PERFORMANCE OF SUMMER CROPS IN RICE FALLOWS AND ITS EFFECT ON SUCCEEDING TRANSPLANTED RICE

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DECLARATION

I hereby declare that this thesis entitled **"Performance of summer crops in rice fallows and its effect on succeeding transplanted rice"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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21-12-2009 (2007-11-112)

CERTIFICATE

Certified that this thesis entitled **"Performance of summer crops in rice fallows and its effect on succeeding transplanted rice"** is a record of research work done independently by **Mr. Shrikant.P.Golabhavi (2007-11-112)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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Dedicated to

My Ever Loving

late grandpa's

V.B. Chouraddi,

R.V.Yadahalli

and

late grandma K.R.Yadahalli.

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SHRIKANT, P. G.

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LIST OF ABBREVIATIONS

@	-	At the rate of
˚C	-	Degree Celsius
%	-	Per cent
CD	-	Critical difference
cm	-	Centimetre
DAS	-	Days after sowing
DAP	-	Days after planting
et al.	-	And others
Fig.	-	Figure
FYM	-	Farm yard manure
g cc^{-1}	-	Gram per cubic centimeter
ha $^{-1}$	-	Per hectare
HI	-	Harvest index
$hill^{-1}$	-	Per hill
K	-	Potassium
kg^{-1}	-	Per kilogram
LAI	-	Leaf area index
m^{-2}	-	Per metre square
N	-	Nitrogen
No. m^{-2}	-	Number per metre square
NS	-	Non-significant
$panicle^{-1}$	-	Per panicle
P	-	Phosphorus
Rd	-	Relative density
Rdw	-	Relative dry weight
Rs.	-	Rupees
RYE	-	Rice yield equivalent
S	-	Significant
SDR	-	Summed dominance ratio
SEm	-	Standard error mean
t	-	Tonnes
viz.	-	Namely
WDMP	-	Weed dry matter production

INTRODUCTION

1. INTRODUCTION

Kerala is a consumer state for raw and processed products of food crops, pulse and oil seed and late vegetables. The states unique climate and physiography, though promotes cultivation and production of export oriented plantation and spices crops, limits the scope for attaining self sufficiency in food production.

The low diversity of cereal crops in the state synonymising it with rice, the low acreage under food crops with hardly any scope for area expansion and lack of irrigation facilities, especially during summer season stand in the way of increasing food production of the state to any substantial extend. Of the net rice area of 7157 ha in the two southern districts of Thiruvananthapuram and Kollam summer rice is practically nil, that leave the entire area as fallow (Farm guide 2008).

Among the cereal crops, rice requires the most water, even with innovative water saving irrigation techniques (Bouman and Tuong, 2001). Crop diversification and judicious cropping of summer rice fallows with short duration aerobic crops of higher water productivity alone holds promise for improving the total food production. Cropping summer rice fallows with oil seed crops sesamum and groundnut recorded significantly higher net return and water productivity than continuous cropping with three crops of rice (Mathew et al. 1996).

Including root crop, sweet potato was reported to have high production potential and higher water productivity 12.4 –18 kg m^{-3} (Prasad et al. 1997). Inclusion of vegetables in rice based cropping sequence increased the water productivity 2-3 times compared to other non vegetables based crop sequences.

Summer cropping with upland crops and residue incorporation has beneficial effect on the soil health and fertility and also facilitate effective utilization of residual soil moisture and nutrients (Sasidhar, 1978; Pushpakumari et al. 1991 and Kumar et al., 1993)

The diverse effects on soil health due to the differential absorption or accretion of nutrients by the alternate crop may also affect the succeeding rice crop. It could lead to decline in carbon sequestration and soil productivity (Bronson et al., 1997). Increased aeration could also lead to changes in the weed community (Mortimer and Hill,1999), increased emission of nitrous oxide and reduced emission of methane (Wassmann et al., 2000).

With these backgrounds an investigation was conducted at CSRC Karamana during the summer season and virippu seasons of 2008 with the following objectives.

1) To study the performance of different upland crops in the summer rice fallows of southern Kerala in terms of resource utilisation, yield and soil health.

2) To study the carry over effect of summer upland crops on the succeeding rice crop.

3) To asses the economic feasibility of adopting the different upland crops in summer rice fallows.

4) To arrive at a sound package of practices for summer rice fallow utilizations for enhancing the productivity of the cropping system.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Rice culture in the lowland ecosystem being rainfed, the scope of taking a summer crop of rice in many places is dismal for want of irrigation water. Hence, crop diversification and cropping summer rice fallows with less water guzzling short duration crops only can hold promise for increasing the food production and the farmer's income. Diverse effect on soil health due to differential absorption or accretion of nutrients by the alternate crop may also affect the succeeding rice crop. In the present study, attempts were made to identify the upland crop most suitable for the summer rice fallows of southern Kerala for enhancing the productivity of the cropping system and the net return to the farmers. Also it will help to delineate the associated soil health problems and ways to solve them so as to sustain the productivity of the succeeding rice crop. The literature falling within the scope of the investigation is reviewed in this chapter. Research information on other related crops and cropping systems are reviewed where pertinent literature is lacking.

2.1. WEED FLORA

2.1.1. Weed flora of summer crops

Nedunzhiyan (1996) reported that sweet potato was found to be associated with 22 weed species consisting mostly of *Celosia argentea, Digitaria sanguinalis, Cleome viscosa* and *Cyperus rotundus*.

The most dominant weeds that appeared immediately after the planting of sweet potato were *Celosia argentea, Digitaria sanguinalis,* *Cleome viscosa, Ageratum conyzoides and Cyperus rotundus* (Nedunchezhiyan and Satapathy., 2002 b).

Porwal (2002) reported that the associated weeds in sweet potato were *Chenopodium album, Chenopodium murale, Spergula arvensis, Trianthema portulacastrum, Anagallis arvensis, Cynodon dactylon, Cyperus rotundus*, and *Parthenium hysterophorus*.

Predominant weeds in sweet potato were junglerice (*Echinochloa colona*), purple nutsedge (*Cyperus rotundus*), spleen pigweed (*Amaranthus dubius*) and dayflower (*Commelina diffusa*) (Lugo and Diaz., 2007).

Weeds identified in sesame included *Boerhavia diffusa*, *Amaranthus viridis*, *Digitaria sanguinalis*, *Dactyloctenium aegyptium* and *Cyperus rotundus* (Venkatakrishnan and Gnanamurthy., 1998).

The predominant weeds in summer sesamum were *Cleome viscosa, Euphorbia prostrata, Gynandropsis pentaphylla [Cleome gynandra], Trianthema portulacastrum, Echinochloa colona*, *Panicum repens and Cyperus rotundus* by Kavimani et al. (2001).

The major weeds in sesame grown in rice fallow *were Cynodon dactylon, Echinochloa colona, Cyperus rotundus* and *Trianthema portulacastrum* (Punia et al., 2001 ; Krishnaprabu and Kalyanasundaram, 2007).

Sesame grown in kharif seasons was heavily invaded by *Amaranthus viridis, Phyllanthus niruri, Trianthema portulacastrum, Cynodon dactylon, Digera arvensis* and Celosia *argentea* (Yadav, 2004).

Thakur (2005) reported that the dominant weeds in sesame crop grown during the kharif season were *Panicum dichotomiflorum, Echinochloa colonum, Echinochloa crus-galli, Cynodon dactylon, Cyperus iria* and

Cyperus difformis. The dominant weed species in sesame during the summer *were Cynodon dactylon, Echinochloa colona, Digitaria sanguinalis, Cyperus rotundus, Digera arvens* and *Physalis minima* (Ghosh and Ghosh, 2006).

Misra et al. (1993) reported that during the winter season, annual weeds like *Chenopodium album*, *Melilotus spp*. and *Anagallis arvensis* were common in grain amaranth.

The dominant grasses and broadleaved weeds in amaranth grown during the summer season were (*Amaranthus hybridus*, *Simsia amplexicaulis*, *Eleusine multiflora, Lopezia racemosa* and *Portulaca oleracea*) (Alavez et al., 1998).

Mathew and Sreenivasan (1998) reported that in cowpea (*Vigna unguiculata* var. Kanakamony) dicotyledonous weeds dominated during the summer, whereas during the kharif, grasses [*Poaceae*] and sedges [*Cyperaceae*] were dominant.

The major weed flora in summer cowpea [*Vigna unguiculata* (L.) Walp.] at harvest were *Dactyloctenium aegyptium* (41.8%), *Eleusine indica* (15.7%), *Gnaphalium indicum* (14.4%), *Cyperus rotundus* (12.8%), *Echinochloa crus-galli* (8.4%) and *Sorghum halepense* (6.9%) (Tripathi and Govindra Singh, 2001).

The dominant weed species in cowpea were *Digitaria sanguinalis*, and other major weed species, such as *Cyperus amuricus, Portulaca oleracea*, and *Amaranthus retroflexus* (Lee KwangHoe, 2007).

2.1.2. Weed flora in transplanted rice

Total weed flora in rice has a proportion of 70 per cent grasses, 25 per cent sedges and 5 per cent broad leaved weeds (Tomar, 1991).

Major weeds of the rice fields were *Echinochloa crusgalli*, *Echinochloa colona*, *Cynodon dactylon* and *Panicum repens* among grasses, *Cyperus difformis*, *Cyperus iria* and *Fimbristylis miliacea* among the sedges and *Ammania baccifera*, *Ludwigia parviflora*, *Eclipta alba*, *Marsilea quadrifoliata, Phyllanthus niruri*, *Ipomoea reptens*, *Sphaeranthus indicus* and *Portulaca oleracea* among the broad leaved weeds (Verma et al., 1987 and Thirumurugan et al., 1992).

Thomas and Abraham (1998) reported *Echinochloa crusgalli*, *Monochoria vaginalis*, *Cyperus difformis*, *Cyperus iria, Fimbristylis miliacea, Sphenoclea zeylanica, Ludwigia perennis* and *Marsilea quadrifoliata* as the major weeds of transplanted weeds of Kerala.

The major weed flora of the transplanted rice consisted of grasses, sedges and broad leaved weeds, the predominant grassy weeds were *Echinochloa crus-galli*, *E. colona*, *Cynodon dactylon*, *Cyperus rotundus, Cyperus iria, Cyperus difformis* and *Fimbristylis miliacea* were the important sedges. *Ammannia baccifera* and *Ludwigia parviflora* dominated the broad leaved weeds (Dhiman Mukherjee, 2005).

The major weeds of transplanted rice crop and their importance value index (IVI) were in the order *Sphenoclea zeylanica* (44.8), *Echinochloa colona* (34.0), *Panicum repens* (30.7) and *Echinochloa crus-galli* (25.7) (Natarajan, 2007).

2.1.3. Weed dry weight

Das and Datta (1995) reported that weed dry matter accumulation, particularly grassy weeds, in kharif rice crop was significantly depressed in treatments including biofertilizers (*Sesbania aculeata, Sesbania rostrata and Corchorus olitorius* (jute), and was lowest with *Corchorus olitorius*.

Dogbe (1998) reported that exploiting soil moisture by growing cowpea before rice or protecting the soil with a cover crop significantly reduced dry weed biomass in rice and lowest weed weights and highest rice yield were obtained with combinations of pre-rice legume and post rice soil cover. Chandrasekhar et al. (1998) reported that the sesame haulm incorporation reduced weed growth by 40 per cent.

Choubey et al. (1998) reported that the dry weight of the weeds under the continuous submergence (5 ± 2 cm) of water in rice was 53.8 and 11.4 g m^{-2} during 1993 and 1994 respectively and in unweeded condition the dry weight was 131.1 and 26.7 g m^{-2} during 1993 and 1994 respectively.

Dry matter accumulation of weeds in sweet potato increased with the duration of weed infestation. Weed dry weight in completely weed infestation up to 45 days after planting (DAP) and at harvest were 247 and 3241 kg ha^{-1} respectively (Nedunchezhiyan and Satapathy, 2002 a).

Weed density and dry weight were similar at 15 days after planting and at harvest in sweet potato (Nedunchezhiyan and Satapathy, 2002 b).

Sesame grown with a fertilizer application of 30:40:40 kg N, P and K ha^{-1} contains a weed dry matter of 34.59 g m^{-2} at 40 days after sowing (DAS) (Singh et al., 2003 a).

Intercropping of green manure in wet-seeded rice system during the kharif and rabi seasons significantly reduced the total weed dry weight and nutrient removal by weeds compared to non green manure plots (Sathyamoorthy et al., 2004).

Osten et al. (2006) reported that weed dry matter levels above 2500 kg ha^{-1} resulted in net decreases in the inherent soil nitrogen.

Lee KwangHoe (2007) found that the total shoot dry weight of weeds was the highest in the control (fallow) plot, and the lowest in the cowpea plot, indicating that cowpea most effectively suppressed the growth of weeds.

Krishnaprabu and Kalyanasundaram (2007) reported that the weed dry weight in summer rice fallow sesame under weedy check was 30.20 g m^{-2}.

Increasing pumpkin population up to 10000 -15000 plants ha^{-1} reduced weed dry biomass by 36-57% (Olasantan, 2007).

Subramanyam et al. (2007) reported that unchecked weed growth in transplanted rice produced a dry matter of 190.8 g m^{-2}.

2.1.4. Nutrient uptake by weeds

Removal of nutrients by weeds in rice was estimated as 26 kg N, 4 kg P_2O_5 and 21 kg K_2O ha^{-1} (Ramamoorthy, 1991).

Rana and Angiras (1999) reported that in the unweeded control, weeds depleted 107.0, 15.5 and 112.8 kg ha^{-1} of nitrogen, phosphorus and potassium, respectively which was 60.8, 6.85 and 46.6 kg more than the total uptake of these nutrients by rice.

Nitrogen, phosphorus and potassium removed by weeds in sweet potato increased with the duration of weed infestation. Weeds removed 45.4, 19.2 and 61.7 kg N, P and K ha^{-1} respectively from completely weed infested sweet potato (Nedunchezhiyan and Satapathy, 2002a).

Subramanyam et al. (2007) reported that unchecked weed growth removed 17.7, 7.02 and 19.12 kg N, P, K ha^{-1} respectively in transplanted rice grown in sandy loam soil.

2.2. EFFECT OF SUMMER CROPS ON PHYSICO – CHEMICAL PROPERTIES OF THE SOIL

2.2.1. Soil physical properties

Boparai and Yadvinder Singh (1992) reported that application of the green manure to wetland rice increased the water stable aggregates, reduced the soil bulk density and increased the infiltration rate.

Sesbania green manuring and green gram residue incorporation resulted in reduction in bulk density and increase in soil aggregation which in turn increased infiltration and percolation rate and hydraulic conductivity of soil (Mandal et al., 1999).

Bazejczak and Dawidowski (1999) reported that intensification of crop production using modern agricultural machinery and by reducing the crop rotation can cause deterioration of the soil physical state.

Menon et al. (1999 a) reported that compared to the cropped areas, fallowing during the summer resulted in a greater degradation in soil physical properties compared with soils cropped with legumes.

Sharma et al. (2001) reported that the integrated use of inorganic and organics through farmyard manure, crop residues of wheat and green manuring of daincha decreased the bulk density.

Sheeba and Kumarasamy (2002) observed that the bulk density was lower in manure treatments (farmyard manure, green leaf manure and urban compost) than in control. However, soil porosity, maximum water-holding capacity and volume expansion were higher in manure treatments compared to the control. Among the manures studied, FYM showed the strongest influence on soil physical properties.

Channabasavanna et al. (2002) observed that poor physical and chemical properties of soil under the rice monocropping system, while in crop rotation and incorporation of green leaf manure or green manure, recycling of organic residues in the farming system approach improved the soil health.

Inclusion of summer cowpea helped decrease the bulk density in the surface (0-15 cm) and sub-surface (15-30 and 30-45 cm) soil layers (Dwivedi et al., 2003).

Phogat et al. (2004) reported that inclusion of green manure crops in the cropping system improved the soil structure and cation exchange capacity of the soil over the control plots.

2.2.2. Soil chemical properties

2.2.2.1. Soil organic carbon

With fertilization and crop residue retention, a higher organic carbon level was maintained than in the unfertilized treatment with crop residue removal (Kang, 1993).

Nambiar (1994) reported increase in the organic carbon content due to the application of farm yard manure.

Reddy et al. (1995) reported that soil organic carbon content at 60 days after sowing rice was highest with cowpea as the preceding crop.

Introduction of the legume crop like grain cowpea in rice based cropping system was observed to have a positive influence on the organic carbon content of the soil (Singh et al., 1996).

Cultivation of summer crops could lead to decline in carbon sequestration and soil productivity (Bronson et al., 1997).

The cropping systems with legumes and N application increased soil organic carbon and soil N balance (Subhash Chandra Gautam, 1997). Thakur et al. (1999) reported that green manuring improved soil organic carbon from 0.52 to 0.56 per cent.

Panda et al. (1999) reported that addition of biomass in the form of roots and plant residues to the soil due to continuous cropping and manuring increased the organic matter and organic carbon content of the soil.

Sesbania green manuring and mung bean residue incorporation increased soil organic carbon over summer fallow by 0.105-0.135 percentage points, Kjeldahl N by 0.01 percentage points and available P by 5-5.5 kg ha^{-1} (Sharma et al., 2000).

Puste et al. (2001) reported that 25% of total applied N was saved by the application of inorganic N in combination with organic sources (crop residues, well decomposed cow dung, danicha as green manure) without significant yield reduction with simultaneous improvement of soil chemical properties (pH, organic matter, available N, P, K, and CEC).

Integrated use of inorganic and organics through farmyard manure, crop residues of wheat and green manuring of daincha improved the soil organic carbon (Sharma et al., 2001).

Paikaray et al. (2002) reported that soil fertility in terms of organic carbon (0.03 – 0.06%) increased under green manure, summer cowpea fodder, wheat straw incorporation and higher levels of inorganic N.

Dwivedi et al. (2003) reported that soil organic carbon content in 0-15 and 15-30 cm depths was greater compared to initial organic carbon in summer cowpea plots.

Inclusion of a green manure crop in rice based cropping system has bean reported to improve the soil quality through build of soil organic carbon (Ramesh and Chandrashekharan, 2004).

Phogat et al. (2004) reported that high organic carbon content in green manure incorporated soil than in the control.

Green manuring daincha alone had a little effect (8 per cent) on organic carbon content of the soil (Kharub et al., 2004).

Bruun et al. (2006) reported that stocks of soil organic carbon, total N and exchangeable base cations in upland rice were not related to yields, fallow length or cropping intensity.

The organic carbon status of the soil after the rice- rice- daincha and rice-rice- fallow were 0.7 per cent each (Varughese, 2006).

Pillai et al. (2007) reported that inclusion of legumes in the rice based cropping system and integrated nutrient management improved the organic carbon status of the soil.

Saha et al. (2007) reported that the application of daincha green manure along with chemical fertilizers increased organic carbon in sandy loam soil.

Shrikant et al. (2007) reported that transplanting of rice after *Sesbania aculeata* incorporation resulted in significantly increased organic carbon over transplanting rice without green manure incorporation.

2.2.2.2. Soil pH

Kang. (1993) reported that under fallow soil pH level increased over time.

Singha et al. (1993) could not observe any significant difference in soil pH due to the different rice based cropping sequences.

Newaj and Yadav (1994) reported a decrease in soil pH from the initial soil pH value of 7.8 to a lower pH value ranging from 7.5 to 7.6 under all crop sequences, after two years of inclusion of legumes in the cropping sequence.

Thakur et al. (1999) reported that inclusion of daincha and cow pea treatment in cropping sequence had no effect on soil pH.

Phogat et al. (2004) reported that inclusion of green manure crops in the cropping system lower the soil pH over the control plots.

Chander Pal et al. (2007) reported that the chemical fertilizers application (N, P and K) and intensive cropping had negative effect on soil pH and CaCO3 and positive with electrical conductivity and cation exchange capacity.

2.2.2.3. Soil available nutrients

2.2.2.3.1. Soil available nitrogen

Yadav et al. (1991) observed that the apparent nitrogen balance was negative in rice-maize-maize + cowpea (fodder) cropping system.

Singha et al. (1993) reported that the total nitrogen content of the soil was not affected significantly by the different cropping systems. The initial nitrogen status was found to be maintained even after one year cropping, possibly owing to the fixation of nitrogen by legumes.

Sharma and Das (1994) reported that the incorporation of daincha in situ after 48 and 54 days of growth added 81.3 and 85.1 kg N ha^{-1} respectively.

Reddy et al. (1995) reported that incorporation of cowpeas added 76.8 kg N ha^{-1} to the soil.

Inclusion of legume crops like grain cowpea in rice based cropping systems resulted in positive balance for soil nitrogen (Singh et al., 1996).

Mineralization and nitrification of N was negligible during the rice-fallow period due to the dry conditions and low organic matter content (Singh et al., 1999).

A positive effect of fertilizer nitrogen application to rice on Kjeldahl N content of soil was observed in the Sesbania green manured and mung bean residue incorporated plots but not in summer fallow plots (Sharma et al., 2000).

Available nitrogen increased significantly with farmyard manure, crop residues of wheat and green manuring of daincha over their initial status of soil (Sharma et al., 2001).

Mahapatra et al. (2002) reported that summer cropping of legumes showed a positive impact on available soil N, and a significant impact on available P and K and they opined that higher rice grain yield values with summer legumes may be attributed to more nutrient contribution towards nutrition of rice crop as evidenced from high wet soil ammonium-N and N uptake.

Soil fertility in terms of available N (5.8 -22 kg ha^{-1}) increased under green manure, summer cow pea fodder, wheat straw incorporation and higher levels of inorganic N (Paikaray et al., 2002) and they also reported that available N had positive balance in soil due to the addition of *Sesbania* green manure (22.3 kg ha^{-1}), summer cow pea fodder (5.8 kg ha^{-1}) and wheat straw incorporation (12.3 kg ha^{-1}).

