interaction effect of the factors was not significant with respect to dry matter production.

4.1.2 Yield attributing characters

4.1.2.1 Number of productive tillers per hill at harvest

Results are presented in Tables 8 and 9.

Plant density variations did not influence number of productive tillers per hill at harvest.

But, the number of productive tillers per hill was significantly influenced by different weed management practices. Completely weed free plots (w_6) recorded the highest number of productive tillers per hill (5.8), which was on par with w_1. Unweeded check (w_5) recorded significantly the

Table 8 Effect of spacing and weed management treatments on number of productive tillers per hill, length of panicle and weight of panicle

Treatment	Number of productive tillers per hill	Length of panicle (cm)	weight of panicle (g)
s_1	5.58	21.33	11.23
s_2	5.43	22.08	12.48
s_3	5.52	22.00	13.47
F	1.28	2.04	2.70
SE	0.08	0.29	0.38
CD	NS	NS	NS
w_1	5.80	21.73	11.85
w_3	5.43	21.88	12.25
w_4	5.47	21.31	11.71
w_5	4.83	20.97	11.58
w_6	6.01	23.12	14.58
F	22.5**	7.13**	7.81**
SE	0.10	0.32	0.46
CD	0.28	0.89	1.30

** significant at 1 per cent level.

Table 9 Effect of treatment combinations on number of productive tillers per hill length of panicle and weight of panicle

Treatment	Number of productive tillers per hill	Length of panicle (cm)	weight of panicle (g)
s_1w_1	5.73	20.75	10.55
s_1w_3	5.67	21.48	11.62
s_1w_4	5.63	21.04	10.10
s_1w_5	4.87	20.69	10.79
s_1w_6	6.10	22.70	13.11
s_2w_1	6.07	22.14	11.83
s_2w_3	5.33	22.76	13.54
s_2w_4	5.33	22.80	11.06
s_2w_5	4.70	21.31	11.28
s_2w_6	5.50	23.38	14.69
s_3w_1	5.60	22.31	13.17
s_3w_3	5.40	21.39	11.60
s_3w_4	5.23	22.10	13.98
s_3w_5	4.93	20.72	12.68
s_3w_6	6.43	23.27	15.94
F	2.83*	1.07	1.55
SE	0.17	0.56	0.81
CD	0.49	NS	NS

* significant at 5 per cent level

lowest number of productive tiller per hill (4.83). The treatments w_3 and w_4 were on par with respect to the number of productive tillers per hill.

Significant interaction was observed between the factors with respect to the number of productive tillers per hill. With the lowest spacing (s_1), w_1 was found to be as good as w_6. The treatments, w_3 and w_4 also produced number of productive tillers per hill better than unweeded check (w_5). Under medium spacing (s_2), the best result was observed at m_1 followed by m_6. m_3 and m_4 were on par with the unweeded check (m_5). When the planting was done with the widest spacing (s_3), un weeded check (w_6) recorded the maximum number of productive tillers per hill. The number of productive tillers per hill was significantly high at w_1 in comparison with w_3,w_4 and w_5 which were on par.

4.1.2.2 Length of panicle

The results are presented in Tables 8 and 9.

Variations in spacing did not significantly influence the length of panicle.

Different weed management practices significantly influenced length of the panicle. The weed free check recorded significantly the highest panicle length (23.12 cm). Pre-emergent application of Pendimethalin followed by one HW 3 weeks after sowing (w_1) recorded the second highest mean value for panicle length (20.97 cm) and it was on par with w_3 and w_4 (21.88 and 21.34 cm), but was significantly superior to unweeded check (w_5) which registered an average panicle length of 20.97 cm. w_1 and w_4 were on par with the unweeded check.

The interaction of spacing and weed management practice in any way did not influence panicle length.

4.1.2.3 Weight of panicle

The results are presented in Tables 8 and 9.

Different spacings did not significantly influence the weight of panicle.

Among the weed management treatments weed free check recorded the highest panicle weight (14.58), which was significantly superior to all other treatments. Weedy check recorded significantly the lowest panicle weight (11.58). All the other weed management treatments i.e. w_1, w_3 and w_4 were on par with w_5 with respect to weight of panicle.

Spacing-weed control practice interaction did not produce any significant influence on the weight of panicle.

4.1.2.4 Number of spikelets / panicle

The results are presented in Tables 10and 11.

Different spacings did not have any significant influence on the weight of panicle.

The weed management treatments significantly influenced the number of spikelets per panicle. Weed free check (w_6) recorded significantly the highest number of spikelets/panicle (159.84). w_1 resulted in a spikelet number per panicle of 133.87 which was on par with w_3 and superior to w_4 and w_5.

Table 10 Effect of main plot and subplot treatments on number of spikelets per panicle and number of filled grains per panicle

Treatment	Number of spikelets per panicle	Number of filled grains per panicle
s_1	117.29	94.37
s_2	139.24	109.13
s_3	133.62	111.67
F	3.55	1.75
SE	4.34	4.45
CD	NS	NS
w_1	133.87	105.18
w_3	128.62	102.56
w_4	118.60	98.24
w_5	109.33	91.86
w_6	159.84	127.44
F	18.27**	12.36**
SE	4.70	4.45
CD	13.06	11.20

* significant at 5 per cent level ** significant at 1 per cent level.

Table 11 Effect of treatment combinations on number of spikelets per panicle and number of filled grains per panicle

Treatment	Number of spikelets per panicle	Number of filled grains per panicle
s_1w_1	111.93	91.20
s_1w_3	123.00	97.80
s_1w_4	109.60	95.00
s_1w_5	100.60	83.97
s_1w_6	141.60	103.87
s_2w_1	153.87	113.07
s_2w_3	140.80	114.67
s_2w_4	114.73	89.13
s_2w_5	108.33	87.53
s_2w_6	178.47	141.27
s_3w_1	135.80	111.27
s_3w_3	122.07	95.20
s_3w_4	131.47	110.60
s_3w_5	119.33	104.07
s_3w_6	159.47	137.20
F	1.94	273*
SE	10.50	9.95
CD	NS	19.40

* significant at 5 per cent level ** significant at 1 per cent level.

Unweeded check recorded the lowest number of spikelets/panicle (109.33) and it was on par with that of w_4.

The interaction effect of spacing and weed management practices were not significant with respect to the number of spikelets per panicle.

4.1.2.5 Number of filled grains per panicle

The results are presented in Tables 10 and 11.

Different spacings did not significantly influence the number of filled grains per panicle.

Completely weed free plots (w_6) recorded significantly the highest number of filled grains per panicle (127.44). Unweeded check (w_5) recorded the lowest grain number per panicle (19.86) and it was on par with $w_4$and w_3. Other than weed free check, pre-emergent application of Pendimethalin followed by 1 HW at 3 weeks after sowing (w_1) registered the highest number of filled grains per panicle (105.18) and it was effective in controlling the weeds. This treatment was on par with w_3 and w_4.

Interaction effect of spacing and weed management practices had significant influence on number of filled grains/panicle. Whatever the spacing adopted, weed free plots recorded the maximum number of filled grains per panicle. Under close and wider spacings none of the other treatments were found to result in a positive response, but under medium spacing (s_2) w_3 and w_1 were found to be effective.

4.1.2.6 Chaff percentage

The results are presented in Tables 12 and 13.

Neither the spacings nor the weed management treatments influenced the chaff percentage.

4.1.2.7 Thousand grain weight

The result are presented in Tables 12 and 13.

The effect of spacing on the thousand grain weight was not significant.

All weed management treatments were found to be effective in increasing the thousand grain weight. Unweeded check (s_5) and weed free check (w_6) recorded significantly the lowest and the highest thousand grain weight respectively (20.81 and 24.3). The two herbicide treatments were on par with each other with mean values of 22.75 (s_1) and 22.54(w_3) and were superior to s_4.

The interaction effect of spacing and weed management practices did not significantly influence the thousand-grain weight.

4.1.3 Grain yield

The results are presented in tables 14 and 15.

The variation in spacing did not significantly influence the grain yield.

Different weed management practices significantly influenced the grain yield of upland rice. Completely weed free plots (w_6) registered significantly

Table 12 Effect of spacing and weed management treatments on chaff percentage and thousand grain weight

Treatment	Chaff percentage	Thousand grain weight (g)
s_1	20.45	22.75
s_2	21.95	22.25
s_3	16.30	22.25
F	1.46	2.56
SE	0.34	0.18
CD	NS	NS
w_1	21.21	22.54
w_3	20.18	22.75
w_4	19.74	21.76
w_5	16.87	20.81
w_6	19.84	24.23
F	0.77	23.45**
SE	0.31	0.27
CD	NS	0.76

**significant at 1 per cent level

Table 13 Effect of treatment combinations on chaff percentage and thousand grain weight

Treatment	Chaff percentage	Thousand grain weight (g)
s_1w_1	18.80	22.94
s_1w_3	20.49	23.13
s_1w_4	19.92	22.44
s_1w_5	16.62	20.80
s_1w_6	26.45	24.44
s_2w_1	26.62	22.13
s_2w_3	18.73	22.36
s_2w_4	22.52	21.86
s_2w_5	21.01	20.94
s_2w_6	20.85	23.96
s_3w_1	18.21	22.56
s_3w_3	21.32	22.77
s_3w_4	16.77	20.97
s_3w_5	12.98	20.68
s_3w_6	12.23	24.28
F	1.40	0.63
SE	0.69	0.60
CD	NS	NS

Table 14 Effect of spacing and weed management treatments on grain yield, straw yield and harvest index

Treatment	Grain yield (kg ha^{-1})	straw yield (kg ha^{-1})	Harvest index
s_1	2545.00	5118.00	0.33
s_2	2933.33	5927.27	0.33
s_3	2896.67	5897.33	0.33
F	5.78	9.56*	1.46
SE	83.41	135.37	0.01
CD	NS	582.51	NS
w_1	3088.89	6172.78	0.33
w_3	2847.22	5791.11	0.33
w_4	2802.78	5722.33	0.33
w_5	1752.78	3587.11	0.33
w_6	3466.66	6964.33	0.33
F	29.74**	30.66**	0.38
SE	122.94	237.98	0.01
CD	341.29	660.64	NS

**significant at 1 per cent level

Table 15 Effect of treatment combinations on grain yield, straw yield and harvest index

Treatment	Grain yield (kg ha^{-1})	straw yield (kg ha^{-1})	Harvest index
s_1w_1	2966.67	5706.00	0.34
s_1w_3	2450.00	4911.33	0.33
s_1w_4	2583.33	5317.00	0.32
s_1w_5	1508.33	3074.67	0.33
s_1w_6	3216.67	6581.00	0.33
s_2w_1	3233.33	6512.33	0.32
s_2w_3	3391.67	6925.00	0.33
s_2w_4	2883.33	5978.00	0.32
s_2w_5	1600.00	3255.67	0.33
s_2w_6	3558.33	6968.33	0.34
s_3w_1	3066.67	6300.00	0.34
s_3w_3	2700.00	5537.00	0.32
s_3w_4	2941.67	5875.00	0.33
s_3w_5	2150.00	4431.00	0.33
s_3w_6	3625.00	7343.67	0.33
F	1.41	1.62	1.75
SE	274.90	532.14	0.01
CD	NS	NS	NS

the highest grain yield of 3466.66 kg ha^{-1}. Unweeded check (s5) recorded significantly the lowest grain yield of 1752.78 kg ha^{-1} .All the other weed management treatments registered more or less same grain yield.

The interaction effect of spacing and weed management practices did not significantly influence the grain yield.

4.1.4 Straw yield

The result are presented in tables 14 and 15.

Different spacings tried significantly influenced the straw yield. The closest spacing tried (s_1) resulted in significantly the lowest straw yield of 5118.00 kg/ha. An increase in plant density resulted in an increase in straw yield. s_2 and s_3 were on par with respect to straw yield with mean values of 5927.27 and 5897.33 kg ha^{-1}.

The influence of weed management treatments on straw yield also was significant. All the weed management treatments resulted in an increase in straw yield. However, no significant difference in straw yield was observed among w_1, w_3 and w_4. Weed free plots (w_6) registered the highest straw yield of 6964.33 kg ha^{-1} which was significantly higher than all other treatments. Unweeded check (w_5) recorded significantly the lowest straw yield of 3587.11 kg ha^{-1}.

Interaction effect of spacing and weed management treatments was not significant with respect to straw yield.

Plate 1

General view of the experimental site

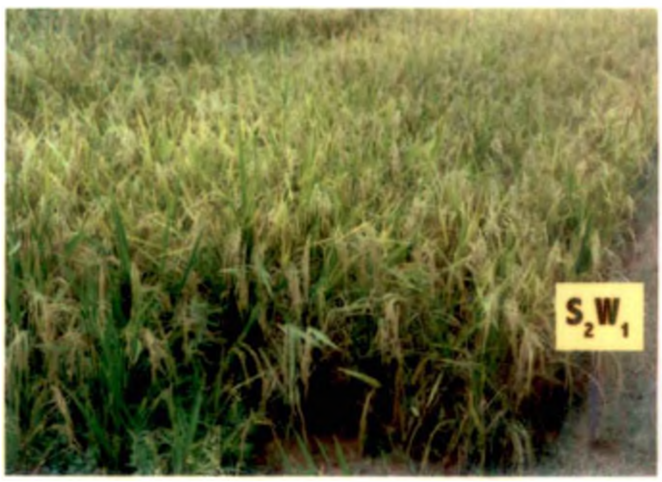


Plate 2

Plot treated with Pendimethalin (1.5 kg a.i.ha^{-1}) + one hand weeding and sown at 20 x 10 cm spacing

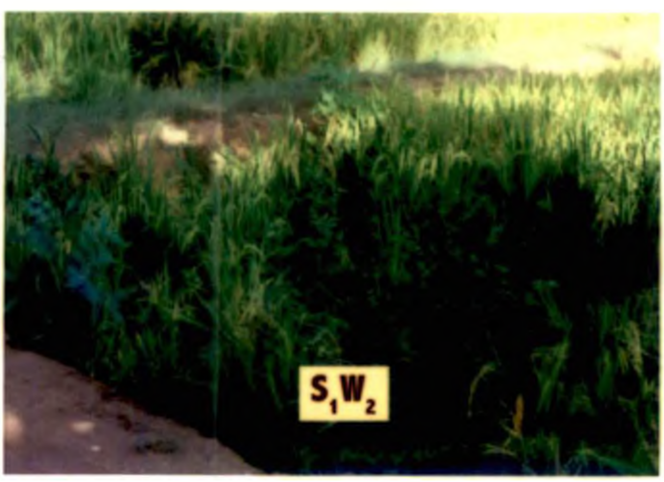


Plate 3

Plot treated with Fluchloralin (1.0 kg a.i.ha^{-1}) + one hand weeding and sown at a spacing of 15 x 10 cm

Plate 4

Plot treated with Butachlor (1.25 kg a.i. ha^{-1}) + one hand weeding and sown at a spacing of 20 x 10 cm spacing

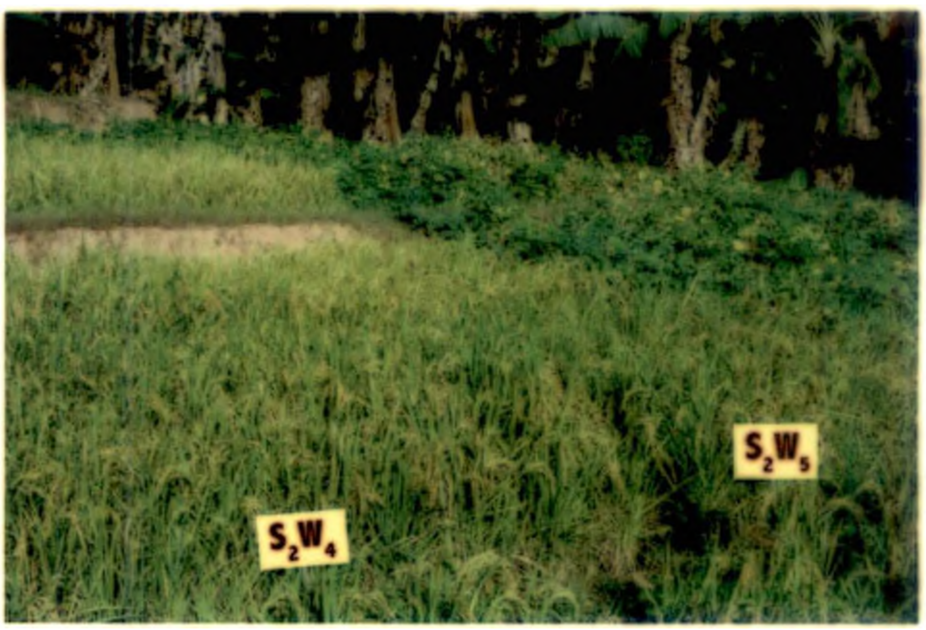


Plate 5

Plot hand weeded twice at 20 and 40 days after sowing and sown at 20 x 10 cm spacing. Near by plot is weedy check

Plate 6

Weedy check sown at a spacing of 20 x 10 cm

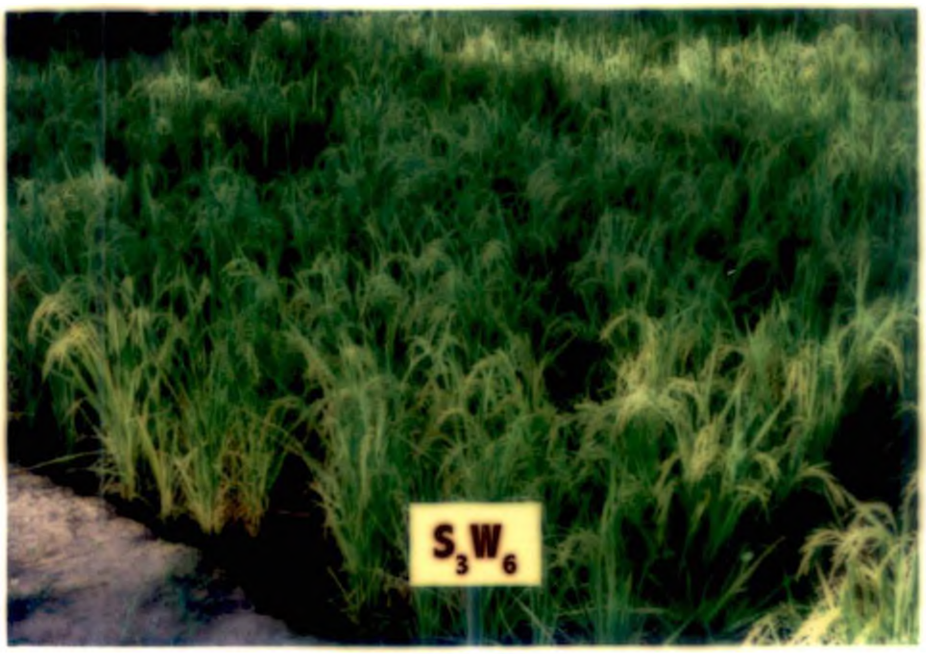


Plate 7

Weed free check sown at 20 x 15 cm spacing

4.1.5 Harvest index

The results are presented in Tables 14 and 15.

The results revealed that spacing, weed management treatments and their interaction had no significant effect on harvest index..

4.2 Observation on weeds

Observation on weeds were taken from the area left apart for that purpose. w_6 (Weed free check) did not have any weeds and hence no observations were taken from those plots. The data on weed population were statically analysed after giving square root transformation ($\sqrt{x+1}$). The periodical observations were analysed meaningfully taking their correlated effect.

4.2.1 Weed species

The different weed species observed in the experimental field were identified and grouped into grasses, broadleaved weeds and sedges. *Echinochloa colona* (L) Link., *Echinochloa crus-galli* (L) P. Beauv. and *Cynodon dactylon* (L) Pers. were the most important grassy weeds present. Among the broadleaved weeds *Cleome rutidosperma* D.C and *Commelina benghalensis* L. were the prominent ones. *Cyperus rotundus* L. and *Cyperus iria* L. were the most problematic sedges observed. Detailed list of all the weed species observed is given in Table 16.

Table 16 weed species observed in the experimental site

Grasses

Cynodon dactylon (L.) Pers.

Echinochloa colona (L.) Link.

Echinochloa crus-galli (L.) P. Beauv.

Eleusine indica (L.) Gaertn.

Panicum sp.

Broadleaved weeds

Amaranthus viridis L.

Boerhaevia diffusa L.

Borreria sp.

Cleome rutidosperma D.C

Cleome viscose L.

Commelina benghalensis L.

Eclipta alba L. Hassk.

Emelia songifolia L.

Euphorbia hirta L.

Ludwigia parviflora (L.) Roxb.

Phyllanthus niruri L.

Portulaca oleracea L.

Trianthema portulacastrum L.

Sedges

Bulbostylis barbata L.

Cyperus deformis L.

Cyperus iria L.

Cyperus rotundus L.

Fymbristylis miliacea Gaudich.

4.2.2 Absolute density

Observations on absolute density of grassy weeds, broadleaved weeds, sedge weeds and total absolute density were recorded at 20, 40 and 60 DAS.

4.2.2.1 Absolute density of grasses

The data on absolute density of grasses at various stages of observation (20, 40 and 60 DAS) are presented in Tables 17 and 18.

No significant difference in absolute density of grasses was observed as a result of different spacings tried at 20 and 40 DAS, but N_3 recorded higher values. s_1 registered the lowest absolute density of grasses at 60 DAS and s_2 was on par with s_3.

The herbicide treatments revealed the following results. At 20 DAS w_1 registered the lowest density of grassy weeds. No significant difference was observed between w_3 and w_2. But at 40 DAS w_1 and w_3 were on par and registered low absolute density of grasses. Here w_2 was found on par with w_4. At 60 DAS the lowest absolute density of grassy weeds was recorded by w_1 and w_3 was found to be on par with w_4. No interaction was observed between spacing and weed management practice at any of the periods of observation.

4.2.2.2 Absolute density of broadleaved Weeds

The results are presented in Tables 19 and 20.

The different spacings tried influenced the absolute density of broadleaved weeds significantly. At 20 DAS s_2 and s_3 were on par with each

Table 17 Effect of spacings and weed management practices on absolute density of grasses at different periods of observation

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean S
s_1	13.44 (3.80)	25.94 (5.19)	29.58 (5.53)	22.43 (4.84)
s_2	12.54 (3.68)	24.10 (5.01)	42.82 (6.62)	25.01 (5.10)
s_3	17.58 (4.31)	28.16 (5.40)	48.00 (7.00)	30.02 (5.57)
				Mean S
w_1	2.46 (1.86)	14.05 (3.88)	20.44 (4.63)	10.97 (3.46)
w_2	10.49 (3.39)	28.81 (5.46)	46.20 (6.87)	26.46 (5.24)
w_3	7.47 (2.91)	15.00 (4.00)	30.02 (5.57)	16.31 (4.16)
w_4	35.00 (6.00)	28.27 (5.41)	29.91 (5.56)	31.04 (5.66)
w_5	29.25 (5.50)	51.71 (7.26)	85.12 (9.28)	53.02 (7.35)
Mean P	14.44 (3.93)	26.04 (5.20)	39.70 (6.38)	

Table 18 Interaction effect of spacings and weed management practices at different periods of observation on absolute density of grasses

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean SW
$s_1 w_1$	0.99 (1.41)	11.82 (3.58)	23.60 (4.96)	10.02 (3.32)
$s_1 w_2$	9.69 (3.27)	48.00 (7.00)	38.94 (6.32)	29.56 (5.53)
$s_1 w_3$	3.80 (2.19)	9.24 (3.20)	18.36 (4.40)	9.63 (3.26)
$s_1 w_4$	37.07 (6.17)	27.94 (5.38)	20.16 (4.60)	27.94 (5.38)
$s_1 w_5$	29.91 (5.56)	45.24 (6.80)	53.46 (7.38)	42.30 (6.58)
$s_2 w_1$	3.33 (2.08)	13.29 (3.78)	21.18 (4.71)	11.39 (3.52)
$s_2 w_2$	13.06 (3.75)	25.11 (5.11)	42.56 (6.60)	25.52 (5.15)
$s_2 w_3$	6.56 (2.75)	16.98 (4.24)	41.25 (6.50)	19.25 (4.50)
$s_2 w_4$	26.46 (5.24)	26.56 (5.25)	29.14 (5.49)	27.41 (5.33)
$s_2 w_5$	19.98 (4.58)	43.62 (6.68)	95.43 (9.82)	48.42 (7.03)
$s_3 w_1$	3.33 (2.08)	17.32 (4.28)	16.98 (4.24)	11.46 (3.53)
$s_3 w_2$	8.92 (3.15)	17.32 (4.28)	58.29 (7.70)	24.40 (5.04)
$s_3 w_3$	13.36 (3.79)	19.79 (4.56)	32.99 (5.83)	21.37 (4.73)
$s_3 w_4$	42.16 (6.57)	30.47 (5.61)	42.43 (6.59)	38.19 (6.26)
$s_3 w_5$	34.52 (5.96)	67.72 (8.29)	112.42 (10.65)	67.88 (8.30)

	S	W	SW	P	SP	WP	SWP
F	4.76	40.26**	1.49	69.86**	2.49*	7.07**	1.72
SE	0.17	0.23	0.41	0.15	0.25	0.33	0.57
CD	NS	0.68	NS	0.41	0.72	0.92	NS

Figures in parenthesis are the transformed values

* significant at 5 per cent level ** significant at 1 per cent level.

Table 19 Effect of spacings and weed management practices on absolute density of broadleaved weeds at different periods of observation

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean S
s_1	222.80 (14.96)	41.12 (6.49)	46.61 (6.90)	88.30 (9.45)
s_2	184.78 (13.63)	41.38 (6.51)	47.72 (6.98)	80.72 (9.04)
s_3	195.84 (14.03)	30.92 (5.65)	52.29 (7.30)	79.82 (8.99)
				Mean W
w_1	159.53 (12.67)	21.47 (4.74)	20.16 (4.60)	52.88 (7.34)
w_2	141.80 (11.95)	26.77 (5.27)	51.71 (7.26)	65.59 (8.16)
w_3	180.44 (13.47)	26.67 (5.26)	37.07 (6.17)	67.89 (8.30)
w_4	273.90 (16.58)	26.04 (5.20)	45.24 (6.80)	89.82 (9.53)
w_5	266.98 (16.37)	111.78 (10.62)	108.41 (10.46)	154.75 (12.48)
Mean P	200.92 (14.21)	37.69 (6.22)	48.84 (7.06)	

Table 20 Interaction effect of spacings and weed management practices at different periods of observation on absolute density of broadleaved weeds

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean SW
$s_1 w_1$	203.20 (14.29)	34.52 (5.96)	13.06 (3.75)	63.00 (8.00)
$s_1 w_2$	124.44 (11.20)	34.52 (5.96)	56.15 (7.56)	66.90 (8.24)
$s_1 w_3$	213.92 (14.66)	19.88 (4.57)	30.14 (5.58)	67.39 (8.27)
$s_1 w_4$	299.33 (17.33)	30.47 (5.61)	45.51 (6.82)	97.41 (9.92)
$s_1 w_5$	298.98 (17.32)	106.33 (10.36)	115.21 (10.78)	163.35 (12.82)
$s_2 w_1$	122.21 (11.10)	22.52 (4.85)	27.73 (5.36)	49.41 (7.10)
$s_2 w_2$	132.40 (11.55)	30.47 (5.61)	54.50 (7.45)	66.24 (8.20)
$s_2 w_3$	153.01 (12.41)	33.11 (5.84)	31.95 (5.74)	63.00 (8.00)
$s_2 w_4$	267.63 (16.39)	26.04 (5.20)	41.38 (6.51)	86.80 (9.37)
$s_2 w_5$	277.89 (16.70)	120.66 (11.03)	95.43 (9.82)	155.75 (12.52)
$s_3 w_1$	158.52 (12.63)	10.56 (3.40)	21.09 (4.70)	46.75 (6.91)
$s_3 w_2$	170.35 (13.09)	16.89 (4.23)	44.97 (6.78)	63.48 (8.03)
$s_3 w_3$	177.22 (13.35)	27.73 (5.36)	50.55 (7.18)	73.48 (8.63)
$s_3 w_4$	255.64 (16.02)	21.85 (4.78)	48.84 (7.06)	85.30 (9.29)
$s_3 w_5$	226.71 (15.09)	108.83 (10.48)	115.42 (10.79)	145.89 (12.12)

	S	W	SW	P	SP	WP	SWP
F	3.95	93.13**	0.72	971.49**	4.71**	15.80**	2.90**
SE	0.13	0.21	0.36	0.14	0.24	0.31	0.55
CD	NS	0.60	NS	0.40	0.69	0.89	1.54

Figures in parenthesis are the transformed values

** significant at 1 per cent level.

other and recorded the lowest absolute density of broadleaved weeds. s_3 recorded the lowest absolute density of broadleaved weeds at 40 DAS and no significant difference was observed between s_1 and s_2. At 60 DAS the broadleaved weed density was more or less similar at over the three spacing, but a higher broadleaved weed density was observed at s_3.

The effect of weed management practices on absolute density of broadleaved weeds differed significantly with period of observation. At 20 DAS least broadleaved weed density was observed at w_2 and w_1 which were on par with each other. w_4 and w_5 recorded the highest broadleaved weed density evidently because of no weeding. At 40 DAS no significant difference was observed among the four weed management treatments but they were significantly lower in comparison with weedy check. At 60 DAS w_1 recorded the lowest absolute density of broadleaved weeds. Here w_3 and w_4 were on par with each other and w_2 recorded higher broadleaved weed density than w_3. The weedy check (w_5) recorded the highest value. All the weed management practices resulted in reduction of weed density. With the treatment w_1 the broadleaved weed density was on par at 40 and 60 DAS but for the rest it showed an increasing trend.

Significant interaction was observed between spacing and weed management practices. s_1w_1 recorded the highest absolute density of broadleaved weeds at 20 DAS and the lowest at 60 DAS. s_1w_2, s_1w_3, s_1w_4 and s_1w_5 recorded the highest value at 20 DAS and the lowest at 40 DAS. In the case of s_2w1, s_2w_2, s_2w_3, s_2w4 and s_2w_5. The highest absolute density of broadleaved weeds was recorded at 20 DAS and the values at 40 and 60 DAS were on par. The treatment combinations of s_3w_1, s_3w_2, s_3w_3, s_3w_4 and s_3w_5 registered the highest absolute density of broadleaved weeds at 20 DAS and the lowest at 40 DAS.

4.2.2.3 Absolute density of sedges

The results are presented in Tables 21 and 22.

The influence of plant densities on the absolute density of sedges was significant. At 20 DAS the absolute density of sedges was lowest at s_2 followed by s_3 and s_1. At 40 DAS density of sedges at s_1 and s_3 were on par but higher than that of s_2. The absolute density of sedges did not varied significantly among different spacings tried at 60 DAS.

The weed management treatments influenced the absolute density of sedges significantly. At 20 DAS w_1 recorded the lowest absolute density of sedges followed by w_2 and w_3, which were on par. At 40 DAS also w_1 recorded the lowest value followed by w_4 and w_3, which were on par. At 60 DAS unweeded check (w_5) recorded the highest absolute density of sedges and all the other treatments were on par. The absolute density of sedges differed significantly between 40 and 60 DAS only in the case of w_2.

