WEED MANAGEMENT IN SEMI-DRY RICE INTERCROPPED WITH GREEN MANURE CROPS

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Weed management in semi-dry rice intercropped with green manure crops"** is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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Certified that this thesis, entitled **"Weed management in semi-dry rice intercropped with green manure crops"** is a record of research work done independently by **Miss.O.N. Resmy** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

Dedicated

to my

Beloved Parents

Introduction

INTRODUCTION

Rice is cultivated in India under diverse ecosystems depending on the agro-climatic and edaphic situations of the region. It is estimated that the area under rainfed and irrigated system in India is 50 per cent each. The situation is almost similar in Kerala also, where 48.4 per cent of the rice area is irrigated and the remaining rainfed. This shows that increasing the productivity of rainfed rice plays an equally important role as that of irrigated rice in meeting the increasing demand of the growing population.

The semi-dry (dry sown lowland) rice is the major rainfed rice ecosystem in Kerala, which constitute more than 60 per cent of the area under rice during kharif season. The semi-dry system involves the growing of rice just like an upland crop upto the 3-4 leaf stage and thereafter bringing it under submergence with the onset of south west monsoon. The absence of stagnant water during the initial 4-6 weeks cause serious problems in semi-dry rice with regard to application of organic manures and weed management, affecting its productivity adversely.

The importance of organic manuring in maintaining soil health, improving nutrient use efficiency and sustaining enhanced productivity in rice is well documented. Stagnant water normally facilitates effective incorporation and efficient decomposition of the added organic manures in lowland rice. In view of the constraints in the incorporation and decomposition of organic manures in semi-dry rice, KAU (2002) has recommended concurrent growing of cowpea for green manure purpose exploiting the premonsoon showers. Cowpea is subsequently incorporated by self decomposition, when the water gets accumulated with the onset of south west monsoon. Though cowpea was found to be an ideal green manure crop for concurrent growing under favourable situations, it was found to have some disadvantages particularly where there is undue delay in the receipt of south west monsoon. The trailing growth habit, poor susceptibility of the grown up plants to water stagnation etc. are some such problems. The situation warrants further refinement of the technology including identification of appropriate green manure crop for the specific situations.

In semi-dry system, absence of stagnant water favours increased weed infestation and causes severe yield reduction. Further, intermittent rains during the early stages cause alternate wetting and drying of soil leading to more than one flush of weeds and will accentuate the weed problem. Physical methods of weed control which require large number of human labour, though effective, are expensive, tedious and time consuming. The effectiveness of herbicide application in suppressing weed pressure efficiently and economically in semi-dry rice has been reported by many authors (Thakur *et al.*, 1993; Mathew, 1999 and Rajendran and Kempuchetty, 1999). The area under chemical weed control in semi-dry rice is fast increasing in recent years in Kerala because of the acute scarcity of labourers and steep hike in labour cost. Intercropping of green manure crop could reduce the weed pressure in semi-dry rice, particularly broad leaved weeds, but it has little effect on grasses and sedges (Musthafa, 1995). Under moisture stress situations usually experienced in semi-dry rice, germination of both rice and green manure crops may be affected leading to inadequate plant population favouring increased weed infestation even under intercropped situations. No information is available regarding the feasibility of using presently recommended or alternate herbicides for weed control in semi-dry rice intercropped with green manure crops, without causing phytotoxicity to the leguminous intercrops. The present study is undertaken in this background with the following broad objectives:

1) To investigate the effect of intercropping of green manure crops on the growth, yield, nutrient uptake and economics of semi-dry rice.
2) To investigate the effect of intercropping on the nature and intensity of weed infestation.
3) To compare the efficiency of horsegram and cowpea as green manure crops, with respect to earliness in growth, moisture stress tolerance, biomass production, easiness in incorporation etc. and
4) To study the effect of herbicides on phytotoxicity, growth, yield and nutrient uptake, in respect of rice and green manure crops.

Review of Literature

2. REVIEW OF LITERATURE

Excessive weed growth is a major constraint in dry sown rice during the Kharif (May-September) season. To combat the menace, efficient weed control is needed. Hand weeding, the widely practiced method, is labour intensive and requires repeated operations for successful weed control. Consequently, chemical weed control by the application of pre and post emergence herbicides is recommended to reduce the cost of weed control. Intercropping of green manure crop is recommended as a means to supply organic manures in semi-dry rice and this practice has the additional benefit of weed suppression.

Research works on the spectrum of weeds in semi-dry rice, its effect on growth and yield and nutrient uptake by rice, intercropping of green manure crops in semi-dry rice and its effect on growth and yield and nutrient uptake of rice, chemical weed control and its effect on weed suppression, growth, yield components and nutrient uptake of rice, and the related aspects are discussed in this chapter.

2.1 WEED SPECTRUM IN SEMI DRY RICE

To adopt efficient weed management strategies, a thorough knowledge about the spectrum of weed growth is necessary. According to Barret and Seaman (1980) about 350 species, in more than 150 genera and 60 plant families, have been reported as weeds of rice. Experiments conducted at Pilicode in rice under semi-dry system identified *Echinochloa crusgalli, Echinochloa colona, Ischaemum rugosum, Cyperus* sp., *Marselia quadrifolia* etc. as predominant weeds (Sudhakara and Nair, 1986). According to Jayasree (1987) and Palaikudy (1989), major weeds in dry sown rice in Kerala comprised of *Isachne miliacea, Echinochloa colona, Sacciolepis interrupta* among grasses and *Cyperus irria* among sedges. Dicot weeds were very few in number and the main species present were *Alternanthera sessilis, Ludwigia* sp. etc. Robinson and Selvaraj (1991) found *Echinochloa colona, Cyperus difformis, Panicum* sp., *Ludwigia parviflora, Cynotis axillaris* as the major weeds in semi-dry rice.

According to Priya (1992), weed spectrum in dry sown rice is diverse and varied considerably between locations. Grasses constituted the major weed flora in dry seeded rice. Among grasses, *Echinochloa colona* was the most serious weed. *Echinochloa crusgalli* was also very common and problematic in semi-dry conditions. Among sedges, *Cyperus rotundus* is most serious in uplands while *Cyperus iria* is most common in semi-dry conditions.

Bhargavi and Reddy (1993) observed *Cyperus rotundus, Echinochloa crusgalli, Cynodon dactylon, Cleome viscosa* and *Euphorbia hirta* as the dominant weed species in semi-dry rice at Tirupathi.

According to Angiras and Sharma (1998), the major weed species in upland rice were *Echinochloa crusgalli, Echinochloa colonum, Cyperus iria, Cyperus difformis, Panicum dichotomiflorum, Commelina benghalensis, Aeschynomene indica* and *Euphorbia heterophylla*. Musthafa and Potty (2001) reported that the weed flora in semi-dry rice at Mannuthy included grasses viz., *Dactyloctenium aegyptium, Echinochloa colonum, Eleusine indica, Digitaria ciliaris, Panicum repens* and *Sacciolepis interrupta*, sedges viz., *Cyperus* sp. and broad leaved weeds viz., *Melochia corchorifolia, Cleome viscosa, Celosia argentea, Euphorbia hirta, Abutilon indicum, Phyllanthus niruri* etc.

2.2 EFFECT OF WEED COMPETITION ON GROWTH, YIELD AND YIELD COMPONENTS OF RICE

High weed density and weed competition reduced the height of the rice (Taric *et al.*, 1980; Patel *et al.*, 1986; Palaikudy, 1989 and Suja, 1989). An increase in plant height due to weed competition has been reported by UAS (1986) and Jayasree (1987).

Jayasree (1987) obtained a negative correlation between the dry matter production of crop and weeds at all stages of the crop with higher correlation at the initial stages, indicating the importance of weed free condition during the early stages of the crop. Singh *et al.* (1987) observed higher rate of dry matter production of weeds in unweeded plots during 15 to 30 days. The crop dry matter was lower in weedy check resulting in lower grain yields (Choudhary and Pradhan, 1988; Singh *et al.*, 1988) Purushothaman *et al.* (1988) reported a higher weed dry matter at harvest for unweeded check resulting in grain yield reduction. A reduction in dry matter production in rice due to weed competition was reported by Suja (1989). In general, rice dry matter yield would be reduced by one kg for every kilogram of weeds produced in the same area (Nyarko and De Datta, 1991).

Sankaran and De Datta (1985) after reviewing the reports of many indian workers reported an yield reduction of 32 to 86 per cent in upland rice due to uncontrolled weed growth. According to Patel *et al.* (1986), weeds reduced the number of total and fertile tillers. Better tillering was reported with effective weed control by Sudhakara and Nair (1986). Severe infestation of weeds in rice fields leads to higher competition for space, light and nutrients and thus resulting in reduced tillering and decreased crop yield (Bhol and Singh, 1987). Palaikudy (1989) observed reduction in the tiller number due to increased weed density and competition. Yield reduction of about 68 per cent in upland direct seeded rice due to weed growth was reported by Vaishya *et al.* (1992).

Population of five plants m^{-2} reduced the rice yield by 34 per cent and population above 40 plants m^{-2} of *Sacciolepis* sp. reduced the yield of rice by more than 40 per cent (KAU, 1997). Loss in yield to the tune of 15 to 73 per cent due to unchecked weed growth was reported by Singh and Mehta (1998). A study conducted by Renu (1999) revealed that competition from *Sacciolepis* sp. alone could reduce grain yield by 50.1 per cent. She also reported that *Sacciolepis* sp. compete with the crop and reduced the height, LAI, tiller production and biomass production of the crop.

Moorthy (1980) noticed a reduction in the number of panicles m^{-2} to the extent of 32 per cent in unweeded plots over hand weeded (twice) plots. Gupta (1984) reported that the percentage of filled grains panicle^{-1} was adversely affected by grassy weeds. Uncontrolled weed growth reduced 1000 grain weight in direct sown rice

(Jayasree, 1987). Suja (1989) observed that hand weeding and effective herbicide treatments produced longer panicles and higher number of spikelets panicle^{-1}. The reason for decreased number of productive tillers in unweeded check may be attributed to the severe competition by weeds leading to low dry matter production and LAI resulting in lesser photosynthetic activity (Swamy *et al.*, 1993). Phogat and Pandey (1998) reported that low grain yield in the control was due to increased crop weed competition, higher dry matter accumulation of weeds, lower effective tiller and 1000 grain weight.

2.3 EFFECT OF WEED COMPETITION ON NUTRIENT UPTAKE

Crop N, P and K uptake was lowest in unweeded plots than in plots weeded 21 to 40 days after transplanting (Varughese and Nair, 1986). Lakshmi *et al.* (1987) reported that the uptake by the crop in the weedy check was 30.9 kg ha^{-1} as against 61 kg ha^{-1} in weed free plot indicating the adverse effect of weeds in reducing crop yields. Moorthy and Mittra (1990) revealed that uptake of N, P and K by rice was proportional to weed control efficiency. According to Biswas and Sattar (1991), the N uptake by rice is decreased as weed density increased and this was reflected in decreased yields. Controlling the weeds allowed more uptake of nutrients by crops, which directly reflected in increased crop yield (Singh and Malik, 1992). As the density of *Isachne miliacea* increased from 50 to 80 plants m^{-2}, the uptake of NPK by rice was reduced from 80 to 64 per cent (Varughese, 1996).

According to Kaushik and Mani (1980), in unweeded plots of direct sown rice under unpuddled condition, weeds depleted 24.7 kg ha^{-1} of N, 5.8 kg ha^{-1} of P and 63.4 kg ha^{-1} of K. Singh and Sharma (1984) reported that N and P content of weeds were higher than those of rice plants at different growth stages under weed infested condition. Most of the N in rice was accumulated after the control of weeds. Weeds removed 24, 7.5 and 30.5 kg ha^{-1} of N, P_2O_5 and K_2O respectively in an unweeded check (Varughese and Nair, 1986). Ramamoorthy (1991) observed that weeds when allowed to compete with crop depleted 25.8, 3.65 and 21.83 kg ha^{-1} of N, P_2O_5 and K_2O respectively during kharif season in upland rice. Uptake of nutrients by weeds inside the crop canopy were comparatively lower than that grew without rice (Varughese, 1996).

2.4 *IN SITU* GREEN MANURING

In situ green manuring involves the growing of green manure crop in the crop field itself. It can be undertaken either by intercropping with the crop or sequential cropping.

2.4.1 Choice of green manure crops

Singh *et al.* (1982) found cowpea (*Vigna unguiculata*) as a better source of green manure as it accumulated more dry matter and nitrogen than sesbania (*S. aculeata*) and clusterbean (*Cyamopsis tetragonoloba*). Singh *et al.* (1988) reported that cowpea and sunhemp (*Crotalaria juncea*) were the most efficient sources followed by Sesbania and mungbean (*Vigna radiata*).

Cluster bean and cowpea are fairly drought tolerant and can be used as both vegetable and green manure crop (Singh *et al.*, 1981). Growing legume as intercrop in cereals has been found economical and beneficial (Chatterjee, 1989). Mathew *et al.* (1991) compared the efficacy of different green manure crops for concurrent cropping and found that cowpea is the best from the point of view of rice yield whereas *Sesbania aculeata* was unsuitable. According to Varughese and Kumari (1993) cowpea and sunhemp are good for dual culture when incorporated on 30th days after sowing (DAS). Bridgit *et al.* (1994) compared the performance of cowpea and sunhemp and found that cowpea has a distinct edge over sunhemp as it produced 80 per cent more green matter in unit time. According to Bhuiyan and Zaman (1996), cowpea (*Vigna unguiculata*) was shown to be superior to daincha (*Sesbania aculeata*) as a green manuring crop with respect to mineral composition and yield for lowland rice. *Sesbania rostrata* was superior to *Sesbania aculeata* and *S. sesban* with respect to biomass production and accumulation. Mandal *et al.* (2000) reported that rice + black gram intercropping system gave significantly higher number of effective tillers of rice per unit area over rice + pigeon pea intercropping system. *Sesbania rostrata* was proved to be a more efficient green manure crop for intercropping in the semi-dry rice (Kalpana *et al.*, 2002).

2.4.2 Nutrient contribution

Tiwari *et al.* (1980) reported an increase in available NPK content of soil in green manured plots over fallow. Bhardwaj and Dev (1985) correlated the green matter production potential and N accumulation of *Sesbania cannabina* and found that it produced 18, 28 and 37 t ha^{-1} of green matter and accumulated 98, 147 and 165 kg N ha^{-1} at 45, 55 and 65 days of growth respectively. Das and Rao (1986) reported that N fixed in the soil and that contained in the root mass are of importance in influencing the crop performance. Investigations by Morris *et al.* (1986) showed that mungbean and cowpea accumulated 44 to 83 kg N ha^{-1} in 30 to 45 days growth.

Benefits to rice by nitrogen fixation through concurrent cropping of azolla was reported by Mathewkutty (1982), Alexander *et al.* (1988) and Ventura and Watanabe (1993). Maskina *et al.* (1989) compared the above ground dry matter and N accumulation of cowpea, sesbania and sunhemp and found that in 50 days they accumulated 3.8, 4.9 and 5.3 t ha^{-1} of dry matter and 76, 97 and 100 kg N ha^{-1} respectively. Introduction of legumes in cropping systems has been advocated as a source of nutrient economy (Balyan and Seth, 1991). Kundu *et al.* (1991) compared the agronomic efficiencies of urea and green manures and found that they did not differ.

Swarup (1988) reported that substantial N content in green manure is released within a decomposition period of one week. According to Gill *et al.* (1994), green manure can be used as a supplement or substitute for mineral N. Singh and Sarawgi (1995) conducted studies on intercropping chickpea with wheat and concluded that some of the fixed nitrogen by the chickpea was likely to be available to wheat at later stages of growth.

Joseph (1998) stated that intercropping green manure crop and incorporating it at early stage (35 DAS) was found beneficial in terms of rice growth and yield, returns, soil fertility dynamics etc., compared to basal green manuring of daincha at 6.25 t ha^{-1} and full dose of N to rice. Conversely, belated incorporation of green manure at 50 to 65 DAS coupled with reduction in N dose to rice adversely affected rice growth, yield and its returns. Singh and Balyan (2000) reported that the introduction of legumes in the cropping system benefited the associated crops.

2.4.3 Effect of *in situ* green manuring on soil properties

Improvement in soil fertility due to green manuring was reported by many authors (Tiwari *et al.*, 1980; Swarup, 1987; Meelu *et al.*, 1992; Duban and Singh, 1994; Sharma, 1995 and Somasundaram *et al.*, 1996). A significant reduction in Eh of water logged soil due to green manuring have been reported by Thind and Chahal (1983) and Khind *et al.* (1987). Better aggregation and aggregate stability led to increased porosity and hydraulic conductivity, reduced bulk density and improved water holding capacity (Singh *et al.*, 1980). Hundal *et al.* (1987) reported that in water logged soils, green manures increased the availability of P through the mechanism of reduction, chelation and favourable changes in soil pH. Khind *et al.* (1987) reported that green manuring helped to achieve a near neutral pH in acidic, non calcareous soils.

Ladha *et al.* (1989) reported that green manuring minimized the loss of nitrogen in flooded situation and made available 80 per cent of the N to the two succeeding crops. Intercropping soybean and green gram in maize showed little improvement in the N status of the soil, but there was slight reduction in P and K contents (Sharma and Choubey, 1991). Bopari *et al.* (1992) found that wet land rice culture caused a break down of soil structure and decreased the infiltration rate through formation of a compact layer at a depth of 5-20 cm. Green manuring was found to effectively correct this soil degradation.

According to Gill *et al.* (1994), green manure can be used as a supplement or substitute for mineral N. Higher levels of Zn, Cu, Mn and Fe were observed in plots treated with FYM followed by plots treated with daincha and wheat straw. In an experiment conducted to evaluate the K uptake pattern in a rice + pulse intercropping system under rainfed condition, rice + greengram combination recorded higher uptake leading to higher grain and rice equivalent yield over rice + black gram (Sarma and Shyam, 1995). According to Tiwari *et al.* (1995), soil N decreased in all treatments after two cycles of rice-wheat cropping except in the green manured plots fertilized with 120 kg N ha^{-1}. Green manures have not only increased grain yield but also enhanced the sustainability of the soil due to higher residual recoveries (Medhi and De Datta, 1996).

Green manuring during kharif season was proved beneficial for improving physico-chemical properties of soil (Bellakki and Badanur, 1997). Chaphale and Badole (1999) reported that incorporation of glyricidia foliage at same site for five years recorded increase in organic carbon, total N, available NPK, water holding capacity and decrease in bulk density of soil over control. According to Sharma *et al.* (2000), green manuring with sesbania and incorporation of mungbean residue interacted positively with inorganic fertilizer in building up soil N.

Good growth of legume crops helps in nodulation and ultimately enriches the nitrogen content in the soil (Das and Mathur, 1980 and Yadav, 1981). Besides supplying nitrogen, green manures favourably influenced the physical properties of the soil, water retention, reduced the leaching loss of nutrients and improved the availability of other plant nutrients like phosphorus, sulphur and zinc through their impact on chemical and biological properties of soils (Singh *et al.*, 1991).

2.4.4 Effect of *in situ* green manuring on nutrient uptake of rice

Favourable effect of green manuring and nitrogen fertilization on the uptake of N has been reported by Debnath and Hajra (1972) and Tiwari *et al.* (1980). Bhardwaj and Dev (1985) obtained an increased N uptake by rice, by the incorporation of *Sesbania canabina*. Swarup (1987) found that not only the N content of the plant was improved but the uptake of N, P, Ca, Mg, Fe, S, Mn and Zn also was improved through green manuring.

Intercropping of pigeonpea and groundnut at 100 per cent population of each, was found most productive and efficient than sole crop as the system utilized the nutrients and water more efficiently than sole crop (Pareek and Turkhede, 1991). Meelu *et al.* (1992) reported an increased N uptake by rice by green manuring with sesbania, crotalaria, soybean and indigo. Incorporation of glyricidia leaves increased the uptake of N both in rice grain and straw (Bal *et al.*, 1993).

According to Reddy *et al.* (1995), N and K uptake was higher due to sunhemp green manuring. The effect of green manuring on P uptake was, however, inconsistent. Vaiyapuri *et al.* (1995) reported that apparent N recovery response ratio and physiological efficiency were significantly influenced by greater levels of green manure. Green manuring has not only increased grain yield but also enhanced the sustainability of the soil due to higher residual recoveries (Medhi and De Datta, 1996).

Musthafa and Potty (1998) reported that simultaneous *in situ* green manuring significantly increased the uptake of certain elements by rice, but reduced the uptake by weeds. By reducing the nutrient removal by weeds, *in situ* green manuring made the nutrients more available and absorbed by the rice which would otherwise have been absorbed by the weeds.

2.4.5 Effect of *in situ* green manuring on growth, yield and yield components of rice

Increased yields with addition of green matter have been reported by Mandal and Bharati (1983), Morris *et al.* (1986) and Mahapatra *et al.* (1987). In the United States, Westcott and Mikkelsen (1987) found that application of 120 kg N ha^{-1} through green manuring with vetch increased rice yield by 2.4 t ha^{-1} over the control. Antil *et al.* (1989) reported an increase in yield of rice due to daincha and greengram. But Mathew *et al.* (1991) reported decreased tiller count by intercropping where he observed that sole crop of rice had an average tiller count of 12.4, while in the intercropped plots, the number ranged between 9.9 and 11.5. Jayachandran and Veerabadran (1996) reported an increase in plant height, leaf area index and total tillers of semi-dry rice as a result of incorporation of intercrops.

Yield response of rice to green manuring in India ranged from 0.65 to 3.1 t ha^{-1} in high yielding varieties and was generally higher than those reported for low yielding rice cultivars. The response was higher under coarse textured soils particularly. In China, rice yields with green manuring increased by 78 per cent in low fertile soils compared with 21.6 per cent in high fertility soils. In Philippines, 30 to 128 per cent increase in rice yield due to incorporation of 40 to 60 days old green manure was reported. In the United States, green manuring with purple vetch increased rice yield over control by 1.0 to 2.5 t ha^{-1}. In SriLanka, a greater than 100 per cent increase in rice yield due to green manuring was reported (Singh *et al.*, 1991). Varughese and Kumari (1993) reported that maximum yield of dry sown rice could be obtained where cowpea and sunhemp were raised as inter crops with rice and incorporated on 30 DAS by light hoeing.

Ramakrishna and Ong (1994) reported that intercropping decreased rice yield slightly and generally increased overall crop production except when groundnuts were the intercrop and determinate legumes are more appropriate than indeterminate ones for intercropping with upland rice. Saravanapandian and Perumal (1994) stated that green manure had a notable effect in improving the yield attributes of rice viz., productive tillers $plant^{-1}$, filled grains $panicle^{-1}$ and 1000 grain weight as compared to FYM and Azospirillum inoculation. *In situ* green manuring effectively minimized the production and decline of non productive tillers in the post flowering phase and contributed to the increased yield (Musthafa, 1995).

Ramamoorthy *et al.* (1996) found that the most productive intercropping regime in terms of grain, straw and rice grain equivalent yields were rice with black gram at 4:1 row ratio compared with rice grown alone or intercropped with greengram, blackgram or soybean at different row ratios. According to Solaiappan *et al.* (1996) various green manures raised during pre-season rice gave higher yield of succeeding rice than rice following pre-season fallow by increasing the values of yield determinants viz. grains $panicle^{-1}$ and 1000 grain weight.

Rice + blackgram increased the net return to 32 per cent compared with sole rice (Ramamoorthy *et al.*, 1997). According to Chaphale and Badole (1999), incorporation of Glyricidia foliage at same site for five years recorded significantly higher grain and straw yield over control. According to Sharma and Ghosh (2000), panicle number was lower but the panicle weight was higher with daincha green manuring than with recommended level of 40 kg N ha^{-1} applied as urea. So green manuring of direct seeded rice with intercropped daincha is beneficial for substituting urea fertilizer upto 40 kg N ha^{-1} and augmenting crop productivity under flood-prone lowland conditions.

Mandal *et al.* (1986) opined that intercropping of cereals with legume is a recognized system for economizing the use of nitrogenous fertilizers and increasing the production per unit area. The system usually gives higher combined yield than sole crops. Singh *et al.* (1992) reported that intercropping of groundnut reduced weed density and increased the rice equivalent yield compared with sole rice. Intercropping of pulses with cereals provides insurance against crop failure in extremely dry years and fairly high yield is achieved in good rainfall years (Singh and Singh, 1995).

Mathew *et al.* (1991) and Bridgit *et al.* (1994) investigated the possibility of raising simultaneous green manure crop with rice in the semi-dry rice culture and found that the system will increase the yield by five q ha^{-1}. Ramamoorthy *et al.* (1994) observed that intercropping of blackgram in rice (1:4 row ratio) gave highest gross returns per hectare as compared to sole crop of rice. The increase in net return under rice and blackgram (4:1 ratio) was 32 per cent compared to sole rice. The mean net return was proved to be superior in intercropping over sole rice.

Quayyam and Maniruzzadin (1995) conducted studies on intercropping of blackgram with upland rice. Rice (67%) and blackgram (33%) combination gave higher net return $hectare^{-1}$ and higher net return $rupee^{-1}$ invested (0.97) compared with pure crop of rice (0.65). Mandal *et al.* (2000) reported that intercropping of blackgram with rice gave the highest rice equivalent yield and the highest net return over the respective sole crops. It was concluded that growing of greengram, blackgram and pigeonpea between rice rows was profitable as the values of relative net returns of rice exceeded unity in all intercropping systems. Sesbania incorporation alone or top dressing with 60 kg N ha^{-1} resulted in an average yield increase of 9.6 and 10.7 per cent over control in rice at Pant Nagar ((Mahapatra *et al.*, 2003). Summer cropping of legumes had shown a positive impact on available soil N, and significantly the available P and K.

2.4.6 Influence of *in situ* green manuring on weed growth

In intercropping systems, crop canopy considerably influences the nature and magnitude of crop weed competition, which is likely to differ with that under sole cropping.

In upland rice + legume intercropping system, in addition to the yield advantage, intercropping cuts down the cost of one weeding also (Ghosh *et al.*, 1986). According to Venkateswaralu and Ahlawat (1986) intercrops suppress weed growth but the efficiency of weed suppression largely depends on the nature of component crops. Moorthy (1990) reported that mixed cropping of rice with greengram, horsegram and cowpea alone did not provide adequate weed suppression because of early emergence of grassy weeds and one supplementary hand weeding improved the condition.

Prusty *et al.* (1990) and Kar *et al.* (1993) observed lower weed growth in intercropping due to the smothering effect caused by the well developed crop canopy. The association of groundnut as intercropping lowered the weed population and dry matter production (Singh *et al.*, 1992). In an experiment to study the effect of weed control in sorghum (*Sorghum bicolor*) - based intercropping system under rainfed situation, Solaiappan *et al.* (1992) reported that intercropping by cowpea suppressed the weeds compared to sorghum sole crop. According to Tiwari *et al.* (1992) density and dry matter of weeds were reduced significantly due to intercrops compared with pure crop.

Intercropping has been reported to minimize the weed control in many crops by Bansal and Bhan (1993). Thakur (1993) found a reduction in weed growth to the extent of 35-40 per cent due to intercropping. Bridgit *et al.* (1994) have also observed a significant reduction in weed biomass through concurrent cropping of cowpea for green manure in semi-dry rice. Of the cowpea intercropping treatments, weed control in terms of weed population density and weed dry weight, was best, if the crop was harvested 45 DAS which gave the highest net return owing to additional returns from green fodder yield as well as the cost involved in weed management (Dutta *et al.*, 1994).

According to Mishra and Gautam (1995), in intercropping system, fewer weeds are expected than in sole crop because of their suppression. According to Musthafa (1995), *in situ* green manuring suppressed the weed growth in the cropped field and the weed biomass production declined by 45 per cent by 20 DAS. The suppression effect was not uniform on all types of weeds. Sedges showed a tendency to increase when BLW declined. Grassy weeds remained unaffected. Intercropping also changes the weed spectrum in rice fields.

According to Rajagopal *et al.* (1998) raising cowpea as a dual crop with maize not only suppress the weed growth but also supplies nutrient to the crop, resulting in higher grain yield, net return and BC ratio compared to sole cropping of maize. Musthafa and Potty (2001) reported that variation in the seed rate of cowpea for simultaneous *in situ* green manuring caused difference in the weed count showing a lower count at higher seed rate. Lesser weed population and DMP at 15 and 30 DAS respectively were recorded under maize + cowpea intercropping system (Bhuvaneshwari *et al.*, 2002). Conjoint cropping of rice + daincha and incorporation of the latter on 37 DAS using "Conoweeder" proved better in terms of reducing total weed density and improving the productivity by 26 per cent over sole rice (Sankar *et al.*, 2003).

2.5 CHEMICAL WEED CONTROL

Kumar and Gill (1981) were of the opinion that application of herbicides particularly pre emergent ones has a special significance in direct seeded rice since weeds and crop seedlings emerge simultaneously and herbicide treatment eliminates weed competition not only in between the crop rows but from the crop rows as well.

The effectiveness of herbicides in weed control in semi-dry rice has been reported by several authors (Thakur *et al.*, 1993 and Mathew, 1999).

2.5.1 Growth and yield components of rice

Plant height, number of fertile tillers, panicle length and number of spikelets panicle^{-1} were increased by application of butachlor (Pradhan and Choudhary, 1989). Singh and Singh (1985) observed that butachlor @ 1.5 kg ai ha^{-1} increased crop growth and yield components over weedy check. According to Ramiah and Muthukrishnan (1992), pre emergence application of pendimethalin @ 1.25 kg ha^{-1}, followed by post-emergence application of 2,4-D @ 1.0 kg ha^{-1} resulted in higher grain yield. The higher grain yield under this treatment could be attributed to better weed control and enhanced tiller production.

Singh *et al.* (1992) reported that pre-emergence application of pendimethalin @ 0.75 kg + 2,4-D @ 0.5 kg ha^{-1} and butachlor @ 0.75 kg + 2,4-D @ 0.50 kg ha^{-1} is adequate to achieve efficient weed control, higher yield and high net return over the control in rice + groundnut intercropping system. Ramamoorthy and Ali (1992) reported promising results with application of pendimethalin in upland rice through improving dry matter production and productive tillers.

Pendimethalin recorded highest grain yield when applied at 0.75 kg ai ha^{-1} at eight and twelve days after sowing in rainfed bunded summer rice (Ali and Sankaran 1984; Verma *et al.*, 1987; Choudhary and Pradhan, 1988 and Mishra and Roy, 1990). According to Kathiresan *et al.* (1997), among the methods of herbicide application, pendimethalin @ 1.0 kg ai ha^{-1} as pre-sowing sand mixed, registered significantly higher grain yield of 2,151 kg ha^{-1} through effective reduction of weeds and weed dry matter that resulted in better seedling growth and productive tillers. Sreenivas (1997) reported that pre emergence application of pendimethalin 1.0 kg ha^{-1} + inter cultivation after 30 days controlled all weeds and resulted in significantly greater yields (1558.7 kg ha^{-1}) compared to the unweeded control (364 kg ha^{-1}). The highest grain yield was recorded in hand weeded plots which was closely followed by the plots treated with pre-emergence application of anilofos at 0.35 kg ha^{-1} in combination with post emergence application of 2,4-D at 1.0 kg ha^{-1} (Singh *et al.*, 2003).