Alok Kumar (2003) reported that farmyard manure (FYM) application at 12-15 t ha^{-1} to rice could add nearly 60 kg N ha^{-1} while the incorporation of 40 to 60 day-old *Sesbania* as green manure add 50 kg N ha^{-1}.

Daincha incorporation before the transplanting of rice showed a positive balance for nitrogen (161.2 kg ha^{-1}) in rice wheat system (Kharub et al., 2004).

Bruun et al. (2006) reported that plant-available N stocks were positively correlated with fallow length. A weaker correlation was found between plant-available P and fallow length. Although shorter fallow periods may reduce the availability of N and P, the results do not point towards a long term degradation of the soil organic carbon as a result of decreasing fallow periods.

Bhargavi et al. (2007) observed that the highest soil available nitrogen balance was recorded with green gram-rice-groundnut after the first year and fallow-rice-groundnut after the second year. Negative soil available nitrogen balance was registered with sesame-rice-sunflower system.

Summer cropping Onattukara rice fallows with ground nut or cowpea resulted in positive nitrogen balance sheet compared to sesamum or bhindi cropping (Pillai et al., 2007).

Saha et al. (2007) reported that the application of daincha green manure along with chemical fertilizers increased the total N in soil.

Shrikant et al. (2007) reported that transplanting of rice after *Sesbania aculeata* incorporation resulted in significantly increased available N over transplanting of rice.

Thus the nitrogen status of the soil is differentially affected by cropping systems and in some cases even severe reduction in soil nitrogen occurs. In general inclusion of the legume in cropping systems improved the nitrogen content of the soil.

2.2.2.3.2. Soil available P

Yadav et al. (1991) observed a positive balance for soil phosphorus in Rice – wheat – fallow, Rice – maize – maize + cow pea (fodder), Rice – toria – wheat – daincha (green manure), Rice – potato + Indian mustard – green gram, Rice – wheat – sugar cane – ratoon - wheat crop sequences.

Studies conducted by Singha et al. (1993) in sandy clay - loam soils of Diphu (Assam) revealed that the available phosphorus status of the soil was not affected significantly by the different cropping sequences studied.

Humphrey (1996) reported that after 5 consecutive sweet potato crop phosphorus was deficient whereas fallow soil had no mineral deficiencies.

Available phosphorus increased significantly with farmyard manure, crop residues of wheat and green manuring of daincha over their initial status of soil (Sharma et al., 2001).

Soil fertility in terms of available P (1.4 – 3.8 kg ha^{-1}) increased under green manure, summer cowpea fodder, wheat straw incorporation and higher levels of inorganic N (Paikaray et al., 2002) and they also reported that available P had positive balance in soil due to the addition of *Sesbania* green manure (3.8 kg ha^{-1}), summer cowpea fodder (1.4 kg ha^{-1}) and wheat straw incorporation (3.4 kg ha^{-1}).

The available P content was, however, invariably low under summer cowpea plots as compared to fallow (Dwivedi et al., 2003).

Green manuring daincha alone had a little effect (4.8 per cent) on availability of phosphorus content of the soil and daincha incorporation before the transplanting of rice showed a positive balance for phosphorus (87.3 kg ha^{-1}) in rice wheat system (Kharub et al., 2004).

Denich et al. (2005) found that the live and dead above-ground biomass of 1-10 year old fallow vegetation amounts to 10-98 t ha^{-1} and in the nutrient balance of a crop/fallow cycle including slash burning and fertilization nutrient losses exceed inputs for N, K, Ca and Mg, but not for P.

The available phosphorus status of the soil after the rice- rice- daincha and rice- rice- fallow were 11.3 and 10.8 kg ha^{-1} (Varughese, 2006).

Bhargavi et al. (2007) observed that the negative balance of soil available phosphorus was registered with fallow-rice-sunflower, sesame-rice-sunflower, sesame-rice-groundnut and fallow-rice-groundnut systems at the end of the first year while phosphorus balance was positive with all the cropping systems tried at the end of the second year.

Saha et al. (2007) reported that the application of daincha green manure along with chemical fertilizers increased the available P and available S in soil.

2.2.2.3.3 Soil available K

Yadav et al. (1991) reported a negative balance for soil potassium in Rice – wheat – fallow, Rice – maize – maize + cow pea (fodder), Rice – toria – wheat – daincha (green manure), Rice – potato + Indian mustard – green gram, Rice – wheat – sugar cane – ratoon - wheat crop sequences.

Prasad et al. (1997) reported that in sweet potato the minimum negative potassium balance (-65 kg ha^{-1}) was recorded in the control (0 kg K_2O ha^{-1}) and the maximum at 100 kg K_2O ha^{-1} (-192 kg ha^{-1}).

Available potassium increased significantly with farmyard manure, crop residues of wheat and green manuring of daincha over their initial status of soil (Sharma et al., 2001).

Soil fertility in terms of available K (2.2 – 17.9 kg ha^{-1}) increased under green manure, summer cow pea fodder, wheat straw incorporation and higher levels of inorganic N (Paikaray et al., 2002) and they also reported that available K had positive balance in soil due to the addition of *Sesbania* green manure (17.9 kg ha^{-1}) and wheat straw incorporation (15.9) but it was negative for summer cow pea fodder incorporation (-10.1 kg ha^{-1}).

Green manuring daincha alone had a little effect (1.3 per cent) on the available of potassium content of the soil and daincha incorporation before the transplanting of rice showed a negative balance for potassium (-58.8 kg ha^{-1}) in rice wheat system (Kharub et al., 2004).

The available potassium status of the soil after the rice- rice- daincha and rice- rice- fallow were 52 and 52.3 kg ha^{-1} (Varughese. 2006).

Water soluble, exchangeable and available potassium are negatively correlated with pH and $CaCO_3$ in surface (0-15 cm) soils after rice in rice-wheat-cowpea cropping system under all the nutrient management treatments but non significant correlation coefficients were found with fixed and lattice potassium (Chander Pal et al., 2007).

Saha et al. (2007) reported that the application of daincha green manure along with chemical fertilizers increased the exchangeable K in soil.

Shrikant et al. (2007) reported that transplanting of rice after *Sesbania aculeata* incorporation significantly increased the available K over transplanting of rice.

2.2.2.3.4. Soil exchangeable calcium and magnesium balance

On the soils with less organic matter, Reddy et al. (1992) observed significant increase in exchangeable Mg when cropped continuously with cowpea as compared cropping of millets.

Kang (1993) reported that under fallow exchangeable calcium and magnesium levels increased over time.

After 34 mono cropping of rice Tran et al., (2006) observed that the cation exchange capacity did not show significant changes and soil could still maintain and provide nutrients for rice. Exchangeable cation Ca++ and Mg ++ were high. The soil is still rich in exchangeable cation Ca++ and Mg ++ for rice.

2.2.2.3.5. Soil available micronutrients Iron (Fe), Zinc (Zn) and Copper (Cu)

Sharma et al. (2001) reported that micronutrient cations decreased in purely inorganic-treated plots over the control. Where as remarkable build up in these cations was noted in organically (farmyard manure, crop residues of wheat and green manuring of daincha) treated plots.

The depletion of micronutrients in the soil (Fe, Cu, Zn) was more in the mineral fertilizer plots than in plots having both mineral fertilizer and *Sesbania* green manure (Alok Kumar 2003).

The Fe status of the soil after 3 crops of rice declined from the initial value, but the decline was least with FYM, followed by green manures. The application of organic manures (*Sesbania, Leucaena*, cowpea, mungbean, wheat straw and FYM) ensured a sustained supply of Fe in soil (Mishra et al., 2004).

The micronutrient status of soil after 3 cycles of rice-wheat cropping system declined over initial values but the decline was the least with FYM followed by green manures. Application of organic manures sustained the supply of Zn and Cu to rice-wheat cropping system soils (Mishra et al., 2006).

After 34 mono cropping of rice Tran et al., (2006) observed high Cu and Zn.

Saha et al. (2007) reported that the application of daincha green manure along with chemical fertilizers increased the available Zn and available iron (Fe) in soil.

2.3. EFFECT OF SUMMER CROPS ON SUCCEEDING RICE CROP

Various crops are reported to leave certain after effects either positive or negative which exerts a marked influence on the growth of the subsequent crops.

The dry matter production, yield attributes and grain yield of kharif transplanted rice was significantly increased when it was preceded by a summer crop of daincha and the green manure incorporated in to the soil before the transplanting of rice (Pushpakumari et al., 1991; Sharma and Das., 1994; Mathew et al., 1996; Quayyum and Maniruzzaman, 1996; Jacob et al., 1999; Kalpana et al., 2000; Puste et al., 2001; Das et al., 2002; Mahapatra et al., 2002; Sriramachandrasekharan et al., 2004 and Shrikant et al., 2007).

Summer cropping legume and soil incorporation significantly increased the productivity of succeeding rice crop (Wu and Yan, 1992; Ali, 1993; Hegade and Dwivedi, 1993; Dogbe, 1998; Rahman et al., 1998; Menon et al., 1999 b; Singh and Verma, 1999; Phogat et al., 2004 and Zamir et al., 2005).

Sumer cropping grain cowpea with haulm incorporation significantly improved the grain yield of the succeeding rice crop (Kumar et al., 1993 and Padhi, 1993).

In situ green manuring with cowpea in summer season boosted the grain yield of the succeeding rice crop and improved the soil physical condition and soil fertility (Danso and Papastylianou, 1992; Singha et al., 1993; Samui et al., 1995; Nanda et al., 1999; Aulakh et al., 2000; Dwivedi et al., 2003 and Usman et al., 2006).

The uptake of nutrients and the nutrient efficiency by the rice and the fertility of the soil were improved when green manuring crops preceded transplanted rice (Mythili et al., 1993; Mondal and Chettri, 1998; Channal and Kandaswamy, 1998 and Savithri et al., 1999)

The preceding summer crop of sesamum exerted a negative effect on the yield attributes and yield of the succeeding rice crop (Kumar et al., 1993; Padhi, 1993; Premasthira and Zungsontiporn, 1999 Gurusamy et al., 2007a and Gurusamy et al., 2007b)

The productivity of rice crop preceded by a summer crop of okra was markedly lower, where as it was the highest when preceded by cowpea (Padhi, 1993).

Siddeswaran (1992) on comparing grain legume, cowpea, Black gram and soybean reported that the haulm yield of cowpea was the highest and its incorporation resulted in grain yield increase of the succeeding rice crop to the tune of 10.4 per cent.

The inclusion of forage cowpea in summer did not affect the leaf area index and yield of subsequent rice when rice received the recommended rates of N and P fertilizers. The absence of either of the fertilizers resulted in a significant yield loss. The magnitude of yield reduction was greater (0.9-3.1 t ha^{-1} in rice) in forage cowpea treatments than in summer fallow (0.5-3.0 t ha^{-1}) (Singh et al., 2003 b).

Pillai et al. (2007) reported that inclusion of groundnut and cowpea in rice-based crop sequences increased the yield of the succeeding crop of rice.

The incorporation of large quantities of above- and below-ground legume biomass (roots and foliage) resulted in substantial residual effects on the subsequent upland rice crop. The residual effects of below-ground biomass (roots, nodules) on the following rice crop were not very pronounced and resulted in similar residual effects as rice, after fallow (Schulz et al., 1999).

A positive correlation was observed between length of fallow and subsequent rice yields, in shifting cultivation systems (Bruun et al., 2006).

Ramesh et al. (2002) reported that the leaf chlorophyll content (Soil Plant Analytical Division value) is the best indicator of photosynthetic activity in rice and leaf chlorophyll content at 79 days after sowing correlated well with the grain yield of rice.

Johnkutty et al. (2000) observed a significant relationship between the leaf N concentration and SPAD value and between Leaf Colour Chart (LCC) and leaf N concentration.

Ramanathan et al. (2000) found that the SPAD threshold range of 36-38 could be optimum for dry season rice crops, and a threshold range of 33-35 for wet season rice in the Cauvery Delta zone.

Argenta et al. (2001) reported that the critical range of SPAD reading corresponding to adequate nitrogen levels were 40 – 42 at panicle initiation stage.

2.4. YIELD OF SUMMER CROPS IN RICE FALLOWS

2.4.1. Economic yield

With the application 75 kg ha^{-1} potassium to the sweet potato produced 24.89 t ha^{-1} foliage yield and 42.77 t ha^{-1} total biomass on fresh weight basis with a harvest index of 0.5 (Byju and Ray, 2002).

Ansary et al. (2003) reported that pumpkin produced the highest fruit number (3.08 $hill^{-1}$) total yield 12.85 kg $hill^{-1}$ and yield (44.57 t ha^{-1}) with 75 kg N ha^{-1}.

Kumar et al. (1993) reported that sesamum grown in summer rice fallows produced the seed yield of 153 kg ha^{-1}.

The highest sesame seed yield (1777 kg ha^{-1}) in summer rice fallow was produced with NPK fertilizer application of 60:75:40 kg ha^{-1} (Basavaraj et al., 2000).

Paul and Savithri (2003) concluded that sesame grown in summer rice fallow with the recommended dose of 30 kg N ha^{-1} produced the tallest plants (73.7 cm), with the highest number of branches per plant (8.0), dry matter (6201 kg ha^{-1}), highest number of capsules per plant (76.8), number of seeds per capsule (59.0) and seed yield (729.5 kg ha^{-1}).

Pillai et al. (2007) reported that sesame grown in Onattukara rice fallows with the KAU package of practices recommendation produced the seed yield of 322 kg ha^{-1}.

The seasme grown in summer rice fallows with application of 35: 23: 23 kg N, P_2O_5 and K_2O ha^{-1} produced a seed yield of 470 kg ha^{-1}. (Krishnaprabu and Kalyanasundaram., 2008).

Amaranthus (*Amaranthus tricolor* L.) grown with the KAU package of practices recommendation produces a yield of 127.1 g m^{-2} at first harvest (35 days after sowing) and 133.0 g m^{-2} at second harvest (60 days after sowing) on fresh weight basis (Preetha, 2005).

Onyango et al. (2008) reported that vegetable amaranth had a dry matter content of 14.5%.

Menon and Nair (1993) reported that sunn hemp [*Crotalaria juncea*], soyabeans, rice beans [*Vigna umbellata*], cowpeas, velvet beans [*Mucuna pruriens*] and black gram [*V. mungo*] grown on rice fallows gave green fodder yields of 21, 4.57, 6.56, 7.98, 3.78 and 6.24 t ha^{-1} respectively.

Kumar et al. (1993) reported that cowpea grown in summer rice fallows in C.S.R.C Karamana with the K.A.U package of practices recommendation produced the yield of 6991 kg ha^{-1}.

Kumari and Ushakumari (2002) reported that cowpea (*Vigna unguiculata* L. Walp) grown with the K.A.U package of practices recommendation produced 837.5 and 1650.0 kg grain and haulm yield ha^{-1} respectively.

Pillai et al. (2007) reported that grain cowpea grown in Onattukara rice fallows with the K.A.U package of practices recommendation produced the yield of 510 kg ha^{-1}. Wang and Yu Qiang (2008) opined that summer cowpea crops planted in the fallow period were predicted to yield 1.3 t/ha of biomass on average (range of 0-5.7 t/ha) if sown every year.

Leguminous green manure species differ widely in biomass production and nitrogen accumulation. The most productive green manure crops yielded about 4 to 5 t $ha^{-1}$of dry matter in 50 to 60 days. The biomass production and nitrogen accumulation of sesbania are mainly controlled by age factor (Singh et al., 1991). *Sesbania aculeata* accumulated the higher amount of biomass (26.3 t ha^{-1}) and it contributes 145 kg ha^{-1} nitrogen (Siddeswaran, 1992).

Kumar et al. (1993) reported that daincha grown in summer rice fallows in C.S.R.C Karamana with the KAU package of practices recommendation produced the yield of 14504 kg ha^{-1}.

Sesbania aculeata at 45 days after sowing produces 2.12 g dry weight per $plant^{-1}$ and 5.96 t ha^{-1}green biomass (Chandra and Pareek, 1998).

Kalidurai (1998) reported that daincha is fast growing and produced dry matter of 2 t ha^{-1} within 45 days.

Daincha grown in rice fallow produced a green matter of 174.5 q ha^{-1} (Thakur et al., 1999).

Daincha grown as a green manure crop in summer rice fallows in C.S.R.C Karamana with the KAU package of practices recommendation produced the yield of 146.50 q ha^{-1} (Varughese, 2006).

2.4.2. Rice yield equivalent

Roy (1997) reported that intercropping rice with sesame (*Sesamum indicum*) produced the highest rice equivalent yield of 3.68 t ha^{-1} and the highest net return.

Rice equivalent yield was highest for the cropping sequence rice–rice–okra followed by rice- rice- cowpea (Raj et al., 1999).

Thakur et al. (1999) reported that daincha and fodder cow pea grown as a summer crops in rice fallows produced a rice grain yield equivalent of 63.70 and 60.61 q ha^{-1}.

Sesame grown as a rice fallow crop had the lowest rice grain equivalent yield (Anbumani et al., 2000).

The green manuring of sesbania and mung bean in rice-wheat system gave an additional rice-equivalent yield of 1.11 and 0.9 t ha^{-1} over wheat and rice, respectively (Singh and Sharma, 2002).

Daincha grown in summer rice fallows in C.S.R.C Karamana with the KAU package of practices recommendation had a rice yield equivalent of 96.23 q ha^{-1} $year^{-1}$ (Varughese, 2006).

Debabrata and Saha (2008) reported that the maximum grain yield of rice (4.2 t ha^{-1}), rice equivalent yield (REY) of onion (26.7 t ha^{-1}) as winter crop and REY of cowpea (9.362 t ha^{-1}) as summer crop were registered in rice-onion (*Allium cepa*)-cowpea (*Vigna unguiculata*) sequence.

Singh et al. (2008) reported that cowpea (fodder) - rice - Pea (green pod) gave the highest rice-equivalent yield (64.47 q ha^{-1}) compared to rice-soybean (fodder) - pea (green pod).

2.5. NUTRIENT UPTAKE BY THE DIFFERENT CROPS

2.5.1. Sweet potato

Howeler (1990) reported that the removal of phosphorus in the harvested product of cassava, sweet potato, Irish potato, yam and taro is very low compared to nitrogen or potassium removal and the external phosphorus requirements (soil solution P) are very low for cassava and yam, intermediate for sweet potato and taro, and high for Irish potato.

Nutrient uptake, by sweet potato especially of K, increased with increasing pH (4.5 to 7.0) (Ila'ava et al., 1995).

Potassium uptake by sweet potato vines and tubers together was maximum 95 kg ha^{-1} where the crop was raised with 80 kg K_2O and with one irrigation. However, significant increase in potassium uptake was noted only with application up to 60 kg K_2O ha^{-1} (Prasad et al., 1997).

Padmaja and Raju (1999) reported that potassium concentration and total potassium uptake in sweet potato increased with increasing potassium application rate. Effects of potassium source were not significant.

Byju and George (2005) reported that potassium is the most important nutrient element needed by sweet potato in terms of nutrient uptake per unit area per unit tuber production.

2.5.2. Pumpkin

Beaulah et al. (2001) reported that N, P and K uptake (255.55, 25.95 and 256.18 kg ha^{-1}) and nitrogen use efficiency under rice fallow conditions were comparatively high in paired row planting of pumpkin + 20 g N/pit.

2.5.3. Sesamum

Regy (1996) observed a removal of 2.64 kg N, 5.04 kg P and 10.15 kg K at a production level of 450 kg seeds per hectare.

Kavimani et al. (2001) reported that sesame raised after rice absorbed 8.87, 1.63 and 8.44 kg ha^{-1} of N, P and K respectively.

The uptake of Nitrogen (N), phosphorus (P) and potassium (K) by sesame was 30.4, 10.2 and 26.3 kg ha^{-1}, respectively and resulted in soil available N, P and K loss of 37.0, 19.8 and 29.0 kg ha^{-1} respectively (Gurusamy et al., 2007 c).

Pillai et al. (2007) reported that sesame grown in Onattukara rice fallows with the KAU package of practices recommendation removed 13.2 kg ha^{-1} of nitrogen.

The seasme grown in summer rice fallows with application of 35: 23: 23 kg N, P_2O_5 and K_2O ha^{-1} removed 30.23, 7.88 and 20.04 kg N, P and K ha^{-1} respectively (Krishnaprabu and Kalyanasundaram, 2008).

2.5.4. Amaranthus

Ca, and Fe content of the raw leaves of amaranth (*Amaranthus tricolor*) and kondhara (*Digera arvensis*) leaves were 3135.0 to 3289.58, 3.35 to 8.98 mg/100 g dry weight respectively (Darshan and Manju, 2004).

Preetha et al. (2005) reported that amaranthus grown with the KAU package of practices recommendation removed 358.6, 39.1 and 371.5 mg N, P and K m^{-2} at the time of first harvest and 390.8, 38.1 and 402.6 mg N, P and K m^{-2} at the time of second harvest.

Sudhir et al. (2006) reported that vegetable amaranth is a rich source of minerals like calcium (1.7 ± 0.04 g/100 g), iron (1233.8 ± 50.02 mg/kg), and zinc (791.7 ± 28.98 mg/kg) Zn was the only mineral exhibiting significant positive association with foliage yield.

The mean Zn content of vegetable amaranth was 5.5 mg/100 g and iron content 18 mg/100 g (Onyango et al., 2008).

2.5.5. Cowpea

Geetha and Varughese (2001) reported that an application of 20:45:20 kg N, P and K ha^{-1} to the vegetable cowpea produced 9487 and 16294 kg pod and haulm yield ha^{-1} respectively.

Kumari and Ushakumari (2002) reported that cowpea (*Vigna unguiculata* L. Walp) grown with the K.A.U package of practices recommendation removed 53.42 kg N, 7.26 kg P, 23.78 kg K, 18.15 kg Ca, 6.67 kg Mg, 287 g Fe, 74.0 g Zn and 44.10 g Cu ha^{-1}.

Vegetable cowpea grown with the K.A.U package of practices recommendation contains 0.37% of total P in plant (Meena and Hameed, 2002).