Significant interaction was observed between spacings and weed management practices adopted. At s_1w_1, s_2w_1, s_2w_2, s_2w_3 and s_2w_4 highest absolute density of sedges was observed at 60 DAS and the lowest at 20 DAS, but s_1w_2, s_1w_3, s_1w_4, s_1w_5 and s_2w_5 registered the highest value at 20 DAS and the lowest at 60 DAS. s_3w_2 and s_3w_3 recorded the lowest absolute density of sedge weeds at 20 DAS and the highest at 40 DAS. s_3w_1 and s_3w_5 recorded the

Table 21 Effect of spacings and weed management practices on of absolute density of sedges at different periods of observation

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean S
s_1	185.32 (13.65)	142.28 (11.97)	122.21 (11.10)	148.82 (12.24)
s_2	83.27 (9.18)	111.57 (10.61)	120.22 (11.01)	104.47 (10.27)
s_3	134.72 (11.65)	151.77 (12.36)	115.21 (10.78)	133.56 (11.60)
				Mean W
w_1	69.90 (8.42)	90.20 (9.55)	101.01 (10.10)	86.61 (9.36)
w_2	98.20 (9.96)	153.75 (12.44)	117.59 (10.89)	122.21 (11.10)
w_3	103.04 (10.20)	133.56 (11.60)	118.25 (10.92)	118.03 (10.91)
w_4	205.21 (14.36)	121.10 (11.05)	105.09 (10.30)	140.61 (11.90)
w_5	209.83 (14.52)	183.69 (13.59)	158.01 (12.61)	183.14 (13.57)
Mean P	131.02 (11.49)	135.72 (11.65)	119.12 (10.96)	

Table 22 Interaction effect of spacings and weed management practices at different periods of observation on absolute density of sedges

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean SW
$s_1 w_1$	68.89 (8.36)	84.93 (9.27)	130.56 (11.47)	93.09 (9.70)
$s_1 w_2$	187.24 (13.72)	186.69 (13.70)	123.32 (11.15)	164.38 (12.86)
$s_1 w_3$	183.42 (13.58)	138.24 (11.80)	125.11 (11.23)	147.84 (12.20)
$s_1 w_4$	275.22 (16.62)	137.06 (11.75)	78.57 (8.92)	153.50 (12.43)
$s_1 w_5$	254.68 (15.99)	176.96 (13.34)	160.80 (12.72)	195.56 (14.02)
$s_2 w_1$	28.70 (5.45)	49.27 (7.09)	85.12 (9.28)	51.85 (7.27)
$s_2 w_2$	50.27 (7.16)	122.21 (11.10)	145.17 (12.09)	101.41 (10.12)
$s_2 w_3$	62.04 (7.94)	103.65 (10.23)	115.64 (10.80)	92.32 (9.66)
$s_2 w_4$	128.50 (11.38)	125.11 (11.23)	113.28 (10.69)	122.21 (11.10)
$s_2 w_5$	193.60 (13.95)	178.02 (13.38)	147.84 (12.20)	172.71 (13.18)
$s_3 w_1$	130.56 (11.47)	150.04 (12.29)	90.58 (9.57)	122.43 (11.11)
$s_3 w_2$	80.00 (9.00)	155.75 (12.52)	87.74 (9.42)	105.30 (10.31)
$s_3 w_3$	81.63 (9.09)	161.82 (12.76)	114.35 (10.74)	116.94 (10.86)
$s_3 w_4$	226.71 (15.09)	102.63 (10.18)	126.46 (11.29)	147.60 (12.19)
$s_3 w_5$	184.78 (13.63)	196.12 (14.04)	165.41 (12.90)	181.79 (13.52)

	S	W	SW	P	SP	WP	SWP
F	61.42**	42.02**	4.91**	4.57*	16.96**	13.80**	4.37**
SE	0.13	0.24	0.41	0.17	0.29	0.37	0.65
CD	0.50	0.69	1.19	0.47	0.82	1.05	1.82

Figures in parenthesis are the transformed values

* significant at 5 per cent level ** significant at 1 per cent level.

lowest value at 60 DAS and the highest at 40 DAS. The lowest sedge weed density was recorded at 40 DAS and the highest at 20 DAS by s_3w_4.

4.2.2.4 Absolute density of all weeds

The results are presented in Tables 23 and 24.

The spacings tried provided the following results. At 20 DAS s_2 recorded the lowest absolute density of all weeds and s_3 recorded the highest. At 40 DAS the absolute density of all weeds were significantly lower at s_2 than rest of the spacings and s_3 and s_1 was at par. At 60 DAS the closest spacing (s_1) registered a significant reduction in absolute density of all weeds but the other two spacings showed more or less the same value

Weed management treatments had a significant effect on absolute density of all weeds. At 20 DAS w_1 recorded the lowest absolute density of all weeds and it was on par with w_2. The highest absolute density of all weeds was recorded at w_4 and it was on par with unweeded check (w_5). At 40 DAS w_1 registered a significant reduction in absolute density of all weeds. w_3 and w_4 also lead to reduction in absolute density of all weeds compared to unweeded check and they were at par. Unweeded check registered the highest absolute density of all weeds. At 60 DAS also the same trend was observed with w_1 and w_5 recording the lowest and the highest absolute density of all weeds.

Spacing-weed management practice interaction significantly influenced the absolute density of all weeds. In plots treated with the treatment combination of s_1w_1, s_1w_3, s_1w_5, s_2w_1,s_2w_3, s_2w_4,s_3w_4 and s_3w_5 the lowest

Table 23 Effect of spacings and weed management practices on absolute density of all weeds at different periods of observation

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean S
s_1	430.39 (20.77)	218.63 (14.82)	203.78 (14.31)	275.56 (16.63)
s_2	279.90 (16.76)	179.10 (13.42)	213.04 (14.63)	222.20 (14.94)
s_3	347.20 (18.66)	216.86 (14.76)	218.93 (14.83)	257.57 (16.08)
				Mean W
w_1	238.32 (15.47)	128.05 (11.36)	143.24 (12.01)	166.70 (12.95)
w_2	247.06 (15.75)	211.28 (14.57)	217.45 (14.78)	224.90 (15.03)
w_3	290.38 (17.07)	177.22 (13.35)	187.51 (13.73)	215.68 (14.72)
w_4	519.75 (22.82)	186.42 (13.69)	182.33 (13.54)	277.22 (16.68)
w_5	507.50 (22.55)	348.69 (18.70)	355.83 (18.89)	401.00 (20.05)
Mean P	349.81 (18.73)	204.35 (14.33)	211.87 (14.59)	

Table 24 Interaction effect of spacings and weed management practices at different periods of observation on absolute density of all weeds

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean SW
$s_1 w_1$	278.22 (16.71)	129.19 (11.41)	168.00 (13.00)	186.96 (13.71)
$s_1 w_2$	324.80 (18.05)	269.27 (16.44)	219.52 (14.85)	269.60 (16.45)
$s_1 w_3$	378.08 (19.47)	167.48 (12.98)	175.89 (13.30)	231.56 (15.25)
$s_1 w_4$	640.61 (25.33)	227.61 (15.12)	146.87 (12.16)	306.65 (17.54)
$s_1 w_5$	589.00 (24.29)	329.15 (18.17)	332.43 (18.26)	408.66 (20.24)
$s_2 w_1$	156.75 (12.56)	85.30 (9.29)	134.26 (11.63)	123.55 (11.16)
$s_2 w_2$	167.74 (12.99)	178.02 (13.38)	242.67 (15.61)	194.72 (13.99)
$s_2 w_3$	227.01 (15.10)	154.25 (12.46)	188.89 (13.78)	188.89 (13.78)
$s_2 w_4$	436.23 (20.91)	178.56 (13.40)	185.32 (13.65)	254.68 (15.99)
$s_2 w_5$	494.51 (22.26)	343.84 (18.57)	340.14 (18.47)	389.85 (19.77)
$s_3 w_1$	293.12 (17.15)	178.02 (13.38)	129.19 (11.41)	194.44 (13.98)
$s_3 w_2$	261.44 (16.20)	191.93 (13.89)	191.93 (13.89)	213.92 (14.66)
$s_3 w_3$	275.89 (16.64)	212.74 (14.62)	198.37 (14.12)	227.92 (15.13)
$s_3 w_4$	492.28 (22.21)	156.75 (12.56)	218.34 (14.81)	272.24 (16.53)
$s_3 w_5$	444.63 (21.11)	373.42 (19.35)	396.60 (19.94)	404.22 (20.13)

	S	W	SW	P	SP	WP	SWP
F	21.81**	265.91**	5.01**	338.51**	22.79**	33.21**	5.40**
SE	0.19	0.16	0.28	0.13	0.23	0.30	0.52
CD	0.73	0.47	0.82	0.38	0.65	0.84	1.46

Figures in parenthesis are the transformed values

** significant at 1 per cent level.

absolute density of all weeds were recorded at 40 DAS and the highest at 20 DAS. The treatment combinations of $s1w_2$, s_1w_4, s_2w_5, s_3w_1, s_3w_2 and s_3w_3 registered highest absolute density of all weeds at 20 DAS and the lowest at 60 DAS. s_2w_2 registered the highest absolute density of all weeds at 60 DAS and values at 20 and 40 DAS were more or less similar.

4.2.3 Relative density

Relative density of grassy weeds, broad leaved weeds and sedge weeds were worked out at 20, 40 and 60 DAS.

4.2.3.1 Relative density of grasses

The results are presented in Tables 25 and 26.

The effect of different spacings on relative density of grassy weeds was significant only at 60 DAS. The closest spacing of 15 x 10 cm recorded significantly the lowest relative density of grasses (16.81). Other two spacings were on par with respect to relative density of monocot weeds

Relative density of grasses was influenced by different weed control methods. At 20 DAS w_1 registered significant reduction in relative density of grasses and all the other weed management practices adopted were on par. At 40 DAS w_3 recorded the lowest relative density of grasses and it was on par with w_5 and w_1. w_2 recorded the highest relative density of grasses, which was on par with w_4. At 60 DAS also w_3 registered the lowest relative density of grasses and it was on par with w_4 and w_1. w_5 resulted in the highest relative density of grasses, but is was more or less same as w_2.

Table 25 Effect of spacings and weed management practices on relative density of grasses at different periods of observation

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean S
s_1	4.24 (2.29)	14.29 (3.91)	16.81 (4.22)	11.06 (3.47)
s_2	7.24 (2.87)	16.31 (4.16)	20.62 (4.65)	14.16 (3.89)
s_3	7.53 (2.92)	14.76 (3.97)	21.85 (4.78)	14.13 (3.89)
				Mean W
w_1	2.80 (1.95)	15.24 (4.03)	17.84 (4.34)	10.83 (3.44)
w_2	8.36 (3.06)	16.72 (4.21)	21.56 (4.75)	15.05 (4.01)
w_3	6.13 (2.67)	12.32 (3.65)	16.81 (4.22)	11.34 (3.51)
w_4	7.82 (2.97)	16.64 (4.20)	17.58 (4.31)	13.64 (3.83)
w_5	7.01 (2.83)	14.76 (3.97)	25.21 (5.12)	14.79 (3.97)
Mean P	6.26 (2.70)	15.10 (4.01)	19.69 (4.55)	

Table 26 Interaction effect of spacings and weed management practices at different periods of observation on relative density of grasses

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean SW
s_1 w_1	1.22 (1.49)	12.84 (3.72)	17.23 (4.27)	8.99 (3.16)
s_1 w_2	5.86 (2.62)	17.58 (4.31)	17.92 (4.35)	13.14 (3.76)
s_1 w_3	2.06 (1.75)	12.25 (3.64)	13.06 (3.75)	8.28 (3.05)
s_1 w_4	7.24 (2.87)	15.32 (4.04)	16.22 (4.15)	12.58 (3.69)
s_1 w_5	6.45 (2.73)	13.75 (3.84)	19.88 (4.57)	12.79 (3.71)
s_2 w_1	4.81 (2.41)	20.90 (4.68)	19.79 (4.56)	14.08 (3.88)
s_2 w_2	9.63 (3.26)	18.18 (4.38)	17.49 (4.30)	14.84 (3.98)
s_2 w_3	10.36 (3.37)	14.21 (3.90)	21.47 (4.74)	15.03 (4.00)
s_2 w_4	6.78 (2.79)	15.97 (4.12)	17.06 (4.25)	12.84 (3.72)
s_2 w_5	5.20 (2.49)	12.62 (3.69)	28.05 (5.39)	13.87 (3.86)
s_3 w_1	2.80 (1.95)	12.54 (3.68)	16.64 (4.20)	9.74 (3.28)
s_3 w_2	9.89 (3.30)	14.60 (3.95)	30.25 (5.59)	17.32 (4.28)
s_3 w_3	7.24 (2.87)	10.70 (3.42)	16.56 (4.19)	11.20 (3.49)
s_3 w_4	9.50 (3.24)	18.62 (4.43)	19.52 (4.53)	15.54 (4.07)
s_3 w_5	9.56 (3.25)	18.18 (4.38)	28.48 (5.43)	17.95 (4.35)

	S	W	SW	P	SP	WP	SWP
F	13.13*	4.19**	1.59	127.44**	1.16	2.60*	1.04
SE	0.74	0.13	0.22	0.08	0.15	0.19	0.33
CD	NS	0.37	NS	0.24	NS	0.53	NS

Figures in parenthesis are the transformed values

* significant at 5 per cent level ** significant at 1 per cent level.

The interaction effect of spacing and weed managements was not significant with respect to relative density of grasses.

4.2.3.2 Relative density of broadleaved weeds

The results are presented in tables 27and 28.

The influence of spacing on the relative density of broadleaved weeds was significant. At 20 DAS s_2 registered the highest relative density of dicot weeds and s_1 and s_3 resulted in more or less similar values. At 40 DAS s_3 recorded the lowest relative density of broadleaved weeds and s_1 and s_2 were at par. At 60 DAS the effect of spacing on relative density of broadleaved weeds were not significant.

At 20 DAS the unweeded check registered the lowest relative density of dicot weeds and it was on par with w_4 and w_2. The highest relative density of broadleaved weeds at this period was observed in w_1. At 40 DAS w_2 recorded the lowest relative density of broadleaved weeds, which was more or less same as that of w_4. Unweeded check (w_5) registered the highest relative density of dicot weeds. At 60 DAS also unweeded check (w_5) showed the highest relative density of broadleaved weeds. w_1 and w_3 were on par with respect to relative density of broadleaved weeds and they showed a significant reduction in relative density of broadleaved weeds.

The treatment combinations of s_1w_1, s_2w_1, s_2w_3, s_2w_5 and s_3w_5 registered the highest relative density of broadleaved weeds at 20 DAS and the lowest at 60 DAS. All the other treatment combinations recorded the highest relative density of broadleaved weeds at 20 DAS and the lowest at 40 DAS.

Table 27 Effect of spacings and weed management practices on relative density of broadleaved weeds at different periods of observation

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean S
s_1	51.27 (7.23)	21.28 (4.72)	23.01 (4.90)	30.55 (5.62)
s_2	63.80 (8.05)	23.114.91)	22.62 (4.86)	34.28 (5.94)
s_3	55.10 (7.49)	15.65 (4.08)	23.60 (4.96)	29.36 (5.51)
				Mean W
w_1	66.57 (8.22)	21.37 (4.73)	17.40 (4.29)	32.02 (5.75)
w_2	53.76 (7.40)	13.44 (3.80)	23.80 (4.98)	28.09 (5.39)
w_3	59.06 (7.75)	18.01 (4.36)	20.44 (4.63)	30.14 (5.58)
w_4	52.73 (7.33)	16.72 (4.21)	24.60 (5.06)	29.62 (5.53)
w_5	51.85 (7.27)	32.18 (5.76)	29.91 (5.56)	37.40 (6.20)
Mean P	56.65 (7.59)	19.88 (4.57)	23.06 (4.91)	

Table 28 Interaction effect of spacings and weed management practices at different periods of observation on relative density of broadleaved weeds

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean SW
$s_1 w_1$	71.76 (8.53)	31.26 (5.68)	12.18 (3.63)	24.67 (5.07)
$s_1 w_2$	37.44 (6.20)	13.90 (3.86)	25.42 (5.14)	26.46 (5.24)
$s_1 w_3$	52.00 (7.28)	15.73 (4.09)	17.92 (4.35)	30.17 (5.58)
$s_1 w_4$	47.86 (6.99)	16.56 (4.19)	30.02 (5.57)	38.02 (6.25)
$s_1 w_5$	50.27 (7.16)	32.29 (5.77)	32.76 (5.81)	38.61 (6.29)
$s_2 w_1$	73.48 (8.63)	28.05 (5.39)	22.62 (4.86)	32.22 (5.76)
$s_2 w_2$	65.26 (8.14)	17.49 (4.30)	22.52 (4.85)	31.83 (5.73)
$s_2 w_3$	62.36 (7.96)	22.33 (4.83)	18.36 (4.40)	30.43 (5.61)
$s_2 w_4$	62.84 (7.99)	15.40 (4.05)	21.85 (4.78)	38.90 (6.32)
$s_2 w_5$	56.00 (7.55)	35.12 (6.01)	28.05 (5.39)	23.97 (5.00)
$s_3 w_1$	55.10 (7.49)	8.73 (3.12)	18.18 (4.38)	27.55 (5.34)
$s_3 w_2$	60.47 (7.84)	9.50 (3.24)	23.50 (4.95)	32.33 (5.77)
$s_3 w_3$	63.16 (8.01)	16.31 (4.16)	25.52 (5.15)	28.20 (5.40)
$s_3 w_4$	48.00 (7.00)	18.27 (4.39)	22.23 (4.82)	35.28 (6.02)
$s_3 w_5$	49.41 (7.10)	29.14 (5.49)	29.03 (5.48)	35.28 (6.02)

	S	W	SW	P	SP	WP	SWP
F	6.93	9.14**	3.51**	489.27**	6.46**	11.55**	3.32**
SE	0.08	0.10	0.18	0.07	0.13	0.17	0.29
CD	NS	0.30	0.51	0.21	0.36	0.47	0.82

Figures in parenthesis are the transformed values

** significant at 1 per cent level.

4.2.3.3 Relative density of sedges

The results are presented in tables 29and 30.

At 20 DAS the highest relative density of sedges was registered at s_2 and the lowest at s_1. At 40 DAS, s_2 recorded the lowest value, which was on par with s1, and s_3 registered the highest relative density of sedges, which was on par with s_1. At 60 DAS the effect of spacing on the relative density of sedges was not significant.

Relative weed density of sedges was significantly influenced by different weed control treatments. At 20 DAS w_1 recorded the lowest relative density of sedges and it was on par with w_3. All the other treatments were on par at this period. At 40 DAS w_5 recorded the lowest relative density of sedges followed by w_1. The rest of the treatments registered more or less similar values. At 60 DAS also unweeded check (w_5) registered the lowest relative density of sedges followed by w_2. All the other treatments were on par.

The treatment combination of s_1w_1 and s_2w_1 registered the lowest relative density of sedges at 20 DAS and the high at 60 DAS. The rest of the treatment combinations recorded the lowest relative density of sedges at 20 DAS and the highest at 40 DAS.

4.2.4 Absolute frequency

Absolute frequency of grasses broadleaved weeds and sedges were recorded at 20,40 and 60 DAS.

Table 29 Effect of spacings and weed management practices on relative density of sedges at different periods of observation

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean S
s_1	41.77 (6.54)	62.84 (7.99)	58.14 (7.69)	53.86 (7.41)
s_2	27.52 (5.34)	59.53 (7.78)	56.00 (7.55)	46.47 (6.89)
s_3	35.97 (6.08)	67.89 (8.30)	53.32 (7.37)	51.56 (7.25)
				Mean W
w_1	28.27 (5.41)	60.31 (7.83)	64.12 (8.07)	49.46 (7.10)
w_2	35.24 (6.02)	69.22 (8.38)	53.76 (7.40)	51.80 (7.27)
w_3	32.41 (5.78)	69.06 (8.37)	62.04 (7.94)	53.22 (7.36)
w_4	38.56 (6.29)	66.24 (8.20)	56.76 (7.60)	53.22 (7.36)
w_5	40.47 (6.44)	52.73 (7.33)	43.76 (6.69)	45.51 (6.82)
Mean P	34.85 (5.99)	63.36 (8.02)	55.83 (7.54)	

Table 30 Interaction effect of spacings and weed management practices at different periods of observation on relative density of sedges

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean SW
$s_1 w_1$	24.81 (5.08)	53.76 (7.40)	70.23 (8.44)	47.63 (6.97)
$s_1 w_2$	55.85 (7.54)	68.56 (8.34)	56.15 (7.56)	60.05 (7.81)
$s_1 w_3$	44.56 (6.75)	71.76 (8.53)	68.56 (8.34)	60.99 (7.87)
$s_1 w_4$	44.02 (6.71)	67.89 (8.30)	52.14 (7.29)	54.25 (7.43)
$s_1 w_5$	42.96 (6.63)	53.76 (7.40)	45.92 (6.85)	47.44 (6.96)
$s_2 w_1$	20.34 (4.62)	50.84 (7.20)	57.37 (7.64)	41.08 (6.49)
$s_2 w_2$	24.81 (5.08)	64.12 (8.07)	59.84 (7.80)	47.77 (6.98)
$s_2 w_3$	25.42 (5.14)	63.48 (8.03)	60.15 (7.82)	47.95 (7.00)
$s_2 w_4$	30.14 (5.58)	68.39 (8.33)	60.47 (7.84)	51.56 (7.25)
$s_2 w_5$	38.56 (6.29)	51.85 (7.27)	43.49 (6.67)	44.47 (6.74)
$s_3 w_1$	41.38 (6.51)	78.21 (8.90)	65.10 (8.13)	60.57 (7.85)
$s_3 w_2$	28.48 (5.43)	75.21 (8.73)	45.79 (6.84)	48.00 (7.00)
$s_3 w_3$	28.81 (5.46)	72.27 (8.56)	57.68 (7.66)	51.22 (7.23)
$s_3 w_4$	42.43 (6.59)	62.68 (7.98)	57.98 (7.68)	54.01 (7.42)
$s_3 w_5$	39.96 (6.40)	52.44 (7.31)	41.90 (6.55)	44.61 (6.75)

	S	W	SW	P	SP	WP	SWP
F	9.55*	4.71**	4.27**	192.85**	7.08**	8.67**	2.27*
SE	0.09	0.11	0.18	0.08	0.13	0.17	0.30
CD	0.34	0.31	0.53	0.21	0.37	0.48	0.83

Figures in parenthesis are the transformed values

* significant at 5 per cent level ** significant at 1 per cent level.

4.2.4.1 Absolute frequency of grasses

The results are presented in tables 31 and 32.

At 20 DAS w_1 registered the lowest absolute frequency of grasses followed by w_3 and w_2. The highest absolute frequency of grasses was recorded at w_4 and it was on par with w_5. At 40 DAS w_1, w_3 and w_2 registered work or less same absolute frequency of grasses, but showed a considerable reduction of absolute frequency of grasses compared to w_4 and w_5. The highest value was recorded by w_5. At 60 DAS w_1, w_3, w_4 and w_5 recorded more or less same value. w_2 recorded the highest value, but it was on par with w_5, w_4 and w_3.

4.2.4.2 Absolute frequency of broadleaved weeds

The results are presented in tables 33 and 34.

Different weed control treatments significantly influenced absolute frequency of broadleaved weeds. At 20 DAS the weed management practices did not significantly influenced the absolute frequency of broadleaved weeds. At 40 DAS w_1 recorded the lowest absolute frequency of dicot weeds, which was on par with w_3. Unweeded check (w_5) recorded the highest value and it was on par with w_2. At 60 DAS w_1 registered a significant reduction in absolute frequency of broadleaved weeds compared to all other treatments. All treatments except w_1 were on par with respect to absolute frequency of broadleaved weeds.

The effect of different spacings and interaction effect of spacing and weed management practices were not significant at any period of observation.

Table 31 Effect of spacings and weed management practices on absolute frequency of grasses at different periods of observation

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean S
s_1	37.81 (6.23)	75.91 (8.77)	81.81 (9.10)	63.53 (8.03)
s_2	50.70 (7.19)	80.36 (9.02)	92.70 (9.68)	73.48 (8.63)
s_3	52.00 (7.28)	81.81 (9.10)	94.45 (9.77)	74.98 (8.72)
				Mean W
w_1	12.91 (3.73)	65.75 (8.17)	73.48 (8.63)	45.83 (6.84)
w_2	47.86 (6.99)	76.09 (8.78)	100.00 (10.05)	73.07 (8.61)
w_3	27.84 (5.37)	63.96 (8.06)	90.78 (9.58)	57.83 (7.67)
w_4	85.68 (9.31)	94.06 (9.75)	90.78 (9.58)	90.14 (9.55)
w_5	81.99 (9.11)	100.00 (10.05)	93.67 (9.73)	91.74 (9.63)
Mean P	46.63 (6.90)	79.33 (8.96)	89.54 (9.52)	

Table 32 Interaction effect of spacing and weed management practices at different periods of observation on absolute frequency of grasses

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean SW
$s_1 w_1$	4.62 (2.37)	57.83 (7.67)	73.65 (8.64)	37.77 (6.23)
$s_1 w_2$	47.86 (6.99)	100.00 (10.05)	100.00 (10.05)	80.54 (9.03)
$s_1 w_3$	8.30 (3.05)	40.73 (6.46)	73.65 (8.64)	35.60 (6.05)
$s_1 w_4$	82.91 (9.16)	91.35 (9.61)	81.45 (9.08)	85.18 (9.28)
$s_1 w_5$	91.35 (9.61)	100.00 (10.05)	0.17 (1.08)	46.79 (6.91)
$s_2 w_1$	18.45 (4.41)	66.08 (8.19)	73.65 (8.64)	49.13 (7.08)
$s_2 w_2$	66.08 (8.19)	73.65 (8.64)	0.10 (1.05)	34.52 (5.96)
$s_2 w_3$	25.01 (5.10)	73.65 (8.64)	100.00 (10.05)	61.88 (7.93)
$s_2 w_4$	91.35 (9.61)	91.35 (9.61)	91.35 (9.61)	91.35 (9.61)
$s_2 w_5$	73.65 (8.64)	100.00 (10.05)	100.00 (10.05)	90.78 (9.58)
$s_3 w_1$	18.45 (4.41)	73.65 (8.64)	73.65 (8.64)	51.27 (7.23)
$s_3 w_2$	32.41 (5.78)	57.83 (7.67)	100.00 (10.05)	60.36 (7.83)
$s_3 w_3$	62.36 (7.96)	81.45 (9.08)	100.00 (10.05)	80.54 (9.03)
$s_3 w_4$	82.91 (9.16)	100.00 (10.05)	100.00 (10.05)	94.13 (9.75)
$s_3 w_5$	81.45 (9.08)	100.00 (10.05)	100.00 (10.05)	93.61 (9.73)

	S	W	SW	P	SP	WP	SWP
F	2.92	16.54**	2.27	47.79**	0.35	6.34**	0.94
SE	0.22	0.30	0.51	0.20	0.34	0.45	0.77
CD	NS	0.86	NS	0.56	NS	1.25	NS

Figures in parenthesis are the transformed values

** significant at 1 per cent level.

Table 33 Effect of spacings and weed management practices on absolute frequency of broadleaved weeds at different periods of observation

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean S
s_1	100.00 (10.05)	84.01 (9.22)	88.87(9.48)	90.84 (9.58)
s_2	100.00 (10.05)	91.35 (9.61)	94.65(9.78)	95.30 (9.81)
s_3	98.20 (9.96)	78.92 (8.94)	96.42(9.87)	90.97 (9.59)
				Mean W
w_1	97.01 (9.90)	74.00 (8.66)	74.00(8.66)	81.33 (9.07)
w_2	100.00 (10.05)	88.49 (9.46)	100.00(10.05)	96.09 (9.85)
w_3	100.00 (10.05)	76.62 (8.81)	94.06(9.75)	89.95 (9.54)
w_4	100.00 (10.05)	85.12 (9.28)	100.00(10.05)	94.91 (9.79)
w_5	100.00 (10.05)	100.00 (10.05)	100.00(10.05)	100.00 (10.05)
Mean P	99.40 (10.02)	84.63 (9.25)	93.31 (9.71)	

Table 34 Interaction effect of spacings and weed management practices at different periods of observation on absolute frequency of broadleaved weeds

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean SW
$s_1 w_1$	100.00 (10.05)	73.65 (8.64)	57.83 (7.67)	76.21 (8.79)
$s_1 w_2$	100.00 (10.05)	91.35 (9.61)	100.00 (10.05)	97.08 (9.90)
$s_1 w_3$	100.00 (10.05)	66.08 (8.19)	91.35 (9.61)	85.18 (9.28)
$s_1 w_4$	100.00 (10.05)	91.35 (9.61)	100.00 (10.05)	97.08 (9.90)
$s_1 w_5$	100.00 (10.05)	100.00 (10.05)	99.00 (10.0)	99.67 (10.03)
$s_2 w_1$	100.00 (10.05)	82.91 (9.16)	82.91 (9.16)	88.43 (9.46)
$s_2 w_2$	100.00 (10.05)	91.35 (9.61)	100.00 (10.05)	97.08 (9.90)
$s_2 w_3$	100.00 (10.05)	91.35 (9.61)	91.35 (9.61)	94.19 (9.76)
$s_2 w_4$	100.00 (10.05)	91.35 (9.61)	100.00 (10.05)	97.08 (9.90)
$s_2 w_5$	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)
$s_3 w_1$	91.35 (9.61)	66.08 (8.19)	82.91 (9.16)	79.76 (8.99)
$s_3 w_2$	100.00 (10.05)	82.91 (9.16)	100.00 (10.05)	94.13 (9.75)
$s_3 w_3$	100.00 (10.05)	73.65 (8.64)	100.00 (10.05)	90.78 (9.58)
$s_3 w_4$	100.00 (10.05)	73.65 (8.64)	100.00 (10.05)	90.78 (9.58)
$s_3 w_5$	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)

	S	W	SW	P	SP	WP	SWP
F	1.45	9.82**	0.77	19.20**	2.27	3.20**	0.89
SE	0.11	0.12	0.21	0.29	0.15	0.20	0.34
CD	NS	0.35	NS	0.25	NS	0.55	NS

Figures in parenthesis are the transformed values

** significant at 1 per cent level.

4.2.4.3 Absolute frequency of sedges

The results are presented in Tables 35and 36.

Different weed control treatments, spacings and their interaction did not have any significant effect on absolute frequency of sedges at all period of observation.

4.2.5 Relative frequency

Relative weed frequency of grasses, broadleaved weeds and sedges were calculated at 20, 40 and 60 DAS.

4.2.5.1 Relative frequency of grasses

The results are presented in Tables 37 and 38.

The different weed management practices had significant effect on relative frequency of monocot weeds. At 20 DAS w_1 registered the lowest relative frequency of grasses followed by w_3 and w_2. The highest value was recorded by w_4 and it was on par with w_5. At 40 DAS w_4 registered the highest relative frequency of grasses and all the other treatments were on par. At 60 DAS the effect of weed management practices on relative frequency of grasses was not significant.

Different spacings and spacing weed management practice interaction did not significantly influence the relative frequency of grassy weeds at any period of observation.

Table 35 Effect of spacings and weed management practices on absolute frequency of sedges at different periods of observation

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean S
s_1	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)	100.00 (10.5)
s_2	94.45 (9.77)	100.00 (10.05)	100.00 (10.05)	98.14 (9.96)
s_3	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)	100.00 (10.5)
				Mean W
w_1	93.67 (9.73)	100.00 (10.05)	100.00 (10.05)	97.87 (9.94)
w_2	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)	100.00 (10.5)
w_3	97.01 (9.90)	100.00 (10.05)	100.00 (10.05)	99.00 (10.00)
w_4	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)	100.00 (10.5)
w_5	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)	100.00 (10.5)
Mean P	98.13 (9.96)	100.00 (10.05)	100.00 (10.05)	

Table 36 Interaction effect of spacings, weed management practices and periods of observation on absolute frequency of sedges

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean SW
$s_1 w_1$	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)
$s_1 w_2$	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)
$s_1 w_3$	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)
$s_1 w_4$	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)
$s_1 w_5$	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)
$s_2 w_1$	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)
$s_2 w_2$	100.00 (10.05)	81.45 (9.08)	100.00 (10.05)	93.61 (9.73)
$s_2 w_3$	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)
$s_2 w_4$	100.00 (10.05)	91.16 (9.60)	100.00 (10.05)	97.01 (9.90)
$s_2 w_5$	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)
$s_3 w_1$	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)
$s_3 w_2$	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)
$s_3 w_3$	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)
$s_3 w_4$	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)
$s_3 w_5$	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)	100.00 (10.05)

	S	W	SW	P	SP	WP	SWP
F	0.99	0.85	0.86	1.77	1.80	0.83	0.82
SE	0.05	0.05	0.09	0.04	0.07	0.09	0.16
CD	NS	NS	NS	NS	NS	NS	NS

Figures in parenthesis are the transformed values

Table 37 Effect of spacings and weed management practices on relative frequency of grasses at different periods of observation

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean S
s_1	14.44 (3.93)	28.59 (5.44)	29.80 (5.55)	23.73 (4.97)
s_2	19.70 (4.55)	29.25 (5.50)	32.06 (5.75)	26.74 (5.27)
s_3	19.70 (4.55)	30.92 (5.65)	32.29 (5.77)	27.34 (5.32)
				Mean W
w_1	6.34 (2.71)	27.09 (5.30)	29.36 (5.51)	11.98 (3.60)
w_2	19.79 (4.56)	28.38 (5.42)	33.34 (5.86)	26.88 (5.28)
w_3	11.53 (3.54)	25.94 (5.19)	31.60 (5.71)	22.17 (4.81)
w_4	29.91 (5.56)	33.57 (5.88)	31.04 (5.66)	31.49 (5.70)
w_5	28.81 (5.46)	33.34 (5.86)	31.72 (5.72)	31.26 (5.68)
Mean P	15.15 (4.02)	29.58 (5.53)	31.39 (5.69)	

Table 38 Interaction effect of spacings and weed management practices at different periods of observation on relative frequency of grasses

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean SW
$s_1 w_1$	2.35 (1.83)	24.81 (5.08)	31.38 (5.69)	16.64 (4.20)
$s_1 w_2$	18.89 (4.46)	34.28 (5.94)	33.34 (5.86)	28.38 (5.42)
$s_1 w_3$	3.80 (2.19)	19.52 (4.53)	27.41 (5.33)	15.13 (4.02)
$s_1 w_4$	29.25 (5.50)	32.18 (5.76)	28.48 (5.43)	29.95 (5.56)
$s_1 w_5$	31.26 (5.68)	33.34 (5.86)	28.48 (5.43)	31.00 (5.66)
$s_2 w_1$	9.18 (3.19)	26.35 (5.23)	28.38 (5.42)	20.28 (4.61)
$s_2 w_2$	24.70 (5.07)	27.41 (5.33)	33.34 (5.86)	28.38 (5.42)
$s_2 w_3$	11.53 (3.54)	27.41 (5.33)	34.28 (5.94)	23.37 (4.94)
$s_2 w_4$	31.26 (5.68)	32.18 (5.76)	31.26 (5.68)	31.57 (5.71)
$s_2 w_5$	26.56 (5.25)	33.34 (5.86)	33.34 (5.86)	31.00 (5.66)
$s_3 w_1$	8.61 (3.10)	30.36 (5.60)	28.38 (5.42)	21.15 (4.71)
$s_3 w_2$	13.82 (3.85)	23.90 (4.99)	33.34 (5.86)	23.01 (4.90)
$s_3 w_3$	22.91 (4.89)	31.49 (5.70)	33.34 (5.86)	29.07 (5.48)
$s_3 w_4$	29.25 (5.50)	36.58 (6.13)	33.34 (5.86)	32.99 (5.83)
$s_3 w_5$	28.48 (5.43)	33.34 (5.86)	33.34 (5.86)	31.68 (5.72)

	S	W	SW	P	SP	WP	SWP
F	2.25	11.19**	1.84	47.00**	0.68	6.94**	0.97
SE	0.13	0.16	0.27	0.11	0.19	0.24	0.42
CD	NS	0.46	NS	0.30	NS	0.67	NS

Figures in parenthesis are the transformed values

** significant at 1 per cent level.

4.2.5.2 Relative frequency of broad leaved weeds

The results are presented in Tables 39 and 40.