According to (Samnotra *et al.*, 2003) the lowest plant matter and grain yield was recorded in control plot. At 80 DAT, maximum dry weight was recorded in weed free treatment followed by anilofos + 2,4-D (1.0 + 1.0 kg ha^{-1}), two hand weedings (20 and 40 DAT) respectively, further higher grain yield and straw yield were recorded in weed free treatment, which may be attributed due to highest number of grains $panicle^{-1}$ and number of tillers m^{-2}. Weed free treatment was found to be the best with the highest grain and straw yield as well as length of panicle and number of panicle m^{-2}, followed by anilofos + 2,4-D (0.4 + 1.0 kg ha^{-1}), butachlor + 2,4-D (1.5 + 1.0 kg ha^{-1}), respectively (Sharma *et al.*, 2003). A study conducted by Varma and Kumar (2003) revealed that number of tillers $hill^{-1}$, number of tillers m^{-2}, number of panicle m^{-2}, number of grains $panicle^{-1}$, test weight as well as grain yield (q ha^{-1}) of rice was recorded to be highest with the use of pendimethalin which was closely followed by the use of butachlor.

According to Phogat and Pandey (1996), anilofos, butachlor, pendimethalin and pretilachlor significantly increased the grain yield and proved statistically superior to the control. Sequential application of anilofos supplemented with 2,4-D Na salt gave higher grain yield and benefit-cost ratio in rice (Behera and Jena, 1998). Choudhary and Thakuria (1998) reported an increase in grain yield of rice with increase in doses of anilofos, butachlor and pendimethalin.

Kulmi (1992) reported that among the different herbicides used for weed control in rice, pretilachlor @ 1.0 kg ha^{-1} resulted in the highest grain yield, followed by piperophos @ 1.25 kg ha^{-1} and oxadiazon @ 1.0 kg ha^{-1}. Pretilachlor plus safener either at 0.45 or 0.60 kg ha^{-1}, combination of butachlor and pretilachlor at 1.00 and 0.5 kg ha^{-1} respectively in 1992 and butachlor 1.00 kg ha^{-1} followed by hand weeding 25 days after sowing in 1993 recorded comparable yields as that of hand weeding 20 and 40 days after sowing (Choudhary and Thakuria, 1998). Pre-emergence application of pretilachlor plus safener hand weeding in semi dry rice significantly increased the total grain productivity of the cropping system (Rajendran and Kempuchetty, 1999).

2.5.2 Growth and yield components of leguminous crops

According to Bhan *et al.* (1983) and Mohanty *et al.* (1997), herbicides mainly fluchloralin and pendimethalin can successfully be utilized for combating the weeds (mostly grasses and broad leaved ones) in groundnut. Natarajan *et al.* (1997) observed that herbicides like metribuzin (0.5 to 1 kg ai ha^{-1}), fluchloralin (1 kg ai ha^{-1}) and pendimethalin (1 kg ai ha^{-1}) can be used for weed control in soybean and the herbicides integrated with one hand weeding gave more yield than herbicides alone. Patel *et al.* (1997) observed that pendimethalin @ 1.5 kg ai ha^{-1} as pre emergence and fluchloralin @ 1.0 kg ai ha^{-1} as pre planting incorporation increased the pod yield of groundnut by controlling the weeds.

Pendimethalin and alachlor as pre emergence and fluchloralin as pre plant application at 1.5 kg ai ha^{-1} are relatively more effective for weed control in soybean (Jain *et al.*, 1998; Bhalla *et al.*, 1998 and Raskar and Bhol, 2002). Pannerselvam and Lourduraj (2000) reported that pre emergence herbicide viz. pendimethalin @ 0.75 kg ai ha^{-1} can be safely applied in soybean to control the weeds.

Ramesh *et al.* (2000) conducted an investigation to assess the effect of different herbicides applied to soybean on soil dehydrogenase and urease activity with pre emergent herbicides like alachlor @ 2 kg ai ha^{-1} and pendimethalin @ 1 kg ai ha^{-1} and post emergent herbicides like anilofos @ 1.5 kg ai ha^{-1}, fenaxy prop-p-ethyl @ 50 g ai ha^{-1} and imazethapyr @ 75 g ai ha^{-1}. Among these herbicides, none was found phytotoxic.

Singh *et al.* (2000) reported that pendimethalin and isopoturon were found slightly phytotoxic to Indian mustard at 1.0 kg ai ha^{-1} and pendimethalin @ 0.75 kg ai ha^{-1} was found giving satisfactory weed control with no visible phytotoxic effect on the crop. In an experiment conducted to study the influence of weed control methods on growth, yield and economics of rainfed soybean at farmers field, Kushwah and

Kushwaha (2001) observed that significantly lower number of weeds m^{-2} and weed dry matter were obtained with the use of pendimethalin supplemented with one hand weeding.

Singh and Giri (2001) observed that in sunflower and groundnut, combined application of pendimethalin and one hand weeding recorded the lowest weed dry weight and the highest yield. According to Sharma *et al.* (2002), pre emergence application of oxyfluorfen was found the most useful in reducing the weed density and weed biomass followed by hand weeding and pendimethalin treatments in indian mustard.

Vaddi *et al.* (2001) observed that pre emergence application of pendimethalin @ 1.0 kg ai ha^{-1} with cultural practices recorded significantly higher seed yield than the treatments involving post emergence application of glyphosate @ 4 l ha^{-1} in combination with cultural practices and the cultural practices alone. An experiment conducted on greengram, revealed that two hand weedings at 20 and 40 DAS significantly increased grain yield, and reduced the weed population, closely followed by pendimethalin @ 1.0 kg ha^{-1} with one hand weeding at 20 DAS (Sofi and Elamathi, 2003). In a field experiment conducted during summer, the highest plant height was recorded by alachlor @ 2.0 kg ha^{-1} and pendimethalin @ 1.5 kg ha^{-1}, while the maximum number of pods $plant^{-1}$ were observed in hand weeding twice and pendimethalin @ 1.5 kg ha^{-1}. Maximum grain yield was obtained in hand weeding twice (20 and 40 DAS) followed by alachlor @ 2.0 kg ha^{-1}. The lowest grain yield was obtained in unweeded control (Srivastava and Kaleem, 2003).

2.5.3 Control of weeds

According to Raju and Reddy (1986) butachlor possess strong selectivity against *Echinochloa* sp. and controls most broad leaved weeds, annual sedges and grasses in rice. Bhol and Singh (1987) reported poor control of grassy weeds with butachlor due to rapid decomposition by U.V. light under irrigated conditions and quick degradation by soil microbes. Mishra *et al.* (1988) reported that anilofos @

0.3 and 0.4 kg ha^{-1} lacked adequate activity against BLW in wet seeded rice. Efficacy of anilofos in controlling weeds in rice was reported by Walia *et al.* (1992). According to Avudaithai and Veerabadran (2000), pre emergence application of anilofos effectively controlled the grass but not the broad leaved weeds and late germinated sedges. Among the different doses tested, anilofos 0.6 kg ha^{-1} recorded the maximum weed control resulting in maximum plant height (Ravi *et al.*, 2000).

Butachlor applied four days after seeding rice, was more efficient in suppressing weeds at a dose of 2.0 kg ha^{-1} than at 1.0 kg ha^{-1} (Chandrakar, 1991). Krishnasamy and Krishnasamy (1996) reported that butachlor @ 0.75 kg ha^{-1} applied at first sowing rain followed by one hand weeding on 40 DAS was effective in controlling the weeds and increasing the yields of premonsoon sown sorghum based cowpea intercropping system and consequently the net returns in rainfed vertisols. A field experiment was conducted by Saha and Srivastava (1992) to study chemical weed control in pigeonpea [*Cajanus cajan* (L.) Millsp.] + rice (*Oryza sativa* L.) + mixed cropping system. When the effectiveness of herbicides were compared benthiocarb @ 1.5 kg ha^{-1} proved the most effective in suppressing the weeds, followed by butachlor @ 2 kg ai ha^{-1} and pendimethalin @ 1.5 kg ai ha^{-1}.

Gowda and Devi (1984) observed that pre emergence application of pendimethalin at 1.25 to 1.5 kg ai ha^{-1} was effective against dicotyledonous weeds and its effect persisted upto harvest. Application of pendimethalin followed by one hand weeding on 25 to 30 DAS was found to achieve good control over weeds by reducing weed dry weight (Singh and Prakash, 1990). Bhattacharya and Mandal (1991) reported excellent control of broadleaved and grassy weeds with anilofos, butachlor, pendimethalin and pretilachlor failed to control *Eclipta alba* but was very effective against grassy weeds at 1.0 kg ha^{-1}.

Joseph and Bridgit (1993) reported that pre emergence application of pendimethalin, and pre emergence application of either pendimethalin, butachlor or thiobencarb followed by hand weeding once were found equally effective as hand weeding twice. In an experiment conducted to study the influence of different soil moisture regimes on weed-dynamics in direct seeded upland rice (*Oryza sativa*) +

blackgram (*Phaseolus mungo*) intercropping system, pre emergence application of pendimethalin 1.25 kg ha^{-1} followed by one hand weeding at 35 days after sowing was found effective against annual grasses (Ramamoorthy *et al.*, 1997).

Tomar (1991) obtained the best weed control and lowest dry matter production, when pretilachlor was used @ 1.25 kg ha^{-1} in transplanted rice. Rajendran and Kempuchetty (1999) reported that pretilachlor plus safener @ 0.3 kg ha^{-1} followed by hand weeding 25 days after sowing effectively controlled the weeds in semi-dry rice.

An experiment was conducted during the Kharif season 1992, to study the effect of continuous use of herbicides on weed dynamics, and their control in upland direct seeded rice (*Oryza sativa*) - blackgram (*Phaseolus mungo*) intercropping system. Pre emergence application of pendimethalin (1.25 kg ha^{-1}) followed by one hand-weeding at 35 days after sowing was found effective against annual grasses. Continuous use of herbicides resulted in weed shift from annuals to perennials (Ramamoorthy *et al.*, 1997).

Considering the importance of weed control in rice, a study on comparative performance of different weedicides viz., 2,4-D, butachlor, pendimethalin, granular as well as liquid, to control the weeds in rice was conducted by Varma and Kumar (2003). The study revealed that the use of all the herbicides was found more effective and economical than twice manual weeding. The use of Pendimethalin (liquid) proved to be most effective in weed control in rice.

2.5.4 Nutrient uptake

Suja and Abraham (1991) reported that towards harvest stage the variations in nutrient uptake by crop between the different treatments got widened resulting in significantly higher uptake of all the nutrients for hand weeding and herbicide treatments. This might be because of the better growth and dry matter production of crop due to the absence of competition from weeds during the critical stages of crop-weed competition for the major nutrients. Application of pendimethalin 1.0 kg ha^{-1}

followed by one hand weeding was found to be effective in checking the removal of nutrients by weeds and promoted nutrient uptake by crop and consequent increase in yield (Kathiresan and Veerabadran, 1991). Controlling the weeds allowed more uptake of nutrients by crops, which directly reflected in increased crop yield (Singh and Malik, 1992).

Jayakumar *et al.* (1987) reported that in unweeded plots weeds removed 10 kg P ha^{-1}, which was ten times more than when the plots were treated with chemicals or weeded manually, and the uptake was reduced by 50 per cent. Successful weed management in upland rice with thiobencarb application @ 1.5 kg ai ha^{-1} reduced the N uptake by weeds which ultimately was made available to the crop, resulted in increased fertilizer use efficiency and grain yield (Sharma and Gupta, 1992).

Hand weeding and chemical weeding treatments significantly decreased the nutrient removal through weeds as well as increased the uptake by crop and gave higher grain (Choubey *et al.*, 1999).

2.5.5 Phytotoxicity to rice and intercrops

According to Arceo and Mercado (1981), application of butachlor two days before sowing exhibited the lowest phytotoxicity in rice with improved weed control than when applied at 6 days after sowing (DAS). Rao and Rao (1990) found that application of butachlor 1.5 kg ai ha^{-1} on three DAS to be useful in controlling *Echinochloa colonum* without any phytotoxic effect on rice seedlings. Emmanuel *et al.* (1991) observed that butachlor did not inhibit rice seed germination. In an experiment where 11 kinds of vegetable seeds were used to bioassay the toxicity of butachlor, that of lettuces (*Lactuca Scariola* var. sativa) was the most sensitive and the length of lettuce seedlings were markedly inhibited by butachlor at one ppm (Yeh and Huang, 1996).

Application of pendimethalin immediately after sowing or after the receipt of rain resulted in rice injury, but when the application was delayed by four days after emergence or after rain, no crop injury was noticed (IRRI, 1979). Ali *et al.* (1985)

reported reduction in rice yield due to phytotoxic effect of butachlor @ 1.0 kg ha^{-1} at 8 days after sowing. Significantly higher spikelet sterility was caused by pendimethalin which could probably be due to its influence on translocation of photosynthates to the grains (Angiras and Sharma, 1998).

In a field trial conducted at two sites in Indonesia to determine the effects of pretilachlor 300 EC, pretilachlor 500 EC and piperophos 500 EC, applied four days after direct sowing of low land rice, the height and tiller number of rice was unaffected by the herbicides, but those treated with pretilachlor 500 EC and piperophos 500 EC exhibited medium to very severe symptoms of toxicity when examined 14 and 28 but not 42 days after sowing (Marzuki and Bangun, 1990).

Oxyfluorfen application on rice resulted in initial yellowing, which was later recovered after about 2 to 3 weeks (Mukhopadhyay and Mandal, 1982). According to Yasin *et al.* (1988), no inhibitory effect on rice seed germination was noticed by the application of oxyfluorfen. Toxicity by oxyfluorfen was confirmed by an experiment at Madurai in semi-dry rice where phytotoxic symptoms observed in rice seedlings by the application of oxyfluorfen which completely disappeared later (Porpavai and Ramiah, 1992).

Exposure of weed and crop to thiobencarb had no impact on germination and did not markedly affect photosynthesis or respiration of rice seedlings. The inhibition of top growth with the application of thiobencarb was severe in case of *Echinochloa crusgalli* but temporary in the case of rice and it was due to the inhibition in cell elongation governed by auxin and protein synthesis (Ichizen, 1980). Om *et al.* (1988) reported that thiobencarb was phytotoxic at pre or post sowing. Rao and Rao (1990) found that application of thiobencarb at 1.87 and 2.50 kg ai ha^{-1} was found effective in controlling *Echinochloa colona* without any phytotoxic effect on rice seedlings.

In a field experiment conducted to study the effect of weed management practices on growth and yield of rice-fallow blackgram, the growth of blackgram crop was affected with different herbicide treatments because of their varying degree of phytotoxicity on blackgram crop. The sand mix applications of butachlor, anilofos, fluchloralin and pendimethalin had not much effect on crop growth but the EC formulations of all the herbicides except butachlor were found to be more phytotoxic to the crop. Among these herbicides, pendimethalin at 1.5 kg ha^{-1} as EC application at one day after harvesting of rice caused severe phytotoxic effect on blackgram and severely affected the crop stand and establishment (Appanna *et al.*, 1997).

According to Balasubramanian *et al.* (1999) the pre-emergence herbicides thiobencarb, butachlor, pretilachlor and anilofos applied at recommended doses continuously for four seasons in rice resulted in soil residues below toxic levels and residues in plant parts lower than the maximum allowable level. The herbicide residues found in the soil after rice was harvested were below toxic levels and hence did not influence the germination and yield of blackgram (*Vigna mungo*) raised subsequently.

Reviews on chemical weed control in general showed that pendimethalin can be used safely both in rice and pulses. However, reports on the effect of other rice herbicides on pulses are scarce, it justifies the present study.

Materials and Methods

3. MATERIALS AND METHODS

The research project entitled "Weed management in semi-dry rice intercropped with green manure crops" was undertaken at the Agricultural Research Station (ARS), Mannuthy of Kerala Agricultural University during April to August, 2002. The details of materials used and methods adopted in the conduct of the experiment are presented in this chapter.

3.1 LOCATION

The experiment was conducted at the Agricultural Research Station, Mannuthy, Thrissur. The station is geographically situated at 10° 31' N latitude, 76° 13' E longitude and at an altitude of 40.3 m above mean sea level. It is located six kilometers away from Thrissur on the southern side of NH 47.

3.1.1 Soil

Soil of the experimental site is texturally classified as sandy loam, belonging to the taxonomical order oxisol. The soil is acidic in reaction with a pH of 5.6. Field capacity of the soil was 19.7 per cent and the permanent wilting point was 11.3 per cent. The basic physico-chemical properties of the soil are presented in Table 1.

3.1.2 Climate

The area of the experimental site enjoys a typical humid tropical climate. The normal weather of the area and the weather which prevailed during the experimental period are presented in Appendix I and Appendix II and illustrated in Fig.1a and 1b, and Fig.2a and 2b respectively. The mean annual rainfall of the area is 2669 mm with 75 per cent received during south west monsoon, 16.6 per cent during North East monsoon and rest being distributed in the summer months. The relative humidity of the area during virippu season normally ranges from 73 (May) to 86 (July) per cent and the bright sunshine hours from 3.4 (June - July) to 7.1 (May). The relative

Table 1. Basic physico-chemical properties of the soil of the experimental site

Parameters	Value	Method used
a) Mechanical composition		Hydrometer method (Piper, 1966)
Sand (%)	75.9	
Silt (%)	4.4	
Clay (%)	18.4	
b) Physical characteristics		
Bulk density (g cc^{-1})	1.33	
Water holding capacity (%)	49.1	
c) Chemical properties		
Organic Carbon (%)	0.66	Walkley and Black method (Jackson, 1958)
Available Nitrogen (kg ha^{-1})	276.0	Alkaline permanganate distillation (Subbiah and Asija, 1956)
Available Phosphorus (kg ha^{-1})	19.3	Bray extractant - Ascorbic acid reductant method (Watanabe and Olsen, 1965)
Available Potassium (kg ha^{-1})	89.6	Neutral normal ammonium acetate extractant flame photometry (Jackson, 1958)

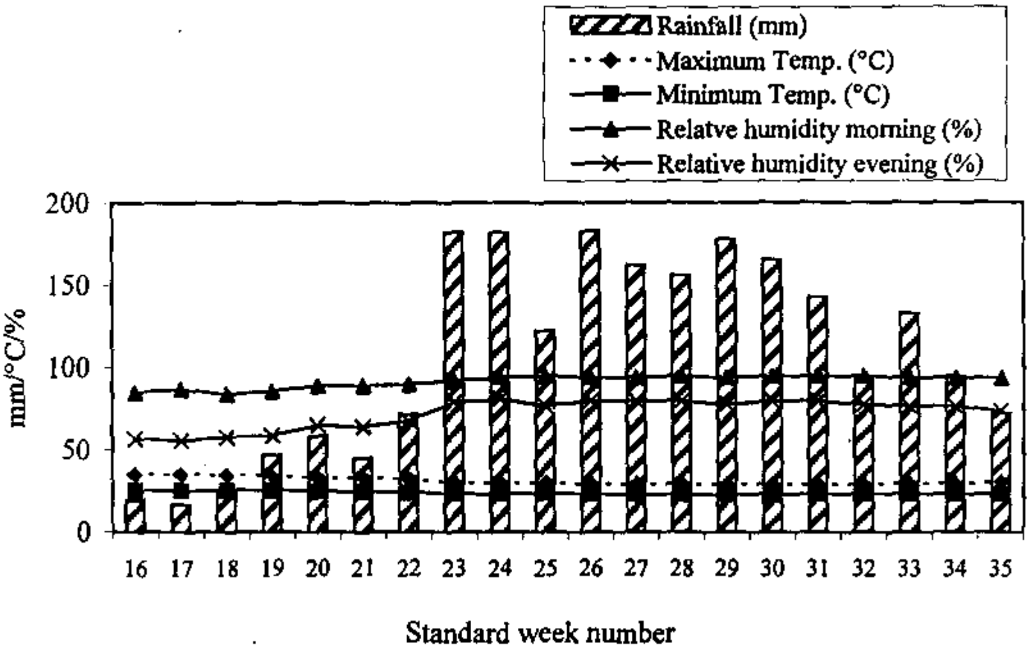

Fig. 1a. Weekly data on rainfall, temperature and humidity during the period corresponding to cropping season averaged over 12 years (1991-2002)

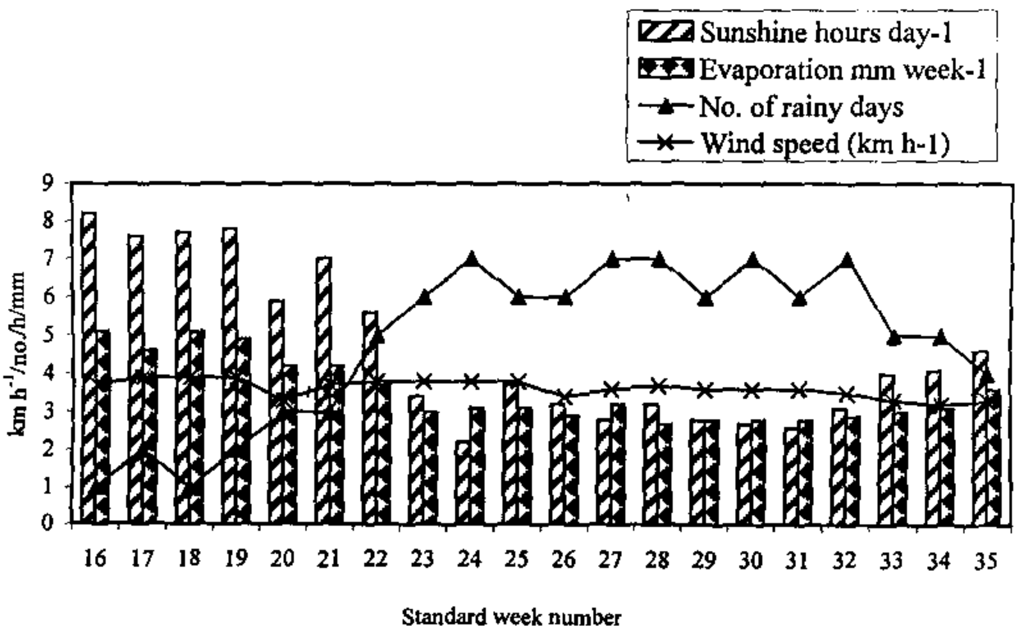

Fig. 1b. Weekly data on sunshine hours, no. of rainy days, evaporation and wind speed during the period corresponding to cropping season averaged over twelve years (1991-2002)

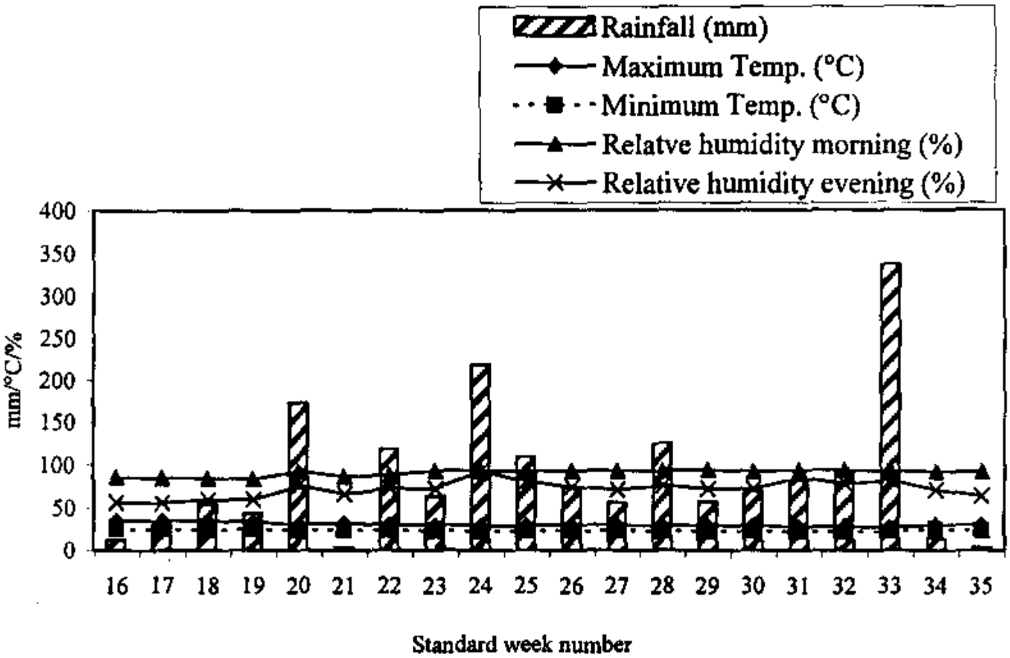

Fig. 2a. Weekly data on rainfall, temperature and humidity during the cropping season

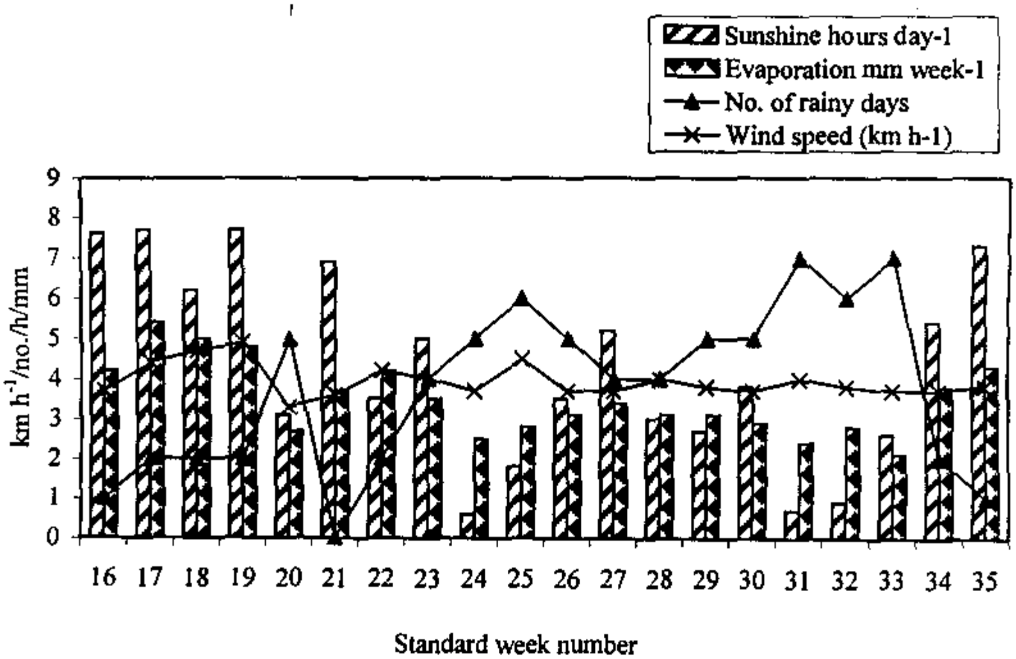

Fig. 2b. Weekly data on sunshine hours, no. of rainy days, evaporation and wind speed during the cropping season

humidity recorded during the cropping period ranged from 84 (June-July) to 87 (May) per cent and the bright sunshine hours from 2.7 (June-July) to 3.1 (August). The weather which prevailed during the experimental period was normal.

3.1.3 Season

The field trial was conducted during the early virippu season from April to August, 2002.

3.2 MATERIAL USED

3.2.1 Seeds

3.2.1.1 Rice

The rice variety used for the experiment was Jyothi, a red kernelled, short duration variety of 110-120 days duration. Jyothi is a variety suitable for direct seeding during virippu (kharif) season. The grains are long and bold. The variety is tolerant to BPH and susceptable to sheath blight and capable of producing moderately good yields even under stress conditions.

3.2.1.2 Cowpea

Kanakamony (PTB-1), a pure line selection of cowpea was used as one of the green manure crop for intercropping.

3.2.1.3 Horse gram

Local variety of horse gram is used as the other green manure crop for intercropping.

3.2.1.4 Herbicides

3.2.1.4.1 Anilofos

Molecular formula	-	$CH_3H_{19}ClNO_3PS_2$
Chemical family	-	Organophosphorus
Mode of action	-	Selective herbicide, absorbed through the roots and to some extent, through the leaves

3.2.1.4.2 Butachlor

Molecular formula	-	$C_{17}H_{26}ClNO_2$
Chemical family	-	Acetamide
Mode of action	-	Selective systemic herbicide, absorbed primarily by the germinating roots, with translocation throughout the plant, giving higher concentrations in vegetative parts than in reproductive parts.

3.2.1.4.3 Pendimethalin

Molecular formula	-	$C_{13}H_{19}N_3O_4$
Chemical family	-	Nitrocompound
Mode of action	-	Selective systemic herbicide, absorbed by the roots and leaves. Inhibits cell division and cell elongation. Affected plants die shortly after germination or following emergence from the soil.

3.2.1.4.4 Pretilachlor

Molecular formula	-	$C_{17}H_{26}ClNO_2$
Chemical family	-	Acetamide
Mode of action	-	Selective herbicide.

3.2.2 Cropping history

The experimental site is a double crop paddy wetland, where a semi-dry crop is taken during April-May to August-September and a transplanted crop during September-October to December-January every year. The land is usually left fallow during the summer season.

3.2.3 Treatments

The experiment consisted of 14 treatments. The details of the treatments are furnished below.

T_1 - Rice + cowpea with Butachlor (Buta) @ 1.25 kg ai ha^{-1}

T_2 - Rice + cowpea with Pendimethalin (Pendi) @ 1.5 kg ai ha^{-1}

T_3 - Rice + cowpea with Pretilachlor (Pret) @ 0.75 kg ai ha^{-1}

T_4 - Rice + cowpea with Anilofos (Anilo) @ 0.40 kg ai ha^{-1}

T_5 - Rice + cowpea with hand weeding (HW) (twice)

T_6 - Rice + cowpea with no weeding (NW)

T_7 - Rice + horsegram with Butachlor @ 1.25 kg ai ha^{-1}

T_8 - Rice + horsegram with Pendimethalin @ 1.5 kg ai ha^{-1}

T_9 - Rice + horsegram with Pretilachlor @ 0.75 kg ai ha^{-1}

T_{10} - Rice + horsegram with Anilofos @ 0.40 kg ai ha^{-1}

T_{11} - Rice + horsegram with hand weeding (twice)

T_{12} - Rice + horsegram with no weeding

T_{13} - Rice alone with hand weeding (twice)

T_{14} - Rice alone with no weeding

3.2.4 Design and layout

Design - RBD

Replications - 3

Gross plot size - 5 x 4 m; Net plot size - 3.3 x 3.2 m (Apart from the border rows all around the plot, a sampling strip of 50 cm width along with two more border rows were left along the 5.0 m side which was excluded from the gross plot); Spacing - 20 x 10 cm.

The layout plan is given in Fig.3. Treatment without concurrent cropping and treatment with concurrent cropping are presented in Plates 1a and 1b.

System of intercropping: One row of green manure crop was sown between two rows of rice.

