ECOFRIENDLY WEED MANAGEMENT PRACTICES IN TRANSPLANTED RICE

BY

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THESIS
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1999

Dedicated to everlasting memory

of my

Dear Father and Brother

DECLARATION

*I hereby declare that this thesis entitled "**Ecofriendly weed management practices in transplanted 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

*Certified that this thesis entitled "**Ecofriendly weed management practices in transplanted rice**" is a record of research work done independently by* **Mr. RENJAN. B.** *under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.*

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LIST OF ABBREVIATIONS USED IN THIS THESIS

m	-	Metre
cm	-	Centimetre
%	-	Per cent
°C	-	Degree Celsius
g	-	Gram
kg	-	Kilogram
t	-	Tonnes
var.	-	Variety
LAI	-	Leaf Area Index
DAT	-	Days After Transplanting
PI	-	Panicle Initiation
ANOVA	-	Analysis of Variance
N	-	Nitrogen
P	-	Phosphorus
K	-	Potassium
KAU	-	Kerala Agricultural University
ha	-	Hectare
Fig.	-	Figure
POP	-	Package of Practices
Ns	-	Non Significant
CWF	-	Complete Weed Free
DMP	-	Dry Matter Production
HW	-	Hand weeding
Chl	-	Chemical
BLW	-	Broad Leaved Weeds
RD	-	Relative Density
IV	-	Importance Value
WCE		Weed Control Efficiency
WI		Weed Index
BCR		Benefit Cost Ratio

INTRODUCTION

1. INTRODUCTION

The advent of the Green Revolution in India had ushered a substantial increase in rice production. However, it has now been realised that the such increase were only marginal when compared to several other rice growing nations of Asia. Rice production in India is at crossroads today. Minimising the use of chemicals without reducing the income assumes much importance in the present concept of ecofriendly agriculture.

Weed management has always been one of the major expenditure involving operations for rice production, as good quantum of the total labour engaged has been devoted to traditional weeding practices. It has been estimated that about 100-800 manhours per hectare are needed for weeding alone depending on weed infestation. Competition between weeds and crop plants are mainly for nutrients, water sunlight and space. The direct and the most important effect of weeds is the reduction in crop yield resulting from the competition for above factors. Muthukrishnan *et al.* (1997) estimated an yield reduction to the tune of 41.4 per cent by weeds in transplanted rice. Further, weed infestation deteriorates the quality of rice, increases cost of operation such as harvesting, drying and cleaning. By altering the microclimate and serving as alternate host, the weeds harbour pest and disease organisms.

In Kerala, the area under rice cultivation is decreasing day by day. A reduction of about 28 per cent in the rice growing area was noticed during 1984 to 1996. During 1996-97, out of the total area under rice in Kerala, 1.63 lakh ha are cultivated during *Virippu* season, 2.10 lakh ha during *Mundakan* season and 0.56 lakh ha during *Punja* season (Farm Guide, 1999). Of these three seasons, weed problem is more during the first crop *Virippu* season.

Among the different methods employed in weed management, manual weeding is the most effective method of weed control. Due to the exorbitant wage rate combined with low efficiency and non-availability of labour during the peak periods in Kerala, hand weeding becomes a burden for cultivators. Moreover, the drudgery in hand weeding necessitated the use of chemicals for economic weed management in rice. But, during the *Virippu* season the efficiency of applied herbicide is questionable. The intermittent and heavy rain results in leaching and run off of chemicals to the water bodies and other fields causing environmental pollution and low weed control efficiency. The use of non-chemical methods are relevant in this context.

Suraci (1987) observed that non-chemical weed management methods like ploughing, burning and flooding could act directly by controlling the existing weed population and indirectly by inhibiting weed seed germination. The tillage operations help in the early germination of the weed seed bank in the soil and control them prior to sowing/planting of crop.

With this background, the present investigation was undertaken to evolve an eco-friendly weed management practice in transplanted rice during the *Virippu* (first crop) season with the following objectives:

* To develop a package of ecofriendly weed management practices.

* To study the change in weed flora due to different type of land preparation.

* To assess the nutrient uptake of the crop and weeds.

* To work out the economics of rice production.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The knowledge of rice weeds in relation to land-time-nutrient management is a pre-requisite to formulate an ecofriendly and effective weed management technique. Studies made on the various aspects of crop-weed competition and "land-time-nutrient management" and its effect on weed management are reviewed here..

2.1 Weed spectrum in rice fields

Weed flora varies widely with respect to varying ecological conditions.

Survey reports of Kumar and Gautam (1986), Muthiah *et al.* (1986), Tiwari *et al.* (1986) and Jayasree (1987) indicated that grass weeds occupied a major per cent of total weeds followed by sedges and aquatic weeds in direct sown flooded rice. Janiya and Moody (1987) found that the weed flora was similar in transplanted and wet seeded rice but variation was greatly influenced by weed control methods.

Important weed species observed in transplanted rice as observed by different workers are presented in Table 1.

Table 1

Important weed species observed in transplanted rice

Grasses	Sedges	Broad leaved weeds	Reference
Echinochloa colona (L.) Link	*Cyperus iria* (L.)	*Eclipta alba*	AICRPWC (1985)
E.crusgalli (Beauv.)	*C.difformias*, *Scirpus* sp.	*Ammania baccifera* (L.) *Ludwigia parviflora* (Roxb)	
Brachiaria platyphylla (Criseb)	*Fimbristylis miliaceae*		
E.colona (L.) Link	*Cyperus rotundus*	*Ludwigia adscendens*	Kandaswamy and Palaniappan (1990)
Echinochloa crusgalli (Beauv)	*Cyperus differmis* (linn)	*Ammania baccifera* (L.)	Dhiman and Nandal (1995)
E.colona (L.) Link		*Ludwigia paarviflora* (Roxb)	Das and Saharay (1996)
		Marsilea quadrifoliata (L.)	
E.colona (L.) Link	*Scirpus spp*		Nandal and Singh (1993)
	Cyperus iria (L.)		
Paspalum distichum	*Cyperus iria* (L.)		Dhiman and Nandal (1995)
Ischaemum rugosum			
Cynodon dactylon (L.) Pers.	*Fimbristylis miliaceae* (L.) Vahl.		Balasubramanian (1996)
Panicum repens			
Paspalum distichum	*Scirpus erectus*	*Marsilia* sp	Das and Saharay (1996)
Cynodon dactylon			
Eleusine indica		*Commelina benghalensis* L.	Sharma and Tomar (1996)

2.1.1. Weed density

Sarkar and Moody (1983) and Verma *et al.* (1987) reported more number of grassy weeds in association with rice. Whereas, Chinnusamy (1985) observed the dominance of grasses and sedges over broad leaved weeds. Venugopal and Kondap (1985) also reported similar observation.

Tomer (1991) observed that of the total weed flora, grasses, sedges and broad leaved weeds in rice accounted to 70, 25 and 5 per cent respectively. Balasubramanian (1996) noticed that the total weed density under un-weeded conditions ranged from 89.6 to 112.8 m^{-2} at 20 days after transplanting (DAT), increased to 135.5 to 152.9 m^{-2} at 40 DAT, and remained more or less at the same level at the time of harvest of rice. He also reported that grass weed density increased up to 40 DAT but declined at maturity while the sedges population increased with advancing growth stage of rice. The density of broad leaved weeds nearly doubled from 20 to 40 DAT and increased further at harvest.

According to Asokaraja (1994) grasses and sedges exerted severe competition during the early period, which caused broad leaved weeds to emerge subsequently coinciding with the cessation of growth of the earlier types.

2.2. Rice weed competition

Stressful levels of environmental factors such as nutrient availability, water, light and temperature influenced crop weed interaction which interfered with weed control and weed control strategies (Patterson, 1995).

Mukhopadhyay *et al.* (1992) estimated that weeds in India caused an annual loss of Rs.1980 crores. Estimates also showed that weeds reduced rice yield by 61 and 48 percent during monsoon and summer respectively (Premsekhar, 1996).

.2.2.1. Critical weed free period

It has been reported that the critical period of crop-weed competition was between 21 to 40 DAT in transplanted rice (Varughese, 1978 and Sukumari , 1982).

According to Sasidhar (1983) weed competition was critical during the first 40 days after transplanting paddy and yield reduction was not significant by the presence of weeds thereafter. Soman (1988) also reported that the weed number and competition was severe up to 40 DAT. However Mukhopadhyay *et al.* (1992) observed the first 25 to 65 days of rice as the critical period.

Bhan and Mishra (1993) pointed out that the critical period of crop-weed competition in transplanted rice is 4 to 6 weeks after transplanting.

Critical period of weed competition in rice was the first one third of the crop growing season (Tjitrosemito, 1993).

Weed free period of 30 days during the initial crop growth stage was found to be favourable to prevent yield losses caused by weeds. (Moody and De Datta , 1986; Broar *et al.* 1994).

Chaudhary et *al.* (1995) observed that mean yield of grain was the highest in the plot kept weed free throughout crop growth. But this was not significantly different from grain yield obtained from plots kept weed free until 60 DAT.

2.2.2. Effect of crop-weed competition on growth of rice

Weeds exert a direct influence on the growth of rice crop.

Ali and Sankaran (1975) noticed that severe infestation of weeds suppressed the height of rice plants.

Significant reduction in dry matter production due to weeds was reported in the weed control experiments conducted in direct seeded rice (AICRPWC, 1985).

At maturity of rice, the plant height under unweeded check was less by 16.38 to 21.68 cm and dry matter production was reduced by 5.84 to 7.01 t ha^{-1} compared with hand weeding twice (Balasubramanian, 1996).

Mabbayad and Moody (1992) noticed a reduction in tiller number and crop growth rate due to weed competition in rice plants.

2.2.3. Effects of crop-weed competition on yield attributes and yield of rice

Ramamoorthy *et al.* (1974) found that competition reduced the productive tillers. Balasubramanian (1996) pointed out that productive tillers were only 5 to 7 $hill^{-1}$ under unweeded check as against 10.5 to 11.6 $hill^{-1}$ with twice hand weedings.

Sridhar *et al.* (1976) reported least number of panicle in unweeded plots. Weed competition in rice lowered the plant number by 37 per cent, filled grains panicle^{-1} by 13 per cent and test weight by 4 per cent (Ghobrial, 1981). Arya *et al.* (1991) and Varshney (1991) reported a decrease in thousand grain weight due to weed competition. Reduction in panicle length and thousand grain weight due to weed competition have been reported by Mabbayad and Moody (1992).

Muthukrishnan *et al.* (1997) observed that the number of panicle m^{-2} in hand weeded plot was significantly higher than unweeded check which were 528 and 356 respectively.

Pillai and Rao (1974) estimated about 15 to 20 per cent yield reduction in transplanted rice due to weeds. Yield loss of 50 to 64 per cent due to uncontrolled weed growth was also reported by Moody (1990).

Weeds effectively compete with rice up to 40 to 45 DAT and reduced grain yield ranging from 10 to 83 per cent (AICRIP, 1991). According to Kumari and Rao (1993); Reddy and Gautam (1993) competition stress of weeds exerted reduction in yield of transplanted rice by about 50 per cent. Yield reduction of 30 to 40 per cent was estimated by Bhan and Mishra (1993) due to weed competition.

Yield loss of 1.48 t ha^{-1} due to weed competition was reported by Sankaran *et al.* (1993). Chaudhary *et al.* (1995) recorded an yield reduction of 49.5 per cent from the unweeded plot of rice.

Maximum yield of 52.3 q ha^{-1} was registered from weed free treatment while unweeded check yielded 39.9 q ha^{-1} (Dhiman and Nandan, 1995). They also observed no yield variation between hand weeded and herbicide applied plots.

2.2.4. Crop-weed competition and nutrient removal

2.2.4.1. Effect of competition on the nutrient removal by rice

Increased N, P and K uptake by rice through weed control was reported by Ali and Sankaran (1984). Kolhe *et al.* (1986) suggested timely weed control in transplanted rice resulted in saving of 11.5, 1.5 and 13.2 kg ha^{-1} of N, P_2O_5 and K_2O respectively. Varshney (1990) also observed considerable saving of N, P and K through weed control methods in transplanted rice.

From two-year study on rice, Nandal and Singh (1993) reported an increase in nutrient uptake of rice by weed control treatments. Chaudhary *et al.* (1995) showed that season long weed free condition resulted is higher accumulation of N, P and K in rice.

Madhu and Nanjappa (1997) showed that the rate of increase in the uptake of nutrients (N, P_2O_5 and K_2O) by rice crop was proportional to the dry matter production. He also pointed out that the total uptake of N, P and K by crop was significantly lower in unweeded check.

2.2.4.2. Effect of crop-weed competition on the nutrient removal by weeds

Weeds remove considerable quantity of nutrients from soil and it is found to be much more than the crop plants.

Rethinam and Sankaran (1974) estimated that weeds remove 62.1, 20.0 and 65.3 kg ha^{-1} of N, P and K in rice.

Nutrient loss of 86.5 kg N, 12.4 kg P_2O_5 and 134 kg K_2O ha^{-1} due to unchecked weed competition was reported by Chandrakar and Chandrakar (1992). Among the rice weeds *Echnochloa* spp. is the most competitive weeds for nutrients Sahai and Bhan (1992).

In transplanted rice, the nutrient depletion by weeds was estimated to be 10.9, 2.6 and 9.8 kg ha^{-1} of N, P_2O_5 and K_2O respectively (Bhan and Mishra, 1993).

Balasubramanian (1996) estimated nutrient removal by weeds as 25.10, 6.03 and 20.68 and 30.78, 7.42 and 25.32 kg ha^{-1} of N, P_2O_5 and K_2O at 40 DAT and harvest respectively.

Madhu and Nanjappa (1997) showed that the rate of increase in the uptake of major nutrients by weeds was proportional to the dry matter production.

2.3. Summer ploughing as a tool for weed management

Manipulation of agronomic practices is an effective tool in the weed management for rice.

Conventional land preparation for effective weed control normally required one ploughing and two harrowings. Increased tillage frequency is essential to minimise weed population of perennial weeds such as *Paspalum distichum* (De Datta, 1978; Diop, 1982; Shad and De Datta, 1986).

Castin and Moody (1985) advocated that good land preparation should preceed the post plant weed control methods to prevent yield losses.

Verma *et al.* (1983) stated that summer ploughing reduced the weed problem in subsequent rice crop. He also reported that tillage practices could be used as an important weed control practice in areas where chemical usage was not practiced. Diop and Moody (1989) observed that land preparation during the dry season caused a reduction in perennial weeds. Effectiveness of summer ploughing for efficient weed control was also reported by Patel and Mehta (1989).

Summer ploughing during rice fallow season well before planting has often been recommended as an effective cultural method of weed control in many crops (Arunachalam *et al.* 1992; Ganesaraja *et al.* 1992; Thirumurugan *et al* 1992).

Arai and Matsunaka (1968) reported reduction in the emergence of *Echinochloa crusgalli* when the field was ploughed to a depth of 15 to 18 cm in dry season. Population of the grass species *Echinochloa colona* was reduced with deep ploughing (Smith and Moody, 1979). However, Moody (1982 and 1991) noticed that, land preparation during the dry season reduced *Cyperus rotundus* significantly.

Ilangovan (1991) observed that summer ploughing, followed by puddling with tractor drawn cage wheel effectively suppressed the weeds. The perennial weed *Paspalum distichum,* which is hard to control by herbicide, was effectively controlled by summer ploughing.

Arunachalam *et al.* (1992) and Ganesaraja *et al.* (1992) reported that summer ploughing and puddling effectively controlled grasses and sedges. In case of perennials, both top and underground growth is injured or destroyed by summer tillage and the tubers of sedges are exposed for desiccation (Tewari and Singh, 1991; Rao, 1992).

While comparing the tillage at planting and summer tillage, Balasubramanian (1996) observed a reduction of 57.1 to 67.5 per cent in sedge density, 7.2 to 20.8 per cent grass count and 7.3 to 18.0 per cent in broad leaved weed density.

But Das and Saharay (1996) noticed a significant increase in the number of *Scirpus erectus* with increase in tillage.

2.3.1. Effect of summer ploughing on growth and yield of rice.

Choudhary (1989) recorded higher leaf area index and dry matter production of rice with summer ploughing. Balasubramanian (1996) observed that 'summer ploughing enhanced the growth attributes of rice such as plant height and leaf area index. The increase in plant height at maturity was 2.55 to 3.58 cm in the summer ploughed treatment over tillage at planting. He added that leaf area index was increased by 0.34 to 0.43 with summer ploughing.

Pande and Bhan (1964) studied the effect of four ploughings with country plough followed by harrowing, and one ploughing with mould board plough followed by harrowing. They found that there was no significant difference in grain yield between the two treatments. But, according to Subramanian (1969) the treatments receiving two or four ploughings were superior to one ploughing in terms of rice yield under low land condition.

Rice yield was increased by summer ploughing followed by puddling with cage wheel (Ilangovan, 1991).

Summer ploughing and two puddling followed by application of anilofos with one hand weeding was observed to enhance rice grain yield (Arunachalam *et al.* 1992). Ganesaraja *et al.* (1992) found that two summer ploughings and application of butachlor @ 1.5 kg ha^{-1} along with one hand weeding on 30 DAT registered 63.8 per cent higher grain yield over control.

2.4. Stale seed bed technique for weed management

All *et al.* (1979) and Sumner *et al.* (1981) reported that stale seed bed practice prior to planting reduced the weed population. However, in a stale seed bed programme, planting usually will occur in some emerged vegetation, which necessitates the timely use of herbicide for weed control (Stougaard *et al.*, 1984; Elmore and Heatherly, 1988; Buchler and Werling, 1989 and Bruff and Shaw, 1992).

According to Heatherly *et al.* (1986) successful form of reduced tillage is stale seed bed system which use some degree of tillage.

Hosmani and Meti (1993) observed that stale seed bed encouraged a flush of new weed seedlings, which can be controlled very easily prior to planting and reduced the crop-weed competition in succeeding crops.

The advantage of stale seed bed practice in weed control was emphasised by Hosmani and Chittapur (1996) and Krishnarajan and Meyyazhagan (1996).

2.5. Skipping/delaying basal application of nitrogen

According to Mohapatra *et al.* (1983), the application of nitrogen at two to three weeks after emergence was better than basal application at sowing. The common practice of applying nitrogen in the standing water between transplanting and early tillering by farmers of South East Asia was not advantageous (De Datta, 1988).

Panda *et al.* (1988) found that with split application of urea at three weeks after germination and mid tillering stages, apparent nitrogen recovery of 49 to 68 per cent was recorded.

Skipping basal application of nitrogen at the time of transplanting was found desirable in many cases. This was based on the fact that the slow growth of rice plant in early stages, resulted in intense weed competition and the nitrogenous fertilizers applied at the time of transplanting was utilized more by weeds than by crops (YCES-Annual Report, 1989).

Kandasamy and Palaniappan (1990) recorded that initial 50 per cent of nitrogen could be applied at 10 DAS when sprouted seeds were sown in puddled rice.

Sharma *et al.* (1993) reported that delayed nitrogen application up to 15 DAT resulted in the highest fertilizer recovery. Stutterheim, *et al.* (1994) stated that reduced basal dressing enhanced the apparent nitrogen recovery ranging between 21 to 32 per cent.

During the first crop season, when the basal application of nitrogen is not possible due to incessant rains, basal dose can be shifted to 15 days after transplanting (KAU, 1996).

2.5.1. Effect of skipping basal application of nitrogen on growth and yield of rice

Sandayappan (1972), Ramaswami (1975) and Kandasamy (1983) observed that skipping basal application of nitrogen to 10 DAT reduced the height of plants in *Kharif* and *Rabi*.

Muralikrishnasamy (1996) reported that plant height and dry matter production were the least in plots where basal application of nitrogen was skipped.

Gopalaswamy and Raj (1977) reported that basal skipping of nitrogen lead to reduced panicle length. Kandasamy (1983) also observed that skipping one-third nitrogen to 10 DAT reduced the panicle length of rice.

Mallick *et al.* (1978), Mickelson *et al.* (1979), Mohapatra *et al.* (1983) and Chinnusamy (1985) observed that placement of urea super granule 10 DAT gave the maximum thousand seed weight.

Abdus Sattar and Sakai (1982) noted that incorporation of basal dose of urea 4 DAT increased the grain yield.

According to Ram *et al.* (1984) delaying the first dose of nitrogen application from a week after germination to 30 DAS or till maximum tillering stage favourably influenced the yield components and yield of direct seeded rice. Choubey *et al.* (1985) obtained significantly higher grain yield with nitrogen application at interculture, tillering and panicle initiation stages.

Wagh and Thorat (1987) reported that application of 50 per cent nitrogen at 8 DAT, 30 per cent at tillering and 10 per cent each at panicle initiation and flowering resulted in higher grain yield.

Application of nitrogen at 10, 30, 45 and 60 DAS gave the highest grain yield in direct seeded rice (Bhattacharyya and Singh, 1992).

Shukla *et al.* (1993) recorded that split application of nitrogen (half at 7 DAT and rest half in two equal instalments at maximum tillering and panicle initiation stages) as ammonium sulphate or prilled urea had similar effect on grain yield.

Basal skipping of nitrogen to 4 DAT caused increased straw yield (Abdus Satar and Sakai, 1982). Increase in straw yield of rice by application of urea super granule (USG) 10 DAT was reported by Ayyasamy *et al.* (1983), Dhrubachandranpal (1983), Reddy *et al.* (1983) and Chinnusamy (1985). Shukla *et al.* (1993) observed that skipping nitrogen 7 DAT gave the highest straw yield.

2.5.2. Effect of skipping basal application of nitrogen on weed parameters

Sukumar (1981) and Kandasamy (1983) reported that time of application of basal dose of nitrogen had no significant influence on weed growth due to the smoothering effect of aggressive growth of rice.

Chinnusamy (1985) found that the nitrogen management system greatly influenced the number of weeds in both *Kharif* and *Rabi*. Reduced weed population was observed with placement of USG at 10 DAT as well as three splits of prilled urea. She also observed that USG at 10 DAT lowered sedge population whereas, grass population was not affected by basal skipping of nitrogen.

The weed flora and weed dry matter production increased in proportion of applied nitrogen at the early stage of the crop causing indirect nutrient loss (Channabasavanna and Shetty (1994) and Muralikrishnasamy (1996)).

Muralikrishnasamy (1996) recorded maximum weed population in plots where 50 per cent of nitrogen was applied as basal and the least weed population was noticed when the basal nitrogen (25 per cent) was applied at initial tillering.

Studies of Pandey *et al.* (1997) revealed that split application of nitrogen at different stages did not influence the weed population, but the weed biomass was reduced when the basal application was restricted to one-fourth.

2.6. Manual weeding

Hand weeding continues to be the most common method of weed management in any system of rice culture.

Moody (1982) observed that the effect of hand weeding given to the first crop of rice was found to be carried over to the second crop. But Verma *et al.* (1987) found that hand weeding could not stop re-emergence of sedges.

Hand weeding resulted in higher grain yield of rice (Azad *et al.* 1990; Choudhury *et al.* 1992; Krishnasamy *et al.* 1992; Singh *et al.* 1992; Singh *et al.* 1994 and Pandey *et al.* 1997). Hand weeding was more effective and the most common tool to control weeds in transplanted rice (Muthukrishnan *et al.* 1997).

Balasubramanian (1996) pointed out that number of productive tillers in rice was enhanced by hand weeding twice.

Pandey *et al.* (1997) recorded that maximum grain yield and net profit of Rs.6704 ha^{-1} was obtained from the hand weeded plots.

Patel and Mehta (1989) indicated highest reduction in weed biomass with soil solarization and hand weeding. The reduction of weed dry weight due to hand weeding was 88 per cent (Raju and Reddy, 1986). Hand weeding twice registered a high weed control index of 81.9 per cent (Kathiresan and Surendran, 1992).

2.7. Herbicide weed control

Butachlor applied @ 1.5 kg ha^{-1} as spray or sand mix gave the highest yield (Sankaran and Thiagarajan, 1982). Pillai *et al.* (1983) reported that the grain yield in transplanted rice with single application of butachlor was comparable to that in hand weeding check.

But Chinnusamy (1985) concluded that butachlor and 2 hand weeding reduced the total weed population than two hand weedings.

Janiya and Moody (1988) found that butachlor and hand weeding resulted in significant reduction in weed dry weight with respect to weed control.

Pandey and Shukla (1990) reported that oxadizon, butachlor and anilofos were very effective in reducing weed density in transplanted and puddled seeded rice.

Arunachalam *et al.* (1992) reported that summer ploughing and pre-emergence application of butachlor @1.5 kg ha^{-1} or anilofos @ 0.4 kg ha^{-1} followed by one hand weeding 30 DAT controlled weeds effectively and registered higher grain yield.

Mishra *et al.* (1992) observed that application of butachlor @ 1.5 kg ha^{-1}, anilofos @ 0.5 kg ha^{-1} reduced dry weight of weeds four to six fold. Herbicide check were statistically similar to weed free treatment (Nandal and Singh, 1993).

According to Dhiman and Nandal (1995) lowest weed index was recorded under weed free condition followed by Pretilachlor 0.75 kg ha^{-1}, hand weeding twice, and butachlor 1.5 kg ha^{-1}.

Sivaperumal (1995) showed that butachlor @ 1.25 kg ha^{-1} and one hand weeding at 30 DAT recorded higher grain yield over two hand weedings in *rabi* season.

While comparing different weed management practices, Muthukrishnan *et al.* (1997) observed that hand weeded plots and the plots receiving the butachlor @ 1.5 kg ha^{-1} and butachlor @ 1.0 kg ha^{-1} + 2, 4-D Na Salt @ 0.4 kg ha^{-1} recorded maximum number of panicle m^{-2} and grain yield. They also concluded that butachlor @ 1.5 kg ha^{-i} was found to be the most effective treatment in minimising weed dry weight.

However, in a continuous six season crop study at IRRI by Janiya and Moody (1987) revealed that weedicides were superior in reducing the weed dry weight in the beginning and later all herbicide treatment were found inferior to hand weeding in controlling weeds. Similar trends were observed in grain yield also.

3. MATERIALS AND METHODS

A field experiment was conducted in the State Seed Farm, Kottarakkara to develop a package of ecofriendly measures for economic weed control in transplanted rice.

3.1. Experimental site

The experiment was undertaken in the wet lands of State Seed Farm, Kottarakara, Kollam District to represent the rice growing belt of South Kerala. This station, under the Department of Agriculture, is located between 8° 58′and 8° 59′ North latitude and between 76°46′ and 76°47′ East longitudes.

The experimental field was in a typical ribbon valley situated in between sloppy laterite dry lands. Irrigation facilities were available all round the year.

3.2. Soil

The soil of the experimental site was very deep, ill drained, yellowish brown to very dark grayish brown loamy soils of 'Pooyappally' series, developed from alluvial and colluvial deposits under warm humid tropical climate. This soil is a member of coarse loamy mixed isohyperthermic family of Aquic Tropofluvents (Soil Survey of Kottarakara Taluk, 1993). Soil type in the experimental plot was clay loam. The physico-chemical properties of the soil are presented in the Table 2

MATERIALS AND METHODS

Table 2

Physical and chemical properties of the soil of the experimental field

A <u>Physical Properties</u>	
Mechanical composition	
Coarse sand	13.8%
Fine sand	29.3%
Silt	32.5%
Clay	23.3%
B <u>Chemical properties</u>	
p^H	5.6
C.E.C.	4.480 me 100 g^{-1}
Available nitrogen	0.02%
Available phosphorus	19.2 kg ha^{-1}
Available potassium	82 kg ha^{-1}

Plate No. 1

Rice growing belt of State Seed Farm, Kottarakkara

Plate No. 2

General view of the experimental site

3.3. Climate

A warm humid tropical climate prevailed in the area. The meteorological data recorded at the Farming System Research Station, Sadanandapuram, Kottarakkara (KAU) during crop season were collected and presented in Appendix 1 and Fig. 1.

3.4. Cropping season

The experiment was conducted during the *Virippu* season (first crop) of 1998-99 i.e. from April to August 1998. Sowing and transplanting were done on 13th May and 2nd June respectively. The crop was harvested on 31st August 1998.

3.5. Cropping history

The experimental area was under bulk crop of rice during the past several years.

3.6. Materials

3.6.1. Seed material

The rice variety, *Jyothi* was used for the experiment. It is the progeny of the cross between Ptb10 and IR-8, released from Rice Research Station, Pattambi, Kerala. *Jyothi* is a short duration variety (110-115 days) of high yielding nature, recommended for *Virippu* cultivation in the State.

Seeds of *Jyothi* with 96 per cent germination was obtained from the Regional Office of National Seeds Corporation, Ltd., Karamana, Thiruvananthapuram.

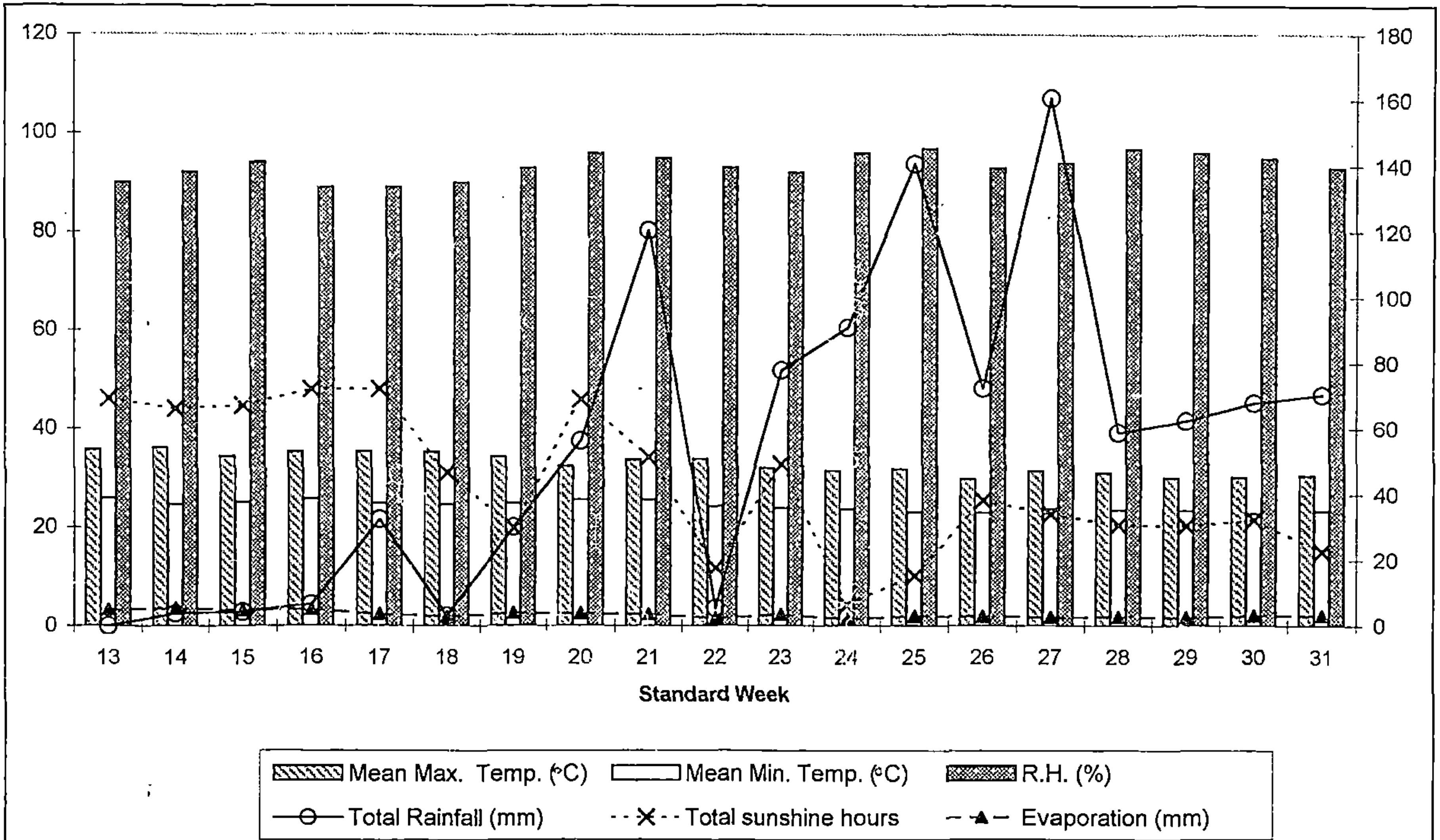

Fig. 1. Weather parameters during the cropping period (April 1998 to August 1998)

3.6.2. Manures and fertilizers

Cowdung analysing to 0.4 per cent Nitrogen, 0.3 per cent P_2O_5 and 0.2 per cent K_2O and lime with a neutralising value of 135 were used for the experiment. Chemical fertilizers viz., Urea analysing to 46 per cent nitrogen, Mussoriphos to 20 per cent P_2O_5 and Muriate of Potash to 60 per cent K_2O were used as per treatments.

3.6.3. Herbicide

The pre-emergent herbicide Butachlor was used as the chemical weedicide in the study. The chemical available under the trade name "Heptlachlor 50 EC" is manufactured by Hindustan India Ltd.

3.7. Methods

3.7.1. Design and layout

Factorial combinations of 2 levels of summer ploughing, 2 levels of stale seed bed, 2 methods of nitrogen application and 4 controls were tried in a Randomised Block Design. The experiment altogether comprised of 12 treatments replicated three times. Detailed layout plan of the experiment is given in Fig. 2.

3.7.2. Treatments

1. Summer ploughing/digging (SP)

   SP_1 - one summer ploughing/digging – during the last week of April.

   SP_2 - Two summer ploughing/digging - during the second and last week of April.

2. Stale seed bed practices (S)

S_o – No stale seed bed practice adopted

S_1 - Stale seed bed practice adopted.

3. Nitrogen application (N)

N_p - Normal practice as per POP recommendation.

N_m – modified nitrogen application – basal application of N skipped and applied as first top dressing at 10 DAT.

The eight combination of the above treatments and the four control treatments as given below:

T_1 - $SP_1 S_o N_p$

T_2 - $SP_1 S_o N_m$

T_3 - $SP_1 S_1 N_p$

T_4 - $SP_1 S_1 N_m$

T_5 - $SP_2 S_o N_p$

T_6 - $SP_2 S_o N_m$

T_7 - $SP_2 S_1 N_p$

T_8 - $SP_2 S_1 N_m$

Hand weeding was done once uniformly to all the above treatment combinations at 30 DAT.