The different spacings tried did not significantly influence the relative frequency values of broadleaved weeds.

Different weed control treatments produced the following results. At 20 DAS w_4 registered the lowest relative frequency of broadleaved weeds and it was on par with unweeded check (w_5). The highest relative frequency of broadleaved weeds was recorded by w_1, which was on par with w_3. At 40 DAS there was no significant difference in relative frequency of broadleaved weeds among treatments. At 60 DAS w_1 registered the lowest relative frequency of broadleaved weeds followed by w_3. The rest of the treatments were on par with respect to relative frequency of broadleaved weeds

Spacing- weed management interaction did not significantly influence the relative frequency values of broadleaved weeds.

4.2.5.3 Relative frequency of sedges

The results are presented in Tables 41 and 42.

Different spacings, weed management practices and their interaction did not influence the relative frequency of sedges significantly.

4.2.6 Summed dominance ratio

SDR was calculated at 20, 40 and 60 DAS for grasses, broadleaved weeds and sedges.

Table 39 Effect of spacings and weed management practices on relative frequency of broadleaved weeds at different periods of observation

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean S
s_1	40.73 (6.46)	31.95 (5.74)	32.52 (5.79)	34.96 (6.00)
s_2	40.34 (6.43)	33.46 (5.87)	32.87 (5.82)	35.48 (6.04)
s_3	38.69 (6.30)	29.91 (5.56)	33.11 (5.84)	33.81 (5.90)
				Mean W
w_1	46.20 (6.87)	30.58 (5.62)	29.58 (5.53)	35.08 (6.01)
w_2	40.22 (6.42)	33.34 (5.86)	33.34 (5.86)	3.5.56 (6.05)
w_3	43.49 (6.67)	31.49 (5.70)	32.99 (5.83)	3.5.80 (6.07)
w_4	35.00 (6.00)	90.97 (9.59)	34.40 (5.95)	50.55 (7.18)
w_5	35.48 (6.04)	33.34 (5.86)	34.05 (5.92)	34.28 (5.94)
Mean P	39.94 (6.40)	37.75 (6.23)	32.84 (5.82)	

Table 40 Interaction effect of spacings and weed management practices at different periods of observation on relative frequency of broadleaved weeds

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean SW
$s_1 w_1$	48.14 (7.01)	31.38 (5.69)	24.81 (5.08)	34.13 (5.93)
$s_1 w_2$	40.22 (6.42)	31.26 (5.68)	33.34 (5.86)	34.84 (5.99)
$s_1 w_3$	46.61 (6.90)	31.72 (5.72)	34.28 (5.94)	37.27 (6.19)
$s_1 w_4$	35.36 (6.03)	32.18 (5.76)	35.60 (6.05)	34.36 (5.95)
$s_1 w_5$	34.28 (5.94)	33.34 (5.86)	35.48 (6.04)	34.36 (5.95)
$s_2 w_1$	48.14 (7.01)	33.22 (5.85)	32.18 (5.76)	37.52 (6.21)
$s_2 w_2$	37.56 (6.21)	34.28 (5.94)	33.34 (5.86)	35.04 (6.00)
$s_2 w_3$	46.20 (6.87)	34.28 (5.94)	31.26 (5.68)	36.99 (6.16)
$s_2 w_4$	34.28 (5.94)	32.18 (5.76)	34.28 (5.94)	33.57 (5.88)
$s_2 w_5$	36.58 (6.13)	33.34 (5.86)	33.34 (5.86)	34.40 (5.95)
$s_3 w_1$	42.30 (6.58)	27.41 (5.33)	32.18 (5.76)	33.69 (5.89)
$s_3 w_2$	42.96 (6.63)	34.28 (5.94)	33.34 (5.86)	36.74 (6.14)
$s_3 w_3$	37.94 (6.24)	28.48 (5.43)	33.34 (5.86)	33.14 (5.84)
$s_3 w_4$	35.36 (6.03)	26.56 (5.25)	33.34 (5.86)	31.64 (5.71)
$s_3 w_5$	35.48 (6.04)	33.34 (5.86)	33.34 (5.86)	34.05 (5.92)

	S	W	SW	P	SP	WP	SWP
F	0.96	1.84	1.23	55.80**	1.13	6.93**	1.21
SE	0.07	0.06	0.11	0.05	0.08	0.11	0.19
CD	NS	NS	NS	0.14	NS	0.31	NS

Figures in parenthesis are the transformed values

** significant at 1 per cent level.

Table 41 Effect of spacings and weed management practices on relative frequency of sedges at different periods of observation

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean S
s_1	40.73 (6.46)	38.69 (6.30)	37.07 (6.17)	38.82 (6.31)
s_2	37.81 (6.23)	36.95 (6.16)	34.88 (5.99)	36.54 (6.13)
s_3	39.45 (6.36)	38.31 (6.27)	34.40 (5.95)	37.36 (6.19)
				Mean W
w_1	44.43 (6.74)	41.64 (6.53)	40.47 (6.44)	42.16 (6.57)
w_2	40.22 (6.42)	37.81 (6.23)	33.34 (5.86)	37.07 (6.17)
w_3	42.16 (6.57)	41.38 (6.51)	35.12 (6.01)	39.49 (6.36)
w_4	35.00 (6.00)	35.72 (6.06)	34.40 (5.95)	35.04 (6.00)
w_5	35.48 (6.04)	33.34 (5.86)	34.05 (5.92)	34.28 (5.94)
Mean P	39.35 (6.35)	37.94 (6.24)	35.44 (6.04)	

Table 42 Interaction effect of spacings and weed management practices at different periods of observation on relative frequency of sedges

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean SW
$s_1 w_1$	48.14 (7.01)	43.22 (6.65)	43.49 (6.67)	44.92 (6.78)
$s_1 w_2$	40.22 (6.42)	34.28 (5.94)	33.34 (5.86)	35.89 (6.07)
$s_1 w_3$	46.61 (6.90)	48.14 (7.01)	37.94 (6.24)	44.11 (6.72)
$s_1 w_4$	35.36 (6.03)	35.36 (6.03)	35.48 (6.04)	35.40 (6.03)
$s_1 w_5$	34.28 (5.94)	33.34 (5.86)	35.48 (6.04)	34.36 (5.95)
$s_2 w_1$	39.07 (6.33)	40.22 (6.42)	30.70 (5.63)	36.54 (6.13)
$s_2 w_2$	37.56 (6.21)	37.94 (6.24)	33.34 (5.86)	36.25 (6.10)
$s_2 w_3$	42.03 (6.56)	37.94 (6.24)	34.28 (5.94)	38.02 (6.25)
$s_2 w_4$	34.28 (5.94)	35.36 (6.03)	34.28 (5.94)	34.64 (5.97)
$s_2 w_5$	36.58 (6.13)	33.34 (5.86)	33.34 (5.86)	34.40 (5.95)
$s_3 w_1$	46.20 (6.87)	41.64 (6.53)	38.94 (6.32)	42.21 (6.57)
$s_3 w_2$	42.96 (6.63)	41.51 (6.52)	33.34 (5.86)	39.15 (6.34)
$s_3 w_3$	37.94 (6.24)	38.69 (6.30)	33.34 (5.86)	36.62 (6.13)
$s_3 w_4$	35.36 (6.03)	36.58 (6.13)	33.34 (5.86)	35.08 (6.01)
$s_3 w_5$	35.48 (6.04)	33.34 (5.86)	33.34 (5.86)	34.05 (5.92)

	S	W	SW	P	SP	WP	SWP
F	3.37	13.78**	1.96	12.79**	0.52	2.02	0.67
SE	0.05	0.07	0.11	0.04	0.08	0.10	0.17
CD	NS	0.20	NS	0.13	NS	NS	NS

Figures in parenthesis are the transformed values

** significant at 1 per cent level.

4.2.6.1 SDR of gasses

The results are presented in Tables 43 and 44.

Different spacing did not influence the SDR of grasses significantly .

The weed management treatments revealed the following results. At 20 DAS w_1 registered the lowest SDR of grasses followed by w_3 and w_2. w_4 recorded the highest value and it was on par with unweeded check (w_5). At 40 DAS w_4 registered the highest SDR of grasses and the rest of the treatments were on par. The effect of weed management practices on SDR of grasses was not significant at 60 DAS.

The interaction effect was not significant with respect to SDR of grasses.

4.1.6.2 SDR of broadleaved weeds

The results are presented in Tables 45 and 46.

Different spacing adopted caused a significant variation in the SDR of broadleaved weeds. At 20 DAS s_2 registered the highest SDR of broadleaved weeds and the other two spacings were on par. At 40 DAS s_3 recorded the lowest SDR of broadleaved weeds and s_2 recorded the highest value, but both of them were on par with s_1. Plant spacing did not significantly influence the SDR of broadleaved weeds at 60 DAS.

The effect of weed management treatments on SDR of broadleaved weeds was significant at all periods of observation. At 20 DAS w_1 registered

Table 43 Effect of spacings and weed management practices on summed dominance ratio of grasses at different periods of observation

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean S
s_1	16.47 (4.18)	35.84 (6.07)	38.44 (6.28)	29.36 (5.51)
s_2	23.50 (4.95)	37.56 (6.21)	42.43 (6.59)	34.01 (5.92)
s_3	23.60 (4.96)	38.44 (6.28)	43.36 (6.66)	34.60 (5.97)
				Mean W
w_1	7.53 (2.92)	35.00 (6.00)	38.31 (6.27)	24.64 (5.06)
w_2	23.30 (4.93)	36.82 (6.15)	44.29 (6.73)	34.24 (5.94)
w_3	14.52 (3.94)	32.29 (5.77)	40.09 (6.41)	27.87 (5.37)
w_4	33.93 (5.91)	42.03 (6.56)	39.83 (6.39)	38.52 (6.29)
w_5	32.41 (5.78)	40.73 (6.46)	44.70 (6.76)	39.11 (6.33)
Mean P	21.05 (4.70)	37.29 (6.19)	41.40 (6.51)	

Table 44 Interaction effect of spacings and weed management practices at different periods of observation on summed dominance ratio of grasses

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean SW
s_1 w_1	2.76 (1.94)	31.26 (5.68)	40.09 (6.41)	20.87 (4.68)
s_1 w_2	21.85 (4.78)	43.09 (6.64)	42.43 (6.59)	35.04 (6.00)
s_1 w_3	4.57 (2.36)	25.94 (5.19)	33.93 (5.91)	19.13 (4.49)
s_1 w_4	33.11 (5.84)	39.96 (6.40)	36.82 (6.15)	36.58 (6.13)
s_1 w_5	34.52 (5.96)	40.22 (6.42)	39.20 (6.34)	37.14 (6.24)
s_2 w_1	11.39 (3.52)	36.95 (6.16)	38.44 (6.28)	27.30 (5.32)
s_2 w_2	29.58 (5.53)	36.70 (6.14)	42.16 (6.57)	35.97 (6.08)
s_2 w_3	16.72 (4.21)	34.52 (5.96)	45.10 (6.79)	30.96 (5.65)
s_2 w_4	34.64 (5.97)	40.34 (6.43)	39.83 (6.39)	38.23 (6.26)
s_2 w_5	29.14 (5.49)	39.70 (6.38)	47.44 (6.96)	38.40 (6.28)
s_3 w_1	9.82 (3.29)	36.70 (6.14)	36.70 (6.14)	25.95 (5.19)
s_3 w_2	18.98 (4.47)	31.26 (5.68)	48.56 (7.04)	31.83 (5.73)
s_3 w_3	26.56 (5.25)	36.95 (6.16)	41.64 (6.53)	34.76 (5.98)
s_3 w_4	33.93 (5.91)	45.92 (6.85)	43.09 (6.64)	40.82 (6.47)
s_3 w_5	33.69 (5.89)	42.43 (6.59)	47.58 (6.97)	41.03 (6.48)

	S	W	SW	P	SP	WP	SWP
F	3.56	11.52**	1.48	73.42**	0.83	6.34**	1.04
SE	0.13	0.17	0.29	0.11	0.20	0.25	0.44
CD	NS	0.48	NS	0.32	NS	0.71	NS

Figures in parenthesis are the transformed values

** significant at 1 per cent level.

Table 45 Effect of spacings and weed management practices on summed dominance ratio of broadleaved weeds at different periods of observation

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean S
s_1	66.57 (8.22)	42.96 (6.63)	44.29 (6.73)	50.74 (7.19)
s_2	72.44 (8.57)	45.24 (6.80)	44.29 (6.73)	53.27 (7.37)
s_3	66.40 (8.21)	38.19 (6.26)	44.97 (6.78)	49.17 (7.08)
				Mean W
w_1	79.64 (8.98)	42.03 (6.56)	38.44 (6.28)	51.90 (7.27)
w_2	67.39 (8.27)	40.09 (6.41)	45.24 (6.80)	50.27 (7.16)
w_3	73.30 (8.62)	40.60 (6.45)	43.22 (6.65)	51.42 (7.24)
w_4	61.41 (7.90)	38.69 (6.30)	46.75 (6.91)	48.51 (7.04)
w_5	61.41 (7.90)	49.41 (7.10)	49.13 (7.08)	53.17 (7.38)
Mean P	68.45 (8.33)	42.08 (6.56)	44.50 (6.75)	

Table 46 Interaction effect of spacings and weed management practices at different periods of observation on summed dominance ratio of broadleaved weeds

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean SW
s_1 w_1	84.19 (9.23)	47.72 (6.98)	30.92 (5.65)	52.10 (7.29)
s_1 w_2	59.06 (7.75)	38.19 (6.26)	46.06 (6.86)	47.40 (6.96)
s_1 w_3	72.62 (8.58)	39.70 (6.38)	43.36 (6.66)	50.94 (7.21)
s_1 w_4	59.22 (7.76)	40.47 (6.44)	50.70 (7.19)	49.84 (7.13)
s_1 w_5	59.53 (7.78)	49.55 (7.11)	52.14 (7.29)	53.66 (7.39)
s_2 w_1	84.75 (9.26)	47.30 (6.95)	43.49 (6.67)	57.17 (7.63)
s_2 w_2	70.23 (8.44)	43.09 (6.64)	44.70 (6.76)	52.00 (7.28)
s_2 w_3	77.68 (8.87)	45.51 (6.82)	40.47 (6.44)	53.42 (7.38)
s_2 w_4	65.75 (8.17)	39.96 (6.40)	45.51 (6.82)	49.84 (7.13)
s_2 w_5	64.45 (8.09)	50.98 (7.21)	47.44 (6.96)	54.06 (7.42)
s_3 w_1	70.06 (8.43)	32.06 (5.75)	41.38 (6.51)	46.56 (6.90)
s_3 w_2	73.13 (8.61)	39.20 (6.34)	45.10 (6.79)	51.51 (7.25)
s_3 w_3	69.73 (8.41)	36.82 (6.15)	46.06 (6.86)	49.98 (7.14)
s_3 w_4	59.37 (7.77)	35.72 (6.06)	44.70 (6.76)	46.11 (6.86)
s_3 w_5	60.31 (7.83)	48.00 (7.00)	47.86 (6.99)	51.90 (7.27)

	S	W	SW	P	SP	WP	SWP
F	9.57*	2.69	1.66	372.60**	3.85**	14.41**	2.56**
SE	0.05	0.07	0.13	0:05	0.09	0.11	0.19
CD	0.18	NS	NS	0.14	0.25	0.32	0.55

Figures in parenthesis are the transformed values

* significant at 5 per cent level ** significant at 1 per cent level.

the highest SDR of broadleaved weeds followed by w_3 and w_2. w_4 and w_5 were on par and showed significant reduction in SDR of broadleaved weeds. At 40 DAS unweeded check registered the highest SDR of broadleaved weeds and all the treatments recorded more or less the same value. At 60 DAS the lowest SDR of broadleaved weeds was recorded by w_1 followed by w_3. The rest of the treatments were on par.

The interaction effect was significant with respect to SDR of broadleaved weeds. The treatment combinations of s_1w_1, s_2w_1, s_2w_3, and s_2w_5 and s_3w_5 registered the highest SDR of broadleaved weeds at 20DAS and the lowest value was recorded at 60DAS. The rest of the treatment combinations recorded the highest SDR of broadleaved weeds at 20DAS and the lowest at 40 DAS.

4.1.6.3 SDR of sedges

The results are presented in Tables 47 and 48.

The effect of spacing on SDR of sedges was significant. At 20 DAS s_1 recorded the highest SDR of sedges and s_2 recorded the lowest value. At 40 DAS s_2 registered the lowest SDR of sedges and s_3 recorded the highest and both of them were on par with s_1. At 60 DAS s_3 resulted in the lowest SDR of sedges and it was on par with s_2. The highest SDR of sedges was recorded at s_1 and it was also on par with w_2.

The weed management treatments significantly influenced the SDR of sedges. At 20 DAS the weed management practices did not significantly influence the SDR of sedges. At 40 DAS unweeded check (w_5) recorded the

Table 47 Effect of spacings and weed management practices on summed dominance ratio of sedges at different periods of observation

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean S
s_1	62.20 (7.95)	70.40 (8.45)	66.24 (8.20)	66.24 (8.20)
s_2	51.85 (7.27)	66.73 (8.23)	63.00 (8.00)	60.36 (7.83)
s_3	57.68 (7.66)	72.27 (8.56)	61.25 (7.89)	63.59 (8.04)
				Mean W
w_1	58.75 (7.73)	72.27 (8.56)	72.62 (8.58)	67.72 (8.29)
w_2	58.29 (7.70)	72.44 (8.57)	60.31 (7.83)	63.53 (8.03)
w_3	58.60 (7.72)	76.09 (8.78)	66.24 (8.20)	66.79 (8.23)
w_4	54.35 (7.44)	68.89 (8.36)	63.00 (8.00)	61.94 (7.93)
w_5	55.70 (7.53)	59.68 (7.79)	56.00 (7.55)	57.12 (7.62)
Mean P	57.14 (7.63)	69.77 (8.41)	63.50 (8.03)	

Table 48 Interaction effect of spacings and weed management practices at different periods of observation on summed dominance ratio of sedges

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean SW
$s_1 w_1$	60.94 (7.87)	70.74 (8.47)	78.74 (8.93)	69.95 (8.42)
$s_1 w_2$	68.22 (8.32)	68.56 (8.34)	61.41 (7.90)	66.02 (8.19)
$s_1 w_3$	68.89 (8.36)	84.01 (9.22)	72.10 (8.55)	74.86 (8.71)
$s_1 w_4$	57.37 (7.64)	69.39 (8.39)	61.88 (7.93)	62.79 (7.99)
$s_1 w_5$	55.85 (7.54)	60.15 (7.82)	58.44 (7.71)	58.14 (7.69)
s2w1	49.27 (7.09)	65.59 (8.16)	67.89 (8.30)	60.62 (7.85)
$s_2 w_2$	49.98 (7.14)	70.06 (8.43)	63.32 (8.02)	60.83 (7.86)
$s_2 w_3$	55.25 (7.50)	69.73 (8.41)	64.45 (8.09)	63.00 (8.00)
$s_2 w_4$	49.41 (7.10)	69.56 (8.40)	64.61 (8.10)	60.88 (7.87)
$s_2 w_5$	55.85 (7.54)	59.37 (7.77)	55.10 (7.49)	56.76 (7.60)
$s_3 w_1$	67.06 (8.25)	80.90 (9.05)	71.42 (8.51)	73.02 (8.60)
$s_3 w_2$	57.52 (7.65)	79.10 (8.95)	56.30 (7.57)	63.91 (8.06)
$s_3 w_3$	52.44 (7.31)	74.86 (8.71)	62.20 (7.95)	62.84 (7.99)
$s_3 w_4$	56.61 (7.59)	67.89 (8.30)	62.36 (7.96)	62.20 (7.95)
$s_3 w_5$	55.55 (7.52)	59.53 (7.78)	54.35 (7.44)	56.46 (7.58)

	S	W	SW	P	SP	WP	SWP
F	37.56**	12.16**	2.76*	65.62**	4.76**	4.23**	1.60
SE	0.03	0.08	0.13	0.05	0.08	0.11	0.19
CD	0.12	0.22	0.38	0.14	0.24	0.30	NS

Figures in parenthesis are the transformed values

* significant at 5 per cent level ** significant at 1 per cent level.

lowest SDR of sedges and w_3 registered the highest. The rest of the treatments were on par. At 60 DAS w_1 resulted in the highest SDR of sedges. The lowest value was recorded by unweeded check and it was on par with w_2.

4.2.7 Weed control efficiency

Weed control efficiency of grasses, broadleaved weeds and sedges were recorded at 20, 40 and 60 DAS.

4.2.7.1 Weed control efficiency of grasses

The results are presented in Tables 49 and 50.

At 20 DAS the spacing treatments did not influence the weed control efficiency of grasses significantly. The effect of weed management treatments on weed control efficiency of grasses was significant at 20 DAS. The plots treated with pendimethalin and a HW at three weeks after sowing recorded the highest weed control efficiency of grasses with a mean value of 91.93. The lowest weed control efficiency was registered by w_2 and this treatment was on par with w_3 with respect to weed control efficiency of grasses. The interaction effect did not influence the weed control efficiency of grasses significantly at 20 DAS.

At 40 DAS different spacings adopted significantly influence the weed control efficiency of grasses. The lowest grass weed control efficiency was observed in plots sown at 15 x 10 cm spacing (s_1) with a mean value of 45.72. This treatment was on par with s_2 but lower than s_3, which recorded the highest weed control efficiency of grasses (78.35). The weed management

Table 49 Effect of spacings and weed management practices on weed control efficiency of grasses at different periods of observation

Treatment	20 DAS	40 DAS	60 DAS
s_1	77.94	45.72	46.70
s_2	63.08	51.30	73.47
s_3	74.80	78.35	64.10
F	4.38	7.05*	0.86
CD	NS	17.43	NS
w_1	91.93	72.45	69.84
w_2	55.18	36.43	37.01
w_3	68.71	68.89	65.97
w_4	-	42.71	59.54
F	5.10*	21.27**	6.80**
CD	57.27	12.43	16.73

Table 50 Effect of treatment combination on weed control efficiency of grasses at different periods of observation

Treatment	20 DAS	40 DAS	60 DAS
s_1w_1	97.77	73.68	47.97
s_1w_2	59.93	-7.44	21.13
s_1w_3	76.19	79.58	66.55
s_1w_4	-	37.04	51.15
s_2w_1	86.54	69.37	76.71
s_2w_2	30.81	42.43	46.13
s_2w_3	71.89	57.30	62.85
s_2w_4	-	36.08	68.18
s_3w_1	91.55	74.30	84.85
s_3w_2	74.80	74.30	77.09
s_3w_3	58.04	69.80	68.52
s_3w_4	-	55.01	59.29
F	1.09	9.90**	0.90
CD	NS	20.30	NS

* significant at 5 per cent level ** significant at 1 per cent level.

treatments also significantly affected the weed control efficiency of grasses at 40 DAS. The lowest grass weed control efficiency of 36.43 was observed in plots treated with fluchloralin and a HW at three weeks after sowing (w_2). This treatment was on par with w_4 but significantly lower than the rest of treatments. w_1 recorded the highest weed control efficiency of grasses at 40 DAS (72.45) and it was on par with w_3 but higher than rest of the treatments. SW interaction also significantly influenced the weed control efficiency of grasses. s_1w_2 recorded the lowest weed control efficiency of grasses (-7.44) at 40 DAS. The highest grass weed control efficiency of 79.58 was recorded by s_1s_3 and it was on par with s_1w_1, s_2w_1, s_3w_1, s_3w_2 and s_3w_3.

At 60 DAS the spacing treatments did not significantly influence the weed control efficiency of grasses. The weed management treatments influenced the grass weed control efficiency significantly at 60 DAS. w_2 registered the lowest grass weed control efficiency of 37.01. The other treatments were on par with each other with respect to weed control efficiency of grasses. The interaction effect of spacing and weed management practices on grass weed control efficiency was not significant at 60 DAS.

4.7.2 Weed control efficiency of broadleaved weeds

The results are presented in Tables 51 and 52.

At 20 DAS, different spacings, weed management treatments and their interaction significantly influenced the weed control efficiency of broadleaved weeds. Among different spacings the widest spacing of 20 x 15 cm (s_3) recorded the lowest weed control efficiency of broadleaved weeds (30.02). s_2

Table 51 Effect of spacings and weed management practices on weed control efficiency of broadleaved weeds at different periods of observation

Treatment	20 DAS	40 DAS	60 DAS
s_1	38.66	71.52	66.47
s_2	49.90	75.93	57.88
s_3	30.02	81.02	63.78
F	13.07*	1.26	1.12
CD	10.83	NS	NS
w_1	39.88	79.13	80.50
w_2	46.15	75.17	49.55
w_3	32.55	74.61	63.66
w_4	-	75.71	57.23
F	5.93*	0.68	10.29**
CD	8.61	NS	12.24

Table 52 Effect of treatment combination on weed control efficiency of broadleaved weeds at different periods of observation

Treatment	20 DAS	40 DAS	60 DAS
s_1w_1	30.63	66.83	88.72
s_1w_2	57.66	66.83	46.58
s_1w_3	27.70	81.15	70.33
s_1w_4	-	71.30	60.24
s_2w_1	54.84	80.30	70.96
s_2w_2	52.05	74.67	41.13
s_2w_3	43.47	71.20	65.66
s_2w_4	-	77.54	53.74
s_3w_1	34.16	72.60	81.83
s_3w_2	29.40	84.02	60.62
s_3w_3	26.49	71.48	55.00
s_3w_4	-	78.30	57.68
F	3.91*	3.97*	1.16
CD	14.90	12.75	NS

* significant at 5 per cent level ** significant at 1 per cent level.

recorded the highest broadleaved weed control efficiency of 49.90. Among the various weed control methods (subplot treatments) the lowest weed control efficiency of broadleaved weeds (32.55) was recorded by w_3 and it was on par with w_1 (39.88) but significantly lower than w_2 (46.15). w_2 and w_1 were on par with each other with respect to weed control efficiency of broadleaved weeds. The influence of interaction on weed control efficiency of broadleaved weeds was significant at 20 DAS. The lowest broadleaved weed control efficiency of 26.49 was recorded at s_3w_3 (26.49) and it was on par with all other treatments except s_1w_2, s_2w_1, s_2w_2 and s_2w_3.

At 40 DAS the spacing and weed management treatments did not significantly influence the weed control efficiency of broadleaved weeds.

At 60 DAS the spacing treatments and its interaction with weed management treatments did not influence the broadleaved weed control efficiency significantly. The weed control treatments significantly affected the broadleaved weed control efficiency. w_1 recorded the highest broadleaved weed control efficiency of 80.50. The lowest weed control efficiency of broadleaved weeds as recorded by w_2 (49.55) and it was on par with w_4 (57.23) but significantly lower than the other treatments.

4.2.7.3 Weed control efficiency of sedges

The results are presented in Tables 53 and 54.

At 20 DAS the spacing treatments significantly influenced the sedge weed control efficiency. The highest sedge weed control efficiency of 69.74 was recorded by s_2. This treatment was on par with s_3 but higher than s_1. The

Table 53 Effect of spacings and weed management practices on weed control efficiency of sedges at different periods of observation

Treatment	20 DAS	40 DAS	60 DAS
s_1	44.59	21.47	28.41
s_2	69.74	43.03	22.02
s_3	52.06	25.24	35.08
F	9.86*	5.22	0.91
CD	16.15	NS	NS
w_1	63.76	47.40	35.11
w_2	52.11	38.86	23.29
w_3	50.51	25.47	24.27
w_4	-	32.93	31.33
F	2.24	11.46**	3.80*
CD	NS	12.33	8.64

Table 54 Effect of treatment combination on weed control efficiency of sedges at different periods of observation

Treatment	20 DAS	40 DAS	60 DAS
s_1w_1	73.81	49.88	18.19
s_1w_2	29.60	-6.40	22.56
s_1w_3	30.36	20.40	22.03
s_1w_4	-	22.01	50.84
s_2w_1	81.61	71.76	42.38
s_2w_2	66.79	29.65	1.16
s_2w_3	60.82	41.77	21.59
s_2w_4	-	28.94	22.93
s_3w_1	35.88	20.55	44.76
s_3w_2	59.96	18.33	46.16
s_3w_3	60.35	14.24	29.20
s_3w_4	-	47.83	20.21
F	5.67**	5.53**	11.26**
CD	25.79	21.35	14.97

* significant at 5 per cent level ** significant at 1 per cent level.

lowest sedge weed control efficiency of 44.59 was recorded at the closest spacing of 15 x 10 cm (s_1), which was on par with s_3 but lower than s_2. The weed control treatments did not have any significant effect on the sedge weed control efficiency at 20 DAS. The interaction effect was significant with respect to sedge weed control efficiency at 20 DAS. The lowest sedge weed control efficiency of 29.60 was recorded by the treatment combination s_1w_2. This treatment was on par with s_1w_3 and s_3w_1 but lower than rest of the treatments. s_2w_1 recorded the highest sedge weed control efficiency (81.61) and it was on par with s_1w_1 and s_2w_2 but higher than all other treatments.

At 40 DAS the spacing treatments did not significantly influence the sedge weed control efficiency. The influence of weed management treatments on sedge weed control efficiency was significant at 40 DAS. The lowest sedge weed control efficiency of 25.47 was recorded by w_3, which was on par with w_4 but lower than rest of the treatments. w_1 (47.40) and w_2 (38.86) were on par with each other with respect to sedge weed control efficiency but they were superior to rest of the treatments. The interaction effect had significant influence on sedge weed control efficiency at 40 DAS. s_1w_2 recorded the lowest sedge weed control efficiency (-6.40). This treatment was on par with s_3w_3 but was significantly lower than rest of the treatments. s_2w_1 recorded the highest sedge weed control efficiency of 71.76.

At 60 DAS different spacings and their interaction with weed management practices did not significantly influence the sedge weed control efficiency. The effect of subplot treatments on the sedge weed control efficiency was significant at 60 DAS. w_2 recorded the lowest sedge weed control efficiency of 23.29, which was on par with all the treatments except w_1 (35.11).

4.2.7.4 Total weed control efficiency

The results are presented in Tables 55 and 56.