3.3 FIELD EXPERIMENT

3.3.1 Sowing and harvesting

Date of sowing - 27-4-02

Date of harvesting - 26-8-02

Duration of the crop - 121 days

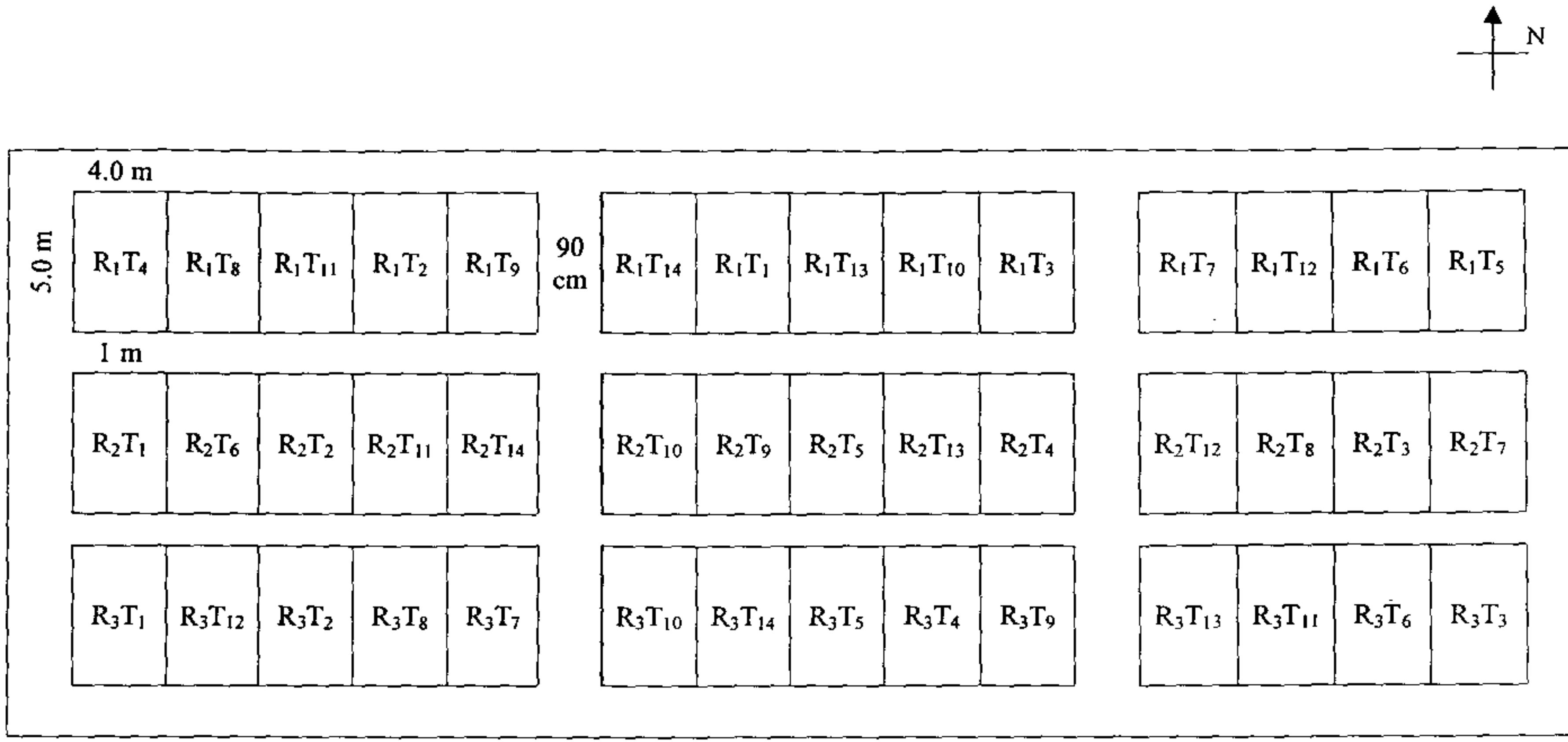

Fig. 3. Layout of the experimental field

Plate 1a. Treatment without concurrent cropping

Plate 1b. Treatment with concurrent cropping

3.3.2 Crop husbandry

3.3.2.1 Land preparation

The experimental field was ploughed using tractor drawn disc plough and pulverized using rotovator. The plots of size 5 x 4 m were made forming ridges around the plots. The individual plots were perfectly levelled manually before sowing.

3.3.2.2 Sowing

Sowing was done in finely prepared soil by dibbling. The soil moisture was optimum at the time of sowing with the receipt of pre-monsoon showers.

3.3.2.3 Manures and fertilizer

FYM @ 5 t ha^{-1} was applied uniformly to plots and incorporated by digging before sowing.

Urea (46% N), Mussorie Rock Phosphate (20% P_2O_5) and MOP (60% K_2O) were the fertilizers used for the experiment. Fertilizers were applied uniformly to all the plots at the rate of 70:35:35 kg N, P_2O_5 and K_2O ha^{-1}. The entire quantity of P, 2/3 N and 1/2 K were applied as basal and the remaining quantity of N and K were applied as top dressing at panicle initiation stage (KAU, 2002).

3.3.2.4 After cultivation

Pre-emergent herbicides were applied in the plots on the second day of sowing as per the treatments.

Thinning was done on ten DAS to maintain the required plant population.

At 30 and 60 DAS, hand weeding was done in the hand weeding treatments.

By the onset of monsoon, the field got flooded by 55 DAS and the greenmanure crops were wilted and self decomposed within a period of one week.

3.3.2.5 Harvesting

Harvesting was done at 121 days after sowing. Two border rows all around the plots were harvested first and removed. A sampling strip of 50 cm width with two additional border rows were also left on one side. Six hills were uprooted at random from each plot for observations on panicle characteristics and for chemical analysis. Remaining crop was harvested and threshed. The grain and straw were sun dried for two days and the weight recorded.

3.3.3 Observations

Six hills were randomly selected from each plot as suggested by Gomez (1972) for recording the growth and yield observations except seedling population, number of tillers m^{-2} and number of panicle^{-2}. The following observations were recorded at different growth stages.

3.3.3.1 Observations on growth characters

3.3.3.1.1 Rice

3.3.3.1.1.1 Seedling population

Number of seedlings were counted from a randomly selected quadrat of 0.25 m^2 from each plot and expressed as number of seedlings m^{-2}. It was done from one to ten days after sowing at two days intervals.

3.3.3.1.1.2 Height of the plant

Plant height was measured from the base to the tip of the top most leaf at active tillering stage (ATS), panicle initiation stage (PIS) and flowering (Flg.). At harvest, the height was recorded from the base of the plant to the tip of the longest panicle and the mean height was computed and expressed in cm.

3.3.3.1.1.3 Number of tillers m^{-2}

The number of tillers were counted from a quadrat of 0.25 m^2 selected at random at ATS, PIS, Flg and harvest and expressed as number of tillers m^{-2}.

3.3.3.1.1.4 Leaf area

Leaf area was calculated at ATS, PIS and Flg using the length-width method suggested by Gomez (1972). Accordingly, leaf area = k x l x w where

k = adjustment factor

l = the length of leaf

w = the maximum width of leaf

(at seedling and harvest - 0.67, ATS and PIS - 0.75)

LAI was calculated from the leaf area considering the area occupied by the plants.

3.3.3.1.1.5 Dry matter production

Dry matter production (DMP) was estimated at ATS, PIS, Flg and harvest. At each observation, sample hills were uprooted, washed free of soil, oven dried at 70-80°C to constant weight and dry matter production was computed and expressed in kg ha^{-1}. At harvest, the sum total of grain and straw yields were taken as the total DMP.

3.3.3.1.1.6 Root:shoot ratio

Root:shoot ratio was worked out at ATS, PIS, Flg and harvest. At each observation, sample hills were uprooted, washed free of soil, oven dried at 70°-80°C to constant weight, root and shoot separated, weighed and expressed as root:shoot ratio.

3.3.3.1.2 Green manure crops

3.3.3.1.2.1 Seedling population

Number of seedlings were counted from a randomly selected quadrat of 0.25 m^2 from each plot and expressed as number of seedlings m^{-2}. It was done from seedling up to 10 DAS at two days interval.

3.3.3.1.2.2 Height of the plant

Height of the plant was measured from the scar of the first cotyledonous leaves of the plant to the tip of the growing point and expressed in cm at 20 and 40 DAS.

3.3.3.1.2.3 Nodule count

The plants were uprooted carefully at 20 and 40 DAS, washed the roots free of soil particles and nodules on the tap root and lateral roots were counted and expressed as number of nddules plant^{-1}.

3.3.3.1.2.4 Leaf area

In cowpea and horsegram, the following formulae were adopted (Puttaswamy *et al.*, 1976).

In cowpea, leaf area = l x b x No. of leaflets x 0.704

In horsegram, leaf area = l x b x 1.72

LAI was calculated from the leaf area considering the area occupied by the plants.

3.3.3.1.2.5 Dry matter production

DMP was estimated at 20 and 40 DAS. The sample plants were uprooted, washed free of soil, oven dried at 70-80°C to constant weight and dry matter production was computed and expressed in kg ha^{-1}.

3.3.3.1.2.6 Root:shoot ratio

Root:shoot ratio was worked out at 20 and 40 DAS. The sample plants were uprooted, washed free of soil, oven dried at 70-80°C to constant weight, root and shoot separated, weighed and expressed as root:shoot ratio.

3.3.3.2 Observations on yield and yield attributes of rice

3.3.3.2.1 Days to 50 per cent flowering

Number of days taken by 50 per cent of the plants to come to flowering from the date of sowing was recorded from each plot.

3.3.3.2.2 Number of panicles m^{-2}

At harvest, number of panicles were counted from a randomly selected quadrat of 0.25 m^2 from each plot and expressed as number of panicles m^{-2}.

3.3.3.2.3 Panicle weight

Ten main panicles were collected from each plot at random, mean weight worked out and expressed in g.

3.3.3.2.4 Number of filled grains panicle^{-1}

The filled grains from ten randomly selected panicles were counted and the average worked out.

3.3.3.2.5 Percentage of filled grains

The grains from the randomly selected panicles from each plot were separated to filled and unfilled grains and counted to workout the percentage of filled grains.

3.3.3.2.6 1000 grain weight

1000 grains collected from the randomly selected panicles from each plot was counted and the weight recorded in g.

3.3.3.2.7 Straw yield

Straw from the net plot was dried in sun, uniformly weighed and expressed in kg ha^{-1}.

3.3.3.2.8 Grain yield

The grain from each plots were sun dried, cleaned, winnowed, weighed and expressed in kg ha^{-1}.

3.3.3.2.9 Harvest index (HI)

Harvest index was calculated using the data on grain yield and straw yield as per the following formula.

$$HI = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Grain + Straw yield (kg ha}^{-1}\text{)}}$$

3.3.3.3 Observations on weed incidence

The observations on weeds were taken from plot from the sampling strip using a 50 cm x 50 cm (0.25 m^2) iron quadrat. The following observations were recorded.

3.3.3.3.1 Weed count

The weed count from the sampling unit in each plot was taken species wise and recorded as number m^{-2}. The observations were taken at 30, 60, 90 DAS and at harvest. The count of major weeds (species wise) as well as total grass, sedge and broad leaved weeds recorded.

3.3.3.3.2 Weed dry matter production

The weeds from the sampling area in each plot were uprooted, dried initially in shade and then in a hot air oven at 70°C and the weed dry weight was recorded in g m^{-2} at 30, 60, 90 DAS and at harvest.

3.3.3.4 Plant analysis

Sample plants collected from each plot at ATS, PIS and harvest were sun dried, oven dried to constant weight, grain and straw separated, ground, digested and nutrient content estimated. The N content (microkjeldhal method), P content (vanadomolybdo phosphoric yellow colour method) and K content (Flame photometer method) were estimated for grain and straw separately (Jackson, 1958). Similarly, NPK content of green manure crops at self decomposition stage (45 DAS) and weeds at 60, 90 DAS and at harvest were also estimated.

3.3.3.4.1 Uptake of nutrients

The content of N, P, K were multiplied with the respective dry matter yields to get the uptake values and expressed as kg ha^{-1}. Uptake values were calculated for rice, green manure crops and weeds at different stages of growth.

3.3.3.5 Economics of treatments

The labour charges of the locality, cost of inputs and extra treatment costs were taken together and gross expenditure was computed and expressed in Rupees ha^{-1}. The price of paddy and that of the straw at current local market prices were taken as total receipts for computing gross return and expressed in Rupees ha^{-1}. Benefit:cost ratio was worked out by dividing the gross return with the total expenditure per hectare.

3.3.3.6 Soil analysis

Soil samples were collected from the experimental area before and after the experiment and one week after self decomposition of the green manure crop from each plot, dried in shade, sieved through 2 mm sieve and analysed.

The available N content of the soil was estimated by alkaline permanganate method (Subbiah and Asija, 1956), available P by Bray's method and available K by ammonium acetate method (Jackson, 1958).

Results

4. RESULTS

A field experiment was conducted during kharif 2002 at ARS, Mannuthy to study the effect of weed management in semi-dry rice intercropped with green manure crops. The data collected from the experiment were analysed statistically and the results are presented in this chapter.

4.1 GROWTH CHARACTERS

4.1.1 Rice

4.1.1.1 Seedling population

The population of rice seedlings was significantly influenced by the treatments during all the periods of observation(Table 2). At five DAS, the maximum number of seedlings was observed in T_1 (R + CP + Buta) and T_9 (R + Hg + Pret) which were on par with most of the remaining treatments except T_5, T_{11} and T_{13}. Both at seven and nine DAS, T_8 (R + Hg + Pendi) recorded the maximum seedling population but was on par with T_3, T_6, T_7, T_9, T_{12} and T_{14}.

4.1.1.2 Height of the plant

Regarding height of the plants(Table 3) at ATS, significant difference was noticed among treatments. T_2 (R + CP + Pendi) recorded the maximum height but it was on par with T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11} and T_{12}. The lowest height was recorded by T_{14} (R + HW) followed by T_1 (R + CP + Buta).

At PIS, maximum height was noticed in T_5 (R + CP + HW) eventhough T_3, T_7, T_9, T_{11} and T_{13} were also statistically on par. Plant heights were comparatively lower in T_1, T_4, T_{12} and T_{14} and the lowest height was recorded by T_4 (R + CP + Anilo).

At flowering and harvest stages, maximum height was noticed in T_9 (R + Hg + Pret). It was on par with T_2, T_3, T_5, T_7, T_8, T_{11} and T_{13}. Plant height was

Table 2. Effect of treatments on population of rice seedlings m^{-2}

Treatments	Days after sowing		
	Five	Seven	Nine
T_1 - R + CP + Buta	95.3^{a}	107.0^{ab}	115.0^{bcd}
T_2 - R + CP + Pendi	63.7^{ab}	87.3^{abc}	100.3^{cde}
T_3 - R + CP + Pret	78.3^{ab}	92.0^{abc}	121.3^{abcd}
T_4 - R + CP + Anilo	72.7^{ab}	90.0^{abc}	100.0^{de}
T_5 - R + CP + HW	55.7^{b}	74.7^{c}	115.7^{bcd}
T_6 - R + CP + NW	69.0^{ab}	92.7^{abc}	126.0^{ab}
T_7 - R + Hg + Buta	80.3^{ab}	103.7^{ab}	124.7^{ab}
T_8 - R + Hg + Pendi	81.0^{ab}	111.7^{a}	140.3^{a}
T_9 - R + Hg + Pret	94.3^{a}	105.0^{ab}	117.3^{abcd}
T_{10} - R + Hg + Anilo	63.0^{ab}	84.3^{bc}	131.0^{ab}
T_{11} - R + Hg + HW	53.7^{b}	70.3^{c}	100.0^{de}
T_{12} - R + Hg + NW	79.0^{ab}	101.7^{ab}	123.3^{abc}
T_{13} - R + HW	54.3^{b}	74.0^{c}	109.3^{bcd}
T_{14} - R + NW	75.3^{ab}	88.7^{abc}	118.0^{abcd}

The values followed by same letters do not differ significantly in DMRT

Table 3. Effect of treatments on height (cm) of rice

Treatments	Crop growth stages			
	ATS	PIS	Flg	Harvest
T_1 - R + CP + Buta	40.9 ^{cd}	57.3 ^{d}	85.7 ^{bc}	85.3 ^{bc}
T_2 - R + CP + Pendi	52.7 ^{a}	59.8 ^{cd}	87.5 ^{ab}	86.7 ^{ab}
T_3 - R + CP + Pret	48.4 ^{abc}	68.5 ^{a}	88.9 ^{ab}	88.6 ^{ab}
T_4 - R + CP + Anilo	46.3 ^{abcd}	55.9 ^{d}	80.9 ^{d}	80.4 ^{d}
T_5 - R + CP + HW	44.8 ^{abcd}	69.9 ^{a}	88.3 ^{ab}	87.9 ^{ab}
T_6 - R + CP + NW	51.5 ^{ab}	61.4 ^{bcd}	86.0 ^{bc}	85.4 ^{bc}
T_7 - R + Hg + Buta	47.5 ^{abc}	64.8 ^{abc}	88.2 ^{ab}	87.7 ^{ab}
T_8 - R + Hg + Pendi	47.8 ^{abc}	60.7 ^{cd}	88.1 ^{ab}	87.6 ^{ab}
T_9 - R + Hg + Pret	50.0 ^{ab}	69.7 ^{a}	91.5 ^{a}	91.0 ^{a}
T_{10} - R + Hg + Anilo	49.8 ^{ab}	59.8 ^{cd}	82.9 ^{cd}	82.1 ^{cd}
T_{11} - R + Hg + HW	45.3 ^{abcd}	64.8 ^{abc}	88.0 ^{ab}	87.8 ^{ab}
T_{12} - R + Hg + NW	45.5 ^{abcd}	56.5 ^{d}	80.8 ^{d}	80.2 ^{d}
T_{13} - R + HW	43.0 ^{bcd}	66.5 ^{ab}	88.4 ^{ab}	87.9 ^{ab}
T_{14} - R + NW	39.3 ^{d}	58.0 ^{d}	81.2 ^{d}	0.00 ^{e}

The values followed by same letters do not differ significantly in DMRT

relatively lower in T_1, T_6, T_{10}, T_4, T_{12} and T_{14} and the lowest height was recorded by T_{12} (R + Hg + NW).

4.1.1.3 Number of tillers m^{-2}

Significant difference in tiller number m^{-2} was noticed among the treatments during all the four stages of observations (Table 4). At ATS, maximum tiller production was noticed in T_{13} (R + HW) but it was on par with T_7, T_9, T_{11} and T_{14}. Tiller production was comparatively lower in T_1, T_2, T_3, T_4, T_5, T_6, T_8 and T_{10} and no significant difference was noticed among these treatments. Lowest number of tillers m^{-2} was noticed in T_{12}(R + Hg + NW).

At PIS also, maximum number of tillers were noticed in T_{13} (R + HW) which was on par with T_8 (R + Hg + Pendi). Next best treatments with respect to the number of tillers were T_1, T_2, T_3, T_5, T_7, T_9, T_{11} which were comparable. Tiller production was lower in T_6, T_{12} and T_{14} with the lowest in T_{14}(R + NW).

At flowering also, maximum number of tillers was noticed in T_{13} (R + HW) which was on par with T_7 (R + Hg + Buta) and T_{11} (R + Hg + HW). T_{12} (R + Hg + NW) recorded the lowest tiller number followed by T_6 and T_{14}.

At harvest, T_{13} (R + HW) was found to be the best treatment which was significantly superior to all other treatments. Only very few tillers were produced in T_{14} (R + NW), T_{12} (R + Hg + NW) and T_6 (R + CP + NW).

4.1.1.4 Leaf area index (LAI)

At ATS, maximum LAI was recorded by T_{13} (R + HW) which was comparable to T_8. T_{14} (R + NW) recorded the lowest LAI and was comparable to T_1, T_4, T_6 and T_{12} (Table 5).

At PIS, T_{13} (R + HW) recorded the maximum LAI which was comparable to T_2, T_8 and T_9. Lowest LAI was noticed in T_{14} (R + NW) which was comparable to T_6.

Table 4. Effect of treatments on number of tillers m^{-2} of rice

Treatments	Crop growth stages			
	ATS	PIS	Flg	Harvest
T_1 - R + CP + Buta	213.3 ^{bc}	294.7 ^{bc}	241.7 ^{cde}	201.3 ^{de}
T_2 - R + CP + Pendi	227.7 ^{bc}	311.3 ^{b}	233.3 ^{de}	229.7 ^{cd}
T_3 - R + CP + Pret	214.7 ^{bc}	292.0 ^{bc}	264.7 ^{bcd}	248.0 ^{bc}
T_4 - R + CP + Anilo	228.3 ^{bc}	233.7 ^{c}	199.3 ^{ef}	65.0 ^{g}
T_5 - R + CP + HW	217.7 ^{bc}	298.3 ^{bc}	222.3 ^{def}	171.7 ^{e}
T_6 - R + CP + NW	209.0 ^{bc}	127.7 ^{d}	59.7 ^{g}	27.0 ^{h}
T_7 - R + Hg + Buta	249.0 ^{ab}	326.7 ^{b}	294.0 ^{ab}	233.0 ^{bcd}
T_8 - R + Hg + Pendi	204.0 ^{bc}	421.3 ^{a}	277.3 ^{bc}	223.0 ^{cd}
T_9 - R + Hg + Pret	256.0 ^{ab}	333.0 ^{b}	258.0 ^{bcd}	227.0 ^{cd}
T_{10} - R + Hg + Anilo	228.0 ^{bc}	237.0 ^{c}	186.7 ^{f}	104.0 ^{f}
T_{11} - R + Hg + HW	262.0 ^{ab}	354.3 ^{b}	297.7 ^{ab}	263.7 ^{b}
T_{12} - R + Hg + NW	178.3 ^{c}	138.7 ^{d}	51.7 ^{g}	7.0 ^{h}
T_{13} - R + HW	304.0 ^{a}	454.7 ^{a}	322.3 ^{a}	306.3 ^{a}
T_{14} - R + NW	258.3 ^{ab}	106.3 ^{d}	70.7 ^{g}	0.0 ^{h}

The values followed by same letters do not differ significantly in DMRT

Table 5. Effect of treatments on LAI of rice

Treatments	Crop growth stages		
	ATS	PIS	Flg
T_1 - R + CP + Buta	0.91 ^{def}	2.70 ^{cd}	2.97 ^{b}
T_2 - R + CP + Pendi	1.03 ^{b}	2.84 ^{ab}	3.19 ^{a}
T_3 - R + CP + Pret	0.98 ^{bcde}	2.80 ^{bc}	3.18 ^{a}
T_4 - R + CP + Anilo	0.90 ^{ef}	2.63 ^{d}	2.80 ^{c}
T_5 - R + CP + HW	0.99 ^{bcd}	2.66 ^{d}	3.01 ^{b}
T_6 - R + CP + NW	0.89 ^{f}	2.32 ^{f}	2.71 ^{cd}
T_7 - R + Hg + Buta	1.01 ^{bc}	2.70 ^{cd}	2.99 ^{b}
T_8 - R + Hg + Pendi	1.04 ^{ab}	2.82 ^{ab}	3.22 ^{a}
T_9 - R + Hg + Pret	1.00 ^{bc}	2.76 ^{abc}	3.21 ^{a}
T_{10} - R + Hg + Anilo	0.98 ^{bcde}	2.52 ^{e}	2.83 ^{c}
T_{11} - R + Hg + HW	0.97 ^{bcde}	2.80 ^{bc}	3.17 ^{a}
T_{12} - R + Hg + NW	0.93 ^{cdef}	2.45 ^{e}	2.70 ^{cd}
T_{13} - R + HW	1.11 ^{a}	0.96 ^{a}	3.27 ^{a}
T_{14} - R + NW	0.87 ^{f}	2.31 ^{f}	2.63 ^{d}

The values followed by same letters do not differ significantly in DMRT

At flowering also, T_{13} (R + HW) recorded the highest LAI. T_{13} was comparable with T_2, T_3, T_8, T_9 and T_{11} but superior to T_1, T_5 and T_7. The lowest LAI was recorded by T_{14} (R + NW) but was comparable with T_6 and T_{12}.

4.1.1.5 Dry matter production (DMP)

The DMP of rice was significantly influenced by the treatments at all the stages of observation (Table 6).

At ATS, T_{13} (R + HW) was the best and T_{11} (R + Hg + HW) was on par with it. These treatments were superior to all other treatments. The lowest DMP was noticed in T_{14} (R + NW) which was comparable to T_6 (R + CP + NW).

At PIS, T_{13} (R + HW) has got the highest DMP and it was on par with T_2 (R + CP + Pendi) and T_8 (R + Hg + Pendi). Lowest DMP was recorded by T_{14} (R + NW) which was comparable with T_{12} (R + Hg + NW).

At flowering, T_8 (R + Hg + Pendi) was found to be the best eventhough T_2 (R + CP + Pendi) and T_{13} (R + HW) were statistically on par with T_8 (R + Hg + Pendi). Next best treatments were T_1, T_3, T_5, T_7, T_9 and T_{11} which were on par. The lowest DMP was recorded by T_{14} (R + NW) which was on par with T_{12} (R + Hg + NW). Almost similar results were noticed at harvest also. In all the stages, the highest DMP was noticed in T_{13} (R + HW) and the lowest in T_{14} (R + NW).

4.1.1.6 Root : Shoot ratio

Root : shoot ratio was found to be increasing from ATS to PIS and thereafter reduces upto harvest (Table 7). The root : shoot ratio was found to vary significantly among treatments at all the growth stages. At all the stages, T14 (R + NW) had the maximum root : shoot ratio.

At ATS, lowest root : shoot ratio was recorded by T_8 (R + Hg + Pendi). It was followed by T_{13} (R + HW) and T_{11} (R + Hg + HW). Highest root : shoot ratio was recorded by T_{14} (R + NW) which was comparable to T_4, T_6, T_{10} and T_{12}.

Table 6. Effect of treatments on dry matter production (q ha^{-1}) of rice

Treatments	Crop growth stages			
	ATS	PIS	Flg	Harvest
T_1 - R + CP + Buta	10.35 ^{bc}	14.95 ^{c}	24.35 ^{b}	25.24 ^{e}
T_2 - R + CP + Pendi	10.67 ^{bc}	18.11 ^{ab}	32.30 ^{a}	41.88 ^{abc}
T_3 - R + CP + Pret	11.39 ^{b}	16.03 ^{bc}	25.52 ^{b}	30.85 ^{abc}
T_4 - R + CP + Anilo	10.51 ^{bc}	9.92 ^{de}	8.70 ^{c}	7.95 ^{f}
T_5 - R + CP + HW	10.99 ^{b}	16.55 ^{bc}	22.91 ^{b}	29.70 ^{de}
T_6 - R + CP + NW	6.45 ^{ef}	8.80 ^{ef}	6.41 ^{c}	3.63 ^{f}
T_7 - R + Hg + Buta	11.48 ^{b}	17.00 ^{bc}	26.89 ^{b}	35.03 ^{bcde}
T_8 - R + Hg + Pendi	11.53 ^{b}	18.36 ^{ab}	34.13 ^{a}	45.04 ^{ab}
T_9 - R + Hg + Pret	10.80 ^{b}	17.21 ^{bc}	26.90 ^{b}	36.47 ^{bcde}
T_{10} - R + Hg + Anilo	9.03 ^{cd}	12.26 ^{d}	8.91 ^{c}	10.16 ^{f}
T_{11} - R + Hg + HW	11.96 ^{ab}	17.04 ^{bc}	26.84 ^{b}	36.96 ^{bcd}
T_{12} - R + Hg + NW	7.77 ^{de}	6.68 ^{fg}	4.41 ^{cd}	1.07 ^{f}
T_{13} - R + HW	13.48 ^{a}	20.13 ^{a}	33.97 ^{a}	49.87 ^{a}
T_{14} - R + NW	4.95 ^{f}	5.65 ^{g}	1.28 ^{d}	0.0 ^{f}

The values followed by same letters do not differ significantly in DMRT

Table 7. Effect of treatments on root : shoot ratio of rice

Treatments	Crop growth stages			
	ATS	PIS	Flg	Harvest
T_1 - R + CP + Buta	0.217 ^{cd}	0.323 ^{fg}	0.227 ^{de}	0.183 ^{c}
T_2 - R + CP + Pendi	0.213 ^{cd}	0.320 ^{g}	0.227 ^{de}	0.143 ^{gh}
T_3 - R + CP + Pret	0.227 ^{bcd}	0.327 ^{ef}	0.220 ^{fg}	0.140 ^{hi}
T_4 - R + CP + Anilo	0.270 ^{abc}	0.367 ^{bc}	0.253 ^{ab}	0.180 ^{cd}
T_5 - R + CP + HW	0.213 ^{cd}	0.327 ^{ef}	0.217 ^{gh}	0.177 ^{d}
T_6 - R + CP + NW	0.283 ^{ab}	0.363 ^{c}	0.250 ^{b}	0.190 ^{b}
T_7 - R + Hg + Buta	0.223 ^{cd}	0.320 ^{g}	0.230 ^{d}	0.170 ^{e}
T_8 - R + Hg + Pendi	0.200 ^{d}	0.340 ^{d}	0.223 ^{ef}	0.147 ^{g}
T_9 - R + Hg + Pret	0.217 ^{cd}	0.330 ^{e}	0.217 ^{gh}	0.147 ^{g}
T_{10} - R + Hg + Anilo	0.257 ^{abcd}	0.363 ^{c}	0.243 ^{c}	0.177 ^{d}
T_{11} - R + Hg + HW	0.207 ^{d}	0.313 ^{h}	0.213 ^{h}	0.163 ^{f}
T_{12} - R + Hg + NW	0.253 ^{abcd}	0.370 ^{b}	0.250 ^{b}	0.183 ^{c}
T_{13} - R + HW	0.207 ^{d}	0.307 ^{i}	0.243 ^{c}	0.137 ^{i}
T_{14} - R + NW	0.293 ^{a}	0.377 ^{a}	0.257 ^{a}	0.00 ^{J}

The values followed by same letters do not differ significantly in DMRT

At PIS, root : shoot ratio was significantly influenced by treatments. Lowest root : shoot ratio was recorded by T_{13} (R + HW). A still higher ratio was noticed in T_{11}. Higher root : shoot ratio was recorded by T_4 and T_{12} which were on par and the highest in T_{14} (R + NW).

At flowering, root : shoot ratio was lowest in T_{11} (R + Hg + HW) followed by T_5 and T_9 which were comparable. Higher root : shoot ratio was recorded by T_6, T_{12} and T_4 which were on par. Highest root : shoot ratio was recorded by T_{14} (R + NW) which was comparable to T_4.

At harvest also, significant difference was noticed among treatments regarding root : shoot ratio. Lowest root : shoot ratio was recorded by T_{13} (R + HW) followed by T_3 which was comparable to T_{13}. T_2, T_8 and T_9 were comparable and inferior to the above treatments. Higher root : shoot ratio was recorded by T_6 and the highest by T_{14} (R + NW).

4.1.2 Green manure crops

4.1.2.1 Seedling population

Significant differences were noticed among treatments in seedling population (Table 8) of green manure crops at different days of observation except two DAS. At four DAS, T_{11} (R + Hg + HW) has got the maximum number of seedlings followed by T_9, T_8 and T_7 which were on par with T_{11}. It was followed by treatments T_{12} and T_{10}. All other treatments were on par and significantly different from the above ones. At six and eight DAS, T_7 (R + Hg + Buta) has got the maximum seedling population and treatments T_8, T_9, T_{11} and T_{12} were on par with T_7. It was followed by T_{10} and all other treatments were inferior to T_{10} but were statistically on par. At 12 DAS, i.e., after thinning, maximum population was noticed in T_{12} followed by T_7, T_8, T_{11}, T_{10} and T_9. All other treatments were on par and inferior to T_9.

4.1.2.2 Height of the plant

Regarding the height of green manure crops (Table 9) there was significant difference among the treatments both at 20 and 40 DAS.