T_9 – Complete weed free (CWF)

T_{10} – Unweeded control (Weedy check)

T_{11} - Two hand weeding at 20 and 40 DAT (2 HW)

T_{12} – POP recommendation (Application of a pre-emergent herbicide followed by one hand weeding at 20 DAT)

Gross plot size – 6 x 4 m

Net plot size – 4.5 x 3.6 m

An area of 0.9 x 4 m was set apart in all plots for weed uprooting.

3.7.3. Field preparation

All the cultural practices except weed management were carried out as per Package of Practices Recommendations-Crops (KAU, 1996).

3.7.3.1. Nursery

Wet nursery was raised and seeds were sown in the nursery on 13th May 1998.

3.7.3.2. Main field preparation

The experiment was laid at in three blocks of twelve plots each separated by bunds.

In the case of plots receiving two summer ploughings, first ploughing was given on 13th April 1998 and second on 27th April 1998. In single summer ploughing treatment the ploughing was done on 27th

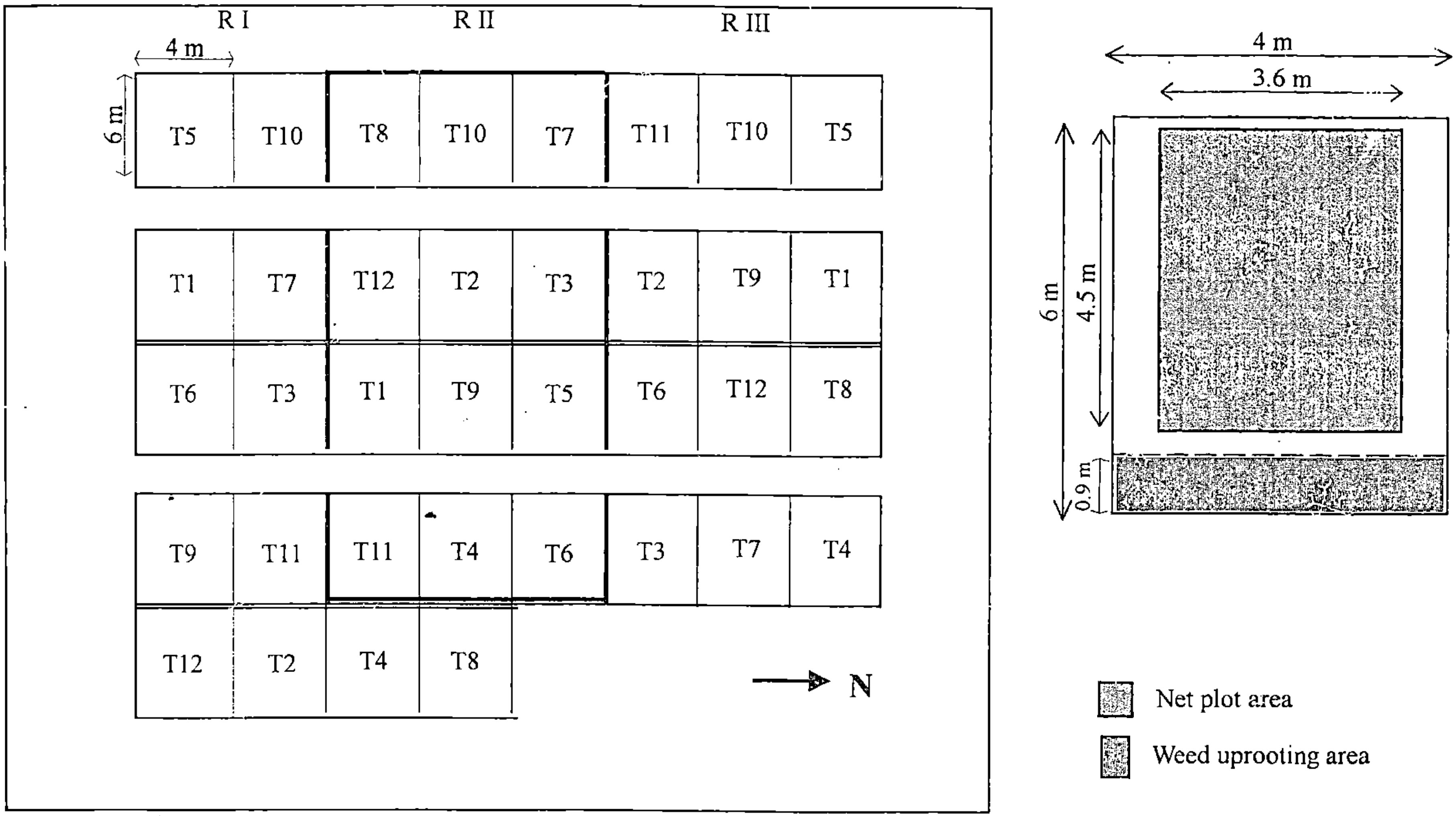

Fig. 2. Layout of the experimental field-Factorial RBD (2 x 2 x 2 + 4)

April 1998. The land preparation was done on 23rd May 1998 for stale seed bed practice and the germinated weeds were then destroyed by flooding and planking on the date of transplanting.

3.7.3.3. Manure/Fertilizers

Well-decomposed farmyard manure was incorporated at the rate of 5 t ha^{-1} in all plots. Ten days prior to transplanting, lime was applied at the rate of 350 kg ha^{-1} and incorporated into the soil.

Urea, Mussoriphos and Muriate of Potash were applied to supply nutrients at the rate of 70, 35and 35 kg ha^{-1} of N, P_2O_5 and K_2O respectively. Two-third dose of nitrogen, full dose of P_2O_5 and half dose of K_2O were applied as basal dose except in T_2, T_4, T_6 and T_8. In these plots only phosphorus (full) and potassium (half dose) were applied as basal and two-third nitrogen applied as top dressing 10 DAT. The remaining doses of N and K were applied at panicle initiation stage to all treatments.

3.7.3.4. Planting

Twenty day old healthy seedlings were gently uprooted, roots were washed in water and transplanted in the main field at a spacing of 15 x 10 cm and at the rate of 2 seedlings/hill.

3.7.3.5. Weeding

Weeding as per treatments was done and a complete weed free plot was also maintained.

In the control plot (T_{12}) a pre-emergent herbicide application was done. Butachlor 50 EC @ 1.5 kg ai ha^{-1} was applied on the sixth day of transplanting. One hand weeding at 20 DAT followed the herbicide application.

3.7.3.6. Water management

The initial water level in the mainfield was maintained at 1.5 cm and subsequently increased to 5cm.

3.7.3.7. Plant protection

One spray of methyl parathion (0.05 per cent) was given against rice swarming caterpillar and one spray of malathion (0.1 per cent) was given against rice bug with knapsack sprayer.

3.7.3.8. Harvest

Ten days before harvest, the field was drained. The net plot was harvested separately, threshed, the weight of grain and straw recorded separately.

3.8. Observations

The biometric observations were recorded from the net plot area and uprooting of weeds was done from the area set apart for the purpose.

3.8.1. Observation on crop

Biometric observations were taken from the net plot and the destructive sampling were done from the third row of the gross plot.

3.8.1.1. Crop growth characters

3.8.1.1.1. Height of the plant

The height of the plant was recorded at 20th, 40th and 60th DAT and at harvest. Height 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 (Gomez, 1972).

3.8.1.1.2. Number of tillers m^{-2}

Tiller count was recorded on 20th, 40th and 60th DAT and at harvest, and expressed as number of tillers m^{-2}.

3.8.1.1.3. Leaf Area Index

Leaf area index (LAI) was computed at panicle initiation stage. Six sample hills were selected to work out LAI. The maximum width 'w' and length 'l' of all the leaves of the middle most tiller were noted and LAI was calculated by the method suggested by Gomez (1972). Leaf area of a single leaf was worked out using the relationship k x l x w, where k is the adjustment factor which is 0.75 at panicle initiation stage.

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

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

3.8.1.1.4. Dry matter production

From each plot, five hills were uprooted on 20th, 40th and 60th DAT and at harvest. They were washed and dried in shade and in a hot air oven till constant weight. The dry weight of the plants were found out and the dry matter production expressed in kg ha^{-1}.

3.8.1.2. Yield attributes

3.8.1.2.1. Number of productive tiller

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

3.8.1.2.2. Weight of panicle

From the sample hills 10 panicles were selected at random and were weighed and weight per panicle worked out.

3.8.1.2.3. Number of spikelet per panicle

The central panicle from each sample hill was threshed separately and the number of spikelet per panicle counted.

3.8.1.2.4. Number of filled grains per panicle

Number of spikelet from each panicle was separated as mentioned above and the count of filled and unfilled grains recorded.

3.8.1.2.5. Sterility percentage

The sterility percentage was worked out using the relationship

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

3.8.1.2.6. Thousand grain weight

Thousand grain weight was calculated and adjusted to14 per cent moisture by the following formula suggested by Gomez (1972).

$$\text{Thousand grain weight} = \frac{100 - M \times W}{86 \times f} \times 100 \qquad \text{where}$$

M is the moisture content of grains, 'W' is the weight of filled grains and 'f' is the number of filled grains.

3.8.1.2.7. Grain yield

The net plot area was harvested individually threshed, dried, winnowed and dry weight recorded. The dry weight was adjusted to 14 per cent moisture and expressed in kg ha^{-1}.

3.8.1.2.8. Straw yield

The straw obtained from the net plot excluding weeds were dried in the sun, weighed and expressed in kg ha^{-1}.

3.8.1.2.9. Harvest Index

From the grain yield and straw yield values, the harvest index was worked out using the following formula

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

3.8.2. Observation on weeds

3.8.2.1. Weed species

The weeds collected from experimental site during the previous *Virippu* season, before the start of the experiment and those collected during the experiment period were grouped into grasses, sedges and broad leaved weeds and the species classified and recorded.

3.8.2.2. Weed count

A 0.25 m^2 iron frame was used for counting the weed number in the net plot area. The count of grasses, sedges and broad leaved weeds was recorded from each plot on 20th, 40th and 60th DAT and at the time of harvest and the weed population was expressed as the number m^{-2}.

3.8.2.3. Weed dry weight

Samples collected from the weed sampling area using $0.25 m^2$ frame on 20th, 40th and 60th DAT and at harvest were dried under shade and later they were oven dried to a constant weight. The dry weight of weeds was expressed as g m^{-2}.

3.8.2.4. Weed control efficiency

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

$$WCE = \frac{WPC - WPT}{WPC} \times 100$$

Where

WPC = weed population in unweeded control plot

WPT = weed population in treated plot.

3.8.2.5. Weed index

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

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

where

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

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

3.8.2.6. Weed density and weed frequency

Weed density (WD) and weed frequency (WF) were computed using the formula suggested by Philips (1959).

$$WD = \frac{\text{Total count of the species from all sites}}{\text{Number of sites where the species is present}} \times 100$$

$$WF = \frac{\text{Number of sites where a particular species occurred}}{\text{Total number of sites surveyed}} \times 100$$

3.8.2.7. Relative density and relative frequency

Relative density (RD) and relative frequency (RF) were calculated using the formula suggested by Philips (1959).

$$RD = \frac{\text{Density of a species}}{\text{Total density of all species}} \times 100$$

$$RF = \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100$$

3.8.2.8. Summed dominance ratio (SDR)

SDR was computed using the following equation by Sen (1981).

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

3.8.2.9. Importance value (IV)

The Importance Value of a species indicates the degree of dominance of a species in a given same plot and calculated using the formula suggested by Philips (1959).

$$IV = \frac{\text{Dry weight of each species in a community}}{\text{Dry weight of all species in a community}} \times 100$$

3.9. Chemical analysis

3.9.1. Soil analysis

Composite soil samples collected before the start of the experiment was analysed to find out the physical composition of the soil, available N, available P_2O_5, available K_2O and p^H and the data presented in Table 2.

3.9.1.1. Physical composition of the soil

Percentage of coarse sand, fine sand, silt and clay were determined by International Pipette Method based on Stokes law (Piper, 1966).

3.9.1.2. Available nitrogen

Available nitrogen was estimated by alkaline-permanganate method (Subbiah and Asija, 1956).

3.9.1.3. Available P_2O_5

Available P_2O_5 was determined by Dickman and Brays molybdenum blue method in a Klett Summerson Photoelectric colorimeter. The soil was extracted with Bray's reagent No. I (0.03 N ammonium flouride in 0.025 N hydrochloric acid) (Jackson, 1967).

3.9.1.4. Available K_2O

Available K_20 was determined in the neutral normal ammonium acetate extract and estimated using EEL Flame Photometer (Jackson, 1967).

3.9.1.5. Soil reaction

P^H of the soil was determined in 1:2.5 soil water suspension using the glass electrode of the Perkin Elmer P^H meter.

3.9.2. Plant and weed analysis

The crop and weed samples uprooted on the 20th, 40th and 60th DAT and at harvest were analysed for total nitrogen, phosphorus and potassium. At harvest, the grain and straw were analysed separately for total nitrogen, phosphorus and potassium and the mean values were recorded.

3.9.2.1. Total nitrogen

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

3.9.2.2. Total phosphorus

Total phosphorus content was estimated by Vanado molybdophosphoric yellow colour method after extraction with triple acid (9:2:1 of HNO_3, H_2SO_4 and $HClO_4$ respectively). The intensity of yellow colour developed was read in a Klett Summerson Photoelecrtric Colorimeter at 660 nm (Jackson, 1967),

3.9.2.3. Total potassium

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

3.10. Uptake studies

The N, P and K uptakes by the crop and weed were obtained as the product of content of these nutrients and the dry weight of crop and weeds and expressed in kg ha^{1}.

3.11. Economics of cultivation

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

$$\text{Net income } (\text{Rs ha}^{-1}) = \text{Gross income} - \text{cost of cultivation}$$

$$\text{Benefit Cost Ratio (BCR)} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.12. Statistical analysis

The data generated from the experiments were subjected to Analysis of variance (ANOVA) technique Cochran and Cox (1957). The variables which do not satisfy the basic assumption of ANOVA were transformed to the scales, percentages and square roots and then analysed. Important correlations were estimated and tested for their significance (Snedecor and Cochran, 1967).

RESULTS

4. RESULTS

A field experiment was carried out at the State Seed Farm, Kottarakkara to study the influence of ecofriendly weed management practices on the weed control efficiency and yield of rice crop. The results of the experiment are presented in this chapter.

4.1 Observation on crop

4.1.1. Biometric observations

Observations were collected from randomly selected five hills in the net plot and observations like plant height, number of tillers per hill, leaf area index and dry matter production were measured.

4.1.1.1. Plant height

The plant height recorded at 20, 40 and 60 days after transplanting (DAT) and at harvest and presented in Table 3.

The treatments had no significant influence on plant height at 20 DAT. But at 40 DAT, the treatment with two summer ploughings (SP_2) showed significant increase in plant height (57.77 cm) compared to one summerploughing (SP_1) with a mean of 55.74 cm. Stale seed bed practice (S) and nitrogen application (N) did not influence the plant height at this stage. The interaction effect of summer ploughing and stale seed bed

Table 3
Main effect of factors SP, S and N and their interactions on plant height (cm) at different intervals after transplanting

Treatment	Days after transplanting 20	40	60	Harvest
SP_1	30.58	55.74	85.39	86.57
SP_2	30.57	57.77	87.57	88.97
CD	Ns	1.57**	1.38**	1.12**
So	30.42	56.35	85.71	87.12
S_1	30.73	56.16	87.26	88.42
CD	Ns	Ns	1.38**	1.12*
N_p	30.90	56.90	86.18	87.67
N_m	30.25	56.61	86.79	87.88
CD	Ns	Ns	Ns	Ns

Interactions

Treatment	20		40		60		Harvest	
	SP_1	SP_2	SP_1	SP_2	SP_1	SP_2	SP_1	SP_2
S_o	30.47	30.37	56.26	56.45	84.80	86.62	86.52	87.73
S_1	30.69	30.76	55.23	59.08	85.98	88.53	86.63	90.22
Mean	30.58	30.57	55.74	57.77	85.39	87.57	86.57	88.97
CD	Ns		2.22**		Ns		1.59**	
N_p	31.03	30.77	56.09	57.70	85.31	87.04	86.90	88.43
N_m	30.13	30.37	55.39	57.83	85.47	88.11	86.24	89.51
Mean	30.58	30.57	55.74	57.77	85.39	87.57	86.57	88.97
CD	Ns		Ns		Ns		Ns	
	S_o	S_1	S_o	S_1	S_o	S_1	S_o	S_1
N_p	30.97	30.83	56.54	57.26	85.34	87.02	86.98	88.36
N_m	29.87	30.63	56.17	57.05	86.08	87.50	87.27	88.49
Mean	30.42	30.73	56.35	56.16	85.71	87.26	87.12	88.42
CD	Ns		Ns		Ns		Ns	

Ns -- Not significant
* -- Significant at 0.05% level
** -- Significant at 0.1% level

(contd...)

Table 3 (contd.)

Interaction effect of factors SP, S and N and controls on plant height (cm) at different intervals after transplanting

Treatment	Days after transplanting			Harvest
	20	40	60	
$T_1 - SP_1 S_o N_p$	31.22	56.37	84.25	86.64
$T_2 - SP_1 S_o N_m$	29.72	56.15	85.35	86.39
$T_3 - SP_1 S_1 N_p$	30.85	55.81	86.37	87.17
$T_4 - SP_1 S_1 N_m$	30.54	54.64	85.59	86.09
$T_5 - SP_2 S_o N_p$	30.73	56.71	86.42	87.31
T_6- $SP_2 S_o N_m$	30.01	56.19	86.81	88.14
$T_7 - SP_2 S_1 N_p$	30.81	58.70	87.67	89.55
$T_8 - SP_2 S_1 N_m$	30.72	59.47	89.40	90.88
T_9 – Complete weed free	31.31	61.11	90.20	92.09
T_{10} – Weedy check	28.10	51.14	61.97	63.90
T_{11} – 2 HW	29.89	56.73	83.95	88.22
T_{12} – Chl + HW	28.07	56.73	84.54	86.43
CD	2.386	3.135	2.766	2.242

practices was found to be significant at 40 DAT. Two summer ploughings with stale seed bed registered the maximum plant height of 59.08cm which was significantly higher than other combinations.

AT 60 DAT and at harvest, two summer ploughings was found better than one summer ploughing in increasing the plant height (87.57 and 88.97cm respectively). Stale seed bed technique also enhanced the plant height at 60 DAT and at harvest with respective mean values of 87.26 and 88.42 cm. Delayed nitrogen application had no significant influence on plant height. In both stages the interaction effect of summer ploughing and nitrogen modification and stale seed bed technique and nitrogen modification were not significant. At harvest, two summer ploughings with stale seed bed was found superior (90.22cm) to other two factor interactions. Treatment combinations did not significantly differ on plant height at 20 DAT. T_8 ($SP_2S_iN_m$) registered the highest plant height than all other observations and was found to be on par with T_7 at 40 DAT, 60 DAT and at harvest and with T_6 at 60 DAT.

Among controls, T_9 and T_{11} were on par and significantly superior to others in plant height (31.31 and 29.89cm) at 20 DAT. The weedy check (T_{10}) and herbicide plot (T_{12}) recorded the lowest plant height 28.10 and 28.07cm respectively . At 40 and 60 DAT and at harvest, T_9 (complete weed free) registered the highest plant height followed by T_{11} (2 hand weeding) and T_{12} which were on par. T_{10} (weedy check) recorded the lowest plant height at all stages.

4.1.1.2. Number of tillers per hill

The results are presented in Table 4

Giving two summer ploughings had no influence on tiller count at 20 DAT while the number was higher (8.63 and 10.58) at 40 DAT and at harvest compared to single summer ploughing (7.78 and 9.47) respectively. Stale seed bed technique significantly increased the tiller count at 20 and 60 DAT only (4.25 and 10.63). Delaying N application had no effect on tiller count at any growth stage of the crop.

Among the two way interactions, combination of summer ploughings and N application significantly influenced the tiller count at 20, 40 and 60 DAT. All the other two way interactions were not significant. At 20 DAT, $SP_1 N_p$, $SP_1 N_m$ and $SP_2 N_m$ were on par and superior to $SP_2 N_p$ with respective mean values of 4.17, 3.93 and 4.40.

At 40 DAT the combinations SP_2N_m, SP_2N_p and SP_1N_p were on par and recorded higher tiller count. At 60 DAT SP_1N_p (10.93) and SP_2N_m (10.67) were found superior to other SP x N combinations in tiller count.

Among the three factor combinations, except T_5 and T_2 all combinations were on par and recorded significantly higher tiller count at 20 DAT. At 40 DAT, T_8 (9.53), T_6 (8.47), T_7 (8.33) and T_3 (8.27) were on par and observed superior to other treatments in tiller count. At 60 DAT, T_3, T_1, T_6, T_7, T_8 were on par and superior to other treatment combinations. At harvest T_6 registered the highest tiller number of 11.07 which was on par with T_5, T_7 and T_8.

Table 4
Main effect of factors SP, S and N and their Interactions on tillers per hill at different intervals after transplanting

Treatment	Days after transplanting			
	20	40	60	Harvest
SP_1	4.05	7.78	10.18	9.47
SP_2	4.10	8.63	10.37	10.58
CD	Ns	0.66**	Ns	0.61**
So	3.90	8.07	9.92	9.95
S_1	4.25	8.35	10.63	10.10
CD	0.33*	Ns	0.58*	Ns
N_p	3.98	8.2	10.50	9.82
N_m	4.17	8.22	10.05	10.23
CD	Ns	Ns	Ns	Ns

Interactions

Treatment	20		40		60		Harvest	
	SP_1	SP_2	SP_1	SP_2	SP_1	SP_2	SP_1	SP_2
S_o	3.77	4.03	7.80	8.33	9.77	10.07	9.27	10.63
S_1	4.33	4.17	7.77	8.93	10.60	10.67	9.67	10.53
Mean	4.05	4.10	7.78	8.63	10.18	10.37	9.47	10.58
CD	Ns		Ns		Ns		Ns	
N_p	4.17	3.80	8.13	8.27	10.93	10.07	9.30	10.33
N_m	3.93	4.40	7.43	9.0	9.43	10.67	9.63	10.83
Mean	4.05	4.10	7.78	8.63	10.18	10.37	9.47	10.58
CD	0.47*		0.93*		0.82**		Ns	
	S_o	S_1	S_o	S_1	S_o	S_1	S_o	S_1
N_p	3.87	4.10	8.10	8.30	10.03	10.97	9.63	10.00
N_m	3.93	4.40	8.03	8.40	9.80	10.30	10.27	10.20
Mean	3.9	4.25	8.07	8.35	9.92	10.63	9.95	10.10
CD	Ns		Ns		Ns		Ns	

Ns -- Not significant
* -- Significant at 0.05% level
** -- Significant at 0.1% level

(contd...)

Table 4 (contd.)

Interaction effect of factors SP, S and N and controls on tillers $hill^{-1}$ at different intervals after transplanting

Treatment	Days after transplanting			Harvest
	20	40	60	
$T_1 - SP_1 S_o N_p$	4.00	8.00	10.53	9.07
$T_2 - SP_1 S_o N_m$	3.53	7.60	9.00	9.47
$T_3 - SP_1 S_1 N_p$	4.33	8.27	11.33	9.53
$T_4 - SP_1 S_1 N_m$	4.33	7.27	9.87	9.80
$T_5 - SP_2 S_o N_p$	3.73	8.20	9.53	10.20
$T_6 - SP_2 S_o N_m$	4.33	8.47	10.60	11.07
$T_7 - SP_2 S_1 N_p$	3.87	8.33	10.60	10.47
$T_8 - SP_2 S_1 N_m$	4.47	9.53	10.73	10.60
T_9 – Complete weed free	4.93	10.17	12.00	11.70
T_{10} – Weedy check	3.13	5.00	5.27	6.07
T_{11} – 2 HW	4.47	7.53	9.07	10.27
T_{12} – Chl + HW	3.80	8.20	10.27	10.07
CD	0.662	1.312	1.167	1.211

The complete weed free plot (T_9) registered the highest tiller count of 4.93, 10.17, 12.0 and 11.70 tillers hill^{-1} during the respective growth stages. The weedy check registered the least tiller count at all stages.

4.1.1.3. Leaf area index

The results are presented in Table 5.

The treatments had significant influence on the leaf area index (LAI) recorded at panicle initiation stage. Providing two summer ploughings, adopting stale seed bed practice and delaying the basal application of N to 10 DAT significantly improved the LAI.

Among the two factor interactions, only summer ploughing and stale seed bed combination was found significant. The highest LAI was registered by SP_2S_1 (4.99) which was superior to other combinations. Considering the combinations, T_8 ($SP_2S_1 N_m$) and T_7 ($SP_2S_1N_p$) were on par and superior to other treatments with respective mean values of 5.16 and 4.82. Among controls, complete weed free (CWF) (T_9) plot recorded the highest LAI of 5.32 and the lowest was by T_{10} (2.20).

4.1.1.4. Dry matter production of crop

The results are presented in Table 6.

Providing two summer ploughings significantly increased the dry matter production (DMP) at all stages though the increase was not significant at 60 DAT. Similarly stale seed bed practice significantly

Table 5

Main effect of factors SP, S and N and their Interactions on leaf area index at panicle initiation stage

Treatment	LAI
Sp_1	4.22
SP_2	4.76
CD	0.17**
S_o	4.36
S_1	4.63
CD	0.17**
N_p	4.41
N_m	4.58
CD	0.17**

Interactions

Treatment	SP_1	SP_2
S_o	4.19	4.53
S_1	4.26	4.99
Mean	4.22	4.76
CD	0.24*	
N_p	4.20	4.61
N_m	4.25	4.91
Mean	4.22	4.76
CD	Ns	
	S_o	S_1
N_p	4.28	4.53
N_m	4.44	4.72
Mean	4.36	4.63
CD	Ns	

Ns -- Not significant
* -- Significant at 0.05% level
** -- Significant at 0.1% level

(contd...)

Table 5 (contd.)

Interaction effect of factors SP. S and N and controls on leaf area index at panicle initiation stage.

Treatments	LAI
T_1-$SP_1S_oN_p$	4.15
T_2-$SP_1S_oN_m$	4.23
T_3-$SP_1S_1N_p$	4.25
T_4-$SP_1S_1N_m$	4.27
T_5-$SP_2S_oN_p$	4.41
T_6-$SP_2S_oN_m$	4.65
T_7-$SP_2S_1N_p$	4.82
T_8-$SP_2S_1N_m$	5.16
T_9-Complete weed free	5.32
T_{10}-Weedy Check	2.20
T_{11}-2 HW	4.48
T_{12}-chl+HW	4.74
CD	0.3401

Table 6

Main effect of factors SP, S and N and their Interactions on dry matter production ($kg\ ha^{-1}$) at different intervals after transplanting

Treatment	20 DAT	40 DAT
SP_1	533.93	2945.29
SP_2	626.45	3326.58
CD	61.47**	229.54**
S_o	525.50	3063.91
S_1	634.88	3207.96
CD	61.47**	Ns
N_p	569.57	3171.39
N_m	590.81	3100.48
CD	Ns	Ns

Interactions

Treatments	20 DAT		40 DAT	
	SP_1	SP_2	SP_1	SP_2
S_o	485.54	565.47	2849.98	3277.84
S_1	582.83	687.44	3040.61	3375.32
Mean	533.93	626:45	2945.29	3326.58
CD	Ns		Ns	
N_p	520.22	618.93	3011.55	3331.24
N_m	547.65	633.98	2879.04	3321.92
Mean	533.93	626.45	2945.29	3326.58
CD	Ns		Ns	
	S_o	S_1	S_o	S_1
N_p	534.82	604.33	2972.43	3370.35
N_m	516.19	665.44	3155.39	3045.58
Mean	525.50	634.88	3063.91	3207.96
CD	Ns		324.62*	

Ns -- Not significant
* -- Significant at 0.05% level
** -- Significant at 0.1% level

(contd...)

Table 6 (contd.)

Main effect of factors SP, S and N and their interaction on dry matter production at different intervals after transplanting

Treatments	60 DAT	Harvest
SP_1	6972.06	8995.10
SP_2	7009.59	9355.09
CD	Ns	337.41*
S_o	6723.99	8993.68
S_1	7257.66	9356.51
CD	326.29**	337.41*
N_p	6997.66	9190.59
N_m	6984.0	9159.60
CD	Ns	Ns

Interactions

Treatments	60 DAT		Harvest	
	SP_1	SP_2	SP_1	SP_2
S_o	6776.13	6671.86	8831.89	9155.47
S_1	7243.06	7272.27	9158.31	9554.71
Mean	7009.59	6972.06	8995.10	9355.09
CD	Ns		Ns	
N_p	7198.77	6796.56	9057.47	9323.71
N_m	6820.42	7147.57	8932.73	9386.47
Mean	7009.59	6972.06	8995.10	9355.09
CD	361.45		Ns	
	S_o	S_1	S_o	S_1
N_p	6778.69	7216.63	9031.12	9350.06
N_m	6669.30	7298.69	8956.24	9362.96
Mean	6723.99	7257.66	8993.68	9356.51
CD	Ns		Ns	

(contd...)

Table 6 (contd.)

Interaction effect of factors SP, S and N and controls on dry matter production ($kg\ ha^{-1}$) at different intervals after transplanting

Treatment	Days after transplanting			Harvest
	20	40	60	
$T_1 - SP_1S_0N_p$	504.56	2758.00	7049.13	9012.13
$T_2 - SP_1S_0N_m$	466.51	2941.36	6503.12	8651.64
$T_3 - SP_1S_1N_p$	535.87	3265.09	7348.40	9102.80
$T_4 - SP_1S_1N_m$	628.79	2816.12	7137.72	9213.81
$T_5 - SP_2S_0N_p$	565.07	3186.87	6508.25	9050.10
$T_6 - SP_2S_0N_m$	565.86	3368.81	6835.48	9260.83
$T_7 - SP_2S_1N_p$	672.78	3475.61	7084.87	9597.32
$T_8 - SP_2S_1N_m$	702.09	3275.03	7459.67	9512.11
T_9 – Complete weed free	737.29	3833.08	8014.41	9952.57
T_{10} – Weedy check	453.59	1704.30	4340.93	6207.23
T_{11} – 2 HW	550.28	2817.66	6582.37	8978.20
T_{12} – Chl + HW	552.36	2634.33	6895.34	8704.40
CD	122.93	459.08	652.59	712.886

enhanced the dry matter production except at 40 DAT. The application of nitrogen fertilizer had no significance on dry matter production at any growth stage of the crop. The interaction effect of summer ploughing and stale seed bed practice was not significant in any observations. But the interaction of SP and N application was found significant at 60 DAT where SP_1N_p (7198.77 kg ha^{-1}) and SP_2N_m (7147.57 kg ha^{-1}) were on par and superior to other combinations. Regarding the interaction effect of stale seed bed and N application, S_1N_p and S_0N_m were on par and superior (3370.35 and 3155.39 kg ha^{-1}) to others at 40 DAT.

Among the treatment combinations T_8 (702.09 kg ha^{-1}), T_7 (672.78 kg ha^{-1}), and T_4 (628.79 kg ha^{-1}) were on par and superior to other combinations at 20 DAT. At 40 DAT T_7, T_6, T_8, T_3 and T_5 were on par and superior to other combinations. At 60 DAT and at harvest T_8, T_3, T_4, T_7, T_1 and T_6 were as par and recorded higher DMP than other combinations. At all stages T_2 registered the lowest dry matter production among treatments.

While comparing controls, complete weed free (T_9) registered the maximum DMP and weedy check (T_{10}) recorded the lowest DMP at all stages.

4.1.2. Yield attributing characters

The results are presented in Table 7

4.1.2.1. Productive tillers/hill at harvest

Two summer ploughing (SP2) significantly increased productive tiller number (9.68) over SP_1 (8.43). Stale seedbed practice enhanced the number of productive tillers $hill^{-1}$ though the increase was not significant. Basal skipping of nitrogen (N_m) significantly improved productive tillers (9.33 $hill^{-1}$) over basal application of nitrogen (N_p) with mean tiller count of 8.78 $hill^{-1}$. All the two way interactions were not significant.

In SP x S x N interactions, T_6, T_8 and T_7 were on par and superior to T_4,T_3 and T_2. The lowest count of productive tillers per hill was registered by T_1 (7.93).

Among controls, CWF (T_9) recorded the highest mean of 11.07 productive tillers per hill. Whereas the lowest was registered by the weedy check (5.07 $hill^{-1}$).

4.1.2.2. Length of panicle

The treatment and their interactions had no significant difference on the length of panicle. However, among treatment combinations all except T_1 ($SP_1S_0N_p$) were on par and T_4 registered the highest panicle length of 20.21 cm. Among controls CWF (T_9) and T_{12} (chemical + HW) were on par and recorded significantly longer panicles with corresponding means of 20.96 and 20.53 cm. Weedy check produced the shortest panicles (17.47 cm).

Table 7

Main effect of factors SP, S and N and their Interactions on yield attributing characters of rice.

Treatment	Number of productive tillers $hill^{-1}$	Length of panicle (cm)	Panicle weight (g)
SP_1	8.43	19.91	2.73
SP_2	9.68	19.86	2.86
CD	0.51**	Ns	0.12*
S_o	8.92	19.73	2.70
S_1	9.20	20.03	2.88
CD	Ns	Ns	0.12**
N_p	8.78	19.71	2.79
N_m	9.33	20.06	2.80
CD	0.51	Ns	Ns

Interactions

Treatments	Number of productive tillers $hill^{-1}$		Length of panicle (cm)		Panicle weight (g)	
	SP_1	SP_2	SP_1	SP_2	SP_1	SP_2
S_o	8.20	9.63	19.69	19.78	2.59	2.82
S_1	8.67	9.73	20.12	19.94	2.86	2.91
Mean	8.43	9.68	19.91	19.86	2.73	2.86
CD	Ns		Ns		Ns	
N_p	8.23	9.33	19.68	19.74	2.73	2.85
N_m	8.63	10.03	20.13	19.98	2.72	2.87
Mean	8.43	9.68	19.91	19.86	2.72	2.86
CD	Ns		Ns		Ns	
	S_o	S_1	S_o	S_1	S_o	S_1
N_p	8.50	9.07	19.55	19.87	2.66	2.92
N_m	9.33	9.33	19.92	20.19	2.75	2.84
Mean	8.92	9.20	19.73	20.03	2.70	2.88
CD	Ns		Ns		Ns	

Ns -- Not significant
* -- Significant at 0.05% level
** -- Significant at 0.1% level

(contd...)