The influence of spacing on total weed control efficiency was significant at 20 and 40 DAS. At 20 DAS s_2 recorded the highest total weed control efficiency of 56.48. s_1 and s_3 were on par with each other with respect to total weed control efficiency. At 40 DAS the closest spacing of 15 x 10 cm (s_1) recorded the lowest total weed control efficiency. s_2 and s_3 registered total weed control efficiencies of 56.47 and 49.64 respectively. These treatments were on par with each other with respect to total weed control efficiency but were significantly higher than s_1. The spacing treatments did not result in any significant variation in total weed control efficiency at 60 DAS.

Spacing treatments significantly influenced the total weed control efficiency at all stages of observation. At 20 DAS, w_3 recorded the lowest total weed control efficiency of 43.50. w_1 and w_2 were on par with respect to total weed control efficiency. At 40 DAS w_1 recorded the highest total weed control efficiency of 62.19. The lowest total weed control efficiency was recorded by w_2 (38.07) and it was on par with w_4. At 60 DAS w_1 and w_2 registered the highest and the lowest total weed control efficiencies with mean values of 63.33 and 37.60 respectively.

Table 55 Effect of spacings and weed management practices on weed control efficiency of all weeds at different periods of observation

Treatment	20 DAS	40 DAS	60 DAS
s_1	46.71	39.50	49.19
s_2	16.48	56.47	44.77
s_3	40.71	49.64	53.23
F	10.49*	16.98**	1.14
CD	12.28	8.13	NS
w_1	52.76	62.19	63.33
w_2	51.64	38.07	37.60
w_3	43.50	48.47	46.60
w_4	-	45.43	48.65
F	11.50**	15.12**	15.75**
CD	4.59	7.71	7.99

Table 56 Effect of treatment combination on weed control efficiency of all weeds at different periods of observation

Treatment	20 DAS	40 DAS	60 DAS
s_1w_1	73.81	60.51	62.26
s_1w_2	29.60	18.20	32.79
s_1w_3	30.36	48.97	46.20
s_1w_4	0.00	30.33	55.51
s_2w_1	81.61	75.05	60.38
s_2w_2	66.79	48.03	28.60
s_2w_3	60.82	54.88	44.32
s_2w_4	0.00	47.92	45.51
s_3w_1	35.88	51.02	67.35
s_3w_2	59.96	47.99	51.40
s_3w_3	60.35	41.55	49.28
s_3w_4	0.00	58.01	44.93
F	5.67**	6.46**	1.98
CD	25.79	13.36	NS

* significant at 5 per cent level ** significant at 1 per cent level.

The interaction effect influenced the total weed control efficiency significantly at 20 and 40 DAS. At 20 DAS s_1w_2 recorded the lowest total weed control efficiency of 29.60 and it was on par with s_1w_3 and s_3w_1. The highest total weed control efficiency of 73.81 was recorded by s_1w_1. This treatment combination was on par with all the treatment combinations except s_1w_2, s_1w_3 and s_3w_1. At 40 DAS s_1w_2 recorded the lowest total weed control efficiency (18.20), which was on par with s_1w_4. The treatment combination s_2w_1 recorded the highest total weed control efficiency of 75.05. The influence of SW interaction on total weed control efficiency was not significant at 60 DAS.

4.2.8 Weed dry weight

The results are presented in Tables 57 and 58.

The spacing treatments did not significantly influence the weed dry weight.

The effect of weed control treatments on weed dry weight was significant. At 20 DAS w_1 registered the lowest weed dry weight and it was on par with w_2 and w_3. The highest weed dry weight was recorded by w_4 and it was on par with unweeded check (w_5). At 40 DAS w_5 recorded the highest weed dry weight followed by w_2. The rest of the treatments were on par. At 60 DAS w_3 registered the lowest weed dry weight and it was on par with w_4. The highest weed dry weight was recorded by w_2 followed by w_5 and w_1.

The interaction did not significantly influence the weed dry weight.

Table 57 Effect of spacings and weed management practices on total weed dry weight at different periods of observation

Treatment	P_1 (20 DAS)	P_2 (40 DAS)	P_3 (60 DAS)	Mean S
s_1	39.06	41.33	94.19	58.19
s_2	27.79	42.22	98.51	56.17
s_3	31.34	45.17	92.43	56.31
				Mean w
w_1	18.93	12.59	29.20	20.24
w_2	22.62	63.41	231.61	105.88
w_3	26.38	15.67	13.47	18.51
w_4	48.82	15.83	14.68	26.44
w_5	46.91	107.04	169.25	107.73
Mean P	32.73	42.91	92.92	

Table 58 Interaction effect of spacings and weed management practices at different periods of observation on total weed dry weight

Treatment	P_1 (20 DAS)	P_2 (40 DAS)	P_3 (60 DAS)	Mean Ss
$s_1 w_1$	18.31	11.76	28.49	19.52
$s_1 w_2$	23.01	64.02	225.75	104.26
$s_1 w_3$	31.88	15.44	31.07	26.13
$s_1 w_4$	16.16	14.78	14.49	15.14
$s_1 w_5$	61.95	100.65	171.13	111.24
$s_2 w_1$	14.69	11.58	28.91	18.39
$s_2 w_2$	17.36	60.27	250.45	109.36
$s_2 w_3$	21.03	14.65	32.59	22.76
$s_2 w_4$	40.69	16.34	16.36	24.46
$s_2 w_5$	45.17	108.26	164.23	105.89
$s_3 w_1$	23.80	14.13	30.19	22.71
$s_3 w_2$	27.49	65.96	218.64	104.03
$s_3 w_3$	26.23	16.92	27.74	23.63
$s_3 w_4$	45.60	16.37	13.18	25.05
$s_3 w_5$	33.60	112.19	172.40	106.06

	S	W	SW	P	SP	WP	SWP
F	0.87	467.69**	0.54	323.50**	2.09	158.26**	1.00
SE	1.21	2.11	3.65	1.86	3.22	4.16	7.20
CD	NS	6.11	NS	5.23	NS	11.69	NS

* significant at 5 per cent level ** significant at 1 per cent level.

The weed dry weight varied significantly with respect to the time of observation. The highest weed dry weight of 92.92 g was recorded at P_3. P_1 registered the lowest weed dry weight of 32.73 g.

4.2.9 Weed index

The results are presented in Table 59.

The spacing treatments did not significantly influence the weed index.

The effect of herbicide treatments on weed index was significant. Unweeded check naturally recorded the highest weed index of 49.14. w_1, w_3 and w_4 were on par with each other with respect to weed index. They recorded the weed index of 10.63, 18.02 and 18.88 respectively.

The spacing-herbicide interaction did not significantly influence the weed index.

4.3 Chemical analysis

4.3.1 Nutrient uptake by the crop

NPK uptake by upland rice is presented in Tables 60 and 61.

4.3.1.1 Nitrogen uptake

Spacing treatments did not significantly influence the nitrogen uptake by the crop.

There was significant effect of herbicide treatment on nitrogen uptake by the crop. Weed free check (w_6) recorded significantly the highest N uptake

Table 59 Effect of spacings, weed management practices and their interaction on weed index

Treatment	weed Index
s_1	26.10
s_2	21.27
s_3	25.13
F	0.70
CD	NS
w_1	10.63
w_3	18.02
w_4	18.88
w_5	49.14
F	18.36*
CD	12.16
s_1w_1	8.2
s_1w_3	22.92
s_1w_4	20.21
s_1w_5	53.09
s_2w_1	7.65
s_2w_3	5.72
s_2w_4	17.84
s_2w_5	53.87
s_3w_1	16.04
s_3w_3	25.43
s_3w_4	18.59
s_3w_5	40.47
F	1.19
CD	NS

* significant at 5 per cent level ** significant at 1 per cent level.

Table 60 Effect of spacing and weed management practices on crop NPK uptake

Treatment	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})
s_1	64.48	27.91	74.55
s_2	70.23	31.19	79.10
s_3	69.77	29.53	78.30
F	6.58	7.33*	2.97
CD	NS	2.38	NS
w_1	71.21	30.11	80.72
w_3	68.38	29.15	76.90
w_4	67.35	28.51	76.85
w_5	63.66	24.45	94.16
w_6	80.18	35.51	87.95
F	33.69**	22.20**	30.86**
CD	4.80	2.46	5.53

*significant at 5 per cent level **significant at 1 per cent level

Table 61 Interaction effect of spacing and weed management practices on crop NPK uptake

Treatment	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})
$s_1 w_1$	70.12	29.05	18.31
$s_1 w_3$	61.80	25.85	23.01
$s_1 w_4$	63.61	26.91	31.88
$s_1 w_5$	50.59	24.03	60.16
$s_1 w_6$	76.26	33.70	61.95
$s_2 w_1$	74.26	32.24	14.69
$s_2 w_3$	75.83	33.41	17.36
$s_2 w_4$	70.60	30.15	21.03
$s_2 w_5$	49.75	24.11	40.69
$s_2 w_6$	80.69	36.05	45.17
$s_3 w_1$	69.25	29.02	23.80
$s_3 w_3$	67.52	28.19	27.49
$s_3 w_4$	67.85	28.48	26.23
$s_3 w_5$	60.65	25.22	45.60
$s_3 w_6$	83.57	36.77	33.60
F	2.11	1.24	1.58
CD	NS	NS	NS

by the crop (80.18 kg ha^{-1}). Weedy check (w_5) recorded the lowest N uptake (63.66 kg ha^{-1}), which was on par with w_4 and w_3, but significantly lower than w_1. The plots treated with pendimethalin followed by a HW at three weeks after sowing (w_1) recorded N uptake of 71.21 kg ha^{-1} and it was on par with w_3 and w_4. No interaction effect was observed between the spacing and weed management treatments.

4.3.1.2 Phosphorus uptake

Spacing treatments significantly influenced the P uptake by the crop. s_1 recorded the lowest P uptake of 27.91 kg ha^{-1} and it was on par with s_3 but was significantly lower than s_2. s_2 recorded the highest crop P uptake of 31.19 kg ha^{-1}.

The effect of weed management treatments on P uptake of the crop was significant. Weed free check (w_6) registered significantly the highest crop P uptake of 35.51 kg ha^{-1} and unweeded check (w_5) recorded significantly the lowest P uptake by the crop with a mean value of 24.45 kg ha^{-1}. w_3 and w_4 were on par with respect to crop P uptake. P uptake in all the treated plots was significantly higher than that at w_5.

Spacing-weed control treatment interaction did not have any effect on nitrogen uptake by the crop.

4.3.1.3 Potassium uptake

Spacing treatments did not influence the K uptake by the crop.

The herbicide treatments significantly influenced the crop K uptake and weed free check (w_6) recorded significantly the highest crop K uptake of 87.95 kg ha^{-1}. Un weeded check (w_5) registered significantly the lowest crop K uptake (64.16 kg ha^{-1}). w_1, w_3 and w_4 recorded a crop K uptake of 80.72, 76.90 and 76.85 kg ha^{-1} respectively and were on par with each other.

The interaction effect did not significantly influence the crop K uptake.

4.3.2 Nutrient uptake by weeds

NPK uptake by weeds were recorded at 20, 40 and 60 DAS.

4.3.2.1 Nitrogen uptake

The results are presented in Tables 62 and 63.

Main plot treatments did not significantly affect N uptake by weeds.

Different weed management strategies adopted (subplot treatments) significantly influenced the weed N uptake. At 20 DAS w_1 registered the lowest N uptake of weeds and it was more or less same as that of w_2 and w_3. w_4 resulted in the highest N uptake by weeds, which was on par with w_5. At 40 DAS unweeded check (w_5) registered the highest weed N uptake followed by w_2. The rest of the treatments were on par. At 60 DAS w_2 resulted in the highest weed N uptake followed by w_5. The lowest weed N uptake was recorded by w_4.

The interaction effect of spacing and weed control treatments did not significantly influence the N uptake by weeds.

Table 62 Effect of spacings and weed management practices on N uptake of weeds at different periods of observation

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean S
s_1	3.32	4.15	7.97	5.15
s_2	2.67	4.28	8.31	5.09
s_3	2.68	4.44	7.76	4.96
				Mean w
w_1	1.67	1.34	2.13	1.71
w_2	1.74	5.84	20.10	9.23
w_3	2.08	1.51	2.28	1.96
w_4	4.59	1.51	1.10	2.40
w_5	4.36	11.24	14.46	10.02
Mean P	2.89	4.29	8.01	

Table 63 Interaction effect of spacings, weed management practices and periods of observation on N uptake of weeds

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean SW
s_1 w_1	1.56	1.31	2.05	1.64
s_1 w_2	1.86	5.60	19.09	8.85
s_1 w_3	2.42	1.51	2.47	2.13
s_1 w_4	5.27	1.51	1.10	2.63
s_1 w_5	5.47	10.82	15.16	10.48
s_2 w_1	1.42	1.23	2.13	1.59
s_2 w_2	1.50	5.86	22.09	9.82
s_2 w_3	1.80	1.49	2.35	1.88
s_2 w_4	4.22	1.60	1.20	2.34
s_2 w_5	4.43	11.21	13.80	9.81
s_3 w_1	2.03	1.46	2.23	1.91
s_3 w_2	1.87	6.07	19.13	9.02
s_3 w_3	2.03	1.53	2.01	1.86
s_3 w_4	4.27	1.42	1.02	2.24
s_3 w_5	3.19	11.70	14.44	9.78

	S	W	SW	P	SP	WP	SWP
F	0.40	587.14**	1.32	471.52**	2.31	296.39**	1.73
SE	0.15	0.17	0.30	0.12	0.21	0.27	0.47
CD	NS	0.50	NS	0.34	NS	0.77	NS

* significant at 5 per cent level ** significant at 1 per cent level.

Nitrogen uptake by weeds was significantly influenced by the period of observation. p_1 and p_3 recorded significantly the lowest and the highest weed N uptake with mean values of 2.89 and 8.01 kg ha $^{-1}$ respectively.

4.3.2.2 Phosphorus uptake

The results are presented in Tables 64 and 65.

The spacing treatments significantly influenced the weed P uptake. At 20 DAS the highest weed P uptake was recorded at s_1 and the lowest at s_2. No significant difference in weed P uptake was observed at 40 DAS. At 60 DAS s_1 registered the highest P uptake by weeds and the other 2 spacings were on par.

The effect of spacing weed management interaction on weed P uptake was not significant. At 20 DAS w_2 registered the lowest weed P uptake and it was on par with w_1. Unweeded check recorded the highest weed P uptake, which was on par with w_4. At 40 DAS w_5 resulted in the highest weed P uptake followed by w_2. The other treatments were on par. At 60 DAS w_2 registered the highest weed P uptake followed by unweeded check (w_5) and w_4 recorded the lowest value.

The interaction effect of spacing and weed management treatments was not significant with respect to P uptake of weeds.

Time of observation significantly influenced the weed P uptake. p_3 recorded significantly the highest P uptake of weeds (1.85 kg ha^{-1}). p_1 and p_2 were on par with respect to weed P uptake.

Table 64 Effect of spacings and weed management practices on P uptake of weeds at different periods of observation

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean S
s_1	1.17	0.95	1.98	1.37
s_2	0.90	0.98	1.80	1.23
s_3	1.01	1.11	1.76	1.29
				Mean w
w_1	0.67	0.35	0.67	0.56
w_2	0.63	1.49	4.52	2.21
w_3	0.90	0.43	0.62	0.65
w_4	1.46	0.44	0.31	0.74
w_5	1.47	2.36	3.11	2.31
Mean P	1.03	1.01	1.85	

Table 65 Interaction effect of spacings and weed management practices at different periods of observation on p uptake of weeds

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean SW
$s_1 w_1$	0.69	0.32	0.78	0.60
$s_1 w_2$	0.72	1.45	5.08	2.42
$s_1 w_3$	0.96	0.41	0.67	0.68
$s_1 w_4$	1.70	0.41	0.32	0.81
$s_1 w_5$	1.78	2.17	3.04	2.33
$s_2 w_1$	0.54	0.32	0.61	0.49
$s_2 w_2$	0.58	1.42	4.40	2.13
$s_2 w_3$	0.73	0.41	0.62	0.59
$s_2 w_4$	1.23	0.45	0.34	0.67
$s_2 w_5$	1.44	2.30	3.01	2.25
$s_3 w_1$	0.79	0.41	0.61	0.60
$s_3 w_2$	0.60	1.60	4.07	2.09
$s_3 w_3$	1.02	0.46	0.57	0.68
$s_3 w_4$	1.44	0.45	0.27	0.72
$s_3 w_5$	1.19	2.62	3.28	2.36

	S	W	SW	P	SP	WP	SWP
F	11.76**	480.59**	1.11	202.86**	3.47*	187.29**	2.19*
SE	0.02	0.04	0.07	0.03	0.06	0.07	0.13
CD	0.08	0.12	NS	0.09	0.16	0.21	0.36

* significant at 5 per cent level ** significant at 1 per cent level.

4.3.2.3 Potassium uptake

The results are presented in Tables 66 and 67.

The various spacings tried did not significantly influence the K uptake of weeds.

The effect of weed management treatments on weed K uptake was significant. At 20 DAS w_1 registered the lowest K uptake of weeds and it was on par with w_2 and w_3. Unweeded check (w_5) and w_4 were on par and they recorded significantly higher weed K uptake than all the other treatments. At 40 DAS unweeded check recorded the highest K uptake of weeds followed by w_2. The rest of the treatments were on par and significantly lower than w_5 and w_2. At 60 DAS w_2 registered the highest weed K uptake followed by w_5. The lowest K uptake of weeds at this period was recorded by w_4.

The interaction effect significantly influenced the weed K uptake. The treatment combination of s_1w_1 registered the highest weed P uptake at 60 DAS and the lowest at 40 DAS. s_2w_1 showed no significant difference in weed P uptake at different periods of observation. s_1w_3, s_2w_3, s_3w_1 and s_3w_3 recorded the lowest weed P uptake at 40 DAS and the highest at 20 DAS. s_1w_4, s_2w_4 and s_3w_4 resulted in the lowest weed P uptake at 60 DAS and the highest at 20 DAS. All the other treatment combinations recorded the lowest weed P uptake at 20 DAS and the highest at 60 DAS.

Weed K uptake varied significantly with the period of observation (P). Significantly the lowest K uptake of weed (2.40 kg ha^{-1}) was recorded at 20 DAS (p_1). p_3 recorded significantly the highest weed K uptake (7.11 kg ha^{-1}).

Table 66 Effect of spacings and weed management practices on K uptake of weeds at different periods of observation

Treatment	p_1 (20 DAS)	p_2 (40 DAS)	p_3 (60 DAS)	Mean S
s_1	2.69	2.92	7.10	4.24
s_2	2.17	3.22	7.38	4.26
s_3	2.33	3.49	6.85	4.22
				Mean w
w_1	1.48	1.02	2.30	1.60
w_2	1.71	4.77	17.07	7.85
w_3	1.95	1.23	2.43	187
w_4	3.48	1.25	1.16	1.96
w_5	3.36	7.78	12.59	7.91
Mean P	2.40	3.21	7.11	

Table 67 Interaction effect of spacings and weed management practices at different periods of observation on K uptake of weeds

Treatment	p_1 20 DAS)	p_2 40 DAS)	p_3 60 DAS	Mean SW
s_1 w_1	1.29	0.94	2.29	1.51
s_1 w_2	1.65	4.44	16.34	7.48
s_1 w_3	2.21	1.21	2.50	1.97
s_1 w_4	4.19	1.16	1.16	2.17
s_1 w_5	4.12	6.87	13.21	8.07
s_2 w_1	1.21	0.93	2.28	1.47
s_2 w_2	1.43	4.29	18.76	8.16
s_2 w_3	1.64	1.15	2.58	1.79
s_2 w_4	3.08	1.27	1.30	1.88
s_2 w_5	3.51	8.45	11.99	7.98
s_3 w_1	1.94	1.18	2.35	1.82
s_3 w_2	2.04	5.59	16.09	7.91
s_3 w_3	2.00	1.33	2.20	1.84
s_3 w_4	3.18	1.31	1.02	1.84
s_3 w_5	2.47	8.02	12.57	7.69

	S	W	SW	P	SP	WP	SWP
F	0.04	426.46**	0.76	377.36**	2.18	172.80**	1.69
SE	0.09	0.16	0.28	0.13	0.23	0.29	0.50
CD	NS	0.47	NS	0.36	NS	0.82	NS

* significant at 5 per cent level ** significant at 1 per cent level.

4.4 Nutrient content of the soil after the experiment

NPK content of the soil after the experiment is presented in Tables 68 and 69.

4.4.1 Soil nitrogen content

The different spacings tried did not have any significant influence on the nitrogen content of the soil after the experiment.

The weed management treatments significantly influenced the nitrogen content of the soil after the experiment. The unweeded check (w_5) recorded significantly the lowest nitrogen content of the soil after the experiment (239.36 kg ha^{-1}). The highest soil nitrogen content after the experiment was observed in w_6 (261.51 kg ha^{-1}) and it was on par with w_3, w_4 and w_1.

The interaction significantly affected the nitrogen content of the soil after the experiment. The highest soil nitrogen content after the experiment was recorded by the treatment combination s_1w_3 (268.80 kg ha^{-1}). s_1w_5 recorded significantly the lowest nitrogen content of soil nitrogen content after the experiment.

4.4.2 Soil Phosphorus content

The effect of various spacings tried did not significantly influence the P content of the soil after the experiment.

The different weed control treatments influenced the soil P content after the experiment significantly. w_2 recorded the lowest P content of the soil after the experiment (83.75 kg ha^{-1}), which was on par with the unweeded

Table 68 Effect of spacing and weed management practices on NPK content of the soil after the experiment

Treatment	N	P	K
s_1	257.02	41.44	256.01
s_2	258.00	40.88	255.54
s_3	255.98	40.84	259.47
F	2.09	0.97	0.90
SE	6.29	0.48	0.90
CD	NS	NS	NS
w_1	258.26	87.00	258.26
w_2	250.94	83.75	250.94
w_3	265.96	86.03	265.96
w_4	261.98	85.76	261.98
w_5	239.36	84.56	239.36
w_6	265.51	87.05	265.52
F	19.53**	13.67**	5.60**
SE	4.40	0.73	0.55
CD	8.98	1.49	1.14

Table 69 Interaction effect of spacing and weed management practices on NPK content of the soil after the experiment

Treatment	N	P	K
$s_1 w_1$	260.35	41.08	86.63
$s_1 w_2$	251.99	40.85	82.58
$s_1 w_3$	268.80	42.59	85.63
$s_1 w_4$	263.95	42.43	85.84
$s_1 w_5$	227.70	37.52	84.91
$s_1 w_6$	263.25	44.17	86.56
$s_2 w_1$	261.83	42.56	87.30
$s_2 w_2$	246.03	36.13	82.94
$s_2 w_3$	263.92	41.28	85.50
$s_2 w_4$	258.13	41.36	86.00
$s_2 w_5$	237.18	40.58	84.63
$s_2 w_6$	266.12	43.35	87.37
$s_3 w_1$	252.60	42.11	87.08
$s_3 w_2$	254.80	38.76	85.72
$s_3 w_3$	265.16	42.07	86.96
$s_3 w_4$	263.84	41.36	85.46
$s_3 w_5$	253.21	38.49	84.15
$s_3 w_6$	267.17	42.62	87.21
F	2.53*	2.34*	0.90
SE	3.11	1.26	0.97
CD	6.34	2.57	NS

* significant at 5 per cent level

check (84.56 kg ha^{-1}). The highest soil P content after the experiment (87.05 kg ha^{-1}) was observed in weed free check (w_6) and it was on par with w_1, w_3 and w_4.

The interaction effect significantly influenced the soil P content after the experiment. s_2w_2 recorded the lowest P content of the soil after the experiment with a mean value of 36.13 kg ha^{-1}. s_1w_6 recorded the highest soil P content after the experiment (44.17 kg ha^{-1}).

4.4.3 Soil potassium content

The effect of different spacings of soil K content after the experiment was not significant.

The weed management treatment affected the soil K content after the experiment significantly. The unweeded check (w_5) recorded significantly the lowest soil K content after the experiment (239.36 kg ha^{-1}). w_3 recorded the highest soil K content after the experiment (265.96 kg ha^{-1}) and this was on par with the weed free check, which recorded 265.52 kg K ha^{-1} in the soil after the experiment.

The interaction effect of spacing and weed management treatments did not have any significant influence on the soil K content after the experiment.

4.5 Protein content of grains

The data on protein content of the grains is presented in Tables 70 and 71.

The difference in spacing did not have any significant influence the protein content of grains.

Table 70 Effect of spacing and weed management practices on grain protein content

Treatment	Grain protein content
s_1	3.92
s_2	3.87
s_3	3.90
F	2.29
SE	0.02
CD	NS
W_1	3.88
W_3	3.88
W_4	3.86
W_5	3.71
W_6	4.16
F	10.34**
SE	0.07
CD	0.14

**significant at 1 per cent level

Table 71 Interaction effect of spacing and weed management practices on grain protein content

Treatment	Grain protein content
$s_1 w_1$	3.90
$s_1 w_3$	3.96
$s_1 w_4$	3.87
$s_1 w_5$	3.74
$s_1 w_6$	4.14
$s_2 w_1$	3.84
$s_2 w_3$	3.85
$s_2 w_4$	3.82
$s_2 w_5$	3.72
$s_2 w_6$	4.14
$s_3 w_1$	3.89
$s_3 w_3$	3.84
$s_3 w_4$	3.88
$s_3 w_5$	3.67
$s_3 w_6$	4.21
F	0.19
SE	0.13
CD	NS

The weed management treatments significantly influenced the grain protein content. The highest protein content of grains was recorded in w_6 (4.16 per cent). This was significantly higher than all other treatments. Weedy check (w_5) registered significantly the lowest grain protein content of 3.71 per cent. w_1, w_3 and w_4 were on par with each other with respect to grain protein content.

The interaction effect did not have any significant influence on the grain protein content.

4.6 Residual effect of herbicides

Residual effect of herbicides on the succeeding crop was assessed by recording the germination percentage of cucumber seeds sown in herbicide treated plots after the harvest of the rice crop. The results are presented in Table 72.

The germination percentage of cucumber seeds was not significantly influenced by the residual effect of herbicides.

4.7 Economic analysis

The net returns and BC ratio were calculated and presented in Tables 73 and 74.

4.7.1 Net returns

Net returns were significantly influenced by the different treatments tried. The closest spacing of 15 x 10 cm recorded significantly the lowest net

Table 72 Residual effect of herbicides on germination percentage of cucumber seeds

Herbicide	Germination percentage
pendimethalin	75.00
Fluchloralin	74.00
Butachlor	74.67
Control	73.66
F	0.29

Table 73 Effect of spacing and weed management practices on net returns and benefit cost ratio

Treatment	Net returns	Benefit : Cost ratio
s_1	3083.55	1.18
s_2	7402.43	1.39
s_3	6907.28	1.37
F	9.77*	13.66*
SE	1069.45	0.04
CD	2968.80	0.12
w_1	11441.11	1.56
w_3	10128.11	1.53
w_4	6462.03	1.29
w_5	3973.47	1.27
w_6	-3019.94	0.92
F	24.38**	20.69**
SE	1645.53	0.07
CD	3396.38	0.16

*significant at 5 per cent level **significant at 1 per cent level

Table 74 Interaction effect of spacing and weed management practices on net returns and benefit cost ratio

Treatment	Net returns	Benefit : Cost ratio
$s_1 w_1$	9743.67	1.47
$s_1 w_3$	5885.17	1.31
$s_1 w_4$	4279.83	1.19
$s_1 w_5$	1076.25	1.07
$s_1 w_6$	-5567.17	0.86
$s_2 w_1$	13023.00	1.64
$s_2 w_3$	15797.92	1.82
$s_2 w_4$	7470.83	1.33
$s_2 w_5$	3044.67	1.21
$s_2 w_6$	-2324.25	0.94
$s_3 w_1$	11556.67	1.57
$s_3 w_3$	8701.25	1.45
$s_3 w_4$	7635.42	1.34
$s_3 w_5$	7799.50	1.53
$s_3 w_6$	-1156.42	0.97
F	1.33	2.00
SE	2850.15	0.14
CD	NS	NS

returns (Rs. 3083.53 per ha). The highest net returns of Rs. 7402.43 was obtained from plots treated with a spacing of 20 x 10 cm (s_2). This treatment was on par with s_3 but recorded significantly higher net returns compared to s_1.

The weed control treatments significantly influenced the net returns. Weed free check (w_6) recorded the lowest net returns (-3015.94). The highest net returns of Rs 11441.11 was obtained from plot treated with pendimethalin followed by one HW at three weeks after sowing (w_1). It was on par with w_3, which recorded net returns of Rs.10128. Plots treated with two HW 20 and 40 DAS (w_4) recorded net returns of Rs 646.02 where as weedy check (w_5) recorded net returns of Rs. 3973.47.

The interaction effect was not significant with respect to the nets returns.

4.7.2 Benefit-cost ratio

The B:C ratio was significantly influenced by spacing treatments. s_1 recorded significantly the lowest BC ratio of 1.18. s_2 and s_3 were on par with respect to BC ratio with mean values 1.39 respectively.

The weed control treatments had a significant impact on BC ratio. w_1 and w_3 recorded BC ratio of 1.56 and 1.53 respectively. They were on par with each other and significantly higher than rest of the treatments. Weed free check (w_6) recorded significantly the lower BC ratio (0.92). w_4 and w_5 were on par with respect to BC ratio (1.29 and 1.27)

The interaction effect did not significantly influence the B : C ratio.

Discussion

5. DISCUSSION

A field experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani to evolve a suitable integrated weed management strategy in upland rice. The results of the experiment are discussed in detail hereunder to bring out the effect of different weed management strategies on weed population, the influence of weed population on crop growth, yield and the economic feasibility of adopting the weed management strategies.

5.1 Observation on weeds

5.1.1 Weed flora

The weed species, which can grow in comparatively low moisture conditions are problematic weeds of upland rice irrespective of the edaphic differences (Sankaran and De Datta, 1985).

The present study indicated that grasses, broadleaved weeds and sedges competed with the crop. Sedges dominated the experimental area and among them *Cyperus rotundus* L. and *Cyperus iria* L. were the predominant ones. This is in line with the findings of Holm and Herberger (1969) and Okafor (1978), that *Cyperus rotundus*. L. is a problematic weed of upland rice wherever it is grown. The major grassy weeds observed in the experimental area were *Echinochloa colona* (L.) Link., *Echinochloa crus-galli* (L) P. Beauv., *Eleusine indica* (L.) Gaertn. and *Cynodon dactylon.* The major broadleaved weeds present were *Cleome rutidosperma.* D.C., *Commelina benghalensis* and *Phyllanthus niruri* L. Several workers have pointed out that

Echinochloa colona (L.) Link., *Echinochloa* crus-galli (L.) P. Beauv., *Cynodon dactylon* (L.) Pears., *Commelina benghalensis* L., *Ipomoea triloba* L., *Fimbristylis* sp., *Phyllanthus niruri* L and *Amaranthus* sp. are most common weeds of upland rice irrespective of edaphic differences (Mukhopadhyay *et al.*, 1972 and Rathi and Tiwari, 1979). Research works conducted at IRRI(1980) also indicated *Cyperus rotundus* L, *Cleome rutidosperma*, D.C., *Echinochloa colona* (L) Link. and *Eleusine* indica (L) Gaertn. as the common weeds of upland rice.

5.1.2 Effect of treatments on weed growth

The influence of treatments on weed growth was analysed based on vegetation analysis parameters. Absolute density (Ad), Relative density (Rd), Absolute frequency (Af), Relative frequency (Rf) Summed dominance ratio (SDR), Weed control efficiency (WCE) and Weed dry weight were the different parameters used for determining the effect of treatments on weed growth.

5.1.2.1 Effect of crop spacing on weed growth

Different spacings tried significantly influenced the total absolute density of weeds (Fig. 9). The medium spacing of 20x 10 cm (s_2) recorded the lowest value. Sedges dominated the experimental area and the high sedge weed count in the closest spacing of 15 x 10 cm (s_1) might be because the close spacing helped to maintain a moist and humid microclimate congenial for their germination. The high absolute density of sedges in s_1 was recorded only at 20 DAS which indicated that after the hand weeding at 20 DAS, further growth of weeds was restricted.