Table 8. Effect of treatments on seedling population (no. m^{-2}) of green manure crops

Treatments	Days after sowing				
	Two	Four	Six	Eight	Twelve
T_1 - R + CP + Buta	0.0 ^{a}	56.3 ^{c}	77.7 ^{c}	78.0 ^{c}	71.3 ^{c}
T_2 - R + CP + Pendi	0.0 ^{a}	51.0 ^{c}	88.7 ^{c}	88.7 ^{c}	79.0 ^{c}
T_3 - R + CP + Pret	1.7 ^{a}	50.3 ^{c}	88.0 ^{c}	88.7 ^{c}	78.7 ^{c}
T_4 - R + CP + Anilo	0.0 ^{a}	47.7 ^{c}	81.7 ^{c}	82.3 ^{c}	80.3 ^{c}
T_5 - R + CP + HW	3.0 ^{a}	52.0 ^{c}	82.0 ^{c}	82.3 ^{c}	80.7 ^{c}
T_6 - R + CP + NW	3.7 ^{a}	42.3 ^{c}	79.3 ^{c}	80.0 ^{c}	79.0 ^{c}
T_7 - R + Hg + Buta	3.0 ^{a}	111.3 ^{ab}	207.7 ^{a}	210.0 ^{a}	200.7 ^{ab}
T_8 - R + Hg + Pendi	1.7 ^{a}	100.7 ^{ab}	201.7 ^{ab}	206.7 ^{ab}	198.7 ^{ab}
T_9 - R + Hg + Pret	0.0 ^{a}	112.3 ^{ab}	179.7 ^{ab}	180.0 ^{ab}	180.0 ^{ab}
T_{10} - R + Hg + Anilo	0.0 ^{a}	98.0 ^{b}	173.0 ^{ab}	174.7 ^{b}	172.0 ^{ab}
T_{11} - R + Hg + HW	0.0 ^{a}	120.0 ^{a}	177.3 ^{ab}	170.0 ^{ab}	174.0 ^{ab}
T_{12} - R + Hg + NW	2.0 ^{a}	103.0 ^{b}	203.7 ^{ab}	204.7 ^{ab}	202.7 ^{a}

The values followed by same letters do not differ significantly in DMRT

Table 9. Effect of treatments on height (cm), LAI, number of nodules plant^{-1}, root : shoot ratio and DMP (q ha^{-1}) of green manure crops

Treatments	Height		LAI		No. of nodules plant^{-1}		Root:shoot ratio		DMP	
	Days after sowing		Days after sowing		Days after sowing		Days after sowing		Days after sowing	
	20	40	20	40	20	40	20	40	20	40
T_1 - R + CP + Buta	41.3 ^{a}	100.3 ^{ab}	1.53 ^{a}	2.46 ^{a}	1.00 ^{a}	2.67 ^{ab}	0.077 ^{g}	0.103 ^{f}	58.48 ^{ab}	338.20 ^{ab}
T_2 - R + CP + Pendi	38.5 ^{a}	104.3 ^{ab}	1.34 ^{ab}	2.23 ^{ab}	1.00 ^{a}	1.67 ^{bcd}	0.070 ^{h}	0.097 ^{g}	41.97 ^{bcd}	377.60 ^{a}
T_3 - R + CP + Pret	39.6 ^{a}	109.9 ^{ab}	1.29 ^{b}	2.18 ^{ab}	1.00 ^{a}	2.33 ^{abc}	0.090 ^{e}	0.110 ^{e}	44.21 ^{abc}	314.60 ^{abc}
T_4 - R + CP + Anilo	40.3 ^{a}	101.1 ^{ab}	1.42 ^{ab}	2.36 ^{ab}	1.00 ^{a}	2.33 ^{abc}	0.082 ^{f}	0.117 ^{d}	53.99 ^{ab}	247.50 ^{abc}
T_5 - R + CP + HW	39.9 ^{a}	114.7 ^{a}	1.40 ^{ab}	2.35 ^{b}	1.00 ^{a}	2.67 ^{ab}	0.085 ^{ef}	0.117 ^{d}	41.72 ^{bcd}	158.40 ^{bc}
T_6 - R + CP + NW	40.0 ^{a}	95.0 ^{b}	1.26 ^{b}	2.20 ^{b}	1.00 ^{a}	3.00 ^{a}	0.071 ^{h}	0.107 ^{ef}	61.22 ^{a}	260.10 ^{abc}
T_7 - R + Hg + Buta	23.1 ^{b}	67.6 ^{c}	0.23 ^{c}	1.43 ^{c}	0.00 ^{c}	1.33 ^{cd}	0.109 ^{cd}	0.153 ^{b}	26.15 ^{de}	187.50 ^{abc}
T_8 - R + Hg + Pendi	22.0 ^{b}	66.2 ^{c}	0.21 ^{c}	1.41 ^{c}	0.00 ^{c}	1.33 ^{cd}	1.107 ^{d}	0.160 ^{a}	33.51 ^{cde}	204.20 ^{abc}
T_9 - R + Hg + Pret	24.1 ^{b}	64.5 ^{c}	0.26 ^{c}	1.47 ^{c}	0.00 ^{c}	1.00 ^{d}	0.114 ^{c}	0.153 ^{b}	23.12 ^{e}	161.90 ^{bc}
T_{10} - R + Hg + Anilo	25.2 ^{b}	67.7 ^{c}	0.26 ^{c}	1.45 ^{c}	0.67 ^{b}	1.00 ^{d}	0.121 ^{b}	0.163 ^{a}	27.00 ^{cde}	295.10 ^{abc}
T_{11} - R + Hg + HW	26.1 ^{b}	52.1 ^{c}	0.26 ^{c}	1.45 ^{c}	0.00 ^{c}	1.33 ^{cd}	0.122 ^{b}	0.143 ^{c}	22.57 ^{e}	123.50 ^{c}
T_{12} - R + Hg + NW	24.3 ^{b}	55.4 ^{c}	0.25 ^{c}	1.43 ^{c}	0.00 ^{c}	1.33 ^{cd}	0.136 ^{a}	0.150 ^{b}	26.21 ^{de}	167.70 ^{bc}

The values followed by same letters do not differ significantly in DMRT

At 20 DAS, all treatments having cowpea as intercrop viz., T_1, T_2, T_3, T_4, T_5 and T_6 were on par but were significantly superior to all those treatments having horsegram as intercrops viz., T_7, T_8, T_9, T_{10}, T_{11} and T_{12}.

At 40 DAS, T_5 (R + CP + HW) has got the maximum height but was comparable to all those treatments having cowpea as intercrops. All the treatments having horsegram as intercrop recorded comparable values. The height of horsegram was invariably lesser than that of cowpea.

4.1.2.3 LAI

Leaf area of intercrops varied significantly both at 20 and 40 DAS (Table 9). At both the days of observations, the LAI of cowpea was significantly more than that of horsegram. However, LAI of all the cowpea intercropped plots were statistically on par at 20 DAS except T_3 and T_6 which were inferior to T_1, T_2, T_4 and T_5. Likewise LAI of horsegram did not vary among the treatments.

At 40 DAS, T_1, T_2, T_3 and T_4 recorded increased heights over T_5 and T_6. The treatments did not vary in the height of horsegram.

4.1.2.4 Nodule count

At 20 DAS, nodules were found only on cowpea except in T_{10} (R + Hg + Anilo) in the case of horsegram, and all cowpea intercropped treatments were on par (Table 9). At 40 DAS, nodules were found in both green manure crops, but their number was very low (Table 9). Number of nodules were more in cowpea when compared to horsegram. Treatments T_1, T_3, T_4, T_5 and T_6 were on par and superior to T_2, T_7, T_8, T_{11}, T_{12}, T_9 and T_{10}.

4.1.2.5 Root : shoot ratio

Appreciable variations in root : shoot ratio was observed among treatments both at 20 and 40 DAS (Table 9).

At 20 DAS, treatments T_2 (R + CP + Pendi) and T_6 (R + CP + NW) recorded lower root : shoot ratio followed by T_1, T_5, T_3, T_4, T_8, T_2, T_9 etc. which were significantly different from the above treatments. Treatments T_{10} and T_{11} recorded higher root : shoot ratio and the highest was recorded in T_{12} (R + Hg + NW).

At 40 DAS, lowest root : shoot ratio was recorded in T_2 (R + CP + Pendi) followed by T_1, T_6, T_3, T_4, T_5, T_{11}, T_{12}, T_7, T_9 and T_8 and the highest in T_{10} (R + Hg + Anilo).

4.1.2.6 Dry matter production (DMP)

DMP of green manure crops varied significantly among treatments both at 20 and 40 DAS (Table 9).

AT 20 DAS, maximum DMP was recorded by T_6 (R + CP + NW) followed by T_1, T_4 and T_3 which were on par. DMP was lowest in T_{11} (R + Hg + HW).

At 40 DAS, T_2 (R + CP + Pendi) recorded the maximum, followed by T_1, T_3, T_6, T_{10}, T_4, T_8 and T_7 which were comparable. The lowest DMP was observed in T_{11} (R + Hg + HW).

4.2 YIELD AND YIELD ATTRIBUTES

The data on yield and yield attributes is presented in Table 10.

4.2.1 Days to 50 per cent flowering

Fifty per cent flowering was noticed early in treatments T_{13} (R + HW) and T_7 (R + Hg + Buta) but was comparable with T_8, T_9 and T_{11}. The maximum number of days were taken by T_3 (R + CP + Pret) and was on par with T_1, T_2, T_4, T_5, T_6, T_{10}, T_{12} and T_{14}.

4.2.2 Panicles m^{-2}

Significant difference was noticed between treatments regarding the number of panicles m^{-2}. The maximum number of panicles m^{-2} was recorded by T_{13}

Table 10. Effect of treatments on yield and yield attributes of rice

Treatments	No. of days to 50 per cent flowering	No. of panicles m^{-2}	Panicle weight (g)	No. of filled grains $panicle^{-1}$	Percentage of filled grains	1000 grain weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
T_1 - R + CP + Buta	89.3^{a}	108.7^{d}	1.74^{abc}	57.0^{bc}	44.7^{cd}	27.89^{a}	1301^{d}	1225^{d}	0.52^{a}
T_2 - R + CP + Pendi	88.0^{abc}	207.0^{bc}	2.20^{a}	59.0^{bc}	51.3^{bc}	27.52^{a}	2147^{abc}	2043^{abc}	0.51^{a}
T_3 - R + CP + Pret	90.3^{a}	208.7^{bc}	1.66^{abc}	57.0^{bc}	53.7^{abc}	27.58^{a}	1761^{bcd}	1326^{d}	0.57^{a}
T_4 - R + CP + Anilo	89.0^{ab}	19.3^{f}	1.06^{de}	58.0^{bc}	43.0^{cd}	26.35^{a}	426^{e}	369^{e}	0.53^{a}
T_5 - R + CP + HW	87.3^{abc}	147.7^{e}	1.36^{cd}	61.0^{bc}	46.0^{cd}	27.26^{a}	1610^{cd}	1360^{d}	0.55^{a}
T_6 - R + CP + NW	89.3^{a}	8.3^{f}	0.71^{ef}	36.3^{d}	22.7^{e}	27.13^{a}	199^{e}	164^{e}	0.54^{a}
T_7 - R + Hg + Buta	84.0^{d}	191.7^{cd}	1.52^{bcd}	52.3^{c}	57.7^{abc}	28.67^{a}	1869^{bcd}	1635^{cd}	0.53^{a}
T_8 - R + Hg + Pendi	85.3^{cd}	186.0^{cd}	2.14^{a}	66.7^{abc}	68.7^{a}	27.77^{a}	2273^{ab}	2231^{ab}	0.50^{a}
T_9 - R + Hg + Pret	85.3^{cd}	181.7^{cd}	2.10^{a}	68.7^{ab}	67.0^{ab}	27.76^{a}	1925^{bc}	1667^{bcd}	0.54^{a}
T_{10} - R + Hg + Anilo	87.7^{abc}	23.3^{f}	1.14^{de}	64.3^{abc}	33.3^{de}	27.71^{a}	561^{e}	455^{e}	0.55^{a}
T_{11} - R + Hg + HW	86.0^{bcd}	224.0^{b}	2.00^{ab}	77.3^{a}	62.7^{ab}	27.35^{a}	1925^{bc}	1771^{bcd}	0.52^{a}
T_{12} - R + Hg + NW	88.7^{ab}	1.7^{f}	0.40^{fg}	24.7^{d}	20.0^{e}	27.89^{a}	66^{e}	41^{e}	0.62^{a}
T_{13} - R + HW	83.7^{d}	269.0^{a}	1.80^{abc}	69.0^{ab}	64.3^{ab}	28.21^{a}	2544^{a}	2443^{a}	0.51^{a}
T_{14} - R + NW	89.3^{a}	0.0^{f}	0.00^{g}	0.0^{e}	0.00^{f}	0.00^{b}	0.00^{e}	0.00^{e}	0.00^{b}

The values followed by same letters do not differ significantly in DMRT

(R + HW) which was superior to all other treatments. It was followed by T_{11}, T_3 and T_2 which were comparable. No panicles was produced in T_{14} (R + NW). Panicle production was minimum in T_{12}, T_6, T_4 and T_{10}.

4.2.3 Panicle weight

Regarding panicle weight the best treatment was T_2 (R + CP + Pendi) followed by T_8, T_9, T_{11}, T_{13}, T_1 and T_3 which were on par with T_2. Other than T_{14} (R + NW), which did not produce any panicle, T_{12} (R + Hg + NW) produced panicles with least weight.

4.2.4 Number of filled grains panicle^{-1}

Number of filled grains panicle^{-1} was highest in T_{11} (R + Hg + HW) followed by T_{13}, T_9, T_8 and T_{10} which were on par with T_{11}. No grains was produced in T_{14} (R + NW). T_{12} (R + Hg + NW) and T_6 (R + CP + NW) were inferior to other treatments in the number of filled grains panicle^{-1}.

4.2.5 Percentage of filled grains

Maximum percentage of filled grains was recorded by T_8 (R + Hg + Pendi) followed by T_9, T_{11}, T_{13}, T_7 and T_3 which were comparable. Minimum percentage of filled grains was noticed in T_{12} (R + Hg + NW), T_6 (R + CP + NW) and T_{10} (R + Hg + Anilo) which were on par.

4.2.6 1000 grain weight

No significant difference was noticed among treatments in respect of 1000 grain weight. However T_7 (R + Hg + Buta) and T_{13} (R + HW) recorded more 1000 grain weight numerically.

4.2.7 Grain yield

Significant difference was noticed among treatments regarding grain yield. Maximum yield was recorded by T_{13} (R + HW) which was on par with T_8 (R + Hg +

Pendi) and T_2 (R + CP + Pendi). No grain production was observed in T_{14} (R + NW). The grain yield was very low in T_4, T_6, T_{10} and T_{12}.

4.2.8 Straw yield

Straw yield varied significantly among treatments. T_{13} (R + HW) recorded the maximum straw yield which was on par with T_8 (R + Hg + Pendi) and T_2 (R + CP + Pendi). Next best treatments were T_9 and T_{11} followed by T_7. No straw yield was obtained from T_{14} (R + NW). The treatments which recorded minimum straw yield were T_{12}, T_6, T_4 and T_{10}.

4.2.9 Harvest Index (HI)

All the treatments except T_{14} were comparable with regard to HI.

4.3 TOTAL WEED COUNT

The effect of treatments on total weed count varied significantly at all the days of observation (Table 11).

In all the plots, the population of weeds was found to be increasing from 30 DAS upto harvest. At 30 DAS, there was no weed infestation in T_{11} (R + Hg + HW), T_5 (R + CP + HW) and T_{13} (R + HW). Weed infestation was minimum in T_2 (R + CP + Pendi), T_1 (R + CP + Buta), T_9 (R + Hg + Pret), T_8 (R + Hg + Pendi), T_3 (R + CP + Pret) and T_7 (R + Hg + Buta) which were on par. By comparing similar treatments having different intercrops, it was found that cowpea is having more weed suppressive effect than horsegram.

At 60 DAS also, the best treatments were T_{13} (R + HW), T_{11} (R + Hg + HW) and T_5 (R + CP + HW) where the weed population was nil. These were on par with T_2, T_3, T_1, T_9 and T_8. T_{14} (R + NW) was found to be inferior to all other treatments where the weed population was very high.

At 90 DAS, the least weed infestation was recorded in T_2 (R + CP + Pendi) followed by T_{13} (R + HW) and T_3 (R + CP + Pret) which were comparable. At harvest

Table 11. Effect of treatments on total weed count (No. m^{-2})

Treatments	Days after sowing			
	30	60	90	Harvest
T_1 - R + CP + Buta	4.60 ^{de} (21.30)	5.50 ^{f} (30.70)	12.60 ^{de} (158.70)	15.60 ^{cd} (244.00)
T_2 - R + CP + Pendi	3.70 ^{de} (13.30)	1.70 ^{f} (2.70)	6.90 ^{g} (48.00)	10.80 ^{d} (117.30)
T_3 - R + CP + Pret	5.70 ^{de} (32.00)	4.80 ^{f} (22.70)	9.10 ^{efg} (84.00)	10.90 ^{d} (118.70)
T_4 - R + CP + Anilo	7.30 ^{cd} (53.30)	8.50 ^{de} (73.30)	12.20 ^{de} (150.70)	15.30 ^{cd} (236.00)
T_5 - R + CP + HW	0.71 ^{e} (0.00)	0.71 ^{f} (0.00)	14.60 ^{cd} (213.30)	20.20 ^{b} (409.30)
T_6 - R + CP + NW	13.00 ^{b} (170.70)	12.80 ^{c} (164.00)	21.80 ^{a} (476.00)	27.30 ^{a} (748.00)
T_7 - R + Hg + Buta	6.51 ^{de} (42.70)	8.90 ^{d} (80.00)	12.70 ^{de} (162.70)	16.21 ^{cd} (262.70)
T_8 - R + Hg + Pendi	5.31 ^{de} (28.00)	6.00 ^{ef} (36.00)	11.40 ^{ef} (130.70)	16.30 ^{c} (268.00)
T_9 - R + Hg + Pret	5.22 ^{de} (26.70)	5.70 ^{f} (32.00)	11.31 ^{ef} (128.00)	14.60 ^{ce} (213.30)
T_{10} - R + Hg + Anilo	9.60 ^{c} (93.30)	11.91 ^{c} (142.70)	16.60 ^{bc} (277.30)	21.00 ^{b} (441.30)
T_{11} - R + Hg + HW	0.71 ^{e} (0.00)	0.71 ^{e} (0.00)	15.70 ^{bc} (248.00)	20.80 ^{b} (433.30)
T_{12} - R + Hg + NW	4.21 ^{b} (17.30)	14.69 ^{b} (217.30)	17.20 ^{b} (294.70)	20.02 ^{b} (408.00)
T_{13} - R + HW	0.71 ^{e} (0.00)	0.71 ^{f} (0.00)	7.69 ^{fg} (60.00)	10.89 ^{d} (118.70)
T_{14} - R + NW	18.01 ^{a} (326.70)	19.52 ^{a} (380.00)	20.11 ^{a} (406.70)	21.62 ^{b} (468.00)

The values followed by same letters do not differ significantly in DMRT
Original values are given in parenthesis

weed population was lower in T_2 (R + CP + Pendi) followed by T_3, T_{13}, T_9, T_4, T_7 and T_1 which were on par. Maximum weed infestation was recorded in T_6 (R + CP + NW) followed by T_{14} (R + NW).

Hand weeding was found to be the best treatment for getting complete control of weeds. Among the different herbicides used, pendimethalin and pretilachlor were superior over butachlor and anilofos. Maximum weed population was noticed in control plots.

4.3.1 Count of broad leaved weeds

The population of broad leaved weeds (BLW) was significantly influenced by treatments at all the days of observations, except harvest (Table 12).

At 30 DAS, complete control of BLW was obtained in hand weeded treatments i.e., T_5, T_{11} and T_{13}. Control of BLW to such an extent could not be achieved with any of the herbicide treatments. However, comparatively good control was achieved by T_2 (R + CP + Pendi) and T_1 (R + CP + Buta). Maximum weed population was noticed in T_{14} (R + NW).

At 60 DAS, in all treatments except T_{14} (R + NW), a reduction in BLW was noticed. Complete control was obtained in T_5 (R + CP + HW), T_9 (R + Hg + Pret), T_{11} (R + Hg + HW) and T_{13} (R + HW). Comparable control of BLW was obtained in T_1, T_2, T_3, T_4 and T_6. The maximum infestation of BLW was observed in T_{14} (R + NW).

At 90 DAS, weed population was found to be still decreasing in all plots except T_3, T_9, T_{11} and T_5. Complete control of BLW was noticed in T_4 (R + CP + Anilo) and T_{13} (R + HW) which was comparable with all other treatments except T_7 (R + Hg + Buta), which recorded the maximum count of BLW.

At harvest, in many of the plots, weed population was found to be increasing. No significant difference was noticed between treatments. T_1 (R + CP +

Table 12. Effect of treatments on count of BLW (No. m^{-2})

Treatments	Days after sowing			
	30	60	90	Harvest
T_1 - R + CP + Buta	3.49 ^{de} (16.00)	1.65 ^{ef} (2.67)	1.18 ^{ab} (1.33)	0.71 ^{a} (0.00)
T_2 - R + CP + Pendi	3.19 ^{de} (13.33)	1.65 ^{ef} (2.67)	1.65 ^{ab} (2.67)	0.71 ^{a} (0.00)
T_3 - R + CP + Pret	5.56 ^{bcd} (30.67)	1.44 ^{ef} (2.67)	2.39 ^{ab} (6.67)	3.64 ^{a} (18.67)
T_4 - R + CP + Anilo	4.99 ^{cd} (25.33)	2.65 ^{def} (6.67)	0.71 ^{b} (0.00)	2.56 ^{a} (8.00)
T_5 - R + CP + HW	0.71 ^{e} (0.00)	0.71 ^{f} (0.00)	1.98 ^{ab} (6.67)	3.43 ^{a} (16.00)
T_6 - R + CP + NW	8.33 ^{ab} (80.00)	3.06 ^{def} (9.33)	2.56 ^{ab} (8.00)	3.81 ^{a} (20.00)
T_7 - R + Hg + Buta	5.99 ^{abcd} (37.33)	3.80 ^{cde} (53.33)	4.27 ^{a} (18.67)	5.42 ^{a} (30.67)
T_8 - R + Hg + Pendi	5.06 ^{cd} (25.33)	4.64 ^{bcd} (21.33)	2.12 ^{ab} (5.33)	2.70 ^{a} (14.67)
T_9 - R + Hg + Pret	5.20 ^{cd} (26.67)	0.71 ^{f} (0.00)	1.44 ^{ab} (2.67)	2.45 ^{a} (8.00)
T_{10} - R + Hg + Anilo	7.75 ^{abc} (62.67)	6.99 ^{b} (20.00)	2.25 ^{ab} (9.33)	3.43 ^{a} (17.33)
T_{11} - R + Hg + HW	0.71 ^{e} (0.00)	0.71 ^{f} (0.00)	1.83 ^{ab} (5.33)	2.37 ^{a} (10.67)
T_{12} - R + Hg + NW	7.82 ^{abc} (61.33)	5.92 ^{bc} (34.67)	3.06 ^{ab} (12.00)	3.92 ^{a} (20.00)
T_{13} - R + HW	0.71 ^{e} (0.00)	0.71 ^{f} (0.00)	0.71 ^{b} (0.00)	2.45 ^{a} (8.00)
T_{14} - R + NW	8.81 ^{a} (81.33)	10.91 ^{a} (100.00)	2.12 ^{ab} (5.33)	3.37 ^{a} (14.67)

Original values are given in parenthesis

The values followed by same letters do not differ significantly in DMRT

Buta) and T_2 (R + CP + Pendi) gave a complete control whereas the highest weed population was noticed in T_7 (R + Hg + Buta).

4.3.2 Count of grasses

Treatments differed appreciably in the count of grasses at all the days of observation (Table 13). Number of grasses were found to be increasing from 30 DAS upto harvest. Among herbicides, effective control of grasses was obtained in pretilachlor (T_3 and T_9) and pendimethalin (T_2 and T_8) treated plots particularly upto 90 DAS followed by hand weeded plots.

At 30 DAS, grass weeds were absent in T_2 (R + CP + Pendi), T_5 (R + CP + HW), T_9 (R + Hg + Pret), T_{11} (R + Hg + HW) and T_{13} (R + HW). The population of grassy weeds was maximum in T_{14} (R + NW) which was significantly higher than all other treatments.

At 60 DAS, complete control of grasses was obtained in T_2 (R + CP + Pendi), T_5 (R + CP + HW), T_{11} (R + Hg + HW) and T_{13} (R + HW) while in T_{14} (R + NW) the population was the highest.

At 90 DAS, population of grasses was lowest in T_2 (R + CP + Pendi) followed by T_{13}, T_3, T_8 and T_9 which were comparable. Treatments T_7, T_4 and T_1 were inferior to the above ones and were on par. Higher population was noticed in T_{14} and the highest in T_6 (R + CP + NW).

At harvest, T_3 (R + CP + Pret) was the best treatment followed by T_2, T_9, T_4, T_7 and T_{13} which were comparable. Maximum population of grasses was observed in T_6 (R + CP + NW). The result indicate that in the case of suppression of grasses also, cowpea play a major role than horsegram.

4.3.3 Count of sedges

The population of sedges was found to be significantly influenced by treatments only at 30 and 60 DAS (Table 14). Control of sedges was found to be

Table 13. Effect of treatments on count of grasses (No. m^{-2})

Treatments	Days after sowing			
	30	60	90	Harvest
T_1 - R + CP + Buta	2.10 ^{cd} (4.00)	5.30 ^{de} (28.00)	12.52 ^{cd} (157.30)	15.60 ^{c} (244.00)
T_2 - R + CP + Pendi	0.71 ^{d} (0.00)	0.71 ^{e} (0.00)	6.71 ^{e} (45.30)	10.79 ^{cd} (117.30)
T_3 - R + CP + Pret	1.10 ^{cd} (1.30)	4.51 ^{de} (20.00)	8.79 ^{de} (77.30)	10.00 ^{d} (100.00)
T_4 - R + CP + Anilo	5.30 ^{c} (28.00)	4.80 ^{de} (22.70)	12.20 ^{cd} (150.70)	15.12 ^{cd} (228.00)
T_5 - R + CP + HW	0.71 ^{d} (0.00)	0.71 ^{e} (0.00)	14.30 ^{bc} (206.70)	19.78 ^{b} (393.30)
T_6 - R + CP + NW	8.12 ^{b} (65.30)	10.31 ^{bc} (106.70)	21.59 ^{a} (468.00)	26.89 ^{a} (728.00)
T_7 - R + Hg + Buta	2.41 ^{cd} (5.30)	7.09 ^{cde} (50.70)	12.00 ^{cd} (144.00)	15.20 ^{cd} (232.00)
T_8 - R + Hg + Pendi	1.12 ^{cd} (1.30)	4.23 ^{de} (17.30)	11.22 ^{de} (125.30)	15.92 ^{c} (253.30)
T_9 - R + Hg + Pret	0.71 ^{d} (0.00)	3.51 ^{de} (12.00)	11.20 ^{de} (125.30)	14.31 ^{cd} (205.30)
T_{10} - R + Hg + Anilo	4.82 ^{cd} (22.70)	8.43 ^{bcd} (70.70)	16.34 ^{b} (268.00)	20.61 ^{b} (424.00)
T_{11} - R + Hg + HW	0.71 ^{d} (0.00)	0.71 ^{e} (0.00)	15.51 ^{b} (242.70)	20.52 ^{b} (422.70)
T_{12} - R + Hg + NW	8.10 ^{b} (66.70)	10.82 ^{b} (117.30)	16.80 ^{b} (282.70)	19.70 ^{b} (388.00)
T_{13} - R + HW	0.71 ^{d} (0.00)	0.71 ^{e} (0.00)	7.72 ^{e} (60.00)	10.50 ^{cd} (110.70)
T_{14} - R + NW	14.01 ^{a} (197.30)	14.30 ^{a} (206.70)	20.00 ^{a} (401.30)	21.30 ^{b} (453.30)

The values followed by same letters do not differ significantly in DMRT
Original values are given in parenthesis

Table 14. Effect of treatments on count of sedges (No. m^{-2})

Treatments	Days after sowing			
	30	60	90	Harvest
T_1 - R + CP + Buta	0.71 ^{c} (0.00)	0.71 ^{d} (0.00)	0.71 ^{a} (0.00)	0.71 ^{a} (0.00)
T_2 - R + CP + Pendi	0.71 ^{c} (0.00)	0.71 ^{d} (0.00)	0.71 ^{a} (0.00)	0.71 ^{a} (0.00)
T_3 - R + CP + Pret	0.71 ^{c} (0.00)	0.71 ^{d} (0.00)	0.71 ^{a} (0.00)	0.71 ^{a} (0.00)
T_4 - R + CP + Anilo	0.71 ^{c} (0.00)	0.71 ^{d} (0.00)	0.71 ^{a} (0.00)	0.71 ^{a} (0.00)
T_5 - R + CP + HW	0.71 ^{c} (0.00)	0.71 ^{d} (0.00)	0.71 ^{a} (0.00)	0.71 ^{a} (0.00)
T_6 - R + CP + NW	4.25 ^{b} (25.33)	0.71 ^{d} (0.00)	0.71 ^{a} (0.00)	0.71 ^{a} (0.00)
T_7 - R + Hg + Buta	0.71 ^{c} (0.00)	0.71 ^{d} (0.00)	0.71 ^{a} (0.00)	0.71 ^{a} (0.00)
T_8 - R + Hg + Pendi	1.18 ^{c} (1.33)	1.92 ^{c} (4.00	0.71 ^{a} (0.00)	0.71 ^{a} (0.00)
T_9 - R + Hg + Pret	0.71 ^{c} (0.00)	0.71 ^{d} (0.00)	0.71 ^{a} (0.00)	0.71 ^{a} (0.00)
T_{10} - R + Hg + Anilo	2.56 ^{bc} (8.00)	2.18 ^{c} (5.33)	0.71 ^{a} (0.00)	0.71 ^{a} (0.00)
T_{11} - R + Hg + HW	0.71 ^{c} (0.00)	0.71 ^{d} (0.00)	0.71 ^{a} (0.00)	0.71 ^{a} (0.00)
T_{12} - R + Hg + NW	6.34 ^{a} (45.33)	3.30 ^{b} (10.67)	0.71 ^{a} (0.00)	0.71 ^{a} (0.00)
T_{13} - R + HW	0.71 ^{c} (0.00)	0.71 ^{d} (0.00)	0.71 ^{a} (0.00)	0.71 ^{a} (0.00)
T_{14} - R + NW	6.94 ^{a} (48.00)	6.47 ^{a} (36.00)	0.71 ^{a} (0.00)	0.71 ^{a} (0.00)

Original values are given in parenthesis

The values followed by same letters do not differ significantly in DMRT

effective by the application of herbicides like pendimethalin, pretilachlor, butachlor and anilofos in the early stages of crop growth. From seeding upto harvest, sedges population in the field was almost negligible. At 30 and 60 DAS, sedge population was observed in T_{10}, T_6, T_{12}, T_{14} and T_8. T_{14} (R + NW) and T_{12} (R + Hg + NW) recorded the maximum population of sedges at 30 and 60 DAS. At 90 DAS and harvest, no sedge population was observed in any of the treatments.

4.4 DRY MATTER PRODUCTION OF WEEDS

Dry matter production (DMP) of weeds was found to vary significantly among treatments during all the periods of observation (Table 15). DMP was found to increse from 30 DAS upto harvest invariably in all treatments.

At 30 DAS, since no weed infestation, DMP was nil in T_5 (R + CP + HW), T_{11} (R + Hg + HW) and T_{13} (R + HW). However, these were on par with T_2, T_1, T_8, T_4, T_9 and T_3. Highest DMP was recorded by T_{14} (R + NW) which was significantly inferior to all other treatments.

At 60 DAS also, DMP was nil in T_5 (R + CP + HW), T_{11} (R + Hg + HW) and T_{13} (R + HW). These were on par with T_2, T_3, T_1, T_9, T_4, T_7, T_{10} and T_8. Higher DMP was noticed in T_6 and T_{12} and the highest in T_{14} (R + NW).

At 90 DAS, significant difference was noticed among treatments regarding DMP of weeds. Eventhough T_2, T_3 and T_{13} were comparable, T_{13} (R + HW) recorded the lowest DMP. Highest DMP was noticed in T_{14} (R + NW) which was significantly inferior to all other treatments.

At harvest, lower DMP was recorded by T_3, T_2, T_1, T_5 and T_9 which were on par. Lowest DMP was recorded by T_{13} (R + HW). T_{10}, T_6 and T_{12} were inferior to the above treatments. The highest DMP was noticed in T_{14} (R + NW) and was significantly inferior to all other treatments.