Pillai et al. (2007) reported that cowpea grown in Onattukara rice fallows with the K.A.U package of practices recommendation removed 32.5 kg ha^{-1} of nitrogen.

2.5.6. Daincha

About eight weeks old daincha plants contained 3 per cent N in addition to K, Ca, Mg, P, S and micronutrients and about 33 kg N, 1 kg P, 14 kg K, 14 kg Ca, 16 kg Mg and 2 kg S are added to the soil ton^{-1} of daincha dry matter applied (Bhuiyan,1988).

Chandra and Pareek (1998) reported that 45 days old *Sesbania aculeata* contains 3.06 per cent N and it accumulated 46.13 kg N ha^{-1}.

Savithri et al. (1999) reported that the micronutrient content of *Sesbania rostrata* was 1968, 40 and 36 µg of Fe, Zn and Cu g^{-1} respectively.

Sole *Sesbania aculeata* green biomass of 12 t ha^{-1} contributes 73.5 kg N ha^{-1} to the succeeding rice crop (Kalpana et al., 2000).

2.5.7. Rice

Narang et al (1990) reported that rice crop yielding 9.5 t ha^{-1} of unhusked rice removed 198 kg N, 31 kg P_2O_5 and 230 kg K_2O ha^{-1} $annum^{-1}$.

Pathak and Ghose (1996) opined that rice being a heavy feeder removed on an average 18.9 kg N, 3.9 kg P_2O_5 and 26.4 kg K_2O t^{-1} of grain.

A continuous fertilizer application of 80: 40: 40 kg N, P, K ha^{-1} in rice - rice system removed 140, 29 and 128 kg N, P, K ha^{-1} respectively in kharif season (Reddy et al., 1999).

Among macronutrients, Mg was having maximum utilization efficiency (grain produced per unit of nutrient accumulated in the plant) and K was having minimum efficiency. Nutrient utilization efficiency was maximum for B and minimum for Mn among micronutrients (Fageria, 2004).

Mishra et al. (2004) reported that the concentration and uptake of Fe by rice was significantly higher with organic manures (*Sesbania, Leucaena*, cowpea, mungbean, wheat straw and FYM).

Patro et al. (2005) reported that integrated use of *Sesbania cannabina* green manure and 180 kg N ha^{-1} recorded 7.1 t ha^{-1} of grain and removed 136.7, 24.2 and 165.1 kg N, P and K ha^{-1} respectively.

Varughese (2006) reported that rice grown with the KAU package of practices recommendation removed 92.8, 13.9 and 109.5 kg N, P and K ha^{-1} respectively during the kharif season.

2.6. WATER PRODUCTIVITY OF DIFFERENT CROPS

Mathew et al. (1996) reported that cropping summer rice fallows with oil seed crops sesamum and groundnut recorded significantly higher water productivity than continuous cropping with three crops of rice.

Sweet potato was reported as a crop of higher water productivity (12.4 – 18 kg m^{-3}) and it varied depending on soil profile moisture supply and was greatest with mulching under rainfed condition (Prasad et al., 1997).

Prasad et al. (1997) reported that water-use efficiency of sweet potato was maximum (1803 kg ha cm^{-1}) under mulched condition followed by rainfed (1604 kg ha cm^{-1}) and irrigated (1237 kg ha cm^{-1}).

Renault et al. (2000) emphasized the importance of nutritional productivity of water and reported the nutritional productivity of water for Fe as 57 mg for potato 36mg for vegetables and 30 mg for cereals m^{-3} of water.

Goswami (2004) reported that inclusion of vegetables in rice based cropping sequence increased the water productivity 2-3 times compared to other non vegetables based crop sequences. The water productivity of sesamum varied between 0.12-0.2, tomato 4.3-7.1, rice 0.5-0.8 and pointed gourd 0.7-1.2 kg m^{-3}.

Cultivation of upland crop in rice fallows hold promise in increasing the system productivity and water productivity (Gangwar et al., 2006).

2.7. ECONOMICS

Green manuring with *Sesbania rostrata* recorded the highest net return and benefit cost ratio followed by incorporation of cowpea/black gram haulms in the rice-rice-pulses/green manure cropping system (Siddeswaran, 1992).

In a study conducted at the Cropping System Research Centre, Karamana on the performance of different summer crops raised in rice fallows, rice – rice – bhindi crop sequences emerged as the most profitable one giving the net profit of Rs. 11329 per hectare followed by rice – rice – cowpea (Rs. 10336 ha^{-1}) and rice – rice – ground nut (Rs. 9457 ha^{-1}) (Kumar et al., 1993).

Mathew et al. (1996) reported that cropping summer rice fallows with oil seed crops sesamum and groundnut recorded significantly higher net return than continuous cropping with three crops of rice.

Thakur et al. (1999) reported that the daincha-treated plot recorded the highest gross income (19952 Rs ha^{-1}), net income (10202 Rs ha^{-1}) and benefit:cost ratio (2.04) as compared to fallow and fodder cow pea.

Nagalikar et al. (1999) reported that the rice-sesame sequence recorded the highest sustainable value index (0.81), benefit:cost ratio (2.89) and production efficiency (38.13), followed by the rice-sunflower sequence and they also suggested that rice-sesame could be recommended as an alternative to rice-rice sequence.

The inclusion of pulses and oilseed crops in rice-based crop sequences gave higher production and monetary gain over the rice-wheat conventional system (Verma and Warsi, 1999).

Raj et al. (1999) reported that the net returns and benefit: cost ratios were highest for the rice - okra sequence, followed by the rice - cowpea sequence.

Olekar et al. (2000) reported that the rice-rice sequence is the most promising, with higher SVI (sustainable value index) and benefit-cost ratio and a low index of variability compared to rice-sesame sequence.

Usman et al. (2006) observed a positive economic benefit across the different rice production systems, although the marginal rates of return were higher when rice was grown after legumes than growing of rice after cassava.

Varughese (2006) reported that the B: C ratio of rice – rice – green manure was 1.43.

Singh et al. (2008) reported that cowpea (fodder)- rice - Pea (green pod) gave the highest net return (Rs. 32573 $ha^{-1}annum^{-1}$), return per rupee investment (Rs. 2.31), net return per day (Rs. 105.40) and return per rupee investment on labour (Rs 4.05).

The systems with more than two crops in a year, particularly inclusion of vegetable, lowered down the stability of the system in respect of yield and economics (Urkurkar et al., 2008).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Field investigations were carried out to study the performance of different upland crops in summer rice fallows of southern Kerala and its carry over effect on the succeeding rice crop in terms of resource utilization, crop yield, economics and soil health so as to arrive at a sound practice of summer rice fallow utilization.

The experiment was carried out during the period extending from February 2008 to October 2008 that covered the summer (third crop) and virippu (the first crop) seasons of rice cultivation. The details regarding materials used and methods adopted for the study are presented in this chapter.

3.1. MATERIALS

3.1.1. Experimental site

The experiment was conducted in the wetlands of the Cropping Systems Research Centre, Karamana, Thiruvananthapuram, a sub-station under the National Agricultural Research Project (Southern Region), Kerala Agricultural University. The research station is geographically located at 8º 29'N latitude and 76º 58' E longitude, at an altitude of 33 m above mean sea level.

3.1.2. Soil characteristics

The soil of the experimental area is sandy clay loam, taxonomically classified as Typic tropofluent and belongs to the order Entisols according to soil classification of FAO / UNESCO (1974). The data on the mechanical composition, physical and chemical properties of the soil of the experimental site are presented in Tables 1 a, 1 b, 1 c respectively.

Table 1 a. Mechanical composition of the soil

Sl. No.	Particulars	Content in soil (%)	Method used
1	Coarse sand	54.9	International Pipette method (Piper, 1950)
2	Fine sand	13.05	
3	Silt	7.5	
4	Clay	22.5	
Textural class: Sandy clay loam			

Table 1 b. Physical properties of the soil

Sl. No.	Particulars	Value	Method used
1	Bulk density ($g\ cc^{-1}$)	1.29	Core method (Gupta and Dakshinamoorthy, 1980)
2	Particle density ($g\ cc^{-1}$)	2.26	Relative density bottle (Black, 1965)
3	Porosity (%)	42.92%	(Black, 1965)

3.1.3. Cropping history of the field

The experimental site was under the general cropping pattern of Rice-Rice-Fallow. Two crops of rice were sequentially raised in 2007 during the "Virippu" (May-June to August-September) and "Mundakan" (September-October to December-January) seasons preceding the experiment.

3.1.4. Weather conditions

The region enjoys a sub humid mega thermal climate with bimodal rain fall during the South West (SW) and North East (NE) monsoons.

Table 1c. Chemical properties of the soil

Sl. No.	Particulars	Content in soil	Method used
1	Organic carbon (per cent)	0.75	Walkley and Black rapid titration method (Walkley and Black, 1934)
2	Available Nitrogen (kg ha^{-1})	288.52	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
3	Available Phosphorus (kg ha^{-1})	16.24	Bray colorimetric method (Jackson,1973)
4	Available Potassium (kg ha^{-1})	183.34	Ammonium Acetate method (Jackson,1973)
5	Exchangeable Calcium (mg kg^{-1})	622.50	Titrimetric method (Hesse, 1971)
6	Exchangeable Magnesium (mg kg^{-1})	298.80	Titrimetric method (Hesse, 1971)
7	Available Iron (kg ha^{-1})	119.08	Atomic absorption spectrophotometer (Lindsay and Norvel, 1978)
8	Available Zinc (kg ha^{-1})	2.89	Atomic absorption spectrophotometer (Lindsay and Norvel, 1978)
9	Available Copper (kg ha^{-1})	6.05	Atomic absorption spectrophotometer (Lindsay and Norvel, 1978)
10	Soil reaction (pH)	5.63	1:2.5 Soil and water using pH meter with glass electrode (Jackson, 1973)
11	Electric conductivity (μsm^{-1})	212.7	1:2.5 Soil and water using EC meter (Jackson, 1973)

Though the average rain fall of the state is 2963 mm Thiruvananthapuram district receives on an average 1610 mm rain fall only, with SW monsoon precipitation of 744.1 mm and NE monsoon precipitation of 538.4 mm and summer and pre monsoon showers of 327.5 mm. The mean monthly maximum temperature ranged from 27.20^{0}C to 32.74^{0}C with a mean of 29.97^{0}C. The mean monthly minimum temperature ranged from 22^{0}C to 26^{0}C with a mean of 24^{0}C. The relative humidity ranged from 31.47 to 92.9 per cent. The meteorological data recorded during the crop period are furnished in Appendix I a and I b and graphically represented in Fig. 1a, 1b, 2a and 2b.

3.1.5. Season, crop and variety

The upland crops were raised during the summer season (December-January to March-April) of 2008. All crops except daincha were sown on 12th February 2008. Daincha was sown on 14th May 2008.The succeeding rice crop was raised during the virippu (May-June to August-September) season. The rice variety Aiswarya was transplanted on 30th June 2008. The seed or planting material of the seven test crops (sweet potato, pumpkin, sesamum, amaranthus, cowpea, daincha and rice) were obtained from the Cropping Systems Research Centre, Karamana.

The details of crops, seasons and the varieties used for the experiment are presented in Table 2. Duration of summer crops is graphically represented in Fig. 3.

3.1.6. Manures and Fertilizers

Farm yard manure having 0.60, 0.45 and 0.80 percent of N, P_2O_5 and K_2O respectively was used as the organic manure. Urea (46 percent N), Rajphos (20 percent P_2O_5) and Muriate of Potash (60 percent K_2O) were used as the inorganic fertilizers for the experiment.

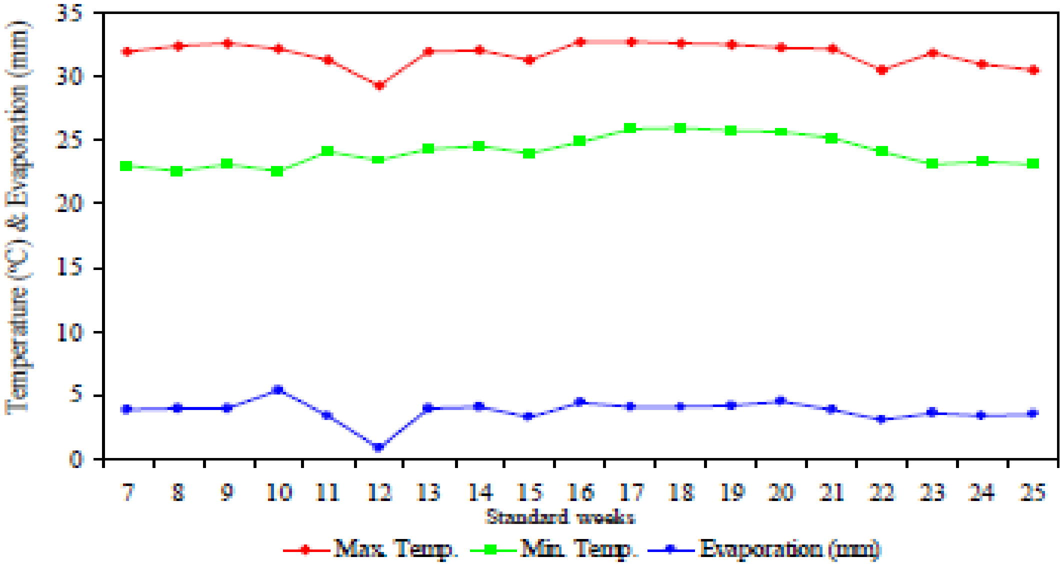


Fig. 1a. Mean weather parameters during the summer season

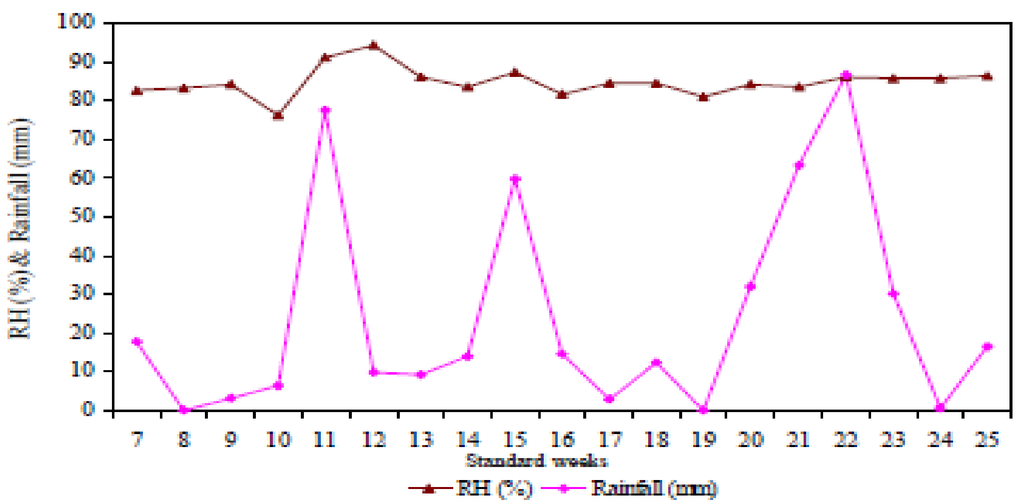


Fig. 1b. Mean weather parameters during the summer season

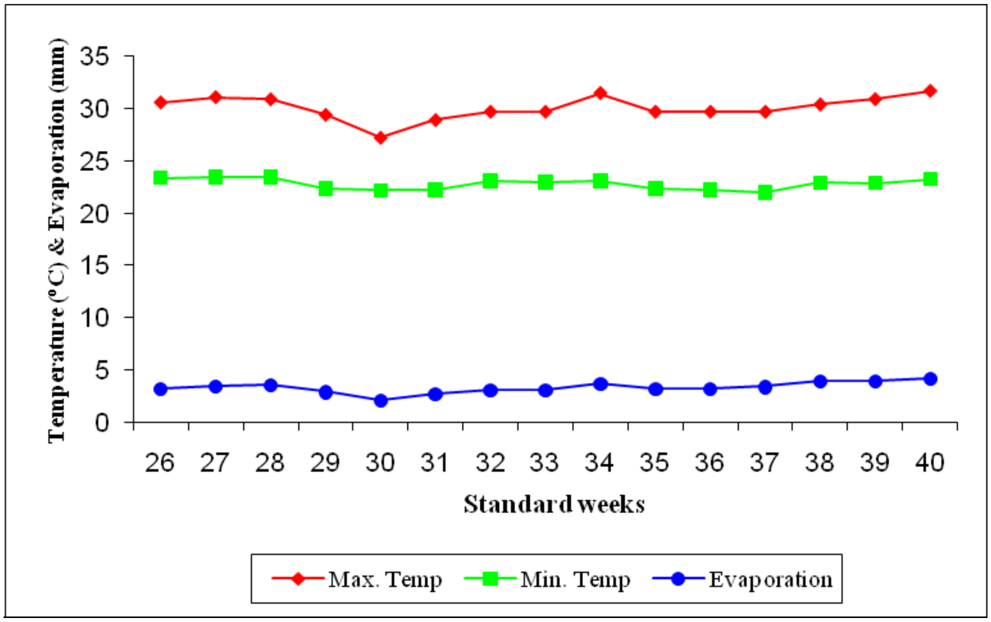


Fig. 2a. Mean weather parameters during the virippu season

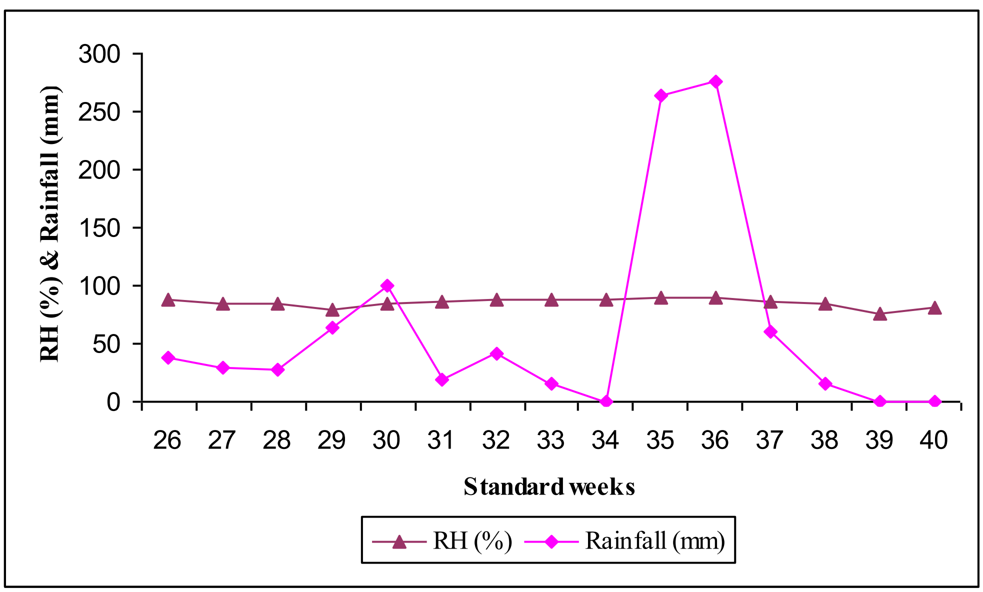


Fig. 2b. Mean weather parameters during the virippu season

Table 2. Details of the cropping season and varieties of the test crops

Crop	Season	Variety	Duration (days)
Sweet potato (*Ipomoea batatas*)	Summer season	Kanhangad	116
Pumpkin (*Cucurbita moschata*)	Summer season	Ambily	79
Sesamum (*Sesamum indicum*)	Summer season	Thilarani	90
Amaranthus (*Amaranthus tricolor*)	Summer season	Arun	46
Cowpea (*Vigna unguiculata* sub sp. *sesquipedalis*)	Summer season	Vellayani local	72
Daincha (*Sesbania aculeata*)	Summer season	-	36
Succeeding rice crop			
Rice (*Oryza sativa*)	Virippu	Aiswarya	120

3.2. METHODS

3.2.1. Plot size

All the field experiments were laid out with the plot size 9 m x 6 m = 54 m^2.

3.2.2. Design and layout

The details of the layout are given below.

Design : Randomized Block Design (RBD)

Treatments : 7

Replications : 3

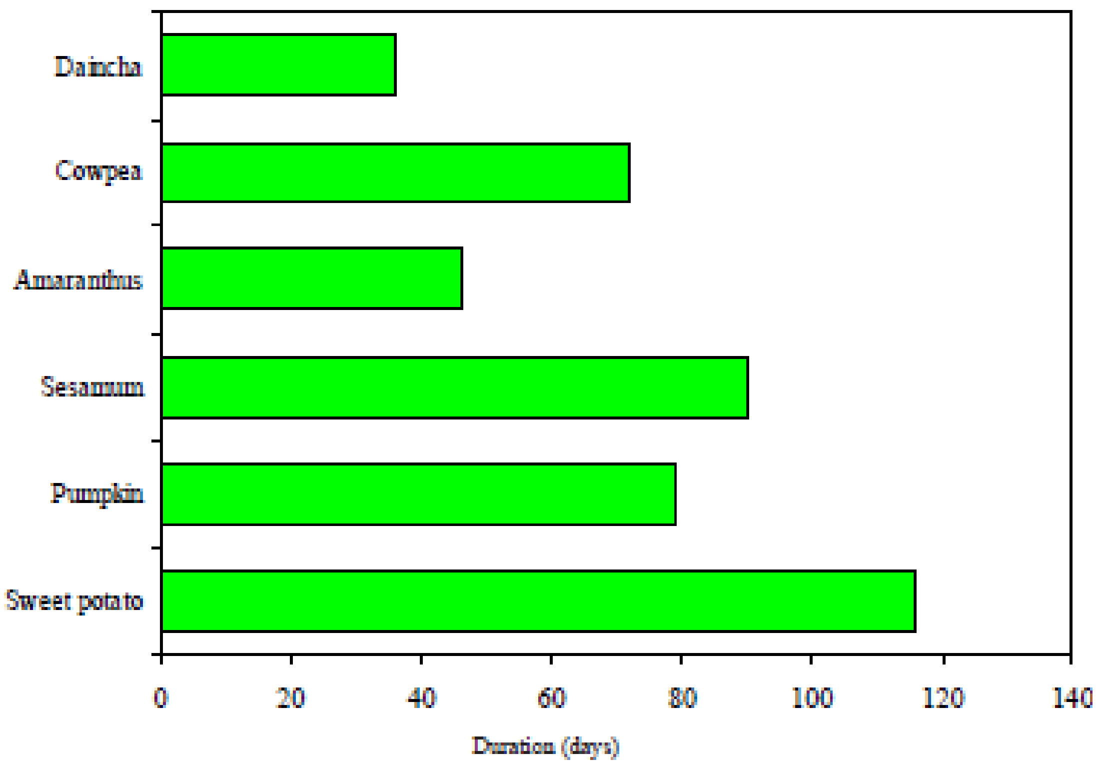


Fig. 3. Duration of the summer crops

3.2.3. Experimental details

The seven treatments consisted of the six upland crops listed below and a control plot of summer rice fallow.