Table 7 (contd.)

Main effect of factors SP, S and N and their Interactions on yield attributing characters of rice

Treatments	Number of grains panicle^{-1}	Number of filled grains panicle^{-1}	Sterility percentage	Thousand grain weight (g)
SP_1	107.42	89.58	16.60	30.52
SP_2	115.92	98.75	15.08	30.98
CD	Ns	8.14*	0.85**	Ns
So	110.25	92.42	16.19	30.19
S_1	113.08	95.92	15.49	31.30
CD	Ns	Ns	Ns	0.84*
N_p	113.33	96.25	15.14	28.42
N_m	110.0	92.08	16.53	30.46
CD	Ns	Ns	0.85**	Ns

Interactions

Treatments	Number of grains panicle^{-1}		Number of filled grains panicle^{-1}		Sterility percentage		Thousand grain weight	
	Sp_1	SP_2	Sp_1	SP_2	Sp_1	SP_2	Sp_1	SP_2
S_o	110.33	110.17	91.17	93.67	17.39	14.98	30.13	30.25
S_1	104.50	121.67	88.0	103.83	15.81	15.17	30.90	31.70
Mean	107.42	115.92	89.58	98.75	16.60	15.08	30.52	30.98
CD	Ns		Ns		1.20*		Ns	
N_p	108.00	118.67	91.17	101.33	15.63	14.65	30.80	31.40
N_m	106.83	113.17	88.0	96.17	17.57	15.50	30.23	30.55
Mean	107.42	115.92	89.58	98.75	16.60	15.08	30.52	30.98
CD	Ns		Ns		Ns		Ns	
.	S_o	S_1	S_o	S_1	S_o	S_1	S_o	S_1
N_p	110.83	115.83	94.0	98.50	15.25	15.04	30.87	31.33
N_m	109.67	110.33	90.83	93.23	17.13	15.94	29.52	31.27
Mean	110.25	113.08	92.42	95.92	16.19	15.49	30.19	31.30
CD	Ns		Ns		Ns		Ns	

Ns -- Not significant

* -- Significant at 0.05% level

** -- Significant at 0.1% level

(contd...)

Table 7 (contd.)

Interaction effect of factors SP, S and N and controls on yield attributing characters of rice

Treatments	No. of productive tillers $hill^{-1}$	Length of panicle (cm)	Panicle weight (g)	Number of grains $panicle^{-1}$	Number of filled grains $panicle^{-1}$	Sterility per-centage	Thousand seed weight (g)
T_1 – $SP_1S_0N_p$	7.93	19.32	2.54	108.00	91.33	15.52	30.90
T_2 – $SP_1S_oN_m$	8.47	20.05	2.64	112.67	91.00	19.26	29.37
T_3 – $SP_1S_1N_p$	8.53	20.03	2.92	108.00	91.00	15.75	30.70
T_4 – $SP_1S_1N_m$	8.80	20.21	2.80	101.00	85.00	15.87	31.10
T_5 – $SP_2S_0N_p$	9.07	19.77	2.78	113.67	96.67	14.97	30.83
T_6 – $SP_2S_0N_m$	10.20	19.78	2.86	106.67	90.67	14.99	29.67
T_7 – $SP_2S_1N_p$	9.60	19.71	2.93	123.67	106.00	14.33	31.97
T_8 - $SP_2S_1N_m$	9.87	20.17	2.89	119.67	101.67	16.00	31.43
T_9 – Complete weed free	11.07	20.96	3.27	136.66	120.00	12.25	32.73
T_{10} – weedy check	5.07	17.47	2.11	106.00	81.33	23.24	26.80
T_{11} – 2HW	9.27	19.69	2.92	122.33	103.67	15.27	30.43
T_{12} – Chl + HW	9.40	20.53	2.60	112.0	94.67	15.48	31.13
CD	1.019	0.737	0.232	18.456	16.282	1.702	1.687

4.1.2.3. Panicle weight

Two summer ploughings and following stale seed bed technique significantly increased panicle weight (2.86 and 2.88 g) over one summer ploughing and no stable seed bed practice. Method of nitrogen application and the two factor interactions had no significant change on panicle weight. Considering the treatment combinations T_7 ($SP_2S_1N_p$) recorded the highest panicle weight of 2.93 g and was on par with T_3, T_4, T_5, T_6 and T_8. Among controls, the complete weed free (T_9) ranked first with a panicle weight of 3.27 g and weedy check (T_{10}) (2.11 g) was observed to produce the least.

4.1.2.4. Number of grains per panicle

Summer ploughing, stale seed bed practice and method of N application and their interactions had no significant influence on the number of grains. However, providing two summer ploughing and adopting stale seed bed practice increased the grain number per panicle. Among treatment combinations, all were on par except T_4 (SP_1S_1Nm) with the least number. The highest grain number 123.67 was registered by T_7 ($SP_2S_1N_p$). While comparing controls, T_9 recorded maximum number of grains (136.66). This was followed by T_{11} and T_{12} which were on par.

4.1.2.5. Number of filled grains per panicle

Two summer ploughings significantly enhanced the number of filled grains (98.75) than single summer ploughing (89.58).

Stale seed bed practice and modification of N application and the two way interactions had no effect on the number of filled grains per panicle. In combinations, the highest number of filled grains was registered by T_7 (106.00) which was on par with other combinations except T_4. Complete weed free (T_9) treatment registered the highest number of filled grains (120.00) and was superior to others. Among the controls, the weedy check recorded the lowest number of filled grain (81.33).

4.1.2.6. Sterility percentage

Two summer ploughings significantly reduced sterility percentage (15.08). Stale seed bed practice had no effect on sterility percentage. Delaying the basal application of nitrogen increased the sterility percentage with a mean of 16.53. Among summer ploughing and stale seed bed interactions the sterility percentage was the lowest in SP_2S_0 (14.98) which was on par with SP_1S_1 and SP_2S_1. The other two way interactions were not significant.

In SP x S x N interaction, T_7 recorded the lowest sterility percentage (14.33) and was on par with other combinations except T_2. Complete weed free (T_9) had the lowest sterility percentage (12.25) and was followed by T_{10} and T_{11} which were on par.

4.1.2.7. Thousand grains weight

Summer ploughing had no significant effect on thousand grain weight. However, the stale seed bed technique increased the thousand grain weight (31.30 g) compared to no stale seed bed (30.19 g). The modification in nitrogen application was not significant on increasing thousand grain weight.

All the two way interactions were non significant in increasing the thousand grain weight.

Among treatment combinations T_7 ($SP_2 S_1 N_p$) registered the highest thousand grain weight of 31.97 g which was on par with other combinations except T_2 and T_6. While comparing controls, the complete weed free plot registered the highest (32.73 g) thousand grain weight and weedy check the lowest (26.80 g). The two hand weeded (T_{11}) and herbicide (T_{12}) applied were on par.

4.1.3. Grain yield

The results are presented in Table 8

The results revealed that the effect of summer ploughing and stale seed bed practice was significant on grain yield. Two summer ploughings was observed superior (3631.31 kg ha^{-1}) to one summer ploughing (3474.62 kg ha^{-1}) in enhancing the grain yield. Stale seed bed technique practice was proved good in increasing the grain yield. But the time of nitrogen application had no effect on grain yield. The two way interactions were also not significant in influencing the grain yield.

Table 8

Main effect of factors SP, S and N and their Interactions on grain, straw yield (kg ha^{-1}) and harvest index of rice

Treatments	Grain yield	Straw yield	HI
SP_1	3474.62	5516.81	0.39
SP_2	3631.31	5723.78	0.39
CD	143.21*	Ns	Ns
S_o	3468.76	5521.25	0.39
S_1	3637.18	5719.33	0.39
CD	143.21*	Ns	Ns
N_p	3553.92	5633.0	0.39
N_m	3552.02	5607.58	0.39
CD	Ns	Ns	Ns

Interactions

Treatments	Grain yield		Straw yield		HI	
	SP_1	SP_2	SP_1	SP_2	SP_1	SP_2
S_o	3387.89	3549.63	5436.66	5605.84	0.39	0.39
S_1	3561.36	3712.99	5596.95	5841.71	0.39	0.39
Mean	3474.62	3631.31	5516.81	5723.78	0.39	0.39
CD	Ns		Ns		Ns	
N_p	3496.16	3611.68	5553.97	5712.03	0.39	0.39
N_m	3453.09	3650.94	5479.64	5735.53	0.39	0.39
Mean	3474.62	3631.31	5516.81	5723.78	0.39	0.39
CD	Ns		Ns		Ns	
	S_o	S_1	S_o	S_1	S_o	S_1
N_p	3482.96	3624.89	5540.83	5725.17	0.39	0.39
N_m	3454.57	3649.46	5501.67	5713.49	0.39	0.39
Mean	3468.76	3637.18	5521.25	5719.33	0.39	0.39
CD	Ns		Ns		Ns	

Ns -- Not significant
* -- Significant at 0.05% level
** -- Significant at 0.1% level

(contd...)

Table 8 (contd.)

Interaction effect of factors SP, S and N and controls on grain and straw yield ($kg\ ha^{-1}$) and harvest index of rice

Treatments	Grain yield	Straw yield	Harvest Index
T_1-$SP_1S_oN_p$	3453.91	5543.55	0.38
T_2-$SP_1S_oN_m$	3321.88	5329.76	0.38
T_3-$SP_1S_1N_p$	3538.41	5564.39	0.39
T_4-$SP_1S_1N_m$	3584.30	5629.51	0.39
T_5-$SP_2S_oN_p$	3512.00	5538.10	0.39
T_6-$SP_2S_oN_p$	3587.26	5673.57	0.39
T_7-$SP_2S_1N_p$	3711.37	5885.95	0.39
T_8-$SP_2S_1N_m$	3714.62	5797.48	0.39
T_9-Complete weed free	3943.64	6008.93	0.39
T_{10}-Weedy Check	2171.48	4035.75	0.35
T_{11}-2HW	3477.67	5500.53	0.38
T_{12}-Chl+HW	3357.53	5346.87	0.38
CD	292.275	447.266	0.017

Among the combinations, all except T_2 ($SP_2 S_0 N_m$) were on par. The highest grain yield was recorded by T_8 ($SP_2 S_1 N_m$) (3714.62 kg ha^{-1}).

Among controls T_9 (CWF) registered the highest grain yield (3943.64 kg ha^{-1}) followed by T_{11} and T_{12} which were on par. Weedy check registered the lowest yield.

4.1.4. Straw yield

The results are presented in Table 8

The treatments and the two factor interactions did not have any significant influence on the straw yield. However, among combinations T_7 had highest straw yield of 5885.95 kg ha^{-1} and was as par with other combinations except T_2. Among the controls, CWF plot recorded maximum mean straw yield of 6008.93 kg ha^{-1} and the lowest was by weedy check 4035.75 kg ha^{-1}.

4.1.5. Harvest Index

The results are presented in Table 8

The main effect and their interactions had no significant effect on the harvest index, the values being 0.39 for all. However, among controls T_9, T_{11} and T_{12} were on par and superior to the weedy check (0.35).

4.2. Observations on weeds

4.2.1. Weed species

The different weed species from the experimental field before and during the experiment were collected, identified and grouped into grasses, sedges and broad leaved weeds (Table 9). The important species before and during the experimental period were *Brachiaria platyphylla* (Criseb) (among grasses), *Cyperus Spp* and *Finbristylis miliaceae* (among sedges), *Monochoria vaginalis* and *Marsilea quadrifoliata* (among broad leaved weeds).

4.2.2. Weed count

Observations on the count of grasses, sedges and broad leaved weeds were recorded at 20, 40, and 60 DAT and at harvest. The data were analysied statistically after giving square root transformation (Öx+1) and presented in tables 10, 11, 12 and 13. T_9 (complete weed free) had no weeds and hence no analysis was necessary.

4.2.2.1. Grass weed count

The results are presented in Table 10

The results revealed that giving two summer ploughings reduced the grass weed count in all observations though the variation was significant only at 60 DAT. At 60 DAT the grass weed count was 13.85 m^{-2} in two summer ploughed plot compared to 24.62 in single summer ploughed plot.

Table 9

Weed species observed from the experimental field before and during the experiment

Before the experiment	During the experiment
Grasses	Grasses
Brachiaria plattyphylla Criseb.	*Brachiaria plattyphylla* Criseb.
Dactyloctenum aegypticum (L.)Beaux	*Dactyloctenum aegypticum* (L.)Beaux
Echinochloa colona (L.) Link	*Echinochloa colona* (L.) Link
Eragrostis interrupta (L.) Beaur.	*Eragrostis interrupta* (L.) Beaur.
Panicum repens	*Panicum repens*
Imperata cylindrica (L.) Beauv	*Imperata cylindrica* (L.) Beauv
Sedges	Sedges
Cyperus difformis (L.)	*Cyperus difformis* (L.)
Cyperus iria (L.)	*Cyperus iria* (L.)
Cyperus sp.	*Cyperus sp.*
Fimbristylis miliaceae (L.) Vahl.	*Fimbristylis miliaceae* (L.) Vahl.
Broad leaved weeds	Broad leaved weeds
Monochoria vaginalis (Burn.) Presl.	*Monochoria vaginalis* (Burn.) Presl.
Marsilea quadrifoliata	*Marsilea quadrifoliata*
Ludwigia parviflora (L.) Roxb.	*Ludwigia parviflora* (L.) Roxb.
Alternanthera sessilis L.	*Alternanthera sessilis* L.

Table 10
Main effect of factors SP, S and N and their Interactions on grass weed count (Number m^{-2}) at different intervals after transplanting

Treatments	Days after transplanting	
	20	40
SP_1	18.43 (4.41)	19.42 (4.52)
SP_2	14.09 (3.89)	13.83 (3.85)
CD	Ns	Ns
S_o	21.84 (4.78)	20.49 (4.64)
S_1	11.35 (3.51)	12.94 (3.73)
CD	0.58**	0.67*
N_p	16.80 (4.22)	17.27 (4.27)
N_m	15.59 (4.07)	15.78 (4.10)
CD	Ns	Ns

Interactions

Treatments	20 DAT		40 DAT	
	SP_1	SP_2	SP_1	SP_2
S_o	21.92 (4.79)	21.75 (4.77)	21.77 (4.77)	19.25 (4.50
S_1	15.22 (4.03)	8.00 (3.00)	17.20 (4.27)	9.25 (3.20)
Mean	(4.41)	(3.89)	(4.52)	(3.85)
CD	Ns		Ns	
N_p	18.22 (4.38)	15.44 (4.05)	19.09 (4.48)	15.53 (4.07
N_m	18.64 (4.43)	12.81 (3.72)	19.76 (4.56)	12.22 (3.64)
Mean	(4.41)	(3.89)	(4.52)	(3.85)
CD	Ns		Ns	
	S_o	S_1	S_o	S_1
N_p	22.88 (4.89)	11.62 (3.55)	22.22 (4.82)	12.91 (3.73)
N_m	20.82 (4.67)	11.08 (3.48)	18.83 (4.45)	12.98 (3.74)
Mean	(4.78)	(3.51)	(4.64)	(3.73)
CD	Ns		Ns	

Ns -- Not significant
* -- Significant at 0.05% level
** -- Significant at 0.1% level
¶ -- The values in parenthesis are transformed values.

(contd...)

Table 10 (contd.)

Main effect of factors SP, S and N and their Interactions on grass weed count (Number m^{-2}) at different intervals after transplanting

Treatments	60 DAT	Harvest
SP_1	24.62 (5.96)	21.21 (4.71)
SP_2	13.85 (3.85)	12.50 (3.67)
CD	0.96*	Ns
S_o	21.57 (4.75)	21.79 (4.77)
S_1	16.34 (4.16)	12.05 (3.61)
CD	Ns	1.06*
N_p	22.36 (4.83)	16.65 (4.20)
N_m	15.67 (4.08)	16.52 (4.19)
CD	Ns	Ns

Interactions

Treatments	60 DAT		Harvest	
	SP_1	SP_2	SP_1	SP_2
S_o	21.10 (4.70)	22.05 (4.80)	25.07 (5.11)	18.73 (4.44)
S_1	28.41 (5.42)	7.45 (2.91)	17.66 (4.32)	7.45 (2.91)
Mean	(5.06)	(3.85)	(4.71)	(3.67)
CD	1.36*		Ns	
N_p	25.76 (5.17)	19.18 (4.49)	19.04 (4.48)	14.41 (3.92)
N_m	23.51 (4.95)	9.34 (3.22)	23.49 (4.95)	10.72 (3.42)
Mean	(5.06)	(3.85)	(4.71)	(3.67)
CD	Ns		Ns	
	S_o	S_1	S_o	S_1
N_p	27.26 (5.32)	17.91 (4.35)	24.39 (5.04)	10.31 (3.36)
N_m	16.52 (4.19)	14.84 (3.98)	19.33 (4.51)	13.92 (3.86)
Mean	(4.75)	(4.16)	(4.77)	(3.61)
CD	Ns		Ns	

(contd...)

Table 10 (contd.)

Interaction effect of factors SP, S and N and controls on grass weed count (Number m^{-2}) at different intervals after transplanting

Treatments	Days after transplanting			Harvest
	20	40	60	
T_1-$SP_1S_oN_p$	20.75 (4.66)	21.16 (4.71)	23.70 (4.97)	25.79 (5.18)
T_2-$SP_1S_oN_m$	23.13 (4.91)	22.39 (4.84)	18.64 (4.43)	24.36 (5.04)
T_3-$SP_1S_1N_p$	15.84 (4.10)	17.12 (4.26)	27.91 (5.38)	13.27 (3.78)
T_4-$SP_1S_1N_m$	14.61 (3.95)	17.29 (4.28)	28.92 (5.47)	22.63(4.86)
T_5-$SP_2S_oN_p$	25.10 (5.11)	23.30 (4.93)	31.07 (5.66)	23.04 (4.90)
T_6-$SP_2S_oN_m$	18.64 (4.43)	15.57 (4.07)	14.52 (3.94)	14.85 (3.98)
T_7-$SP_2S_1N_p$	8.0 (3.0)	9.25 (3.20)	10.03 (3.32)	7.69 (2.95)
T_8-$SP_2S_1N_m$	8.0 (3.0)	9.25 (3.20)	5.20 (2.49)	7.21 (2.87)
T_9-Complete weed free	0 (1)	0 (1)	0 (1)	0(1)
T_{10}-Weedy check	49.33(7.09)	90.67 (9.56)	166.67 (12.94)	173.3 (13.19)
T_{11}-2 HW	34.67 (5.95)	41.33 (6.40)	37.33 (6.02)	18.67 (4.41)
T_{12}-Chl+HW	8.0 (3)	10.67 (3.27)	21.33 (4.70)	10.67 (3.37)
CD	1.16**	Ns	1.93*	Ns

Plate No. 3

One of the best treatment combinations - T_7 (SP_2 S_1 N_p)

Plate No. 4

Thé weedy check plot

Adopting stale seed bed practice significantly reduced the grass weed count at 20 and 40 DAT and at harvest. Delayed application of nitrogen did not cause any variation on the grass weed count.

Among the two factor interactions, SP x S alone was significantly different at 60 DAT and all other combinations were not significant. At 60 DAT SP_2S_1 recorded the lowest grass weed count of 7.45 m^{-2}. Among treatment combinations T_8 ($SP_2S_1N_m$) recorded the lowest grass population in all observations and was an par with T_7 at 20 and 60 DAT. At 40 DAT and at harvest the grass population was not influenced by treatments. Among controls, the weedy check registered the highest grass weed count in all observations and was observed to be on par with two hand weeded plot at 20 DAT. T_{12} (herbicide + HW) recorded the lowest weed count at all observation and was on par with T_{11} (2 HW) at 60 DAT.

4.2.2.2. Sedge weed count

The results are presented in Table 11

Two summer ploughings reduced the sedge weed population to 9.81 m^{-2} at 40 DAT though the reduction was not significant at other stages. Stale seed bed technique helped to reduce the sedge number only at harvest with a mean value of 3.53 compared to no stale seed bed (8.09). Delaying the basal application of N did not produce any variation on sedge weed population. The two factor and three factor interactions also had no influence on sedge weed populations.

Table 11

Main effect of factors SP, S and N and their Interactions on sedge weed count (Number m^{-2}) at different intervals after transplanting

Treatments	Days after transplanting	
	20	40
SP_1	2.05 (1.75)	13.98 (3.87)
SP_2	1.30 (1.52)	9.81 (3.29)
CD	Ns	0.45*
S_o	1.83 (1.68)	11.40 (3.52)
S_1	1.49 (1.58)	12.23 (3.64)
CD	Ns	Ns
N_p	1.62 (1.62)	12.69 (3.70)
N_m	1.70 (1.64)	10.96 (3.46)
CD	Ns	Ns

Interactions

Treatments	20 DAT		40 DAT	
	SP_1	SP_2	SP_1	SP_2
S_o	1.37 (1.54)	2.33 (1.82)	13.09 (3.75)	9.81 (3.29)
S_1	2.81 (1.95)	0.45 (1.21)	14.89 (3.99)	9.81 (3.29)
Mean	(1.75)	(1.52)	(3.87)	(3.29)
CD	Ns		Ns	
N_p	1.62 (1.62)	1.62 (1.62)	15.08 (4.01)	10.49 (3.39)
N_m	2.51 (1.87)	0.99 (1.41)	12.91 (3.73)	9.16 (3.19)
Mean	(1.75)	(1.52)	(3.87)	(3.29)
CD	Ns		Ns	
	S_o	S_1	S_o	S_1
N_p	1.62 (1.62)	1.62 (1.62)	11.18 (3.49)	14.28 (3.91)
N_m	2.05 (1.75)	1.37 (1.54)	11.62 (3.55)	10.32 (3.36)
Mean	(1.68)	(1.58)	(3.52)	(3.64)
CD	Ns		Ns	

Ns -- Not significant

* -- Significant at 0.05% level

** -- Significant at 0.1% level

¶ -- The values in parenthesis are transformed values.

(contd...)

Table 11 (contd.)

Main effect of factors SP, S and N and their Interactions on sedge weed count (Number m^{-2}) at different intervals after transplanting

Treatments	60 DAT	Harvest
SP_1	19.48 (4.53)	7.78 (2.96)
SP_2	13.28 (3.78)	3.76 (2.18)
CD	Ns	Ns
S_o	13.38 (3.79)	8.09 (3.02)
S_1	19.37 (4.51)	3.53 (2.13)
CD	Ns	0.80*
N_p	15.78 (4.10)	5.21 (2.49)
N_m	16.71 (4.21)	6.03 (2.65)
CD	Ns	Ns

Interactions

Treatments	60 DAT		Harvest	
	SP_1	SP_2	SP_1	SP_2
S_o	15.58 (4.07)	11.33 (3.51)	13.03 (3.75)	4.22 (2.28)
S_1	23.80 (4.98)	15.39 (4.05)	3.75 (2.18)	3.32 (2.80)
Mean	(4.53)	(3.78)	(2.96)	(2.18)
CD	Ns		Ns	
N_p	18.89 (4.46)	12.94 (3.73)	6.29 (2.70)	4.22 (2.28)
N_m	20.08 (4.59)	13.63 (3.83)	9.40 (3.22)	3.32 (2.08)
Mean	(4.53)	(3.78)	(2.96)	(2.18)
CD	Ns		Ns	
	S_o	S_1	S_o	S_1
N_p	12.04 (3.61)	20.0 (4.58)	6.87 (2.81)	3.75 (2.18)
N_m	14.77 (3.97)	18.76 (4.45)	9.40 (3.22)	3.32 (2.08)
Mean	(3.79)	(4.51)	(3.02)	(2.13)
CD	Ns		Ns	

Table 11 (contd.)

Interaction effect of factors SP, S and N and controls on sedge weed count (Number m^{-2}) at different intervals after transplanting

Treatments	Days after transplanting			Harvest
	20	40	60	
T_1-$SP_1S_oN_p$	0.99 (1.41)	13.27 (3.78)	14.61 (3.95)	8.73 (3.12)
T_2-$SP_1S_oN_m$	1.78 (1.67)	12.91 (3.73)	16.59 (4.19)	18.11 (4.37)
T_3-$SP_1S_1N_p$	2.33 (1.82)	17.0 (4.24)	23.70 (4.97)	4.20 (2.28)
T_4-$SP_1S_1N_m$	3.32 (2.08)	12.91 (3.73)	23.89 (4.99)	3.32 (2.08)
T_5-$SP_2S_oN_p$	2.33 (1.82)	9.25 (3.20)	9.71 (3.27)	5.20 (2.49)
T_6-$SP_2S_oN_m$	2.33 (1.82)	10.39 (3.37)	13.05 (3.75)	3.33 (2.08)
T_7-$SP_2S_1N_p$	0.99 1.41)	11.79 (3.58)	16.59 (4.19)	3.32 (2.08)
T_8-$SP_2S_1N_m$	0.0 (1.0)	8.0 (3.0)	14.22 (3.90)	3.32 (2.08)
T_9-Complete weed free	0.0 (1.0)	0 (1.0)	0 (1)	0 (1)
T_{10}-Weedy check	10.67 (3.37)	28.0 (5.38)	32.0 (5.73)	13.33 (3.75)
T_{11}-2 HW	12.0 (3.58)	20.0 (4.58)	24.0 (4.81)	8.0 (2.94)
T_{12}-Chl+HW	0.0 (1.0)	14.67 (3.95)	14.67 (3.90)	12.0 (3.4)
CD	Ns	Ns	Ns	Ns

Weedy check (T_{10}) registered the highest sedge population in the observation though the variation was not significant.

4.2.2.3. Broad leaved weed count

The results are presented in Table 12

Two summer ploughings significantly reduced the count of broad leaved weeds at 40 and 60 DAT. Following stale seed bed technique caused a reduction of broad leaved weed count to 5.47 at 40 DAT compared to the count of 8.42 in the no stale seed bed practiced plots. Modification of N application had no significance on BLW count. SP x S, S Px N and S x N interactions were also not significant.

The influence of treatment combinations was significant only at 40 DAT where T_6 ($SP_2S_0N_m$) and T_7 ($SP_2S_1N_p$) registered the lowest BLW number of 2.33 m^{-2} which were on par with T_8 (3.32). Among controls, T_{12} (herbicide +HW) registered the lowest count of BLW at all stages though the variation was significant only at 40 DAT.

4.2.2.4. Total weed count

The results are presented in Table 13

In all observations, two summer ploughings significantly reduced the total weed count. The SP_2 plots recorded mean counts of 17.70, 27.80, 38.49 and 27.69 m^{-2} at 20, 40 and 60 DAT and at harvest respectively. Stale seed bed technique helped to reduce the total weed

Table 12

Main effect of factors SP, S and N and their Interactions on broad leaved weed count (Number m^{-2}) at different intervals after transplanting

Treatments	Days after transplanting	
	20	40
SP_1	4.62 (2.37)	11.21 (3.49)
SP_2	1.37 (1.54)	3.49 (2.12)
CD	Ns	0.48**
S_o	3.42 (2.10)	8.42 (3.07)
S_1	2.27 (1.81)	5.47 (2.54)
CD	Ns	0.48*
N_p	2.90 (1.98)	7.48 (2.91)
N_m	2.74 (1.93)	6.29 (2.70)
CD	Ns	Ns

Interactions

Treatments	20 DAT		40 DAT	
	SP_1	SP_2	SP_1	SP_2
S_o	5.45 (2.54)	1.78 (1.67)	13.86 (3.85)	4.22 (2.28)
S_1	3.85 (2.20)	0.99 (1.41)	8.82 (3.13)	2.81 (1.95)
Mean	(2.37)	(1.54)	(3.49)	(2.12)
CD	Ns		Ns	
N_p	4.82 (2.41)	1.37 (1.54)	11.53 (3.54)	4.22 (2.28)
N_m	4.43 (2.33)	1.37 (1.54)	10.89 (3.45)	2.81 (1.95)
Mean	(2.37)	(1.54)	(3.07)	(2.54)
CD	Ns		Ns	
	S_o	S_1	S_o	S_1
N_p	4.44 (2.33)	1.62 (1.62)	10.14 (3.34)	5.18 (2.49)
N_m	2.51 (1.87)	2.99 (2.00)	6.85 (2.80)	5.76 (2.60)
Mean	(2.10)	(1.81)	(3.07)	(2.54)
CD	Ns		Ns	

Ns -- Not significant
* -- Significant at 0.05% level
** -- Significant at 0.1% level
¶ -- The values in parenthesis are transformed values

(contd...)

Table 12 (contd.)

Main effect of factors SP, S and N and their Interactions on broad leaved weed count (Number m^{-2}) at different intervals after transplanting

Treatments	60 DAT	Harvest
SP_1	19.61 (4.54)	10.46 (3.39)
SP_2	8.78 (3.13)	9.61 (3.26)
CD	0.99**	Ns
S_o	13.17 (3.76)	9.84 (3.29)
S_1	14.23 (3.90)	10.23 (3.35)
CD	Ns	Ns
N_p	15.32 (4.04)	11.02 (3.47)
N_m	12.15 (3.63)	9.08 (3.18)
CD	Ns	Ns

Interactions

Treatments	60 DAT		Harvest	
	SP_1	SP_2	SP_1	SP_2
S_o	17.91(4.35)	9.11(3.18)	10.61(3.41)	9.08 (3.18)
S_1	21.38 (4.73)	8.45 (3.07)	10.31 (3.36)	10.14 (3.34)
Mean	4.54	3.13	3.39	3.26
CD	Ns		Ns	
N_p	20.83 (4.67)	10.61 (3.41)	10.34 (3.37)	11.72 (3.57)
N_m	18.42 (4.41)	7.10 (2.85)	10.59 (3.40)	7.69 (2.95)
Mean	4.54	3.13	3.39	3.26
CD	Ns		Ns	
	S_o	S_1	S_o	S_1
N_p	15.79 (4.10)	14.86 (3.98)	11.31 (3.51)	10.73 (3.42)
N_m	10.77 (3.43)	13.61 (3.82)	8.45 (3.07)	9.73 (3.28)
Mean	3.76	3.90	3.29	3.35
CD	Ns		Ns	

(contd...)

Table 12 (contd.)

Interaction effect of factors SP, S and N and controls on broad leaved weed count (Number m^{-2}) at different intervals after transplanting

Treatments	Days after transplanting			Harvest
	20	40	60	
T_1-$SP_1S_oN_p$	8.0 (3.0)	14.45 (3.93)	19.99 (4.58)	12.06 (3.61)
T_2-$SP_1S_oN_m$	3.32 (2.08)	13.27 (3.78)	15.95 (4.12)	9.25 (3.20)
T_3-$SP_1S_1N_p$	2.33 (1.82)	8.92 (3.15)	21.69 (4.76)	8.73 (3.12)
T_4-$SP_1S_1N_m$	5.66 (2.58)	8.73 (3.12)	21.06 (4.70)	12.0 (3.61)
T_5-$SP_1S_oN_p$	1.78 (1.67)	6.54 (2.75)	12.06 (3.61)	10.59 (3.40)
T_6-$SP_2S_oN_m$	1.78 (1.67)	2.33 (1.82)	6.54 (2.75)	7.69 (2.95)
T_7-$SP_2S_1N_p$	0.99 (1.41)	2.33 (1.82)	9.25 (3.20)	12.91 (3.73)
T_8-$SP_2S_1N_m$	0.99 (1.41)	3.32 (2.08)	7.69 (2.95)	7.69 (2.95)
T_9-Compete weed free	O (1)	0.0 (1)	0 (1)	0 (1)
T_{10}-Weedy Check	14.67 (3.95)	21.33 (4.69)	13.30 (3.75)	20.0 (4.49)
T_{11}-2 HW	13.3 (3.75)	14.67 (3.93)	26.67 (5.06)	16.0 (4.10)
T_{12}-Chl+HW	8.0 (3.0)	5.3 (2.49)	9.3 (3.02)	4.0 (2.07)
CD	Ns	0.96**	Ns	Ns

Table 13

Main effect of factors SP, S and N and their interaction on total weed count (Number m^{-2}) at different intervals after transplanting

Treatments	Days after transplanting	
	20	40
SP_1	27.22 (5.31)	45.19 (6.80)
SP_2	17.70 (4.32)	27.80 (5.37)
CD	0.67**	0.69**
S_o	28.90 (5.47)	41.03 (6.48)
S_1	16.38 (4.17)	31.27 (5.68)
CD	0.67**	0.69*
N_p	22.33 (4.83)	38.31 (6.27)
N_m	22.11 (4.81	33.74 (5.89)
CD	Ns	Ns

Interactions

Treatments	20 DAT		40 DAT	
	SP_1	SP_2	SP_1	SP_2
S_o	30.24 (5.59)	27.59 (5.35)	48.93 (7.07)	33.81 (5.90)
S_1	24.36 (5.04)	9.91 (3.30)	41.61 (6.53)	22.36 (4.83)
Mean	(5.31)	(4.32)	(6.80)	(5.37)
CD	0.94*		Ns	
N_p	25.49 (5.15)	19.38 (4.51)	46.19 (6.87)	31.14 (5.67)
N_m	29.01 (5.48)	16.10 (4.14)	44.21 (6.72)	24.64 (5.06)
Mean	(5.31)	(4.32)	(6.80)	(5.37)
CD	Ns		Ns	
	S_o	S_1	S_o	S_1
N_p	30.48 (5.61)	15.41 (4.05)	44.16 (6.72)	32.86 (5.82)
N_m	27.36 (5.33)	17.39 (4.29)	38.01 (6.25)	29.71 (5.54)
Mean	(5.47)	(4.17)	(6.48)	(5.68)
CD	Ns		Ns	

Ns -- Not significant
* -- Significant at 0.05% level
** -- Significant at 0.1% level
¶ -- The values in parenthesis are transformed values

(contd...)

Table 13 (contd.)