Table 15. Effect of treatments on dry matter production (q ha^{-1}) of weeds

Treatments	Days after sowing			
	30	60	90	Harvest
T_1 - R + CP + Buta	0.41 ^{de}	0.33 ^{d}	11.30 ^{efg}	31.32 ^{cde}
T_2 - R + CP + Pendi	0.20 ^{de}	0.06 ^{d}	6.90 ^{gh}	18.78 ^{de}
T_3 - R + CP + Pret	0.60 ^{de}	0.31 ^{d}	4.90 ^{hi}	11.71 ^{e}
T_4 - R + CP + Anilo	0.53 ^{de}	1.71 ^{cd}	15.73 ^{e}	43.42 ^{c}
T_5 - R + CP + HW	0.00 ^{e}	0.00 ^{d}	8.30 ^{fgh}	32.95 ^{cde}
T_6 - R + CP + NW	2.09 ^{b}	6.20 ^{bc}	25.12 ^{d}	78.97 ^{b}
T_7 - R + Hg + Buta	0.83 ^{cd}	3.09 ^{cd}	13.02 ^{ef}	45.19 ^{c}
T_8 - R + Hg + Pendi	0.45 ^{de}	1.27 ^{d}	11.81 ^{efg}	36.44 ^{cd}
T_9 - R + Hg + Pret	0.53 ^{de}	0.52 ^{d}	11.37 ^{efg}	33.00 ^{cde}
T_{10} - R + Hg + Anilo	1.35 ^{c}	4.44 ^{cd}	31.49 ^{c}	78.46 ^{b}
T_{11} - R + Hg + HW	0.00 ^{e}	0.00 ^{d}	11.82 ^{efg}	40.11 ^{cd}
T_{12} - R + Hg + NW	2.28 ^{b}	9.07 ^{ab}	40.19 ^{b}	82.16 ^{b}
T_{13} - R + HW	0.00 ^{e}	0.00 ^{d}	2.83 ^{i}	9.93 ^{e}
T_{14} - R + NW	3.66 ^{a}	11.82 ^{a}	50.72 ^{a}	104.10 ^{a}

The values followed by same letters do not differ significantly in DMRT

4.5 NUTRIENT UPTAKE BY RICE

Uptake of nutrients was found to increase from ATS to PIS and then decreased (Table 16).

Uptake of N was found to be significantly influenced by the treatments. At ATS, highest uptake was recorded by T_{13} (R + HW) evethough T_8, T_2, T_9, T_7, T_{11} and T_5 were comparable with T_{13}. Uptake was lower in T_4, T_6, T_{12} and the lowest in T_{14} (R + NW). At PIS, T_8 (R + Hg + Pendi) recorded the highest N uptake followed by T_2 and T_{13} which were on par with T_8. Lower uptake was noticed in T_{10}, T_4, T_6, T_{12} and the lowest in T_{14} (R + NW) eventhough it was on par with T_{12} and T_6. At harvest, the highest N uptake was recorded by T_{13} (R + HW) followed by T_2 and T_8. Uptake was lower in T_{10}, T_4, T_6, T_{12} and T_{14} which were comparable.

Regarding the uptake of P, significant difference was noticed among treatments. From ATS to harvest, the highest uptake of P was recorded by T_{13} (R + HW) and the lowest by T_{14} (R + NW). At ATS, T_{12} was comparable with T_{14} and no treatment was comparable with T_{13}. At PIS, T_8 and T_2 were comparable with T_{13}, and T_6 and T_{12} with T_{14}. At harvest, T_8 was comparable with T_{13}, and T_{10}, T_4, T_6 and T_{12} with T_{14}.

Uptake of K was found to vary significantly among treatments during all the periods of observation. Maximum uptake of K was recorded by T_{13} (R + HW) and the minimum by T_{14} (R + NW) from ATS to harvest. At ATS, T_{12} was comparable with T_{14}. At PIS, T_8 and T_2 were comparable with T_{13}, and T_{12} with T_{14}. At harvest T_8 and T_2 were comparable with T_{13}, and T_{10}, T_4, T_6 and T_{12} with T_{14}.

4.6 NUTRIENT CONTRIBUTION BY GREEN MANURE CROPS

Contribution of N was maximum in T_2 (R + CP + Pendi) followed by T_1, T_3, T_6, T_{10} and T_4 which were also on par (Table 17).

Maximum contribution of P was recorded by T_2 (R + CP + Pendi) followed by T_1, T_3, T_{10}, T_6 and T_4 (Table 17). Lower contribution was recorded by T_{11} eventhough treatments T_4 to T_9 were on par with T_{11}.

Table 16. Effect of treatments on uptake of nutrients by rice (kg ha^{-1})

Treatments	Nitrogen			Phosphorus			Potassium		
	ATS	PIS	Harvest	ATS	PIS	Harvest	ATS	PIS	Harvest
T_1 - R + CP + Buta	40.8 ^{bc}	54.8 ^{c}	33.6 ^{d}	4.13 ^{cd}	5.28 ^{d}	3.35 ^{d}	44.38 ^{c}	55.60 ^{b}	32.00 ^{c}
T_2 - R + CP + Pendi	49.7 ^{ab}	71.7 ^{a}	56.7 ^{ab}	5.19 ^{b}	6.74 ^{abc}	5.53 ^{bc}	53.73 ^{b}	73.91 ^{a}	48.73 ^{ab}
T_3 - R + CP + Pret	42.0 ^{bc}	55.0 ^{c}	42.6 ^{bcd}	4.70 ^{bc}	5.60 ^{cd}	3.96 ^{cd}	47.26 ^{bc}	57.56 ^{b}	38.57 ^{bc}
T_4 - R + CP + Anilo	27.8 ^{de}	18.7 ^{d}	10.8 ^{e}	2.83 ^{ef}	1.79 ^{e}	1.10 ^{e}	29.57 ^{de}	19.72 ^{c}	9.60 ^{d}
T_5 - R + CP + HW	44.2 ^{ab}	48.9 ^{c}	35.9 ^{cd}	4.92 ^{bc}	5.20 ^{d}	4.05 ^{cd}	49.91 ^{bc}	51.89 ^{b}	36.95 ^{bc}
T_6 - R + CP + NW	22.6 ^{ef}	13.1 ^{de}	4.9 ^{e}	2.58 ^{fg}	1.34 ^{ef}	0.50 ^{e}	25.84 ^{ef}	14.44 ^{c}	4.46 ^{d}
T_7 - R + Hg + Buta	47.2 ^{ab}	57.8 ^{bc}	47.6 ^{bcd}	5.17 ^{b}	5.86 ^{cd}	4.64 ^{bcd}	49.94 ^{bc}	59.57 ^{b}	41.57 ^{bc}
T_8 - R + Hg + Pendi	50.5 ^{ab}	72.2 ^{a}	52.4 ^{abc}	5.39 ^{b}	7.42 ^{ab}	6.03 ^{ab}	53.63 ^{b}	76.23 ^{a}	51.50 ^{ab}
T_9 - R + Hg + Pret	48.8 ^{ab}	58.9 ^{bc}	48.8 ^{bcd}	5.05 ^{b}	6.02 ^{cd}	4.92 ^{bcd}	50.78 ^{bc}	59.59 ^{b}	43.90 ^{bc}
T_{10} - R + Hg + Anilo	33.7 ^{cd}	19.5 ^{d}	13.8 ^{e}	3.57 ^{de}	1.84 ^{e}	1.37 ^{e}	36.22 ^{d}	19.61 ^{c}	12.64 ^{d}
T_{11} - R + Hg + HW	46.6 ^{ab}	58.5 ^{bc}	50.1 ^{bcd}	5.05 ^{b}	6.19 ^{bcd}	4.97 ^{bcd}	51.23 ^{bc}	60.83 ^{b}	43.52 ^{bc}
T_{12} - R + Hg + NW	18.4 ^{ef}	9.2 ^{de}	1.5 ^{e}	1.09 ^{gh}	0.94 ^{ef}	0.14 ^{e}	19.61 ^{fg}	9.76 ^{cd}	1.44 ^{d}
T_{13} - R + HW	53.0 ^{a}	69.7 ^{ab}	66.8 ^{a}	6.24 ^{a}	7.83 ^{a}	7.21 ^{a}	61.72 ^{a}	77.62 ^{a}	60.15 ^{a}
T_{14} - R + NW	13.7 ^{f}	2.5 ^{e}	0.0 ^{e}	1.69 ^{h}	0.29 ^{f}	0.00 ^{e}	16.48 ^{g}	2.88 ^{d}	0.00 ^{d}

The values followed by same letters do not differ significantly in DMRT

Table 17. Effect of treatments on the contribution of nutrients (kg ha^{-1}) by green manure crops at the time of self decomposition

Treatments	Nutrients		
	Nitrogen	Phosphorus	Potassium
T_1 - R + CP + Buta	11.06^{a} (131.30)	3.31^{ab} (11.24)	7.80^{ab} (67.31)
T_2 - R + CP + Pendi	11.70^{a} (137.70)	3.58^{a} (12.54)	8.58^{a} (73.89)
T_3 - R + CP + Pret	10.65^{ab} (117.40)	3.24^{abc} (10.23)	7.83^{ab} (61.96)
T_4 - R + CP + Anilo	9.19^{abc} (87.75)	2.82^{abcd} (7.73)	6.84^{abc} (48.76)
T_5 - R + CP + HW	7.03^{c} (52.77)	2.32^{bcd} (5.22)	5.51^{bc} (32.03)
T_6 - R + CP + NW	9.64^{abc} (95.35)	2.93^{abcd} (8.32)	6.69^{abc} (46.36)
T_7 - R + Hg + Buta	7.36^{bc} (56.13)	2.46^{bcd} (5.81)	5.26^{bc} (28.29)
T_8 - R + Hg + Pendi	7.48^{bc} (57.05)	2.56^{bcd} (6.22)	5.65^{bc} (32.38)
T_9 - R + Hg + Pret	6.85^{c} (49.18)	2.26^{cd} (4.91)	4.74^{c} (23.48)
T_{10} - R + Hg + Anilo	9.34^{abc} (88.31)	3.09^{abc} (9.18)	6.52^{abc} (42.89)
T_{11} - R + Hg + HW	6.07^{c} (36.44)	2.07^{d} (3.77)	4.39^{c} (18.78)
T_{12} - R + Hg + NW	7.08^{c} (49.97)	2.37^{bcd} (5.07)	4.86^{c} (23.22)
T_{13} - R + HW	0.71^{d} (0.00)	0.71^{e} (0.00)	0.71^{d} (0.00)
T_{14} - R + NW	0.71^{d} (0.00)	0.71^{e} (0.00)	0.71^{ad} (0.00)

Original values are given in parenthesis
The values followed by same letters do not differ significantly in DMRT

Contribution of K was also maximum in T_2 (R + CP + Pendi) followed by T_3, T_1, T_4, T_6 and T_{10} (Table 17). Lower contribution was noticed in T_{11}, T_9 and T_{12} eventhough T_7, T_5, T_8, T_{10}, T_6 and T_4 were also comparable.

4.7 NUTRIENT UPTAKE BY WEEDS

From 30 DAS upto harvest, an increase in nutrient uptake was recorded by weeds (Table 18). During all periods of observation, uptake by weeds was found to vary significantly among treatments.

Regarding the uptake of N, significant difference was noticed among treatments. At 30 DAS, since no weed infestation, uptake of N was nil in all the hand weeded plots viz., T_5 (R + CP + HW), T_{11} (R + Hg + HW) and T_{13} (R + HW). However these were on par with T_2, T_1, T_8 and T_4. Highest uptake of N was recorded by T_{14} (R + NW) which was significantly inferior to all other treatments. At 60 DAS also, zero uptake was noticed in T_5, T_{13} and T_{11} followed by T_2, T_3, T_1, T_9 and T_8. Maximum uptake value was recorded by T_{14} (R + NW). At 90 DAS, lowest uptake was recorded by T_{13} (R + HW) followed by T_3, T_2 and T_5. T_{14} recorded the maximum uptake value. At harvest, T_{13} (R + HW) was found to be the best treatment followed by T_3, T_2, T_1, T_5, T_8 and T_9 which were on par. Higher uptake was recorded by T_6, T_{10}, T_{14} and the highest by T_{14} (R + NW).

Uptake of P was found to be significantly influenced by the treatments. At 30 and 60 DAS, zero uptake was recorded by T_{11} (R + Hg + HW), T_{13} (R + HW) and T_5 (R + CP + HW). At 30 DAS, treatments T_2 to T_9 except T_6 and at 60 DAS treatments T_8, T_9, T_3, T_1 and T_2 were on par with T_{11}, T_{13} and T_5. At 90 DAS, lowest uptake was noticed in T_{13} (R + HW) followed by T_3 and T_2. At harvest also, T_{13} (R + HW) recorded the lowest uptake value even though T_3, T_2, T_1, T_5 and T_9 were comparable. In all the stages of observation, highest uptake of P was recorded by T_{14} (R + NW) which was significantly different from all other treatments.

Uptake of K was found to vary significantly among the treatments from 30 DAS upto harvest. At 30 and 60 DAS, zero uptake was recorded by the hand weeded treatments (T_5, T_{11} and T_{13}). At 30 DAS, treatments T_2, T_1, T_3, T_4, T_8, T_9 and at 60 DAS, treatments T_4, T_8, T_9, T_1, T_3 and T_2 were comparable with T_5, T_{11} and T_{13}. At 90

Table 18. Effect of treatments on uptake of nutrients (kg ha^{-1}) by weeds

Treatments	Nitrogen				Phosphorus				Potassium			
	Days after sowing				Days after sowing				Days after sowing			
	30	60	90	Harvest	30	60	90	Harvest	30	60	90	Harvest
T_1 - R + CP + Buta	1.18 ^{de}	0.95 ^{ef}	21.58 ^{ef}	37.18 ^{bcd}	0.277 ^{bc}	0.113 ^{g}	3.23 ^{efg}	7.13 ^{cde}	1.79 ^{de}	1.32 ^{e}	40.3 ^{efg}	97.0 ^{bcd}
T_2 - R + CP + Pendi	0.59 ^{de}	0.16 ^{ef}	13.63 ^{fg}	21.05 ^{cd}	0.433 ^{cd}	0.020 ^{g}	2.07 ^{ghi}	4.36 ^{de}	0.89 ^{de}	0.24 ^{e}	25.1 ^{ghi}	56.7 ^{cd}
T_3 - R + CP + Pret	1.74 ^{de}	0.80 ^{ef}	9.18 ^{g}	14.36 ^{c}	0.130 ^{cd}	0.113 ^{g}	1.42 ^{hi}	2.80 ^{e}	2.63 ^{de}	0.28 ^{e}	17.3 ^{hi}	35.5 ^{d}
T_4 - R + CP + Anilo	1.52 ^{de}	4.35 ^{e}	28.53 ^{e}	52.12 ^{b}	0.117 ^{cd}	0.623 ^{f}	4.60 ^{e}	8.96 ^{cd}	2.31 ^{de}	5.76 ^{e}	56.0 ^{e}	127.3 ^{bc}
T_5 - R + CP + HW	0.00 ^{e}	0.00 ^{f}	16.01 ^{fg}	45.79 ^{bc}	0.000 ^{d}	0.000 ^{g}	2.45 ^{fgh}	7.45 ^{cde}	0.00 ^{e}	0.00 ^{e}	30.3 ^{fgh}	99.3 ^{bcd}
T_6 - R + CP + NW	6.07 ^{b}	15.39 ^{c}	44.80 ^{d}	91.66 ^{a}	0.477 ^{b}	2.340 ^{c}	6.78 ^{d}	17.76 ^{b}	9.18 ^{b}	24.8 ^{c}	86.7 ^{d}	235.1 ^{a}
T_7 - R + Hg + Buta	2.40 ^{cde}	8.77 ^{d}	25.27 ^{ef}	56.31 ^{b}	0.183 ^{cd}	0.197 ^{e}	3.89 ^{ef}	10.30 ^{c}	3.63 ^{cd}	12.42 ^{d}	46.8 ^{ef}	137.3 ^{b}
T_8 - R + Hg + Pendi	1.30 ^{de}	3.62 ^{ef}	22.82 ^{ef}	48.83 ^{bc}	0.097 ^{cd}	0.487 ^{fg}	3.23 ^{efg}	8.99 ^{cd}	1.96 ^{de}	5.02 ^{e}	42.9 ^{efg}	108.9 ^{bc}
T_9 - R + Hg + Pret	5.24 ^{bc}	1.43 ^{ef}	22.36 ^{ef}	39.93 ^{bcd}	0.117 ^{cd}	0.183 ^{fg}	3.29 ^{efg}	7.67 ^{cde}	2.32 ^{de}	2.04 ^{e}	40.4 ^{efg}	100.2 ^{bcd}
T_{10} - R + Hg + Anilo	3.93 ^{bcd}	11.79 ^{cd}	59.87 ^{c}	95.06 ^{a}	0.307 ^{bc}	1.653 ^{d}	9.55 ^{c}	16.70 ^{b}	5.94 ^{c}	17.66 ^{d}	108.8 ^{c}	235.5 ^{a}
T_{11} - R + Hg + HW	0.00 ^{e}	0.00 ^{f}	22.99 ^{ef}	57.15 ^{b}	0.000 ^{d}	0.000 ^{g}	3.38 ^{efg}	9.22 ^{cd}	0.00 ^{e}	0.00 ^{e}	43.2 ^{efg}	124.7 ^{bc}
T_{12} - R + Hg + NW	6.63 ^{b}	25.44 ^{b}	71.49 ^{b}	112.80 ^{a}	0.517 ^{b}	3.260 ^{b}	10.95 ^{b}	16.97 ^{b}	10.02 ^{b}	36.10 ^{b}	140.7 ^{b}	240.6 ^{a}
T_{13} - R + HW	0.00 ^{e}	0.00 ^{f}	4.95 ^{g}	11.25 ^{d}	0.000 ^{d}	0.000 ^{g}	0.84 ^{i}	2.28 ^{e}	0.00 ^{e}	0.00 ^{e}	9.8 ^{i}	30.1 ^{d}
T_{14} - R + NW	10.60 ^{a}	42.35 ^{a}	88.42 ^{a}	108.80 ^{a}	0.840 ^{a}	6.250 ^{a}	14.17 ^{a}	22.88 ^{a}	16.11 ^{a}	61.77 ^{a}	172.4 ^{a}	302.0 ^{a}

The values followed by same letters do not differ significantly in DMRT

DAS, lowest uptake was noticed in T_{13} (R + HW) followed by T_3 and T_2. In all the three stages of observation, highest uptake value was recorded by T_{14} (R + NW) which was significantly inferior to all other treatments. At harvest, lowest uptake was noticed in T_{13} followed by T_3, T_2, T_1, T_5 and T_9 which were on par. T_{14} recorded the maximum uptake followed by T_{12}, T_{10} and T_6.

4.8 NUTRIENT STATUS OF THE SOIL AFTER GREEN MANURE INCORPORATION AND AFTER HARVEST

The N content of the soil showed an increase after incorporation of the green manure crops over pre experiment status but subsequently declined after the harvest of the crop (Table 19). All the treatments were on par in their post-experiment N status. Monitoring N status after one week of decomposition of the green manure crops indicated that all the cowpea intercropped plots were superior to horsegram intercropped plots which inturn were superior to the rice monocropped plots. The maximum N content was recorded by T_2 (R + CP + Pendi) which was comparable with all the cowpea intercropped treatments (T_1 to T_6) and T_7 (R + Hg + Buta.). T_2 was superior to all the horsegram intercropped treatments except T_7.

One week after self decomposition, P content of soil was found to increase over pre-experiment soil status and significant difference was noticed among treatments. Cowpea inter cropped butachlor treated plots (T_1) recorded the maximum P content followed by T_5 (R + CP + HW) which were on par and comparable with cowpea intercropped pendimethalin treated plots (T_2) also. The lowest P content was noticed in T_{14} (R + NW). P content of soil was found to decrease at harvest and found to vary significantly among treatments. Maximum P content was noticed in T_5 (R + CP + HW) followed by T_8 (R + Hg + Pendi) and the least in T_{14} (R + NW).

The K content of soil varied significantly among treatments after the incorporation of green manure crops as well as after the harvest of the crop. Following the decomposition of green manure crops, K content in soil was increased. Highest K content was recorded by T_9 (R + Hg + Pret) and comparable values were recorded by T_2, T_5, T_3, T_6 and T_7. Lowest values were recorded by T_{13} (R + HW) and T_{14} (R + NW). With regard to post-experiment soil status, highest K content was recorded by

Table 19. Effect of treatments on the available nutrient status (kg ha^{-1}) of soil

Treatments	Nitrogen		Phosphorus		Potassium	
	After green manure incorporation	After harvest	After green manure incorporation	After harvest	After green manure incorporation	After harvest
T_1 - R + CP + Buta	476.7 ^{ab}	213.2 ^{a}	36.60 ^{a}	15.66 ^{ab}	206.1 ^{bcde}	106.8 ^{a}
T_2 - R + CP + Pendi	491.3 ^{a}	238.3 ^{a}	31.88 ^{ab}	16.51 ^{ab}	247.1 ^{a}	96.3 ^{ab}
T_3 - R + CP + Pret	464.1 ^{ab}	227.9 ^{a}	28.90 ^{bcd}	16.59 ^{ab}	230.0 ^{abc}	84.4 ^{bc}
T_4 - R + CP + Anilo	414.0 ^{abc}	230.0 ^{a}	24.17 ^{cdef}	16.06 ^{ab}	198.6 ^{cde}	80.6 ^{bc}
T_5 - R + CP + HW	462.2 ^{ab}	230.0 ^{a}	35.56 ^{a}	17.13 ^{a}	242.7 ^{ab}	79.9 ^{bc}
T_6 - R + CP + NW	416.0 ^{abc}	223.7 ^{a}	24.42 ^{cdef}	14.00 ^{bcd}	214.3 ^{abcd}	76.2 ^{c}
T_7 - R + Hg + Buta	421.6 ^{abc}	238.3 ^{a}	27.57 ^{bcd}	14.09 ^{bcd}	214.3 ^{abcd}	76.2 ^{c}
T_8 - R + Hg + Pendi	401.4 ^{bc}	236.2 ^{a}	29.42 ^{bc}	17.07 ^{a}	184.4 ^{de}	73.9 ^{c}
T_9 - R + Hg + Pret	405.6 ^{bc}	234.2 ^{a}	27.92 ^{bcd}	14.33 ^{bcd}	247.6 ^{a}	72.4 ^{c}
T_{10} - R + Hg + Anilo	399.3 ^{bc}	236.2 ^{a}	26.11 ^{cde}	15.74 ^{ab}	185.2 ^{de}	72.4 ^{c}
T_{11} - R + Hg + HW	407.7 ^{bc}	232.1 ^{a}	26.36 ^{cde}	15.62 ^{ab}	185.9 ^{de}	71.7 ^{c}
T_{12} - R + Hg + NW	393.0 ^{bc}	223.7 ^{a}	23.53 ^{def}	14.87 ^{abc}	188.9 ^{de}	68.7 ^{c}
T_{13} - R + HW	374.2 ^{c}	219.5 ^{a}	21.67 ^{ef}	12.79 ^{cd}	172.5 ^{e}	68.7 ^{c}
T_{14} - R + NW	365.9 ^{c}	207.0 ^{a}	19.61 ^{f}	11.98 ^{d}	169.5 ^{e}	67.2 ^{c}

The values followed by same letters do not differ significantly in DMRT

T_1 (R + CP + Buta) which was on par with T_2 (R + CP + Pendi) and significantly superior to all other treatments. All the treatments, other than T_1 (R + CP + Buta) and T_2 (R + CP + Pendi), were comparable.

4.9 ECONOMICS OF TREATMENTS

Among the different treatments, cost of cultivation was highest in T_{13} (R + HW) (Table 20). The highest gross income was derived from T_{13} followed by T_8 (R + Hg + Pendi) and T_2 (R + CP + Pendi). Net income was highest in T_{13} followed by T_8 and T_7 (R + Hg + Buta). Highest benefit : cost ratio (B : C ratio) was recorded by T_8 (R + Hg + Pendi) which was closely followed by T_{13}. Gross return, net return and B : C ratio was least for T_{14} (R + NW).

Comparing the mean of two concurrent growing system involving green manure crops (Appendix XV), horsegram found to be economically viable than cowpea. When different weed management systems under intercropping situations were compared, pendimethalin was found the best followed by pretilachlor and butachlor.

Table 20. Economics of the treatments (Rs. ha^{-1})

Treatments	Cost of cultivation	Returns		B/C ratio
		Gross return	Net return	
T_1 - R + CP + Buta	13699	12854	-845	0.93
T_2 - R + CP + Pendi	16852	21257	4405	1.26
T_3 - R + CP + Pret	14181	16743	2562	1.18
T_4 - R + CP + Anilo	12520	4148	-8372	0.33
T_5 - R + CP + HW	15501	15600	99	1.01
T_6 - R + CP + NW	11211	1919	-9292	0.17
T_7 - R + Hg + Buta	13524	18220	4696	1.35
T_8 - R + Hg + Pendi	16677	22645	5968	1.36
T_9 - R + Hg + Pret	14706	18737	4031	1.27
T_{10} - R + Hg + Anilo	12245	5404	-6841	0.44
T_{11} - R + Hg + HW	16126	18946	2820	1.17
T_{12} - R + Hg + NW	11126	612	-10514	0.06
T_{13} - R + HW	18801	25240	6439	1.34
T_{14} - R + NW	10181	0	-10181	0

Data not statistically analysed

Cost of inputs

Herbicides

Butachlor - Rs. 175 l^{-1}
Pendimethalin - Rs. 598 l^{-1}
Pretilachlor - Rs. 480 l^{-1}
Anilofos - Rs. 376 l^{-1}

Seeds

Rice - Rs. 12 kg^{-1}
Cowpea - Rs. 25 kg^{-1}
Horsegram - Rs. 15 kg^{-1}

Fertilizers

Cowdung - Rs. 350 t^{-1}
Urea - Rs. 5.5 kg^{-1}
Rajphos - Rs. 2.0 kg^{-1}
MOP - Rs. 6.0 kg^{-1}

Labour cost

Men - Rs. 130 day^{-1}
Women - Rs. 100 day^{-1}
Tractor - Rs. 200 h^{-1}

Price of produce

Grain - Rs. 8.0 kg^{-1}
Straw - Rs. 2.0 kg^{-1}

Discussion

5. DISCUSSION

A field experiment was conducted to study the effect of weed management in semi-dry rice intercropped with green manure crops at Agricultural Research Station, Mannuthy. The results obtained from the study are discussed in this chapter.

5.1 CONCURRENT GROWING OF GREEN MANURE CROPS

Monitoring the population of rice seedlings m^{-2} (Table 2 and Appendix III) at two days interval showed progressive increase from 5 DAS to 9 DAS irrespective of treatments. Inadequacy and non uniformity in soil moisture content is generally experienced in dry sown rainfed situations (Thomas *et al.*, 1997) leading to non uniformity in germination and seedling population of rice. A similar situation was prevalent in the present study also, as revealed from the data on increasing seedling population from 5 DAS onwards. However, comparison of the density of seedlings among the intercropping and monocropping situations revealed no appreciable variation.

The height of rice in intercropped and monocropped plots did not vary significantly (Table 3; Appendix III and Fig. 4). However, a close perusal of the data revealed that the height of rice was more in both the intercropping treatments, over the monocropped rice at active tillering stage, indicating the beneficial effect of intercropping of leguminous green manure crops in the early growth of rice. In the subsequent stages, height of rice was found to be more in the monocropped rice. A scrutiny of the height of green manure plants at 20 and 40 DAS showed that the green manure plants exceeded the height of rice at 40 DAS. This might have led to a slight suppression in height of rice in intercropped treatments. Height suppression of plants under intercropping was earlier reported by George (1982).

Comparison of the other growth parameters of rice i.e., number of tillers m^{-2}, LAI and DMP (Tables 4, 5 & 6; Appendices IV & V and Fig. 5 & 6), indicated considerable variation between cowpea and horse gram intercropped plots,

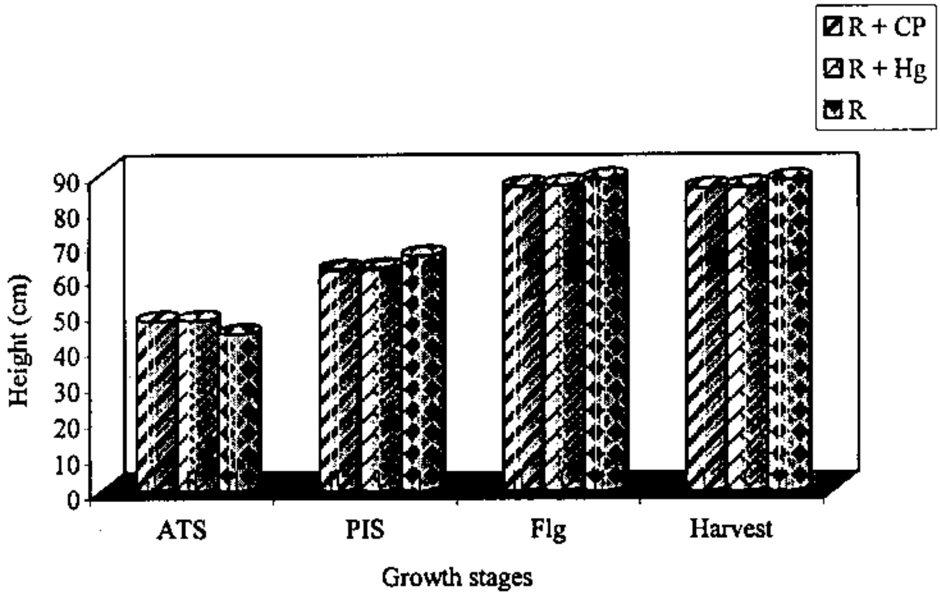

Fig. 4. Effect of concurrent growing of green manure crops on height of rice

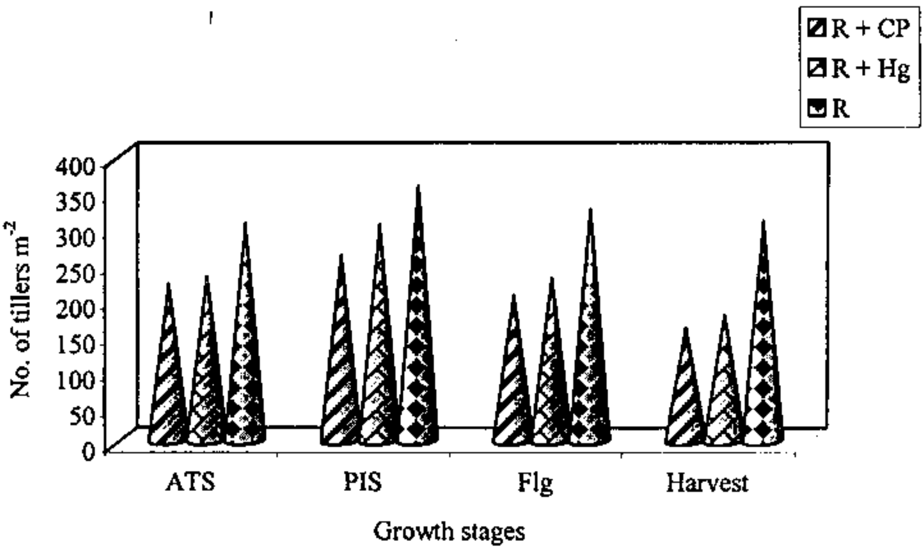

Fig. 5. Effect of concurrent growing of green manure crops on number of tillers of rice

except in the case of LAI, particularly in the latter stages. Intercropping with horsegram encouraged better growth of rice over cowpea intercropping. Rice was found to put forth improved vegetative growth in the absence of concurrent growing of green manure crops. This was against the findings of Kalpana *et al.* (2002), who reported improvement in the vegetative growth of rice in intercropped treatments. A close scrutiny of the data further revealed that tiller number showed a declining trend in all the treatments after the panicle initiation stage. The rate of decline was observed to be more in cowpea intercropped treatments followed by horsegram intercropping and monocropping. Intercropping of green manure crops in rice is recommended to benefit the growth of rice by way of nutrient addition from green manure crops. It is achieved by maintaining the growth of intercrops in such a way that they do not cause competition to rice. In the concurrent growing system, the green manure crops are allowed to grow only up to about 45 DAS when self decomposition in stagnant water will occur with the onset of south west monsoon. The success of the recommendation largely depends on the timely onset of monsoon. In the present experiment, the onset of south west monsoon was unduly delayed, leading to the continuance of the green manure crop in the field for an unduly long period. Being characterized with quick growth rate, their continuance caused severe competition to rice, resulting in the suppression of growth of rice (Plates 2a to 2d). Owing to the higher growth rate (Moorthy, 1990), the growth suppression was found to be more in cowpea intercropped rice than in horsegram intercropped one.