Fig. 3 Effect of spacing and weed management practices on absolute density of grasses at different periods of observation

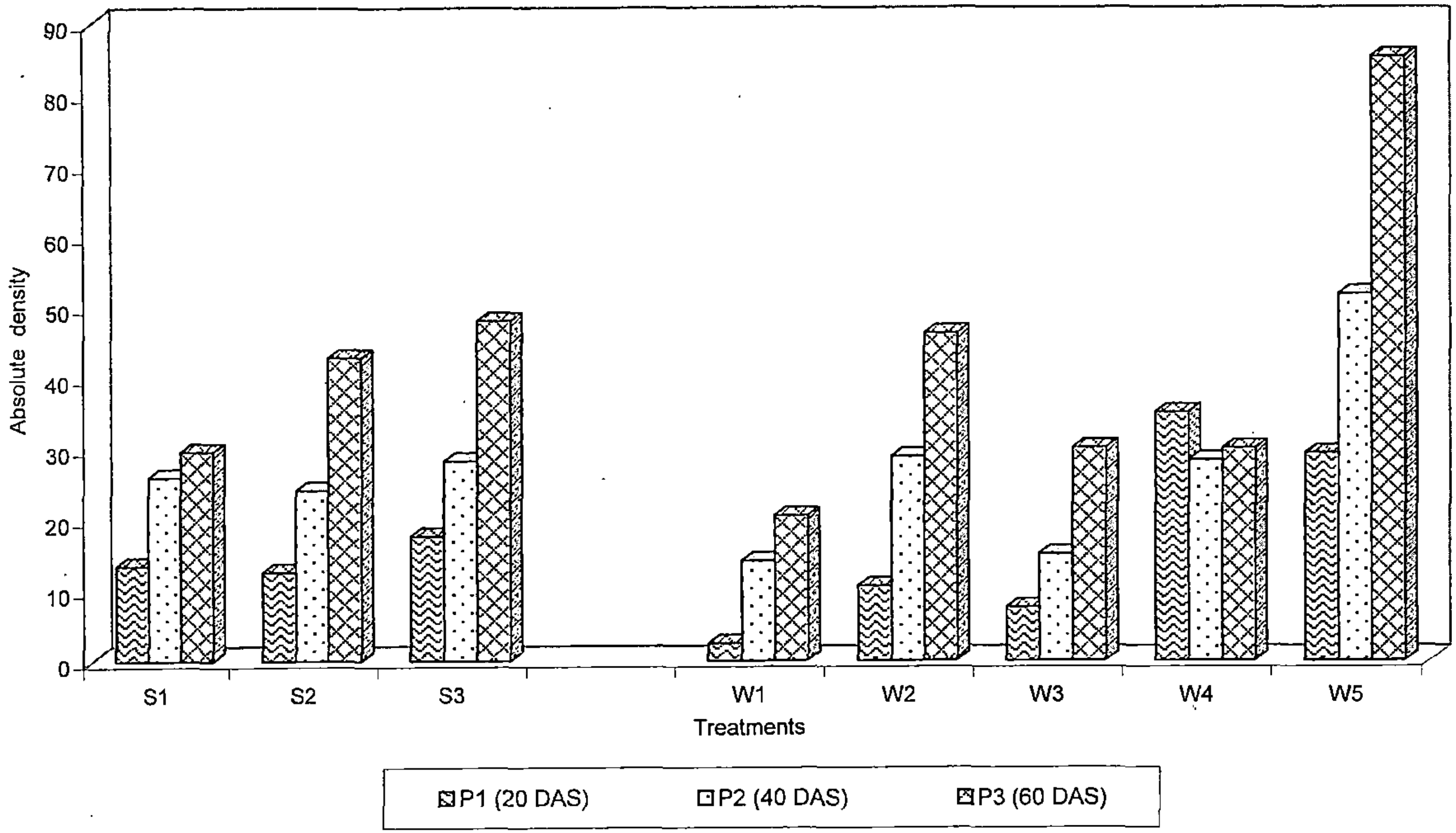


Fig. 4 Interaction effect of spacing and weed management practices on absolute density of grasses at different periods of observation

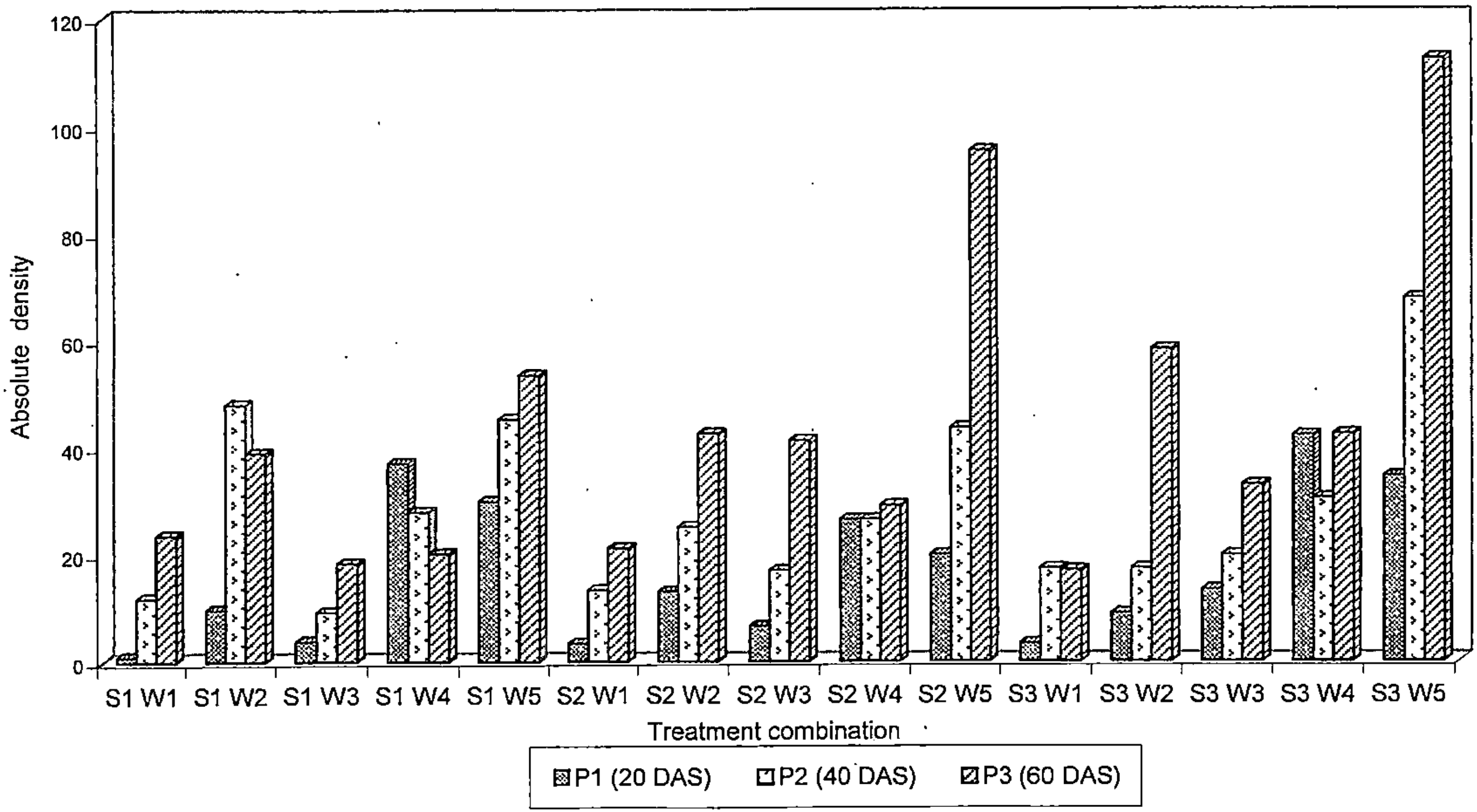


Fig. 5 Effect of spacing and weed management practices on absolute density of broadleaved weeds at different periods of observation

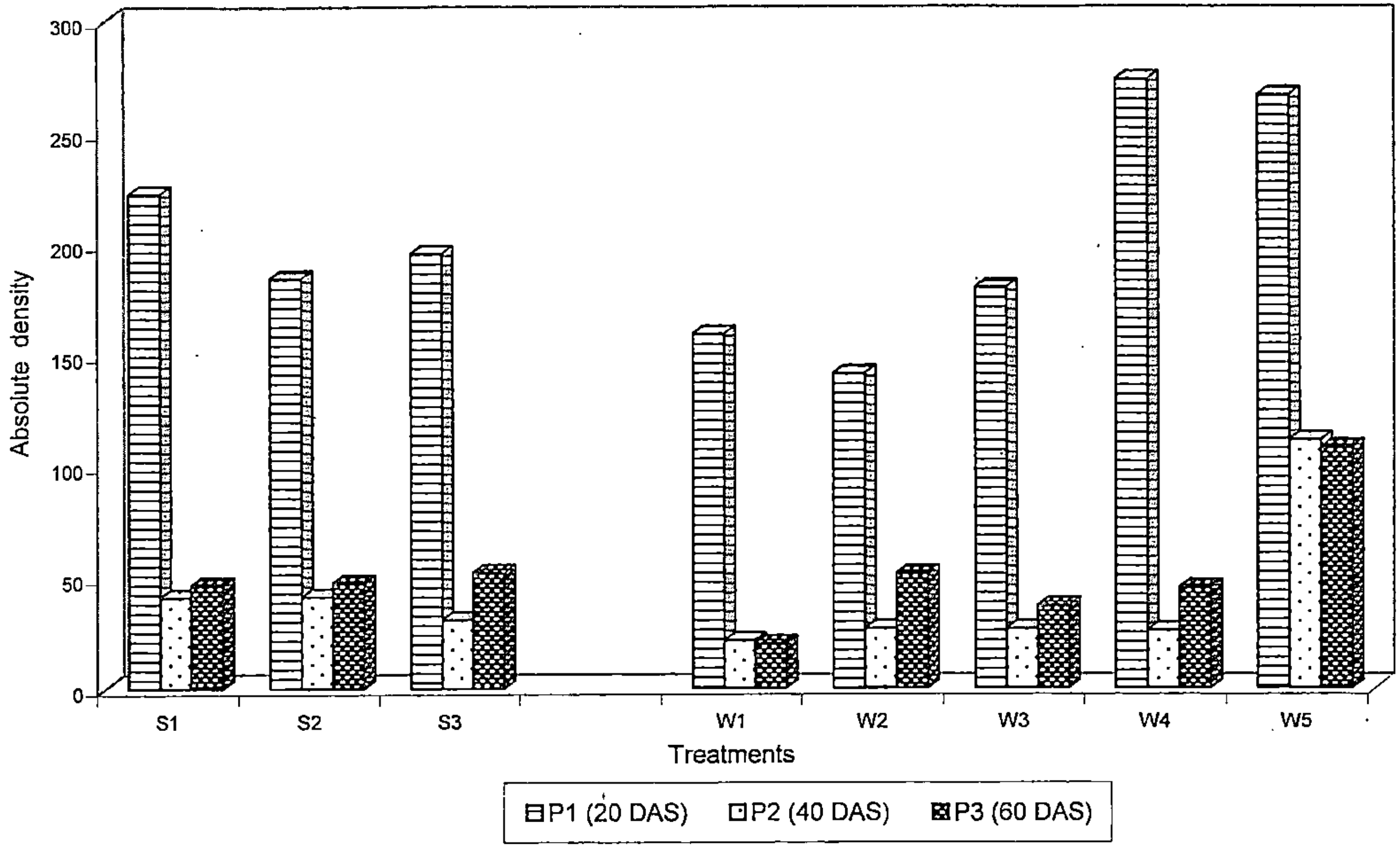


Fig. 6 Interaction effect of spacing and weed management practices on absolute density of broadleaved weeds at different periods of observation

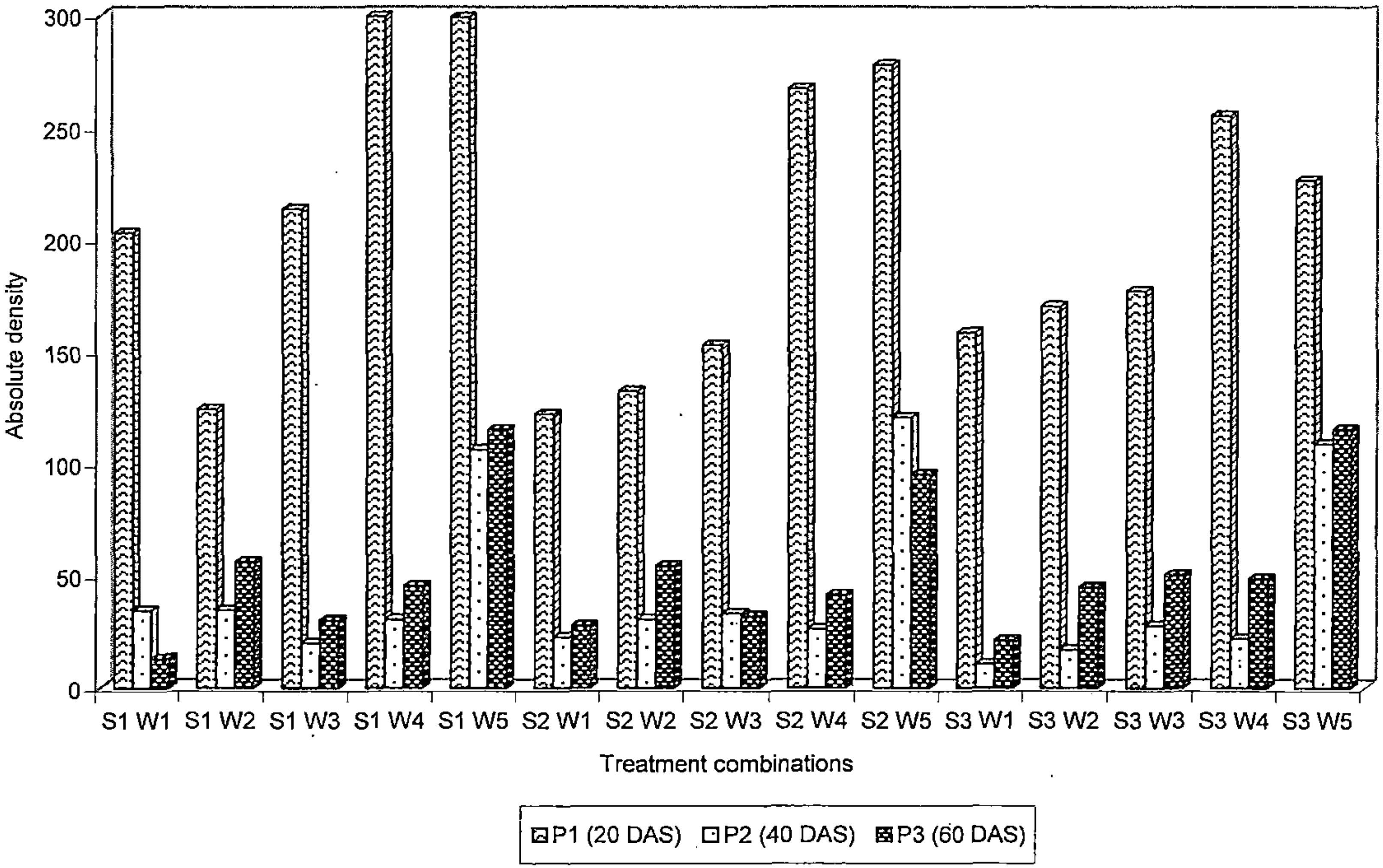


Fig. 7 Effect of spacing and weed management practices on absolute density of sedges at different periods of observation

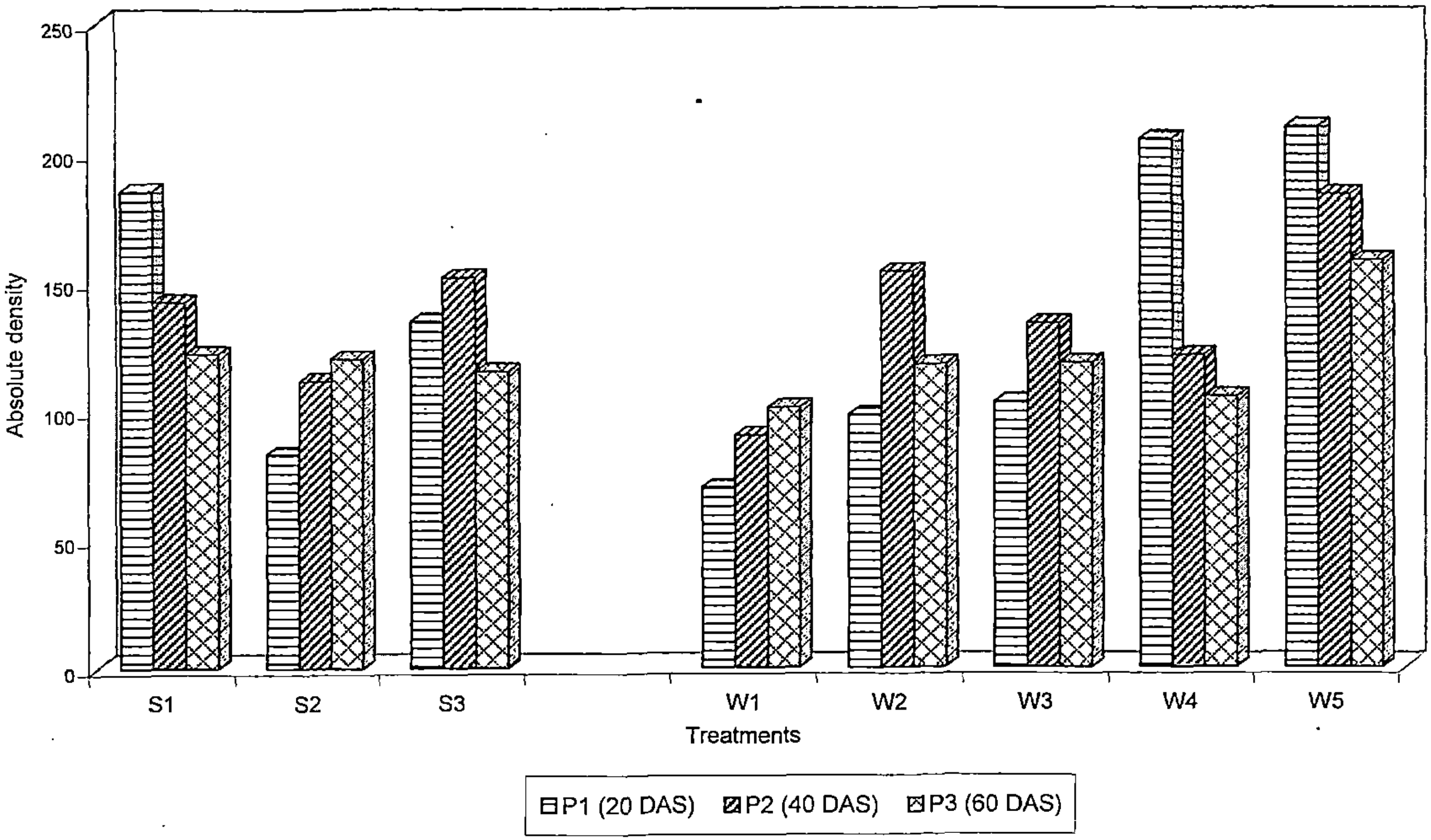


Fig. 8 Interaction effect of spacing and weed management practices on absolute density of sedges at different periods of observation

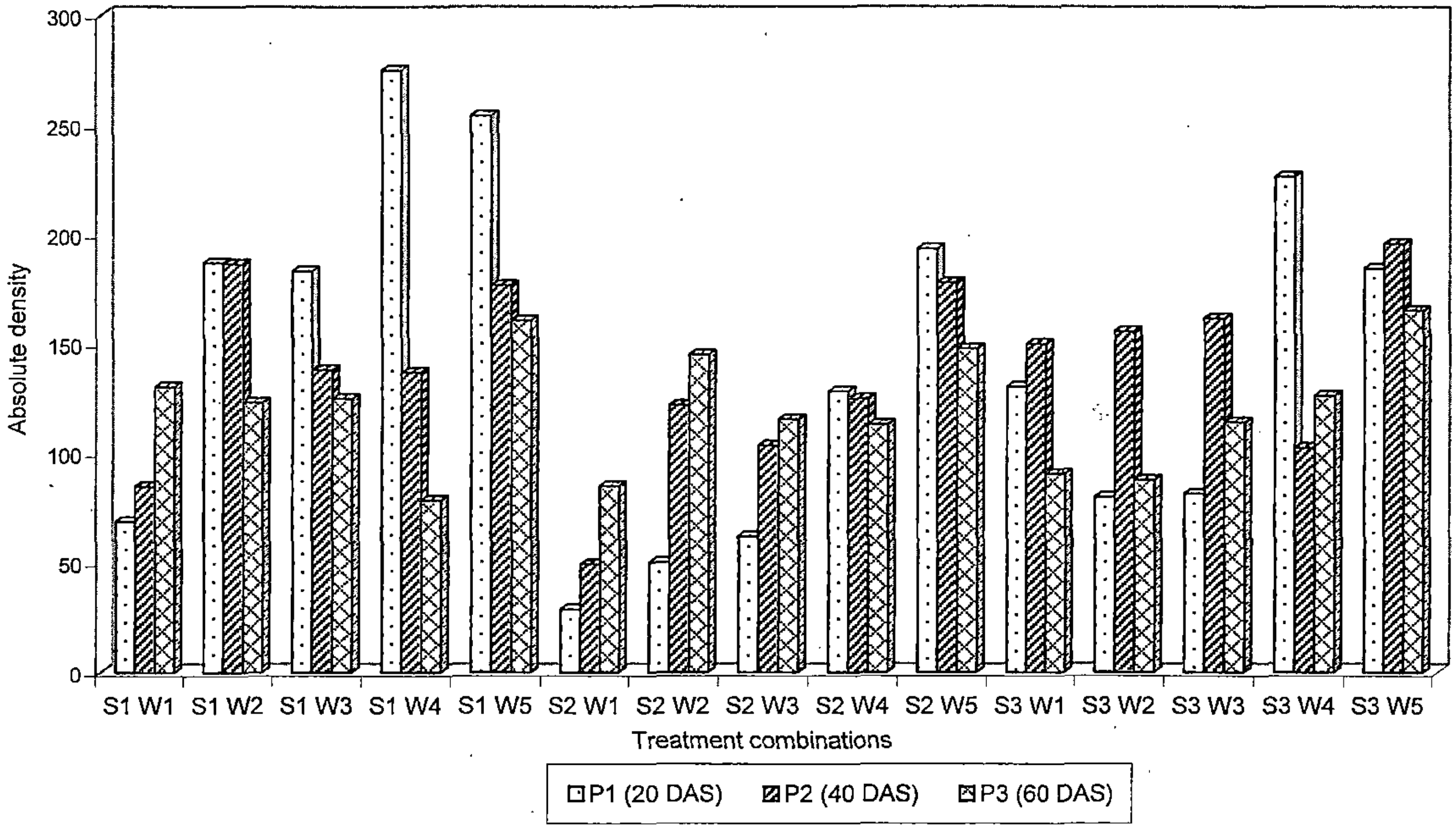


Fig. 9 Effect of spacing and weed management practices on absolute density of all weeds at different periods of observation

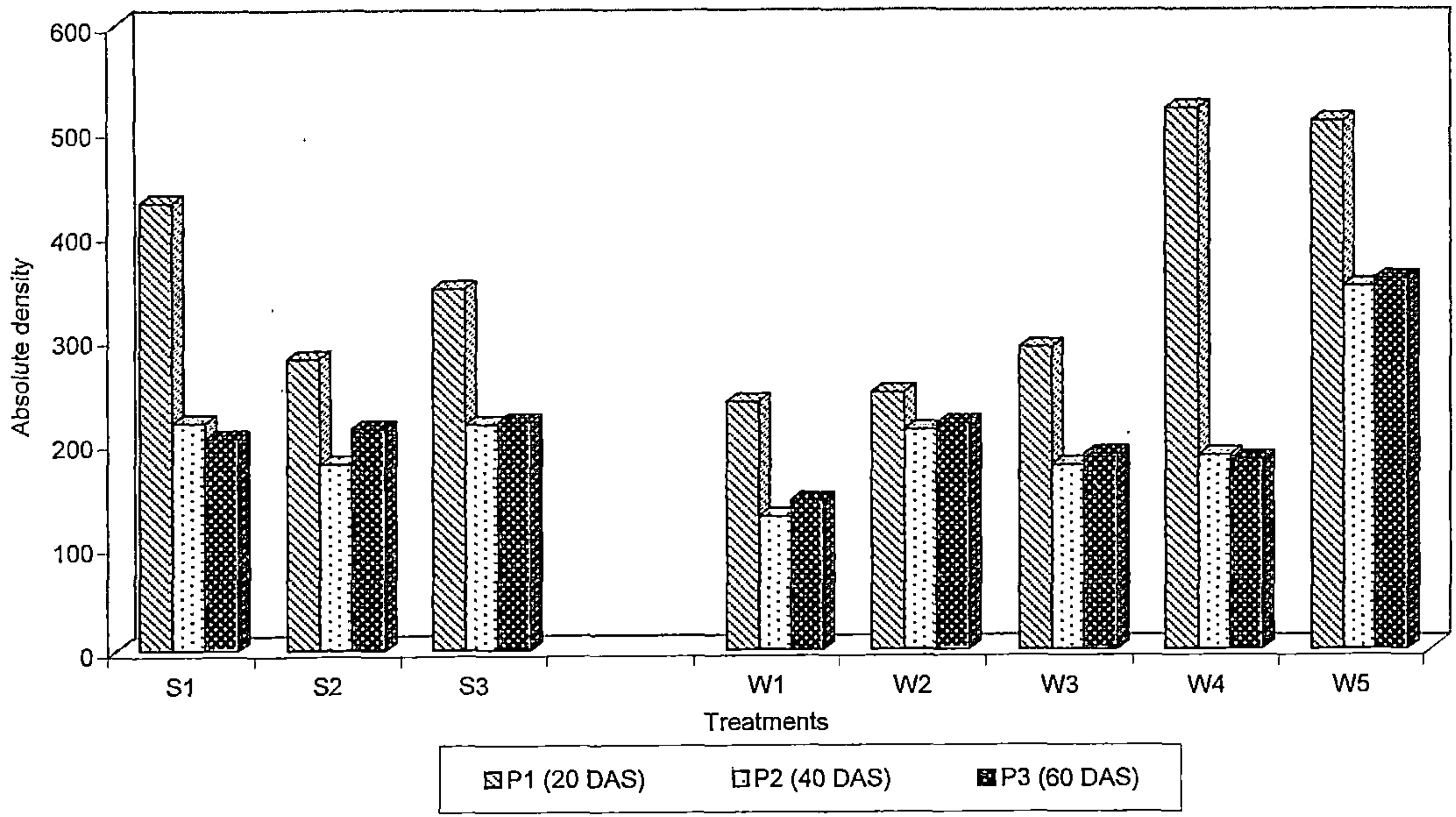
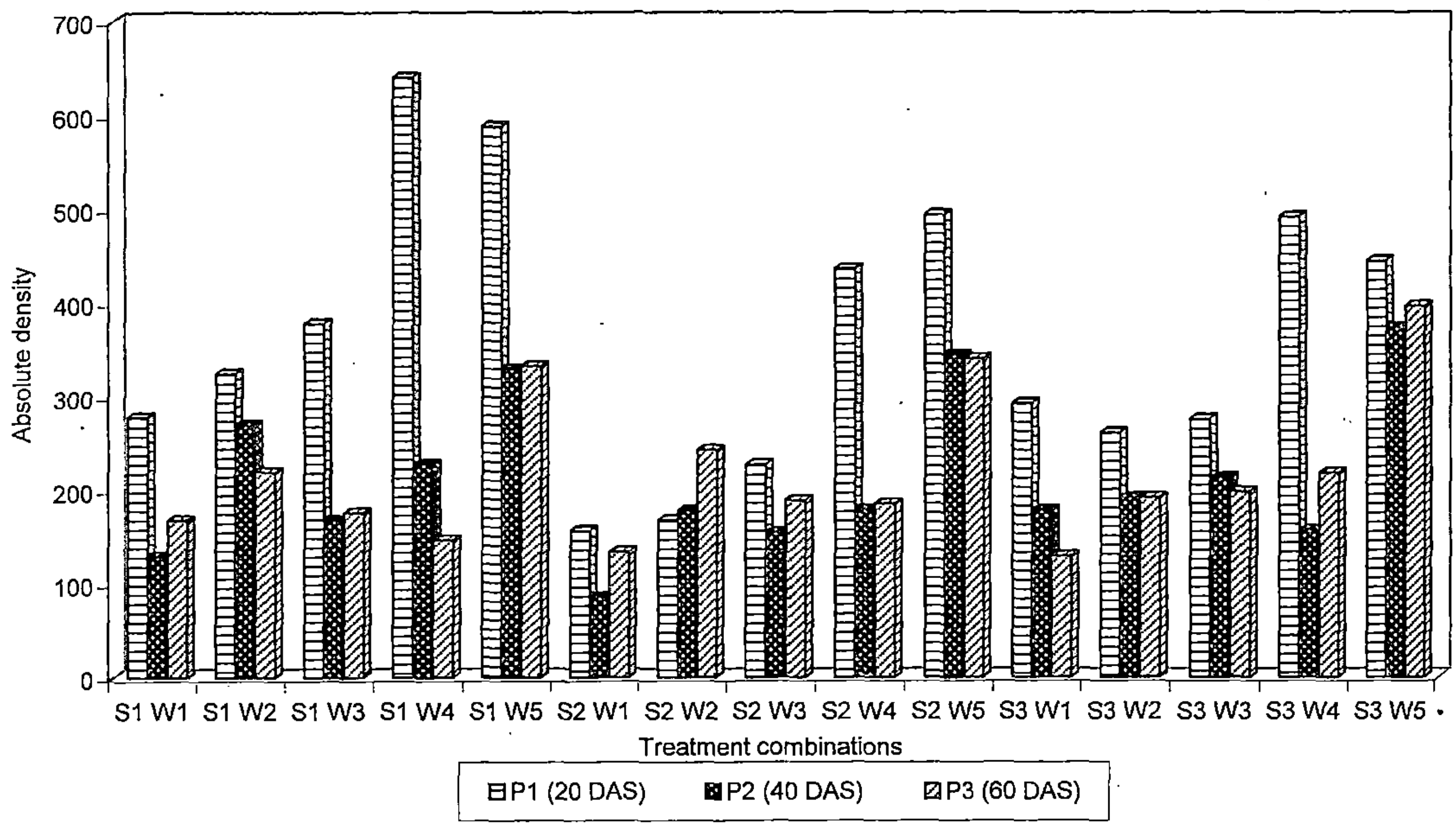


Fig. 10 Interaction effect of spacing and weed management practices on absolute density of all weeds at different periods of observation



The data showed that spacing did not have significant influence on total weed dry weight and hence the high absolute weed density at s_1 was probably due to more number of tiny weed seedlings. This is in line with the reports of Yamaguchi *et al.* (1978) that even though spacing influenced total absolute density it did not have much influence on weed competition or weed biomass production.

5.1.2.2 Effect of Weed management practices on weed growth

The weed management practices adopted influenced the weed growth of all types of weeds and resulted in significant reduction in weed population.

Different pre-emergent herbicides reduced the total absolute density of weeds compared to unweeded check at all periods of observation.

Pre-emergent application of pendimethalin followed by HW at 3 weeks after sowing recorded the lowest total absolute density at all stages of crop growth (Fig. 9). The ability of pendimethalin to control weeds effectively in upland rice was reported by several earlier workers (Ramamoorthy, 1991; Ramamoorthy *et al.*, 1998).

Pre-emergent application of pendimethalin was found effective in controlling weeds at all stages of crop growth. Pendimethalin application followed by a HW at 3 weeks after sowing (w1) recorded the highest weed control efficiency for grasses and broadleaved weeds compared to all other treatments. Sharanappa *et al.* (1994) reported that pendimethalin significantly reduced the population of grassy weeds and broadleaved weeds. Thakur and Bassi (1994) also have reported that pendimethalin followed by one hand weeding provided high weed control efficiency of 67.9 per cent. But the relative frequency of sedges was significantly high in pendimethalin treatment compared to all other treatments. This is presumably because of the fact that the effective control of grasses and broadleaved weeds offered more space and less completion for sedges. It is evident from Table 41 that all the herbicide treatments had significantly higher relative frequency of sedges compared to hand weeded plot and unweeded check indicating that the herbicides controlled grasses and broadleaved weeds more effectively than sedges.

The pre-emergent application of pendimethalin caused considerable reduction in total weed dry weight compared to unweeded check at 20 DAS. The reduction in weed dry weight by pendimethalin application followed by a HW at 3 weeks after sowing significant at all stages with a mean value of 20.24 g/m^2 against 107.73 g/m^2 in the unweeded check. This is in conformity with the reports of Gogoi and Kalitha (1990). The effectiveness of pendimethalin in reducing the density and dry weight of weeds were also observed by Pandey and Tiwari (1994)and Mutanal *et al.* (1997).