T_1 : Control (summer rice fallow)
T_2 : Sweet potato
T_3 : Pumpkin
T_4 : Sesamum
T_5 : Amaranthus
T_6 : Cowpea
T_7 : Daincha

The layout plan of the experiment is given in Fig. 4.

3.2.4. Crop management of summer crops

All the crops were raised by adopting the Package of Practices Recommendations: Crops (2007) of the Kerala Agricultural University.

3.2.4.1. Field preparation

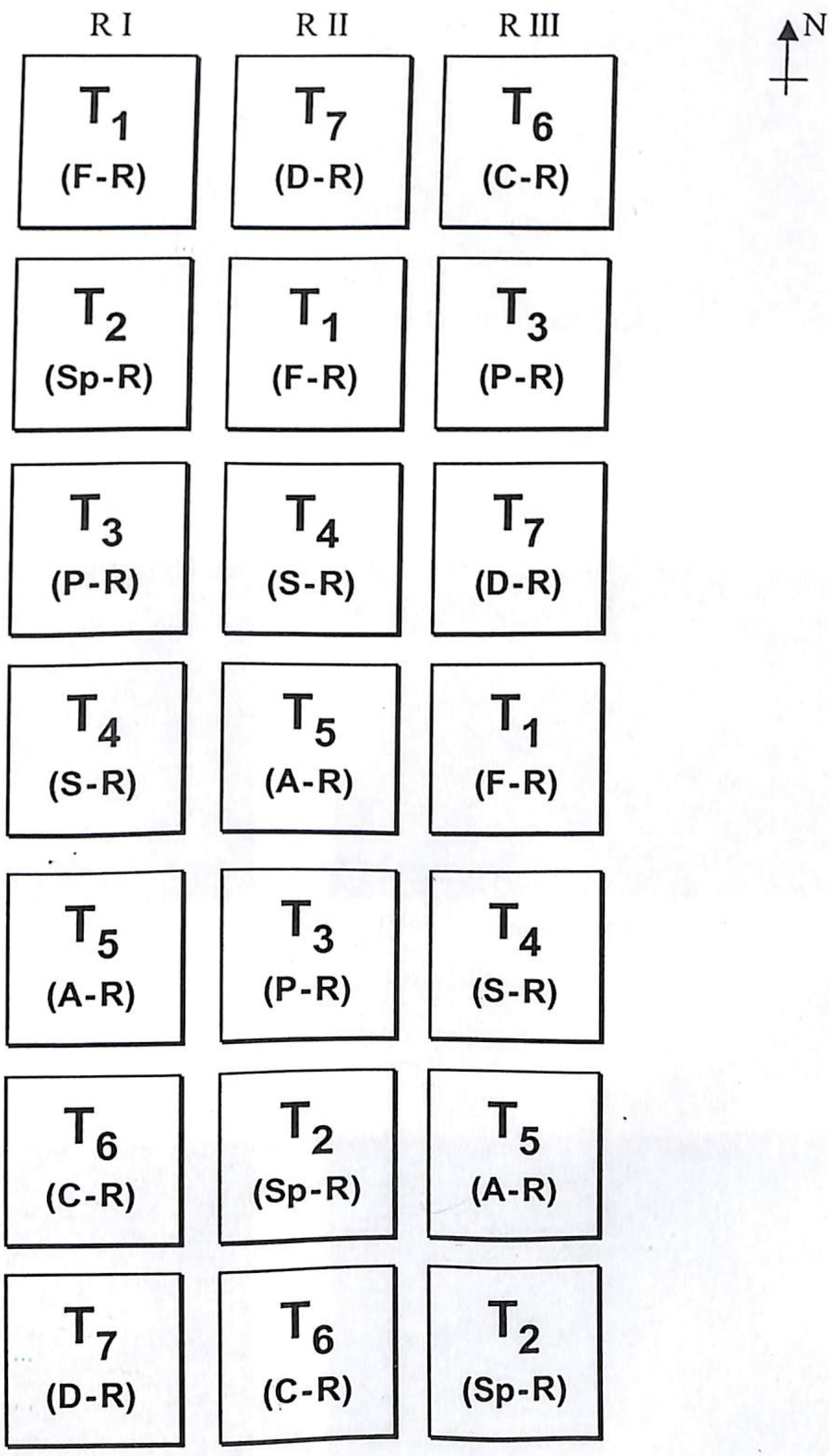
The field was thoroughly tilled, clods broken and the soil brought to good tilth.

3.2.4.1.1. Sweet potato

Ridges of 30cm height were formed 60cm apart for planting vine cuttings.

3.2.4.1.2. Pumpkin

Raised circular seed beds of 30 cm height and 100 cm diameter were formed at a spacing of 4.5m x 2m (center to center) and pits of 60 cm



F-R = Fallow - Rice
Sp-R = Sweet potato - Rice
P-R = Pumpkin - Rice
S-R = Sesamum - Rice
A-R = Amaranthus - Rice
C-R = Cowpea - Rice
D-R = Daincha - Rice

Fig. 4. Layout plan of the Experiment

Sweet potato

Pumpkin

Sesamum

Amaranthus

Vegetable cowpea

Daincha

Plate 1. Field view of summer crops

Plate 1. Field view of summer crops

diameter and 30 cm depth taken on its centre. Well rotten farm yard manure was mixed with top soil and the pits filled.

3.2.4.1.3. Sesamum

Field was prepared to a fine tilth and properly levelled.

3.2.4.1.4. Amaranthus

The plot was prepared in to raised beds, 150 cm wide close to one another with a drainage channels in between. Shallow trenches 30 cm wide were taken on them 30 cm apart for transplanting seedlings.

3.2.4.1.5. Cowpea

Raised circular level seed beds of 30 cm height and 90 cm diameter were taken at a spacing of 2 m x 2 m, on the center of which shallow pits of 30 cm diameter were formed for planting cowpea seeds.

3.2.4.1.6. Daincha

Soil was dug twice and the weed vegetation removed to get a clean field.

3.2.4.2. Seeds and sowing

3.2.4.2.1. Sweet potato

Forty five days old vine cuttings of 25 cm length were planted on the ridges at a spacing of 20 cm between vines. The vines were planted with the middle portion deep in the soil and the two cut ends exposed to the surface.

3.2.4.2.2. Pumpkin

Pumpkin seeds were sown at the rate of five seeds per pit. After two weeks the unhealthy seedlings were removed retaining three healthy seedlings.

3.2.4.2.3. Sesamum

Sesamum seeds were broadcasted at the rate of five kg ha^{-1}. Before sowing the seeds were mixed with sand three times its volume to ensure uniform coverage of seeds. The seeds were covered by harrowing and planking.

3.2.4.2.4. Amaranthus

Twenty five days old seedlings were transplanted in the shallow trenches at a distance of 20 cm in two rows.

3.2.4.2.5. Cowpea

Cowpea seeds were sown at the rate of three seeds per pit.

3.2.4.2.6. Daincha

The seeds of the daincha were broadcasted at the rate of 25 kg ha^{-1}.

3.2.4.3. Manuring and fertilizer applications

Organic manure was applied basally and incorporated into the soil. Nitrogen, phosphorus and potassium nutrients were applied at the scheduled time as per rates recommended for the crops in the Package of Practices Recommendations: Crops (2007) of the Kerala Agricultural University (Table 3).

3.2.4.4. After cultivation

3.2.4.4.1. Sweet potato

Crop was weeded and earthed up twice at second and fifth week after planting the vines were occasionally turned during the active growth phase in order to prevent the development of small slender tubers at the nodes.

Table 3. Schedule of application and nutrient doses for the treatment crops

Treatment crop	Recommended dose				Schedule of application	
	FYM	N	P_2O_5	K_2O	Basal	Topdressing
Sweet potato	10	75	50	75	½ N, Full dose of P and K	½ N at 30 DAP
Pumpkin	22.5	70	25	25	½ N, Full dose P and K	¼ N each at vining and full blooming
Sesamum	5	30	15	30	¾ N, Full dose P and K	¼ N at 30 DAS
Amaranthus	50	100	50	50	½ N, Full dose P and K	¼ N after each harvest
Cowpea	20	20	30	10	½ N, Full dose P and K	½ N at 20 DAS
Daincha	Nil	Nil	Nil	Nil	Nil	Nil

DAS (Days After Sowing); DAP (Days After Planting)

FYM (t ha^{-1}) N: P_2O_5: K_2O ((kg ha^{-1})

3.2.4.4.2. Pumpkin

Trailing of vine was done by spreading dried twigs on the ground. Weeding and raking of the soil were done at the time of fertilizer application.

3.2.4.4.3. Sesamum

Thinning was done at the 15 cm high growth stage of the crop to maintain a spacing of 20 cm x 15 cm. The crop was inter cultivated at 15 and 40 DAS.

3.2.4.4.4. Amaranthus

Regular hand weeding was carried out.

3.2.4.4.5. Cowpea

Hoeing and weeding were done at the time of application of second dose of nitrogen.

3.2.4.5. Irrigation

The cropped plots, except that of daincha were given life saving irrigation by pot watering. Aluminium pots of 10 liters capacity were used for this purpose. Daincha was grown with residual soil moisture and rain fall.

Irrigation was quantified at 80 per cent of the mean daily evaporation of the previous week, deducting the rain fall contribution. The crop was pot watered in the evening once in 3 days or varying with the precipitation received.

3.2.4.6. Plant protection

3.2.4.6.1. Sweet potato

The vines were dipped in 0.05% monocrotophos suspension for five minutes prior to planting to control sweet potato weevil.

3.2.4.6.2. Pumpkin

Prior to sowing, carbaryl 10% DP was incorporated in to the pit to destroy fruit fly and red pumpkin beetle pupae. Bait trapping was done for the control of fruit fly.

3.2.4.6.3. Sesamum

No pesticides were used since there was no severe incidence of pests and diseases.

3.2.4.6.4. Amaranthus

No pesticides were used since there was no severe incidence of pests and diseases.

3.2.4.6.5. Cowpea

Quinolphos at 0.03% concentration was spayed to control pea aphid.

3.2.4.7. Harvest

3.2.4.7.1. Sweet potato

The crop was harvested when the leaves turned yellow and tubers matured. The tubers were dug out without causing injury. Border row crops were harvested separately.

3.2.4.7.2. Pumpkin

Fruits were harvested as and when they matured. First harvest was done at 61 days after planting (DAS) and last harvest was done at 79 DAS.

3.2.4.7.3. Sesamum

The crop matured 90 days after sowing. Harvesting was done by uprooting the plants when the capsules turned yellowish. Border row plants were harvested separately. The root portions of the harvested plants were cut and the plants stacked in bundles weighed and kept for four days. These bundles were spread, dried in the sun and beaten with sticks to break the capsules. This process of drying in the sun and beating with the sticks were repeated for 3 days. The seeds collected were cleaned and dried in the sun for 7 days.

3.2.4.7.4. Amaranthus

The plants were ready for first harvest at 25 days after planting (DAP) and the second harvest was done 46 DAP. The plants were cut at the ground level, cleaned and weighed.

3.2.4.7.5. Cowpea

The pods were picked as and when they matured. The first harvest was done 56 days after sowing (DAS) and the last harvest 72 DAS.

3.2.4.7.6. Daincha

At flowering stage the crop was cut at the ground level, weighed and incorporated in to the soil.

3.2.5. Economic yield

3.2.5.1. Sweet potato

The vines in the net area were cut and removed. The tubers were dug out, cleaned weighed and yield expressed in kg ha^{-1} on fresh weight basis.

3.2.5.2. Pumpkin

The harvested fruits were weighed cumulative total weight worked out and expressed in kg ha^{-1} on fresh weight basis.

3.2.5.3. Sesamum

The plants in the net area were harvested separately, the seeds were collected by breaking open the capsules and fresh weight noted. The seeds were cleaned, dried to constant moisture content and expressed in kg ha^{-1} on dry weight basis.

3.2.5.4. Amaranthus

The plants in the net area were harvested separately weighed and expressed in kg ha^{-1} on fresh weight basis.

3.2.5.5. Cowpea

The cumulative total weight of the pods was arrived at by adding the yield from each harvest and expressed in kg ha^{-1} on fresh weight basis.

3.2.5.6. Daincha

The plants in the net area were harvested separately weighed and expressed in kg ha^{-1} on fresh weight basis.

3.2.6. Vegetative yield (Vine and haulms)

At harvest the vines of sweet potato, pumpkin and cowpea were cut at ground level, bundled and fresh weight recorded treatment wise. The bundles of sesamum plants with root cut off were also similarly weighed treatment wise before stacking and vegetative yield worked out.

3.2.7. Total biological yield

The total biological yield was worked out from the following relation ship.

Total biological yield = Economic yield + Vegetative yield.

Total biological yield was expressed in kg ha^{-1}.

3.2.8. Dry matter content of economic and vegetative yield

Three samples, each weighing 1.0 kg on fresh weight basis were taken both for economic and vegetative yield chopped to small pieces, sun dried for 2 days and later in a hot air oven at 80^0C to constant weight. In sesamum the samples consisted of whole plant with root portion cut off. The capsules were separated and fresh weight of haulms recorded. The capsules were broken and seeds collected and the fresh weight of seeds recorded. The samples were dried to constant weight. The driage was expressed as a percentage of the fresh weight and dry matter yield in kg ha^{-1}.

3.2.9. Rice yield equivalent

Rice yield equivalent was calculated using the formula

$$\text{Rice yield equivalent} = \text{Economic yield of test crop in kg ha}^{-1} \times \frac{\text{Price of the test crop kg}^{-1}}{\text{Price of the rice kg}^{-1}}$$

3.2.10. Calorific value of economic yield m^{-2}

Calorific value of economic produce m^{-2} was calculated using the following relation.

$$\text{Economic yield of test crop kg m}^{-2} \times \text{Energy yield kg}^{-1} \text{ of test crop in calories.}$$

3.2.11. Per day production

The per day production of the crop was worked out from the following relation ship.

$$\text{Per day production} = \frac{\text{Economic yield kg ha}^{-1}}{\text{Duration of the crop in days}}$$ and expressed in kg ha^{-1} day^{-1}

3.2.12. Water productivity

Water productivity was worked out by dividing the economic yield in kg ha^{-1} by the total quantity of water both by irrigation and precipitation in m^{3} ha^{-1} used by the crop and expressed in units of kg m^{-3}.

3.2.13. Biometric observations on weeds

3.2.13.1. Weed count

Weed samples were collected at 40 days after sowing (DAS) and at harvest of the crop, from 4 randomly selected sampling areas within the net plot, marked out using a quadrat of 0.25 m^{2}. The average weed count in a quadrat of 0.25 m^{2} area was arrived at and the data were computed to give the weed count m^{-2}.

3.2.13.2. Weed spectrum

Samples collected for recording weed count as detailed in 3.2.13.1 were identified and grouped as grasses, sedges and broad leaved weeds.

3.2.13.3. Weed dry weight

The weed sample used for weed spectrum analysis as detailed in 3.2.13.2 were washed free of soil, air dried and later oven dried at 80^{o}C for 48 hours and weight recorded group wise. The weed dry weight of each group of weed was expressed in kg ha^{-1}.

3.2.13.4. Weed vegetation analysis

The following analyses were made using the formula outlined by Bhandari (1981).

3.2.13.4.1. Relative density (Rd)

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

3.2.13.4.2. Relative dry weight (Rdw)

$$\text{Rdw}\% = \frac{\text{Dry weight of a given species}}{\text{Total dry weight of all species}} \times 100$$

3.2.13.4.3. Summed dominance ratio (SDR)

Summed dominance ratio per cent at days after sowing (40 DAS) and at harvest was computed by using the formula suggested by Janiya and Moody (1989).

$$\text{SDR} = \frac{\text{Rd} + \text{Rdw}}{2}$$

where SDR = Summed Dominance Ratio

Rd = Relative density

Rdw = Relative dry weight

3.2.14. Crop management of succeeding rice crop

3.2.14.1. Nursery management

3.2.14.1.1. Seed bed preparation

The nursery area of 114 m^2 was ploughed twice after uniformly applying farm yard manure @ 1 kg m^{-2}, puddled and leveled after removing the weeds and stubbles. After the soil settled, raised level seed beds 10 cm high and 1 m wide were formed.

3.2.14.1.2. Seeds and Sowing

Pre germinated seeds @ 70 kg ha^{-1} were uniformly sown on the seed beds on 10^{th} June, 2008. The beds were kept drained keeping sufficient moisture in the soil and later irrigated to shallow depth on the fifth day after sowing. The depth of the water was gradually increased to 5 cm.

3.2.14.2. Main field

3.2.14.2.1. Field preparation and lay out

The experimental area was ploughed twice, weeds, stubbles stubbels and organic manure incorporated and allowed to decompose for two weeks. The plots were laid out into three blocks with seven plots. The basal doses of fertilizers were applied and field puddled and levelled. The field was laid out in to three blocks each with seven plots precisely following the lay out plan of the previous summer crop. The plots and blocks were separated with field bunds of 30 cm width and height. Irrigation channels of 30 cm width were provided between the blocks. The lay out plan is given in Fig. 3.

3.2.14.2.2. Manures and fertilizers

Organic manure @ 5 t ha^{-1} was applied as Farm Yard Manure (FYM) well in advance of planting as basal application and incorporated into the soil. Fertilizers were applied @ 90 - 45 – 45 kg ha^{-1} of N, P_2O_5 and K_2O respectively following the schedule and rates recommended in the Package of Practice Recommendations: Crops (2007) of the Kerala Agricultural University. The entire dose of phosphorus and half the dose each of nitrogen and potassium were applied basally at the time of puddling and levelling. The remaining half of nitrogen and potassic fertilizers were applied in two equal splits, at maximum tillering and panicle initiation stages.

3.2.14.2.3. Transplanting

Twenty day old healthy seedlings were gently uprooted from the nursery and transplanted in the main field at 3 – 4 cm depth at the rate of two seedlings per hill; following a spacing of 20 x 15 cm. Loose bundles of healthy seedlings were kept as reserve for gap filling.

3.2.14.2.4. Inter cultivation and Weed management

Gap filling was done one week after transplanting using the reserved seedlings and hand weedings done at 20 and 40 days after transplanting

3.2.14.2.5. Water management

During transplanting a shallow depth of 1.5 cm water was maintained in the field and later water depth was gradually increased with crop growth. Standing water at a near depth of 5 cm was maintained throughout the cropping period, with occasional drainage for top dressing of fertilizers. The field was drained 13 days before harvest.

3.2.14.2.6. Plant protection

Integrated pest management practices as par Package of Practice Recommendations: Crops (2007) of the Kerala Agricultural University were followed for pest and disease control.

3.2.14.2.7. Harvest

The crop was harvested at 100 days after planting (DAP). The two border rows were harvested separately. The crop in the net area of each plot was harvested, threshed, cleaned and grains dried to 14 per cent moisture. The grain yield from individual plot was recorded separately. The straw from each plot was sun dried to constant weight, and weight recorded.

3.2.14.3. Biometric observations

Biometric observations were recorded as per the guide lines of the All India Coordinated Rice Improvement Project, Hyderabad (Ten Hare, 1977). In each plot, 10 plants in the net plot area were selected at random and labeled as the sample plants for biometric observation.

3.2.14.3.1. Growth attributes

3.2.14.3.1.1. Plant height

The plant height was recorded from the surface of the soil to the tip of the top most leaf at maximum tillering stage and to the tip of the tallest panicle at harvest. The mean value of all the 10 sample hills was recorded in cm.

3.2.14.3.1.2. Number of tillers hill^{-1}

The numbers of tillers of the ten sample plant were counted and the mean value hill^{-1} at maximum tillering stage was arrived at.

3.2.14.3.1.3. Days to 50 per cent flowering

Total number of days from date of sowing in nursery to the date at which 50 per cent of the plants in the net plot area flowered were counted for each plot and recorded.

3.2.14.3.1.4. SPAD readings

SPAD reading were recorded with the help of chlorophyll meter (Konica Minolta Model SPAD 502) from the ten sample hills at maximum tillering and flowering stages and mean values for each stage worked out.

3.2.14.3.1.5. Leaf area index (LAI) at flowering

The leaf area index of the crop at flowering stage was computed without removing the leaves by using the formula suggested by Palanisamy and Gomez (1974).

$$LAI = \frac{K\ (L \times W)\ (\text{Number of leaves hill}^{-1})}{\text{Area occupied by the plant}}$$

where,

K = Adjustment factor 0.75

L = Leaf length (cm)

W = Maximum leaf width (cm)

3.2.14.3.2. Yield attributes

3.2.7.3.2.1. Number of panicles hill^{-1}

The number of panicles of the ten sample plant was counted and the mean value hill^{-1} was arrived at.

3.2.14.3.2.2. Mean panicle weight

All the panicles of the 10 labeled sample plants were collected, oven dried at 80 ^{0}C for 24 hours and total weight and number recorded. The mean panicle weight was computed and expressed in grams.