Main effect of factors SP, S and N and their interaction on total weed count (Number m^{-2}) at different intervals after transplanting

Treatments	60 DAT	Harvest
SP_1	65.39 (8.15)	41.30 (6.50)
SP_2	38.49 (6.28)	27.69 (5.36)
CD	1.29**	0.97*
S_o	50.19 (7.15)	42.19 (6.57)
S_1	51.96 (7.28)	26.97 (5.29)
CD	Ns	0.97*
N_p	56.09 (7.56)	34.78 (5.98)
N_m	46.28 (6.88)	33.56 (5.88)
CD	Ns	Ns

Interactions

Treatments	60 DAT		Harvest	
	SP_1	SP_2	SP_1	SP_2
S_o	56.34 (7.57)	44.38 (6.74)	50.95 (7.21)	34.24 (5.94)
S_1	75.09 (8.72)	33.01 (5.83)	32.65 (5.80)	21.81 (4.78)
Mean	(8.15)	(6.28)	(6.50)	(95.36)
CD	Ns		Ns	
N_p	67.24 (8.26)	45.93 (6.85)	37.52 (6.21)	32.14 (5.76)
N_m	63.55 (8.03)	31.69 (5.72)	45.27 (6.80)	23.55 (4.96)
Mean	(8.15)	(6.28)	(6.50)	(5.36)
CD	Ns		Ns	
	S_o	S_1	S_o	S_1
N_p	56.67 (7.59)	55.52 (7.52)	44.57 (6.75)	26.17 (5.21)
N_m	44.09 (6.71)	48.52 (7.04)	39.87 (6.39)	27.77 (5.36)
Mean	(7.15)	(7.28)	(6.57)	(5.29)
CD	Ns		Ns	

(contd...)

Table 13 (contd.)

Interaction effect of factors SP, S and N and controls on total weed count (Number m^{-2}) at different intervals after transplanting

Treatments	Days after transplanting			Harvest
	20	40	60	
T_1-$SP_1S_oN_p$	30.32 (5.60)	49.0 (7.07)	59.43 (7.77)	49.36 (7.10)
T_2-$SP_1S_oN_m$	30.17 (5.58)	48.86 (7.06)	53.33 (7.37)	52.56 (7.32)
T_3-$SP_{1s}1N_p$	21.06 (4.70)	43.46 (6.67)	75.53 (8.75)	27.27 (5.32)
T_4-$SP_1S_1N_m$	27.88 (5.37)	39.79 (6.39)	74.65 (8.70)	38.50 (6.29)
T_5-$SP_2S_oN_p$	30.64 (5.62)	39.57 (6.37)	53.97 (7.41)	40.02 (6.40)
T_6-$SP_2S_oN_m$	24.69 (5.07)	28.49 (5.43)	35.71 (6.06)	28.90 (5.47)
T_7-$SP_2S_1N_p$	10.59 (3.40)	23.70 (4.97)	38.53 (6.29)	25.10 (5.11)
T_8-$SP_2S_1N_m$	9.25 (3.20)	21.06 (4.70)	27.91 (5.38)	18.73 (4.44)
T_9-Complete weed free	0 (1)	0 (1)	0 (1)	0 (1)
T_{10}-Weedy check	74.67 (8.69)	140.0 (11.86)	212.0 (14.59)	206.67 (14.39)
T_{11}-2HW	60.0 (7.78)	76.0 (8.73)	88.0 (9.14)	41.33 (6.47)
T_{12}-Chl+HW	16.0 (4.12)	30.67 (5.59)	45.33 (6.74)	26.67 (5.20)
CD	1.33**	1.39**	Ns	Ns

count significantly in all observations except at 60 DAT. The basal skipping of N had no influence on total weed count.

The two way combinations except SP x S at 20 DAT had no influence on total weed count. At 20 DAT, SP_2S_1 registered the lowest total weed count of 9.91 m^{-2} while the other combinations were on par.

Among treatment combinations, T_8 registered the lowest total weed count at 20 and 40 DAT and was found to be on par with T_7 at 20 DAT and T_6 and T_7 at 40 DAT. At 60 DAT and at harvest the variation in weed count was not significant.

The herbicide applied plot (T_{12}) recorded the lowest total weed count at all stages. However, the reduction was significant at 20 (16.00) and 40 DAT (30.67).

4.2.3. Total weed dry matter production

The results are presented in Table 14

Perusal of data indicated that SP and method of application of N had no significant influence on total dry matter production of weeds. Stale seed bed technique caused significant reduction in weed dry weight at 20 DAT only. The stale seed bed practice registered the total dry weight of 2.85 g m^{-2} at 20 DAT.

Table 14

Main effect of factors SP, S and N and their 2 way interaction on total dry matter production of weeds (g m^{-2}) at different intervals after transplanting

Treatments	Days after transplanting			Harvest
	20	40	60	
SP_1	5.04	5.35	7.44	8.27
SP_2	5.62	3.02	5.59	5.94
CD	Ns	Ns	Ns	Ns
S_o	7.82	4.97	7.30	7.96
S_1	2.85	3.40	5.73	6.25
CD	4.48*	Ns	Ns	Ns
N_p	5.71	4.41	6.54	6.89
N_m	4.95	3.96	6.49	7.32
CD	Ns	Ns	Ns	Ns

Interactions

Treatments	20 DAT		40 DAT		60 DAT		Harvest	
	SP_1	SP_2	SP_1	SP_2	SP_1	SP_2	SP_1	SP_2
S_o	6.67	8.97	6.08	3.87	8.18	6.41	9.42	6.49
S_1	3.41	2.28	4.62	2.17	6.69	4.77	7.12	5.39
Mean	5.04	5.62	5.35	3.02	7.44	5.59	8.27	5.94
CD	Ns		Ns		Ns		Ns	
N_p	5.46	5.97	5.08	3.74	6.83	6.25	7.48	6.30
N_m	4.62	5.28	5.62	2.30	8.05	4.94	9.05	5.59
Mean	5.04	5.62	5.35	3.02	7.44	5.59	8.27	5.94
CD	Ns		Ns		Ns		Ns	
	S_o	S_1	S_o	S_1	S_o	S_1	S_o	S_1
N_p	7.91	3.51	5.0	3.82	6.79	6.29	7.39	6.39
N_m	7.73	2.18	4.95	2.98	7.81	5.18	8.52	6.12
Mean	7.82	2.85	4.97	3.40	7.30	5.73	7.96	6.25
CD	Ns		Ns		Ns		Ns	

Ns -- Not significant
* -- Significant at 0.05% level
** -- Significant at 0.1% level

(contd...)

Table 14 (contd.)

Interaction effect of factors SP, S and N and controls on total dry matter production of weeds (g m^{-2}) at different intervals after transplanting

Treatments	Days after transplanting			Harvest
	20	40	60	
T_1-$SP_1S_oN_p$	6.66	5.51	6.98	8.03
T_2-$SP_1S_oN_m$	6.68	6.64	9.39	10.81
T_3-$SP_1S_1N_p$	4.25	4.65	6.68	6.94
T_4-$SP_1S_1N_m$	2.57	4.60	6.71	7.29
T_5-$SP_2S_oN_p$	9.16	4.48	6.59	6.76
T_6-$SP_2S_oN_m$	8.78	3.25	6.23	6.23
T_7-$SP_2S_1N_p$	2.77	2.99	5.90	5.83
T_8-$SP_2S_1N_m$	1.79	1.36	3.64	4.94
T_9-Complete weed free	0	0	0	0
T_{10}-Weedy check	43.18	129.43	147.26	141.18
T_{11}-2 HW	40.23	9.71	5.22	8.39
T_{12}-Chl+HW	5.72	7	5.65	9.65
CD	Ns	Ns	Ns	Ns

* Weedy check exempted from analysis

All the two factor and three factor interactions were not statistically significant on total dry weight of weeds. Dry matter production of weeds was the lowest in T_8 among treatments. Comparing controls T_{12} registered the lowest DMP at 20 and 40 DAT. After that two hand weeded plot recorded the lowest total weed dry matter production.

4.2.4. Calculated weed parameters

From the values of weed count and dry matter production following parameters were worked out.

4.2.4.1. Weed density

The results presented in tables 15, 16 and 17 are the worked out mean values of weed density which were exempted from statistical analysis.

4.2.4.1.1. Grass weed density

The results are presented in Table 15

The mean values revealed that among weed species, the grass species dominated throughout the crop growth stages. T_7 ($Sp_2S_1N_p$) and T_8 ($SP_2S_1N_m$) recorded the lowest grass weed density at all stages. Among controls T_{12} (chemical + HW) recorded the lowest grass weed density at 20, 40and 60 DAT and at harvest with mean values of 8, 10.67, 21.33 and 10.67. The highest grass weed density was observed in weedy check.

Table 15

Effect of treatments and controls on grass weed density at different intervals after transplanting

Treatments	Days after transplanting			Harvest
	20	40	60	
T_1-$SP_1S_oN_p$	21.33	21.33	24.0	28.0
T_2-$SP_1S_oN_m$	24.00	22.67	20.0	25.33
T_3-$SP_1S_1N_p$	16.00	17.33	28.0	13.33
T_4-$SP_1S_1N_m$	14.67	17.33	29.33	22.67
T_5-$SP_2S_oN_p$	25.23	24.00	34.67	25.33
T_6-$SP_2S_oN_m$	20.00	16.00	16.00	18.67
T_7-$SP_2S_1N_p$	8.00	9.33	10.67	8.00
T_8-$SP_2S_1N_m$	8.00	9.33	5.33	8.00
T_9-Complete weed free	0	0	0	0
T_{10}-Weedy check	49.33	90.67	166.67	173.33
T_{11}-2 HW	34.67	41.33	37.33	18.67
T_{12}-Chl+HW	8.00	10.67	21.33	10.67

(Worked out mean values, data not statistically analysed)

4.2.4.1.2. Sedge weed density

The results are presented in Table 16

At 20 and 40 DAT, T_8 recorded the lowest sedge weed density (0 and 8). At 60 DAT, T_5 was observed to have the lowest sedge density of 10.67. At harvest T_4, T_6, T_7 and T_8 recorded the lowest sedge density (4.0). Among controls, T_{12} registered the lowest density at all observations T_{11} at harvest.

4.2.4.1.3. Broad leaved weed density

The results are presented in Table 17

The treatment combinations T_7 and T_8 recorded the lowest weed density at 20 DAT. T_6 and T_7 (2.67) had the lowest broad leaved density at 40 DAT whereas the density was the lowest (6.67) in T_6 at 60 DAT. At harvest, T_6 and T_8 were observed to have the lowest density of BLW (8.0). Among controls, T_{12} registered the lowest BLW density at all stages.

4.2.4.2. Relative density (RD)

Relative density of weed species worked out at different intervals were subjected to suitable transformations where ever needed and analysed. The results are presented in Tables 18, 19 and 20.

4.2.4.2.1. Relative density of grasses

The results are presented in Table 18

The summer ploughing, stale seed bed and basal skipping of N

Table 16

Effect of treatments and controls on sedge weed density at different intervals after transplanting.

Treatment	Days after transplanting			Harvest
	20	40	60	
T_1-$SP_1S_0N_p$	1.33	13.33	14.67	9.33
T_2-$SP_1S_oN_m$	2.67	13.33	17.33	18.67
T_3-$SP_1S_1N_p$	2.67	17.33	24.0	5.33
T_4-$SP_1S_1N_m$	4.0	13.33	24.0	4.0
T_5-$SP_2S_oN_p$	2.67	9.33	10.67	5.33
T_6-$SP_2S_oN_m$	2.67	10.67	13.33	4.0
T_7-$SP_2S_1N_p$	1.33	12.0	17.33	4.0
T_8-$SP_2S_1N_m$	0	8.0	14.67	4.0
T_9-Complete weed free	0	0	0	0
T_{10}-Weedy check	10.67	28.0	32.0	13.33
T_{11}-2 HW	12.0	20.0	24.0	8.0
T_{12}-Chl+HW	0	14.67	14.67	12.0

(Worked out mean values, data not statistically analysed)

Table 17

Effect of treatments and controls on broad leaved weed density at different intervals after transplanting

Treatments	Days after transplanting			Harvest
	20	40	60	
T_1-$SP_1S_0N_p$	8.0	14.67	21.33	13.33
T_2-$SP_1S_oN_m$	4.0	13.33	17.33	9.33
T_3-$SP_1S_1N_p$	2.67	9.33	24.0	9.33
T_4-$SP_1S_1N_m$	10.67	9.33	21.33	12.0
T_5-$SP_2S_oN_p$	2.67	6.67	13.33	10.67
T_6-$SP_2S_oN_m$	2.67	2.67	6.67	8.0
T_7-$SP_2S_1N_p$	1.33	2.67	12.0	13.33
T_8-$SP_2S_1N_m$	1.33	4.0	8.0	8.0
T_9-Complete weed free	0	0	0	0
T_{10}-Weedy check	14.67	21.33	13.36	20.0
T_{11}-2 HW	13.33	14.67	26.67	16.0
T_{12}-Chl+HW	8.0	5.33	9.33	4.0

(Worked out mean values, data not statistically analysed)

Table 18

Main effect of factors SP, S and N and their interactions on Relative Density of grasses at different intervals after transplanting

Treatment	Days after transplanting	
	20	40
SP_1	69.33	43.43
SP_2	81.10	49.14
CD	Ns	Ns
S_o	75.31	50.55
S_1	75.12	42.02
CD	Ns	6.89*
N_p	75.98	45.08
N_m	74.45	47.49
CD	Ns	Ns

Interactions

Treatments	20 DAT		40 DAT	
	SP_1	SP_2	SP_1	SP_2
S_o	71.75	78.87	44.55	56.56
S_1	66.91	83.34	42.21	41.73
Mean	69.33	81.10	43.43	49.14
CD	Ns		Ns	
N_p	71.71	80.26	41.44	48.72
N_m	66.95	81.95	45.42	49.57
Mean	69.33	81.10	43.43	49.14
CD	Ns		Ns	
	S_o	S_1	S_o	S_1
N_p	75.34	76.63	50.80	39.36
N_m	75.28	73.61	50.31	44.68
Mean	75.31	75.12	50.55	42.02
CD	Ns		Ns	

Ns -- Not significant
* -- Significant at 0.05% level
** -- Significant at 0.1% level
¶ -- The values in parenthesis are transformed values.

(contd...)

Table 18 (contd.)

Main effect of factors SP, S and N and their interactions on Relative Density of grasses at different intervals after transplanting

Treatments	60 DAT	Harvest
SP_1	38.57 (38.38)	52.61 (46.48)
SP_2	35.92 (36.81)	43.99 (41.53)
CD	Ns	Ns
S_o	43.23 (41.09)	50.71 (45.39)
S_1	31.45 (34.10)	45.89 (42.62)
CD	6.43*	Ns
N_p	41.31 (39.98)	48.24 (43.97)
N_m	33.26 (35.21)	48.35 (44.04)
CD	Ns	Ns

Interactions

Treatments	60 DAT		Harvest	
	SP_1	SP_2	SP_1	SP_2
S_o	38.40 (38.27)	48.12 (43.91)	49.35 (44.61)	52.07 (46.17)
S_1	38.75 (38.48)	24.58 (29.71)	55.86 (48.35)	36.08 (36.90)
Mean	(38.38)	(36.81)	(46.48)	(41.53)
CD	9.09*		Ns	
N_p	39.38 (38.85)	43.26 (41.11)	52.33 (46.32)	44.16 (41.63)
N_m	37.77 (37.90)	28.90 (32.51)	52.89 (46,64)	43.83 (41.44)
Mean	(38.38)	(36.81)	(46.48)	(41.53)
CD	Ns		Ns	
	S_o	S_1	S_o	S_1
N_p	48.28 (43.99)	34.52 (35.97)	53.89 (47.21)	42.61 (40.73)
N_m	38.25 (38.19)	28.46 (32.23)	47.52 (43.56)	49.18 (44.51)
Ean	(49.01)	(34.10)	(45.39)	(42.62)
CD	Ns		Ns	

(contd...)

Table 18 (contd.)

Interaction effect of factors SP, S and N on relative density of grasses at different intervals after transplanting

Treatments	Days after transplanting			Harvest
	20 DAT	40	60	
T_1-$SP_1S_0N_p$	67.94	43.33	40.49 (30.50)	52.01 (46.13)
T_2-$SP_1S_oN_m$	75.56	45.77	36.33 (37.05)	46.69 (43.09)
T_3-$SP_1S_1N_p$	75.48	39.55	38:28 (38.20)	52.66 (46.50)
T_4-$SP_1S_1N_m$	58.33	45.07	39.22 (38.76)	59.04 (50.19)
T_5-$SP_2S_oN_p$	82.74	58.26	56.11 (48.49)	55.77 (48.29)
T_6-$SP_2S_oN_m$	75.00	54.85	40.18 (39.32)	48.36 (44.04)
T_7-$SP_2S_1N_p$	77.78	39.17	30.86 (33.73)	32.86 (34.96)
T_8-$SP_2S_1N_m$	88.89	44.29	18.81 (25.69)	39.36 (38.84)
T_9-Complete weed free	0	0	0 (1)	0 (1)
T_{10}-Weedy check	66.38	64.75	78.61 (62.52)	84.04 (66.58)
T_{11}-2 HW	58.25	52.69	43.03 (40.98)	45.38 (42.32)
T_{12}-Chl+HW	50	31.75	49.53 (44.75)	41.66 (39.89)
CD	Ns	Ns	Ns	Ns

and their interactions had no significance on relative density of grasses at 20 DAT. Stale seed bed technique significantly reduced RD of grasses at 40 and 60 DAT with respective means of 42.02 and 31.45. The method of nitrogen application also had no effect on RD of grasses. The interaction effect except SP x S at 60 DAT were not significant. SP_2S_1 was observed to have lowest RD of grasses (24.58) which was on par with SP_1S_0 and SP_1S_1.

All the three factor interactions had no influence in relative density of grasses. Among controls, weedy check registered the highest RD at all observations.

4.2.4.2.2. Relative density of sedges

The results are presented in Table 19

Summer ploughing had no influence in reducing the RD of sedges at any observation. Stale seed bed practice enhanced the RD of sedges at 40 and 60 DAT, the mean values being 40.54 and 39.81 respectively. Basal skipping of N had no effect on RD of sedges. The interaction effects also had no effect on changing the RD of sedges.

Among controls the lowest RD of sedges was recorded by weedy check at all observations except that at 20 DAT. At 20 DAT the sedge population was zero in herbicide applied plot (T_{12}). However, the change in RD of sedges was not significant.

Table 19

Main effect of factors SP, S and N and their Interactions on relative density of sedges at different intervals after transplanting

Treatments	Days after transplanting	
	20 DAT	40 DAT
SP_1	7.88 (2.98)	31.57
SP_2	5.14 (2.48)	37.66
CD	Ns	Ns
S_o	6.65 (2.77)	28.70
S_1	6.25 (2.69)	40.54
CD	Ns	8.39**
N_p	6.04 (2.65)	35.46
N_m	6.87 (2.81)	33.78
CD	Ns	Ns

Interactions

Treatments	20 DAT		40 DAT	
	SP_1	SP_2	SP_1	SP_2
S_o	4.69 (2.39)	8.91 (3.15)	26.84	30.57
S_1	11.78 (3.58)	2.28 (1.81)	36.31	44.76
Mean	(2.98)	(2.48)	31.57	37.66
CD	Ns		Ns	
N_p	5.59 (2.57)	6.51 (2.74)	33.63	37.29
N_m	10.52 (3.39)	3.92 (2.22)	29.51	38.04
Mean	(2.98)	(2.48)	31.57	37.66
CD	Ns		Ns	
	S_o	S_1	S_o	S_1
N_p	4.84 (2.42)	7.36 (2.89)	25.90	45.02
N_m	8.72 (3.12)	5.22 (2.49)	31.51	36.05
Mean	(2.77)	(2.69)	28.70	40.54
CD	Ns		Ns	

Ns -- Not significant

* -- Significant at 0.05% level

** -- Significant at 0.1% level

¶ -- The values in parenthesis are transformed values

(contd...)

Table 19 (contd.)

Main effect of factors SP, S and N and their Interactions on relative density of sedges at different intervals after transplanting

Treatments	60 DAT	Harvest
SP_1	30.11	15.79 (23.40)
SP_2	39.06	12.05 (20.30)
CD	Ns	Ns
S_o	29.36	19.48 (26.18)
S_1	39.81	9.07 (17.52)
CD	10.03*	Ns
N_p	30.74	12.35(20.57)
N_m	38.43	15.44 (23.13)
CD	Ns	Ns

Interactions

Treatments	60 DAT		Harvest	
	SP_1	SP_2	SP_1	SP_2
S_o	28.18	30.54	25.32 (30.20)	14.24 (22.17)
S_1	32.04	47.59	8.17 (16.80)	10.01 (18.44)
Mean	30.11	39.06	(23.40)	(20.30)
CD	Ns		Ns	
N_p	28.93	32.55	13.41 (21.47)	11.33 (19.67)
N_m	31.28	45.58	18.31 (25.33)	12.78 (20.94)
Mean	30.11	39.06	(23.40)	(20.30)
CD	Ns		Ns	
	S_o	S_1	S_o	S_1
N_p	24.17	37.31	15.03 (22.80)	9.91 (18.34)
N_m	34.54	42.32	24.36 (29.56)	8.26 (16.70)
Mean	30.74	38.43	(26.18)	(17.52)
CD	Ns		Ns	

(contd...)

Table 19 (contd.)

Interaction effect of factors SP, S and N and controls on relative density of sedges at different intervals after transplanting

Treatments	Days after transplanting			Harvest
	20	40	60	
T_1-$SP_1S_0N_p$	2.88 (1.97)	27.22	25.85	16.95 (24.30)
T_2-$SP_1S_oN_m$	6.85 (2.80)	26.45	30.51	34.74 (36.10)
T_3-$SP_1S_1N_p$	9.01 (3.16)	40.04	32.02	10.23 (18.65)
T_4-$SP_1S_1N_m$	14.89 (3.99)	32.57	32.05	6.32 (14.55)
T_5-$SP_2S_oN_p$	7.19 (2.86)	24.57	22.50	13.21 (21.31)
T_6-$SP_2S_oN_m$	10.79 (3.43)	36.56	38.57	15.31 (23.02)
T_7-$SP_2S_1N_p$	5.86 (2.62)	50.0	42.61	9.58 (18.03)
T_8-$SP_2S_1N_m$	0 (1.0)	39.52	52.58	10.44 (18.85)
T_9-Complete weed free	0 (1.0)	0	0	0 (1)
T_{10}-Weedy check	(3.84)	19.95	15.10	(14.47)
T_{11}-2 HW	(4.56)	27.48	27.69	(25.31)
T_{12}-Chl+HW	0 (1)	51.27	32.63	(39.98)
CD	Ns	Ns	Ns	Ns

4.2.4.2.3. Relative density of broad leaved weeds

The results are presented in Table 20

The RD of BLW at 40 DAT alone showed significant reduction by two summer ploughings with mean value of 10.84 compared to single summer ploughing (24.38). Stale seed bed technique and basal skipping of nitrogen and interactions had no influence on changing the RD of BLW. The RD of BLW had no variation among controls.

4.2.4.3. Weed frequency

The mean values of weed frequency are presented in Tables 21, 22 and 23 and were not subjected to statistical analysis.

4.2.4.3.1. Grass weed frequency

The results are presented in Table 21

The grass weed frequency was cent percent in all treatments during all growth stages.

4.2.4.3.2. Sedge weed frequency

The results are presented in Table 22

Among treatments T_1, T_2 and T_7 registered the lowest sedge weed density (33.33) at 20 DAT. At 40 and 60 DAT the frequency was cent percent in all treatments. At harvest the frequency was observed to be low in T_3, T_4, T_6, T_7 and T_8.

Table 20

Main effect of factors SP, S and N and their Interactions on relative density of broad leaved weeds at different intervals after transplanting

Treatments	Days after transplanting	
	20 DAT	40 DAT
SP_1	13.32 (3.78)	24.38 (5.04)
SP_2	5.54 (2.56)	10.84 (3.44)
CD	Ns	0.83**
S_o	10.19 (3.34)	18.93 (4.46)
S_1	7.98 (3.00)	15.11 (4.01)
CD	Ns	Ns
N_p	10.59 (3.40)	17.88 (4.34)
N_m	7.63 (2.94)	16.08 (4.13)
CD	Ns	Ns

Interactions

Treatments	20 DAT		40 DAT	
	SP_1	SP_2	SP_1	SP_2
S_o	16.61 (4.2)	5.22 (2.49)	28.45 (5.43)	11.26 (3.50)
S_1	10.37 (3.37)	5.86 (2.62)	20.61 (4.65)	10.42 (3.38)
Mean	(3.78)	(2.56)	(5.04)	(3.44)
CD	Ns		Ns	
N_p	17.62 (4.31)	5.22 (2.49)	24.42 (5.04)	12.30 (3.65)
N_m	9.59 (3.25)	5.86 (2.62)	24.33 (5.03)	9.45 (3.23)
Mean	(3.78)	(2.56)	(5.04)	(3.44)
CD	Ns		Ns	
	S_o	S_1	S_o	S_1
N_p	13.67 (3.83)	7.87 (2.98)	22.61 (4.86)	13.67 (3.83)
N_m	7.18 (2.86)	8.09 (3.01)	15.56 (4.07)	16.62 (4.20)
Mean	(3.34)	(2.94)	(4.46)	(4.01)
CD	Ns		Ns	

Ns -- Not significant
* -- Significant at 0.05% level
** -- Significant at 0.1% level
¶ -- The values in parenthesis are transformed values

(contd...)

Table 20 (contd.)

Main effect of factors SP, S and N and their Interactions on relative density of broad leaved weeds at different intervals after transplanting

Treatments	60 DAT	Harvest
SP_1	29.51 (5.52)	27.22 (31.43)
Sp_2	21.30 (4.72)	38.72 (38.46)
CD	Ns	Ns
S_o	25.49 (5.15)	26.21 (30.78)
S_1	25.01 (5.10)	39.83 (39.12)
CD	Ns	Ns
N_p	24.50 (5.05)	35.30 (36.44)
N_m	26.01 (5.20)	30.42 (33.46)
CD	Ns	Ns

Interactions

Treatments	60 DAT		Harvest	
	SP_1	SP_2	SP_1	SP_2
S_o	31.23 (5.68)	20.31 (4.62)	22.96 (28.62)	29.59 (39.24)
S_1	27.84 (5.37)	22.32 (4.83)	31.70 (34.25)	48.27 (43.99)
Mean	(5.52)	(4.72)	(31.43)	(38.46)
CD	Ns		Ns	
N_p	29.76 (5.55)	19.72 (4.55)	30.07 (33.24)	40.72 (39.63)
N_m	29.27 (5.50)	22.94 (4.89)	24.46 (29.63)	36.74 (37.29)
Mean	(5.52)	(4.72)	(31.43)	(38.46)
CD	Ns		Ns	
	S_o	S_1	S_o	S_1
N_p	26.59 (5.25)	22.48 (4.85)	29.14 (32.66)	41.72 (40.22)
N_m	24.41 (5.04)	27.66 (5.35)	23.88 (28.90)	37.97 (38.02)
Mean	(5.15)	(5.10)	(30.78)	(39.12)
CD	Ns		Ns	

(contd…)

Table 20 (contd.)

Interaction effect of factors SP, S and N and controls on relative density of broad leaved weeds at different intervals after transplanting

Treatments	Days after transplanting			Harvest
	20	40	60	
T_1-$SP_1S_0N_p$	27.02 (5.29)	29.35 (5.51)	32.07 (5.75)	31.02
T_2-$SP_1S_oN_m$	8.61 (3.10)	27.56 (5.34)	30.40 (5.60)	18.24
T_3-$SP_1S_1N_p$	10.13 (3.34)	19.94 (4.58)	27.54 (5.34)	32.41
T_4-$SP_1S_1N_m$	10.62 (3.41)	21.30 (4.72)	28.15 (5 40)	31.59
T_5-$SP_2S_oN_p$	4.60 (2.37)	16.71 (4.21)	21.61 (4.75)	31.11
T_6-$SP_2S_oN_m$	5.86 (2.62)	6.80 (2.79)	19.05 (4.48)	30.11
T_7-$SP_2S_1N_p$	5.86 (2.62)	8.52 (3.09)	17.92 (4.35)	51.94
T_8-$SP_2S_1N_m$	5.86 (2.62)	12.49 (3.67)	27.18 (5.31)	45.0
T_9-Complete weed free	0 (1)	0 (1)	0 (1)	0 (1)
T_{10}-Weedy check	(4.53)	(4.01)	(2.67)	9.63
T_{11}-2 HW	(4.77)	(4.53)	(5.46)	38.65
T_{12}-Chl+HW	(7.14)	(4.23)	(4.21)	16.67
CD	Ns	Ns	Ns	Ns

Table 21

Effect of treatments and controls on grass weed frequency at different intervals after transplanting

Treatments	Days after transplanting			Harvest
	20	40	60	
T_1-$SP_1S_0N_p$	100	100	100	100
T_2-$SP_1S_oN_m$	100	100	100	100
T_3-$SP_1S_1N_p$	100	100	100	100
T_4-$SP_1S_1N_m$	100	100	100	100
T_5-$SP_2S_oN_p$	100	100	100	100
T_6-$SP_2S_oN_m$	100	100	100	100
T_7-$SP_2S_1N_p$	100	100	100	100
T_8-$SP_2S_1N_m$	100	100	100	100
T_9-Ccomplete weed free	0	0	0	0
T_{10}-Weedy check	100	100	100	100
T_{11}-2 HW	100	100	100	100
T_{12}-Chl+HW	100	100	100	100

* Worked out mean values, data not statistically analysed.

Table 22

Effect of treatments and controls on sedge weed frequency at different interval after transplanting

Treatments	Days after transplanting			Harvest
	20	40	60	
T_1-$SP_1S_0N_p$	33.33	100	100	100
T_2-$SP_1S_oN_m$	33.33	100	100	100
T_3-$SP_1S_1N_p$	66.67	100	100	66.67
T_4-$SP_1S_1N_m$	66.67	100	100	66.67
T_5-$SP_2S_oN_p$	66.67	100	100	100
T_6-$SP_2S_oN_m$	66.67	100	100	66.67
T_7-$SP_2S_1N_p$	33.33	100	100	66.67
T_8-$SP_2S_1N_m$	0	100	100	66.67
T_9-Complete weed free	0	0	0	0
T_{10}-Weedy check	100	100	100	100
T_{11}-2 HW	100	100	100	100
T_{12}-Chl+HW	0	100	100	100

* Worked out mean values, data not statistically analysed

The controls registered cent per cent values at 40 and 60 DAT and at harvest where as the frequency was zero in T_{12} (herbicide + HW) at 20 DAT.

4.2.4.3.3. Broad leaved frequency

The results are presented in Table 23

Comparison of treatments revealed that the lowest frequency (33.33) was observed at 20 DAT. At 40 DAT T_6, T_7 and T_8 recorded the lowest while T_7 ($SP_2S_1N_p$) recorded the lowest frequency (66.67) at 60 DAT. At harvest cent percent frequency was showed in all treatments.

Among controls all the observations registered a frequency value of 100 except for T_{12} at harvest (66.67).

4.2.4.4. Relative frequency

The results presented in tables 24, 25 and 26 are the mean relative frequency values which were not subjected to statistical analysis.

4.2.4.4.1. Relative frequency of grasses

The results are presented in Table 24

Among treatments, T_1 and T_3 recorded the lowest relative frequency (42.86) at 20 DAT. AT 40 DAT except T_6, T_7 and T_8 all other combinations registered the lowest relative frequency of 33.33. Relative frequency of grasses were lower in all treatments (33.33) except T_7 at 60 DAT, where as T_1, T_2 T_5 and T_6 registered the lowest value at harvest.

Table 23

Effect of treatments and controls on broad leaved weed frequency at different intervals after transplanting.

Treatments	Days after transplanting			Harvest
	20	40	60	
T_1-$SP_1S_0N_p$	100	100	100	100
T_2-$SP_1S_oN_m$	66.67	100	100	100
T_3-$SP_1S_1N_p$	66.67	100	100	100
T_4-$SP_1S_1N_m$	33.33	100	100	100
T_5-$SP_2S_oN_p$	33.33	100	100	100
T_6-$SP_2S_oN_m$	33.33	66.67	100	100
T_7-$SP_2S_1N_p$	33.33	66.67	66.67	100
T_8-$SP_2S_1N_m$	33.33	66.67	100	100
T_9-Complete weed free	0	0	0	0
T_{10}-Weedy check	100	100	100	100
T_{11}-2 HW	100	100	100	100
T_{12}-Chl+HW	100	100	100	66.67

* Worked out mean values, data not statistically analysed

Table 24

Effect of treatments and controls on relative frequency of grasses at different intervals after transplanting

Treatments	Days after transplanting			Harvest
	20	40	60	
T_1-$SP_1S_0N_p$	42.86	33.33	33.33	33.33
T_2-$SP_1S_oN_m$	50.0	33.33	33.33	33.33
T_3-$SP_1S_1N_p$	42.86	33.33	33.33	37.50
T_4-$SP_1S_1N_m$	50.0	33.33	33.33	37.50
T_5-$SP_2S_oN_p$	50.0	33.33	33.33	33.33
T_6-$SP_2S_oN_m$	50.0	37.50	33.33	33.33
T_7-$SP_2S_1N_p$	60.0	37.50	37.50	37.50
T_8-$SP_2S_1N_m$	75.0	37.50	33.33	37.50
T_9-Complete weed free	0	0	0	0
T_{10}-Weedy check	33.33	33.33	33.33	33.33
T_{11}-2 HW	33.33	33.33	33.33	33.33
T_{12}-Chl+HW	50.0	33.33	33.33	37.50

* Worked out mean values, data not statistically analysed

Among controls not much variation was observed. However T_{12} recorded slightly higher value at 20 DAT and at harvest.

4.2.4.4.2. Relative frequency of sedges

The results are presented in Table 25

T_1 ($SP_1 S_0 N_P$) recorded the lowest relative frequency of sedges (14.28) at 20 DAT. T_1, T_2, T_3, T_4 and T_5 registered the lowest relative frequency of sedges (33.33) at 40 DAT. All treatment combination except T_7 had low relative frequency values at 60 DAT. At harvest T_3, T_4, T_6, T_7 and T_8 registered the lowest relative frequency value of 25.0.