Pre-emergent application of fluchloralin registered very low total absolute density at 20 DAS, which was on par with pendimethalin and significantly lower than all other treatments. Bhan and Singh (1979) reported that fluchloralin is effective in controlling weeds in irrigated rice. But the application of fluchloralin in the present experiment lead to acute phytotoxicity and the crop stand was reduced. This reduction in crop stand resulted significant increase in weed population as weeds obtained more space for growth and the fluchloralin treated plots recorded total dry weight of weeds on par with that of unweeded check. At 60 DAS the weed dry weight in fluchloralin treated plots (231.61 g/m^2) was much higher than unweeded check (169. 25 g/m^2).

Pre-emergent application of butachlor followed by a HW at 3 weeks after sowing (w_3) was very effective in controlling grasses and broadleaved weeds but the effect on sedges was meagre. The reduction in grass and broadleaved weed population by butachlor application probably led to higher relative frequency of sedges. The ability of butachlor to control grasses and broadleaved weeds effectively was reported by Misra *et al.* (1988) and Singh and Singh (1986).

Two hand weedings at 20 and 40 DAS (w_4) also was effective in reducing the total absolute density of weeds compared to unweeded check. However, the absolute weed density was very high at 20 DAS were up on the first weeding was done. Hand weeded plots (w_4) recorded much lower weed dry weight compared to unweeded check but significantly higher than pendimethalin and butachlor treated plots. Moreover, the hand weeded plots recorded the lowest relative frequency of sedges among the treatments, which was on par with unweeded check. Taking all these facts into consideration, it can be concluded that two HW at 20 and 40 DAS gives good control of all types of weeds, but leads to weed competition at the initial growth period of the crop. Similar findings were reported by Nandal and Singh (1995) and Pande *et al* (1997).

5.1.2.3 Effect of crop spacing and weed management interaction on weed growth

The crop spacing weed management interaction affected the extent of weed control. The interaction effect significantly influenced the total absolute density of weeds. The treatment combination of 20 x 10 cm spacing and pendimethalin application followed by a hand weeding at three weeks after sowing (s_2w_1) resulted in the lowest total absolute density ($11.16/m^2$). This was significantly lower than all the other treatment combinations. This reduction in absolute density can be attributed to the effect of medium spacing (20 x 10 cm), which offered enough crop competition for the weeds and the effect of pendimethalin, which effectively reduced the total weed population. The unweeded check sown at the spacings of 15x10 and 20x10 cm registered very high total absolute density. These treatment combinations were on par with each other and significantly higher than the rest of the treatment combinations. The unweeded condition can be the cause of such high weed density in these treatment combinations and in the absence of weeding the different spacings could not exert considerable influence on the weed density.

5.1.3 Effect of treatments on Nutrient uptake by the weeds

5.1.3.1 Effect of crop spacing on Nutrient uptake by the weeds

The various spacings tried as main plot treatments did not significantly influence the N and K uptake by weeds, but the effect on P uptake was substantial. This might be due to higher P uptake of weeds compared to N and K uptake. The medium spacing of 20 x 10 cm recorded the lowest P uptake, obviously because of the lowest weed density at this spacing.

5.1.3.2 Effect of weed management practices on Nutrient uptake by weeds

Weed management practices had significant influence on nutrient uptake by weeds. Pre-emergent application of Pendimethalin or Butachlor followed by a HW at 3 weeks after sowing resulted in lower NPK uptake compared to all other treatments. Two HW at 20 and 40 DAS also was very effective in reducing the nutrient uptake by weeds. Similar observations were made earlier by Singh and Sharma (1994). Fluchloralin application led to very high nutrient uptake, comparable to unweeded check.

5.1.3.3 Effect of crop spacing and weed management interaction on weed nutrient uptake

Interaction effect of crop spacing with weed management practice was not significant with respect to nutrient uptake by weeds.

5.2 Observations on crop

5.2.1 Effect of treatments on crop growth characters

5.2.1.1 Effect of crop spacing on crop growth characters

Plant height was not influenced by the different spacings, but the effect on tillering was substantial. Number of tillers at harvest was highest at the widest spacing of 20 x 15 cm (S_3). This was because the lower plant density, which allowed more space for tillering of the plants. Similar observations were recorded by Villanueva *et al.* (1988) also. The LAI increased as the plant density increased and the closest spacing of 15 x 10 (S_1) recorded the lowest LAI.

Fig 11 Effect of spacing and weed management practices on weed dry weight at different periods of observation

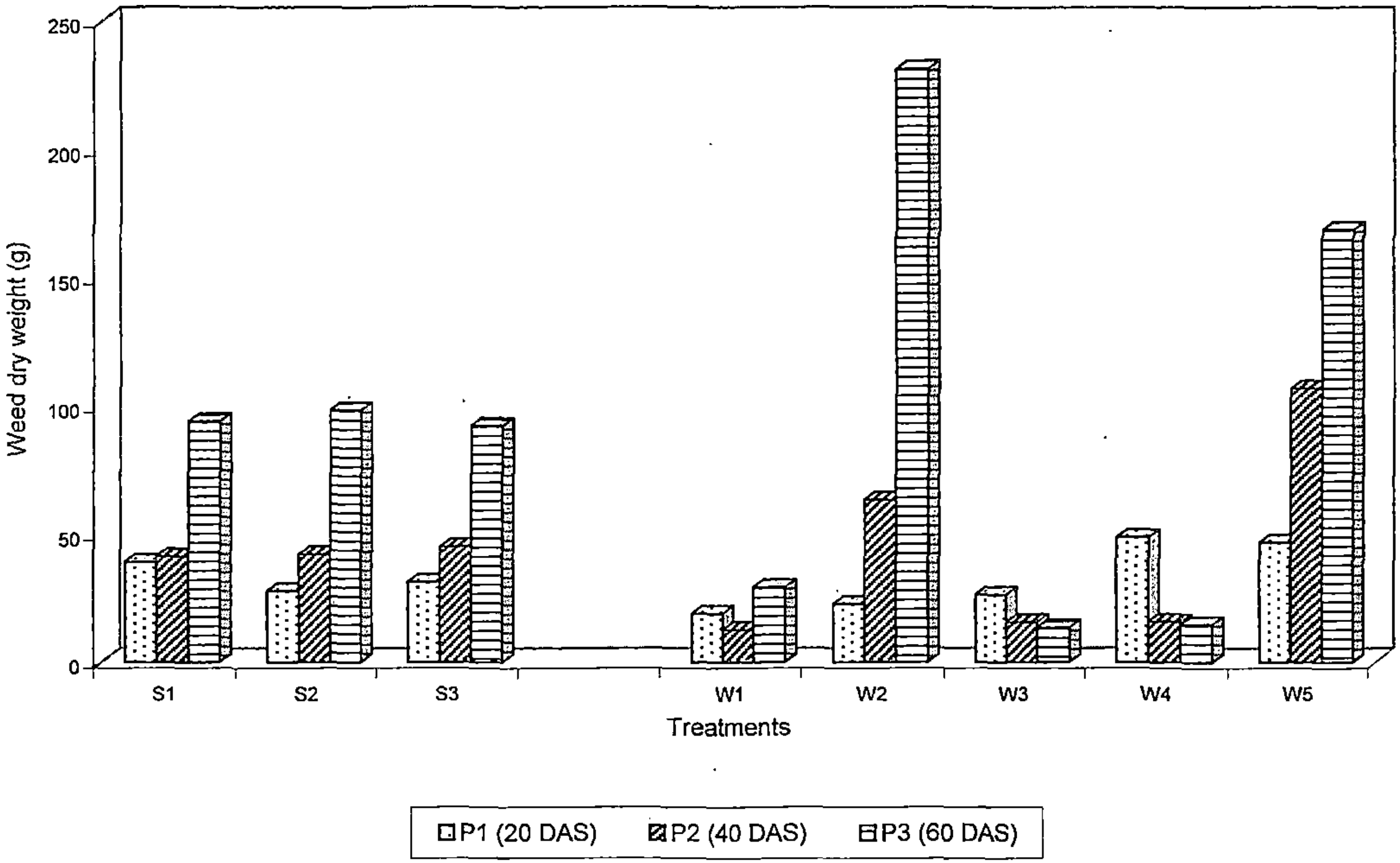


Fig 12 Interaction effect of spacing and weed management practices on weed dry weight at different periods of observation

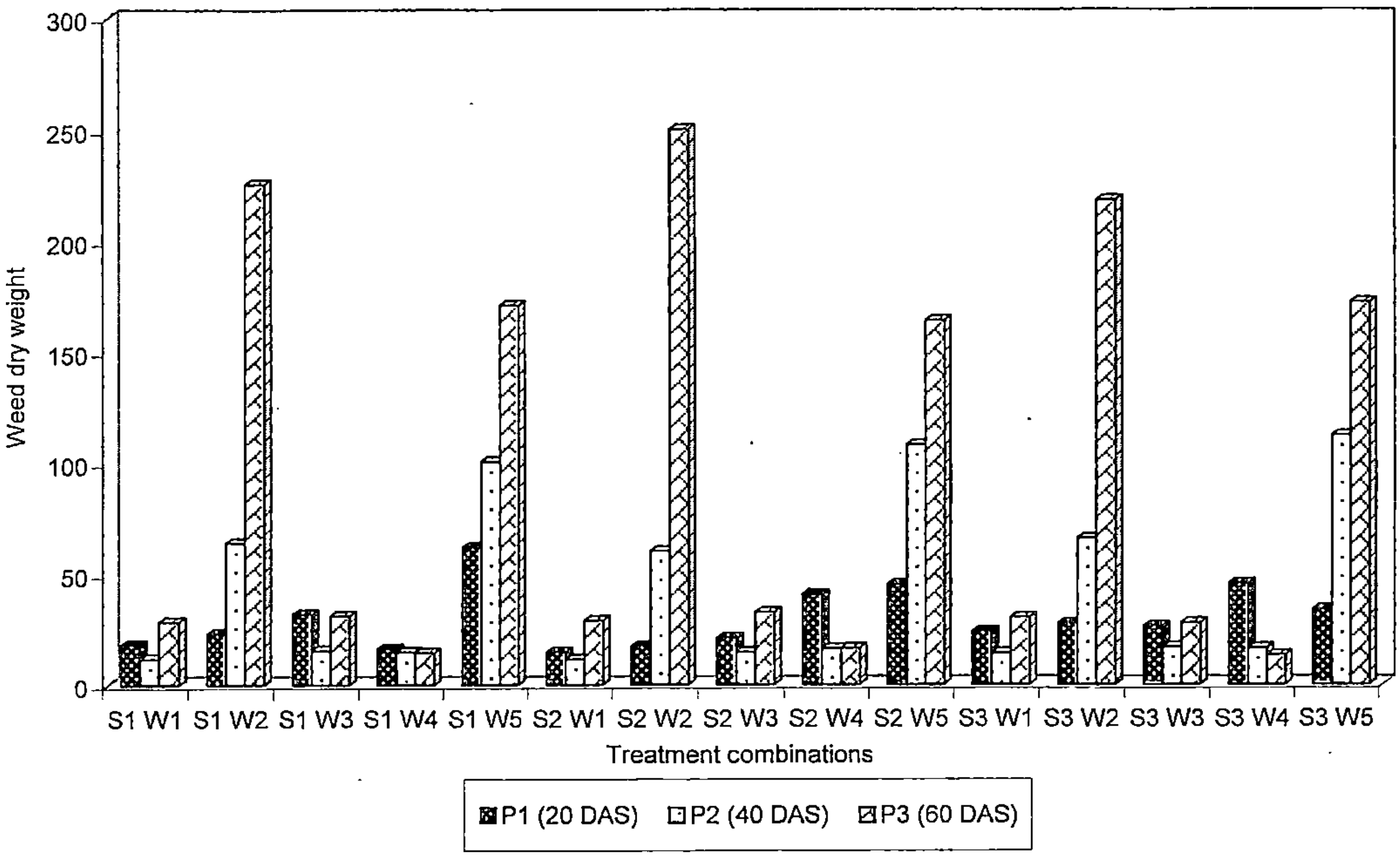


Fig 13 Effect of spacing and weed management practices on N uptake of weeds at different periods of observation

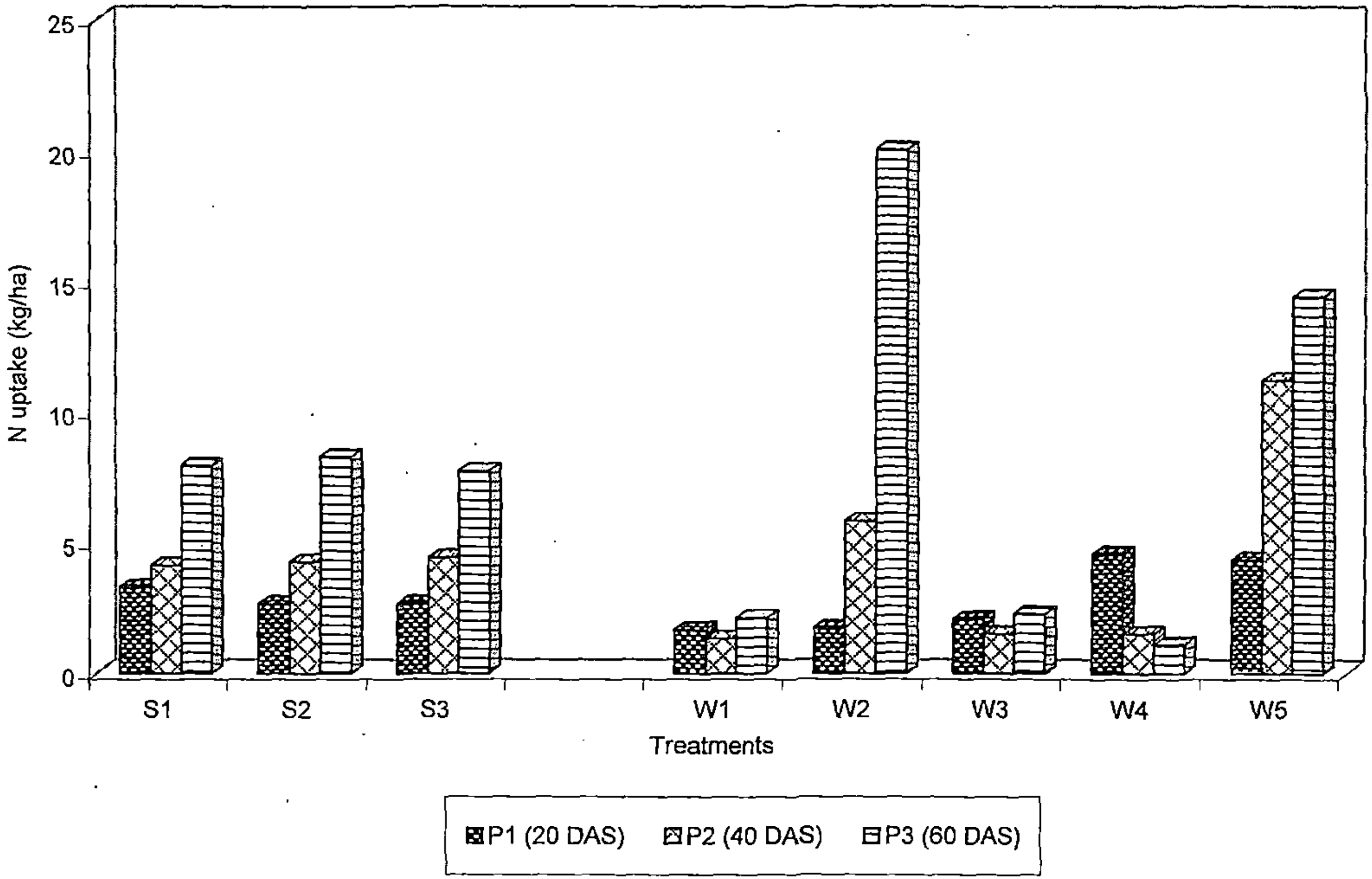


Fig. 14 Interaction effect of spacing and weed management practices on N uptake of weeds at different periods of observation

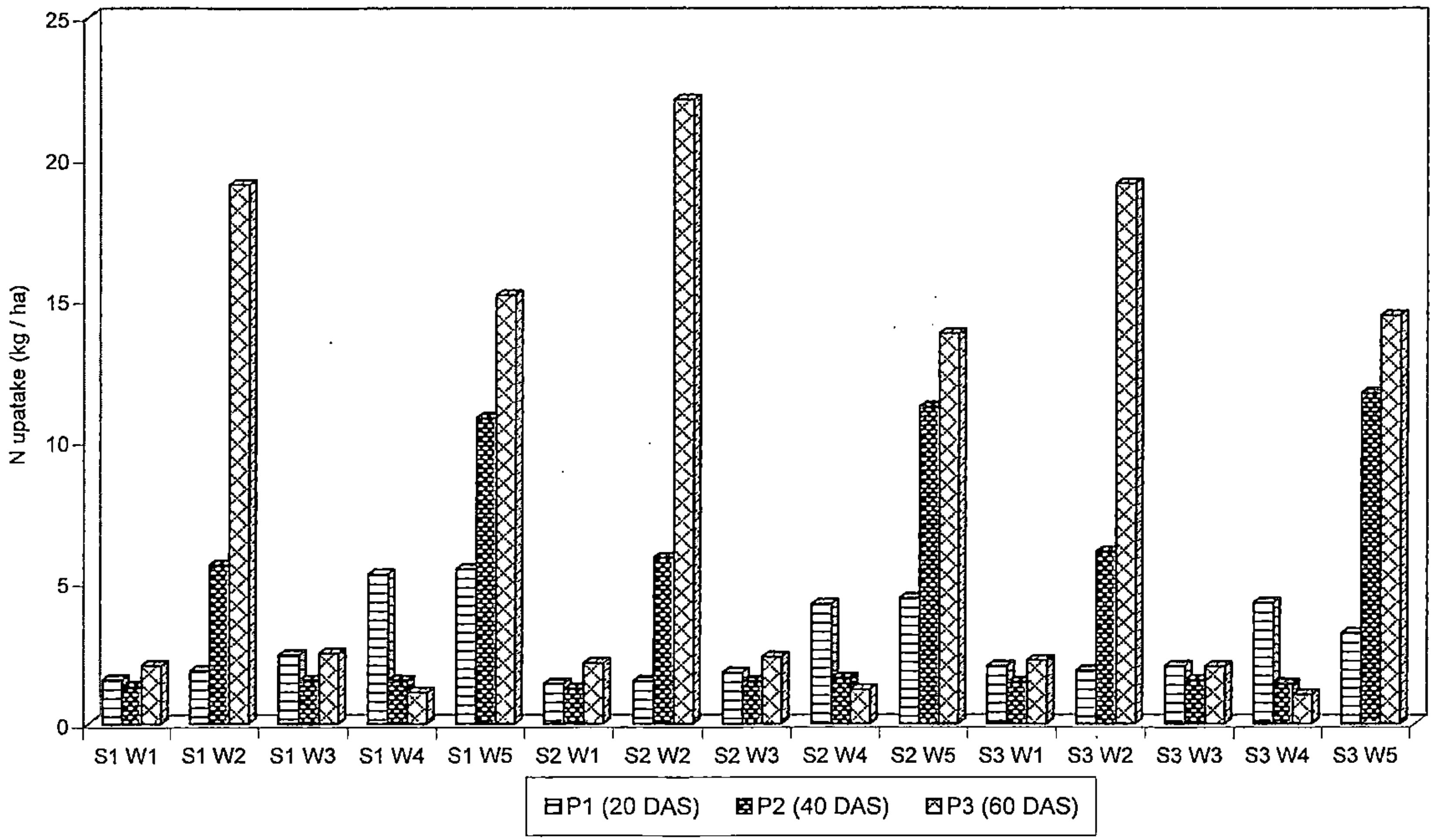


Fig. 15 Effect of spacing and weed management practices on P uptake of weeds at different periods of observation

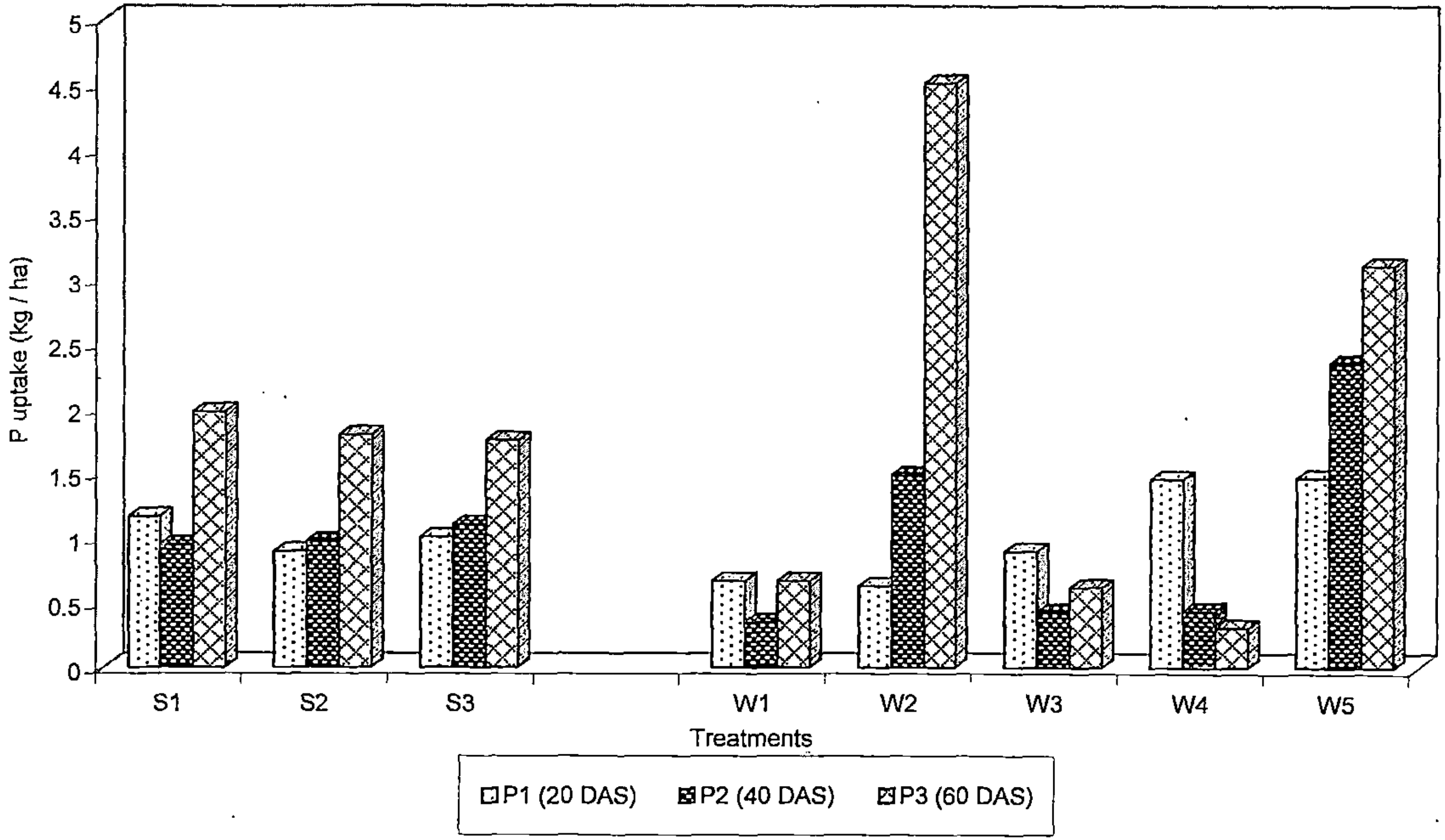


Fig. 16 Interaction effect of spacing and weed management practices on P uptake of weeds at different periods of observation

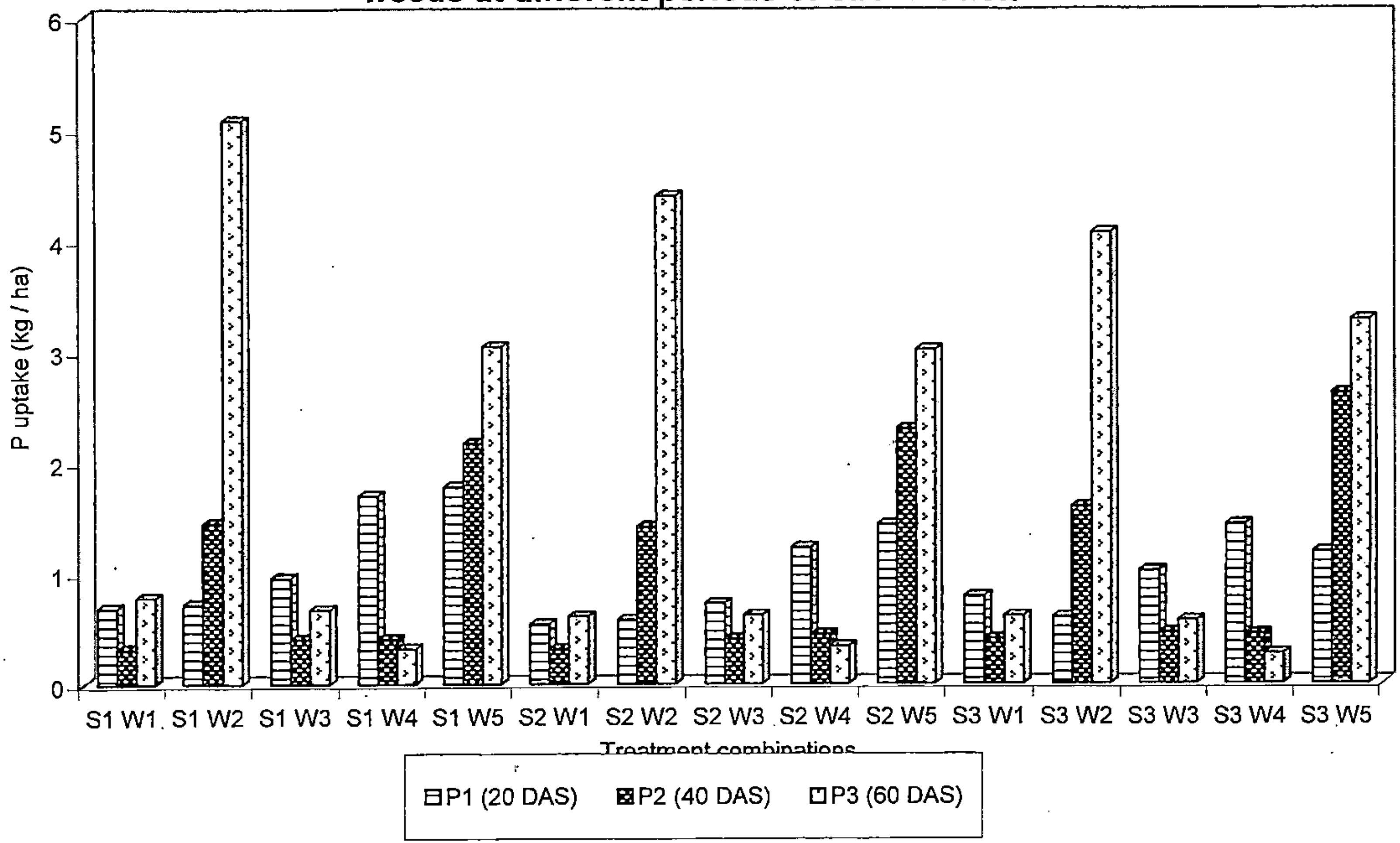


Fig. 17 Effect of spacing and weed management practices on K uptake of weeds at different periods of observation

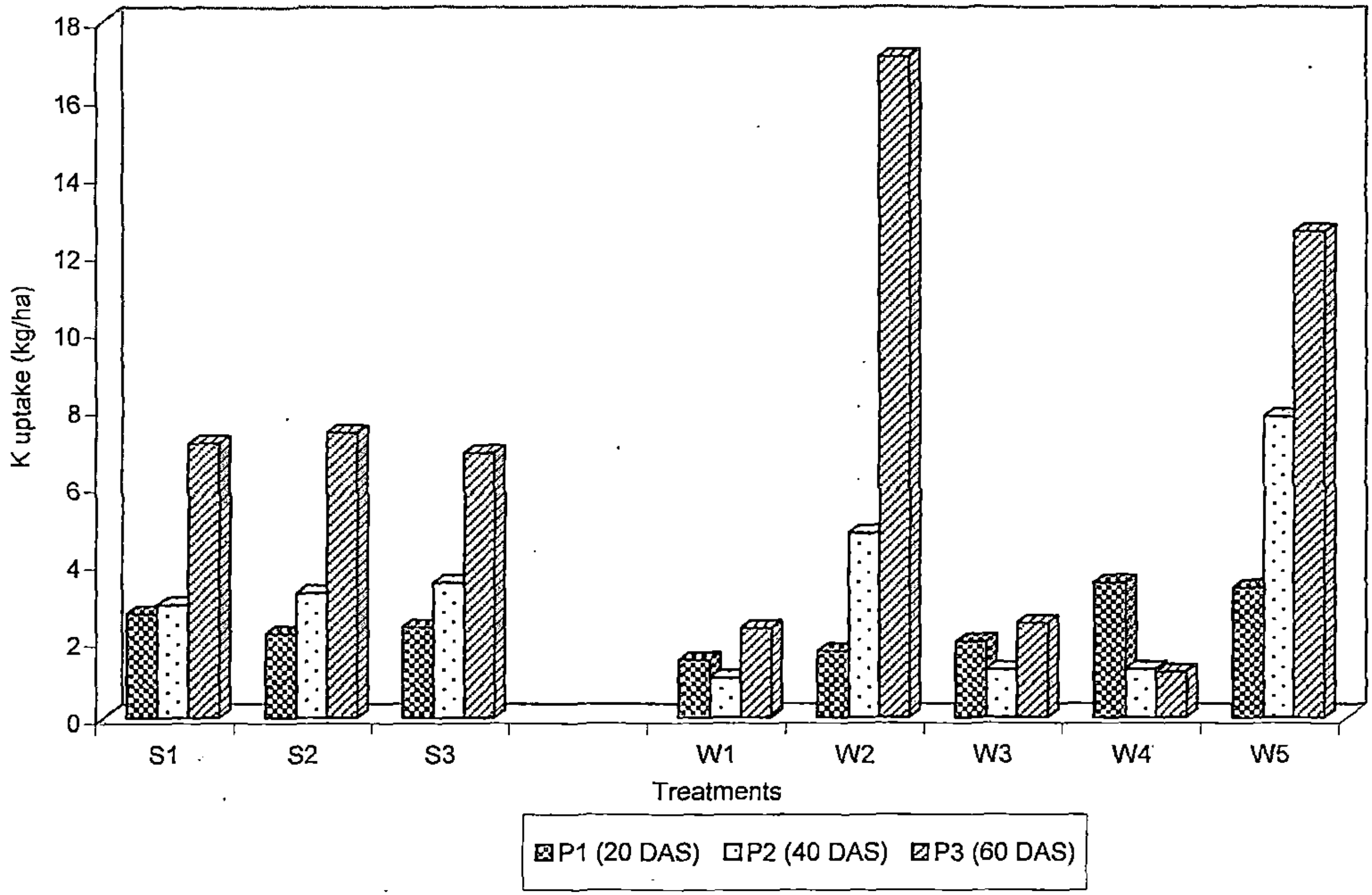


Fig. 18 Interaction effect of spacing and weed management practices on K uptake of weeds at different periods of observation