3.2.14.3.2.3. Mean number of grains per panicle

The panicles collected for finding mean panicle weight in 3.2.14.3.2.2 were counted, threshed, grains separated from chaff and the weight of the filled grain recorded. Three lots, each of 1000 grains were weighed and the mean weight of 1000 grains recorded. From the data, the total number of grains of all the panicles were computed and finally the mean number of grains panicle^{-1}worked out.

3.2.14.3.2.4. Thousand grain weight

The grain lot used in 3.2.14.3.2.3 for finding the mean number of grains panicle^{-1} was dried to 14 per cent moisture content. Three lots of grain, each of 1000 numbers were counted and mean weight of the lot recorded and expressed in g (Yoshida *et al.,* 1976).

3.2.14.4. Grain yield

The crop in the net area of each plot was harvested, threshed, cleaned and dried to 14 per cent moisture content and weight recorded .The grain yield was expressed in kg ha^{-1}.

3.2.14.5. Straw yield

The straw from each plot obtained from 3.2.14.4 was sun dried to constant weight and expressed in kg ha^{-1}.

3.2.14.6. Harvest Index (HI)

The harvest index per cent was calculated using the formula suggested by Donald and Humblin (1976).

$$HI = \frac{\text{Grain yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

where, HI = Harvest Index

Biological yield = Grain yield + straw yield

3.2.14.7. Biometric observations on weeds

3.2.14.7.1. Weed count

Weed counts was recorded at 40 days after transplanting (DAT) and at harvest as detailed in 3.2.13.1.

3.2.14.7.2. Weed spectrum

Weed spectrum analysis was done at 40 days after transplanting (DAT) and at harvest as detailed in 3.2.13.2.

3.2.14.7.3. Weed dry weight

Weed dry weight was recorded at 40 DAT and at harvest as detailed in 3.2.13.3.

3.2.14.7.4. Weed vegetation analysis

The following analyses were made using the formula outlined by Bhandari (1981) as detailed in 3.2.13.4.

3.2.14.7.4.1. Relative density (Rd)

The analysis was done as detailed in 3.2.13.4.1.

3.2.14.7.4.2. Relative dry weight (Rdw)

The analysis was done as detailed in 3.2.13.4.2.

3.2.7.7.4.3. Summed dominance ratio (SDR)

The analysis was done as detailed in 3.2.13.4.3

3.2.14.8. Soil physical analysis

3.2. 14.8.1. Bulk density of soil

Bulk density of the soil before treatment application and at harvest of the summer crop and rice crop were recorded treatments wise by core sampler method as described by Gupta and Dakshinamoorthy (1980).

3.2.14.8.2. Particle density of soil

Particle density of the soil before treatment application of the summer crop was recorded by relative density bottle (Black, 1965).

3.2.14.8.3. Porosity

Soil porosity per cent was worked out from the following relationship.

$$\text{Porosity} = 1 - \left(\frac{\text{Bulk denisty}}{\text{Particle density}} \right) \times 100$$

3.2.14.9. Chemical analysis

3.2.14.9.1. Soil analysis

Pre experiment and post harvest composite soil samples were collected using screw auger upto 15 cm depth and analysed for mechanical composition (Piper, 1950) and chemical properties such as organic carbon (Walkley and Black, 1934), available nitrogen (Subbiah and Asija, 1956), available phosphorus (Jackson, 1973) and available potassium (Jackson, 1973), exchangable calcium and magnecium (Hesse,1971) and available iron, zinc and copper (Lindsay and Norvel, 1978). The electrical conductivity was recorded by EC meter (1:2.5 soil and water suspension) and pH by electronics pH meter (1:2.5 soil and water suspension) as suggested by Jackson (1973).

3.2.14.9.2. Plant analysis and uptake of nutrients

Chemical analysis of crop and weed samples for nitrogen, phosphorus, potassium, calcium, magnesium, iron, zinc and copper content was carried out for the computation of nutrient uptake by crops and nutrient removal by weeds. The values were expressed in kg ha^{-1}. The analysis was carried out following standard procedures detailed in Table 4.

Table 4. Methods of plant analysis

Sl. No.	Nutrient	Method	Reference
1	Nitrogen	Microkjeldahl	Yoshida *et al*. (1976)
2	Phosphorus	Colorimetry, Triple acid digestion	Jackson (1973)
3	Potassium	Spectrophotometry, Triple acid digestion	Jackson (1973)
4	Calcium	Titrimetric method	Hesse (1971)
5	Magnesium	Titrimetric method	Hesse (1971)
6	Iron	Atomic absorption spectrophotometer	Lindsay and Norvel (1978)
7	Zinc	Atomic absorption spectrophotometer	Lindsay and
8	Copper	Atomic absorption spectrophotometer	Lindsay and

3.2.14.10. Nutrient balance studies

Nutrient balance sheet of the soil was worked out by subtracting the computed balance of the nutrient from the actual balance. The computed balance was worked out by subtracting the total quantity of nutrient removed by the crop in a sequence from that added by crop residues, manures and fertilizers and soil. The actual balance of the nutrients is indicated by the available nutrient status of soil. A positive balance indicated soil storage and negative balance indicated depletion (Palaniappan, 1985).

3.2.14.11. Economic analysis

The net return per hectare for each treatment was worked out by subtracting the cost of cultivation of the treatment from its gross return. Benefit - cost ratio (return per rupee invested) for each treatment was worked out by dividing the gross return of the treatment by its cost of cultivation. The details of the cost of inputs and the price of out puts used in calculating the costs and returns are furnished in Appendix II.

3.2.14.12. Statistical analysis

The data on various characters recorded in the summer crop and the succeeding rice crop were statistically analyzed following the procedure outlined by Gomez and Gomez (1983). Data involving percentage values were subjected to angular transformation. The data on weed count and weed dry weight involving zero values were transformed using the formula $\sqrt{x+1}$ and statistically analyzed. For significant results, the critical differences were worked out at 5 percent probability level. Treatment differences having non significant results at 5 per cent probability level were denoted as “NS”.

RESULTS

4. RESULTS

The results of the field experiments conducted at the Cropping Systems Research Centre, Karamana, Thiruvananthapuram, during February to October 2008, spread over the summer (third crop) and the succeeding virippu (first crop) seasons of rice cultivation to study the performance of upland crops in the summer rice fallows and its effect on succeeding transplanted rice crop, so as to formulate a sound practice of summer rice fallow utilization are presented in this chapter.

4.1 SUMMER CROP

4.1.1. Studies on weeds

4.1.1.1. Weed spectrum analysis (Table 5)

Weeds species belonging to seven families were found to occur in the various summer crops and in the control. The predominant species under the grassy weeds were *Echinochloa colona* (L.) Link, *Digitaria ciliaris* (Retz. Koel), *Isachne miliacea* (Roth.) and *Digitaria sanguinalis* (L.) Scop. The dominant species under the sedges were *Cyperus iria* (L.), *Cyperus compressus* (L.) and *Fimbristylis milliacea* (L.) Vahl. The important broad- leaved weeds consisted of *Phyllanthus niruri* (L.), *Oldenlandia affinis* (Roemer & Schultes. DC.), *Eclipta alba* (L.), *Eclipta prostrata* (L.), *Ludwigia parviflora* (Roxb.) and *Cleome viscosa* (L.).

Individual summer crops showed distinct variation in their associated weed flora. Grasses and sedges weeds were found to be totally absent in the daincha crop.

Table 5. Weed flora of the experimental field as influenced of summer crops

Name of the weed	Family	T_1 (Control)	T_2 (Sweet potato)	T_3 (Pumpkin)	T_4 (Sesamum)	T_5 (Amaranthus)	T_6 (Cowpea)	T_7 (Daincha)
I. Grasses								
Echinochloa colona (L.) Link	Gramineae	✓	✓	✓	✓	✓	✓	x
Digitaria ciliaris (Retz. Koel)	Gramineae	✓	x	x	x	x	x	x
Isachne miliacea (Roth.)	Gramineae	✓	x	✓	✓	✓	✓	x
Digitaria sanguinalis (L.) Scop.	Gramineae	✓	x	x	x	✓	✓	x
II. Sedges						✓	✓	
Cyperus iria (L.)	Cyperaceae	✓	x	✓	x	✓	✓	x
Cyperus compressus (L.)	Cyperaceae	✓	x	x	x	✓	✓	x
Fimbristylis milliacea (L.) Vahl.	Cyperaceae	✓	x	x	✓	x	✓	x
III. Broad-leaved weeds		✓	✓		✓		✓	
Phyllanthus niruri (L.)	Euphorbiaceae	✓	✓	✓	✓	✓	✓	✓
Oldenlandia affinis (Roemer & Schultes. DC.)	Rubiaceae	✓		✓	✓	x	✓	✓
Eclipta alba (L.)	Compositae	✓	x	✓	✓	✓	x	x
Eclipta prostrata (L.)	Compositae	x	x	x	x	x	x	✓
Ludwigia parviflora (Roxb.)	Onagraceae	x	x	x	x	✓	✓	x
Cleome viscosa (*L.*)	Capparaceae	x	x	x	✓	x	x	✓

✓ Present x Absent Control is fallow.

4.1.1.2. Weed population (Numbers m^{-2})

4.1.1.2.1. Weed population of grasses m^{-2} (Table 6)

At 40 days after planting (DAP) all the treatments showed significant effect on the grassy weed population m^{-2}. Among the treatments T_1 (Control) recorded significantly higher population of grassy weeds (177.33 m^{-2}) than all other treatments. Among the other treatments T_4 (Sesamum) recorded higher number of weeds (41.33 m^{-2}) but was on par with all other treatments except T_1 (Control) and T_7 (Daincha). The treatment T_7 (Daincha) had no grassy weed infestation at all.

At harvest high population of grassy weeds (148 m^{-2}) were noted in T_6 (Cowpea) followed by T_1 (Control) which were significantly higher than that in the rest of the treatments. Lower population of weeds was recorded in T_5 (Amaranthus) which was on par with T_2 (Sweet potato), T_3 (Pumpkin) and T_4 (Sesamum). Treatment T_7 (Daincha) as in vegetative stage, had no grassy weed infestation at all.

4.1.1.2.2. Population of sedge weeds m^{-2} (Table 6)

Significant difference was noticed between the different treatments on the sedges population at 40 DAP. Only T_1 (Control) had significant incidence of sedge weeds (113.33 m^{-2}). The summer crops T_4 (Sesamum) had only sparse incidence of sedge weeds (1.33 m^{-2}). There was no sedge weed population in T_2 (Sweet potato), T_3 (Pumpkin), T_6 (Cowpea) and T_7 (Daincha).

The treatment effect on population of sedge weed was significant at the harvest stage also. Significantly higher weed population (52 m^{-2}) was noticed in T_1 (Control) which was on par with T_6 (Cowpea). There was no incidence of sedge weeds in T_2 (Sweet potato) and T_7 (Daincha). All other treatments had low incidence of sedge weeds and were on par.

Table 6. Effect of summer crop on weed density (No m^{-2})

Treatments	40 Days after planting				At harvest			
	Grasses	Sedges	Broad-leaved weeds	Total	Grasses	Sedges	Broad-leaved weeds	Total
T_1 (Control)	13.21 (177.33)	10.35 (113.33)	6.39 (40)	18.21 (330.67)	10.80 (120)	7.22 (52)	7.16 (52)	14.99 (224)
T_2 (Sweet potato)	4.26 (17.33)	1 (0)	3.40 (10.67)	5.38 (28)	6.67 (44)	1 (0)	4.28 (17.33)	7.87 (61.33)
T_3 (Pumpkin)	4.37 (18.67)	1 (0)	1.41 (1.33)	4.49 (20)	7.21 (52)	3.21 (14.67)	3.94 (16.00)	9.10 (82.67)
T_4 (Sesamum)	6.40 (41.33)	1.41 (1.33)	4.80 (25.33)	8.30 (68)	7.05 (53.33)	2.49 (5.33)	4.78 (22.67)	8.94 (81.33)
T_5 (Amaranthus)*	5.32 (28)	1.41 (1.33)	1 (0)	5.43 (29.33)	5.32 (28)	1.41 (1.33)	1 (0)	5.43 (29.33)
T_6 (Cowpea)	5.35 (28.00)	1 (0)	1.41 (1.33)	5.47 (29.33)	12 (148)	6.61 (44)	5.19 (26.67)	14.75 (218.67)
T_7 (Daincha)**	1 (0)	1 (0)	5.86 (33.33)	5.86 (33.33)	1 (0)	1 (0)	5.86 (33.33)	5.86 (33.33)
SEm	0.70	0.73	0.53	0.43	1.49	1.14	0.81	1.08
CD (p = 0.05)	2.16	2.26	1.63	1.33	3.26	2.48	1.77	2.35

Figures in parenthesis are the original values Values are $\sqrt{x+1}$ transformed. * Amaranthus was harvested at 46 DAS
** Daincha was harvested at 36 DAS Control is fallow

4.1.1.2.3. Population of broad leaved weeds m^{-2} (Table 6)

The effect of summer cropping was significant on the incidence of broad-leaved weeds. Broad- leaved weed population (40 m^{-2}) was highest in T_1 (Control). It was on par with T_4 (Sesamum) and T_7 (Daincha) and significantly higher than all other treatments. In T_5 (Amaranthus) there was no incidence of broad- leaved weeds.

The treatment effect on population of broad- leaved weeds was significant at harvest stage also. The weed population (52 m^{-2}) in T_1 (Control) was on par with T_7 (Daincha) and significantly higher than all other treatments. In T_5 (Amaranthus) there was no incidence of broad- leaved weeds.

4.1.1.2.4. Total population of weeds m^{-2} (Table 6)

The effect of treatments on the total population of weeds was found to be significant at 40 days after planting (DAP). The treatment plot T_1 (Control) had significantly higher total population of weeds (330.67 m^{-2}) than all other treatments. The lowest total weed population (20 m^{-2}) was observed in T_3 (Pumpkin) which was on par with T_2 (Sweet potato), T_5 (Amaranthus) and T_6 (Cowpea).

The total weed population at harvest stage was highest (224 m^{-2}) in T_1 (Control) and was on par with T_6 (Cowpea) and significantly higher than all the other treatments. The lowest weed population (29.33 m^{-2}) was recorded in T_5 (Amaranthus) and it was on par with T_7 (Daincha).

4.1.1.3. Weed dry matter production (WDMP)

4.1.1.3.1. WDMP of grasses (Table 7)

At 40 DAP, the treatment T_1 (Control) recorded the highest weed dry matter production (630.53 kg ha^{-1}). Among the different crops T_4 (Sesamum) recorded the highest WDMP of grasses, but was on par with all the treatments except T_7 (Daincha) which had absolutely nil value.

At harvest, the pattern of WDMP changed completely and T_6 (Cowpea) recorded higher value and was on par with T_1 (Control) and T_4 (Sesamum). The T_7 (Daincha) retained the no grass WDMP status. The other treatments were on par.

4.1.1.3.2. WDMP of Sedges (Table 7)

At 40 DAP, the WDMP of sedges in different treatments were found to be significant. Significantly higher WDMP of sedges (147.47 kg ha^{-1}) was recorded by T_1 (Control). The WDMP of sedges in T_2 (Sweet potato), T_3 (Pumpkin), T_6 (Cowpea) and T_7 (Daincha) was nil.

However at harvest, though T_1 (Control) maintained the lead in WDMP, T_6 (Cowpea) had enough WDMP to be on par with T_1. Treatments T_2 (Sweet potato) and T_7 (Daincha) maintained the absolute nil values. All other treatments were on par.

4.1.1.3.3. WDMP of broad- leaved weeds (Table 7)

The WDMP of the broad-leaved weeds was significantly influenced by the treatments. Treatment T_1 (Control) recorded highest WDMP (361.07 kg ha^{-1}) followed by T_7 (Daincha) (58.67 kg ha^{-1}). In treatment T_5 (Amaranthus) WDMP of broad- leaved weed was nil. All the other treatments except T_1 (Control) were statistically on par.

At harvest significantly higher WDMP (74 kg ha^{-1}) was recorded by T_1 (Control) and was on par with T_4 (Sesamum), T_6 (Cowpea) and T_7 (Daincha). In treatment T_5 (Amaranthus) WDMP of broad- leaved weed was nil.

Table 7. Effect of summer crops on weed dry matter production (kg ha^{-1})

Treatments	40 Days after planting				At harvest			
	Grasses	Sedges	Broad-leaved weeds	Total	Grasses	Sedges	Broad-leaved weeds	Total
T_1 (Control)	24.51 (630.53)	12.07 (147.47)	16.61 (361.07)	33.26 (1139.07)	18.70 (361.07)	14.91 (225.07)	8.57 (74)	25.68 (660.13)
T_2 (Sweet potato)	9.39 (96.80)	1 (0)	3.53 (11.87)	10.16 (108.67)	10.77 (116)	1 (0)	5.64 (30.93)	12.12 (146.93)
T_3 (Pumpkin)	7.55 (60.67)	1 (0)	1.35 (1.07)	7.61 (61.73)	13.72 (205.33)	7.15 (72.80)	4.82 (25.20)	17.06 (303.33)
T_4 (Sesamum)	12.22 (207.07)	2.05 (3.73)	3.72 (16.53)	13.50 (227.33)	14.69 (244)	2.68 (6.40)	7.78 (67.47)	17.56 (317.87)
T_5 (Amaranthus)*	10.05 (103.60)	3.63 (13.47)	1 (0)	10.68 (117.07)	10.05 (103.60)	3.63 (13.47)	1 (0)	10.68 (117.07)
T_6 (Cowpea)	6.68 (44.53)	1 (0)	1.83 (2.80)	6.91 (47.33)	21.78 (480)	10.79 (128.40)	7.92 (62.93)	25.65 (671.33)
T_7 (Daincha)**	1 (0)	1 (0)	7.70 (58.67)	7.70 (58.67)	1 (0)	1 (0)	7.70 (58.67)	7.70 (58.67)
SEm	2.65	0.61	2.48	2.67	3.33	2.58	1.10	2.73
CD (p = 0.05)	8.18	1.88	7.64	8.24	7.25	5.64	2.40	5.95

Figures in parenthesis are original values   Values are $\sqrt{x+1}$ transformed.   * Amaranthus was harvested at 46 DAS
** Daincha was harvested at 36 DAS   Control is fallow

4.1.1.3.4. Total WDMP (Table 7)

The effect of summer crops and the control on the total WDMP was found to be significant at 40 days after planting. Significantly higher WDMP (1139.07 kg ha^{-1}) was recorded in T_1 (Control).The lowest total WDMP (47.33 kg ha^{-1}) was observed in T_6 (Cowpea) which was on par with all other treatments except T_1 (Control).

At harvest significantly higher total WDMP (671.33 kg ha^{-1}) was recorded in T_6 (Cowpea) which was on par with that of T_1 (Control). The lowest WDMP (58.67 kg ha^{-1}) was noted in T_7 (Daincha) and it was on par with that T_2 (Sweet potato).

4.1.1.4. Relative weed density (per cent)

4.1.1.4.1. Relative weed density (per cent) of grass weeds (Table 8)

The relative density of grasses, sedges and broad- leaved weeds both at 40 days after planting and at harvest in the summer crops differed significantly.

Treatment T_5 (Amaranthus) recorded highest relative weed density (96.30%) for grasses and it was on par with that of T_3 (Pumpkin) and T_6 (Cowpea). Treatments T_2 (Sweet potato) and T_4 (Sesamum) recorded values on par with that of T_1 (Control). The lowest relative weed density of grasses in T_7 (Daincha) was nil. Treatment T_3 (Pumpkin), T_5 (Amaranthus) and T_6 (Cowpea) were on par on this aspect.

At harvest time T_5 (Amaranthus) had significantly higher relative density of grasses weeds. Treatment T_7 (Daincha) recorded the nil value.

Table 8. Effect of summer crop on relative weed density (%)

Treatments	40 Days after planting			At harvest		
	Grasses	Sedges	Broad- leaved weeds	Grasses	Sedges	Broad- leaved weeds
T_1 (Control)	47.39 (53.95)	34.99 (33.95)	20.33 (12.10)	46.41 (52.17)	28.91 (23.84)	28.78 (24.00)
T_2 (Sweet potato)	51.62 (61.31)	0.71 (0)	38.34 (38.69)	57.62 (71.30)	0.71 (0)	32.34 (28.70)
T_3 (Pumpkin)	83.09 (95.83)	0.71 (0)	6.90 (4.17)	52.32 (62.39)	17.67 (15.88)	26.13 (21.73)
T_4 (Sesamum)	53.04 (60.77)	4.82 (2.08)	35.73 (37.15)	51.40 (60.12)	15.16 (7.03)	34.10 (32.85)
T_5 (Amaranthus)*	83.50 (96.30)	6.49 (3.70)	0.71 (0)	83.50 (96.30)	6.49 (3.70)	0.71 (0)
T_6 (Cowpea)	83.08 (95.83)	0.71 (0)	6.89 (4.17)	54.79 (66.70)	26.16 (19.58)	21.00 (13.72)
T_7 (Daincha)**	0.71 (0)	0.71 (0)	90 (100)	0.71 (0)	0.71 (0)	90 (100)
SEm	5.96	3.99	5.40	6.98	7.73	6.67
CD (p = 0.05)	18.35	12.30	16.65	15.20	16.85	14.53

Figures in parenthesis are original values   Values are $\sqrt{x+1}$ transformed.   * Amaranthus was harvested at 46 DAS
** Daincha was harvested at 36 DAS   Control is fallow

4.1.1.4.2. Relative weed density (per cent) of sedges (Table 8)

At 40 DAP, the relative weed density of sedges was maximum (33.95%) in T_1 (Control) and significantly higher than that of all other treatment. Treatments T_2 (Sweet potato), T_3 (Pumpkin), T_6 (Cowpea) and T_7 (Daincha) recorded absolute nil values.