While comparing controls, the relative frequency was zero for T_{12} at 20 DAT. No variation was observed at 40 and 60 DAT though the frequency values are slightly higher for T_{12} at harvest.

4.2.4.4.3. Relative frequency of broad leaved weeds

The results are presented in Table 26

Among treatments T_4, T_5 and T_6 recorded the lowest relative frequency (16.67) at 20 DAT. AT 40 DAT T_6, T_7 and T_8 registered the lowest relative frequency of BLW. At 60 DAT T_7 ($SP_2S_1N_P$) observed the lowest mean of 25.00. The treatments T_1, T_2 and T_5 registered the lowest relative frequency (33.33)at harvest.

Comparison of controls, indicated no variation in relative frequency of BLW though T_{12} showed an increase at 20 DAT and decrease at harvest.

Table 25

Effect of treatments and controls on relative frequency of sedges at different intervals after transplanting

Treatments	Days after transplanting			Harvest
	20	40	60	
T_1-$SP_1S_0N_p$	14.28	33.33	33.33	33.33
T_2-$SP_1S_oN_m$	16.67	33.33	33.33	33.33
T_3-$SP_1S_1N_p$	28.57	33.33	33.33	25.0
T_4-$SP_1S_1N_m$	33.34	33.33	33.33	25.0
T_5-$SP_2S_oN_p$	33.34	33.33	33.33	33.33
T_6-$SP_2S_oN_m$	33.34	37.50	33.33	25.0
T_7-$SP_2S_1N_p$	19.99	37.50	37.50	25.0
T_8-$SP_2S_1N_m$	0	37.50	33.33	25.0
T_9-Complete weed free	0	0	0	0
T_{10}-Weedy check	33.33	33.33	33.33	33.33
T_{11}-2 HW	33.33	33.33	33.33	33.33
T_{12}-Chl+HW	0	33.33	33.33	37.50

* Worked out mean values, data not statistically analysed

Table 26

Effect of treatments and controls on relative frequency of broad leaved weeds at different intervals after transplanting.

Treatments	Days after transplanting			Harvest
	20	40	60	
T_1-$SP_1S_0N_p$	42.86	33.33	33.33	33.33
T_2-$SP_1S_oN_m$	33.34	33.33	33.33	33.33
T_3-$SP_1S_1N_p$	28.57	33.33	33.33	37.50
T_4-$SP_1S_1N_m$	16.67	33.33	33.33	37.50
T_5-$SP_2S_oN_p$	16.67	33.33	33.33	33.33
T_6-$SP_2S_oN_m$	16.67	25.0	33.33	37.50
T_7-$SP_2S_1N_p$	19.99	25.0	25.0	37.50
T_8-$SP_2S_1N_m$	24.99	25.0	33.33	37.50
T_9-Complete weed free	0	0	0	0
T_{10}-Weedy check	33.33	33.33	33.33	33.33
T_{11}-2 HW	33.33	33.33	33.33	33.33
T_{12}-Chl+HW	50.0	33.33	33.33	25.0

* Worked out mean values, data not statistically analysed

4.2.4.5. Summed dominance ratio

The results are presented in Table 27 and 28

Grasses dominated through out the growth stages. But the data did not give consistency in different observations. Even though the dominance was highest by grasses, at later stages sedges and BLW increased in number. T_8 (81.95), T_6 (46.18), T_5 (44.58) and T_4 (48.26) dominated among grasses at 20, 40 and 60 DAT and at harvest respectively. Among sedgesT_8 dominated at 40 and 60 DAT while T_4 and T_2 dominated at 20 DAT and at harvest respectively. Among BLW, T_1 ($SP_1S_0N_P$) dominated all observations except T_7, at harvest.

Weedy check (T_{10}) recorded the highest grass weed dominance. Among controls T_{11} (2 HW) registered the highest SDR values of BLW the values being 27.57, 26.58, 31.30 and 34.71 at all observations.

4.2.4.6. Importance value (IV)

The results are presented in Table 29 and 30

The observations revealed that the importance value of grasses was higher than that of sedges and BLW. Among the combinations IV of weed species was not consistent in earlier observations. At 20 DAT T_3 and T_{12} registered the highest IV of grasses whereas T_2 and T_{11} recorded higher IV of sedges and T_4 had the highest IV of BLW. AT 40 DAT T_7 (78.53) had the highest IV for grasses T_5 and T_6 for sedges and T_{12} for BLW. Towards the later stages i.e., at 60 DAT and at harvest the

Table 27

Summed dominance ratio of grasses, sedges and broad leaved weeds at 20 and 40 DAT

Treatments	20 DAT			40 DAT		
	Grasses	Sedges	BLW	Grasses	Sedges	BLW
T_1-$SP_1S_0N_p$	55.40	9.52	35.08	31.67	30.28	31.39
T_2-$SP_1S_oN_m$	62.78	15.0	22.23	39.55	29.89	30.56
T_3-$SP_1S_1N_p$	59.17	20.0	20.83	36.44	36.69	26.87
T_4-$SP_1S_1N_m$	54.17	26.39	19.45	39.20	32.95	27.84
T_5-$SP_2S_oN_p$	66.37	21.14	12.50	45.79	28.95	25.25
T_6-$SP_2S_oN_m$	62.50	23.62	13.89	46.18	37.03	16.79
T_7-$SP_2S_1N_p$	68.89	15.55	15.55	38.33	35.42	17.92
T_8-$SP_2S_1N_m$	81.95	0	18.05	40.89	38.51	20.60
T_9-Complete weed free	0	0	0	0	0	0
T_{10}-Weedy check	49.86	23.65	26.49	49.04	26.64	24.32
T_{11}-2 HW	45.79	26.64	27.57	43.01	30.41	26.58
T_{12}-Chl+HW	50.0	0	25.0	32.54	42.30	25.16

* Worked out mean values, data not statistically analysed

Table 28

Summed dominance ratio of grasses, sedges and broad leaved weeds at 60 DAT and at harvest

Treatments	60 DAT			Harvest		
	Grasses	Sedges	BLW	Grasses	Sedges	BLW
T_1-$SP_1S_0N_p$	36.99	29.59	33.26	42.59	25.23	32.18
T_2-$SP_1S_oN_m$	53.79	31.92	32.84	40.05	34.17	25.79
T_3-$SP_1S_1N_p$	35.93	32.68	31.38	44.91	20.14	34.96
T_4-$SP_1S_1N_m$	36.41	32.69	30.90	48.26	17.20	34.54
T_5-$SP_2S_oN_p$	44.58	27.92	27.50	44.44	23.33	32.23
T_6-$SP_2S_oN_m$	37.40	35.95	26.65	42.58	23.61	33.81
T_7-$SP_2S_1N_p$	35.27	40.06	24.67	35.84	19.45	44.71
T_8-$SP_2S_1N_m$	26.29	42.96	30.75	38.75	20.0	41.25
T_9-Complete weed free	0	0	0	0	0	0
T_{10}-Weedy check	56.02	24.21	19.77	58.69	19.83	21.48
T_{11}-2 HW	38.18	30.51	31.30	39.36	25.93	34.71
T_{12}-Chl+HW	41.44	32.99	25.57	39.59	39.59	20.82

* Worked out mean values, data not statistically analysed

Table 29

Importance value of grasses, sedges and broad leaved weeds at 20 and 40 DAT.

Treatments	20 DAT			40 DAT		
	Grass	Sedge	BLW	Grass	Sedge	BLW
T_1-$SP_1S_0N_p$	96.03	0	3.97	58.29	23.81	17.90
T_2-$SP_1S_oN_m$	86.27	12.41	1.46	62.84	22.54	14.61
T_3-$SP_1S_1N_p$	98.69	0.55	0.75	46.06	42.96	11.53
T_4-$SP_1S_1N_m$	77.85	9.04	13.11	47.34	35.34	17.31
T_5-$SP_2S_oN_p$	95.79	3.06	1.05	43.66	55.20	1.14
T_6-$SP_2S_oN_m$	95.44	3.83	0.72	45.32	54.68	0
T_7-$SP_2S_1N_p$	91.33	6.74	0	78.53	21.47	0
T_8-$SP_2S_1N_m$	100	0	0	45.22	51.85	2.92
T_9-Complete weed free	0	0	0	0	0	0
T_{10}-Weedy check	79.90	13.36	6.73	76.06	19.88	4.05
T_{11}-2 HW	80.95	11.68	7.36	42.12	48.43	9.46
T_{12}-Chl+HW	98.45	1.09	0.46	38.55	40.48	20.97

* Worked out mean values, data not statistically analysed

Table 30

Importance value of grasses, sedges and broad leaved weeds at 60 DAT and at harvest.

Treatments	60 DAT			Harvest		
	Grass	Sedge	BLW	Grass	Sedge	BLW
T_1-$SP_1S_0N_p$	50.82	24.40	24.78	39.01	31.02	29.96
T_2-$SP_1S_oN_m$	51.47	21.06	27.47	37.18	30.17	32.65
T_3-$SP_1S_1N_p$	38.81	32.60	28.63	30.02	35.89	34.09
T_4-$SP_1S_1N_m$	42.03	30.28	27.69	30.76	35.11	34.13
T_5-$SP_2S_oN_p$	42.90	35.31	21.79	32.09	42.31	25.59
T_6-$SP_2S_oN_m$	33.04	44.51	22.45	26.03	45.55	28.41
T_7-$SP_2S_1N_p$	50.30	23.43	26.28	36.38	30.58	33.03
T_8-$SP_2S_1N_m$	37.96	27.63	34.41	29.14	39.25	31.62
T_9-Complete weed free	0	0	0	0	0	0
T_{10}-Weedy check	74.20	19.8	6.0	70.22	22.05	7.73
T_{11}-2 HW	48.48	37.49	14.03	46.66	30.84	22.50
T_{12}-Chl+HW	47.48	37.77	14.75	39.51	32.83	27.66

* Worked out mean values, data not statistically analysed

weedy check registered the highest IV of grasses and $T_6 (SP_2 S_0 N_m)$ for sedges. However, the IV of BLW varied and T_8 had the highest (34.41) at 60 DAT and T_3 and T_4 registered the maximum mean value of 34.09 and 34.13 at harvest.

4.2.5. Weed control efficiency

The results are presented in Table 31

Two summer ploughings significantly improved the weed control efficiency (WCE) at all stages of observation, the mean values being 74.48, 79.31, 80.71 and 85.52. The stale seed bed technique increased the WCE at 20 DAT and at harvest (76.02 and 86.26). Basal skipping of nitrogen did not result in any significant effect in WCE.

All the two way interactions were not significant. Among treatments, T_8 recorded the highest weed control efficiency at all stages. It was on par with T_7, T_6, T_5 and T4 at 40 DAT. The treatment combinations except T_3 were on par with T_8 at 60 DAT and the combinations except T_1 and T_2 were on par with T_8 at harvest.

Among controls, the WCE was zero in weedy check and cent percentage in complete weed free (T_9). The herbicide plot recorded significantly higher WCE than hand weeded plot at all observations except at harvest. At harvest both treatments were on par.

Table 31

Main effect of factors SP, S and N and their Interactions on weed control efficiency at different intervals after transplanting

Treatments	Days after transplanting	
	20 DAT	40 DAT
SP_1	61.95	67.04
SP_2	74.48	79.31
CD	11.45*	6.95**
S_o	60.41	69.83
S_1	76.02	76.52
CD	11.45*	Ns
N_p	68.09	71.66
N_m	68.34	74.69
CD	Ns	Ns

Interactions

Treatments	20 DAT		40 DAT	
	SP_1	SP_2	SP_1	SP_2
S_o	58.36	62.47	64.62	75.03
S_1	65.54	86.50	69.45	83.59
Mean	61.95	74.48	67.04	79.31
CD	Ns		Ns	
N_p	64.28	71.89	66.15	77.17
N_m	59.61	77.08	67.93	81.45
Mean	61.95	74.48	67.04	79.31
CD	Ns		Ns	
	S_0	S_1	S_o	S_1
N_p	58.15	78.02	67.99	75.33
N_m	62.68	74.01	71.66	77.72
Mean	60.41	76.02	69.83	76.52
CD	Ns		Ns	

Ns -- Not significant

* -- Significant at 0.05% level

** -- Significant at 0.1% level

(cont...)

Table 31 (contd.)
Main effect of factors SP, S and N and their Interactions on weed control efficiency at different intervals after transplanting

Treatments	60 DAT	Harvest
SP_1	68.76	79.26
SP_2	80.71	85.52
CD	10.24*	5.66*
S_o	75.16	78.52
S_1	74.31	86.26
CD	Ns	5.66*
N_p	72.29	82.23
N_m	77.18	82.54
CD	Ns	Ns

Interactions

Treatments	60 DAT		Harvest	
	SP_1	SP_2	SP_1	SP_2
S_o	73.05	77.28	74.94	82.09
S_1	64.48	84.14	83.57	88.95
Mean	68.76	80.71	79.26	85.52
CD	Ns		Ns	
N_p	67.92	76.67	80.70	83.77
N_m	69.61	84.76	77.81	87.27
Mean	68.76	80.71	79.26	85.52
CD	Ns		Ns	
	S_o	S_1	S_o	S_1
N_p	71.66	72.93	77.60	86.87
N_m	78.67	75.70	79.43	85.66
Mean	75.16	74.31	78.52	86.26
CD	Ns		Ns	

(contd...)

Table 31 (contd.)

Interaction effect of factors SP, S and N and controls on weed control efficiency and weed index at different intervals after transplanting

Treatments	Days after transplanting			Harvest	Weed index
	20	40	60		
T_1-$SP_1S_0N_p$	57.91	64.31	71.46	75.34	12.42
T_2-$SP_1S_0N_m$	58.81	64.93	74.63	74.55	15.78
T_3-$SP_1S_1N_p$	70.66	67.98	64.37	86.06	10.24
T_4-$SP_1S_1N_m$	60.41	70.92	64.59	81.08	9.07
T_5-$SP_2S_0N_p$	58.39	71.67	71.85	79.86	10.95
T_6-$SP_2S_0N_m$	66.54	78.39	82.71	84.31	9.04
T_7-$SP_2S_1N_p$	85.38	82.68	81.48	87.68	5.92
T_8-$SP_2S_1N_m$	87.61	84.51	86.80	90.23	5.82
T_9-Complete weed free	100	100	100	100	0
T_{10}-Weedy check	0	0	0	0	44.92
T_{11}-2 HW	17.61	44.47	57.38	79.46	11.77
T_{12}-Chl+HW	78.40	77.72	78.84	86.79	14.78
CD	22.91	13.89	20.47	11.32	7.95

4.2.6. Weed Index (WI)

The results are presented in Tables 31 and 32

Summer ploughing had no significant influence on weed index. Stale seed bed technique significantly lowered weed index (7.76) over no stale seed bed practice (12.05). Modification in nitrogen application had no influence on weed index.

All the two way combinations were not significant. Among treatment combinations, T_8 recorded the lowest weed index (5.82) which was on par with all treatment combinations except T_2.

Among controls, the highest weed index was observed in weedy check and the index was zero in complete weed free treatment. T_{11} and T_{12} were on par.

4.3.. Nutrient up take studies

4.3.1. Nutrient uptake by rice

The nutrient uptake by rice estimated at 20, 40 and 60 DAT and at harvest are presented in Tables 33, 34 and 35.

4.3.1.1. Nitrogen uptake by rice

The results are presented in Table 33

Two summer ploughings significantly increased the nitrogen uptake by rice at all observations except at 60 DAT when compared to single

Table 32

Main effect of factors SP, S and N and their Interactions on weed index at different intervals after transplanting

SP_1	11.88
SP_2	7.93
CD	Ns
S_o	12.05
S_1	7.76
CD	3.98*
N_p	9.88
N_m	9.93
CD	Ns

Interactions

Treatments	SP_1	SP_2
S_o	14.10	10.00
S_1	9.66	5.87
Mean	11.66	7.93
CD	Ns	
N_p	11.33	8.44
N_m	12.43	7.43
Mean	11.88	7.93
CD	Ns	
	S_o	S_1
N_p	11.69	8.08
N_m	12.41	7.44
Mean	12.05	7.76
CD	Ns	

Table 33

Main effect of factors SP, S and N and their interactions on nitrogen uptake of rice (kg ha^{-1}) at different intervals after transplanting

Treatments	20 DAT	40 DAT
SP_1	9.22	44.09
SP_2	11.27	51.75
CD	1.08**	3.62*
S_o	9.35	46.36
S_1	11.15	49.47
CD	1.08**	Ns
N_p	10.40	48.67
N_m	10.10	47.17
CD	Ns	Ns

Interactions

Treatments	20 DAT		40 DAT	
	SP_1	SP_2	SP_1	SP_2
S_o	8.38	10.32	42.06	50.66
S_2	10.07	12.23	46.11	52.84
Mean	9.22	11.72	44.09	51.75
CD	Ns		Ns	
N_p	9.33	11.47	45.57	51.77
N_m	9.12	11.08	42.61	51.73
Mean	9.22	11.27	44.09	51.75
CD	Ns		Ns	
	S_o	S_1	S_o	S_1
N_p	9.33	11.47	44.87	52.47
N_m	9.12	11.08	47.86	46.48
Mean	9.35	11.15	46.36	49.47
CD	Ns		5.12*	

Ns -- Not significant
* -- Significant at 0.05% level
** -- Significant at 0.1% level

(contd...)

Table 33 (contd.)

Main effect of factors SP, S and N and their interactions on nitrogen uptake of rice (kg ha^{-1}) at different intervals after transplanting

Treatments	60 DAT	Harvest
SP_1	108.65	120.79
SP_2	110.18	129.67
CD	Ns	5.29**
S_o	104.75	121.39
S_1	114.07	129.06
CD	5.77**	5.29**
N_p	109.58	125.61
N_m	109.24	124.85
CD	Ns	Ns

Interactions

Treatments	60 DAT		Harvest	
	SP_1	SP_2	SP_1	SP_2
S_o	103.77	105.73	116.76	126.03
S_1	113.52	114.62	124.82	133.30
Mean	108.65	110.18	120.79	129.67
CD	Ns		Ns	
N_p	112.45	106.71	122.23	128.98
N_m	104.84	113.64	119.35	130.35
Mean	108.65	110.18	120.79	129.67
CD	6.82*		Ns	
	S_o	S_1	S_o	S_1
N_p	105.26	113.90	121.77	129.44
N_m	104.24	114.25	121.01	128.68
Mean	104.75	114.07	121.39	129.06
CD	Ns		Ns	

(contd...)

Table 33 (contd.)

Interaction effect of factors SP, S, and N and controls on nitrogen uptake of rice (kg ha^{-1}) at different intervals after transplanting

Treatments	Days after transplanting			Harvest
	20	40	60	
T_1-$SP_1S_0N_p$	9.07	40.88	107.88	119.53
T_2-$SP_1S_oN_m$	7.68	43.25	99.65	113.98
T_3-$SP_1S_1N_p$	9.59	50.25	117.01	124.92
T_4-$SP_1S_1N_m$	10.55	41.97	110.04	124.72
T_5-$SP_2S_oN_p$	10.65	48.86	102.64	124.01
T_6-$SP_2S_oN_m$	9.99	52.47	108.83	128.05
T_7-$SP_2S_1N_p$	12.28	54.68	110.78	133.95
T_8-$SP_2S_1N_m$	12.17	50.99	118.46	132.65
T_9-Complete weed free	13.20	60.04	125.91	144.37
T_{10}-Weedy check	6.18	22.59	53.83	82.97
T_{11}-2 HW	9.05	40.70	121.61	126.25
T_{12}-Chl+HW	9.08	40.05	111.55	119.09
CD	2.17	7.25	11.54	10.58

summer ploughing. Stale seed bed technique enhanced the uptake of nitrogen (11.15, 49.47, 114.07 and 129.06 kg ha^{-1}) at all stages though the increase was not *significant* at 40 DAT. Basal skipping of nitrogen had no influence on the nitrogen uptake by rice.

Among the two way interactions, only S x N interaction at 40 DAT and SP x N interaction at 60 DAT were found significant. At 40 DAT S_1N_p registered the highest nitrogen uptake (52.47 kg ha^{-1}) which was on par with S_oN_m (47.86 kg ha^{-1}). At 60 DAT SP_2N_m (113.64 kg ha^{-1}) was found superior and was on par with SP_1N_p (112.45 kg ha^{-1}).

Among treatment combinations, T_7 (12.28 kg ha^{-1}) recorded the highest nitrogen uptake which was on par with T_8 (12.17) at 20 DAT. At 40 DAT T_7 ($SP_2S_1N_p$) registered the highest nitrogen uptake of 54.68 kg ha^{-1} and was on par with T_8, T_3, T_5 and T_6. At 60 DAT $SP_2S_1N_m$ (T_8) recorded the highest nitrogen uptake of 118.46 kg ha^{-1} which was on par with T_7, T_6, T_5, T_4, T_3 and T_1. Though T_7 registered the highest uptake value of 133.95 kg ha^{-1} at harvest it was on par with all other combination except T_1 (119.53) and T_2 (113.98 kg ha^{-1}).

While comparing controls, complete weed free plot (T_9) recorded the highest nitrogen uptake of 13.20, 60.04, 125.91 and 144.37 kg ha^{-1} at 20, 40 and 60 DAT and at harvest. Two hand weeded plot (T_{12}) and herbicide + HW plot (T_{11}) were observed to be on par at all stages of observations. The lowest nitrogen uptake was noticed in weedy check.

4.3.1.2. Phosphorus uptake by rice

The results are presented in table 34

Two summer ploughings significantly increased phosphorus uptake at all stages of observations. The stale seed bed technique significantly increased phosphorus uptake at 20 DAT (5.46) and at 60 DAT (57.67) compared to the P uptake values of (4.41 and 52.33 kg ha^{-1}) in plots where no stale seed practice was followed. Delaying the basal application of nitrogen had no significance on phosphorus uptake.

Among the two way interactions, only SP x N at 60 DAT significantly influenced phosphorus uptake. SP_2N_m recorded the highest phosphorus uptake of 57.92 kg ha^{-1} which was on par with $SP_2 N_p$ (54.98 kg ha^{-1}) and $SP_1 N_p$ (54.95 kg ha^{-1}).

Among treatment combinations, T_8 recorded the highest phosphorus uptake (6.21 kg ha^{-1}) at 20 DAT and was on par with T_7 (6.12 kg ha^{-1}). The remaining combinations except T_2 were on par. At 40 DAT, T_7 recorded the highest uptake (21.67 kg ha^{-1}) which was on par with T8, T6, T5 and T_3.

At 60 DAT, T_8 registered the highest P uptake of 61.01 kg ha^{-1} and was on par with T_7 (57.27 kg ha^{-1}) and T_3 (56.47 kg ha^{-1}). The highest P uptake (69.01 kg ha^{-1}) was recorded by T_7 at harvest and was observed to be on par with T_5, T_6 and T_7.

Table 34

Main effect of factors SP, S and N and their Interactions on phosphorous uptake of rice (kg ha^{-1}) at different intervals after transplanting

Treatments	20 DAT	40 DAT
SP_1	4.41	17.51
SP_2	5.46	20.68
CD	0.52**	1.43**
S_o	4.41	18.56
S_1	5.46	19.63
CD	0.52**	Ns
N_p	4.92	19.38
N_m	4.95	18.81
CD	Ns	Ns

Interactions

Treatments	20 DAT		40 DAT	
	SP_1	SP_2	SP_1	SP_2
S_o	4.08	4.75	16.83	20.29
S_1	4.75	6.16	18.18	21.07
Mean	4.41	5.46	17.51	20.68
CD	Ns		Ns	
N_p	4.39	5.44	18.02	20.74
N_m	4.44	5.47	16.99	20.62
Mean	4.41	5.46	17.51	20.68
CD	Ns		Ns	
	S_o	S_1	S_o	S_1
N_p	4.52	5.31	18.31	20.46
N_m	4.30	5.61	18.82	18.80
Mean	4.41	5.46	18.56	19.63
CD	Ns		Ns	

Ns -- Not significant
* -- Significant at 0.05% level
** -- Significant at 0.1% level

(contd...)

Table 34 (contd.)

Main effect of factors SP, S and N and their Interactions on phosphorous uptake of rice (kg ha^{-1}) at different intervals after transplanting

Treatments	60 DAT	Harvest
SP_1	53.54	62.23
SP_2	56.45	66.92
CD	2.43*	2.72*
S_o	52.33	63.50
S_1	57.67	65.65
CD	2.43**	Ns
N_p	54.96	65.06
N_m	55.03	64.09
CD	Ns	Ns

Interactions

Treatments	60 DAT		Harvest	
	SP_1	SP_2	SP_1	SP_2
S_o	50.89	53.76	61.43	65.57
S_1	56.19	59.14	63.03	68.27
Mean	52.54	56.45	62.23	66.92
CD	Ns		Ns	
N_p	54.95	54.98	63.38	66.74
N_m	52.14	57.92	61.03	67.09
Mean	53.54	56.45	62.23	66.92
CD	3.43*		Ns	
	S_o	S_1	S_o	S_1
N_p	53.06	56.87	64.01	66.11
N_m	51.59	53.46	62.99	65.18
Mean	52.33	57.67	63.50	65.65
CD	Ns		Ns	

(contd...)

Table 34 (contd.)

Interaction effect of factors SP, S, and N and controls on phosphorous uptake of rice (kg ha^{-1}) at different intervals after transplanting

Treatments	Days after transplanting			Harvest
	20	40	60	
T_1-$SP_1S_0N_p$	4.28	16.80	53.43	63.54
T_2-$SP_1S_oN_m$	3.87	16.87	48.36	59.32
T_3-$SP_1S_1N_p$	4.49	19.25	56.47	63.21
T_4-$SP_1S_1N_m$	5.01	17.12	55.92	62.84
T_5-$SP_2S_oN_p$	4.76	19.81	52.69	64.47
T_6-$SP_2S_oN_m$	4.73	20.76	54.83	66.66
T_7-$SP_2S_1N_p$	6.12	21.67	57.27	69.01
T_8-$SP_2S_1N_m$	6.21	20.47	61.01	67.52
T_9-Complete weed free	6.96	25.61	66.87	71.46
T_{10}-Weedy check	3.33	9.19	26.71	42.98
T_{11}-2 HW	4.01	17.26	50.02	65.84
T_{12}-Chl+HW	4.63	16.26	51.49	58.74
CD	1.03	2.86	4.85	5.43

Table 35

Mean effect of factors SP, S and N and their Interactions on potassium uptake of rice (kg ha^{-1}) at different intervals after transplanting

Treatments	20 DAT	40 DAT
SP_1	12.38	49.35
SP_2	14.19	56.57
CD	1.43**	3.86**
S_o	12.32	51.73
S_1	14.97	54.19
CD	1.43**	Ns
N_p	13.22	56.42
N_m	14.07	52.50
CD	Ns	Ns

Interactions

Treatments	20 DAT		40 DAT	
	SP_1	SP_2	SP_1	SP_2
S_o	11.07	13.57	48.03	55.46
S_1	12.79	15.34	50.68	57.71
Mean	12.38	14.91	49.35	56.57
CD	Ns		Ns	
N_p	11.97	14.47	50.41	56.43
N_m	12.79	15.34	48.29	56.70
Mean	12.38	14.91	49.35	56.57
CD	Ns		Ns	
	S_o	S_1	S_o	S_1
N_p	12.60	13.85	50.18	56.66
N_m	12.04	16.09	53.27	51.72
Mean	12.32	14.97	51.73	54.19
CD	Ns		5.46*	

Ns -- Not significant
* -- Significant at 0.05% level
** -- Significant at 0.1% level

(contd...)

Table 35 (contd.)

Interaction effect of factors SP, S and N and controls on potassium uptake of rice (kg ha^{-1}) at different intervals after transplanting

Treatments	Days after transplanting			Harvest
	20	40	60	
T_1-$SP_1S_0N_p$	11.99	46.60	104.17	114.37
T_2-$SP_1S_oN_m$	10.15	49.46	99.42	100.66
T_3-$SP_1S_1N_p$	11.96	54.23	107.37	119.31
T_4-$SP_1S_1N_m$	15.43	47.13	106.31	116.71
T_5-$SP_2S_oN_p$	13.21	53.77	107.71	107.27
T_6-$SP_2S_oN_m$	13.93	57.08	108.11	115.44
T_7-$SP_2S_1N_p$	15.74	59.09	114.90	119.84
T_8-$SP_2S_1N_m$	16.76	56.32	116.47	120.71
T_9-Complete weed free	18.86	66.09	122.42	139.85
T_{10}-Weedy check	8.52	24.23	71.71	63.50
T_{11}-2 HW	11.93	47.33	102.97	104.19
T_{12}-Chl+HW	12.02	44.25	99.77	106.53
CD	2.85	7.73	8.49	10.93

Comparing the controls, complete weed free plot (T_9) recorded the highest K uptake of 18.66, 66.09, 122.42 and 139.85 kg ha^{-1} at 20, 40 and 60 DAT and at harvest respectively. The T_{11} and T_{12} were on par and followed T_9 at all stages of observations.

4.3.2. Nutrient uptake by weeds

The weed samples collected at 20, 40 and 60 DAT and at harvest were analysed for nitrogen, phosphorus and potassium.

4.3.2.1. Nitrogen uptake by weeds

The results are presented in table 36

Two summer ploughings significantly reduced the nitrogen uptake by weeds at all stages of observations except at 20 DAT. Adopting stale seed bed technique also reduced nitrogen uptake by weeds with mean values of 0.44, 1.05 and 1.27 kg ha^{-1} at 40 and 60 DAT and at harvest respectively. At all stages of observations, basal skipping of nitrogen did not influence the nitrogen uptake.

Among the two way interactions, the SP x N was significant at 40 DAT and at harvest stage. At 40 DAT SP_2 N_m registered the lowest N uptake of 0.28 kg ha^{-1}. At harvest SP_2N_m recorded the lowest nitrogen uptake (1.09) which was on par with SP_2N_p (1.23).

Among treatment combinations, T_4 and T_8 recorded the lowest nitrogen uptake by weeds at 20 and 40 DAT. At 60 DAT and

Table 36

Main effect of factors SP, S and N and their Interactions on nitrogen uptake of weeds (kg ha^{-1}) at different intervals after transplanting

Treatments	20 DAT	40 DAT
SP_1	0.66	0.71
SP_2	0.70	0.38
CD	Ns	0.12**
S_o	1.0	0.65
S_1	0.36	0.44
CD	Ns	0.12**
N_p	0.73	0.58
N_m	0.62	0.51
CD	Ns	Ns

Interactions

Treatments	20 DAT		40 DAT	
	SP_1	SP_2	SP_1	SP_2
S_o	0.88	1.12	0.81	0.50
S_1	0.44	0.28	0.61	0.26
Mean	0.66	0.70	0.71	0.38
CD	Ns		Ns	
N_p	0.72	0.75	0.68	0.48
N_m	0.60	0.65	0.74	0.28
Mean	0.66	0.70	0.71	0.38
CD	Ns		0.16*	
	S_o	S_1	S_o	S_1
N_p	1.02	0.45	0.67	0.50
N_m	0.97	0.27	0.64	0.37
Mean	1.0	0.36	0.65	0.44
CD	Ns		Ns	

Ns -- Not significant
* -- Significant at 0.05% level
** -- Significant at 0.1% level

(contd...)

Table 36 (contd.)

Main effect of factors SP, S and N and their Interactions on nitrogen uptake of weeds (kg ha^{-1}) at different intervals after transplanting

Treatments	60 DAT	Harvest
SP_1	1.43	1.74
SP_2	0.96	1.16
CD	0.21**	0.2**
S_o	1.33	1.63
S_1	1.05	1.27
CD	0.21*	0.2**
N_p	1.18	1.4
N_m	1.21	1.5
CD	Ns	Ns

Interactions

Treatments	60 DAT		Harvest	
	SP_1	SP_2	SP_1	SP_2
S_o	1.58	1.08	1.99	1.26
S_1	1.27	0.83	1.48	1.06
Mean	1.43	0.96	1.74	1.16
CD	Ns		Ns	
N_p	1.32	1.04	1.56	1.23
N_m	1.54	0.88	1.91	1.09
Mean	1.43	0.96	1.74	1.16
CD	Ns		0.29*	
	S_o	S_1	S_o	S_1
N_p	1.22	1.13	1.49	1.30
N_m	1.44	0.97	1.76	1.24
Mean	1.33	1.05	1.63	1.27
CD	Ns		Ns	

(contd...)

Table 36 (contd.)

Interaction of factors SP, S and N and controls on nitrogen uptake of weeds (kg ha^{-1}) at different intervals after transplanting

Treatments	Days after transplanting			Harvest
	20	40	60	
T_1-$SP_1S_0N_p$	0.89	0.75	1.37	1.67
T_2-$SP_1S_oN_m$	0.87	0.87	1.80	2.31
T_3-$SP_1S_1N_p$	0.55	0.62	1.26	1.46
T_4-$SP_1S_1N_m$	0.33	0.61	1.28	1.51
T_5-$SP_2S_oN_p$	1.15	0.58	1.08	1.32
T_6-$SP_2S_oN_m$	1.08	0.42	1.08	1.21
T_7-$SP_2S_1N_p$	0.34	0.38	0.99	1.15
T_8-$SP_2S_1N_m$	0.22	0.14	0.67	0.98
T_9-Complete weed free	0	0	0	0
T_{10}-Weedy check	7.25	23.38	33.57	33.92
T_{11}-2 HW	6.79	1.3	1.03	1.66
T_{12}-Chl+HW	0.72	0.94	1.09	1.90
CD	0.13	0.23	0.42	0.41

at harvest T_5, T_6, T_7 and T_8 were on par and registered lower nitrogen uptake values.

While comparing controls, weedy check registered the highest nitrogen removal in all stages of observations. 2 HW (T_{11}) was statistically on par with herbicide plot (T_{12}) except at 20 DAT where T_{11} recorded a higher nutrient uptake (6.79 kg ha^{-1}) than T_{12}.

4.3.2.2. Phosphorus uptake by weeds

The results are presented in Table 37

Two summer ploughing and adopting stale seed bed technique significantly reduced the phosphorus uptake by weeds at all stages except at 20 DAT. Skipping basal application of nitrogen did not cause any difference in P uptake.