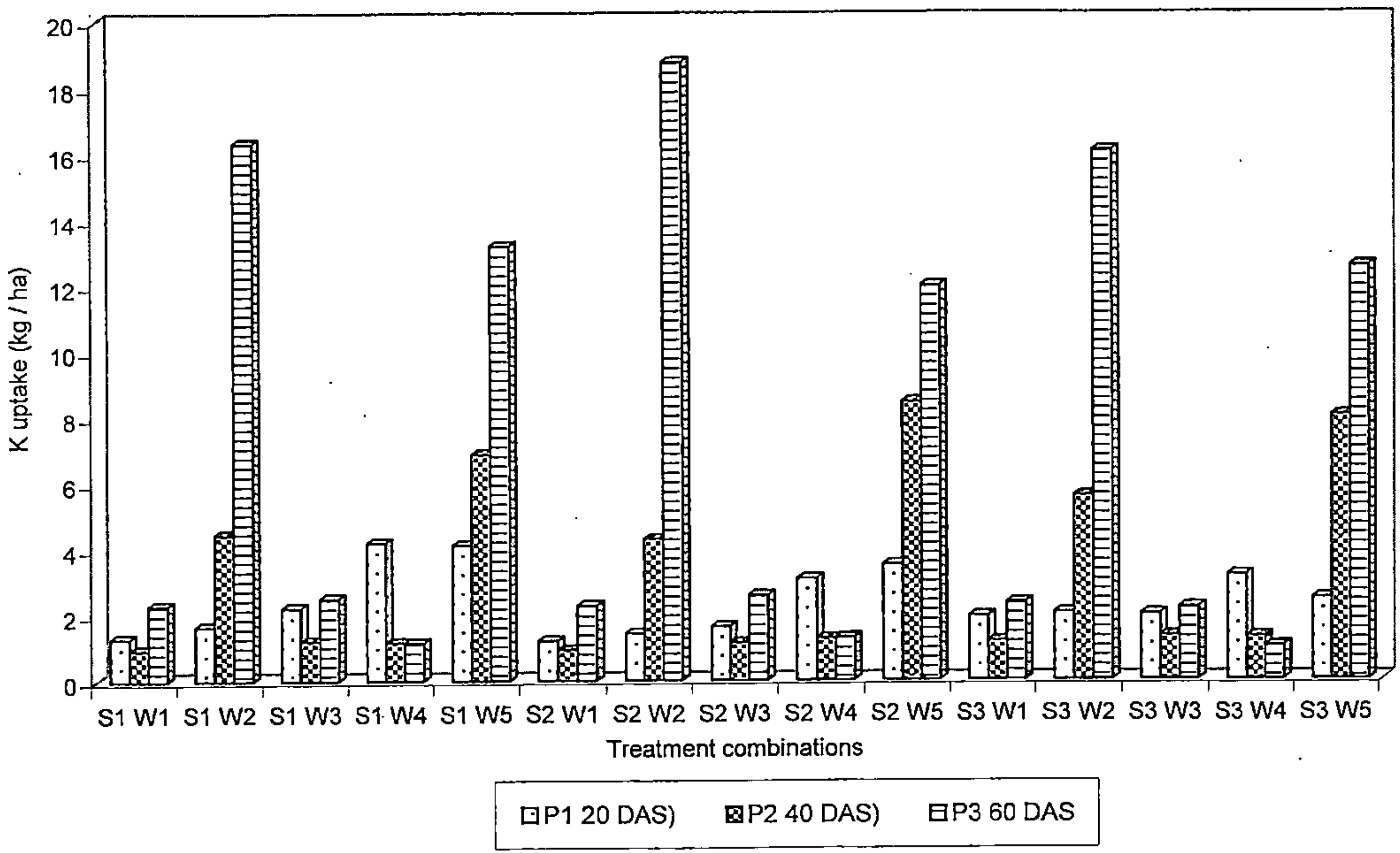


Fig. 19 Effect of spacing and weed management practices on weed control efficiency of grasses at different periods of observation

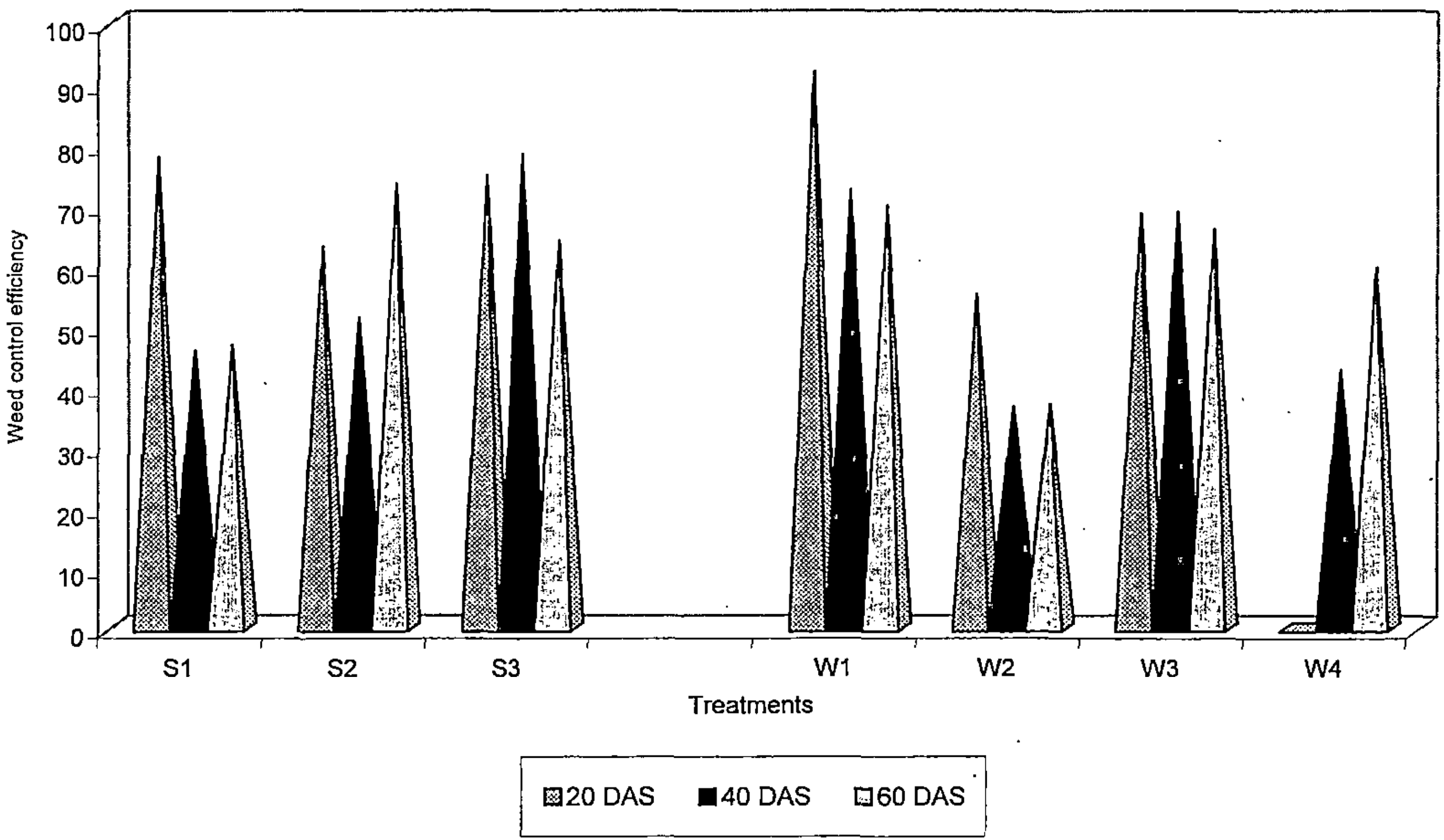


Fig. 20 Interaction effect of spacing and weed management practices on weed control efficiency of grasses at different periods of observation

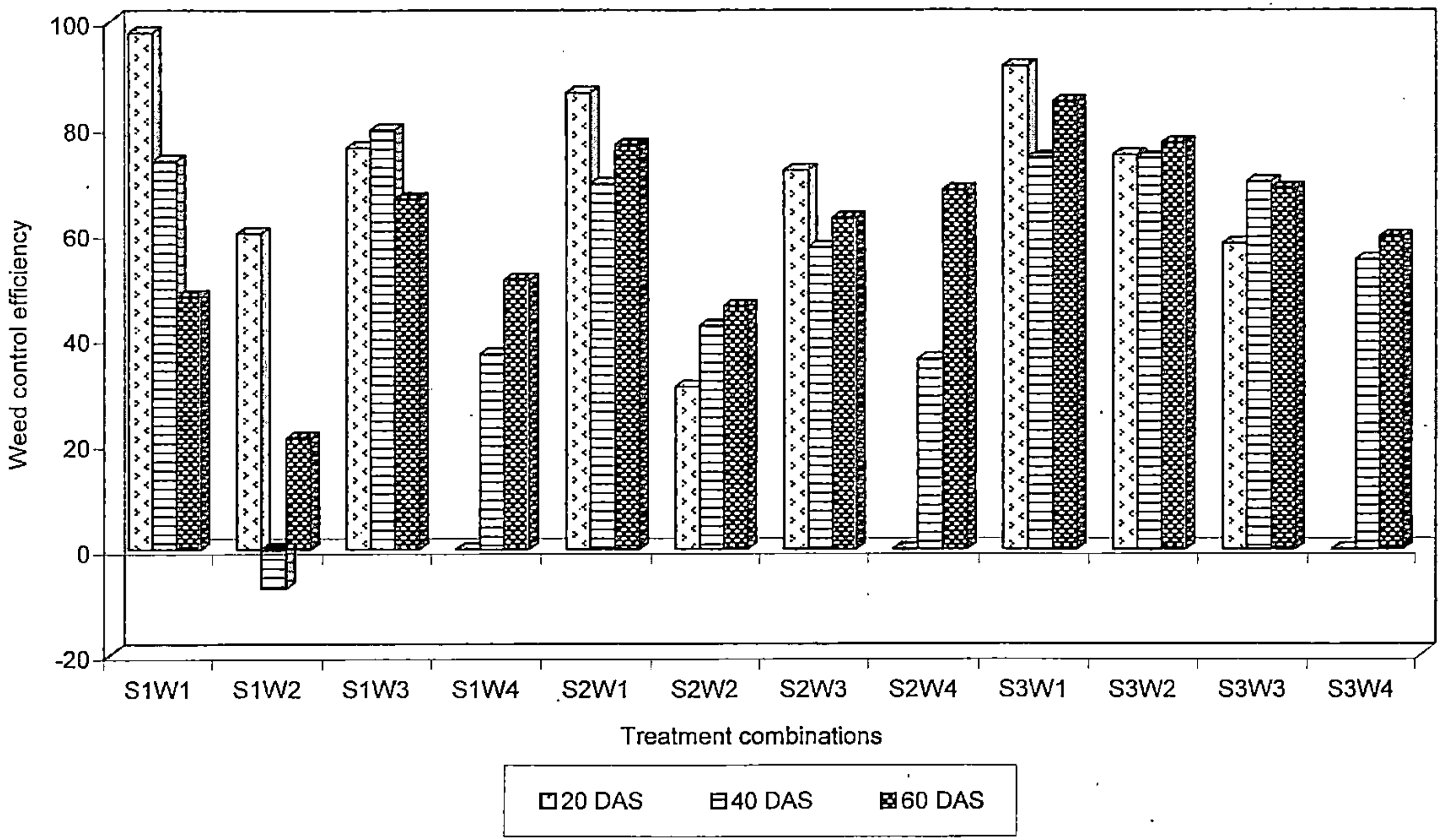


Fig. 21 Effect of spacing and weed management practices on weed control efficiency of broadleaved weeds at different periods of observation

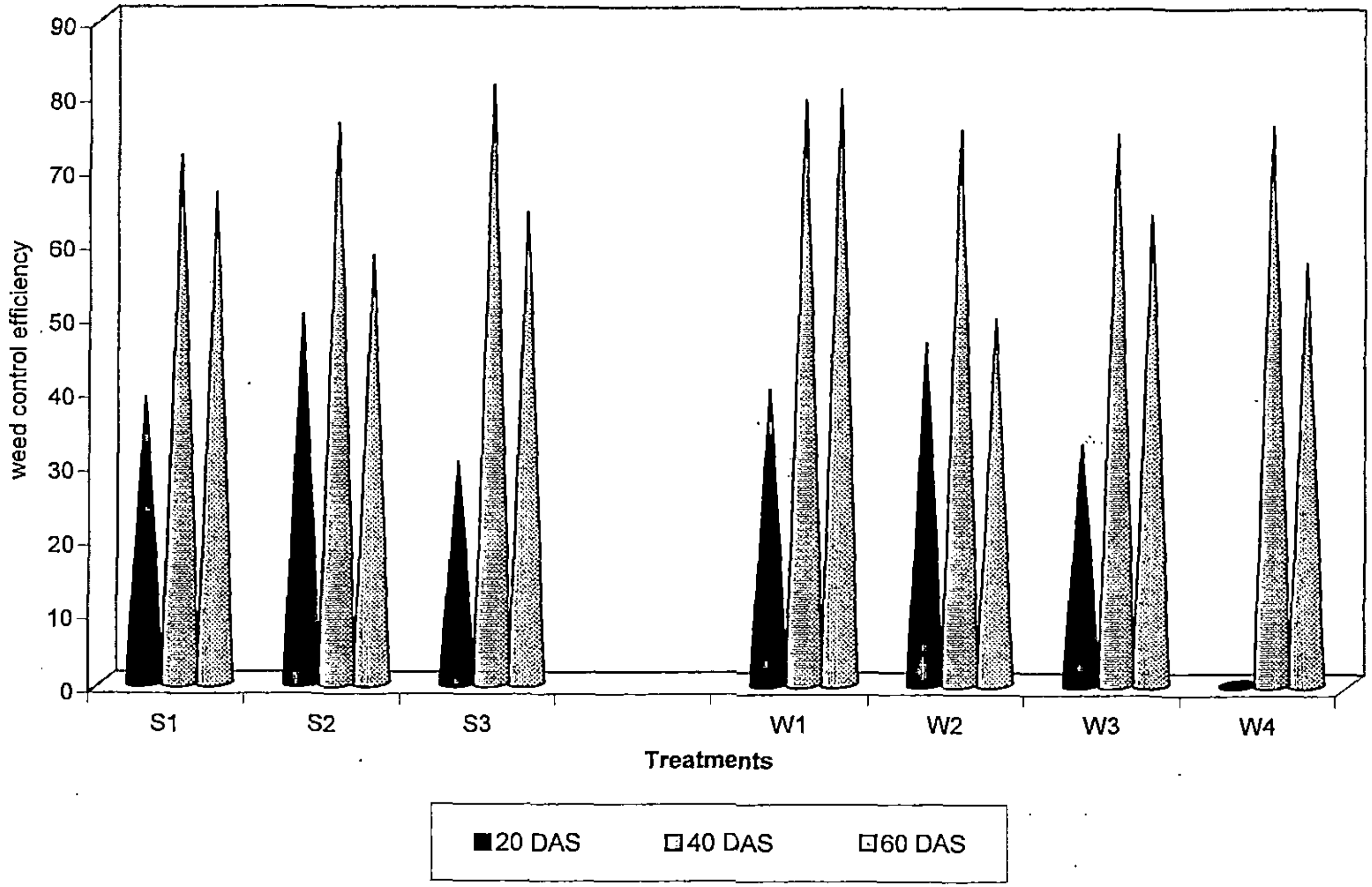


Fig. 22 Interaction effect of spacing and weed management practices on weed control efficiency of broadleaved weeds at different periods of observation

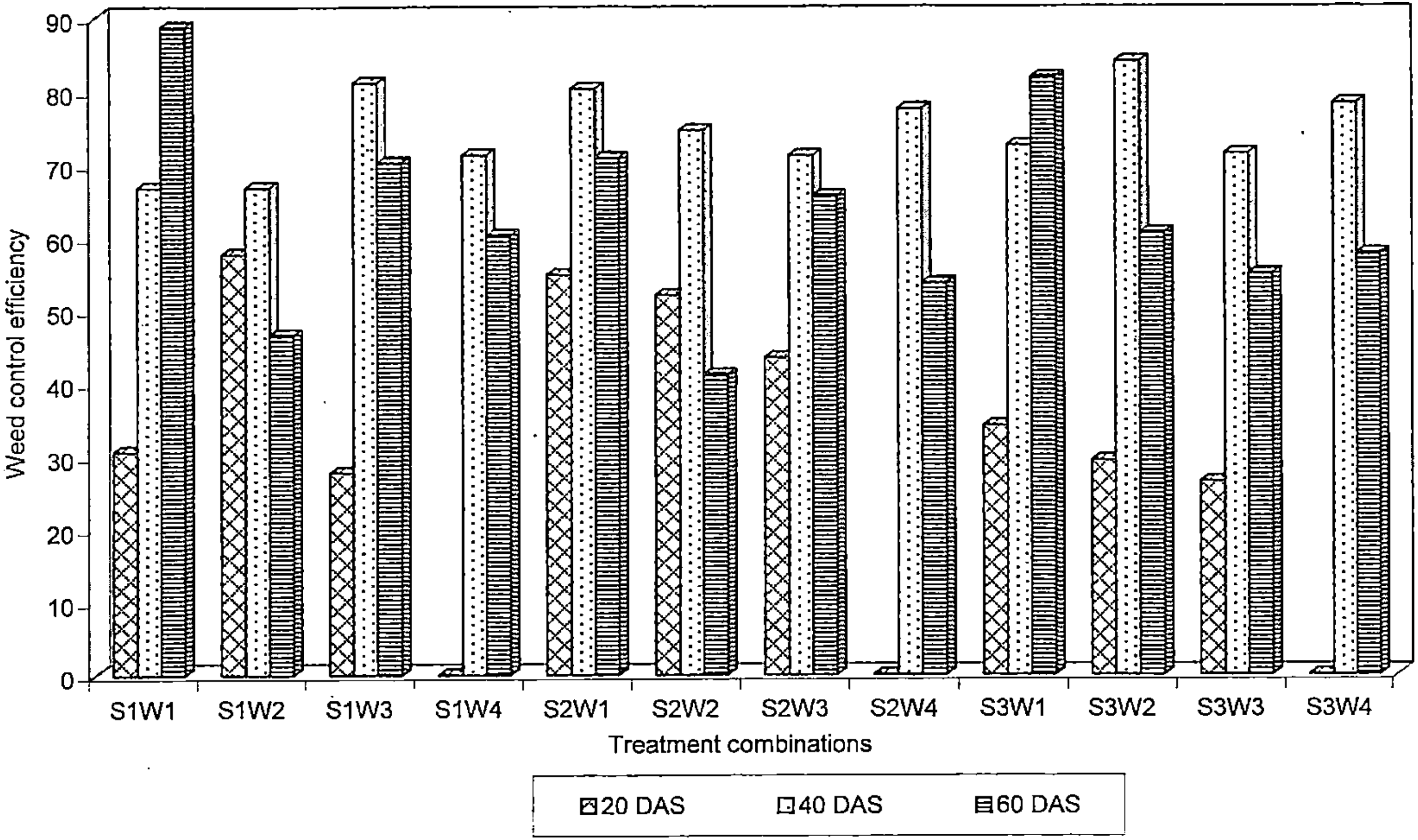


Fig. 23 Effect of spacing and weed management practices on weed control efficiency of sedges at different periods of observation

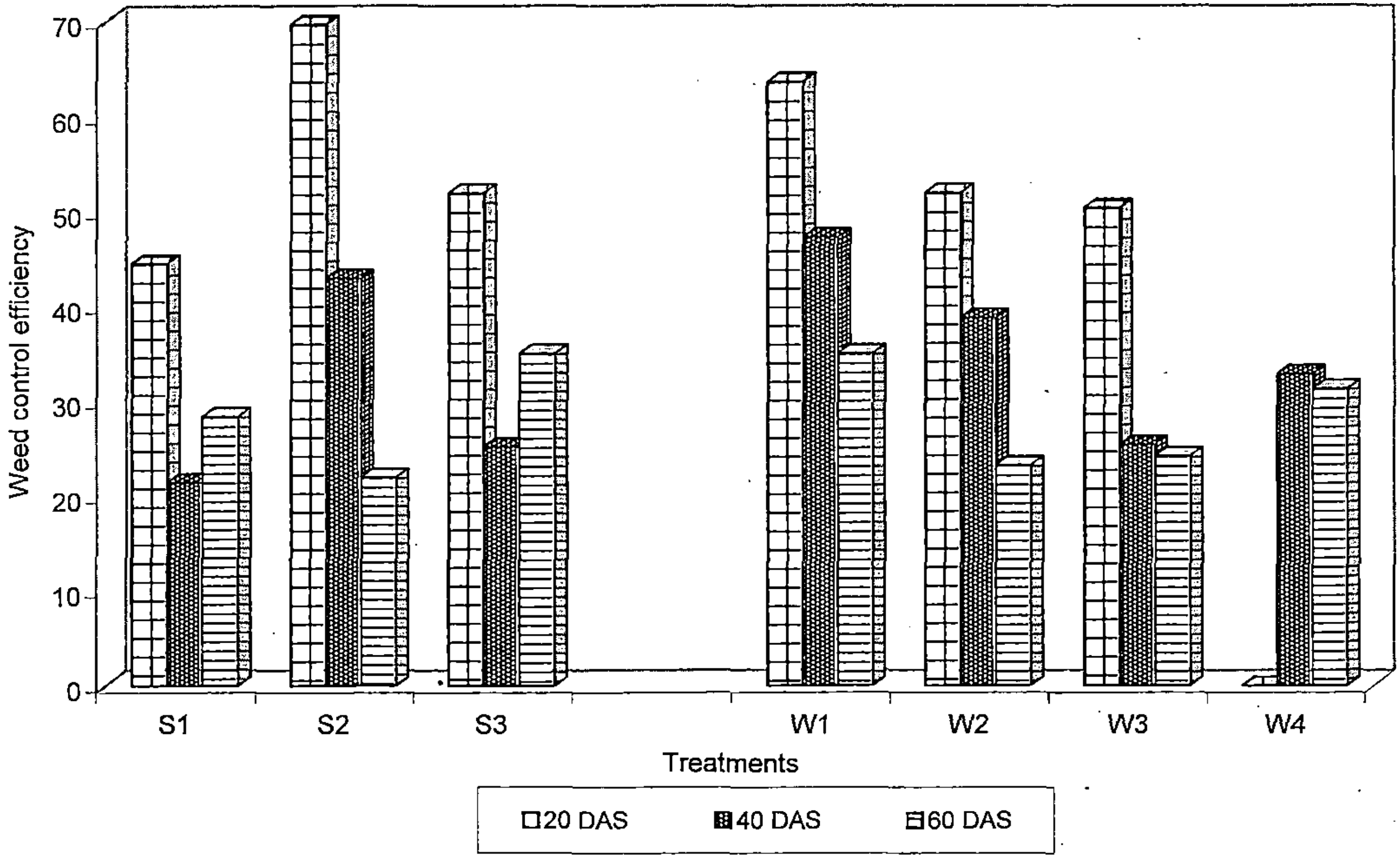


Fig. 24 Interaction effect of spacing and weed management practices on weed control efficiency of sedges at different periods of observation

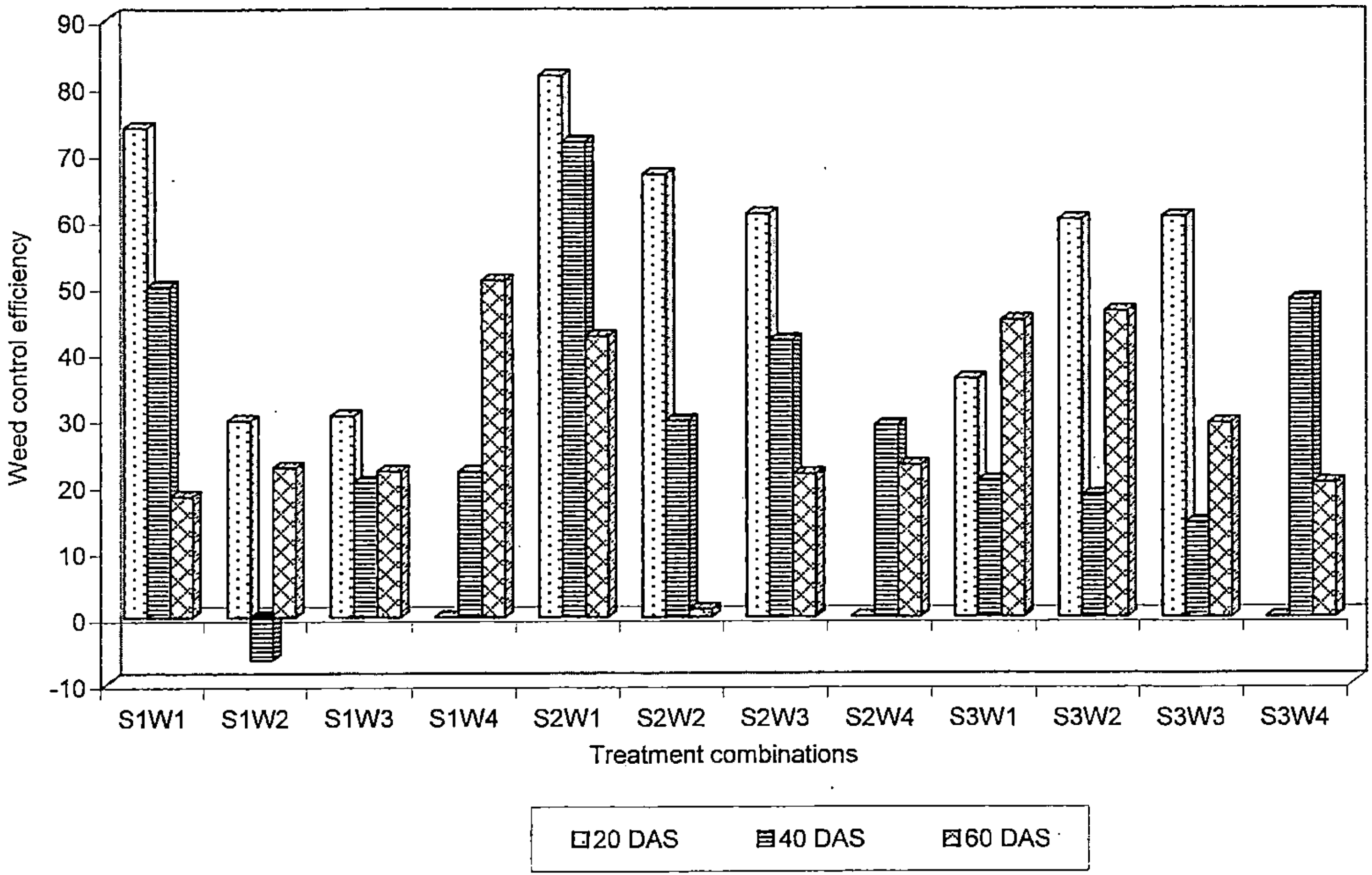


Fig. 25 Effect of spacing and weed management practices on weed control efficiency of all weeds at different periods of observation

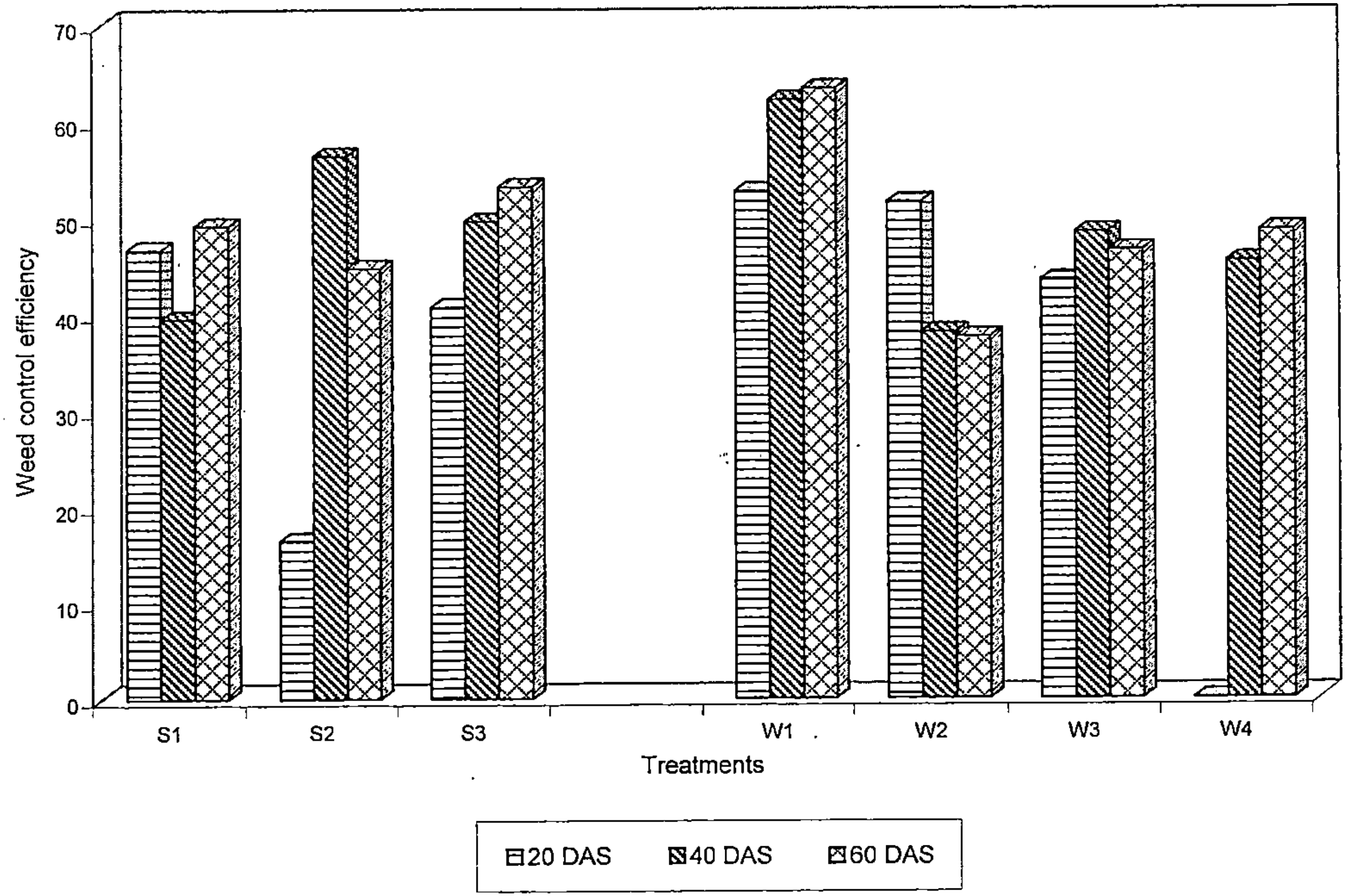
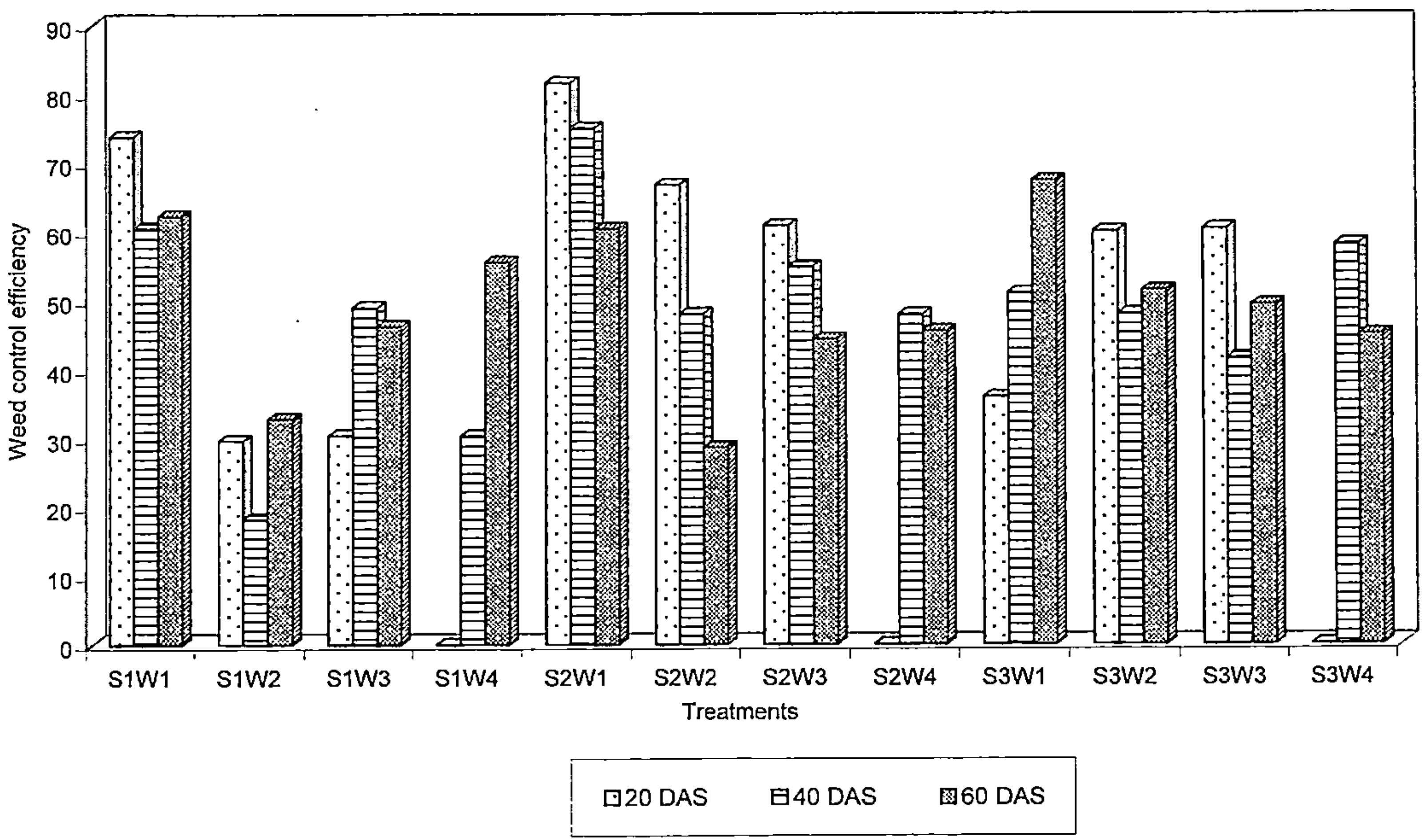


Fig. 26 Interaction effect of spacing and weed management practices on total weed control efficiency at different periods of observation



5.2.1.2 Effect of weed management practices on crop growth characters

Plant height was not influenced much by weed management practices except at 30 DAS, where the fluchloralin treated plots showed stunted growth. This is in contradiction to the findings of Tasic *et al.* (1980) and Olofintoye *et al.* (1984), where unweeded check recorded significantly higher plant height compared to weedy check. Unweeded check recorded the lowest LAI while the weed free check recorded the highest LAI. This is because of the better plant growth in weed free plots as a result of lesser weed competition. But Olofintoye *et al.* (1983) did not observe any significant difference in LAI among treatments. The number of tillers per hill and dry matter production were also highest in the weed free check, which was on par with all treatments except unweeded check and fluchloralin treated plots. This result is in line with the findings of Tasic *et al* (1980).