The highest yield of grain and straw was recorded by monocropped rice with hand weeding (T_{13}). It was on par with treatments intercropped with horsegram (T_8) and cowpea (T_2) and receiving pendimethalin application. Averaging the grain yield of rice in treatments intercropped with cowpea and horsegram, it was found that concurrent growing of horsegram has significant superiority over cowpea intercropping (Table 10; Appendix VIII and Fig. 7). A close perusal of the data indicated that the superiority of the monocropped hand weeded treatment (T_{13}) in respect of tiller number, dry matter production and most of the yield attributes such as number of panicles m^{-2}, panicle weight, number of filled grains panicle^{-1} and

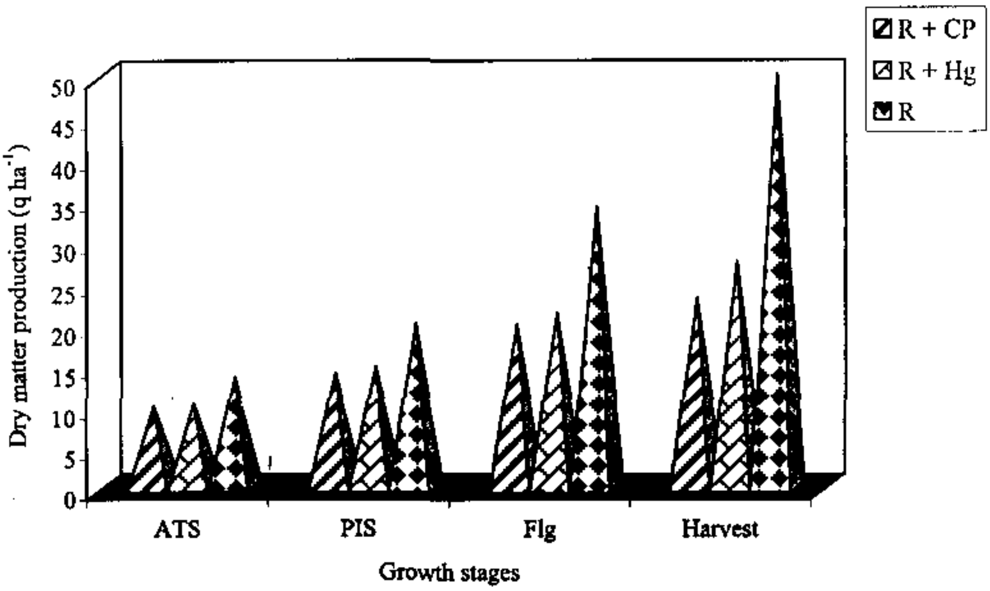

Fig. 6. Effect of concurrent growing of green manure crops on dry matter production of rice

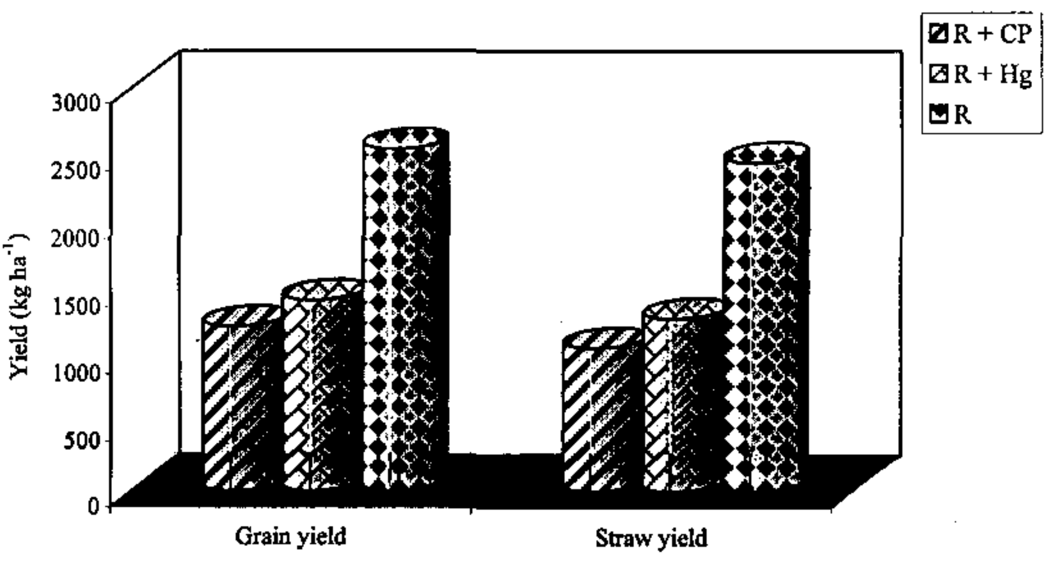

Fig. 7. Effect of concurrent growing of green manure crops on grain and straw yield of rice

Plate 2a. Rice + cowpea + pendimethalin immediately before water stagnation

Plate 2b. Rice + horsegram + pendimethalin immediately before water stagnation

Plate 2c. Rice + handweeding immediately before water stagnation

Plate 2d. General view of the experimental field immediately after water stagnation

percentage of filled grains has contributed to the high yield of grain and straw. Comparable values were recorded in the case of most of the attributes by rice + horsegram (T_8) and rice + cowpea (T_2) with both receiving pendimethalin, particularly the former, resulting in enhanced grain and straw yields in these treatments.

Many workers such as Mathew *et al.* (1991), Musthafa (1995) reported yield increase due to concurrent growing of green manure crops in dry seeded rice. Accordingly, KAU (2002) has recommended the practice as an effective technology for the addition of required quantity of green manure in semi-dry rice. The result of the present study emphasise the need for further refinement of this technology. The study indicated that over growth of green manure crops and their over stay in the field due to delayed monsoon has caused severe competition to the rice crop leading to poor growth and yield of rice in most of the treatments intercropped with cowpea and horsegram. Decrease in grain yield of rice due to intercropping was reported by Ramakrishna and Ong (1994). However, it could be seen that intercropping rice with horsegram invariably out yielded (both grain and straw) those with cowpea, when treatments receiving similar weed control measures were compared. It may be attributed to the lesser vegetative growth of horsegram, compared to cowpea, suggesting that horsegram may be a better choice for concurrent growing in semi-dry situations, wherever delay in the onset of monsoon is anticipated.

The overwhelming influence of concurrent growing of green manure crops on weed suppression is evident from the data on weed population and dry matter production. In respect of the total weed count and weed dry matter production, a progressive increase was observed from 30 DAS to harvest, irrespective of the treatments. Comparing the treatments intercropped with cowpea and horsegram receiving same weed control measure, it could be seen that the total count and weed DMP (Tables 11 & 15; Appendix X and Fig. 8) were invariably higher in treatments intercropped with horsegram. Comparing the unweeded plots with cowpea and horsegram intercropping and rice monocrop, it was observed that intercropping reduced the weed count to the extent of 42.8 to 56.8 per cent up to 60 DAS and thereafter the rate of reduction became lesser. The added advantage of concurrent

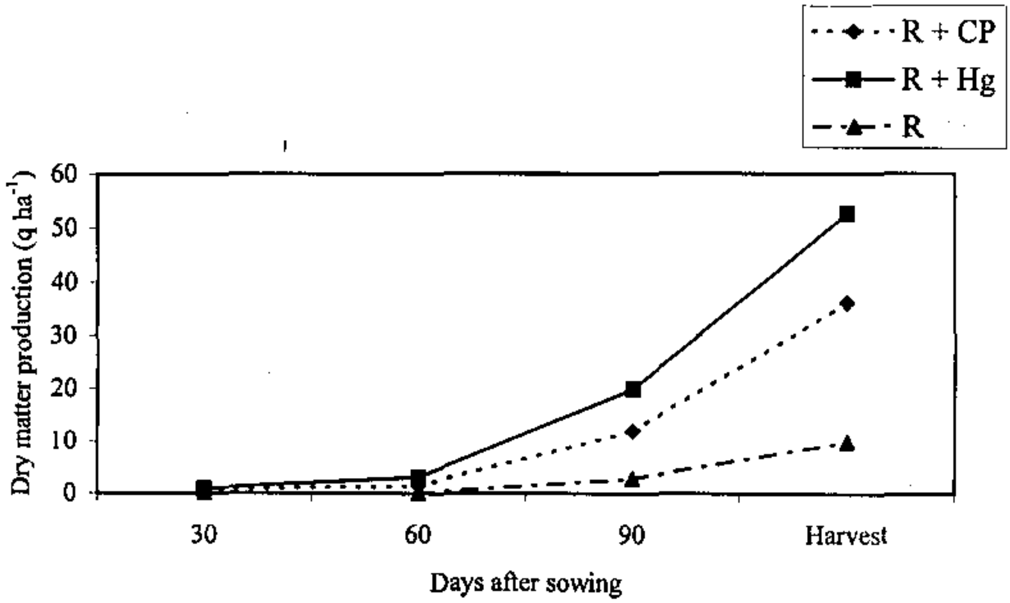

Fig. 8. Effect of concurrent growing of green manure crops on dry matter production of weeds

growing of green manure crops in suppressing the weed infestation in semi-dry rice, is convincingly proved from the study. It is made possible due to the shading of interspaces of rice plants by the vigorous growth of green manure crops discouraging the germination and growth of weeds. Musthafa (1995) reported that in cowpea intercropped plots, light penetration through the canopy is low and that might be the reason for low weed incidence. Smothering effect of cowpea in other crops were also reported by several authors (Krishnasamy and Krishnasamy, 1996; Bhuvaneswari *et al.*, 2002 and Rajagopal *et al.*, 1998).

A detailed analysis of the weed spectrum indicated a different trend from that of the total weed count and DMP. Irrespective of the treatments, the population of grasses showed an identical trend with that of total weed count, with increasing count from 30 DAS to harvest. The population of BLW, however, showed a declining count from 30 DAS to 90 DAS and thereafter slightly increased at harvest. However, the superior effect of cowpea, over horsegram, in suppressing the infestation of both the grasses and BLW were further evident from the data (Tables 12 & 13; Appendix IX and Fig. 9 & 10).

With respect to the population of sedges, it could be seen that concurrent growing of cowpea has practically eradicated sedges, with sedges observed only in the non-weeded cowpea intercropped treatments. However, in the case of horsegram intercropping, sedges were observed in the treatments receiving pendimethalin and anilofos, as well as in non-weeded treatments but only upto 60 DAS. The control of sedges was however total from 30 DAS to harvest in horsegram intercropped treatments involving butachlor and pretilachlor application and hand weeding. This proved the effectiveness of intercrops, particularly cowpea, in controlling sedges.

The nutrient uptake by weeds showed an increasing trend from 30 DAS to harvest in all the treatments. Following a similar trend as that of total weed population and DMP, the uptake of nutrients by weeds was more in treatments intercropped with horsegram in comparison with those intercropped with cowpea. The uptake of N, P and K by weeds was found to be negligible upto 60 DAS in most of the treatments

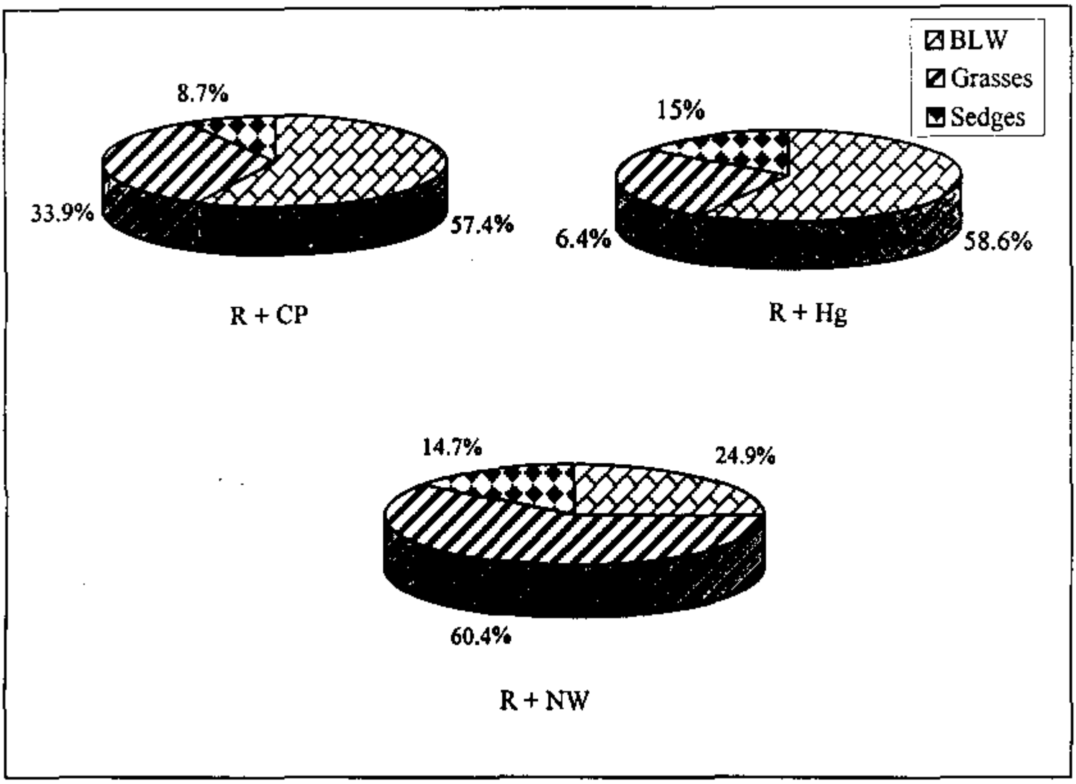

Fig. 9. Effect of concurrent growing of green manure crops on count of BLW, grasses and sedges at 30 days after sowing

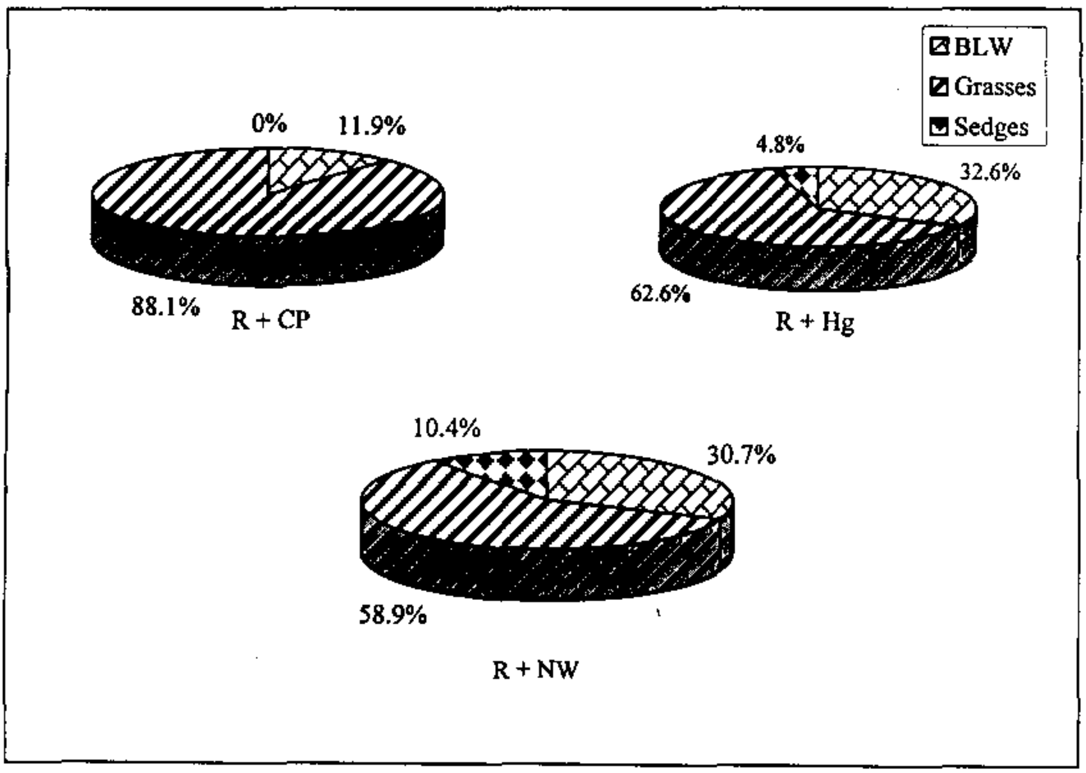

Fig. 10. Effect of concurrent growing of green manure crops on count of BLW, grasses and sedges at 60 days after sowing

involving different combinations of intercropping and weed control measures (Table 18; Appendix XIII and Fig. 11). However, in the case of non-weeded plots, the uptake was significant even during the first 60 days. It was further observed that the uptake of all the three major nutrients by weeds was almost double in monocropped rice, as compared to rice intercropped with cowpea and horsegram. This shows that concurrent growing of cowpea and horsegram can minimize the competition of weeds with rice for nutrients. But simultaneously care should be taken to regulate the population, growth and growing period of the green manure crops grown concurrently with rice so that they themselves do not compete with rice for nutrients. Several authors have reported reduction in nutrient uptake of weeds by intercropping of green manure crops (Musthafa and Potty, 1998 and Solaimalai and Selvam, 1998).

A comparison of the nutrient addition by the green manure crops at the time of self decomposition indicated that the contribution of N, P and K by cowpea was almost double than that of horsegram (Table 17; Appendix XI, Fig. 12 and Plates 3a and 3b). It is a clear reflection of the increased production of biomass by cowpea, over horsegram, attributed to its quick growth rate in the early stages (Bridgit *et al.*, 1994). The extend of nutrient absorption by rice from the added nutrients by green manure crops influences the productivity of rice. In this context, horsegram was found to encourage the nutrient absorption by rice compared to cowpea. The uptake of N, P and K by rice (Table 16; Appendix XII and Fig. 13) was found to be higher in the treatments intercropped with horsegram as compared to cowpea and this invariably resulted in the increase in yield of grain and straw of rice in plots intercropped with horsegram. The basic principle of intercropping is that it should not compete with the main crop for nutrients, solar radiation and other growth factors. However, in the present study, the delay in the incorporation of the intercrop might have led to competition for nutrients, light and moisture by rice and green manure crops, adversely affecting the absorption of nutrients by rice. Competition for nutrients due to excess growth of intercrops have been reported by Moorthy (1990).

After the incorporation of the green manure crops, substantial build up of soil fertility, with respect to NPK status, was noticed in treatments involving intercropping, as compared to monoculture (Table 19; Appendix XIV and Fig. 14).

Plate 3a. Rice + horsegram + pendimethalin four days after water stagnation

Plate 3b. Rice + cowpea + anilofos four days after

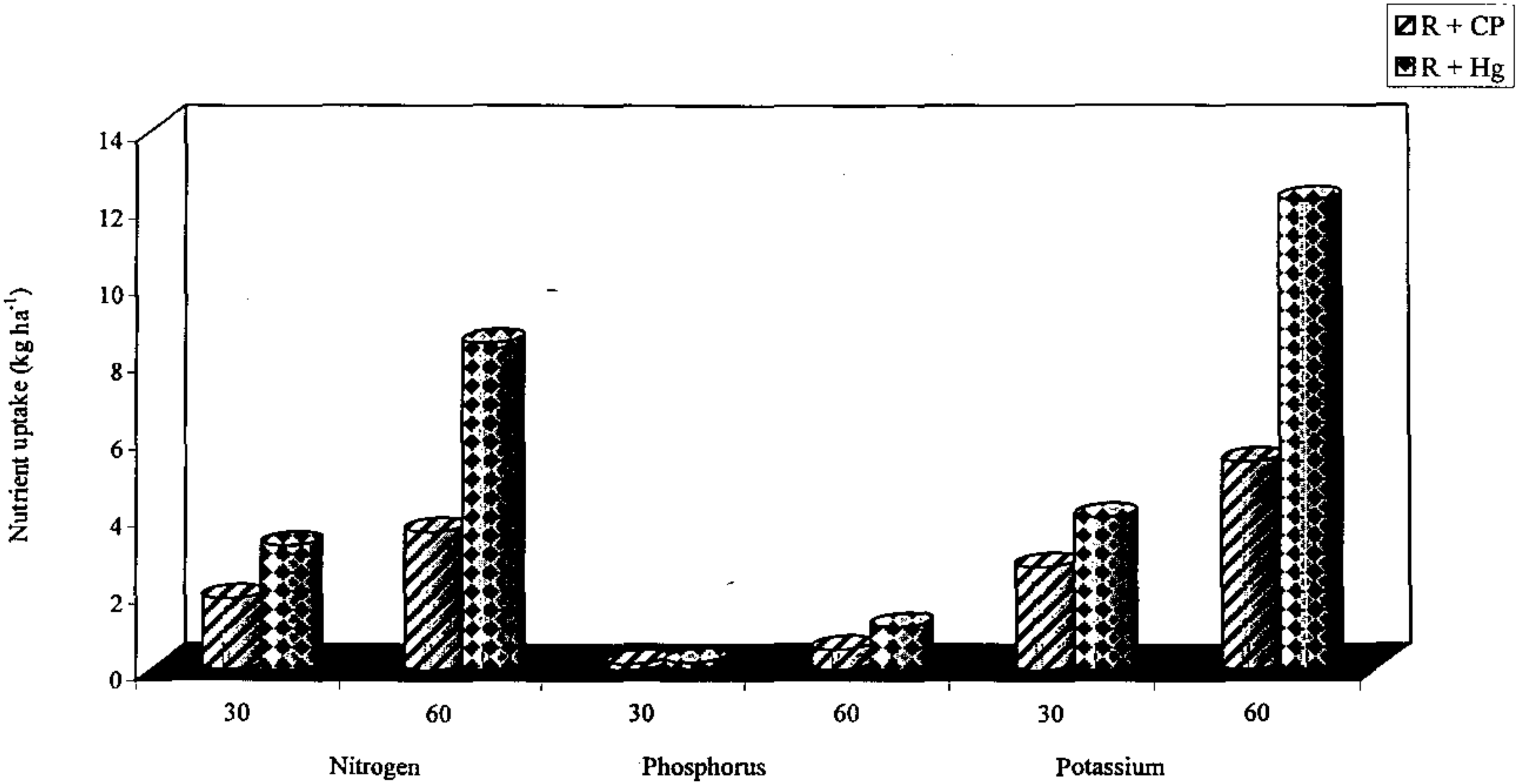

Fig. 11. Effect of concurrent growing of green manure crops on uptake of nutrients by weeds at 30 and 60 DAS

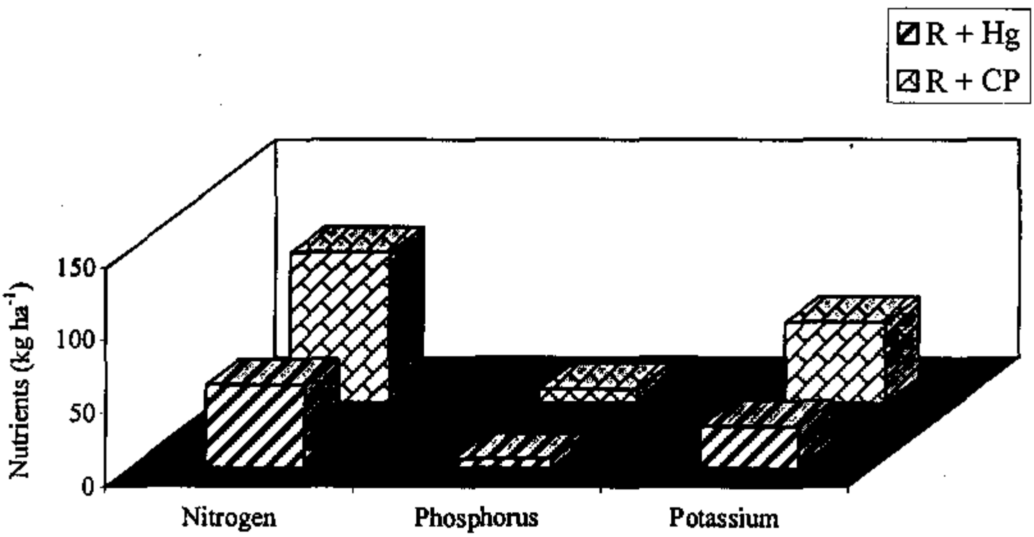

Fig. 12. Effect of concurrent growing of green manure crops on contribution of nutrients at the time of self decomposition

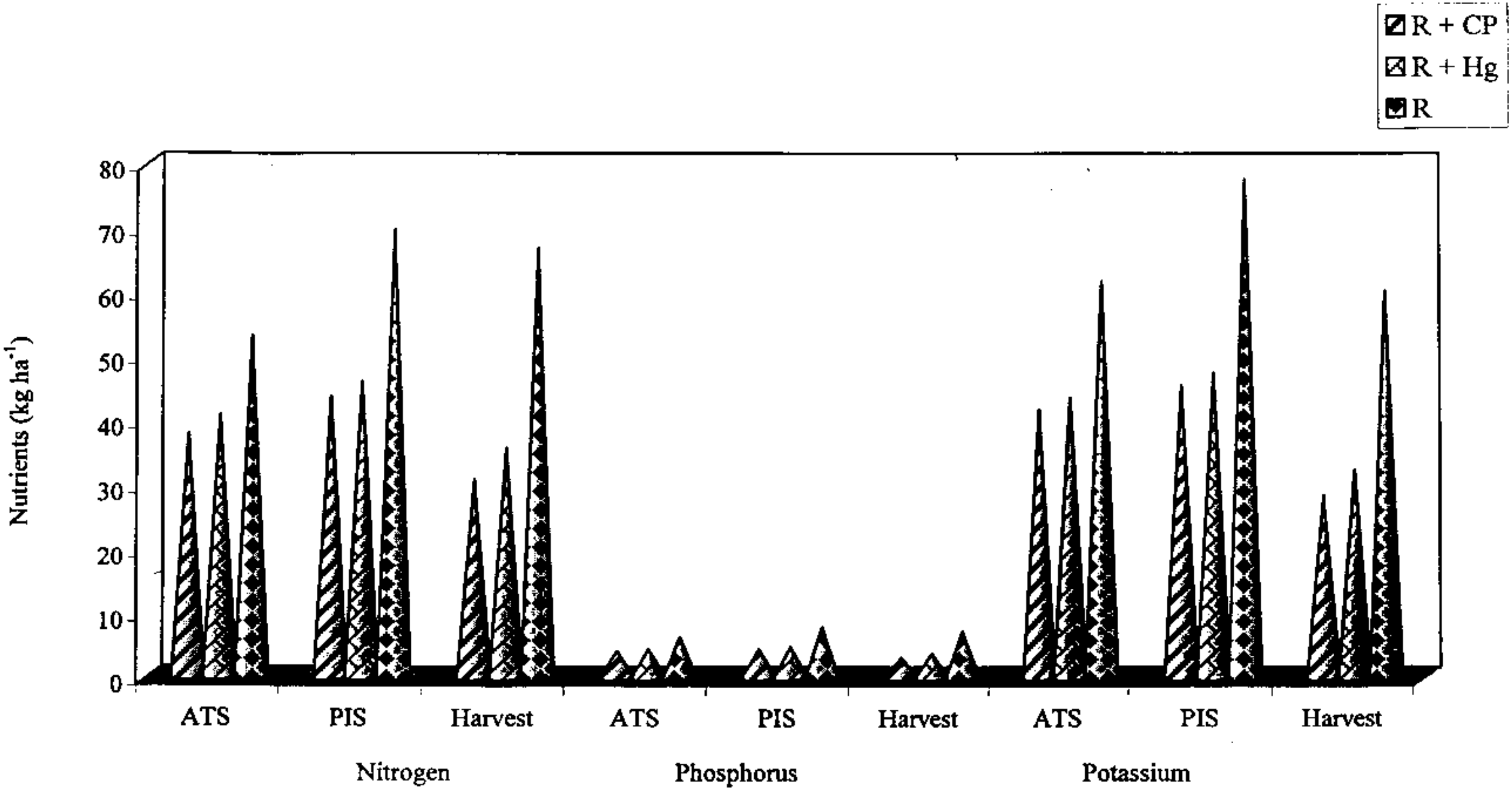

Fig. 13. Effect of concurrent growing of green manure crops on uptake of nutrients by rice

The increase, on an average, was worked out to 79.81, 8.59 and 50.64 kg ha^{-1} of NPK with respect to intercropping with cowpea. The corresponding values for horsegram intercropping were 30.54, 5.15 and 28.58 kg ha^{-1} respectively. However, the delay in the incorporation of green manure crops was the limiting factor in the current study in ensuring enhanced nutrient availability to rice at the critical stages of nutrient need. The failure to exploit the enhanced fertility status for increasing nutrient uptake by rice resulted in the failure of the intercropping treatments to significantly improve the productivity of rice.

Analysis of the nutrient status of the soil after the harvest of the crop indicated the continued superiority of treatments involving intercropping of green manure crops in respect of all the three major nutrients (Table 19; Appendix XIV and Fig. 14). This indicate the positive influence of intercropping green manure crops in sustaining the nutrient status of rice soils, with the possibility of enhanced rice productivity in the succeeding rice (Medhi and De Datta, 1996 and Solaiappan *et al.*, 1996). Increase in soil fertility status due to intercropping of green manure crops was reported by several workers (Somasundaram *et al.*, 1996; Chapali and Badole, 1999 and Sharma *et al.*, 2000).

5.2 WEED MANAGEMENT UNDER INTERCROPPING SITUATIONS

The important weeds noticed in the experimental field included grasses like *Sacciolepis interrupta, Isachne miliacea, Echinochloa colona,* BLW like *Ludwigia parviflora, Phyllanthus niruri, Melochia corchorifolia, Mollugo* sp., sedges like *Cyperus* sp., *Fimbristylis* sp. etc. Somewhat similar weed spectrum was observed in semi-dry rice by Bhargavi and Reddy (1993) and Musthafa and Potty (2001).