At harvest time also highest sedge weed density was noted in T_1 but it was on par with the rest of the treatments, except T_2 (Sweet potato) and T_7 (Daincha) which maintained absolute nil value.

4.1.1.4.3. Relative weed density (per cent) of broad-leaved weeds (Table 8)

At 40 DAP, T_7 (Daincha) recorded 100 per cent value for relative weed density of broad-leaved weeds, where as T_5 (Amaranthus) had absolute nil value.

Moderately high relative density per cent value was noted in T_2 (Sweet potato) which was on par with T_4 (Sesamum). Significantly lower relative density per cent value was noted in T_3 (Pumpkin) and T_6 (Cowpea).

At harvest stage, T_7 (Daincha) maintained the 100 per cent values. Moderate values were recorded by rest of the treatments except T_5 (Amaranthus) and all were on par. Where as T_5 (Amaranthus) recorded absolute nil value.

4.1.1.5. Relative dry weight (per cent)

4.1.1.5.1. Relative dry weight (per cent) of grass weeds (Table 9)

The influence of summer crops was found to be significant with regard to the relative dry weight of grasses at 40 days after planting. Among the various treatments, T_3 (Pumpkin) showed significantly higher relative dry weight (99.03%) of grasses and it was on par with T_2 (Sweet potato), T_5 (Amaranthus) and T_6 (Cowpea). Treatment T_7 (Daincha) recorded nil value.

Table 9. Effect of summer crops on relative dry weight (per cent) weeds

Treatments	40 Days after planting			At harvest		
	Grasses	Sedges	Broad- leaved weeds	Grasses	Sedges	Broad- leaved weeds
T_1 (Control)	49.64 (57.42)	21.38 (13.34)	30.64 (29.24)	46.98 (53.17)	36.06 (35.18)	19.61 (11.65)
T_2 (Sweet potato)	66.86 (81.77)	0.71 (0)	23.11 (18.23)	62.54 (78.74)	0.71 (0)	27.43 (21.26)
T_3 (Pumpkin)	86.72 (99.03)	0.71 (0)	3.27 (0.97)	54.65 (64.97)	24.77 (22.14)	18.46 (12.89)
T_4 (Sesamum)	62.68 (74.28)	7.46 (3.09)	23.74 (22.64)	57.68 (68.23)	8.35 (2.23)	30.54 (29.54)
T_5 (Amaranthus)*	70.78 (88.60)	19.18 (11.40)	0.71 (0)	70.78 (88.60)	19.18 (11.40)	0.71 (0)
T_6 (Cowpea)	77.68 (93.11)	0.71 (0)	12.29 (6.89)	58.61 (72.73)	24.42 (17.72)	17.93 (9.55)
T_7 (Daincha)**	0.71 (0)	0.71 (0)	90 (100)	0.71 (0)	0.71 (0)	90 (100)
SEm	5.99	2.50	6.28	9.23	7.96	7.30
CD (p = 0.05)	18.46	7.69	19.34	20.10	17.35	15.91

Figures in parenthesis are original values Values are $\sqrt{x+1}$ transformed. * Amaranthus was harvested at 46 DAS

** Daincha was harvested at 36 DAS Control is fallow

At harvest, T_5 (Amaranthus) recorded the highest relative dry weight of grasses but it was on par with all other treatments except T_1 (Control) and T_7 (Daincha). Treatment T_7 (Daincha) maintained absolutely nil value.

4.1.1.5.2. Relative dry weight (per cent) of sedge weeds (Table 9)

The relative dry weight of sedges was highest (13.34%) in T_1 (Control) and it was on par with T_5 (Amaranthus). Significantly lower value was recorded in T_4 (Sesamum), where as treatments T_2 (Sweet potato), T_3 (Pumpkin), T_6 (Cowpea) and T_7 (Daincha) recorded absolutely nil values.

At harvest significantly higher relative dry weight of sedges was recorded in T_1 (Control). Treatments T_2 (Sweet potato) and T_7 (Daincha) maintained their absolute nil values. The rest of the treatments were on par.

4.1.1.5.3. Relative dry weight (per cent) of broad- leaved weeds (Table 9)

The relative weed dry weight in T_7 (Daincha) was entirely constituted by broad leaved weeds at 40 DAP as evident from the 100% value, where as T_5 (Amaranthus) recorded absolutely nil value. Compared to the rest, T_3 (Pumpkin) recorded significantly lower value.

At harvest stage also T_7 (Daincha) maintained the dominance with 100% value and T_5 (Amaranthus) recorded absolutely nil value. All the rest were on par.

4.1.1.6. Summed dominance ratio (SDR)

4.1.1.6.1. Summed dominance ratio (per cent) of grasses (Table 10)

At 40 DAP significantly higher value (99.03) was recorded in T_3 (Pumpkin) and it was on par with T_6 (Cowpea) and T_5 (Amaranthus). Treatments T_7 (Daincha) had absolutely nil value. The rest were on par.

Table 10. Effect of summer crops on summed dominance ratio (per cent)

	40 Days after planting			At harvest		
Treatments	Grasses	Sedges	Broad- leaved weeds	Grasses	Sedges	Broad- leaved weeds
T_1 (Control)	48.49 (55.68)	28.80 (23.65)	26.16 (20.67)	46.70 (52.67)	32.58 (29.51)	24.50 (17.82)
T_2 (Sweet potato)	58.22 (71.54)	0.71 (0)	31.74 (28.46)	60.02 (75.02)	0.71 (0)	29.95 (24.98)
T_3 (Pumpkin)	84.62 (97.43)	0.71 (0)	5.37 (2.57)	53.35 (63.68)	22.03 (19.01)	22.68 (17.31)
T_4 (Sesamum)	57.57 (67.52)	6.55 (2.58)	30.73 (29.89)	54.27 (64.17)	12.25 (4.63)	32.53 (31.19)
T_5 (Amaranthus)*	74.86 (92.45)	15.10 (7.55)	0.71 (0)	74.86 (92.45)	15.10 (7.55)	0.71 (0)
T_6 (Cowpea)	79.37 (94.47)	0.71 (0)	10.60 (5.53)	56.61 (69.71)	25.50 (18.65)	19.70 (11.64)
T_7 (Daincha)**	0.71 (0)	0.71 (0)	90 (100)	0.71 (0)	0.71 (0)	90 (100)
SEm	5.47	2.75	4.97	7.78	7.47	6.63
CD (p = 0.05)	16.86	8.47	15.32	16.96	16.27	14.45

Figures in parenthesis are original values   Values are $\sqrt{x+1}$ transformed.   * Amaranthus was harvested at 46 DAS
** Daincha was harvested at 36 DAS   Control is fallow

At harvest T_5 (Amaranthus) recorded the highest dominance ratio (88.60) and it was on par with the rest of the treatments except T_1 (Control) and T_7 (Daincha). Treatment T_7 (Daincha) recorded absolutely nil value.

4.1.1.6.2. Summed dominance ratio (per cent) of sedges (Table 10)

At 40 DAP the highest summed dominance ratio percent of sedges was noted in T_1 (Control) followed by T_5 (Amaranthus) and T_4 (Sesamum) which were significantly differed from each other. Treatments T_2 (Sweet potato), T_3 (Pumpkin), T_6 (Cowpea) and T_7 (Daincha) recorded absolutely nil value.

At harvest T_1 (Control) had significantly higher SDR value (29.51) and it was on par with T_3 (Pumpkin), T_4 (Sesamum), T_5 (Amaranthus) and T_6 (Cowpea). Where as T_2 (Sweet potato) and T_7 (Daincha) recorded absolutely nil value.

4.1.1.6.3. Summed dominance ratio (per cent) of broad- leaved weeds (Table 10)

In T_7 (Daincha) the SDR per cent was solely comprised of broad- leaved weeds, where as it was absolutely nil in T_5 (Amaranthus).

At harvest T_7 (Daincha) mentained the dominance of SDR with 100 per cent value and all the rest were on par.

4.1.2. Yield of summer crops

4.1.2.1. Economic yield of summer crops (Table 11)

The summer crops in rice fallows differed significantly in the harvested yield of economic produce as it varied in nature from tuber to whole plant.

Table 11. Effect of summer crops on the yield, rice yield equivalent and per day production

Treatments	Economic yield (kg ha^{-1})	Total biological yield (kg ha^{-1})	Rice yield equivalent (kg ha^{-1})	Per day production (kg ha^{-1})
T_1 (Control)*	-	-	-	-
T_2 (Sweet potato)	21296	62778	14907	183.59
T_3 (Pumpkin)	17014	26181	17014	215.37
T_4 (Sesamum)	222	10624	1335	2.47
T_5 (Amaranthus)	33388	33388	33388	725.83
T_6 (Cowpea)	5191	30687	10381	72.09
T_7 (Daincha)	14386	14386	1439	399.61
SEm	-	-	1380	-
CD (p = 0.05)	-	-	3076	-

* Not included for stat analysis Sesamum (dry weight basis)

Among the different summer crops Amaranthus produced significantly higher economic yield (33388 kg ha^{-1}) followed by Sweet potato (21296 kg ha^{-1}). As can be expected, it was lowest in Sesamum (222 kg ha^{-1}) it being seed.

4.1.2.2. Total biological yield (Table 11)

The summer crops varied significantly in their total biological yield. Treatment T_2 (Sweet potato) recorded significantly higher (62778 kg ha^{-1}) total biological yield followed by T_5 (Amaranthus) and T_6 (Cowpea) which where on par, where as it was lowest (10624 kg ha^{-1}) in T_4 (Sesamum).

4.1.2.3. Rice yield equivalent (Table 11)

The rice yield equivalent of the summer crops grown in the rice fallows varied significantly.

Among the different summer crops T_5 (Amaranthus) gave significantly higher (33388 kg ha^{-1}) rice yield equivalent followed by T_3 (Pumpkin) with 17014 kg ha^{-1} and T_2 (Sweet potato) with 14907 kg ha^{-1}. Treatments T_4 (Sesamum) recorded the lowest rice yield equivalent (1335 kg ha^{-1}). Treatments T_2 (Sweet potato) and T_3 (Pumpkin) were statistically on par.

4.1.2.4. Per day production (Table 11)

The summer crops, varied significantly in their per day production. Among the summer crops, per day production was significantly higher (725.83 kg ha^{-1}) in T_5 (Amaranthus) followed by T_7 (Daincha) with 399.61 kg ha^{-1}. The lowest per day production was observed in T_4 (Sesamum) with 2.47 kg ha^{-1}.

4.1.2.5. Water productivity (Table 12)

The water productivity of different summer crops grown in the rice fallows varied markedly.

Among the treatments water productivity was highest (14.548 kg m^{-3}) for T_5 (Amaranthus) followed by T_7 (Daincha) with 6.323 kg m^{-3} and T_3 (Pumpkin) with 4.775 kg m^{-3}. The least water productivity was noted with respect to T_4 (Sesamum).

However, when water productivity was worked out in terms of rice yield equivalent the order of best three changed to T_5 (Amaranthus), T_3 (Pumpkin) and T_6 (Cowpea). The lowest water productivity was recorded in T_7 (Daincha).

Table 12. Water productivity of summer crops (kg m^{-3})

Treatments	Soil moisture m^3 ha^{-1}			Economic yield kg ha^{-1}	Water productivity kg m^{-3}	Water productivity based on rice yield equivalent kg m^{-3}
	Irrigation	Rainfall	Total			
T_1 (Control)	-	-	-	-	-	-
T_2 (Sweet potato)	2272	3919	6191	21296	3.440	2.408
T_3 (Pumpkin)	1672	1891	3563	17014	4.775	4.775
T_4 (Sesamum)	2072	2015	4087	222	0.054	0.327
T_5 (Amaranthus)	1152	1143	2295	33388	14.548	14.548
T_6 (Cowpea)	1432	2115	3547	5191	1.463	2.927
T_7 (Daincha)	-	2275	2275	14386	6.323	0.316

4.1.3. Energy yield (cal m^{-2}) (Table 13)

Among the different summer crops T_2 (Sweet potato) recorded highest energy yield of 2555 cal m^{-2} followed by T_5 (Amaranthus) with 1502 cal m^{-2}. The energy yield was lowest (124 cal m^{-2}) in T_4 (Sesamum).

Table 13. Effect of summer crops on calorific values (cal m^{-2}) of edible portion

Treatments	Crops	Energy per 100g edible portion (cal)	Total energy yield m^{-2} (cal)
T_2	Sweet potato	120	2555
T_3	Pumpkin fruit	25	425
T_4	Sesamum seeds	563	124
T_5	Amaranthus (tender)	45	1502
T_6	Cowpea pods	48	249

4.1.4. Nutrient uptake by the summer crops

4.1.4.1. Nitrogen uptake (Table 14)

Nitrogen uptake by the summer crops in rice fallows was found to vary significant. The highest nitrogen uptake by the economic part (76.53 kg ha^{-1}) was recorded by T_7 (Daincha) and the highest uptake by the vegetative parts (102.47 kg ha^{-1}) by T_2 (Sweet potato). Among the different summer crops the total nitrogen uptake was highest (121.75 kg ha^{-1}) in T_2 (Sweet potato). The lowest nitrogen uptake (20.13 kg ha^{-1}) was recorded in T_3 (Pumpkin). Nitrogen uptake in T_2 (Sweet potato) was significantly higher than all other treatments.

Table 14. Uptake of macro nutrients (N, P, K) by the summer crops

Treatment	N uptake (kg ha^{-1})			P uptake (kg ha^{-1})			K uptake (kg ha^{-1})			Grand total (N+P+K) (kg ha^{-1})
	Economic parts	Vegetative parts	Total	Economic parts	Vege-tative parts	Total	Economic parts	Vege-tative parts	Total	
T_1 (Control)*	-	-	-	-	-	-	-	-	-	-
T_2 (Sweet potato)	19.29	102.47	121.75	12.88	35.36	48.24	45.58	183.82	229.40	399.39
T_3 (Pumpkin)	13.67	6.46	20.13	9.04	4.40	13.44	24.83	13.69	38.52	72.09
T_4 (Sesamum)	2.68	21.19	23.87	1	12.15	13.15	0.89	53.49	54.38	91.40
T_5 (Amaranthus)	47.93	47.93	47.93	19.33	19.33	19.33	76.60	76.60	76.60	143.86
T_6 (Cowpea)	9.96	32.08	42.03	2.75	11.86	14.61	10.82	42.44	53.26	109.9
T_7 (Daincha)	76.53	76.53	76.53	13.13	13.13	13.13	88.15	88.15	88.15	177.81
SEm	4.98	4.30	5.17	1.23	2.45	2.24	5.07	5.66	5.27	6.92
CD (p = 0.05)	11.09	9.58	11.51	2.75	5.46	4.99	11.29	12.60	11.74	15.43

*Not included for stat analysis Control is fallow.

4.1.4.2. Phosphorus uptake (Table 14)

Treatment T_2 (Sweet potato) recorded significantly higher uptake (48.24 kg ha^{-1}) of phosphorus, followed by T_5 (Amaranthus) with 19.33 kg ha^{-1} and the lowest uptake (13.13 kg ha^{-1}) of phosphorus was noticed in T_7 (Daincha) and it was on par with treatment T_3 (Pumpkin), T_4 (Sesamum), T_6 (Cowpea).

4.1.4.3. Potassium uptake (Table 14)

Summer crops grown in rice fallows differed significantly on their potassium uptake.

The highest potassium uptake (229.40 kg ha^{-1}) was recorded by T_2 (Sweet potato), followed by T_7 (Daincha) with 88.15 kg ha^{-1}. The lowest (38.52 kg ha^{-1}) uptake in T_3 (Pumpkin). The nutrient uptake by T_2 (Sweet potato) was significantly higher than that of all other treatments.

4.1.4.4. Total macro nutrient uptake (Table 14)

Summer crops grown in the rice fallows varied significantly in their total uptake macro nutrient.

Among the different summer crops the total uptake of nitrogen, phosphorus and potassium was highest (399.39 kg ha^{-1}) in sweet potato followed by T_7 (Daincha) with 177.81 kg ha^{-1}. The uptake was lowest (72.09 kg ha^{-1}) in T_3 (Pumpkin). Each treatments differed significantly from one another.

4.1.4.5. Uptake of secondary nutrients

4.1.4.5.1. Calcium uptake (Table 15)

The summer crops recorded significant variation with regard to the calcium uptake.

Table 15. Uptake of secondary nutrients (Ca and Mg) by the summer crops

Treatment	Ca uptake (kg ha^{-1})			Mg uptake (kg ha^{-1})		
	Economic parts	Vegetative parts	Total	Economic parts	Vegetative parts	Total
T_1 (Control)*	-	-	-	-	-	-
T_2 (Sweet potato)	167.85	604.89	772.74	41.51	45.35	86.86
T_3 (Pumpkin)	45.16	34.52	79.68	11.92	12.96	24.88
T_4 (Sesamum)	-	-	113.54	-	-	52.87
T_5 (Amaranthus)	118.88	118.88	118.88	72.93	72.93	72.93
T_6 (Cowpea)	29.73	129.76	159.48	5.61	45.24	50.85
T_7 (Daincha)	149.46	149.46	149.46	38.35	38.35	38.35
SEm			65.49			17.18
CD (p = 0.05)			145.93			38.29

* Not included for stat analysis   Control is fallow.

Among the summer crops sweet potato had (772.74 kg ha^{-1}) of calcium (604.89 kg ha^{-1} by vegetative part and 167.85 kg ha^{-1} by economic part) which was significantly higher than that of all the second highest was in cowpea that observed only 159.48 kg ha^{-1} (129.76 kg ha^{-1} by vegetative part and 29.73 kg ha^{-1} by economic part). The lowest uptake (79.68 kg ha^{-1}) was observed in pumpkin (34.52 kg ha^{-1} by vegetative part and 45.16 kg ha^{-1} by economic part). The major portion of calcium uptake in general was by the vegetative parts.

4.1.4.5.2. Magnesium uptake (Table 15)

The magnesium uptake by summer crops in rice fallows was found to vary significantly. Among the different summer crops T_2 (Sweet potato) recorded significantly higher magnesium uptake of 86.86 kg ha^{-1} (viz. 45.35 kg ha^{-1} by vegetative part, 41.51 kg ha^{-1} by economic part) and it was on par withT_4 (Sesamum), T_5 (Amaranthus) and T_6 (Cowpea). The uptake was lowest in pumpkin (24.88 kg ha^{-1} viz. 12.96 kg ha^{-1} by vegetative part and 11.92 kg ha^{-1} by economic part). In general magnesium uptake by vegetative part was higher than that of economic parts.

4.1.4.6. Uptake of micronutrients

4.1.4.6.1. Iron uptake (Table 16)

Summer crops grown in rice fallows revealed a significant variation in the uptake of iron. Significantly higher iron uptake was recorded in T_2 (Sweet potato) (37.51 kg ha^{-1}), the major sink being the vegetative parts 27.58 kg ha^{-1}, where as it was significantly lower (4.14 kg ha^{-1}) in T_7 (Daincha).

4.1.4.6.2. Zinc uptake (Table 16)

The uptake of zinc by the summer crops differed significantly. Treatment T_2 (Sweet potato) recorded significantly higher uptake (8.46 kg ha^{-1}) followed by T_4 (Sesamum) with 1.82 kg ha^{-1}. Treatment T_7 (Daincha) had significantly lower (0.12 kg ha^{-1}) uptake.

4.1.4.6.3. Copper uptake (Table 16)

Summer crops grown in rice fallows showed significant variation in the uptake of copper.

Among the different summer crops the copper uptake was significantly higher (7.31 kg ha^{-1}) in T_2 (sweet potato) followed by T_3 (Pumpkin) with 1.05 kg ha^{-1}. The uptake of copper was significantly lower in T_7 (Daincha) with 0.11 kg ha^{-1}.

4.1.5. Nutrient removal by weeds at harvest (Table 17)

Nutrient (nitrogen, phosphorus and potassium) removal by weeds in the summer crops and the control treatment was found to be significantly different.

4.1.5.1. Nitrogen removal by weeds (Table 17)

Among the different treatments weeds in the T_6 (Cowpea) removed significantly higher nitrogen (9.53 kg ha^{-1}) and it was on par with that of T_1 (Control). Nitrogen uptake was significantly lower (1.08 kg ha^{-1}) in T_7 (Daincha) and it was on par with the rest of the treatments except T_1 (Control) and T_7 (Daincha).

4.1.5.2. Phosphorus removal by weeds (Table 17)

The removal of phosphorus by weeds was significantly higher in T_6 (Cowpea) with 1.41 kg ha^{-1} and it was on par with that of T_1 (Control). Where as it was significantly lower in 0.16 kg ha^{-1} in T_7 (Daincha) and was on par with the rest of the treatments except T_1 (Control) and T_7 (Daincha).

Table 16. Uptake of micro nutrients (Fe, Zn and Cu) by the summer crops

Treatment	Fe uptake (kg ha^{-1})			Zn uptake (kg ha^{-1})			Cu uptake (kg ha^{-1})		
	Economic parts	Vegetative parts	Total	Economic parts	Vegetative parts	Total	Economic parts	Vegetative parts	Total
T_1 (Control)*	-	-	-	-	-	-	-	-	-
T_2 (Sweet potato)	9.92	27.58	37.51	2.30	6.16	8.46	2.13	5.18	7.31
T_3 (Pumpkin)	5.13	2.69	7.82	0.79	0.35	1.14	0.72	0.33	1.05
T_4 (Sesamum)	-	-	19.02	-	-	1.82	-	-	0.96
T_5 (Amaranthus)	12.49	12.49	12.49	1.30	1.30	1.30	0.73	0.73	0.73
T_6 (Cowpea)	1.39	6.12	7.51	0.17	0.65	0.82	0.08	0.67	0.75
T_7 (Daincha)	4.14	4.14	4.14	0.12	0.12	0.12	0.11	0.11	0.11
SEm			1.21			0.25			0.31
CD (p = 0.05)			2.71			0.56			0.70

* Not included for stat analysis Control is fallow.