5.2.2 Effect of treatments on yield and yield attributing characters

5.2.2.1 Effect of spacing on yield and yield attributing characters

The yield and yield attributing factors were not much affected by spacing but the straw yield showed a different trend. Pathak and Hazarika (1985) also reported that there was no significant difference in yield of upland rice grown in rows 15, 18 and 21 cm apart. The present findings are also supported by the finding of Yamada *et al.* (1961) that final dry weight of rice per unit area was approximately constant irrespective of plant densities.

5.2.2.2 Effect of weed management practices on yield and yield attributing characters

Various weed management practices adopted, significantly influenced the yield attributes and the yield. Among different yield attributing characters, all except chaff percentage was significantly influenced by weed management practices. Weed free check (W_6) registered the highest value for all of them. This is evidently because of the weed free environment which allowed the crop to utilize it's genetic potential better. Weed competition severely reduced the availability of moisture, nutrients and light to the plant and resulted in the lowest value in weedy check (w_5). The use of herbicides and hand weeding for weed management resulted in significantly higher yield attributes compared to weedy check (w_5). This showed that these practices were effective in reducing the weed competition with the crop and reduced considerably the ill effects of weeds on the crop. Singh and Sharma (1994) also opined that yield attributing characters were enhanced by either two hand weeding or one pre-emergent herbicide followed by a hand weeding. Similar results were reported by Mutanal *et al*. (1997) and Pandey *et al*. (1997).

Chaff percentage did not vary among weed management practices probably because the major factor which affected this yield attribute was insect attack.

Grain yield was significantly influenced by weed management practices. Weed free check recorded the highest grain yield compared to all other treatments. This is because of the weed free environment, which

Fig. 27 Effect of spacing and weed management practices on grain yield and straw yield at different periods of observation

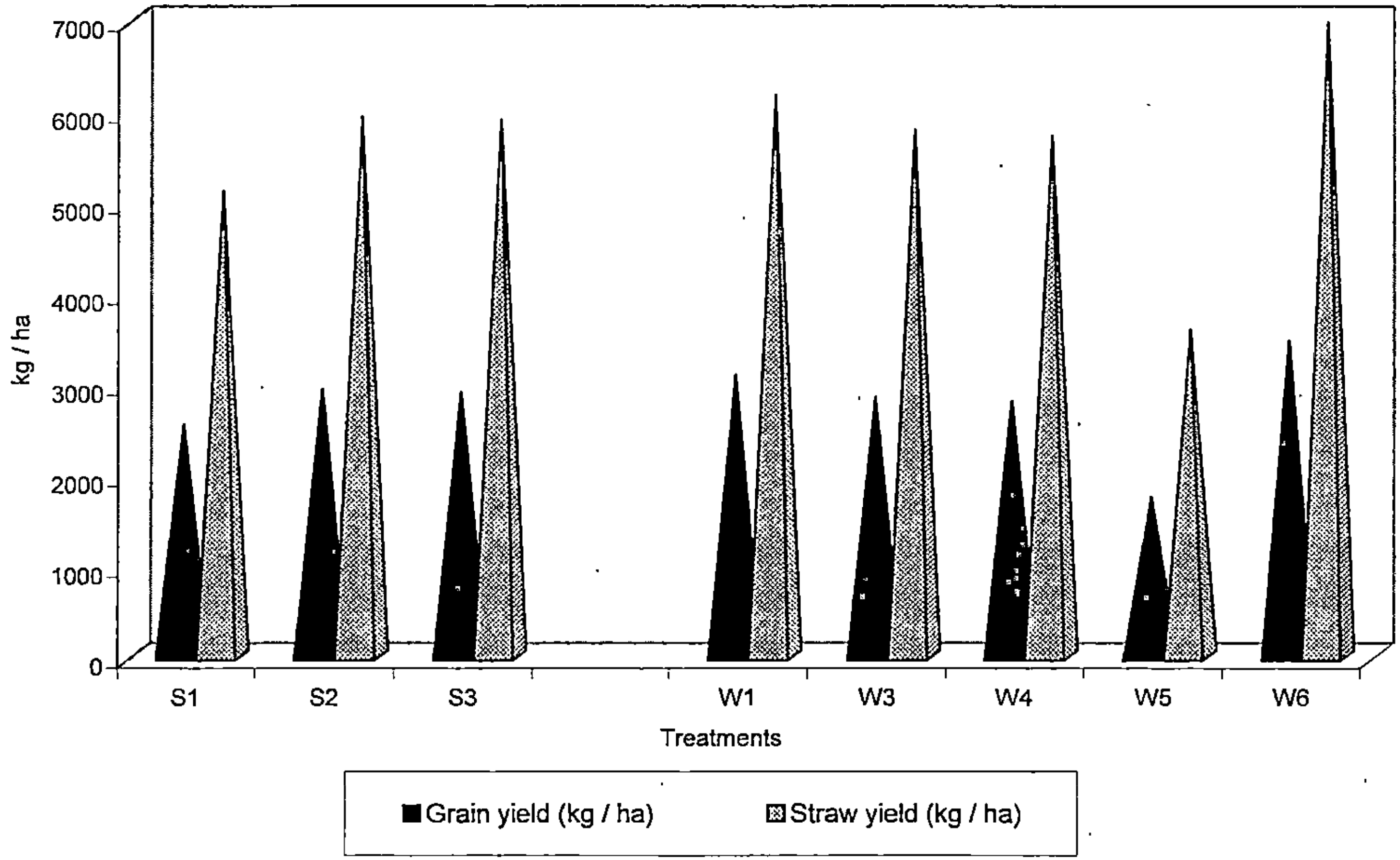


Fig. 28 Interaction effect of spacing and weed management practices on grain yield and straw yield at different periods of observation

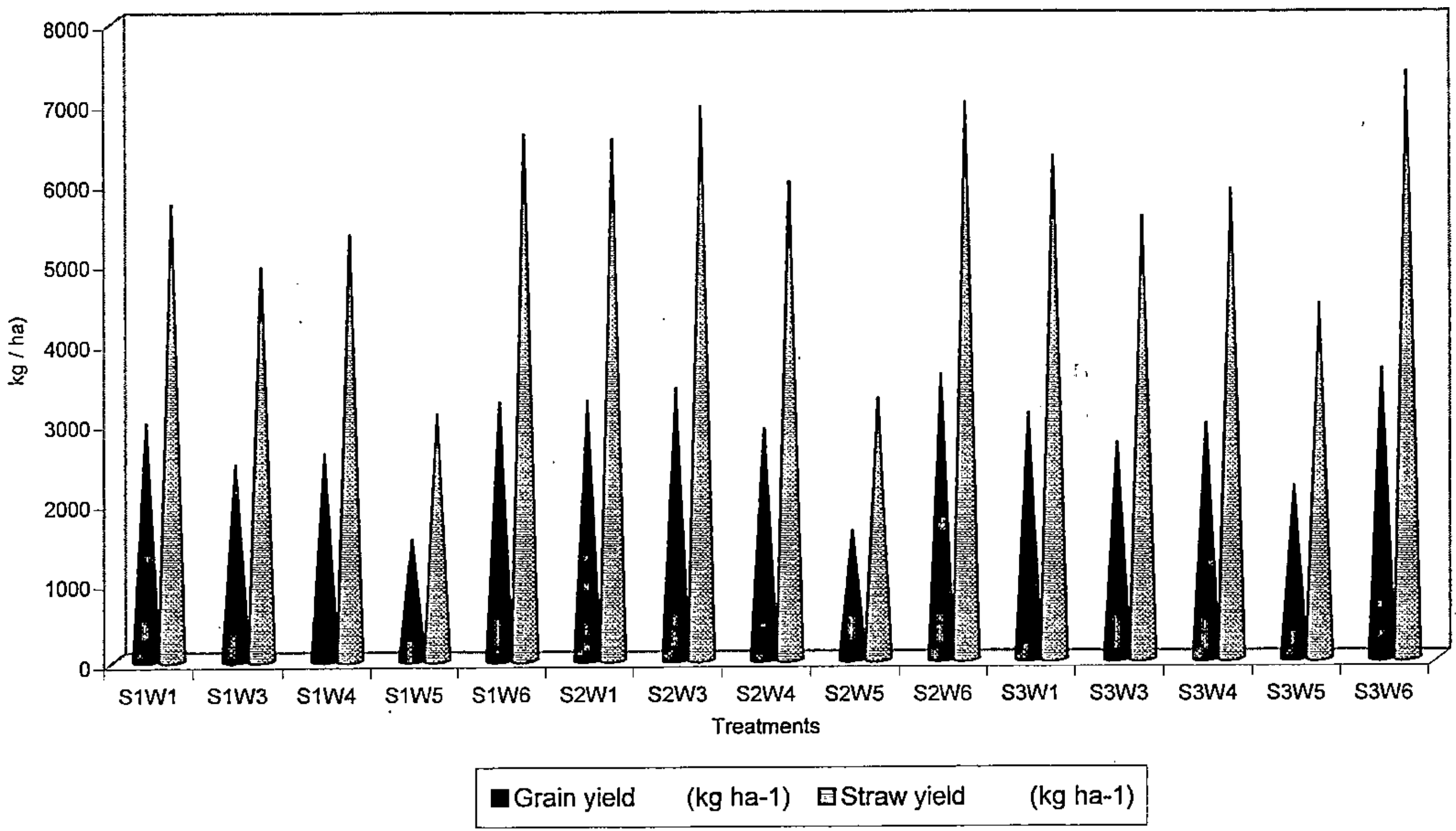


Fig. 29 Effect of spacing and weed management practices on weed index at different periods of observation

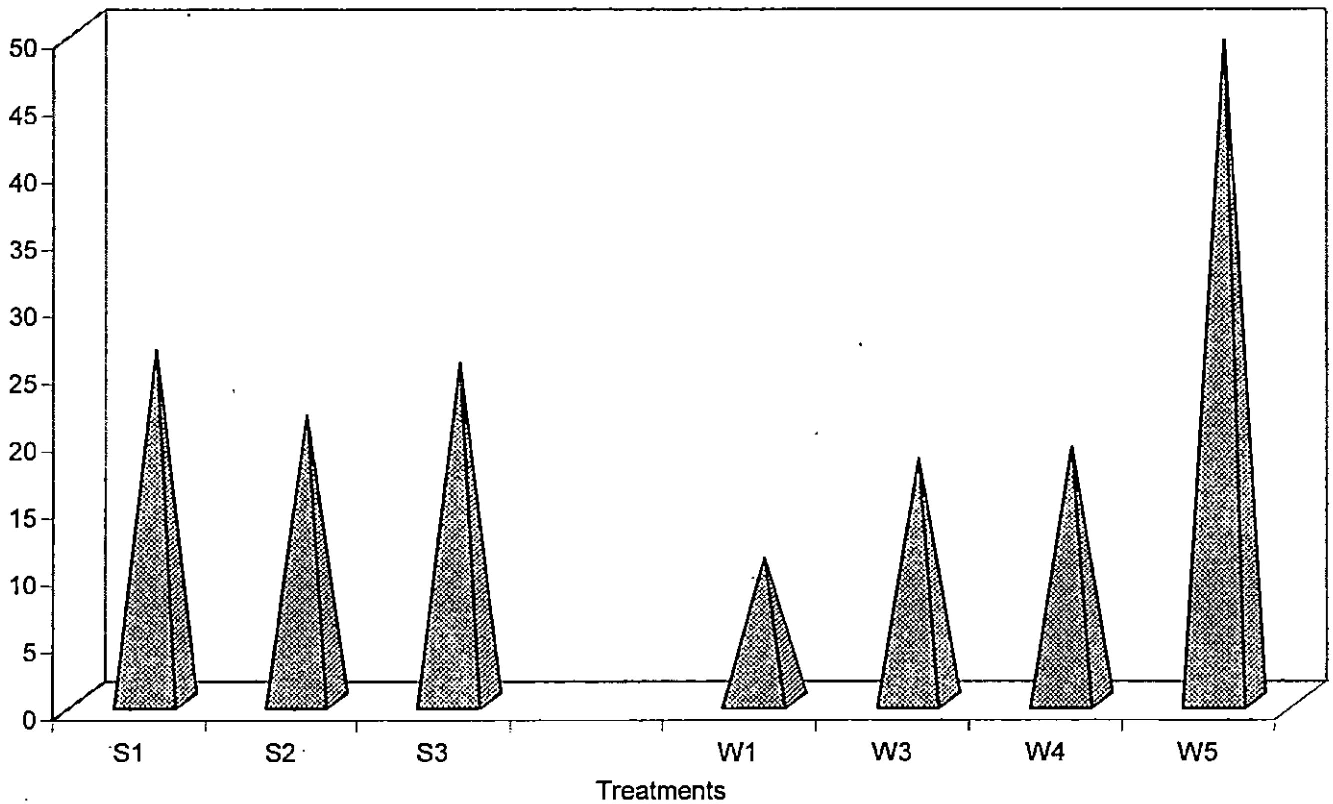
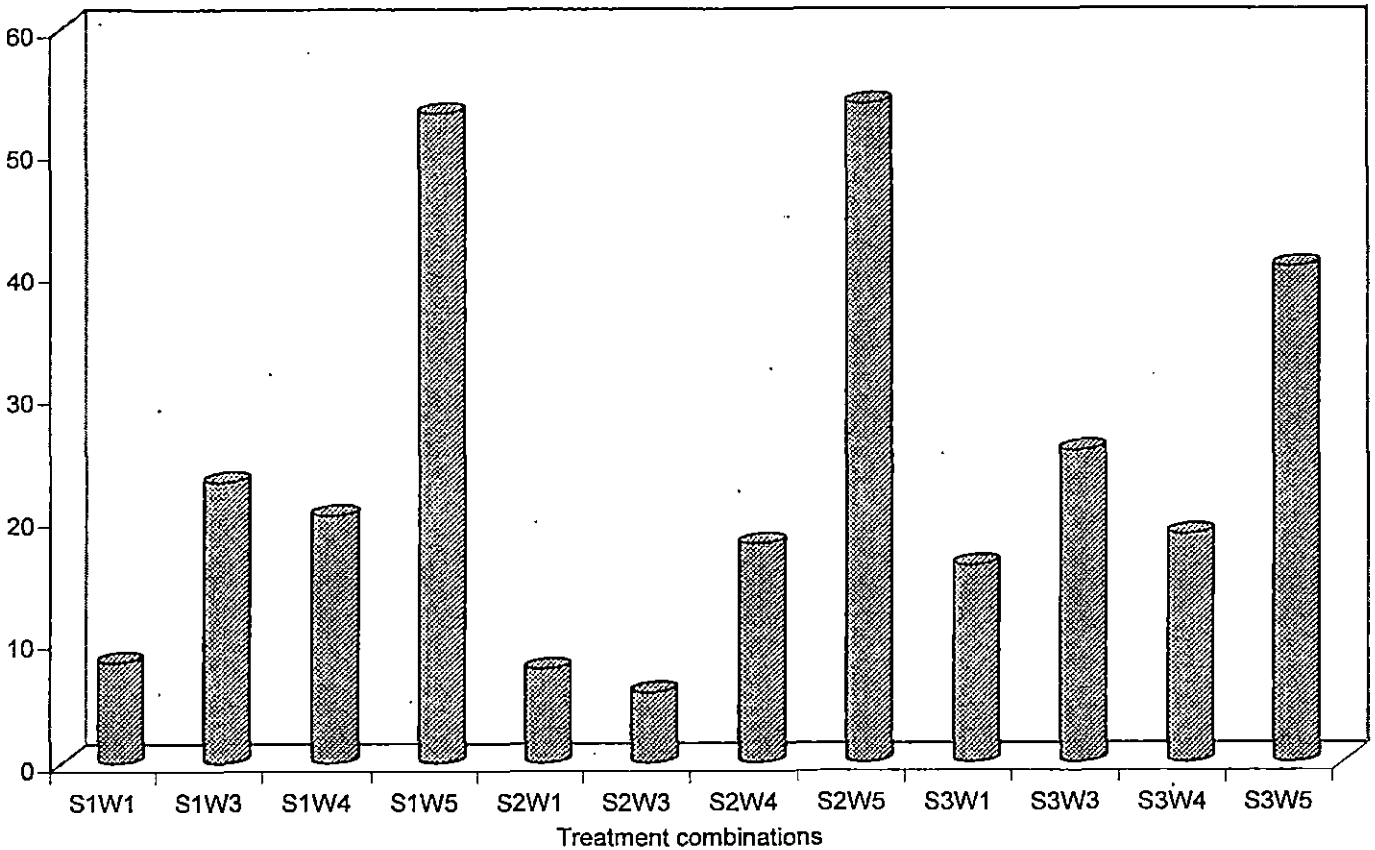


Fig. 30 Interaction effect of spacing and weed management practices on weed index at different stages of observation



provided more nutrients, light, space and moisture for the crop. The crop recorded the highest uptake of nutrients in weed free condition. All these favourable condition led to enhanced yield attributing factors at weed free plots as discussed earlier and this ultimately led to high yield. The plots treated with pendimethalin followed by one HW at 20 DAS, butachlor followed by a HW at 20 DAS and 2 HW at 20 and 40 DAS recorded grain yields on par with each other. Even though the yield from these plots was significantly lower than weed free check, the difference was marginal. The weedy check resulted in a drastic reduction of yield and recorded the lowest grain yield. The high yield in herbicide treated plots and HW plots is because of the better weed control obtained, which had favourable effect on yield attributes as discussed earlier and on crop nutrient uptake (Gogoi and Kalitha, 1990). The higher yield from plots treated with pendimethalin + 1 HW was also reported by Gogoi and Kalitha 1990, Sharanappa *et al.* (1994) and Munroe *et al.*, 1982. Mutanal *et al.* (1997), Pande *et al.* (1997) and Munroe *et al.* (1982) also recognised that Butachlor + 1 HW produces good yield in upland rice. Nandal and Singh (1994) and Pande and Pande (1994) opined that 2 HW gives high yields.

The same trend discussed above for grain yield was also noted for straw yield. The higher straw yields obtained in weed free plots and plots treated with herbicide or HW treatments can be attributed to the high N uptake, high weed control efficiency and better moisture availability to the crop.

5.2.2.3 Effect of Spacing -Weed management practice interaction on yield attributing characters and yield

Among the yield attributes, number of productive tillers per hill and number of filled grains per panicles were affected by spacing weed management interaction effect. The combination of widest spacing and weed free condition resulted in the highest number of productive tillers per hill. This is because of the favourable effect of wide spacing that reduced the plant-to-plant competition. The combination of closest spacing and no weeding resulted in lowest number of productive tillers per hill, evidently due to the very high weed competition and plant -to- plant competition. The same trend was there for the number of filled grains per panicle. Grain yield and straw yield were not influenced by spacing-weed management practice interaction effect.

5.2.3 Nutrient removal by the crop

Different spacing adopted influenced the removal of P only. The medium spacing (s_2) resulted in the highest P uptake by the crop, which in turn was attributed to the better crop growth at the medium spacing as discussed earlier.

Weed management practices significantly influenced the NPK uptake of the crop. Weed free check recorded the highest crop uptake of all three major nutrients. In weed free situation, the lack of weed competition helped the crop to extract more nutrients from the soil resulting in high NPK uptake. Similar results were obtained by Nandal and Singh (1995) also. The herbicide applied plots and hand weeded plots were on par with each other with respect to NPK uptake and they recorded significantly higher nutrient uptake than weedy check. The control of weeds achieved by herbicide application and hand weeding resulted in lesser competition by weeds for nutrients. This resulted in lesser nutrient uptake by weeds and higher nutrient uptake by the crop.

The interaction effect of spacing and weed management practice were not pronounced enough to cause significant variation in crop NPK uptake.

5.3 Nutrient status after the experiment

NPK content of the soil after the experiment was not influenced by different spacings tried, while the weed management practices had significant influence on the soil nutrient status. Nitrogen content was the highest in weed free check, evidently because there was no removal of nitrogen by weeds. Application of pendimethalin and butachlor followed by one HW (w_1 and w_3) and two HW (w_4) resulted in soil N content on par with weed free check after the experiment. The soil N content in plots treated with fluchloralin was significantly lower than other herbicide treated plots because of loss of crop and very high weed N removal. Weed free check recorded the lowest soil N after the experiment.

Phosphorus content of the soil after the experiment was the lowest in plots treated with fluchloralin and was on par with unweeded check and all the other treatments were on par among themselves.

Weedy check recorded the lowest K content of the soil after the experiment followed by pre-emergent application of fluchloralin. This can be attributed to the high K removal by weeds in these plots as discussed earlier. The plots in which weeds were effectively managed recorded high K content of the soil after the experiment because of lesser K removal by weeds.

These findings are in line with that of Pandey and Thakur (1988). They reported that herbicide treated plots recorded very low uptake of major nutrients by weeds compared to weedy check.

5.4 Herbicide persistence in soil

The results of the present study indicated that there was no residual toxicity of herbicides after the cropping season. So it is safe to go for even crops susceptible to these herbicides as the next crop. Several other scientists also have reported the similar lines. Kulashrestha (1987) found out that the half-life of butachlor was around 5 days in soil and 3 days in plant when applied @ 1 or 2 kg a.i. ha $^{-1}$. Similarly pendimethalin is also reported to have no residual toxicity affecting the next crop (Mutanal *et al.*, 1997).

5.5 Economics of Weed Management

Net returns and B:C ratio was affected significantly by different spacings adopted. The closest spacing of 15 x 10 cm (s_1) recorded the lowest net returns and B:C ratio. This is attributed to the high seed cost and reduced returns, due to high plant-to-plant competition. The other two spacings were significantly higher and on par with respect to net returns and B:C ratio.

Net returns and B : C ratio were significantly influenced by the weed management practices. The two herbicide treatments i.e. pre-emergent application of pendimethalin followed by one HW at 20 DAS and pre-emergent application of butachlor followed by a HW at 20 DAS produced the highest returns and B : C ratio compared to all other treatments. Weed free check (w_6) resulted in the lowest net returns and B : C ratio. This is because of the high labour cost involved in keeping the plots weed free. The next lowest amount of Net returns and B : C ratio were obtained from plots hand weeded twice. This is again due to the high amount of labour involved in hand weeding the plots. The results thus indicated that an integrated approach of pre-emerged spray of butachlor or pendimethalin, followed by one HW was the best both in terms of productivity and economics. Similar results were also reported by Gogoi and Kalita (1990), Mutanal *et al.* (1997), Ali and Bhanumurthy (1985) and Ramamoorthy *et al.* (1998).

Summary

SUMMARY

The present study entitled "Integrated weed management in upland rice" was carried out in the Instructional Farm, College of Agriculture, Vellayani during the virippu season of 1999. The main objectives of the experiment were to evolve a suitable integrated weed management strategy for upland rice, to study the effect of spacing on weed population and crop yield and to assess the efficiency and economic feasibility of different weed management strategies in upland rice.

The experiment was laid out in split plot design having three replications with three main plot treatments and six subplot treatments. Three different spacings i.e., 15 x 10 cm, 20 x 10 cm and 20 x 15 cm were the main plot treatments. Sub plot treatments were different weed management strategies consisting of three different herbicides in combination with hand weeding, hand weeding alone twice, unweeded check and weed free check. Pendimethalin, Fluchloralin and Butachlor were the herbicides used in the experiment. The residual effect of herbicides on the soil was also assessed based on the germination percentage of cucumber seeds sown in herbicide treated plots and in control plots after the harvest of the rice crop.

The important results of the experiment are summarised below.

1. The most commonly observed weeds in the experimental site were *Echinochloa colona* (L.) Link., *Echinochloa crus-galli* (L.), P. Beauv and *Cynodon dactylon* among grasses, *Cleome rutidosperma* D.C. and *Commelina benghalensis* L. among broadleaved weeds and *Cyperus rotundus* and *Cyperus iria* among sedges.

2. The fluchloralin treatment (w_2) resulted in phytotoxicity leading to considerable crop loss.

3. Unweeded check (w_5) recorded the highest weed growth throughout the crop growth period.

4. At 60 DAS the fluchloralin treated plots recorded high weed dry weight on par with that of unweeded check because of low competition by the crop.

5. The hand weeded plots resulted in high weed growth comparable to unweeded check up to 20 DAS but controlled weeds very effectively afterwards and resulted in high weed control efficiency at 40 and 60 DAS.

6. Butachlor + one HW at 20 DAS (W_3) and Pendimethalin + one HW at 20 DAS showed high weed control efficiency through out the crop growth period.

7. Pendimethalin application followed by HW at 3 weeks after sowing (w_1) recorded the highest weed control efficiency for grasses and broadleaved weeds at all periods of observation.

8. The relative frequency of sedges was significantly high in pendimethalin treatment compared to all other weed management treatments presumably because of the effective control of grasses and broadleaved weeds offered more space and less competition for sedges.

9. Broadleaved weeds dominated over grasses and sedges at 20 DAS in all plots irrespective of weed management treatments.

10. At 40 and 60 DAS sedges dominated the weed flora in all plots.

11. The dominance of sedges over grasses and broadleaved weeds were comparatively lower in unweeded check than all the plots where weeds were managed indicating the lower efficiency of weed management strategies to control sedges.

12. Pre-emergent application of herbicides markedly reduced the grassy weed population at 20 DAS.

13. Unchecked weed growth extracted the available nutrients and moisture resulting in better weed growth and drymatter production.

14. Different spacings tried did not significantly influence the weed dry weight but the absolute density of weeds was significantly lower at the medium spacing of 20 x 10 (s_2) as the closest spacing supported more number of small weeds.

15. The treatment combination of the medium spacing of 20 x 10 cm and pendimethalin application followed by a hand weeding at three weeks after sowing (s_2w_1) resulted in the lowest absolute density of weeds.

16. The various spacings tried did not significantly influence the N and K uptake by weeds, but the P uptake was affected substantially as the medium spacing of 20 x 10 cm (s_2) recorded the lower P uptake by weeds obviously because of the low weed density.

17. Two HW at 20 and 40 DAS and application of Pendimethalin or Butachlor followed by a HW at three weeks after sowing resulted in significant reduction in NPK uptake by weeds.

18. Spacing did not significantly influence the crop growth character except number of tillers, which was highest at the widest spacing of 20 x 15 cm (s_3).

19. Fluchloralin treatment (w_2) resulted in reduction in plant height at 30 DAS as a result of the phytotoxic effect.

20. All yield attributing characters except chaff percentage was significantly improved by the weed management treatments.

21. Weed free check (s_6) recorded the highest grain yield and unweeded check (s_5) the lowest. Unweeded check recorded 49.14 per cent yield reduction compared to weed free check.

22. All the weed management treatments except fluchloralin resulted in higher yield compared to unweeded check.

23. No herbicide used in this experiment showed residual toxicity after the cropping season.

24. The weed free check (s_6) registered the highest grain protein content and weedy check (s_5) the lowest.

25. Among various spacings tried the closest spacing of 15 x 10 cm was least economic because of higher seed cost and lack of comparatively higher returns.

26. Pendimethalin @ 1.5 kg a.i. ha^{-1} + one hand weeding three weeks after sowing (w_1) and Butachlor @ 1.25 kg a.i. ha^{-1} + one hand weeding three weeks after sowing (w_3) were the most remunerative treatment.

27. Keeping the field weed free during the entire crop growth period was not economic.

Future line of work

From the result of the present study Pendimethalin @ 1.5 kg a.i. ha^{-1} + one hand weeding three weeks after sowing (w_1) and Butachlor @ 1.25 kg a.i. ha^{-1} + one hand weeding three weeks after sowing (w_3) were found to be a remunerative method for weed control. However, both this treatments failed to control sedges. Hence, herbicide combinations and herbicides which can effectively control sedges need to be studied. Chemical weeding before land preparation in upland rice is another area to be studied in detail. Survival mechanisms of weeds including adaptations to soil disturbances and crop competition must be examined to develop cultural practices to minimise weed competition. Vegetation analysis are necessary to understand why changes in weed population occurs with time and different management practices.

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*Original not seen

Appendix

APPENDIX – I

Data on weather parameters during the cropping period (July 4 to October 10)

Standard week	Relative humidity (%)	Temperature (^{0}C)		Evaporation (mm/day)	Rainfall (mm) (Weekly total)
		Maximum	Minimum		
27	84.5	28.3	23.3	2.0	25.8
28	88.1	28.9	23.6	3.0	75.6
29	83.0	28.4	23.3	2.8	22.2
30	85.0	28.9	23.1	3.3	37.2
31	85.4	29.5	23.5	3.4	31.0
32	80.5	30.3	24.3	4.0	1.2
33	82.5	29.7	23.7	4.5	67.6
34	82.8	29.6	23.5	3.6	4.6
35	80.4	29.6	23.3	3.6	2.9
36	79.6	30.5	23.7	4.4	2.5
37	76.2	31.2	23.9	4.6	0.8
38	76.0	32.2	24.4	5.3	0.0
39	84.5	30.2	23.6	2.9	12.2
40	86.7	28.9	23.2	2.3	106.8

INTEGRATED WEED MANAGEMENT
IN
UPLAND RICE

By

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ABSTRACT OF THE THESIS
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ABSTRACT

A field experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram to evolve a suitable integrated weed management practice for upland rice. The study was conducted during the virippu season of 1999.

The field experiment was laid out in split plot design having three replication with three main plot treatments and six subplot treatments. Three different spacings i.e., 15 x 10 cm 15 x 10 cm, 20 x 10 cm and 20 x 15 cm were the main plot treatments. Sub plot treatments were different weed management strategies consisting of three different herbicides in combination with one hand weeding, hand weeding alone twice, unweeded check and weed free check. Pendimethalin, Fluchloralin and Butachlor were the herbicides used in the experiment. The rice variety used for the experiment was Matta Triveni.

The results of the study revealed that grasses, broadleaved weeds and sedges competed with the rice crop. Different weed management practices included in this experiment significantly influenced the intensity and distribution of the weeds, but the fluchloralin treatment (w_2) resulted in phytotoxicity and affected the crop stand considerably.

The application of butachlor + one hand weeding at three weeks after sowing (w_3) and pendimethalin + one hand weeding at three weeks after sowing (w_1) showed very high control over weeds throughout the crop growth period. The plots hand weeded twice at 20 and 40 days after sowing also

registered considerable reduction in weed growth. Among the spacings tried the medium spacing of 20 x 10 cm (s_2) resulted in lowest absolute density of weeds. Although the application of Pendimethalin and Butachlor resulted in good control of grasses and broadleaved weed, their effect on sedges was meagre.

All the weed management treatments except fluchloralin (w_2) resulted in improved yield attributes and significantly higher yield compared to weedy check. Weed free check (s_6) recorded the highest grain yield. Unweeded check recorded the lowest with 49.14 per cent yield reduction compared to weed free check. The various spacings tried did not result in significant difference in yield. No herbicide used in this experiment resulted in residual toxicity after the cropping season.

Pendimethalin @ 1.5 kg a.i. ha^{-1} + one hand weeding three weeks after sowing (w_1) and Butachlor @ 1.25 kg a.i. ha^{-1} + one hand weeding three weeks after sowing (w_3) were the most remunerative treatment and keeping the field weed free during the entire crop growth period was found to be not economic.