Among two way combinations SP x N interaction caused variation in P uptake except at 20 DAT. S x N interaction was significant at 60 DAT only. At 40 DAT, $SP_2 N_m$ recorded the lowest P uptake of 0.11 kg ha^{-1}. At 60 DAT SP_2N_m registered the lowest P uptake (0.23kg ha^{-1}) which was on par with $SP_2 N_p$. The combinations of SP_1 registered higher P uptake. Comparing S x N interaction at 60 DAT, $S_1 N_m$ registered lower P uptake of 0.26 kg ha^{-1} which was on par with $S_1 N_p$ (0.31 kg ha^{-1}) at a harvest SP_2N_m and $SP_2 N_p$ combinations registered the lowest P uptake values of 0.29 and 0.35 kg ha^{-1} respectively.

Table 37

Main effect of factors SP, S and N and their Interactions on phosphorus uptake of weeds (kg ha^{-1}) at different intervals after transplanting

Treatments	20 DAT	40 DAT
SP_1	0.32	0.32
SP_2	0.30	0.15
CD	Ns	0.05**
S_o	0.45	0.28
S_1	0.16	0.18
CD	Ns	0.05**
N_p	0.33	0.24
N_m	0.28	0.22
CD	Ns	Ns

Interactions

Treatments	20 DAT		40 DAT	
	SP_1	SP_2	SP_1	SP_2
S_o	0.43	0.47	0.37	0.20
S_1	0.20	0.12	0.26	0.10
Mean	0.32	0.30	0.32	0.15
CD	Ns		Ns	
N_p	0.34	0.31	0.31	0.19
N_m	0.29	0.28	0.33	0.11
Mean	0.32	0.30	0.32	0.15
CD	Ns		0.06*	
	S_o	S_1	S_o	S_1
N_p	0.46	0.20	0.29	0.21
N_m	0.45	0.12	0.28	0.16
Mean	0.45	0.16	0.28	0.18
CD	Ns		Ns	

Ns -- Not significant
* -- Significant at 0.05% level
** -- Significant at 0.1% level

(contd...)

Table 37 (contd.)

Main effect of factors SP, S and N and their Interactions on phosphorus uptake of weeds (kg ha^{-1}) at different intervals after transplanting

Treatments	60 DAT	Harvest
SP_1	0.41	0.52
SP_2	0.27	0.32
CD	0.06**	0.06**
S_o	0.40	0.48
S_1	0.28	0.36
CD	0.06**	0.06**
N_p	0.34	0.41
N_m	0.34	0.43
CD	Ns	Ns

Interactions

Treatments	60 DAT		Harvest	
	SP_1	SP_2	SP_1	SP_2
S_o	0.47	0.33	0.60	0.36
S_1	0.35	0.22	0.44	0.28
Mean	0.41	0.27	0.52	0.32
CD	Ns		Ns	
N_p	0.36	0.31	0.47	0.35
N_m	0.45	0.23	0.57	0.29
Mean	0.41	0.27	0.52	0.32
CD	0.08**		0.09*	
	S_o	S_1	S_o	S_1
N_p	0.37	0.31	0.44	0.38
N_m	0.43	0.26	0.52	0.34
Mean	0.40	0.28	0.48	0.36
CD	0.08*		Ns	

(contd...)

Table 37 (contd.)

Interaction of factors SP, S and N and controls on phosphorous uptake of weeds (kg ha^{-1}) at different intervals after transplanting

Treatments	Days after transplanting			Harvest
	20	40	60	
T_1-$SP_1S_0N_p$	0.43	0.34	0.37	0.51
T_2-$SP_1S_oN_m$	0.43	0.40	0.56	0.69
T_3-$SP_1S_1N_p$	0.25	0.27	0.35	0.43
T_4-$SP_1S_1N_m$	0.15	0.25	0.35	0.44
T_5-$SP_2S_oN_p$	0.48	0.24	0.36	0.37
T_6-$SP_2S_oN_m$	0.46	0.16	0.30	0.34
T_7-$SP_2S_1N_p$	0.14	0.14	0.27	0.33
T_8-$SP_2S_1N_m$	0.09	0.07	0.16	0.24
T_9-Complete weed free	0	0	0	0
T_{10}-Weedy check	3.75	10.86	8.54	9.48
T_{11}-2 HW	3.5	0.66	0.31	0.54
T_{12}-Chl+HW	0.36	0.33	0.35	0.63
CD	0.68	0.91	0.11	0.12

At 20 and 40 DAT, T_8 recorded the lowest P uptake by weeds, which were on par with other treatment combinations. At 60 DAT T_8 recorded the lowest P uptake of 0.16 kg ha^{-1} which was on par with T_7 (0.27 kg ha^{-1}). The remaining combinations except T_2 were on par. At harvest also T_8 recorded the lowest uptake (0.24 kg ha^{-1}) and was on par with T_7 and T_6. T_2 (SP_1 $S_o N_m$) registered the highest removal of 0.56 kg ha^{-1} and 0.69 kg ha^{-1} phosphorus at 60 DAT and at harvest respectively.

Among controls, weedy cheek (T_{10}) recorded the highest P uptake at all stages. 2 HW (T_{11}) and chemical + HW plot (T_{12}) were on par at all stages except at 20 DAT, where T_{11} registered higher P uptake by weeds than T_{12}.

4.3.2.3. Potassium uptake by weeds

The results are presented in table 38

Two summer ploughings and stale seed bed practice significantly reduced potassium uptake at all stages of observation except at 20 DAT. The basal skipping of nitrogen had no influence on K uptake by weeds.

SP x N interaction was significant at all stages except at 20 DAT. At 40 DAT SP_2 N_m recorded the lowest K uptake (0.40 kg ha^{-1}) and the highest was by SP_1N_m (1.05 kg ha^{-1}) which was superior to others. At 60 DAT also SP_2N_m removed the lowest K uptake (0.63 kg ha^{-1}) which was on par with SP_2N_p (0.80 kg ha^{-1}). At harvest, SP_2N_m recorded the lowest K uptake of 0.76 kg ha^{-1} and was on par with SP_2N_p. In S x N interactions,

Table 38

Main effect of factors SP, S and N and their Interactions on potassium uptake of weeds (kg ha^{-1}) at different intervals after transplanting

Treatments	20 DAT	40 DAT
SP_1	0.90	0.96
SP_2	0.96	0.53
CD	Ns	0.14**
S_o	1.38	0.91
S_1	0.49	0.57
CD	0.74*	0.14**
N_p	0.99	0.76
N_m	0.87	0.72
CD	Ns	Ns

Interactions

Treatments	20 DAT		40 DAT	
	SP_1	SP_2	SP_1	SP_2
S_o	1.21	1.54	1.15	0.67
S_1	0.60	0.38	0.77	0.38
Mean	0.90	0.96	0.96	0.53
CD	Ns		Ns	
N_p	0.96	1.02	0.87	0.65
N_m	0.84	0.90	1.05	0.40
Mean	0.90	0.96	0.96	0.53
CD	Ns		0.20**	
	S_o	S_1	S_o	S_1
N_p	1.39	0.60	0.90	0.63
N_m	1.36	0.38	0.92	0.52
Mean	1.38	0.49	0.91	0.57
CD	Ns		Ns	

Ns -- Not significant
* -- Significant at 0.05% level
** -- Significant at 0.1% level

(contd....)

Table 38 (contd.)

Main effect of factors SP, S and N and their Interactions on potassium uptake of weeds (kg ha^{-1}) at different intervals after transplanting

Treatments	60 DAT	Harvest
SP_1	1.10	1.13
SP_2	0.72	0.80
CD	0.16**	0.14**
S_o	1.02	1.10
S_1	0.79	0.84
CD	0.16**	0.14**
N_p	0.90	0.93
N_m	0.92	1.01
CD	Ns	Ns

Interaction

Treatments	60 DAT		Harvest	
	SP_1	SP_2	SP_1	SP_2
S_o	1.22	0.82	1.31	0.88
S_1	0.97	0.61	0.95	0.72
Mean	1.10	0.72	1.13	0.80
CD	Ns		Ns	
N_p	0.99	0.80	1.01	0.84
N_m	1.21	0.63	1.25	0.76
Mean	1.10	0.72	1.13	0.80
CD	0.23*		0.20*	
	S_o	S_1	S_o	S_1
N_p	0.92	0.87	1.00	0.86
N_m	1.12	0.72	1.20	0.82
Mean	1.02	0.79	1.10	0.84
CD	0.23*		Ns	

(contd...)

Table 38 (contd.)

Interaction of factors SP, S and N and controls on potassium uptake of weeds (kg ha^{-1}) at different intervals after transplanting

Treatments	Days after transplanting			Harvest
	20	40	60	
T_1-$SP_1S_0N_p$	1.19	1.01	1.01	1.09
T_2-$SP_1S_oN_m$	1.22	1.28	1.44	1.54
T_3-$SP_1S_1N_p$	0.74	0.72	0.97	0.93
T_4-$SP_1S_1N_m$	0.45	0.81	0.98	0.97
T_5-$SP_2S_oN_p$	1.58	0.78	0.84	0.91
T_6-$SP_2S_oN_m$	1.50	0.57	0.80	0.86
T_7-$SP_2S_1N_p$	0.46	0.53	0.76	0.78
T_8-$SP_2S_1N_m$	0.30	0.23	0.46	0.66
T_9-Complete weed free	0	0	0	0
T_{10}-Weedy check	8.13	17.29	31.66	22.94
T_{11}-2 HW	7.87	1.91	0.72	1.61
T_{12}-Chl+HW	1.07	1.36	0.69	1.39
CD	1.48	0.28	0.34	0.28

S_1N_m recorded the lowest K removal of 0.72 kg ha^{-1} at 60 DAT which was on par with S_1N_p and S_0N_p.

Among treatment combinations T_8 recorded the lowest K uptake and were on par with other treatments. At 60 DAT T_6, T_7 and T_8 were on par and at harvest T_3, T_5, T_6 and T_7 were on par with T_8 and recorded the lower K uptake by weeds.

While comparing controls, weedy check removed significantly higher amounts of potassium at all stages. T_{11} and T_{12} were on par at all stages except at 20 DAT when the K uptake by T_{11} (7.87 kg ha^{-1}) was found higher than T_{12} (1.07 kg ha^{-1}).

4.4. Economics of crop production.

The results are presented in Table. 39

4.4.1. Net income

Two summer ploughings and stale seed bed technique increased the net income. However, the increase was not significant. The basal skipping of nitrogen and all the interactions had no significance on net income.

Among combinations, T_7 ($SP_1S_1N_p$) registered the highest net income of Rs.7518.06 ha^{-1} which was on par with other combinations.

Table 39

Main effect of factors SP, S and N and their interactions on net income and benefit cost ratio

Treatments	Net income (Rs ha^{-1})	Benefit cost ratio
SP_1	6944.59	1.29
SP_2	6982.89	1.28
CD	Ns	Ns
S_o	6611.31	1.28
S_1	7316.17	1.30
CD	Ns	Ns
N_p	7059.84	1.29
N_m	6867.64	1.28
CD	Ns	Ns

Interactions

Treatments	Net income (Rs ha^{-1})		Benefit cost ratio	
	SP_1	SP_2	SP_1	SP_2
S_o	6621.42	6601.20	1.28	1.27
S_1	7267.76	7364.58	1.30	1.29
Mean	6944.59	6982.89	1.29	1.28
CD	Ns		Ns	
N_p	7203.78	6915.90	1.30	1.28
N_m	6685.40	7049.88	1.29	1.28
Mean	6944.59	6982.89	1.29	1.28
CD	Ns		Ns	
	S_o	S_1	S_o	S_1
N_p	6792.38	7327.30	1.28	1.30
N_m	6430.24	7305.04	1.27	1.30
Mean	6611.31	7316.17	1.28	1.30
CD	Ns		Ns	

Ns -- Not significant
* -- Significant at 0.05% level
** -- Significant at 0.1% level

(contd...)

Table 39 (contd.)

Interaction of factors SP, S and N and controls on net income and benefit cost ratio

Treatments	Net income (Rs ha^{-1})	Cost benefit ratio
T_1-$SP_1S_0N_p$	7271.03	1.312
T_2-$SP_1S_oN_m$	5971.82	1.254
T_3-$SP_1S_1N_p$	7136.54	1.298
T_4-$SP_1S_1N_m$	7398.98	1.307
T_5-$SP_2S_oN_p$	6313.73	1.257
T_6-$SP_2S_oN_m$	6888.66	1.279
T_7-$SP_2S_1N_p$	7518.06	1.298
T_8-$SP_2S_1N_m$	7211.09	1.285
T_9-Complete weed free	3264.19	1.106
T_{10}-Weedy check	2020.72	1.109
T_{11}-2 HW	5923.97	1.239
T_{12}-Chl+HW	7907.48	1.364
CD	2451.25	0.103

Considering controls, herbicide treated plot (T_{12}) registered the highest net income of Rs.7907.48 ha^{-1}. The lowest net income was recorded by weedy check (Rs.2020.72 ha^{-1}) and was on par with complete weed free.

4.4.2. Benefit cost ratio (BCR)

The summer ploughing, stale seed bed technique and basal skipping of N and their interactions had no significance in increasing the benefit cost ratio.

Among treatment combinations T_1 ($SP_1S_0N_p$) registered the highest BCR however all treatments were statistically on par.

While comparing controls, herbicide treated plot registered highest BCR (1.364) which was on par with T_{11} (2 HW plot). The weedy cheek and complete weed free (T_9) were on par and recorded the lowest BCR.

4.5. Correlation studies

Simple correlations of grain and straw yield with other biometric traits were worked out and presented in Table 40 and 41.

The grain yield and straw yield were positively correlated with plant height, LAI, total dry matter production at harvest, productive tillers, panicle weight and thousand grain weight. The sterility percentage was negatively correlated with correlation values of –0.8754 and -0.8364 for grain and straw yield respectively.

Table 40

Simple correlation studies of growth and yield attributes on grain and straw yield. of rice

Character	Grain yield	Straw yield
Plant height	0.9157**	0.8635**
Leaf area index	0.8439**	0.8925**
Total dry matter at harvest	0.9918**	0.9946**
Productive tillers at harvest	0.8246**	0.7754**
Panicle weight	0.8889**	0.8512**
Thousand grain weight	0.8633**	0.8424**
Sterility percentage	-0.8754**	-0.8364**

Table 41

Simple correlation studies of nutrient uptake of rice and weeds and weed parameters on grain and straw yield of rice

Character	Grain yield	Straw yield
Weed count	-0.9054**	-0.8778**
Weed dry weight	-0.9014**	-0.8466**
Weed uptake-nitrogen	-0.6263**	-0.5968**
Weed uptake-phosphorus	-0.6584**	-0.6263**
Weed uptake-potassium	-0.5866**	-0.5517**
Rice uptake-nitrogen	0.9774**	0.9694**
Rice uptake-phosphorus	0.9692**	0.9710**
Rice uptake-potassium	0.9686**	0.9622**

Ns -- Not significant
* -- Significant at 0.05% level
** -- Significant at 0.1% level

Weed count, weed dry weight and nutrient removal by weeds were negatively correlated with grain and straw yield.

The N, P and K uptake by rice showed significant positive correlation with grain yield, the values being 0.9774, 0.9692 and 0.9686 respectively. The N, P and K uptake by rice also showed positive correlation with straw yield.

DISCUSSION

5. DISCUSSION

An experiment was conducted at the State Seed Farm, Kottarakkara to evolve a package of ecofriendly techniques for economic weed management in transplanted rice. The results of the experiment are discussed here under.

5.1. Observation on crop

5.1.1. Effect of summer plolughing on growth and yield of rice

The practice of summer ploughing was found to enhance the growth characters of rice. Giving two summer ploughings (SP_2) increased the plant height at all stages except at 20 DAT (Table 3) and the increase was in the range of 2.03 to 2.4 cm in two times summer ploughed plot compared to single summer ploughing. The tiller count per hill was also improved by two SP. The same trend was observed in the case of LAI recorded at PI stage. Two SP significantly reduced the total weed count at all observations (Table 13). The low weed count coupled with low weed dry matter production due to two SP provided favourable environment for rice growth resulting in better growth character like plant height, tiller count and LAI. This was further evident from the WCE recorded at different stages in two summer ploughed plots (Table 31).

At the early growth stages i.e., at 20 and 40 DAT adopting two SP significantly increased the WCE, the values being 74.58 and 75.31 which was highly beneficial for the better establishment and growth of rice as evident from plant height, tiller number and LAI. Improvement in plant height by summer ploughing was emphasized in the reports of Ali and Sankaran (1975) and Balasubramanian (1996). Significant influence of weeds in reducing the tiller count of rice was also pointed out by Sukumari (1982) and Bindy (1989). The increase in LAI to the tune of 0.34 to 0.43 with SP was also reported by Balasubramanian (1996).

The dry matter production of rice estimated at different intervals emphasized the favourable influence of two SP in enhancing the plant dry matter production. The high WCE in two SP plots and consequent increase in growth characters (height and tiller count) and photosynthetic area (as evident from the increased LAI) enabled the rice plant to accumulate more dry matter at different stages. The reduction in weed dry matter production and weed nutrient uptake helped to enhance grain and straw yield which in turn resulted in high dry matter production at harvest stage. The result of this experiment is in confirmity with the findings of Chaudhary (1989) and Balasubramanian (1996).

In determining the yield attributes and yield summer ploughing also played a positive role. The increase in the number of productive tillers in two SP plots was 1.25 over single SP whereas, the increase in panicle weight was found to be 0.13 g. The number of SP did not have any significant influence on panicle length, number of grains per panicles and thousand grain weight, though the values are slightly higher in two summer ploughed plot. In case of filled grains an increase by 9.17 was observed in two SP plot while the sterility percentage was decreased by 9.16 per cent.

The favourable effect of SP in reducing the weed population has resulted in the better growth, enhanced photosynthetic rate and this resulted in an increase in the number of productive tillers, panicle weight, filled grain count and decrease in sterility percentage. The reduction in yield attributes of rice by weed competition has already been reported by several workers (Ramamoorthy *et al.* 1974; Sukumari 1982; Bindy, 1989). The favourable influence of SP in enhancing the yield attributes of rice and the reduction in weed population was highlighted by Balasubramanian (1996). The improvement in the yield attribute resulted in consequent yield increase in two SP plots. The grain yield increase was to the tune of 156 kg ha^{-1} in two SP plots over single ploughed plot (Fig. 3). The direct influence of growth characters and yield attributes in deciding the grain yield is further established by the correlation studies (Table 40).

The reduced weed dry matter production and enhanced WCE (Fig. 4) has resulted in poor crop-weed competition and improved the

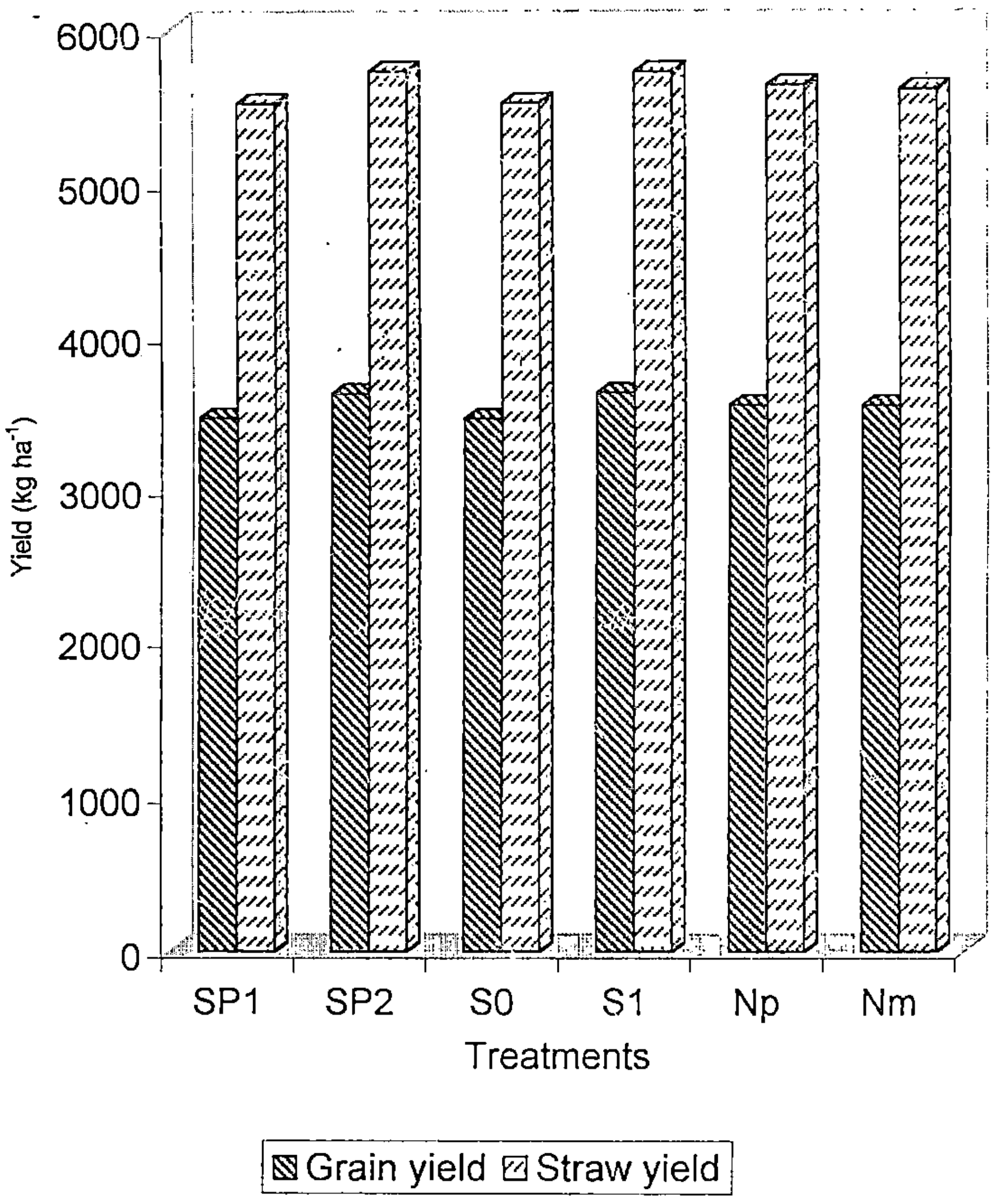

Fig. 3. Effect of summer ploughing, stale seed bed practice and nitrogen application on grain and straw yield of rice

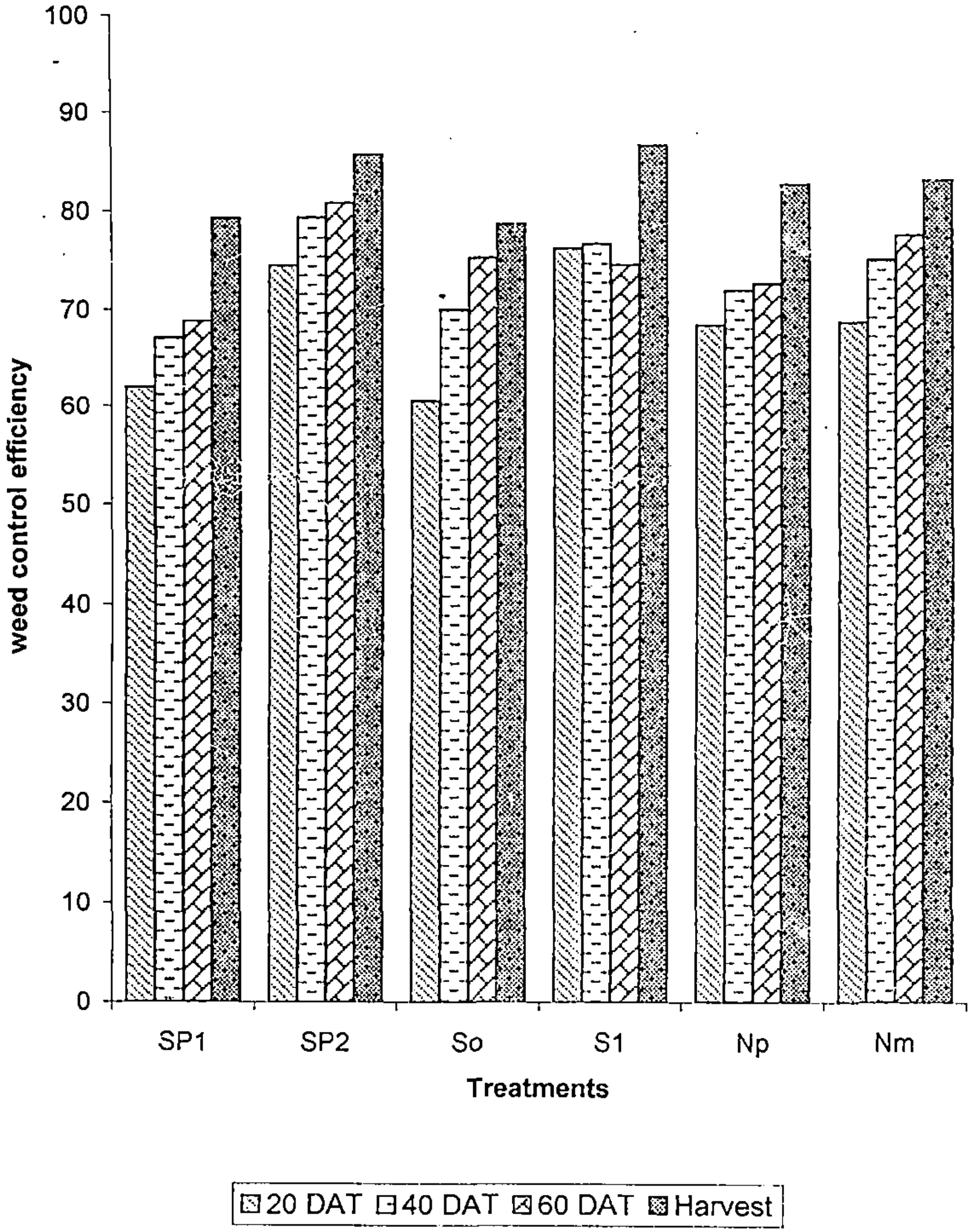

Fig. 4. Effect of summer ploughing, stale seed bed practice and nitrogen application on the weed control efficiency at different intervals after transplanting

growth characters and dry matter production of rice. This in turn enhanced the nutrient uptake by the rice crop in two SP plots (Tables 33, 34 and 35 and Fig. 5) at all stages. The findings are in agreement with the results of Illangovan (1991), Arunachalam *et al.* (1992) and Ganesaraja *et al.* (1992). The non significant effect of SP on straw yield has reflected in the harvest index.

5.1.2. Effect of stale seed bed on growth and yield of rice

The plant height was not significantly influenced by adopting the stale seed bed technique at initial observations. But at 60 DAT and at harvest, the technique of adopting seed bed increased the plant height. The stale seed technique enhanced the tiller count per hill at all stages though significant at 20 and 60 DAT only. The increase were in the tune of 0.15 to 0.71. Leaf area index (LAI) recorded at panicle initiation stage also revealed a significant increase in stale seed bed plot (4.63) compared to no stale seed bed plot (4.36) (Table 5).

The reduction in weed parameters like weed count, weed dry matter and weed nutrient uptake by stale seed bed practice enabled the rice to put forth better growth resulting in higher plant height, tiller count and LAI. Low weed competition, with one hand weeding at 30 DAT resulted in significant variation at 60 DAT. So also, the early weed control by stale seed bed enabled better growth of rice resulting in significant increase in tiller count even at 20 DAT.

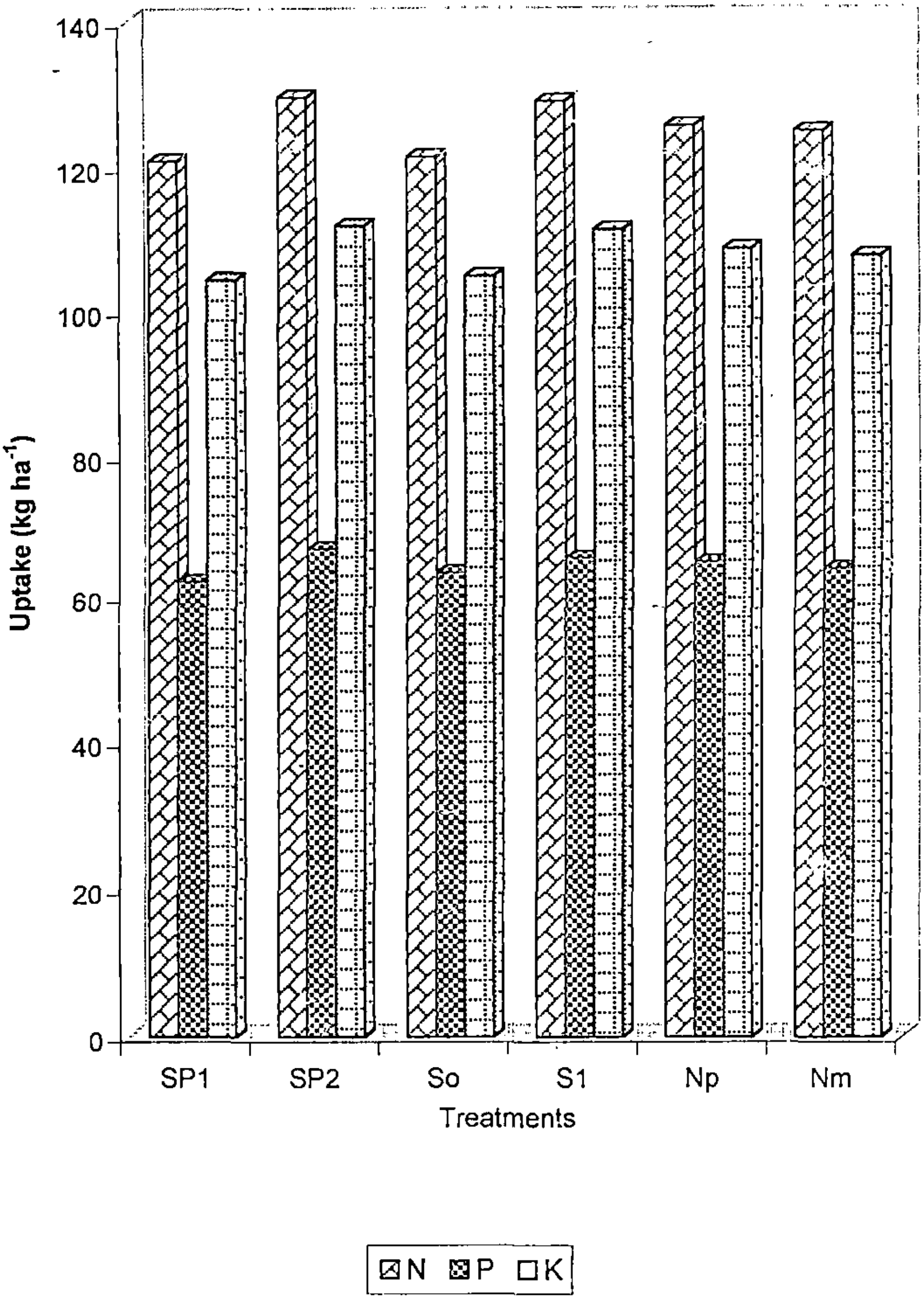

Fig. 5. Effect of summer ploughing, stale seed bed practice and nitrogen application on NPK uptake of rice at harvest

This improvement was further established by WCE values (Table 31) estimated at different intervals. Stale seed bed practice improved the WCE at all stages and was significant at early stages i.e., 20 DAT. The favourable condition at early stages by stale seed bed practice enabled better rice growth. The reduced weed population at early stages resulted in effective in weed control (All *et al.* (1979) and Sumner *et al.* (1981)).

Table 6 indicated that stale seed bed practice increased the DMP at all stages though it was not significant at 40 DAT. The increase of DMP were in the range of 109 to 524 kg ha^{-1}. The better growth character of rice plant as evident from higher plant height, tiller number and LAI in turn contributed to high dry matter production. The nutrient uptake by rice, a product of dry matter production and nutrient content was significantly enhanced by stale seed bed at all stages except at 20 DAT. The effectiveness of stale seed bed practice in weed management (Hosmani and Meti, 1993) reduced the weed count, weed dry matter and nutrient uptake and enhanced the rice crop growth significantly. It was also evident from the weed index values in stale seed bed practice (7.76) over no stale seed bed practice (12.05). The effectiveness of stale seed bed practice with herbicide application in *Glycine max* was reported by Hydrick and Shaw (1994).

The yield attributing characters such as number of productive tillers, number of grains per panicle, filled grains per panicle, length of panicle and sterility percentage were favourably influenced by stale seed bed practices though not significant. The practice also caused increase in panicle weight to the tune of 0.16 g and thousand grain weight by 1.1 g.

The grain yield was significantly increased by adopting stale seed bed technique. The grain yield in stale seed bed practice was increased by 168kg ha^{-1} over no stale seed bed treatment (Fig. 3). The higher grain yield was due to the better growth and yield attributing characters of rice crop. Table 3 to 6 clearly elucidated the improvement in growth characters like plant height, tiller count, LAI and DMP of rice by adopting stale seed bed technique.

The better WCE (Fig. 4) consequent to the treatments increased the dry matter production and NPK uptake of rice (Fig. 5) and this in turn resulted in the better yield. The reduction in total weed count, weed dry matter production, and lower uptake of NPK by weeds favourably influenced the yield attributes and yield. Hosmani and Chittapur (1996) and Krishnarajan and Meyyazhagan (1996) emphasized the advantages of stale seed bed practice for better weed control and yield increase. The present results were in agreement with their findings. The influence of growth parameters and yield attributes in determining rice yield was more evident from the correlation studies (Table 40).

The straw yield though not significant helped to enhance the straw yield by 198 kg ha^{-1} by this method. Stale seed bed method reduced the weed index to 7.76 compared to absence of stale seed bed (12.05). This clearly indicated that competition from weeds could be reduced by adopting stale seed bed practice and thereby increasing the yield.

Parish (1987) described stale seed bed as an effective and useful method to reduce the weed competition in rice crop especially in the early growth stages.

5.1.3. Effect of nitrogen modification on growth and yield of rice

In general, delaying the basal application of nitrogen had no influence on the growth parameters and yield of rice. However, the number of productive tillers was significantly increased by skipping of basal nitrogen application and the increase was 0.55 tillers per hill. Similarly the LAI was improved by skipping basal application of nitrogen (Table 5).