Table 17. Nutrient removal by the weeds in summer crops at harvest (kg ha^{-1})

Treatment	N removal (kg ha^{-1})	P removal (kg ha^{-1})	K removal (kg ha^{-1})	Total removal (kg ha^{-1})
T_1 (Control)*	9.37	1.39	10.30	21.06
T_2 (Sweet potato)	2.09	0.31	2.29	4.69
T_3 (Pumpkin)	4.31	0.64	4.73	9.68
T_4 (Sesamum)	4.51	0.67	4.96	10.14
T_5 (Amaranthus)	1.79	0.26	1.96	4.01
T_6 (Cowpea)	9.53	1.41	10.47	21.42
T_7 (Daincha)	1.08	0.16	1.19	2.43
SEm	1.58	0.23	1.73	3.55
CD (p = 0.05)	3.44	0.51	3.78	7.72

*Control is fallow

4.1.5.3. Potassium removal by weeds (Table 17)

Potassium removal by the weeds was significantly higher in T_6 (Cowpea) with 10.47 kg ha^{-1} and was on par with T_1 (Control). Potassium removal was significantly lower (1.19 kg ha^{-1}) in T_7 (Daincha) and it was on par with T_2 (Sweet potato).

4.1.5.4. Total removal by weeds (Table 17)

The total removal of nitrogen, phosphorus and potassium was significantly higher (21.42 kg ha^{-1}) in T_6 (Cowpea) and was on par with T_1 (Control) with 21.06 kg ha^{-1}. The nutrient removal was lowest in T_7 (Daincha) with 2.43 kg ha^{-1} and it was on par with rest of the treatments except T_1 (Control) and T_7 (Daincha).

4.1.6. Effect of summer crops on physico–chemical characters of the post harvest soil

4.1.6.1. Physical characters

4.1.6.1.1. Bulk density (Table 18)

Neither the summer crops nor summer fallowing exerted any significant influence on the bulk density of the post harvest soil. However (T_2) Sweet potato, (T_4) Sesamum and (T_6) Cowpea treatments recorded comparatively lower values of bulk density.

Table 18. Effect of summer crops on physical properties of the soil

Treatments	Bulk density ($g\ cc^{-1}$)	Particle density ($g\ cc^{-1}$)	Porosity (%)
T_1 (Control)	1.32	2.26	42
T_2 (Sweet potato)	1.25	2.26	45
T_3 (Pumpkin)	1.38	2.26	39
T_4 (Sesamum)	1.25	2.26	45
T_5 (Amaranthus)	1.36	2.26	40
T_6 (Cowpea)	1.26	2.26	44
T_7 (Daincha)	1.36	2.26	40
SEm	0.05	-	2.27
CD ($p = 0.05$)	NS	-	NS

4.1.6.1.2. Porosity (Table 18)

The results revealed that the summer crops with summer fallowing did not significantly affecting the porosity of the post harvest soil.

4.1.6.2. Chemical characters

4.1.6.2.1. Soil reaction (pH) (Table 19)

The summer crops markedly influence the pH values of the post harvest soil with (T_5) amaranthus cropped field recording significantly higher pH values than others. The lowest pH values were recorded in the (T_6) cowpea, (T_7) daincha cropped soil and T_1 (Fallow control) and (T_3) pumpkin were on par and recorded significantly higher pH values than (T_7) daincha.

Table 19. Effect of summer crops on soil reaction (pH) and Electric conductivity

Treatments	pH	Electric conductivity (µsm^{-1})
T_1 (Control)	5.64	118.93
T_2 (Sweet potato)	5.36	63.92
T_3 (Pumpkin)	5.73	254.47
T_4 (Sesamum)	5.61	203.57
T_5 (Amaranthus)	6.13	290.63
T_6 (Cowpea)	5.27	120.48
T_7 (Daincha)	5.26	132.60
SEm	0.17	68.96
CD (p = 0.05)	0.37	NS

4.1.6.2.2. Electric conductivity (Table 19)

The effect of summer crops were found to be non significant on electric conductivity of the post harvest soil.

4.1.6.2.3. Organic carbon (Table 20)

The different treatments had no significant effect on the organic carbon content of the post harvest soil, though T_3 (Pumpkin) and T_5 (Amaranthus) cropped soil recorded relatively higher values.

4.1.6.2.4. Soil available macro nutrient content of post harvest soil

4.1.6.2.4.1. Available nitrogen (Table 20)

Effect of summer crops on the soil available nitrogen was found to be not significant. Among the different treatments T_7 (Daincha) recorded numerically higher quantity of available nitrogen (305.24 kg ha^{-1}) followed by T_2 (Sweet potato) with 301.06 kg ha^{-1}. The treatment T_1 (Control) andT_3 (Pumpkin) were on par and recorded numerically lower quantity of available nitrogen.

4.1.6.2.4.2. Available P_2O_5 (Table 20)

The quantity of available P_2O_5 in the soil was significantly influenced by the different summer crops. The highest quantity of available P_2O_5 (150.78 kg ha^{-1}) was recorded in T_5 (Amaranthus) which is statistically on par with that of T_3 (Pumpkin). The lowest quantity of available P_2O_5 (16.90 kg ha^{-1}) was recorded in T_1 (Control) which was statistically on par with the rest of the treatments except T_3 (Pumpkin) and T_5 (Amaranthus).

4.1.6.2.4.3. Available K_2O (Table 20)

The treatment T_5 (Amaranthus) cropped soil recorded the highest quantity of available K_2O (422.91 kg ha^{-1}) which was significantly higher than that of all other treatments except T_3 (Pumpkin). The available K_2O status of the soil was lowest (91.85 kg ha^{-1}) in T_2 (Sweet potato) which was on par with that of T_6 (Cowpea) and T_7 (Daincha).

4.1.6.2.5. Exchangeable secondary nutrient content of post harvest soil

4.1.6.2.5.1. Exchangeable Ca (Table 20)

The exchangeable calcium content of the post harvest soil was not significantly affected by the different summer crops.

Table 20. Effect of summer crops on Organic carbon and available macro and micro nutrients of the post harvest soil

Treatments	Organic carbon (%)	Nitrogen (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{1})	Exchangeable Ca (mg kg^{-1})	Exchangeable Mg (mg kg^{-1})	Available Iron (kg ha^{-1})	Available Zinc (kg ha^{-1})	Available Copper (kg ha^{-1})
T_1 (Control)	1.29	276.60	16.90	196.48	608.67	41.50	88.20	2.45	6.14
T_2 (Sweet potato)	0.90	301.06	42.65	91.85	650.17	240.70	91.00	2.18	5.66
T_3 (Pumpkin)	1.30	267.60	118.82	335.10	747.00	116.20	97.13	3.27	5.73
T_4 (Sesamum)	1.05	275.96	39.11	200.70	691.67	91.30	119.05	3.19	5.51
T_5 (Amaranthus)	1.33	292.70	150.78	422.91	954.50	448.20	106.41	6.47	5.88
T_6 (Cowpea)	1.07	292.70	42.36	173.38	664.00	66.40	128.23	2.23	5.84
T_7 (Daincha)	1.06	305.24	38.76	103.20	525.67	207.50	181.72	7.31	8.83
SEm	0.17	10.93	25.89	54.58	132.99	80.33	25.63	1.08	0.72
CD ($p = 0.05$)	NS	NS	56.41	118.93	NS	175.02	55.84	2.36	1.56

Control is fallow

4.1.6.2.5.2. Exchangeable Mg (Table 20)

Summer crop showed a significant influence on the exchangeable magnesium. Among the treatments T_5 (Amaranthus) recorded significantly higher quantity of exchangeable magnesium (448.20 mg kg^{-1}) followed by T_2 (Sweet potato) with 240.70 mg kg^{-1} which were on par. The lower quantity of (41.50 mg kg^{-1}) exchangeable magnesium was recorded in T_1 (Control). Treatment T_2 (Sweet potato), T_3 (Pumpkin), T_4 (Sesamum) and T_7 (Daincha) were on par with respect to exchangeable magnesium.

4.1.6.2.6. Soil available micro nutrient content of post harvest soil

4.1.6.2.6.1. Available iron (Table 20)

The data summarized in the Table revealed a significant effect on the available iron during the summer season.

Treatment T_7 (Daincha) cropped soil recorded significantly higher quantity of available iron (181.72 kg ha^{-1}) followed by T_6 (Cowpea) with 128.23 kg ha^{-1} which were on par. It was lowest (88.20 kg ha^{-1}) in T_1 (Control).

4.1.6.2.6.2. Available zinc (Table 20)

The influence of summer crops was found to be significant on the available zinc status of the post harvest soil. Treatment T_7 (Daincha) cropped soil recorded significantly higher quantity of available zinc (7.31 kg ha^{-1}) followed by T_5 (Amaranthus) cropped soil (6.47 kg ha^{-1}) and they were on par. The lowest quantity of available Zn (2.18 kg ha^{-1}) was noted in T_2 (Sweet potato). All the treatments except T_5 (Amaranthus) and T_7 (Daincha) were on par.

4.1.6.2.6.3. Available copper (kg ha^{-1}) (Table 20)

The available copper in the post harvest soil was significantly influenced by the different summer crops. The highest quantity of available copper (8.83 kg ha^{-1}) was recorded in T_7 (Daincha) followed by T_1 (Control) with 6.14 kg ha^{-1} and the lowest (5.51 kg ha^{-1}) quantity of available copper was recorded under T_4 (Sesamum). All the treatments except T_7 (Daincha) were statistically on par.

4.1.7. Economics of summer cropping (Table 21)

Among the treatments, T_6 (Cowpea) incurred the highest expenses (Rs. 58417) followed by T_2 (Sweet potato) with Rs. 43611 ha^{-1} and T_5 (Amaranthus) with Rs. 43324 ha^{-1}.

Table 21.Economic analysis of summer cropping of upland crops in rice fallows (Rs ha^{1})

Treatments	Cost of cultivation (Rs. ha^{-1})	Economic yield (kg ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C ratio
T_1 (Control)	-	-	-	-	-
T_2 (Sweet potato)	43611	21296	149074	105463	3.42
T_3 (Pumpkin)	30513	17014	170140	139627	5.58
T_4 (Sesamum)	20885	222	13346	-7539	0.64
T_5 (Amaranthus)	43324	33388	333880	290556	7.71
T_6 (Cowpea)	58417	5191	103813	45396	1.78
T_7 (Daincha)	6975	14386	14386	6911	2.06

Particulars of calculation detailed in Appendix II

The highest gross return of Rs. 333880 ha^{-1} recorded in T_5 (Amaranthus), followed by T_3 (Pumpkin) with Rs 170140 ha^{-1} and T_2 (Sweet potato) with Rs. 149074 ha^{-1}.

The highest net return of Rs. 290556 ha^{-1} was recorded in T_5 (Amaranthus) followed by T_3 (Pumpkin) with Rs. 139627 ha^{-1} and T_2 (Sweet potato) with Rs. 105463 ha^{-1}.

The highest B:C ratio of 7.71 was observed in T_5 (Amaranthus). The next B:C ratio value of 5.58 was recorded by T_3 (Pumpkin) followed by T_2 (Sweet potato) with the value of 3.42. The least B:C ratio of 0.64 was noted in T_4 (Sesamum) .

4.1.8. Post summer crop soil nutrient balance studies

4.1.8.1. Studies on balance sheet of available soil nitrogen (Table 22)

The post summer crop soil recorded a negative balance of soil available nitrogen except for T_2 (Sweet potato) and T_7 (Daincha).

The highest nutrient status of soil available nitrogen of 688.52 kg ha^{-1} was noted in the pre–cropped summer soil in T_5 (Amaranthus) followed by T_3 (Pumpkin) with 493.52 kg ha^{-1}. The least value was observed in T_1 (Control) and T_7 (Daincha). The highest depletion by the weeds and crop was noted in T_2 (Sweet potato) with 123.84 kg ha^{-1} followed by T_7 (Daincha). The post summer soil had comparatively higher nitrogen status in T_7 (Daincha). The net loss of nitrogen was highest in T_5 (Amaranthus) followed by T_3 (Pumpkin). The least loss was noted in T_1 (Control).

4.1.8.2. Studies on balance sheet of available soil phosphorus (Table 23)

The nutrient balance sheet of post summer crop soil recorded a negative balance of soil available phosphorus except for T_2 (Sweet potato) and T_7 (Daincha).

Table 22. Balance sheet of available nitrogen in the post harvest soil as influenced by the summer crops

Treatments	Addition of Nitrogen (kg ha^{-1})	Removal of nitrogen (kg ha^{-1})			Actual balance of N (kg ha^{-1})	Net loss or gain (kg ha^{-1})
		By weeds	By crop	Total		
T_1 (Control)	288.52	9.37	0	9.37	276.60	-2.55
T_2 (Sweet potato)	423.52	2.09	121.75	123.84	301.06	1.38
T_3 (Pumpkin)	493.52	4.31	20.13	24.44	267.60	-201.48
T_4 (Sesamum)	348.52	4.51	23.87	28.38	275.96	-44.18
T_5 (Amaranthus)	688.52	1.79	47.93	49.72	292.70	-346.10
T_6 (Cowpea)	428.52	9.53	42.03	51.56	292.70	-84.26
T_7 (Daincha)	288.52	1.08	76.53	77.61	305.24	94.33

Control is fallow

Addition of Nitrogen (kg ha^{-1}) to the summer crops

Sources	T_1 (Control)	T_2 (Sweet potato)	T_3 (Pumpkin)	T_4 (Sesamum)	T_5 (Amaranthus)	T_6 (Cowpea)	T_7 (Daincha)
Soil contribution	288.52	288.52	288.52	288.52	288.52	288.52	288.52
Manures	0	60	135	30	300	120	0
Fertilizers	0	75	70	30	100	20	0
Total	288.52	423.52	493.52	348.52	688.52	428.52	288.52

Table 23. Balance sheet of available phosphorus in the soil as influenced by the summer crops

Treatments	Addition of phosphorus (kg ha^{-1})	Removal of Phosphorus (kg ha^{-1})			Actual balance of P (kg ha^{-1})	Net loss or gain (kg ha^{-1})
		By weeds	By crop	Total		
T_1 (Control)	37.19	3.17	0	3.17	16.90	-17.12
T_2 (Sweet potato)	132.19	0.71	110.47	111.18	42.65	21.64
T_3 (Pumpkin)	163.44	1.46	30.78	32.24	118.82	-12.38
T_4 (Sesamum)	74.69	1.53	30.11	31.64	39.11	-3.94
T_5 (Amaranthus)	312.19	0.60	44.27	44.87	150.78	-116.54
T_6 (Cowpea)	157.19	3.23	33.46	36.69	42.36	-78.14
T_7 (Daincha)	37.19	0.37	30.07	30.44	38.76	32.01

Control is fallow
Uptake of nutrients by plants and weeds were converted to P_2O_5

Addition of P_2O_5 (kg ha^{-1}) to the summer crops

Sources	T_1 (Control)	T_2 (Sweet potato)	T_3 (Pumpkin)	T_4 (Sesamum)	T_5 (Amaranthus)	T_6 (Cowpea)	T_7 (Daincha)
Soil contribution	37.19	37.19	37.19	37.19	37.19	37.19	37.19
Manures	0	45	101.25	22.5	225	90	0
Fertilizers	0	50	25	15	50	30	0
Total	37.19	132.19	163.44	74.69	312.19	157.19	37.19

The highest nutrient status of soil available phosphorus of 312.19 kg ha^{-1} was noted in the pre–cropped summer soil in T_5 (Amaranthus) followed by T_3 (Pumpkin) with 163.44 kg ha^{-1}. The least value was observed in T_1 (Control) and T_7 (Daincha). The highest depletion by the weeds and crop was noted in T_2 (Sweet potato) with 111.18 kg ha^{-1} followed by T_5 (Amaranthus). The post summer soil had comparatively higher phosphorus status in T_5 (Amaranthus). The net loss of phosphorus was highest in T_5 (Amaranthus) followed by T_6 (Cowpea). The least loss was noted in T_4 (Sesamum).

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4.1.8.3. Studies on balance sheet of available soil potassium (Table 24)

The nutrient balance sheet of post summer crop soil recorded a negative balance of soil available potassium except for T_2 (Sweet potato) and T_7 (Daincha).

The highest nutrient status of soil available potassium of 670 kg ha^{-1} was noted in the pre–cropped summer soil in T_5 (Amaranthus) followed by T_3 (Pumpkin) with 405 kg ha^{-1}. The least value was observed in T_1 (Control) and T_7 (Daincha). The highest depletion by the weeds and crop was noted in T_2 (Sweet potato) with 278.03 kg ha^{-1} followed by T_7(Daincha). The post summer soil had comparatively higher potassium status in T_5 (Amaranthus). The net loss of potassium was highest in T_5 (Amaranthus) followed by T_6 (Cowpea). The least loss was noted in T_2 (Sweet potato).

4.2. SUCCEEDING RICE (VIRIPPU) CROP

4.2.1. Studies on weeds

4.2.1.1. Weed spectrum analysis (Table 25)

The weed flora belonging to nine different families were found to occur in rice crop. There was a significant reduction in grass weeds.

Table 24. Balance sheet of available potassium in the soil as influenced by the summer crops

Treatments	Addition of Potassium (kg ha^{-1})	Removal of Potassium (kg ha^{-1})			Actual balance of K (kg ha^{-1})	Net loss or gain (kg ha^{-1})
		By weeds	By plant	Total		
T_1 (Control)	220	12.36	0	12.36	196.48	-11.16
T_2 (Sweet potato)	375	2.75	275.28	278.03	91.85	-5.12
T_3 (Pumpkin)	405	5.68	46.22	51.90	335.10	-18.00
T_4 (Sesamum)	290	5.95	65.26	71.21	200.70	-18.09
T_5 (Amaranthus)	670	2.35	91.92	94.27	422.91	-152.82
T_6 (Cowpea)	390	12.57	63.91	76.48	173.38	-140.14
T_7 (Daincha)	220	1.43	105.78	107.21	103.20	-9.59

Uptake of nutrients by plants and weeds were converted to K_2O
Control is fallow

Addition of K_2O (kg ha^{-1}) to the summer crops

Sources	T_1 (Control)	T_2 (Sweet potato)	T_3 (Pumpkin)	T_4 (Sesamum)	T_5 (Amaranthus)	T_6 (Cowpea)	T_7 (Daincha)
Soil contribution	220	220	220	220	220	220	220
Manures	0	80	160	40	400	160	0
Fertilizers	0	75	25	30	50	10	0
Total	220	375	405	290	670	390	220

Table 25. Effect of summer crops on the weed flora of the succeeding rice crops

Name of the weed	Family	T_1 (Control –rice)	T_2 (Sweet potato –rice)	T_3 (Pumpkin– rice)	T_4 (Sesamum – rice)	T_5 (Amaranthus – rice)	T_6 (Cowpea – rice)	T_7 (Daincha – rice)
I. GRASSES								
Echinochloa colona (L. Link)	Gramineae	✓	x	✓	x	x	x	x
Isachne miliacea (Roth.)	Gramineae	✓	x	x	x	x	x	x
II. SEDGES								
Cyperus iria (L.)	Cyperaceae	✓	✓	✓	✓	✓	✓	✓
Cyperus compressus (L.)	Cyperaceae	x	✓	x	x	x	x	x
Schoenoplectus lateriflorus (Gmel. Lye)	Cyperaceae	✓	✓	✓	✓	✓	✓	✓
Fimbristylis milliacea (L. Vahl.)	Cyperaceae	✓	x	x	✓	✓	x	x
Cyperus difformis (L.)	Cyperaceae	✓	✓	x	x	x	x	✓
Eleocharis retroflexa (Retz.)		x	✓	✓	✓	x	x	x
III. BROAD-LEAVED WEEDS								
Ammania baccifera (L.)	Lythraceae	✓	✓	✓	✓	✓	✓	✓
Monochoria vaginalis (Burm.f.)	Potenderiaceae	✓	✓	✓	✓	✓	✓	✓
Dopatrium junceum (Roxb.)	Scrophulariaceae	✓	x	✓	✓	✓	✓	✓
Ludwigia perennis (L.)	Onagraceae	✓	✓	✓	✓	✓	✓	✓
Ludwigia adscendens (L. Hara)	Onagraceae	x	x	✓	✓	x	x	✓
Bergia ammanioides (Roxb.)	Elatinaceae	✓	✓	✓	✓	x	✓	✓
Sphenoclea zeylanica (Gaertn.)	Sphenocleaceae	✓	✓	✓	✓	✓	✓	✓
IV. FERNS								
Marsilia quadrifoliata (L.)	Marsileaceae	x	x	✓	✓	✓	✓	✓

✓ Present x Absent Control is fallow

Sedge weeds were present in all treatments; the predominant species were *Cyperus iria* (L.) and *Schoenoplectus lateriflorus* (Gmel. Lye). There was a abundance of broad- leaved weeds and species belonging to seven families occurred in the rice crop. The *Sphenoclea zeylanica* (Gaertn.), *Monochoria vaginalis* (Burm.f.), *Ludwigia perennis* (L.) and *Ammania baccifera* (L.) were present in all the treatments.

4.2.1.2. Weed population (Numbers m^{-2}) (Table 26)

Weed count of the grasses, sedges, broad- leaved and total weed population at 40 days after transplanting and at harvest were found to be significantly varying with the treatments.

4.2.1.2.1. Population (No m^{-2}) of grass weeds (Table 26)

All the treatments showed a significant effect on grass weed population at 40 DAT. Among the treatments T_1 (control–rice) and T_6 (Cowpea–rice) recorded significantly higher grassy weeds population (9.33) and they were on par with T_3 (Pumpkin– rice) (4.00). There was no significant incidence of grass weeds in T_2 (Sweet potato–rice), T_4 (Sesamum–rice), T_5 (Amaranthus–rice) and T_7 (Daincha–rice).

At harvest stage also the treatments showed significant effect on grassy weed population. Among the treatments T_1 (Fallow–rice) recorded highest number of grassy weeds (10.67 m^{-2}) followed by T_3 (Pumpkin–rice) (4.00) and they were on par. There was no grassy weed incidence in the other treatments.