The influence of the weed control treatments on the germination of rice and green manure crops was observed by monitoring the population of their seedlings at periodic intervals. Though the population of rice seedlings showed variation among the treatments, it did not reveal any definite trend. The data however showed that none of the herbicides tested, adversely affected the germination of rice. This is expected because all the herbicides tested in the present study are already recommended ones

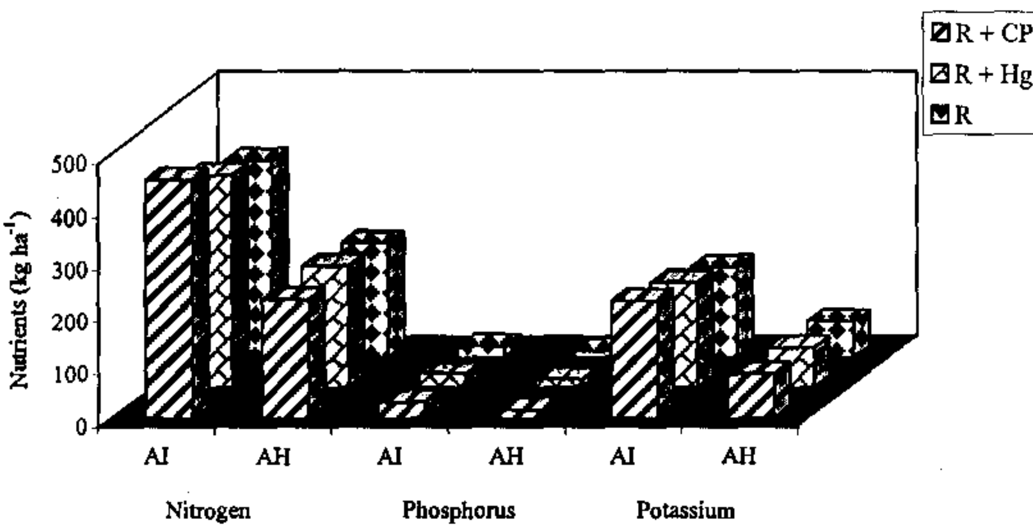

Fig. 14. Effect of concurrent growing of green manure crops on available nutrient content of soil

AI - After green manure incorporation
AH - After harvest

for rice. They are proved to be safe to rice by several studies (Rao and Rao, 1990 and Balasubramanian *et al.*, 1999). The green manure crops were found to have differing responses to herbicide application in respect of the seedling population. In cowpea, higher seedling population was observed in pendimethalin and pretilachlor applied plots and the lower in anilofos and butachlor applied plots. In the case of horsegram, higher population was observed in pendimethalin and butachlor applied plots and the lower in anilofos and pretilachlor applied plots. It can be seen that pendimethalin performed well both in the case of cowpea and horsegram. Likewise, the population was low in anilofos both for horsegram and cowpea. However, by around 13 DAS, the differences in population among the herbicides became narrower and non significant. The results of the study thus indicated that all the herbicides tested can be used in rice-green manure intercropping system without much adverse effect on their population.

A perusal of the data on growth characters viz., height, tiller count and dry matter production (Tables 3, 4 & 6; Appendices III, IV & V and Fig. 15, 16 & 17) indicated the overall superiority of pendimethalin and pretilachlor treated plots, among the herbicide treated plots, during the different growth stages irrespective of the system of intercropping adopted. These herbicides were also found to be comparable with hand weeding during most of the times. Many a times pendimethalin even exceeded hand weeding in respect of the growth attributes. Data on weed count (total, grasses and BLW) as well as weed dry matter production (Tables 11, 12, 13 & 15 and Appendices IX & X) reveal the effectiveness of pendimethalin and pretilachlor in weed suppression, facilitating improved vegetative growth of rice. Better rice growth under minimum weed competition was reported by Singh and Malik (1992). Among the herbicides tested, anilofos was found to be inferior with respect to different growth attributes. The sharp decline in tiller number in anilofos treated plots is to be specifically observed. The inefficacy of anilofos in controlling the weeds, as evident from the data on count of grasses and total weeds as well as total dry matter production justify the result. Anilofos is a herbicide widely recommended under puddled situation and no reports are available on its effectiveness under dry sown condition. Severe growth suppression due to heavy weed competition was observed in

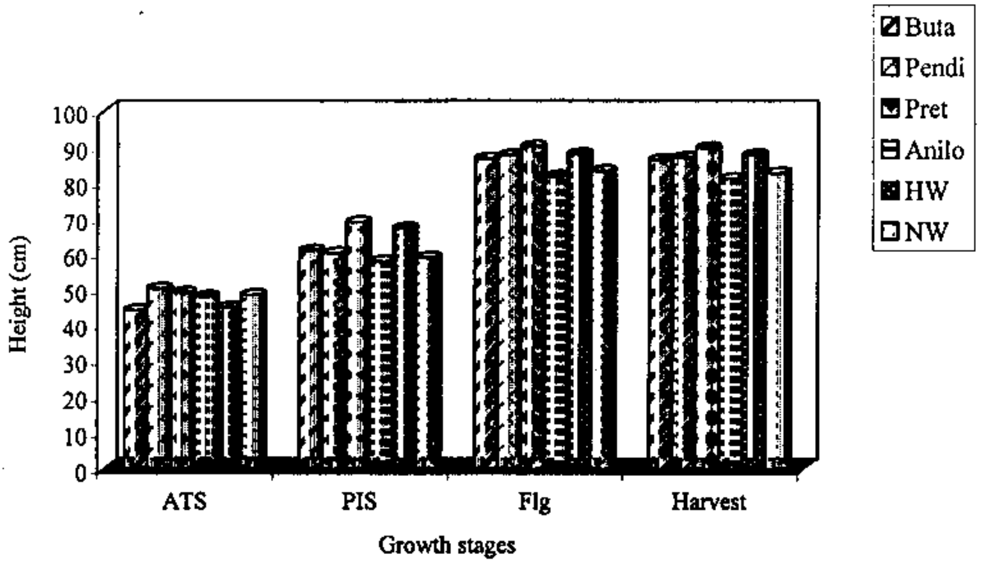

Fig. 15. Effect of weed management under intercropping situations on height of rice

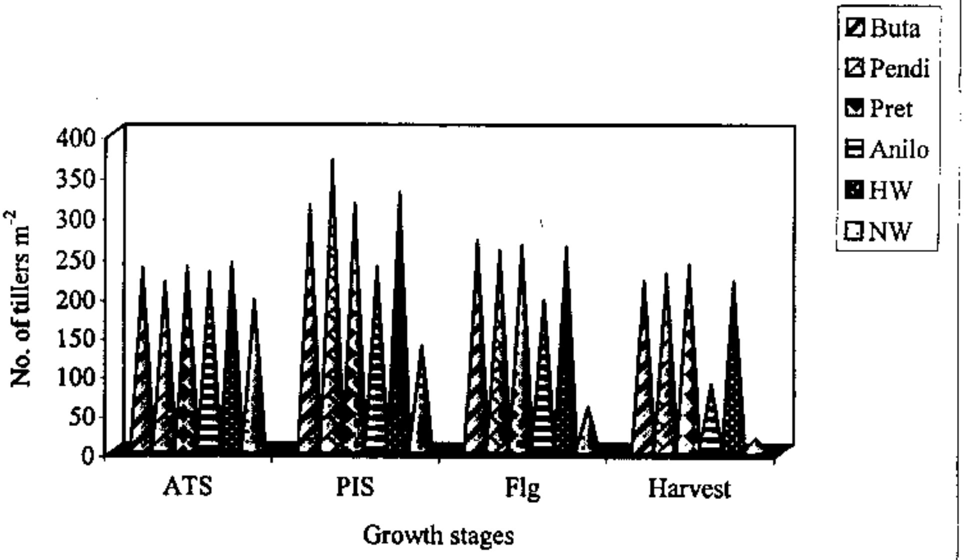

Fig. 16. Effect of weed management under intercropping situations on number of tillers of rice

unweeded plots particularly grass weeds, like *Sacciolepis* sp. Reduction in plant height (Palaikudy, 1989 and Suja, 1989), tiller number (Sudhakara and Nair, 1986, KAU, 1997 and Renu, 1999) and dry matter production (Suja, 1989 and Varshney, 1990) due to weed competition in unweeded treatments were reported by several authors.

The effect of the weed management practices on grain and straw yield of rice followed almost a similar trend both in the case of rice + cowpea and rice + horsegram system (Table 10; Appendix VIII and Fig. 18). In the case of rice + cowpea system, the highest yield recorded by pendimethalin was comparable with pretilachlor, but out yielded all other treatments including hand weeding. In the case of rice + horsegram system, pendimethalin and pretilachlor continued to record high and comparable yields but were also on par with the yields obtained from hand weeding and butachlor treated plots. Improvement in the growth and yield attributes, consequent to effective control of weeds, contributed to the enhanced grain and straw yields in the high yielding treatments. In the case of yield attributes, improvements were particularly observed in the case of number of panicles m^{-2}, panicle weight and percentage of filled grains. Increase in yield and yield attributes due to pre-emergence application of herbicides in dry sown rice has been reported by several authors (Phogat and Pandey, 1996; Sreenivas, 1997 and Varma and Kumar, 2003). While the monocropped rice with no weeding failed to yield any grain, rice + cowpea and rice + horsegram yielded around one to two quintals, which is indicative of the weed suppression effect of concurrent growing of green manure crops. It also indicate the need for an effective weed control measure for achieving high yields even when rice + green manure crop system was followed. Pendimethalin and pretilachlor were observed to be the best herbicides while following concurrent growing of green manure crop in semi-dry rice (Ramamoorthy *et al.*, 1997).

The weed infestation was observed to be of low magnitude upto 60 DAS, mostly dominated by broad leaved weeds. Subsequently the infestation became severe with the weed spectrum dominated by grasses at 90 DAS and harvest. In the current study, in herbicide treated plots, other than the pre-emergence application of herbicide, no other weed control measure, was resorted to. In the case of most of the pre-

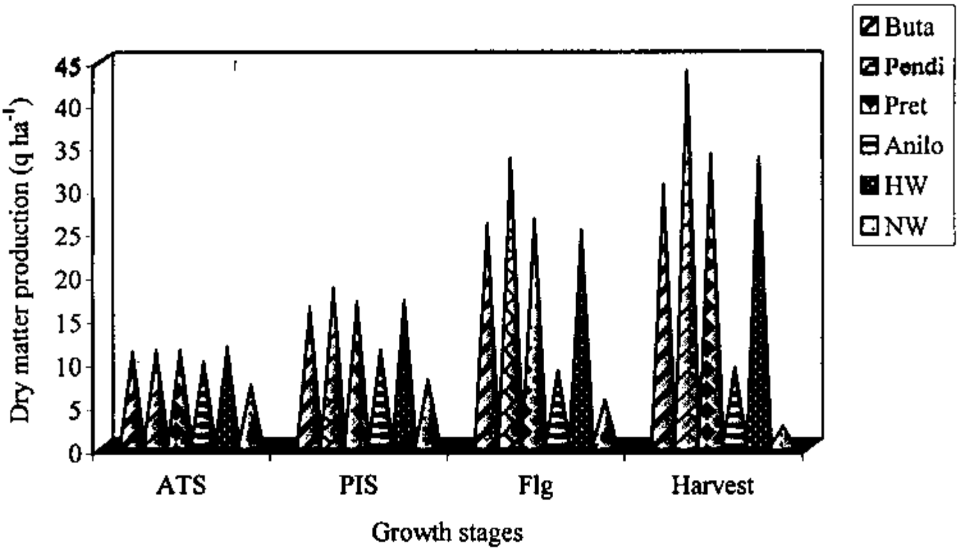

Fig. 17. Effect of weed management under intercropping situations on dry matter production of rice

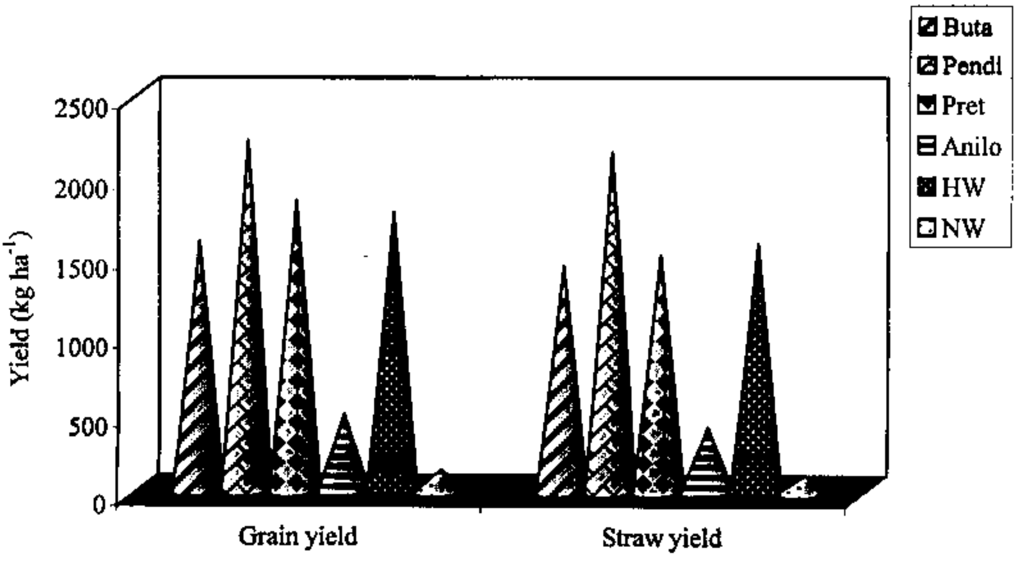

Fig. 18. Effect of weed management under intercropping situations on grain and straw yield of rice

emergence herbicide, the residual effect lasted to around 45 to 60 days only (Suja and Abraham, 1991). The results of the current study brought out the need for either one hand weeding or post-emergence application of herbicide, in addition to the pre-emergence application, to lower the weed population below the threshold level during the critical period of weed control.

The effect of weed control measures on the count and dry matter production (Tables 11 & 15; Appendix X and Fig. 19) of the total weed population was found to be almost identical in both the rice + green manure crop intercropping systems, inspite of the variation in weed intensity between the two systems. The data observed at 30 and 60 DAS revealed effective weed suppression in pendimethalin and pretilachlor treated plots, followed by butachlor. Similar results were reported by several authors (Battacharya and Mandal, 1991 and Joseph and Bridgit, 1993). Anilofos, however, failed to suppress weeds in the present study. Data at 90 DAS and harvest showed moderate to heavy weed infestation in all the treatments receiving pre-emergence application of herbicides, revealing their failure to check the weed growth during the critical period of weed control. It may also be observed that the number and dry matter production of weeds was higher in hand weeded treatments, as compared to herbicides except anilofos at 90 DAS and harvest bringing out the effectiveness of herbicides over manual weeding in prolonged weed control (Joseph and Bridgit, 1993).

Analysis of weed spectrum, vis-à-vis weed control treatments, indicated the predominance of grass weeds (Tables 11, 12, 13 & 14; Appendix IX and Fig. 20 and 21). Herbicide effectiveness in the suppression of grass weeds was observed only up to 60 DAS and it followed the order of pendimethalin, pretilachlor and butachlor. Anilofos was least effective. Population of sedges was substantial only at 30 DAS in rice + cowpea system, and at 30 and 60 DAS in rice + horsegram system. All the weed management practices, including manual weeding, were effective in achieving complete control of sedges in rice + cowpea system, while substantial control was obtained in pendimethalin and anilofos treated plots in rice + horsegram system. In general, the weed competition due to sedges was minimum in the present study. With

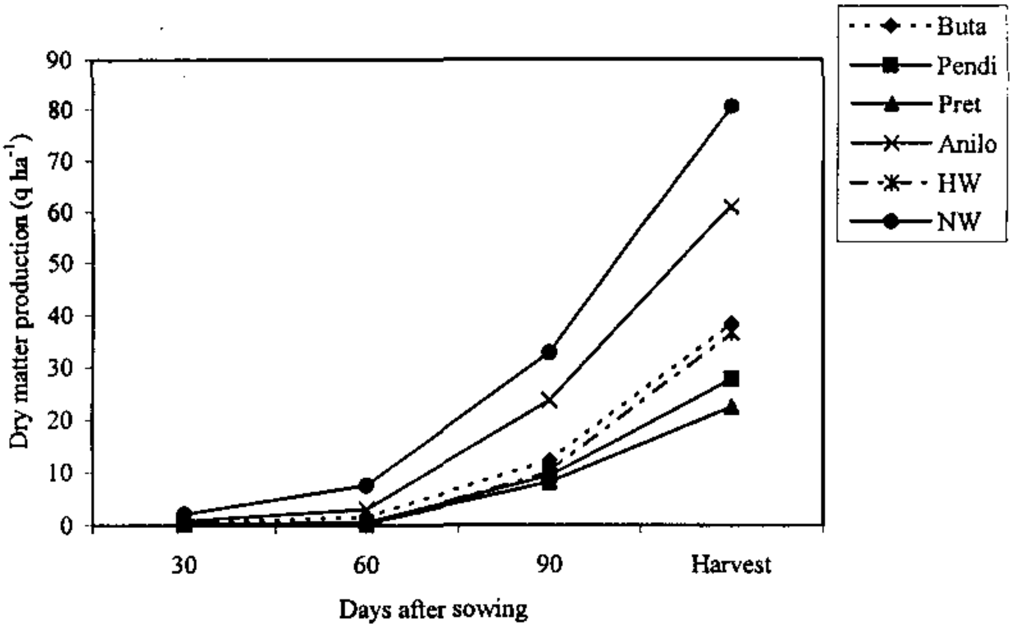

Fig. 19. Effect of weed management under intercropping situations on dry matter production of weeds

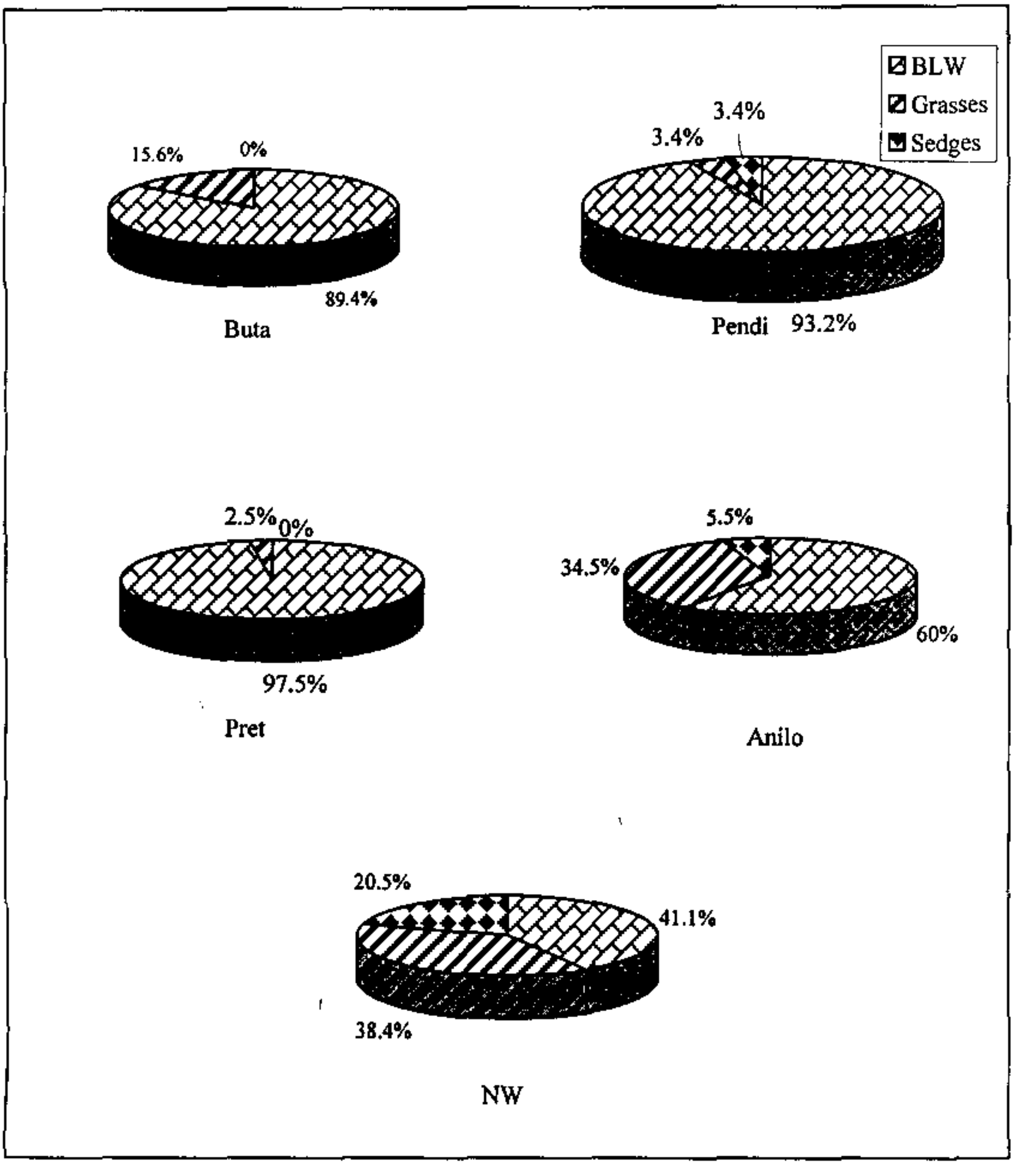

Fig. 20. Effect of weed management under intercropping situations on count of BLW, grasses and sedges at 30 days after sowing

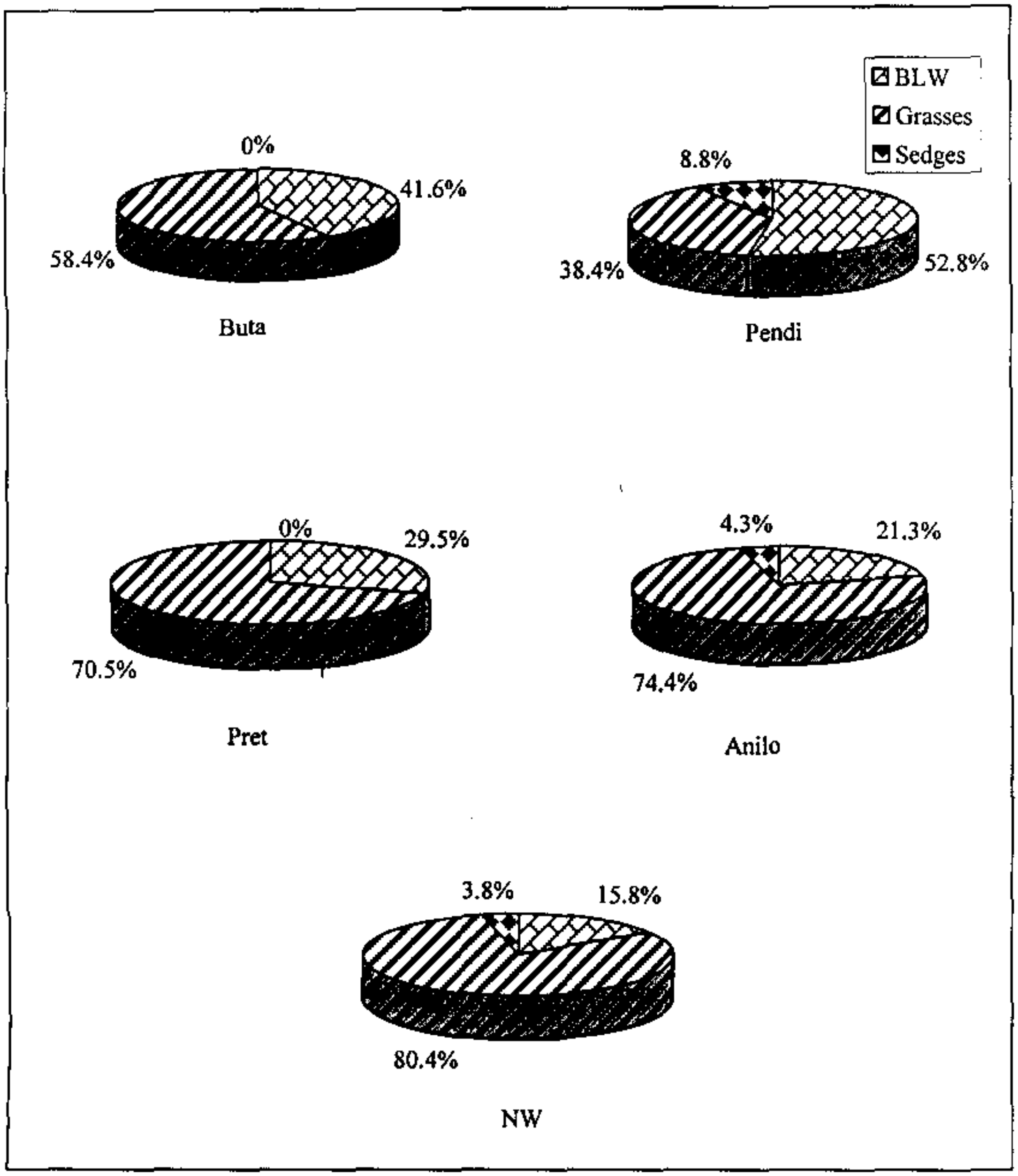

Fig. 21. Effect of weed management under intercropping situations on count of BLW, grasses and sedges at 60 days after sowing

regard to BLW, all the four herbicides could achieve effective weed suppression in the rice + cowpea system, while in the case of rice + horsegram system, pendimethalin and pretilachlor performed appreciably better. Variation in the response to herbicide application in different cropping system has been earlier reported by Saha and Srivastava (1992).

The uptake of N, P and K by weeds was found to increase with advancement in the growth stage of the crop, irrespective of treatments. The unchecked growth of weeds in unweeded control led to heavy absorption of nutrients by weeds posing severe competition to rice for nutrients. The absorption of nutrients by weeds was found to be very heavy from 60 DAS onwards. Application of pre-emergent herbicides, except anilofos, could decrease the uptake of all the three major nutrients by weeds particularly at 30 and 60 DAS (Table 18; Appendix XIII and Fig. 22), contributing to improved growth and yield of rice. It could be seen that the efficiency of the herbicides in controlling the DMP of weeds reflects directly on the nutrient uptake by weeds. Reduction in nutrient uptake by weeds in dry sown rice by application of herbicides has been reported by several authors (Suja and Abraham, 1991; Singh and Malik, 1992; Choubey *et al.*, 1999).

The uptake of major nutrients (Table 16; Appendix XII and Fig. 23) by rice was found to significantly vary among the weed management treatments and it was observed to have a direct relation with the weed control efficiency of the respective treatments. The pattern of nutrient uptake follows almost a similar trend as that of the DMP of rice which in turn is influenced by the variation in weed pressure. Irrespective of the system of cropping, pendimethalin and pretilachlor treated plots recorded higher uptake of N, P and K at all the three growth stages followed by butachlor. The lowest uptake among herbicides was recorded by anilofos. Hand weeded treatments recorded comparable values of nutrient uptake with that of herbicide treated plots. However, it could be seen that manual weeding was invariably superior in nutrient uptake at PIS and harvest in lieu of the reduced weed pressure facilitated by a second hand weeding. The competition for nutrients by weeds was so intense that the uptake of nutrients by rice was extremely low in unweeded control. The study revealed that improved

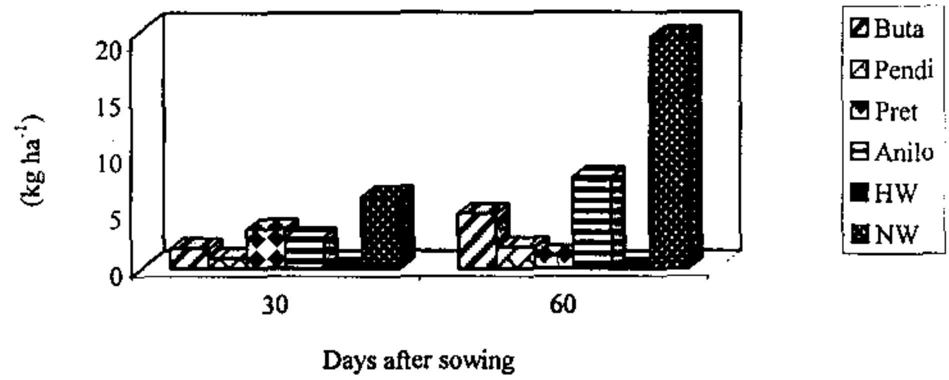

Fig. 22a. Nitrogen

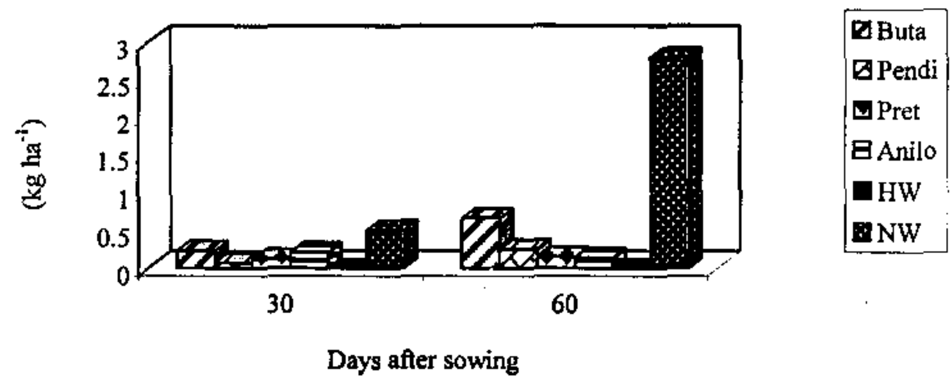

Fig. 22b. Phosphorus

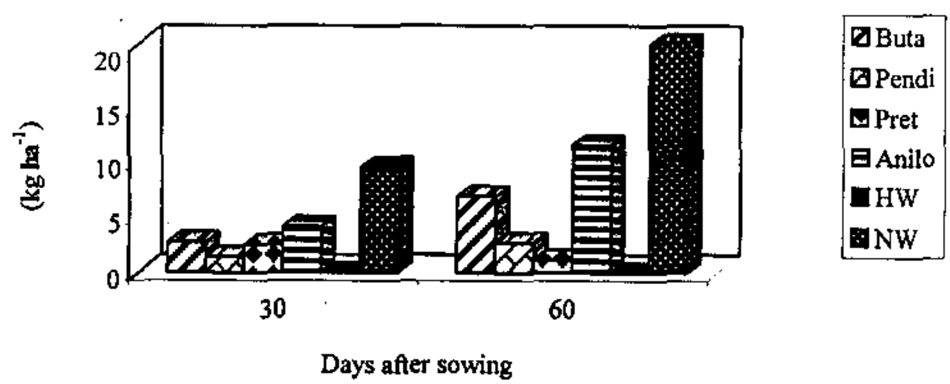

Fig. 22c. Potassium

Fig. 22a, b, c. Effect of weed management under intercropping situations on uptake of nutrients by weeds at 30 and 60 DAS

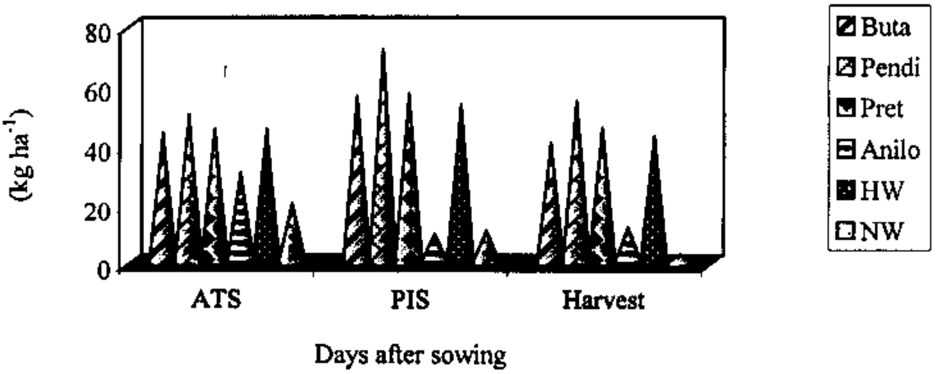

Fig. 23a. Nitrogen

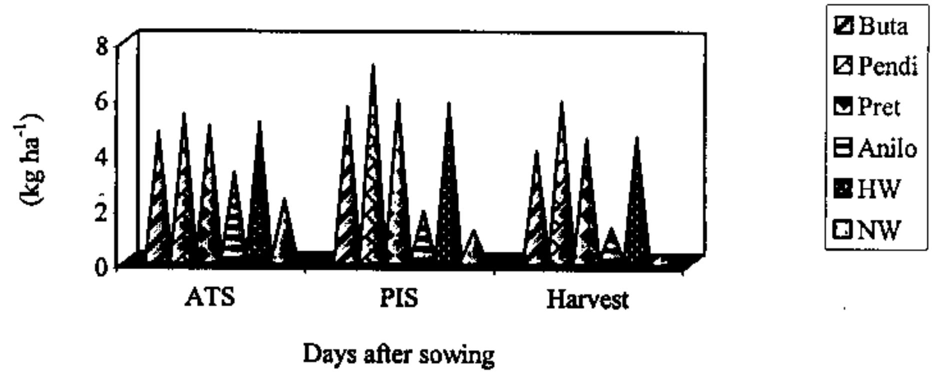

Fig. 23b. Phosphorus

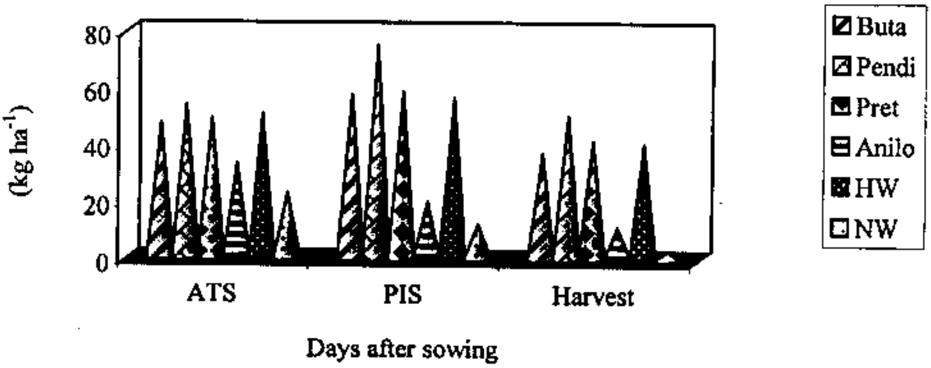

Fig. 23c. Potassium

Fig. 23a, b, c. Effect of weed management under intercropping situations on uptake of nutrients by rice

nutrient uptake due to reduced weed pressure is a major factor contributing to enhanced yield in dry sown rice as indicated by the high yield in plots treated with pendimethalin and pretilachlor. The results corroborates the findings of Kathiresan *et al.* (1997), Rajendran and Kempuchetty (1999) and Varma and Kumar (2003).