The improvement in these yield determinants could be attributed to the better nitrogen use efficiency by the crop. However, this favourable influence was not reflected in the rice yield as observed by Abdus Sattar and Sakai (1982) and Wagh and Thorat (1987).

5.1.4. Effect of SP x S, SP x N and S x N interactions on growth and yield of rice

Two summer ploughings combined with stale seed bed technique enhanced the plant height in the range of 3.7 to 3.85 cm compared to other SP x S combinations. LAI was also improved by SP_2S_1 combination. Two summer ploughings along with stale seed bed effectively reduced the weed competition as evident from reduced weed count (Table 13) and weed dry matter production (Table 14).

Providing two summer ploughings enhanced the drying and desiccation of weed propagates and this combined with stale seed bed technique before transplanting enabled the germination of majority of viable weed seeds in soil and thus reduced the weed population. Roberts and Potter (1980) reported the advantage of stale seed bed in reducing weed seed bank in top layer. The favourable effect of summer ploughing in reducing the weed population was highlighted by Ali and Sankaran (1975), Choudhary (1989) and Balasubramanian (1996).

The SP x N interaction significantly influenced the tiller count only. The increase in tiller count was in the range of 0.23 to 1.57 up to the 60 DAT. Mabbayad and Moody (1992) observed increase in tiller count and crop growth due to better weed management. In the present study also the SP x N combination reduced the weed population and helped to improve the tiller count.

The DMP of rice was influenced by S x N combination at 40 DAT and SP x N at 60 DAT. At the 40 DAT, S_1N_p produced the highest DMP of 3370.35 kg ha^{-1} which was on par with S_0N_m and S_1N_m. The present practice, i.e. no stale seed bed practice with basal nitrogen application was found to be inferior in dry matter production of rice. The weed growth will be more in these plots in early stages and this along with ample nitrogen availability reduced the crop growth and dry matter production. At 60 DAT, SP_1N_p and SP_2N_m combinations increased the DMP to the range of 400 kg ha^{-1} compared to other SP x N combination.

The higher accumulation of DMP by the above combinations due to reduced weed competition have resulted in higher nutrient uptake by the crop (Tables 33, 34 and 35). At 40 DAT, S_1N_p and S_0N_m registered the highest nitrogen and phosphorus uptake by rice due to high DMP. Similarly at 60 DAT SP_2N_m and SP_1N_p recorded the highest NPK uptake compared to other SP x N combination. Ali and Sankaran (1984) and Varshney (1990) observed improvement in nutrient uptake in rice by weed management. The two way interactions had no significant influence on grain yield, straw yield, harvest index and weed index.

5.1.5. Effect of SPxSxN on growth and yield of rice

The combinations of SP, S and N significantly enhanced the growth characters like plant height, tiller number, LAI and dry matter production. All treatment combinations enhanced plant height over hand weeding up to 60 DAT and the highest was in T_8 ($SP_2S_1N_m$) at all stages. The treatments T_7 and T_8 were also observed to be on par with complete weed free plot which recorded the highest plant height. Similarly the treatment combinations favoured tiller production. The combination T_8, T_6 and T_3 were observed to be superior in increasing the tiller count. LAI at panicle initiation stage was maximum in T_8 (SP_2 S_1N_m) and T_7 ($SP_2S_1N_p$) treatments. Compared to the traditional hand weeding the increase in LAI in these treatment combinations were 0.68 and 0.34 respectively. The weedy check registered the lowest plant height, tiller number and LAI. (The values being 63.90 cm at harvest, 6.07 tillers hill^{-1} at harvest and 2.20 at PI stage). The advantage of treatments in enhancing the growth characters could be, due to the effect of summer ploughing and stale seed bed practice in reducing the weed competition in rice. In general, the treatments T_8 and T_7 i.e., SP_2S_1 with or without delayed nitrogen was observed to be the best in enhancing the growth of rice. The favourable influence of summer ploughing on plant height, tiller count and leaf area index was also reported by Balasubramanian (1996). The growth attributes in weedy check was the lowest in confirmity with the findings of Bindy (1989) and Balasubramanian (1996).

The improvement in growth attributes by the treatment combination resulted in enhanced dry matter production of rice. During the early growth stages T_8 ($SP_2S_1N_m$), T_7 ($SP_2S_1N_p$) and T_4 ($SP_1S_1N_m$) were observed superior indicating the effectiveness of stale seed bed with one or two summer ploughing in controlling the weeds and enhancing rice growth. This was the result of better weed control as evident from the weed control efficiency values. T_8 recorded the highest WCE at all stages (Fig. 6).

At all stages T_2 ($SP_1S_0N_m$) registered significantly the lowest dry matter production. The poor growth resulted in poor dry matter production. Similar findings were also observed by Muralikrishnasamy (1996).

The nutrient uptake values clearly showed the superiority of T_7 and T_8 over other combinations indicating that SP_2S_1 combinations could effectively control weeds and enhance crop growth. The lower weed count, reduced weed dry weight and higher WCE in T_7 and T_8 resulted in lesser weed competition. Compared to weedy check T_7 and T_8 enhanced the nutrient uptake to the tune of 49.68 to 50.98 kg ha^{-1} nitrogen, 24.54 to 26.03 kg ha^{-1} phosphorus and 43.19 to 44.76 kg ha^{-1} of potassium at harvest (Fig. 7).

The treatment combinations enhanced the yield attributes like the number of productive tillers and panicle length. T_6, T_7 and T_8 were on par and superior to others in the productive tiller count and an increase of 0.93 (T_6) was observed over two HW. In the case of panicle length the mean values in treatment combinations ranged from 19.32 to 20.21 cm while the weedy check recorded a panicle length of 17.47 cm The reduction in

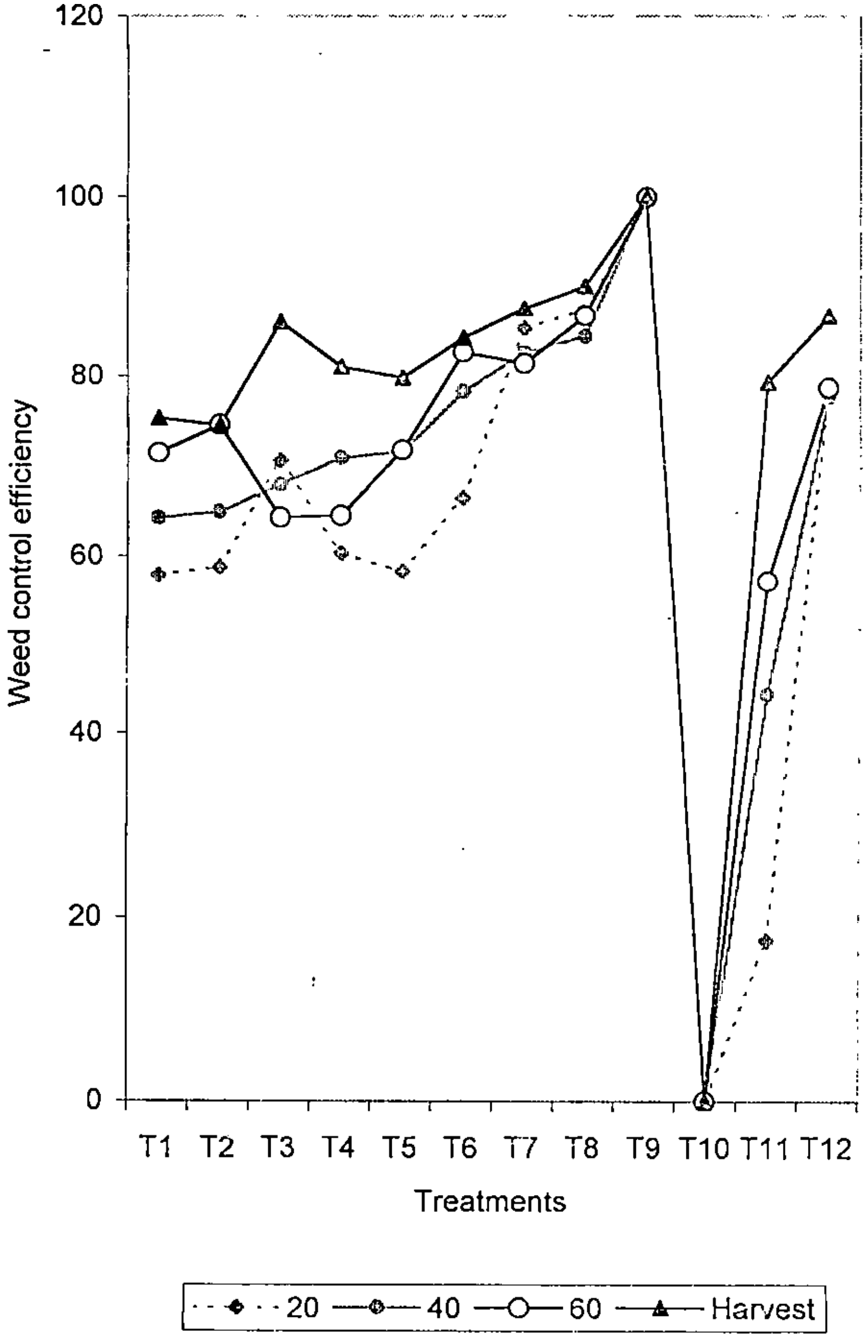

Fig. 6. Effect of treatment combinations (SP, S and N) and controls on the weed control efficiency at different intervals after transplanting

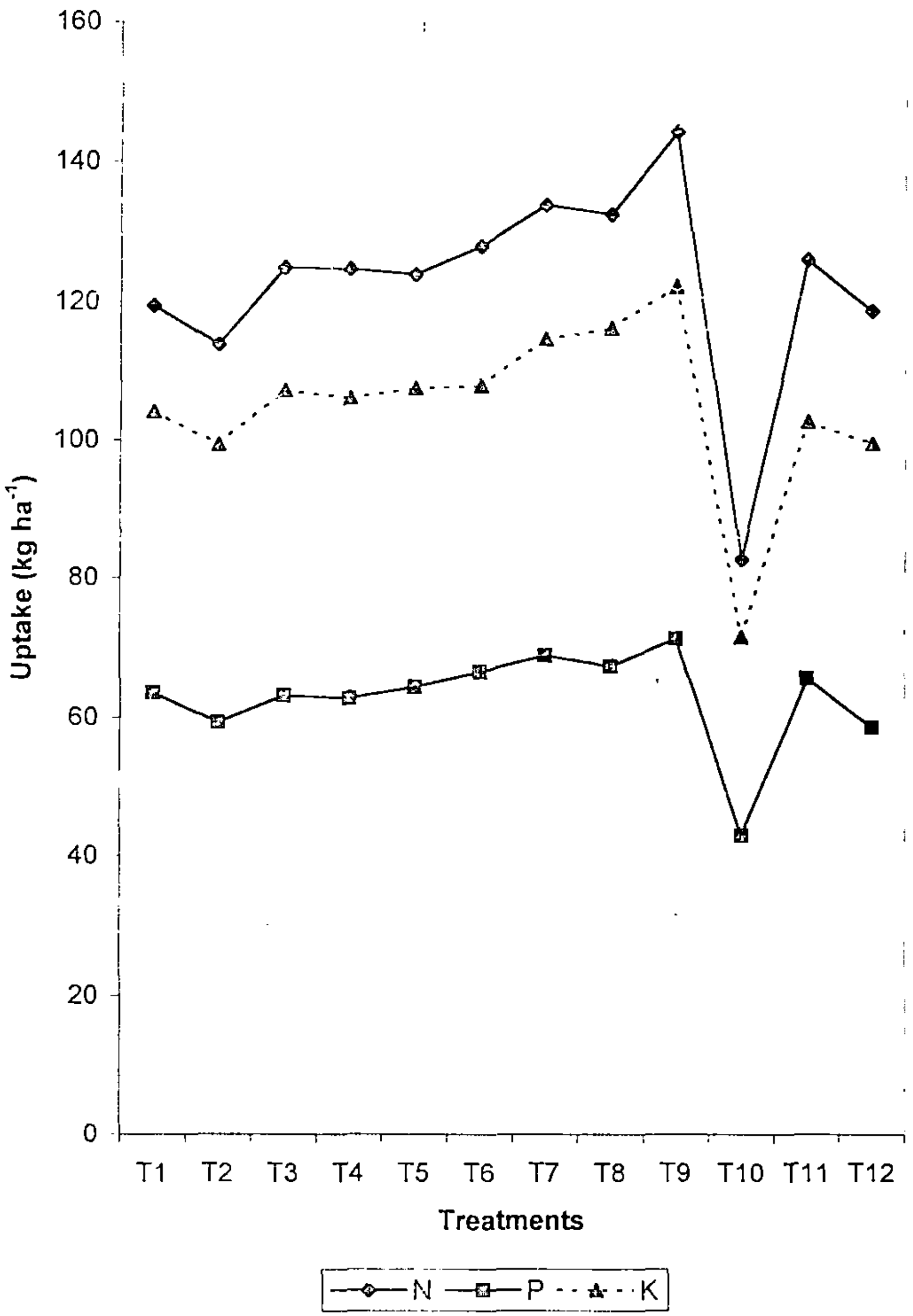

Fig. 7. Effect of treatment combinations (SP, S and N) and controls on NPK uptake of rice at harvest

panicle length due to weed competition was reported earlier by Mabbayad and Moody (1992).

$SP_2S_1N_p$ (T_7) recorded the highest values for panicle weight, number of grains per panicle, number of filled grains per panicle, thousand grain weight and the lowest sterility percentage and was closely followed by T_8 and on par with other treatment combinations. This trend is reflected in the grain yield also.

T_8 (SP_2S_1 N_m) recorded the highest grain yield by 3714.62 kg ha^{-1} which was on par with all treatment combinations except T_2 (Fig. 8). This can be well explained by the highest weed control efficiency in T_8 at all stages and low weed index (Fig. 9) which in turn enhanced the growth, nutrient uptake and dry matter production of rice. The improvement in growth led to improvement in yield attributes.

The present study registered an yield reduction of 44.94 per cent by weeds and the treatment combination especially T_8 and T_7 could increase in the yield by 1543.14 kg ha^{-1} and 1539.89 kg ha^{-1} over the weedy check. The results were in agreement with the finding of Moody (1990), who recorded an yield reduction of 50 to 64 per cent due to weeds while Sankaran *et al.* (1993) observed an yield loss of 1.48 t ha^{-1} due to weed competition.

The treatment combinations effectively reduced the weed competition and enhanced the rice yield. This was further evident from

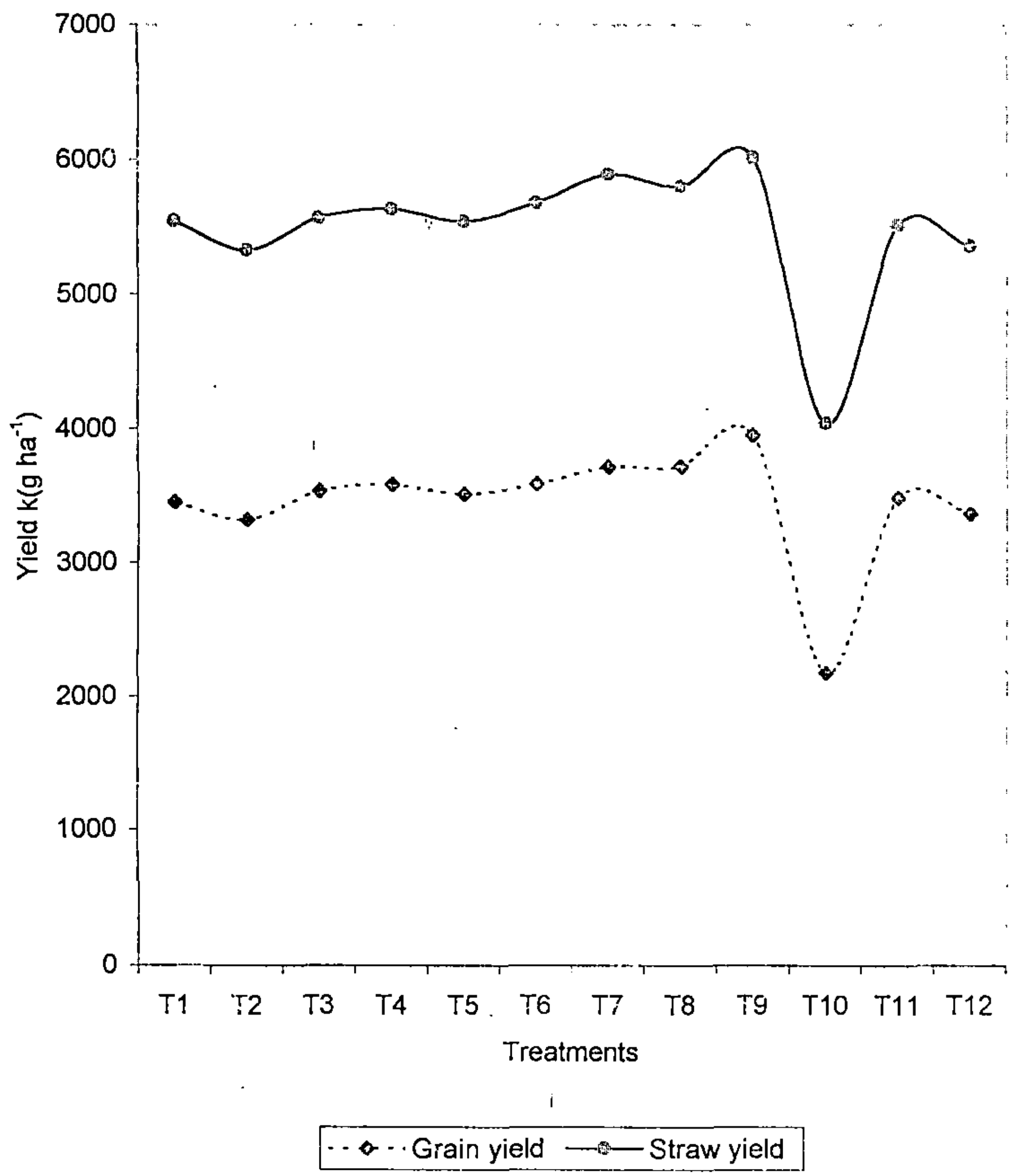

Fig. 8. Effect of treatment combinations (SP, S and N) and controls on the grain and straw yield of rice

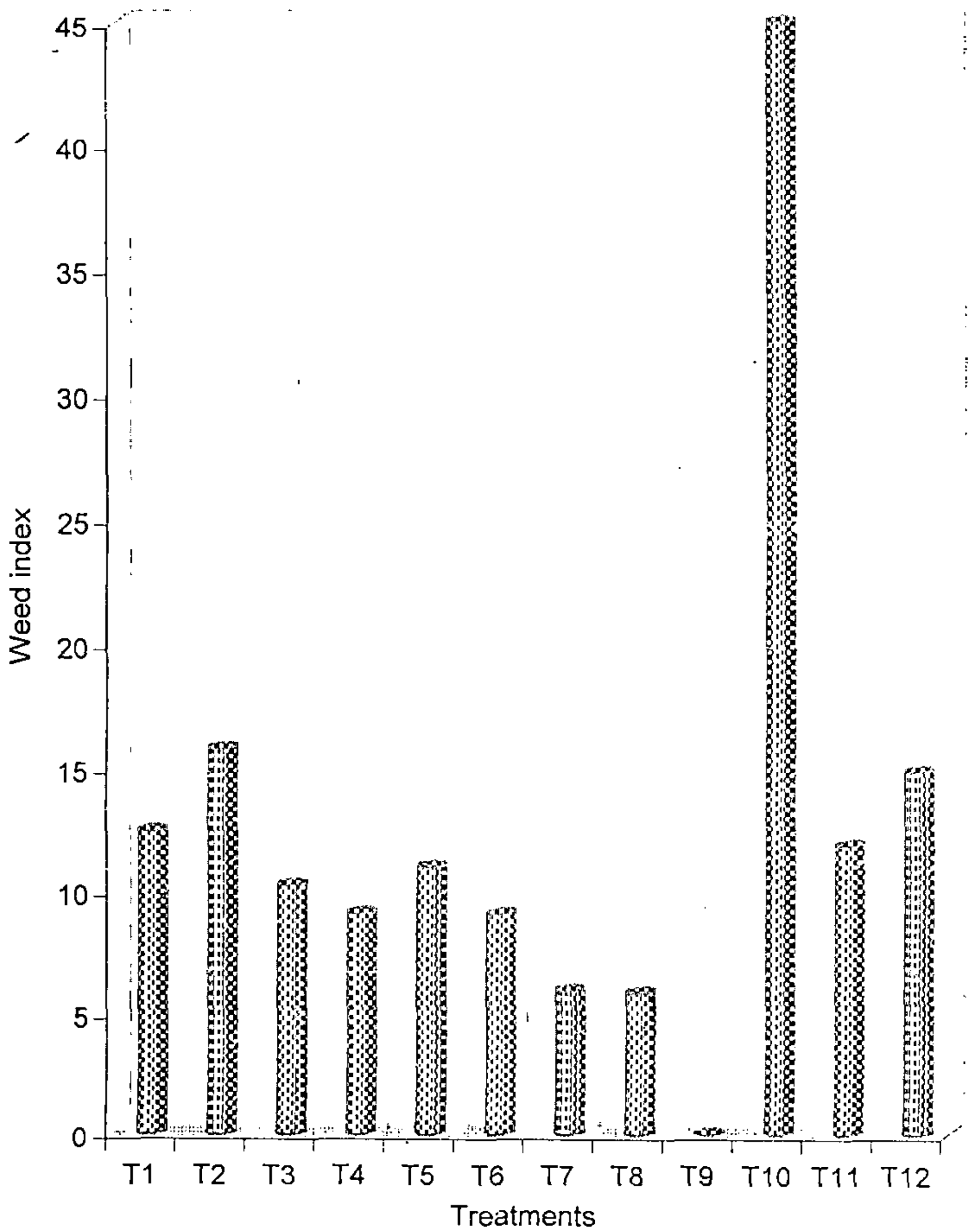

Fig. 9. Effect of treatment combinations (SP, S and N) and controls on the weed index

the high correlation values obtained for yield attributes and grain and straw yield (Table 40)

All treatments increased the straw yield over weedy check and the increase being 32.84 per cent. The weed management practices increased plant height, tiller count, nutrient uptake and dry matter production which helped to improved the straw yield. The improvement in straw yield by treatment combination was to the tune of 1294.01 to 1850.20 kg ha^{-1} over weedy check.

The growth characters viz. plant height, LAI and DMP had significant positive correlation with straw yield, the 'r' values being 0.8635, 0.8439 and 0.9946 respectively (Table 40). This supports the present finding.

5.2. Observation on weeds

5.2.1 Effect of summer ploughing on weed management

The effect of summer ploughing was pronounced in reducing the total weed population in rice field at all growth stages. Giving two summer ploughings was observed more effective in reducing the total weed population than one summer ploughing. However, compared to the hand weeded plot, one summer ploughing was also effective in reducing the weed count in rice up to 60 DAT. The reduction in total weed count in summer ploughed plot was attributed to the reduction in the count of grasses, sedges and BLWS due to summer ploughing.

The grass weed count was reduced by two summer ploughings over single ploughing, though the reduction was significant only at 60 DAT. This observation was contrary to the findings of Moody (1982 and 1991) who pointed out that land preparation in dry season had no effect on grass population. However, De Datta (1978) opined tillage as the most practical method of controlling *Paspalum distichum*. In sedge count also, two SP plots recorded the least count ranging from one to nine throughout the growth stage. Reduction in population of *Cyperus rotundus* by summer ploughing was reported by Moody (1982 and 1991). The count of BLW was also reduced and the reduction was to half at 40 and 60 DAT by two SP over single ploughing. However, the weed population in single ploughing was much lower than hand weeded plots.

The results in table 14 also pointed out that not only the weed count but also the total weed dry matter production showed significant reduction by summer ploughing, the difference between the two levels being non significant (Fig. 10). Compared to the total weed dry matter production in hand weeded plot single SP was also effective in reducing the weed dry matter production. The efficiency of summer ploughing in fallow period as an effective cultural method of weed control has been emphasized by Arunachalam *et.al*. (1992); Ganeswaraja *et al*. (1992) and Thirumurughan *et al*. (1992).

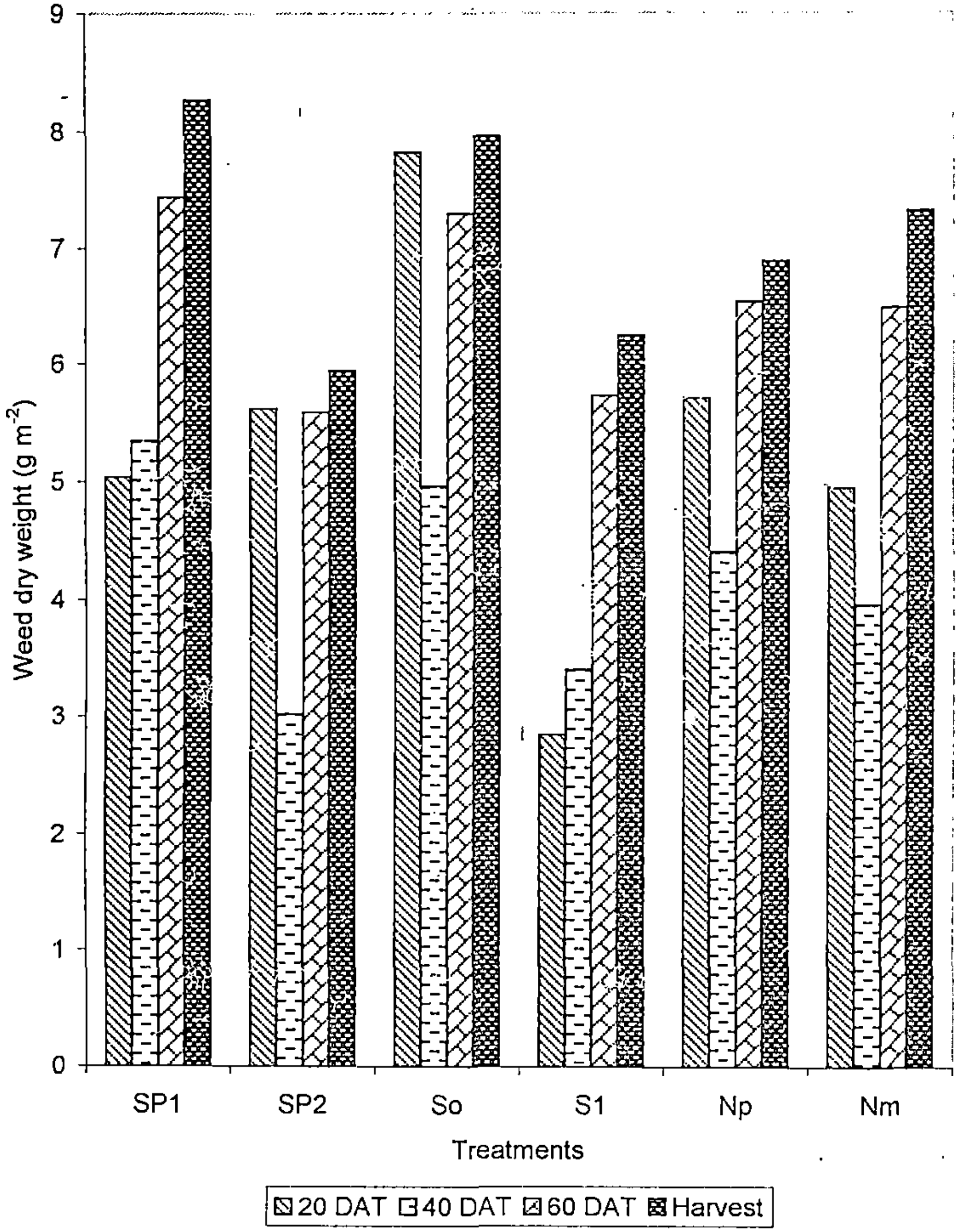

Fig. 10. Effect of summer ploughing, stale seed bed practice and nitrogen application on the total weed dry weight at different interevals after transplanting

The densities of grasses, sedges and BLWs recorded at different stages also showed reduction in summer ploughed plots especially up to 40 DAT. Summer ploughing promoted weed seed germination through soil turn over and the exposed seed and seedlings will be destroyed by the solar radiation. More over, the tubers of sedges were exposed and desiccated by sunlight (Tewari and Singh 1991 and Rao 1992) causing reduction in total weed population and the density of weed species.

So also, the grass weeds dominated throughout the growth stages as evident from its RD values, SDR and IV presented in Tables 18, 27, 28, 29 and 30. The dominance of grass was more in early stages i.e., up to 40 DAT. The early high grass weed dominance was attributed to the persistence and early emergence of grass weed species. Asokaraja (1994) observed that grasses and sedges exerted severe competition at early stages. The relatively dry period in early *Kharif* and increasing wetness and high moisture towards advancing crop season might have resulted in high grass weed dominance in early stages (Balasubramanian, 1996).

In sedges, the SDR values was the lowest at 20 DAT and showed gradual increase up to 60 DAT and declined at harvest (Tables 27 and 28) though no observable variation was noticed between one and two summer ploughings. Summer ploughing was effective in desiccating the sedge tubers and it was evident from the low IV of sedges (Tables 29 and 30). Similar reduction in sedge population by SP was also reported by Moody (1982 and 1991).

In case of broad leaved weeds, increase was observed after 40 DAT. The dominance of BLW at harvest could be due to their late emergence and longer life span. At the early stage grasses and sedges exerted severe competition for BLW causing their delayed emergence (Asokaraja, 1994).

Apart from the count, and their relative parameters the competition was also assessed through the dry matter production and nutrient removal. The DMP of weeds in summer ploughed plots ranged from 5.04 to 5.62 gm^{-2} at 20 DAT, 3.02 to 5.35 gm^{-2} at 40 DAT, 5.59 to 7.44 gm^{-2} at 60 DAT and 5.94 to 8.27 gm^{-2} at harvest. Compared to 40, 9.71, 5.2 and 8.39 gm^{-2} in hand weeded plots. This clearly emphasised the usefulness of summer ploughing in reducing the weed DMP during early stages which is highly beneficial in reducing crop weed competition.

The nutrient uptake by weeds which is a product of DMP and nutrient content was drastically reduced by summer ploughing. Comparing the nutrient uptake in weedy check (33.92 kg N, 9.48 kg P, 22.94 kg K per hectare at harvest); the N,P,K uptake values in SP plots were much lower ranging from 1.16 to 1.74, 0.32 to 0.52 and 0.82 to 1.13 kg NPK ha^{-1} at different growth stages (Tables 36, 37 and 38). In the early stages also the nutrient uptake by weeds was very low indicating the favourable influence of SP in reducing weed dry matter and consequently nutrient uptake. Reduction in nutrient uptake by weeds by adopting SP was also reported by Balasubramanian (1996). Thus summer ploughing helped in considerable saving of nutrients for rice crop as observed by Varshney (1990) and there by reducing the rice competition by weeds.

The results clearly showed the usefulness of summer ploughing in reducing the weed count, dry weight, density, dominance and uptake of nutrients by weeds during early growth stages. The influence of these parameters are evident in weed control efficiency. The WCE was significantly increased at all observations by two summer ploughings owing to reduced weed population in the plots.

5.2.2. Stale seed bed practice and weed competition

Stale seed bed practice has helped to reduce the total weed population throughout the crop growth stage. The total weed count was reduced to nearly half at 20 DAT and one-fourth at 40 DAT compared to no stale seed bed practice. The positive influence of stale seed bed on the total weed count was attributed to its effect in reducing the population of grasses and BLW especially at early growth stages.

Stale seed bed enhanced the early germination of weed seeds at the top layer which was later destroyed by the subsequent cultural operations and this helped to drain out the weed seed bank from the soil. The effectiveness of stale seed bed practice in reducing the weed population was reported by All *et al.* (1979), Sumner *et al.* (1981) and Hosmani and Meti (1993). The present study was in conformity with their results.

Considering the species variation, grass weed count was reduced to 50 per cent by adopting stale seed bed up to 40^{th} day observation. The BLW population also showed a decreasing trend up to 40 DAT though not significant at 20 DAT. Grasses, being the early emerging species are better controlled by stale seed bed practice where as the BLW, due to their late emergence were not effectively controlled by this weed management practice at early stages.

Sedge population was unaffected by stale seed bed in early growth stages and a slight increase was observed subsequently. Sedges being propagated through underground bulbs showed germination of dormant underground propagules after the crop planting. More over, sedges had difficulty in up rooting during the hand weeding given at 30 DAT.

The reduction in total weed number by stale seed bed was also reflected in the reduced weed density of the weed species when compared to the hand weeded plots.

The relative density of grasses and BLW were reduced by stale seed bed practice. At 40 DAT and 60 DAT, RD of grasses were significantly lowered by stale seed bed practice and the frequency values reduced from 50 to 42 at 40 DAT and 43 to 31 at 60 DAT. The variation in weed count caused this variation in relative density values. Providing stale seed bed practice and adopting one hand weeding at 30 DAT helped to reduce the relative density of grasses after that. However, at 40 DAT and 60 DAT observations, RD of sedges were found significantly enhanced due to their enhanced count. Though the population of grass weeds was reduced by stale seed bed at early stages they indeed showed their dominance over sedges and BLW up to the hand weeding time i.e., at 30 DAT. After this weeding, the effective removal of the grass species tend to reduce their dominance where as, the late emerging sedges and BLW dominated in later stages. This dominance was the result of increased sedge count at 40 and 60 DAT and BLW count at 60 DAT and at harvest stages. Similar trend was observed in importance values, where the IV of grasses showed decreasing trend towards harvest whereas, the IV of sedges and BLW increases towards harvest. The variation in dry weight of the weed species has resulted in the variation in IV values.

Stale seed bed practice caused a reduction in dry matter production of weeds throughout the growth stages and the reduction was more pronounced at 20 DAT where more than 70 per cent reduction in weed dry weight was observed by stale seed bed (Fig. 10). The positive effect of stale seed in draining the weed seed bank in soil and there by drastically reducing further weed emergence caused a reduction in weed number and consequently the DMP.

The nutrient uptake by weeds was also reduced by stale seed bed practice. Regarding N, P and K uptake, there was significant reduction in uptake values. The reduction in weed count, production of weaker seedlings and consequent reduction in weed dry matter production by stale seed bed practice resulted in the reduced nutrient uptake by weeds which in turn helped in considerable saving of nutrients for rice (Varshney, 1990).

5.2.3. Effect of SPxS, SPxN and SxN interaction on weed control

Among the two way interactions SP_2S_1 combination in general was observed to have significant influence on crop weed competition. This combination registered the lowest total weed count at all observations. At 20 DAT two summer ploughings with stale seed bed method drastically lowered the total weed population to approximately one-third compared to SP_1S_0 combination. All combinations of SPxS reduced the weed count at 40 and 60 DAT and at harvest though the variation was not significant. Providing two summer ploughings enhanced the drying and desiccation of propagules and this combined with stale seed bed practice enabled the germination of a majority of viable weed seed bank in soil which in turn reduced the total weed count. Roberts and Potter (1980) opined that when dry weather followed the cultivation, percentage of seedling emerging from soil seed bank declined.

SP_2S_1 combination reduced the count of grasses, sedges and BLW throughout the growth stages (Tables 10, 11 and 12). The reduction in count of grasses, sedges and BLW in SP_2S_1 plots in turn caused reduction in total weed count. The SP_2S_1 combination reduced the density of grasses, sedges and BLW over SP_1S_1 combination. Though a general reduction in RD of grasses was observed by SP_2S_1 combination, the RD of sedges and BLW were unaffected among the combinations. All these clearly indicated the effectiveness of two summer ploughings with stale seed bed practice for controlling the early emerging weed species of rice field.

In all SP_2S_1 combination (i.e., T_7 and T_8) the dominance of grasses (Tables 27 and 28) was more in early stages, sedges gradually acquire dominance by 40^{th} day continued up to 60^{th} day and then decreased. Verma *et al.* (1987) reported that grass weeds dominated more than 75 per cent of total weed flora in rice. Similar observation on grass weed dominance in rice was reported by Sarkar and Moody (1983), Tomer (1991) and Asokaraja (1994). In case of dominance of BLW also SP_2S_1 combination showed increasing trend with increase in crop growth. The dominance of grass in early growth period caused subsequent emergence of BLW at later stages coinciding with the cessation of growth of earlier emerged grass species resulting in high dominance of BLW at later stages (Asokaraja, 1994).

The SP_2S_1 combination reduced the total DMP of weeds at all stages of observation. The solarization effect caused by two summer ploughings in desiccating of weed propagules coupled with stale seed bed practice destroyed the viable weed reserve in soil resulting in low weed population and low dry weight. The hand weeding given at 30 DAT further helped to reduce the weed dry matter production after 30 DAT.

The combination of SP_2S_1 however reduced the rice-weed competition effectively up to 40 DAT which is the recommended weed free period in transplanted crop.

The SPxS interaction effect had no significant influence in the nutrient uptake by weeds. However, SP_2S_1 combinations recorded the lowest uptake values at all stages.

The SP_2N_m combination was observed significant in reducing the count of grasses and BLW at all stages and the count of sedges up to 40 DAT. Enhancing the desiccation of weed population coupled with reduction in nitrogen availability at the early stage might have caused the reduction in weed flora as observed by Channabasavanna and Shetty (1994) and Muralikrishnasamy (1996).

In S_1N_m combination also caused reduction in DMP of weeds. The effect of summer ploughing and the reduced availability of nitrogen to weeds in early stage (due to the delayed application at 10 DAT) significantly declined the initial weed population and dry matter production. After that stages, the established rice crop will be in a better position to shift the crop-weed competition in favour of rice crop. The increase in weed dry matter production in proportion of applied nitrogen at early crop stage causing indirect nutrient loss was reported by Channabasavanna and Shetty (1994) and Muralikrishnasamy (1996).

The combination of two summer ploughings with modified nitrogen application significantly reduced the nutrient uptake by weeds. The N, P and K uptake values by weeds showed reduction from 40 DAT onwards when two SP was combined with delayed nitrogen application. The reduced dry matter production of weeds caused a reduction in the nutrient uptake. The desirability of skipping basal application of nitrogen at transplanting to avoid its utilization by weeds was reported in YCES, Annual Report, 1989.

5.2.4. Interaction effect of SPxSxN on weed control

Considering the combination effect of SP, S and N, significant reduction in total weed count was observed up to 40 DAT. SP_2S_1 combination with normal and modified N application were on par regarding total weed count at 20 DAT whereas, $SP_2S_0N_m$ and $SP_2S_1N_r$

were on par at 40 DAT. The efficiency of two SP with stale seed bed was more pronounced in the 20^{th} day stage since the practice had a favourable influence on reducing the weed seed bank. When compared to two HW treatments, this initial reduction was highly significant in reducing crop-weed competition. Providing one hand weeding uniformly to all treatments (except controls) at 30 DAT helped better removal of weeds and enhanced crop growth which in turn helped to smother the weeds after that. This caused no variation among the treatment at 60 DAT and at harvest.

The total weed count (Table 13) at 20 DAT was 60 m^{-2} in hand weeded plot whereas, the pre planting weed management techniques reduced the weed count to 9 to 30. At 40 DAT also the count in treatment plots ranged from 21 to 49 while it was 76 m^{-2} in hand weeded plot.

Advantage of pre planting weed management practices in reducing the total weed count was emphasized by Balasubramanian (1996). The reduction in total weed count was the result of reduction in count of grasses, sedges and BLW in treatment plots.

Grass weed count was the lowest in T_7 ($SP_2S_1N_p$) and T_8 ($SP_2S_1N_m$) throughout the crop growth. The count ranged from 8 to 20 at 20 DAT in treatment combinations whereas, it was in the range of 32 to 49 in hand weeded plots. At 40 DAT the variation was not significant among treatments as one hand weeding was given at 30 DAT.

Sedge weed population ranged from 0 to 3 in SP,S and N combinations at 20 DAT compared to 10 to 12 in control plots. But towards later stages the sedge population showed an increasing trend, though the treatment caused reduction in sedge population compared to hand weeding. However, the increase was obvious after the critical weed free stage in rice crop. Giving one hand weeding at 30 DAT in treatment plot did not result in significant reduction of sedge weed count at 40 DAT. The inefficiency of hand weeding in reemergence of sedges was also reported by Verma *et al.* (1987).

The late emerging character of BLW resulted in non significant BLW count at 20 DAT. The effect of pre plant tillage treatments along with one HW at 30 DAT helped to reduce the count at 40 DAT. At 40 DAT the count was 21.33 m^{-2} in weedy check whereas, the count ranged from 2 to 14 in treatment combinations. Similar finding of late emergence of BLW were reported by Asokaraja (1994).

The reduced count of weed species in different replications also resulted in reduced density of weed species in pre plant tillage treatments. Grass and sedge weed density was the lowest in T_7 ($SP_2S_1N_p$) and T_8 ($SP_2S_1N_m$) at all stages of observations. In treatment plots the grass weed density ranged from 8 to 25 at 20 DAT and 9 to 24 at 40 DAT whereas, the respective values were 49.33 and 90.67 in weedy check and 34.67 and 41.33 in hand weeded plots.

In sedge weed density also the treatment combination reduced the density over weedy check or hand weeded plots. The density of BLW was reduced in T_6, T_7 and T_8 combinations especially at early stages compared to two HW plots indicating the favourable influence of two SP and stale seed bed practice.

Relative density, measure of density of one species in comparison with others was unaffected by the treatment combination. Weed frequency and relative frequency of each species were not affected by treatment combinations.

SDR and IV also revealed that the combination did not cause any observable variation of each species (Fig. 11). But the general trend of early dominance of grass species and later dominance of sedges and BLW as discussed earlier was observed.

The total dry matter production of weeds was unaffected by treatment combinations. However, compared to the hand weeded plots, all combinations reduced the DMP to almost one-fourth during the first observation at 20 DAT and further reduction was not so marked (Fig. 12). This was attributed to the uniform removal of weeds by hand weeding done at 30 DAT. Compared to the weedy check the reduction in dry matter production by treatment was to the tune of 78 to 98 per cent at different stages (Table 14).

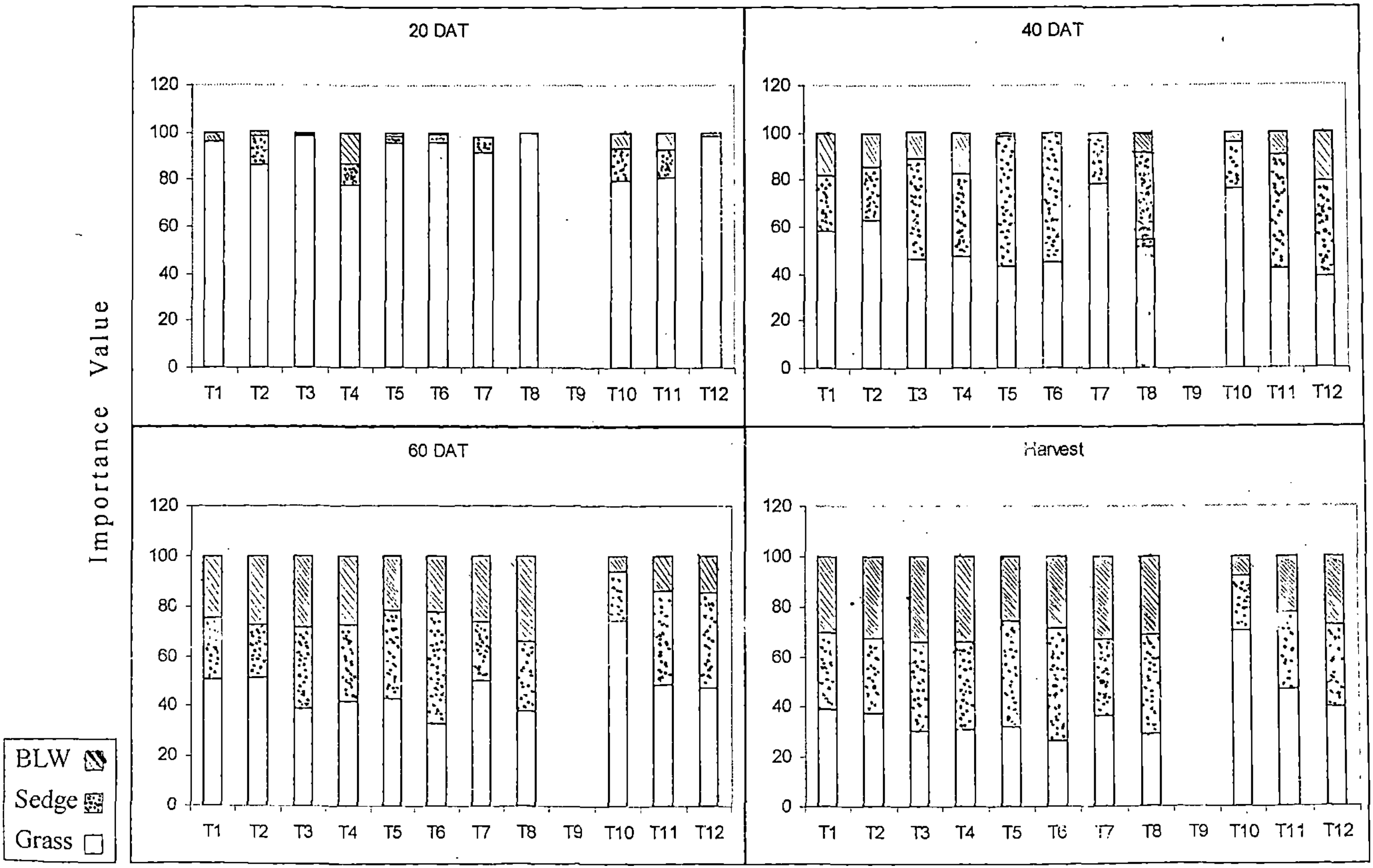

Fig. 11. Effect of treatment combinations (SP. S and N) and controls on importance value of grasses, sedges and broad leaved weeds at different intervals after transplanting.

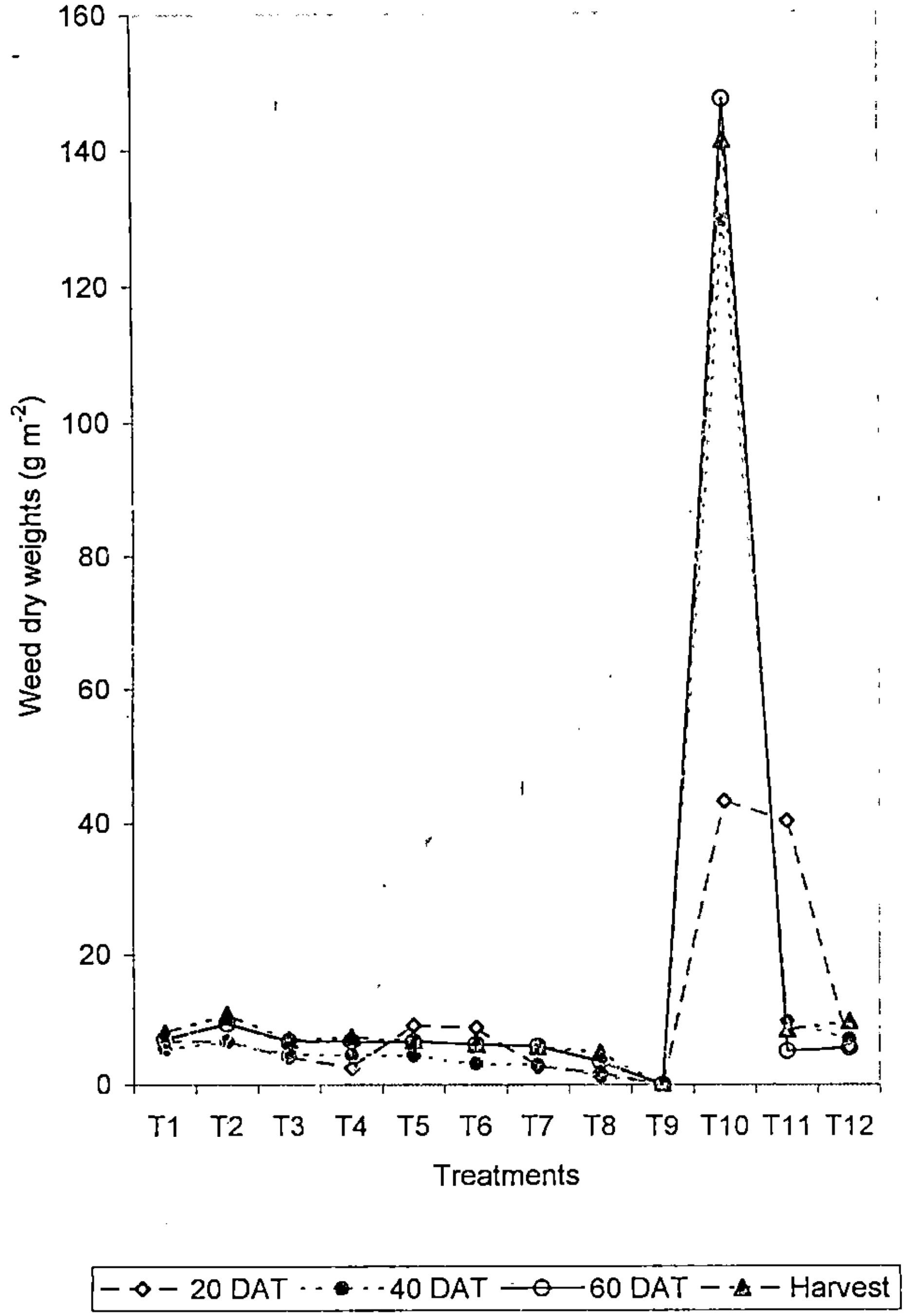

Fig. 12. Effect of treatment combinations (SP, S and N) and controls on total weed dry weight at different intervals after transplanting

The nitrogen uptake showed a reduction in T_7 and T_8 plots. Compared to two hand weeded plots the treatment combination were highly efficient in reducing the uptake of N by weeds up to the critical weed free period of rice crop.

The lowest P uptake was observed in $SP_2S_1N_m$ which were on par with other combinations at 20 and 40 DAT. T_8 registered the lowest P uptake throughout the life stage of crop. Compared to hand weeding the pre planting tillage treatments with delayed N application were helpful in reducing the N uptake of weeds up to 40 DAT.

T_8 ($SP_2S_0N_m$) recorded the lowest K uptake by weed at all stages. At 20 DAT all treatments were on par and K uptake was reduced to one-seventh by treatments. The effect of SP, stale seed bed and delayed N application reduced nutrient uptake by weeds at 20 DAT and the hand weeding given at 30 DAT helped in the further reduction of the weed population, dry matter and subsequent nutrient uptake. Madhu and Nanjappa (1997) showed the rate of increase in the uptake of major nutrients by weeds was proportional to the DMP.

5.3. Economics of crop production through weed management

Giving two summer ploughings increased the net income to Rs.6982.89 compared to single summer ploughing Rs.6974.59. However, the benefit cost ratio analysis showed the better BCR for single SP (1.29) over two SP (1.28). This was due to higher expenditure involved in two ploughings. The stale seed bed technique increased net income by more than Rs.700 than the absence of stale seed bed. The higher grain and straw yield along with the reduced expenditure resulted in higher net income and BCR. The basal skipping of nitrogen had no influence on net income. than the absence of stale seed bed. The higher grain and straw yield along with the lower expenditure exerted higher net income and CBR. The basal skipping of nitrogen had no influence on net income.

When compared to existing hand weeding practice, all the treatments showed their superiority in increasing net income. The lowest was Rs.47.85 in T_2 ($SP_1S_0N_m$) and highest being Rs.1594.09 in T_7 ($SP_2S_1N_p$). Except T_2 and T_5, all other combinations enhanced the net income about Rs.1000 ha^{-1} compared to traditional hand weeding practice.

The highest net income Rs.7907.48 was observed in T_{12} (herbicide treatment followed by hand weeding at 20 DAT) which was on par with all treatment combinations. The enhanced yield by the treatments helped to improve the net income. Similar yield improvement in herbicide treated plot followed by one hand weeding was also observed by Sivaperumal (1995). The highest BCR was registered by T_{12} (1.364), which was on par with all treatment combinations. Among treatments, T_1 (SP_1 S_0 N_p) recorded the highest BCR of 1.312. The reduced expenditure involved in one summer ploughing resulted in high BCR.

The combination of summer ploughing and stale seed practice was effective in reducing the weed competition and enhancing the yield and income. These combinations were economic over the traditional hand weeding practice and was on par with herbicide application treatment (Fig. 13). Though herbicide application is effective and economic during the initial periods, continuous application of the same was found to be inferior to hand weeding in reducing the weed population and enhancing rice yield (Janiya and Moody, 1987). Moreover, in the present concept of organic farming and environment friendly crop production, the herbicide use should be replaced with some other economic ecofriendly measures. The results of the study confirmed the use of summer ploughing and stale seed bed practices as ecofriendly and economic weed management practices. The combination of two summer ploughings with stale seed bed followed by one hand weeding at 30 DAT was economic and at same time effective. Hence this practice can replace the traditional weed

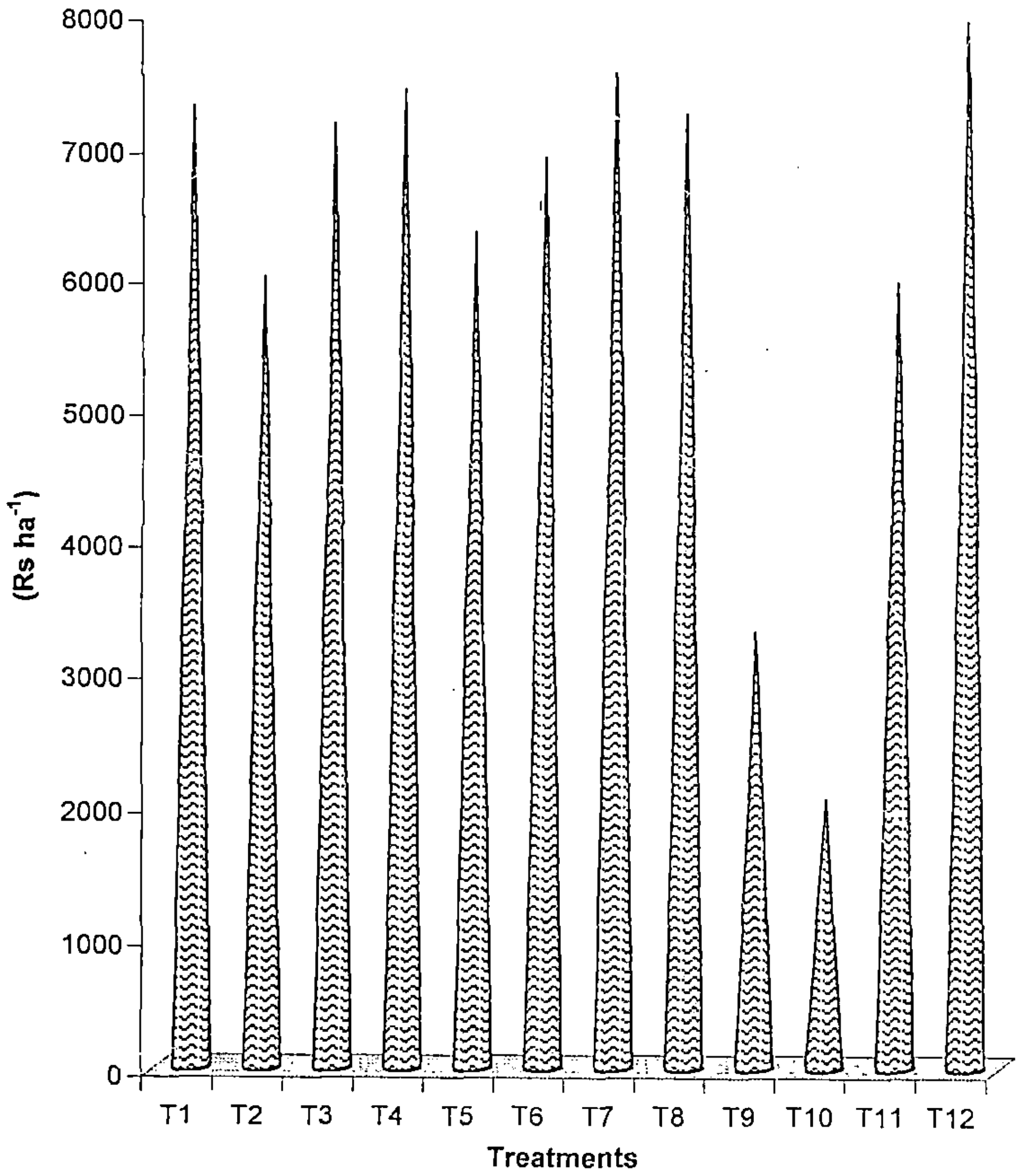

Fig. 13. Effect of treatment combinations (SP, S and N) and controls on net income

management practice (two hand weedings) and also the herbicide application in rice especially when water regulation is difficult due to continuous rains in first crop season.

Future line of work

The present investigation was carried out only during the *Virippu* season. The effect of different treatments on weed control efficiency in subsequent season need to be investigated. So also the changes in weed flora over a period of time needs detailed studies. The effect of treatments on the seed bank can also be taken up. The present results need multi location verification trials in major rice growing tracts of Kerala. Moreover, the possibility of replacing the manual energy for summer ploughing/digging by tractor power and its effect on weed flora and economics need further investigations.

SUMMARY

SUMMARY

An investigation on "Ecofriendly weed management practices in transplanted rice" was carried out at the State Seed Farm, Kottarakkara during the period from April 1998 to August 1998 with an objective to evolve economic and ecofriendly weed management practices in transplanted rice. The treatments consisted of summer ploughing (single summer ploughing – SP_1 and two summer ploughings – SP_2), Stale seed bed practice (without stale seed bed S_0 and with stale seed bed – S_1) and nitrogen application (Package of practice recommendation — N_p and delayed nitrogen application up to 10 DAT—N_m) along with four controls (complete weed free, weedy check, two hand weeding at 20 and 40 DAT and one pre-emergent herbicide followed by one hand weeding at 20 DAT). The experiment was laid out during the first crop season in factorial Randomised Block Design with three replications. The salient results of the experiment are briefly summarised below.

1. SP, S and N had no influence on plant height at 20 DAT, whereas SP_2 increased the plant height at subsequent observations. The stale seed bed adoption increased the plant height at 60 DAT and at harvest compared to no stale seed bed practice. The basal skipping of nitrogen had no influence on plant height. T_8 ($SP_2 S_1 N_m$) registered the highest plant height at all observations.

2. SP_2 and stale seed bed practice enhanced the tiller count. Delaying N application had no effect on tiller count at any growth stage of the crop. Among interactions, SP_2N_m registered the highest tiller count. T_6, T_7 and T_8 recorded significantly higher tiller count at all observations.

3. Providing two summer ploughings, adopting stale seed bed practice and delaying the basal application of nitrogen to 10 DAT significantly improved the LAI. Among combinations T_8 and T_7 were found superior to others.
4. The practice of two summer ploughings and stale seed bed positively influenced the dry matter production of rice. T_4, T_6, T_7 and T_8 recorded higher DMP of rice throughout the growth stage. All growth attributes were the highest in complete weed free plot.
5. Two summer ploughings and stale seed bed practice increased the number of productive tillers, panicle weight and number of tiller grains per panicle and reduced the sterility percentage. Effect of basal skipping of nitrogen was non significant on yield attributes of rice. The panicle weight, number of grains and filled grains per panicle were maximum and the sterility percentage was minimum in T_7.
6. SP_2, S_1 increased the grain and straw yield. However the increase was significant only in grain yield. Delayed N application and the two way interactions did not have any influence on yield. Among the treatment combinations T_8 (SP_2S_1 N_m) recorded the highest grain yield (3714.62 kg ha^{-1}) and T_7 ($SP_2S_1N_p$) recorded the highest straw yield (5885.95 kg ha^{-1}) which were on par with other combinations except T_2. The weedy check registered the lowest grain and straw yield. The HI was unaffected by treatments.
7. Important weed species observed before and during the experimental period were *Brachiaria platyphylla* (Criseb) (among grasses), *Cyperus sp* and *Fimbristylis miliaceae* (among sedges), *Monochoria vaginalis* and *Marsilea quadrifoliata* (among broad leaved weeds)

8. Two summer ploughing and stale seed bed practices reduced the grass weed count at all observations. The basal skipping of nitrogen reduced the grass weed count though the reduction was not significant. T_8 and T_7 recorded the lowest grass weed count than other combinations. Herbicide treated plot (T_{12}) was found to be on par with traditional hand weeding twice practice (T_{11}).

9. The count of sedges and BLW were reduced by summer ploughing and stale seed bed practice. Basal skipping of nitrogen had no influence on weed count. T_6, T_7 and T_8 registered the lower counts.

10. At all stages the total weed count and DMP were reduced by SP and S treatments. Among combinations, T_8 registered the lowest DMP of weeds. Weedy check registered the highest weed dry matter production at all observations.

11. T_7 and T_8 recorded the lowest grass weed density throughout the observations. T_8 registered the lowest sedge weed density at 20 and 40 DAT while T_5 registered the lowest at 60 DAT. At harvest T_4, T_7 and T_8 recorded the lowest sedge weed density. Among controls, herbicide treated plot (T_{12}) recorded the lowest grass, sedge and BLW density while weedy check registered the highest.

12. In all treatments, grass weed frequency was cent per cent at all stages. T_1, T_2 and T_7 registered the lowest sedge weed frequency at 20 DAT while at 40 and 60 DAT the frequency was cent per cent. At harvest, the lowest sedge weed frequency was observed in T_3, T_4, T_6, T_7 and T_8. Though T_6, T_7 and T_8 recorded the lowest BLW frequency at early stages, the frequency was cent per cent at harvest in all treatments.

13. The relative frequency of grasses, sedges and BLW, showed variation among treatments and at harvest. T_1, T_2 and T_5 recorded the lowest grass and BLW and sedge frequency was the lowest in T_3, T_4, T_6, T_7 and T_8.

14. Grass weed dominated at initial stages and sedges and BLW showed dominance at later stages. Treatments T_8, T_6, T_5 and T_4 showed high weed dominance in early stages. Sedge weed dominance was maximum for T_8 at 40 and 60 DAT. While the dominance was the highest for T_4 and T_2 at 20 DAT and at harvest. Among treatments T_1 showed more dominance of BLWs.

15. The importance value of grasses was higher than that of sedges and BLW.

16. Two summer ploughings and adoption of stale seed bed improved weed control efficiency. T_8 recorded the highest WCE at all stages. Herbicide plot recorded higher WCE than traditional hand weeded plots.

17. Stale seed bed practice lowered the weed index. T_8 recorded the lowest weed index, which was on par with all treatments combinations except T_2. Highest weed index was recorded in weedy check.

18. Two summer ploughings and adoption of stale seed bed technique significantly improved N, P and K uptake of rice at all stages. Among combinations, T_7 ($SP_2S_1N_p$) and T_8 ($SP_2S_1N_m$) recorded the highest uptake of N, P and K at all observations.

19. Two summer ploughings and stale seed bed technique significantly reduced the N,P and K uptake by weeds. T_7 and T_8 treatments were effective in reducing NPK uptake by weeds.

20. Providing two summer ploughings and stale seed bed technique enhanced the net income and T_7 recorded the highest net income of Rs.7518.06

21. The herbicide treatment recorded the highest benefit cost ratio of 1.364 and was on par with T_1, T_3, T_4, T_6, T_7 and T_8.

22. The grain and straw yield were positively correlated with plant height, LAI, total dry matter production at harvest, productive tillers, panicle weight, thousand grain weight and NPK uptake by the crop. The correlation values were negative for weed count, weed dry matter production and nutrient removal by weeds.

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* Originals not seen

APPENDIX

APPENDIX I

Weather parameters during the cropping period (April 1998 to August 1998)

Sl. No.	Standard Week	Date	Mean Max. Temp. (°C)	Mean Min. Temp. (°C)	R.H. (F.N) (%)	R.H. (A.N) (%)	Total Rainfall (mm)	Sunshine hours (Total)	Sunshine hours (Daily average)	Evaporation (mm)
1	13	26-1 Apr	35.8	25.9	90	66	0.0	69.2	9.9	5.0
2	14	2-8	36.2	24.7	92	56	3.8	66.1	9.4	5.3
3	15	9-15	34.5	25.1	94	57	4.3	67.0	9.6	4.8
4	16	16-22	35.3	25.8	89	59	6.5	72.0	10.3	4.9
5	17	23-29	35.4	24.9	89	68	32.5	72.1	6.7	3.7
6	18	30-6 May	35.3	24.7	90	61	3.0	46.7	4.7	2.9
7	19	9-13	34.4	24.9	93	74	30.1	29.9	9.8	3.9
8	20	14-20	32,5	25.6	96	70	56.4	68.9	6.7	3.8
9	21	21-27	33.8	25.6	95	72	120.5	51.4	7.6	3.5
10	22	28-3 Jun	33.9	24.3	93	72	5.5	17.8	2.5	2.3
11	23	4-10	32.0	23.9	92	78	77.8	49.2	7.0	3.4
12	24	11-17	31.5	23.7	96	83	90.8	6.3	0.9	2.1
13	25	18-24	31.9	23.1	97	65	140.8	15.3	4,9	3.0
14	26	25-1 Jul	29.9	23.0	93	77	72.3	38.3	2.5	2.8
15	27	2-8	31.5	23.8	94	76	160.7	34.2	5.9	2.6
16	28	9-15	31.2	23.6	97	77	58.9	30.9	5.5	2.7
17	29	16-22	30.1	23.4	96	72	62.4	30.5	4.9	2.5
18	30	23-29	30.2	22.9	95	71	67.9	32.4	4.4	3.1
19	31	30-5 Aug	30.6	23.4	93	78	70.4	22.7	4.6	3.1

Source : Farming System Research Station, Sadanandapuram, Kottarakkara

ECOFRIENDLY WEED MANAGEMENT PRACTICES IN TRANSPLANTED RICE

BY

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ABSTRACT OF THE THESIS
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ABSTRACT

An investigation was undertaken at the State Seed Farm, Kottarakkara during *Virippu* 1998 to evolve ecofriendly weed management practices in transplanted rice. The experiment was laid out as factorial randomised block design with three replications. The treatments included, two levels each of summer ploughings, stale seed bed technique, and nitrogen application along with four controls (complete weed free, weedy check, hand weeded twice and pre-emergent herbicide followed by hand weeding).

Two summer ploughings enhanced the growth characters of rice such as plant height, tiller count and LAI. Dry matter production and nutrient uptake of rice were also enhanced by two summer ploughings. Yield attributes and grain yield was significantly improved by two summer ploughings. The count of grasses, sedges and BLW and the total weed population was reduced by this practice. The dry matter production of weeds and NPK uptake by weeds were reduced by two summer ploghings. Weed control efficiency was also increased at all stages.

Adoption of stale seed bed technique enhanced the plant height, tiller count, LAI, dry matter production and nutrient uptake of rice. The yield attributes and grain yield were significantly increased by the practice and the weed index was significantly reduced. The total weed population was also reduced at all observations. The count of grasses and BLW reduced up to 40 DAT, while sedge population was unaffected by the adoption of stale seed bed practice. Relative density of grasses and sedges were also reduced by this technique. The weed dry matter production, and nutrient uptake were reduced and weed control efficiency was increased by the stale seed bed practice.

Delaying the basal application of nitrogen up to 10 DAT had no influence on the crop-weed competition and yield.

The treatment combinations enhanced the growth and yield. T_7 and T_8 recorded the higher dry matter production and nutrient uptake of rice. These treatments also resulted in higher grain yield and lower weed index than other combinations. They also recorded the lowest total weed count, weed frequency and weed density at all stage of observations. Moreover, the combinations of summer ploughing, stale seed bed and nitrogen application helped to reduce the weed dry matter production and nutrient uptake.

Compared to existing hand weeding practice all treatments showed their superiority in increasing the net income especially. T_7 and T_8. T_1 registered the highest benefit cost ratio. The benefit cost ratio of treatment combinations was comparable to herbicide application.