The data on growth, dry matter production and nutrient addition by the two green manure crops indicated their differential response to weed management practices. Pendimethalin and butachlor was found to perform equally well in both the cropping systems in terms of DMP and nutrient contribution (Table 9 & 17; Appendix XI and Fig. 24). However, it was observed that anilofos recorded the maximum DMP and NPK addition in respect of rice + horsegram system, while it recorded the lowest DMP and NPK addition in respect of rice + cowpea system. The performance of pretilachlor was comparable to pendimethalin and butachlor in both the systems. It may be recalled that almost a similar trend in response was observed in the case of population of the green manure crops, the effect of which might have well reflected in DMP and nutrient addition. The overall results suggests that pendimethalin, pretilachlor and butachlor can be used both in the rice + cowpea and rice + horsegram cropping system, in view of their favourable effect on the growth and nutrient contribution, apart from their superior weed control efficiency. Earlier reports also suggest that these herbicides are safe to leguminous green manure crops (Balasubramanian *et al.*, 1999). Considering the poor weed control efficiency and varied response in the different cropping systems, anilofos is not preferred for pre-emergence application in rice + cowpea and rice + horsegram systems.

Data on the fertility status of the soil after the incorporation of green manure crops showed the superiority of pendimethalin, pretilachlor and butachlor, as well as that of hand weeding (Table 19; Appendix XIV and Fig. 25). The performance of anilofos was invariably poor. The improvement in NPK status of the soil can be attributed to the increased contribution of nutrients by green manure crops in the absence of significant competition from weeds that inturn enhanced the growth and yield in rice. Though the post experiment analysis showed build up of NPK status in intercropped plots, as compared to monocropping, the variation between the weed

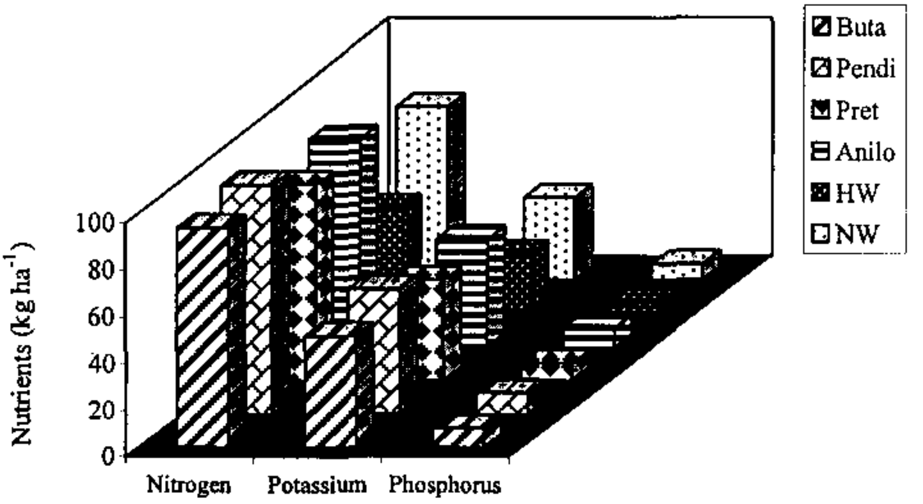

Fig. 24. Effect of weed management on the contribution of nutrients by green manure crops

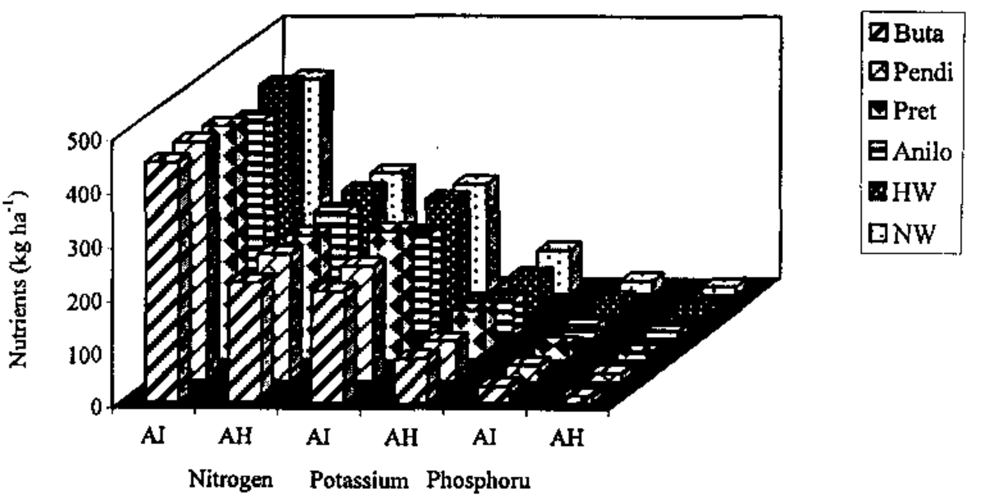

Fig. 25. Effect of weed management under intercropping situations on available nutrient content of soil

AI - After green manure incorporation
AH - After harvest

management practices was not found to follow a definite trend. This may be due to the incorporation of substantial quantity of weeds in treatments where the weed control efficiency is less and the increased uptake of nutrients by rice crop in treatments where the weed control efficiency is high.

An integrated weed management strategy including the application of selective herbicides, particularly pre-emergent ones along with biological means of intercropping was proved to be successful from the point of view of weed management, soil fertility build up and crop yield in semi-dry rice.

Summary

6. SUMMARY

An investigation to study the effect of weed management in semi-dry rice intercropped with green manure crops was conducted during early kharif season of 2002 at Agricultural Research Station, Mannuthy. The salient findings of the study are summarized below:

Concurrent growing of green manure crops

Regarding the growth characters of rice, seedling population was found higher under green manure intercropping over rice monocropping and that too under horsegram intercropping. Height was more in intercropped plots when compared to monocropping at active tillering stage. From panicle initiation stage up to harvest, more height was recorded under rice monocropping. Horsegram encouraged better growth of rice over cowpea with respect to height, number of tillers m^{-2}, leaf area index and dry matter production.

Considering the yield and yield attributes of rice, number of panicles m^{-2}, panicle weight, percentage of filled grains, grain yield and straw yield were more in horsegram intercropped plots than cowpea intercropped plots. The 1000 grain weight and harvest index was found more under cowpea intercropping than horsegram. When the intercropped treatments were compared to monocropped ones, all the yield and yield attributing characters except harvest index was found more under rice monocropping. The highest yield of grain and straw was recorded by monocropped rice with hand weeding (T_{13}) which was on par with treatments intercropped with horsegram (T_8) and cowpea (T_2) with both receiving pendimethalin application, while the monocropped rice with no weeding failed to yield any grain.

Considering the economics of treatments, concurrent growing of horsegram was proved economically viable than cowpea, irrespective of the herbicide treatments. Among the different treatments, the cost of production was highest in T_{13} (R + HW). Though the net income was highest in T_{13}, benefit : cost ratio was found highest in T_8 (R + Hg + Pendi) which was closely followed by T_{13}.

Comparing the unweeded plots with cowpea and horsegram intercropping and rice monocropping, it was observed that intercropping reduced the weed count to the extent of 42.8 to 56.8 per cent upto 60 days after sowing and thereafter the rate of reduction became lesser. In suppressing the population of all types of weeds (BLW, grasses and sedges), cowpea was found superior to horsegram.

Uptake of all the three major nutrients by rice was found higher in treatments intercropped with horsegram as compared to cowpea.

The contribution of N, P and K by cowpea at the time of self decomposition was almost double than that of horsegram. An increase in soil fertility status due to intercropping of green manure crops was noticed and the increase, on an average, was worked out to 79.81, 8.59 and 50.64 kg ha^{-1} of NPK with respect to intercropping with cowpea and 30.54, 5.15 and 28.56 kg ha^{-1} of NPK with respect to intercropping with horsegram, as compared to monoculture.

Weed management under intercropping situations

All the herbicides tested (butachlor, pendimethalin, pretilachlor and anilofos) were found safe to rice and green manure crops with no symptoms of phytotoxicity. Among the four herbicides, pendimethalin and pretilachlor expressed overall superiority than butachlor which inturn is superior to anilofos regarding the growth characters viz., height, number of tillers m^{-2}, leaf area index and dry matter production of rice during different growth stages, irrespective of the system of intercropping adopted.

Regarding yield and yield attributes, higher values were recorded in pendimethalin treated plots which was comparable to pretilachlor treated plots.

Effective weed suppression (BLW, grasses and sedges) was noticed in treatments receiving pendimethalin and pretilachlor followed by butachlor during 30 and 60 days after sowing, while anilofos failed to suppress the weeds.

Higher uptake of all the three major nutrients by rice was recorded by pendimethalin treated plots which was comparable to pretilachlor leading to a lower uptake of nutrients by the weeds.

Fertility status of the soil after the incorporation of green manure crops was found high in treatments receiving pendimethalin, pretilachlor and butachlor when compared to those receiving anilofos.

Considering the economics of treatments under intercropping situations, pendimethalin (B/C ratio 1.31) was found the best followed by pretilachlor (B/C ratio 1.23) and butachlor (B/C ratio 1.14).

Concurrent growing of horsegram in semi-dry rice up to the onset of south west monsoon along with pre-emergent application of herbicides was found successful from the point of view of weed management, soil fertility build up and yield enhancement in semi-dry rice.

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Appendices

APPENDIX I

Weekly weather data during the period corresponding to cropping season averaged over twelve years (1991-2002)

Standard week No.	Temperature (°C)			Relative humidity (%)		Sunshine hours day^{-1}	Evaporation mm day^{-1}	Rainfall mm $week^{-1}$	No. of rainy days	Wind speed ($km\ h^{-1}$)
	Maximum	Minimum	Mean	Morning	Evening					
16	35.0	25.2	30.1	85	57	8.2	5.1	19.1	1	3.7
17	34.9	25.0	30.0	87	56	7.6	4.6	16.6	2	3.9
18	34.6	25.1	29.9	84	58	7.7	5.1	25.7	1	3.9
19	34.3	25.3	29.8	86	59	7.8	4.9	47.2	2	3.9
20	32.7	24.6	28.7	89	65	5.9	4.2	58.4	3	3.3
21	33.0	24.5	28.8	89	64	7.0	4.2	45.0	3	3.7
22	32.2	24.0	28.1	90	68	5.6	3.8	72.0	5	3.8
23	29.8	23.1	26.5	92	79	3.4	3.0	182.0	6	3.8
24	29.6	23.2	26.4	94	81	2.2	3.1	181.5	7	3.8
25	29.9	23.4	26.7	95	77	3.7	3.1	122.2	6	3.8
26	29.1	23.0	26.1	94	80	3.2	2.9	182.5	6	3.4
27	29.2	22.8	26.0	94	80	2.8	3.2	161.9	7	3.6
28	29.0	22.7	25.9	95	80	3.2	2.7	156.0	7	3.7
29	29.2	22.8	26.0	94	78	2.8	2.8	177.7	6	3.6
30	28.9	22.9	25.9	95	80	2.7	2.8	165.2	7	3.6
31	28.8	23.1	26.0	95	80	2.6	2.8	142.6	6	3.6
32	29.2	23.2	26.2	95	78	3.1	2.9	92.5	7	3.5
33	29.5	23.2	26.4	94	77	4.0	3.0	132.8	5	3.3
34	29.5	23.3	26.4	94	77	4.1	3.1	95.2	5	3.2
35	30.4	23.1	26.8	94	74	4.6	3.6	73.1	4	3.3

APPENDIX II

Weekly weather data during crop season in 2002

Standard week No.	Temperature (°C)			Relative humidity (%)		Sunshine hours day^{-1}	Evaporation mm day^{-1}	Rainfall mm $week^{-1}$	No. of rainy days	Wind speed (km h^{-1})
	Maximum	Minimum	Mean	Morning	Evening					
16	35.2	25.4	30.3	86	57	7.6	4.2	12.2	1	3.7
17	35.3	24.9	30.1	85	56	7.7	5.4	31.0	2	4.4
18	35.6	24.5	29.6	85	60	6.2	5.0	54.4	2	4.7
19	33.7	25.3	29.5	84	60	7.7	4.8	44.2	2	4.9
20	30.8	24.0	27.4	93	76	3.1	2.7	173.2	5	3.3
21	32.2	24.2	28.2	87	67	6.9	3.7	4.0	0	3.6
22	30.8	24.0	27.4	89	73	3.5	4.2	119.0	2	4.2
23	30.7	23.4	27.1	94	73	5.0	3.5	64.2	4	4.0
24	28.9	22.5	25.7	94	93	0.6	2.5	219.1	5	3.7
25	29.5	23.3	26.4	93	81	1.8	2.8	109.8	6	4.5
26	30.5	23.7	27.1	94	75	3.5	3.1	74.6	5	3.7
27	30.3	23.6	26.9	94	72	5.2	3.4	57.0	4	3.7
28	29.4	23.1	26.3	94	77	3.0	3.1	126.0	4	4.0
29	29.7	22.7	26.2	95	73	2.7	3.1	58.0	5	3.8
30	29.9	22.9	26.4	93	73	3.8	2.9	70.4	5	3.7
31	28.1	22.5	25.3	95	86	0.7	2.4	83.5	7	4.0
32	28.6	22.2	25.4	95	79	0.9	2.8	94.0	6	3.8
33	27.9	22.8	25.4	94	83	2.6	2.1	337.0	7	3.7
34	30.1	25.4	27.8	93	72	5.4	3.8	13.8	2	3.7
35	30.9	24.1	27.5	93	65	7.3	4.3	3.8	1	3.8

APPENDIX III

Effect of treatments on seedling population and height of rice

Treatments	Seedling population (No. m^{-2})			Height of the plant (cm)			
	Days after sowing			Growth stages			
	Five	Seven	Nine	ATS	PIS	Flg	Harvest
Intercropping							
R + CP	72.4	90.6	113.0	47.4	62.1	86.2	85.7
R + Hg	75.2	96.1	122.7	47.6	62.7	86.5	86.0
Control							
R + HW	54.0	74.0	109.0	43.8	66.5	88.3	87.9
R + NW	75.0	89.0	118.0	39.2	58.0	81.1	80.6
Herbicides							
Buta	87.8	105.3	119.8	44.1	61.0	86.9	86.5
Pendi	72.3	99.5	120.3	50.2	60.2	87.8	87.1
Pret	86.3	98.5	119.3	49.1	69.1	90.2	89.7
Anilo	67.8	87.1	115.5	48.0	57.8	81.9	81.2
HW	54.6	72.5	107.8	45.0	67.3	88.1	87.8
NW	74.0	97.1	124.6	48.5	58.9	83.4	82.8

APPENDIX IV

Effect of treatments on number of tillers and LAI of rice

Treatments	No. of tillers m^{-2}				LAI of rice		
	Growth stages				Growth stages		
	ATS	PIS	Flg	Harvest	ATS	PIS	Flg
Intercropping							
R + CP	219.1	259.6	203.5	157.1	0.95	2.66	2.98
R + Hg	229.6	301.8	227.6	176.3	0.99	2.67	3.02
Control							
R + HW	304.0	354.7	322.3	306.3	1.11	2.90	3.27
R + NW	258.3	106.3	70.7	3.3	0.87	2.34	2.63
Herbicides							
Buta	233.2	310.7	267.8	217.2	0.96	2.70	2.98
Pendi	215.8	366.3	255.3	226.3	1.03	2.83	3.21
Pret	235.3	312.5	261.3	237.5	0.99	2.78	2.20
Anilo	228.2	235.3	193.0	84.5	0.94	2.57	2.81
HW	239.8	326.3	260.0	217.7	0.98	2.73	3.09
NW	193.7	133.2	55.7	17.0	0.91	2.39	2.71

APPENDIX V

Effect of treatments on dry matter production and root : shoot ratio of rice

Treatments	Dry matter production (q ha^{-1})				Root shoot ratio			
	Growth stages				Growth stages			
	ATS	PIS	Flg	Harvest	ATS	PIS	Flg	Harvest
Intercropping								
R + CP	10.1	14.1	20.0	23.2	0.24	0.33	0.23	0.17
R + Hg	10.4	14.8	21.4	27.5	0.23	0.34	0.23	0.16
Control								
R + HW	13.5	20.1	34.0	49.9	0.21	0.31	0.24	0.14
R + NW	5.0	5.6	1.3	0	0.29	0.38	0.26	0.20
Herbicides								
Buta	10.9	16.0	25.6	30.1	0.22	0.32	0.23	0.18
Pendi	11.1	18.2	33.2	43.5	0.21	0.33	0.23	0.15
Pret	11.1	16.6	26.2	33.7	0.22	0.33	0.22	0.14
Anilo	9.8	11.1	8.8	9.1	0.26	0.37	0.25	0.18
HW	11.5	16.8	24.9	33.3	0.21	0.32	0.22	0.17
NW	7.1	7.7	5.4	2.4	0.27	0.37	0.25	0.19

APPENDIX VI

Effect of treatments on seedling population and height of green manure crops

Treatments	Seedling population (No. m^{-2})					Height of the plant (cm)	
	Days after sowing					Days after sowing	
	Two	Four	Six	Eight	Thirteen	20	40
Intercropping							
R + CP	1.4	49.9	82.9	83.3	78.2	32.2	104.2
R + Hg	1.1	108.9	190.5	191.0	188.0	24.2	62.3
Herbicides							
Buta	1.5	83.8	142.7	144.0	136.0	31.2	84.0
Pendi	0.8	79.8	145.2	147.7	138.8	30.3	85.3
Pret	0.8	81.3	133.8	134.3	129.3	31.9	87.2
Anilo	0.0	72.8	127.3	128.5	126.2	32.8	84.4
HW	1.5	86.0	129.7	130.2	136.0	33.0	83.4
NW	2.8	72.7	141.5	142.3	140.8	32.2	75.2

APPENDIX VII

Effect of treatments on LAI, nodule count, root:shoot ratio and DMP of green manure crops

Treatments	Leaf area index		Nodule count (no plant^{-1})		Root:shoot ratio		DMP (q ha^{-1})	
	Days after sowing		Days after sowing		Days after sowing		Days after sowing	
	20	40	20	40	20	40	20	40
Intercropping								
R + CP	1.37	2.29	1.00	2.44	0.08	0.11	50.26	282.72
R + Hg	0.25	1.44	0.11	1.22	0.12	0.15	26.43	189.99
Herbicides								
Buta	0.88	1.95	0.50	2.00	0.09	0.13	42.32	262.85
Pendi	0.78	1.82	0.50	1.50	0.09	0.13	37.74	290.89
Pret	0.78	1.83	0.50	1.67	0.10	0.13	33.66	238.25
Anilo	0.84	1.91	0.83	1.67	0.10	0.14	40.49	271.32
HW	0.83	1.90	0.50	2.00	0.10	0.13	32.15	140.95
NW	0.76	1.82	0.50	2.17	0.10	0.13	43.71	213.85

APPENDIX VIII

Effect of treatments on yield and yield attributes of rice

Treatments	No. of days to 50% flowering	No. of panicles m^{-2}	Panicle weight (g)	No. of filled grains $panicle^{-1}$	Percentage of filled grains	1000 grain weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	HI
Intercropping									
R + CP	88.9	116.6	1.5	55.3	43.6	27.3	1241	1081	0.54
R + Hg	86.2	134.7	1.6	59.0	51.6	24.8	1437	1300	0.48
Control									
R + HW	83.7	269.0	1.80	69.0	64.3	28.2	2544	2443	0.51
R + NW	89.3	0	0	0	0	0	0	0	0
Herbicides									
Buta	86.7	150.2	1.6	54.7	51.2	28.3	1585	1430	0.52
Pendi	86.7	196.5	2.2	62.8	60.0	27.7	2210	2137	0.51
Pret	87.8	195.2	1.9	62.8	60.3	27.7	1843	1496	0.56
Anilo	88.3	21.3	1.1	61.2	38.2	27.0	494	412	0.54
HW	86.7	185.8	1.7	69.2	54.3	27.3	1768	1566	0.54
NW	89.0	5.0	0.6	30.5	21.3	18.2	133	103	0.38

APPENDIX IX

Effect of treatments on count of BLW, grasses and sedges

Treatments	BLW (No. m^2)				Grasses (No. m^2)				Sedges (No. m^2)			
	Days after sowing				Days after sowing				Days after sowing			
	30	60	90	Harvest	30	60	90	Harvest	30	60	90	Harvest
Intercropping												
R + CP	27.6	4.0	4.2	10.4	16.4	29.6	184.2	301.8	4.2	0	0	0
R + Hg	35.6	23.3	8.9	16.9	16.0	44.7	198.0	320.9	9.1	3.3	0	0
Control												
R + HW	0	0	0	8.0	0	0	60.0	110.7	0	0	0	0
R + NW	81.3	108.0	5.3	14.7	197.3	206.7	401.3	453.3	48.0	36.0	0	0
Herbicides												
Buta	26.7	28.0	10.0	15.3	4.7	39.3	150.7	238.0	0	0	0	0
Pendi	19.3	12.0	4.0	7.3	0.7	8.7	85.3	185.3	0.7	2.0	0	0
Pret	28.7	6.7	4.7	13.3	0.7	16.0	101.3	152.7	0	0	0	0
Anilo	44.0	13.3	4.7	12.7	25.3	46.7	209.3	326.0	4.0	2.7	0	0
HW	0	0	6.0	13.3	0	0	224.7	408.0	0	0	0	0
NW	70.7	22.0	10.0	20.0	66.0	112.0	375.3	558.0	35.3	5.3	0	0

APPENDIX X

Effect of treatments on total count and DMP of weeds

Treatments	Total weed count (No. m^2)				DMP of weed (q ha^{-1})			
	Days after sowing				Days after sowing			
	30	60	90	Harvest	30	60	90	Harvest
Intercropping								
R + CP	48.4	48.9	188.4	312.2	6.4	14.3	120.4	361.9
R + Hg	60.7	84.7	206.9	337.8	9.1	30.6	199.5	525.6
Control								
R + HW	0	0	60.0	118.7	0	0	28.3	99.3
R + NW	326.7	380.0	405.7	468.0	36.6	118.2	507.2	1041.3
Herbicides								
Buta	32.0	55.3	160.7	253.3	6.2	17.1	121.6	382.6
Pendi	20.7	19.3	89.3	192.7	3.3	6.7	93.5	276.1
Pret	29.3	27.3	106.0	166.0	5.7	4.2	81.3	223.6
Anilo	73.3	108.0	214.0	338.7	9.4	30.7	236.2	609.4
HW	0	0	230.7	421.3	0	0	100.6	365.3
NW	172.0	190.7	385.3	578.0	21.8	76.3	326.5	805.6

APPENDIX XI

Effect of treatments on the contribution of nutrients by green manure crop at the time of self decomposition

	Nutrients (kg ha^{-1})		
	Nitrogen	Phosphorus	Potassium
Intercropping			
R + CP	103.7	9.2	55.0
R + Hg	56.1	5.8	28.1
Herbicides			
Buta	93.6	8.5	47.8
Pendi	97.3	9.3	53.1
Pret	83.3	7.5	42.7
Anilo	88.0	8.4	45.8
HW	44.6	4.5	25.4
NW	72.6	6.7	34.7

APPENDIX XII

Effect of treatments on uptake of nutrients by rice

Treatments	Nitrogen (kg ha^{-1})			Phosphorus (kg ha^{-1})			Potassium (kg ha^{-1})		
	Growth stages			Growth stages			Growth stages		
	ATS	PIS	Harvest	ATS	PIS	Harvest	ATS	PIS	Harvest
<u>Intercropping</u>									
R + CP	37.9	43.7	30.8	4.1	4.3	3.1	41.8	45.5	28.4
R + Hg	40.9	46.0	35.7	4.4	4.7	3.7	43.6	47.5	32.4
<u>Control</u>									
R + HW	53.0	69.7	66.8	6.2	7.8	7.2	61.7	77.6	60.2
R + NW	13.7	2.5	0	1.7	0.3	0	16.5	2.9	0
<u>Herbicides</u>									
Buta	44.0	56.3	40.6	4.7	5.6	4.0	47.2	57.6	36.8
Pendi	50.1	71.9	54.6	5.3	7.1	5.8	53.7	75.1	50.1
Pret	45.4	57.0	45.7	4.9	5.8	4.4	49.0	58.6	41.2
Anilo	30.8	10.1	12.3	3.2	1.8	1.2	32.9	19.7	11.1
HW	45.4	53.7	43.0	5.0	5.7	4.5	50.6	56.4	40.2
NW	20.5	11.1	3.2	2.2	1.1	0.3	22.7	12.1	3.0

APPENDIX XIII

Effect of treatments on uptake of nutrients by weeds

Treatments	Nitrogen ($kg\ ha^{-1}$)				Phosphorus ($kg\ ha^{-1}$)				Potassium ($kg\ ha^{-1}$)			
	Days after sowing				Days after sowing				Days after sowing			
	30	60	90	Harvest	30	60	90	Harvest	30	60	90	Harvest
<u>Intercropping</u>												
R + CP	1.9	3.6	22.3	43.7	0.2	0.5	3.4	8.1	2.7	5.4	42.6	108.5
R + Hg	3.3	8.5	37.5	68.4	0.2	1.1	5.7	11.6	4.0	12.2	70.5	157.9
<u>Control</u>												
R + HW	0	0	5.0	11.3	0	0	0.8	2.3	0	0	9.8	30.1
R + NW	10.7	42.4	88.4	108.9	0.8	6.3	14.2	22.9	16.1	61.8	172.4	302.0
<u>Herbicides</u>												
Buta	1.8	4.9	23.4	46.8	0.2	0.7	3.6	8.7	2.7	6.9	43.6	117.1
Pendi	0.9	1.9	18.2	34.9	0.1	0.3	2.7	6.7	1.4	2.6	34.0	82.8
Pret	3.5	1.1	15.8	27.1	0.1	0.2	2.4	5.2	2.5	1.2	28.9	67.9
Anilo	2.7	8.1	44.2	73.6	0.2	0.1	7.1	12.8	4.1	11.7	32.4	181.4
HW	0	0	19.5	51.5	0	0	2.9	8.3	0	0	36.7	112.0
NW	6.4	20.4	58.2	102.2	0.5	2.8	8.9	17.4	9.6	30.5	113.7	237.8

APPENDIX XIV

Effect of treatments on available nutrient content of soil

Treatments	Nitrogen ($kg\ ha^{-1}$)		Phosphorus ($kg\ ha^{-1}$)		Potassium ($kg\ ha^{-1}$)	
	After green manure incorporation	Post experiment	After green manure incorporation	Post experiment	After green manure incorporation	Post experiment
Intercropping						
R + CP	454.0	227.2	30.3	16.0	223.1	83.9
R + Hg	404.8	233.5	26.8	15.3	201.1	75.8
Control						
R + HW	374.2	219.5	21.7	12.8	172.5	68.7
R + NW	365.9	207.0	19.6	12.0	169.5	68.7
Herbicides						
Buta	449.1	225.8	32.1	14.9	210.2	84.4
Pendi	446.4	237.3	30.7	16.8	215.8	76.2
Pret	434.9	231.0	28.4	15.5	238.8	91.5
Anilo	406.6	233.1	25.1	15.9	191.9	73.2
HW	434.9	231.0	31.0	16.4	214.3	73.6
NW	404.6	223.7	24.0	14.4	201.6	80.3

APPENDIX XV

Economics of the treatments (Rs. ha^{-1})

Treatments	Cost of cultivation	Returns		B/C ratio
		Gross return	Net return	
Intercropping				
R + CP	13994	12087	-1907	0.86
R + Hg	14067	14094	27	1.00
Control				
R + HW	18301	25240	6439	1.38
R + NW	10181	0	-10181	0
Herbicides				
Buta	13611	15537	1926	1.14
Pendi	16764	21951	5187	1.31
Pret	14443	17740	3297	1.23
Anilo	12382	4776	-7606	0.39
HW	15813	17273	1460	1.09
NW	11168	1266	-9902	0.11

WEED MANAGEMENT IN SEMI-DRY RICE INTERCROPPED WITH GREEN MANURE CROPS

By

O. N. RESMY

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

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Kerala Agricultural University

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ABSTRACT

An investigation was conducted during the kharif season of 2002 at Agricultural Research Station, Mannuthy to formulate weed management practices in semi-dry rice intercropped with green manure crops. Fourteen treatments were laid out in RBD with three replications involving combinations of two green manure crops (cowpea and horsegram) for *in situ* green manuring and six weed management treatments (butachlor, pendimethalin, pretilachlor, anilofos, handweeding and control) in addition to rice monocropping .

Results of the study revealed that an integrated strategy encompassing the application of pre-emergence herbicides and intercropping of green manure crops was successful from the point of view of weed management, organic manure addition and crop yield in semi-dry rice. Among the fourteen treatments tried, the highest yield of grain and straw was recorded by monocropped rice with hand weeding (T_{13}) which was on par with treatments intercropped with horsegram (T_8) and cowpea (T_2), both receiving pendimethalin application. Intercropping with horsegram encouraged better growth of rice over cowpea. Averaging the grain yield of rice in intercropping treatments, it was found that concurrent growing of horsegram has significant superiority over cowpea.

Comparing the unweeded plots with cowpea or horsegram intercropping and rice monocrop, it was observed that intercropping reduced the weed count to the extent of 42.8 to 56.8 per cent upto 60 DAS and cowpea was found superior in suppressing the population of weeds.

The contribution of N, P and K by cowpea at the time of self decomposition was almost double that of horsegram, leading to an increased soil fertility status.

Pendimethalin, pretilachlor and butachlor can be used safely both in rice + cowpea and rice + horsegram cropping systems and they favoured growth and yield of green manure crops and rice, apart from their superior weed control efficiency.