4.2.1.2.2. Population (No m^{-2}) of sedge weeds (Table 26)

The significant difference was noticed between the different treatments on the sedges population at 40 DAT. Treatment T_2 (Sweet potato–rice) recorded significantly higher population of sedge weeds (84.00) and was on par with that of T_3 (Pumpkin–rice) (74.67).

Significantly lower sedge population was observed in T_6 (Cowpea– rice) (4.00) and it was on par with that of T_7 (Daincha– rice).

The significant difference was observed between treatments on the sedges population at harvest. Treatment T_1 (Fallow–rice) recorded significantly higher sedges population (58.67 m^{-2}) and it was on par with that of T_2 (Sweet potato–rice) T_3 (Pumpkin–rice) and T_4 (Sesamum–rice). Significantly lower sedge weed population (5.33) was noted in T_7 (Daincha–rice) and it was on par with that of T_5 (Amaranthus–rice) and T_6 (Cowpea–rice).

4.2.1.2.3. Population (No m^{-2}) of broad- leaved weeds (Table 26)

The treatments varied significantly in the broad-leaved weed population. Broad-leaved weed population was significantly higher (288.00 m^{-2}) in T_2 (Sweet potato–rice) and it was on par with T_3 (Pumpkin–rice) (276.00 m^{-2}) and T_1 (Control–rice). Weed population was lowest (68.00 m^{-2}) in T_7 (Daincha– rice).

The broad- leaved weed population was found to be significantly influenced by the treatments. Broad- leaved weed population was significantly higher (290.67 m^{-2}) in T_5 (Amaranthus– rice) and it was on par with T_1 (Fallow–rice) and T_2 (Sweet potato–rice). Treatment T_7 (Daincha– rice) recorded lowest broad- leaved weed population (68.00 m^{-2}).

4.2.1.2.4. Total weed population (No m^{-2}) (Table 26)

The influence of treatments on total weed population was found to be significant at 40 DAT. Treatment T_2 (Sweet potato–rice) recorded the highest total weed population (372.00 m^{-2}) followed by T_3 (Pumpkin–rice) (354.67 m^{-2}). The lowest total weed population was recorded in T_7 (Daincha–rice) (89.33 m^{-2}). Treatment T_1 (Fallow–rice), T_2 (Sweet potato– rice) and T_3 (Pumpkin– rice) were on par with regard to the total weed population.

Table 26. Effect of preceding summer upland crops on weed population (No m^{-2}) of succeeding rice crop

Treatments	Weed population (No m^{-2}) at 40 Days after transplanting				Weed population (No m^{-2}) at harvest			
	Grass	Sedge	Broad-leaved weed	Total	Grass	Sedge	Broad-leaved weed	Total
T_1 (Control–rice)	2.91 (9.33)	6.89 (46.67)	13.30 (177.33)	15.27 (233.33)	3.08 (10.67)	7.60 (58.67)	13.10 (181.33)	15.43 (250.67)
T_2 (Sweet potato–rice)	1 (0)	9.19 (84.00)	16.30 (288.00)	18.92 (372.00)	1 (0)	6.80 (56)	12.71 (162.67)	14.64 (218.67)
T_3 (Pumpkin–rice)	2.08 (4.00)	8.37 (74.67)	16.61 (276.00)	18.76 (354.67)	2.08 (4.00)	6.90 (52)	10.62 (112)	12.92 (168)
T_4 (Sesamum–rice)	1 (0)	6.81 (48.00)	11.13 (124.00)	13.05 (172.00)	1 (0)	5.08 (25.33)	10.69 (114.67)	11.84 (140)
T_5 (Amaranthus–rice)	1 (0)	6.98 (49.33)	10.93 (120.00)	12.94 (169.33)	1 (0)	4.10 (16)	16.84 (290.67)	17.34 (306.67)
T_6 (Cowpea–rice)	2.91 (9.33)	2.08 (4.00)	8.98 (81.33)	9.68 (94.67)	1 (0)	3.37 (10.67)	9.41 (88)	9.98 (98.67)
T_7 (Daincha–rice)	1 (0)	4.66 (21.33)	8.28 68.00)	9.47 (89.33)	1 (0)	2.33 (5.33)	8.17 (68)	8.53 (73.33)
SEm	0.47	0.92	1.36	1.18	0.46	1.06	1.37	1.45
CD (p = 0.05)	1.45	2.84	4.18	3.66	1.40	3.28	4.23	4.50

Figures in parenthesis are the original values Values are $\sqrt{x+1}$ transformed Control is fallow

The effect of treatments on total weed population was found to be significant at harvest. Treatment T_5 (Amaranthus–rice) (306.67 m^{-2}) recorded the highest total weed population followed by T_1 (Fallow–rice) (250.67 m^{-2}). The lowest total weed population was observed in T_7 (Daincha–rice) (73.33 m^{-2}). Treatment T_1 (Fallow–rice), T_2 (Sweet potato– rice) and T_5 (Amaranthus– rice) were statistically on par.

4.2.1.3. Weed dry matter production (WDMP) Table 27

4.2.1.3.1. WDMP of grasses (Table 27)

Treatments had no significant effect on WDMP of grasses both at 40 DAT and at harvest.

4.2.1.3.2. WDMP of sedges (Table 27)

The weed dry matter production (WDMP) of the sedges at 40 days after transplanting varied significantly. Among the different treatments T_2 (Sweet potato–rice) recorded the highest dry weight (118.53 kg ha^{-1}) of the sedges followed by T_1 (Fallow–rice) (87.33 kg ha^{-1}). The lowest dry weight of the sedges was recorded in T_6 (Cowpea–rice) (4.67 kg ha^{-1}). Treatment T_1 (Fallow–rice), T_2 (Sweet potato– rice) and T_5 (Amaranthus–rice) were statistically on par with respect to the dry weight of the sedges.

At harvest the WDMP of sedges was not significantly influenced by the treatments.

4.2.1.3.3. WDMP of broad- leaved weeds (Table 27)

The weed dry matter production (WDMP) of broad- leaved weeds both at 40 DAT and at harvest were not significantly influenced by the treatments.

4.2.1.3.4. Total WDMP (Table 27)

The total WDMP both at 40 DAT and at harvest did not vary significantly by the treatments.

Table 27. Effect of summer crops on the weed dry matter production (WDMP) (kg ha^{-1}) in succeeding rice crop

Treatments	40 Days after transplanting				At harvest			
	Grass	Sedge	Broad-leaved weed	Total	Grass	Sedge	Broad-leaved weed	Total
T_1 (Control–rice)	3.90 (18.67)	9.18 (87.33)	12.19 (149.07)	15.87 (255.07)	1.94 (4.53)	5.35 (29.47)	10.60 (118.67)	12.03 (152.67)
T_2 (Sweet potato–rice)	1 (0)	10.58 (118.53)	13.02 (172.40)	16.90 (290.93)	1 (0)	5.91 (44.93)	10.72 (115.07)	12.50 (160)
T_3 (Pumpkin–rice)	3.18 (18.67)	4.75 (31.33)	10.08 (109.33)	11.85 (159.33)	1.41 (1.33)	3.20 (11.47)	8.08 (72.80)	8.89 (85.60)
T_4 (Sesamum–rice)	1.34 (1.07)	5.86 (34.80)	8.78 (81.20)	10.54 (117.07)	1 (0	5.35 (27.73)	8.77 (77.33)	10.25 (105.07)
T_5 (Amaranthus–rice)	1 (0)	7.12 (52.13)	14.97 (284.13)	16.66 (336.27)	1 (0)	4.60 (23.20)	13.10 (174.93)	14.02 (198.13)
T_6 (Cowpea–rice)	4.11 (22.93)	2.31 (4.67)	12.75 (169.87)	13.68 (197.47)	1.11 (0.27)	2.60 (7.33)	9.52 (96.40)	9.91 (104)
T_7 (Daincha–rice)	1 (0)	5.39 (29.33)	8.93 (83.07)	10.44 (112.40)	1 (0)	1.23 (0.53)	5.74 (34)	5.80 (34.53)
SEm	1.26	1.46	2.40	2.74	0.41	1.16	1.59	1.67
CD (p = 0.05)	NS	4.49	NS	NS	NS	NS	NS	NS

Figures in parenthesis are the original values Values are $\sqrt{x+1}$ transformed Control is fallow

4.2.1.4. Relative weed density (per cent) (Table 28)

4.2.1.4.1. Relative weed density (per cent) of grass (Table 28)

The relative density of grasses at 40 days after transplanting was found to be significantly influenced by the treatments. The relative density per cent of grasses was significantly higher (8.65%) in T_6 (Cowpea–rice). Treatments T_2 (Sweet potato–rice), T_4 (Sesamum–rice), T_5 (Amaranthus– rice) and T_7 (Daincha–rice) recorded nil values. Treatment T_6 (Cowpea– rice) was significantly differ from all others except T_1 (Control–rice).

At harvest treatment T_1 (Control–rice) recorded significantly higher (8.66%) relative density per cent of grasses which was on par with T_3 (Pumpkin–rice) and all other treatments were recorded nil values.

4.2.1.4.2. Relative weed density (per cent) of sedge (Table 28)

The relative weed density per cent of sedge was varied significantly at 40 DAT. Among the different treatment T_5 (Amaranthus–rice) recorded significantly higher (28.28%) relative density of sedges and it was lower in T_6 (Cowpea–rice) (5.18%). All the treatments were on par except T_6 (Cowpea–rice).

At harvest relative weed density per cent of sedge was not varied significantly by the treatments.

4.2.1.4.3. Relative weed density (per cent) of broad-leaved weeds (Table 28)

The relative weed density (per cent) of broad- leaved weed was not significantly varied by the treatments both at 40 DAT and at harvest.

4.2.1.5. Relative dry weight (per cent) (Table 29)

4.2.1.5.1. Relative dry weight (per cent) of grass weeds (Table 29)

Treatments had no significant effect on the relative dry weight (per cent) of grass weeds both at 40 DAT and at harvest.

Table 28. Effect of summer crops on relative density (per cent) of weeds of the succeeding rice crop

Treatments	40 Days after transplanting			At harvest		
	Grass	Sedge	Broad- leaved weed	Grass	Sedge	Broad- leaved weed
T_1 (Control–rice)	9.86 (4.42)	26.60 (20.07)	60.39 (75.52)	8.66 (3.38)	29.91 (24.97)	57.82 (71.65)
T_2 (Sweet potato–rice)	0.71 (0.00)	31.30 (28.26)	58.66 (71.74)	0.71 (0.00)	26.31 (22.52)	63.66 (77.48)
T_3 (Pumpkin–rice)	4.69 (1.05)	25.87 (19.59)	63.38 (79.36)	7.31 (2.42)	31.36 (28.43)	56.84 (69.15)
T_4 (Sesamum–rice)	0.71 (0.00)	30.72 (26.42)	59.24 (73.58)	0.71 (0.00)	25.42 (19.02)	64.54 (80.98)
T_5 (Amaranthus–rice)	0.71 (0.00)	32.08 (28.28)	57.89 (71.72)	0.71 (0.00)	13.89 (6.15)	76.07 (93.85)
T_6 (Cowpea–rice)	16.56 (8.65)	10.24 (5.18)	68.90 (86.17)	0.71 (0.00)	19.15 (11.20)	70.82 (88.80)
T_7 (Daincha–rice)	0.71 (0.00)	28.74 (23.30)	61.23 (76.70)	0.71 (0.00)	14.13 (8.96)	75.85 (91.04)
SEm	2.27	4.32	4.12	2.25	5.48	5.30
CD (p = 0.05)	7.00	13.32	NS	6.93	NS	NS

Figures in parenthesis are original values   Values are angular transformed   Control is fallow

Table 29. Effect of summer crops on relative dry weight (per cent) of weeds of the succeeding rice crop

Treatments	40 Days after transplanting			At harvest		
	Grass	Sedge	Broad- leaved weed	Grass	Sedge	Broad- leaved weed
T_1 (Control–rice)	11.77 (6.23)	34.89 (33.00)	51.39 (60.78)	5.41 (2.61)	26.05 (19.49)	62.27 (77.90)
T_2 (Sweet potato–rice)	0.71 (0.00)	38.43 (39.06)	51.54 (60.94)	0.71 (0.00)	25.53 (23.00)	64.43 (77.00)
T_3 (Pumpkin–rice)	8.80 (6.60)	20.14 (13.49)	65.91 (79.91)	3.06 (0.85)	21.86 (17.11)	66.93 (82.04)
T_4 (Sesamum–rice)	2.47 (0.55)	33.69 (30.82)	55.93 (68.63)	0.71 (0.00)	31.44 (27.48)	58.53 (72.52)
T_5 (Amaranthus–rice)	0.71 (0.00)	28.05 (22.88)	61.91 (77.12)	0.71 (0.00)	19.55 (12.95)	70.42 (87.05)
T_6 (Cowpea–rice)	13.45 (8.26)	10.10 (3.96)	69.76 (87.77)	0.71 (2.80)	14.22 (7.26)	75.02 (92.03)
T_7 (Daincha–rice)	0.71 (0.00)	31.27 (27.39)	58.70 (72.61)	0.71 (0.00)	6.93 (2.37)	83.05 (97.63)
SEm	5.11	4.26	5.49	2.76	6.44	6.42
CD ($p = 0.05$)	NS	13.13	NS	NS	NS	NS

Figures in parenthesis are original values Values are angular transformed Control is fallow

4.2.1.5.2. Relative dry weight (per cent) of sedge weeds (Table 29)

The treatments significantly influenced the relative dry weight (per cent) of sedge weeds at 40 DAT but not at harvest.

Treatment T_2 (Sweet potato–rice) recorded significantly higher (39.06%) relative dry weight per cent and was on par with all other treatments except T_3 (Pumpkin–rice) and T_6 (Cowpea–rice). The treatment T_6 (Cowpea– rice) had significantly lower relative dry weight per cent.

4.2.1.5.3. Relative dry weight (per cent) of broad- leaved weeds (Table 29)

The treatments did not vary significantly on the relative dry weight (per cent) of broad- leaved weeds both at 40 DAT and at harvest. However broad- leaved weeds constituted higher values of relative dry weight (per cent) of weeds.

4.2.1.6. Summed dominance ratio (per cent) (Table 30)

4.2.1.6.1. Summed dominance ratio per cent of grasses (Table 30)

The summed dominance ratio (per cent) of grasses at 40 days after transplanting was found to significantly vary with treatments, but the values were of lesser magnitude.

Among the different treatments T_6 (Cowpea–rice) (8.46%) recorded highest summed dominance ratio per cent for grasses followed by T_1 (Fallow–rice) (5.32). The treatments T_2 (Sweet potato–rice), T_5 (Amaranthus–rice) and T_7 (Daincha–rice) recorded absolutely nil values. Treatment T_6 (Cowpea–rice) was on par with T_1 (Control–rice) and T_3 (Pumpkin– rice).

However at harvest the treatments exerted no significant effect on the summed dominance ratio.

Table 30. Effect of summer crops on summed dominance ratio (per cent) of weeds of the succeeding rice crop

Treatments	40 Days after transplanting			At harvest		
	Grass	Sedge	Broad- leaved weed	Grass	Sedge	Broad- leaved weed
T_1 (Control–rice)	10.85 (5.32)	30.91 (26.53)	55.79 (68.15)	8.03 (3.00)	28.10 (22.23)	59.86 (74.77)
T_2 (Sweet potato–rice)	0.71 (0.00)	35.00 (33.66)	54.97 (66.34)	0.71 (0.00)	26.02 (22.76)	63.94 (77.24)
T_3 (Pumpkin–rice)	8.28 (3.83)	23.38 (16.54)	64.16 (79.64)	5.97 (1.63)	27.35 (22.77)	61.20 (75.60)
T_4 (Sesamum–rice)	1.74 (0.28)	32.32 (28.62)	57.47 (71.10)	0.71 (0.00)	28.56 (23.25)	61.40 (76.75)
T_5 (Amaranthus–rice)	0.71 (0.00)	30.26 (25.58)	59.71 (74.42)	0.71 (0.00)	16.97 (9.55)	72.99 (90.45)
T_6 (Cowpea–rice)	16.81 (8.46)	11.07 (4.57)	68.84 (86.97)	1.97 (0.35)	17.64 (9.23)	71.95 (90.42)
T_7 (Daincha–rice)	0.71 (0.00)	30.10 (25.35)	59.87 (74.65)	0.71 (0.00)	11.07 (5.66)	78.90 (94.34)
SEm	2.80	3.74	4.04	2.20	5.33	5.18
CD ($p = 0.05$)	8.64	11.54	NS	NS	NS	NS

Figures in parenthesis are original values Values are angular transformed Control is fallow

4.2.1.6.2. Summed dominance ratio per cent of sedges (Table 30)

Significantly higher value of summed dominance ratio per cent of sedges was observed in T_2 (Sweet potato–rice) (33.66%) at 40 DAT and it was on par with all other treatments except T_6 (Cowpea– rice) which recorded significantly lower values compared to all other treatments. The summed dominance ratio per cent did not significantly vary between treatments at harvest stage.

4.2.1.6.3. Summed dominance ratio per cent of broad- leaved weeds (Table 30)

The treatment did not exert any significant effect on the summed dominance ratio per cent values of broad- leaved weeds either at 40 DAT or at harvest stage. However they recorded highest summed dominance ratio per cent value of weeds.

4.2.2. Studies on rice

4.2.2.1. Studies on growth attributes

4.2.2.1.1. Plant height (Table 31)

The results on the plant height at different stages of crop growth *viz.* maximum tillering and harvest are presented in Table 31.

Effect of different summer crops on the height of the succeeding transplanted rice crop was found to be not significant at maximum tillering stage where as at the harvesting stage it was found to be significant. The maximum plant height (120.47 cm) was recorded by the treatment T_5 (Amaranthus–rice) which is statistically on par with all other treatments except T_1 (Fallow–rice).

Table 31. Effect of summer crops on growth attributes of succeeding rice

Treatments	Plant height (cm)		Number of tillers hill^{-1} at MTS	Days to 50% flowering	SPAD reading		LAI at flowering stage
	MTS	Harvest			MTS	Flowering	
T_1 (Control–rice)	59.20	102.80	8.00	87	29.12	37.23	3.12
T_2 (Sweet potato–rice)	63.80	112.43	9.00	86	33.10	38.80	4.35
T_3 (Pumpkin–rice)	62.87	111.47	8.33	87	35.68	38.32	3.62
T_4 (Sesamum–rice)	61.12	113.47	8.33	87	35.72	38.16	3.20
T_5 (Amaranthus–rice)	65.70	120.47	8.67	88	33.99	38.79	4.04
T_6 (Cowpea–rice)	64.73	113.40	9.00	86	32.58	38.34	3.90
T_7 (Daincha– rice)	63.87	117.40	9.33	85	38.65	39.11	4.21
SEm	2.86	4.53	0.93	2.19	2	1.07	0.81
CD (p = 0.05)	NS	9.86	NS	NS	4.37	NS	NS

MTS - Maximum Tillering Stage LAI–Leaf Area Index

4.2.2.1.2. Number of tillers hill $^{-1}$ (Table 31)

The results summarized in Table 31 revealed a non-significant effect on number of tillers hill^{-1} at maximum tillering stage. However, T_7 (Daincha–rice) was found to record numerically more number of tillers hill^{-1} (9.33 tillers hill^{-1}) and T_1 (Control–rice) showed lower value (8 tillers hill^{-1}).

4.2.2.1.3. Days to 50 per cent flowering (Table 31)

The effect of previous seasons previous season summer crops on the days to 50 per cent flowering of the succeeding transplanted rice was found to be not significant.

4.2.2.1.4. SPAD readings (Table 31)

Effect of different summer crops on the SPAD values of the succeeding transplanted rice crop was found to be significant at maximum tillering stage, where as at the harvesting stage it was found to be non significant.

Treatment T_7 (Daincha–rice) recorded significantly higher SPAD value (38.65) at maximum tillering stage, which was statistically on par with T_3 (Pumpkin– rice) and T_4 (Sesamum–rice). The lowest SPAD value was recorded by T_1 (Fallow–rice) (29.12) which was inferior to all other treatments except T_2 (Sweet potato–rice) and T_6 (Cowpea–rice).

4.2.2.1.5. Leaf Area Index (LAI) at flowering (Table 31)

The influence of summer crops on the leaf area index of the virippu rice crop was found to be non significant.

4.2.3. Studies on yield attributes of rice (Table 32)

4.2.3.1. Panicles hill $^{-1}$ (Table 32)

Effect of different summer crops on panicles hill^{-1} of the succeeding rice crop was found to be non significant. Among the different treatments, T_2 (Sweet potato–rice) recorded numerically higher number of panicles (8.67) hill^{-1} compared to others.

4.2.3.2. Mean panicle weight (Table 32)

The influence of different preceding summer crops on the mean panicle weight of the succeeding transplanted rice was observed to be not significant during virippu season. However numerically higher mean panicle weight was noted in T_3 (Pumpkin– rice) and lowest mean panicle weight was recorded in T_1 (Control–rice).

4.2.3.3. Mean no. of grains panicles^{-1} (Table 32)

The data presented in Table 32 revealed that the influence of previous season's summer crops failed to have a significant impact on the mean number of grains per panicle of the succeeding rice crop. However all the treatments were observed to be better than the Fallow (control)–rice with regard to the mean number of grains per panicle.

4.2.3.4. Thousand grain weight (Table 32)

The effect of previous season's summer crops on thousand grain weight of rice was found to be non-significant. Treatment T_4 (Sesamum–rice) (30.01g) was found to record numerically better values than other treatments.

4.2.3.5. Grain yield (Table 32)

The effect of previous season's summer crops on grain yield of succeeding rice crop was not significant.

Table 32. Effect of summer crops on the yield attributes, grain and straw yield of succeeding rice

Treatments	Number of panicles hill^{-1}	Mean panicle weight (g)	Mean no. of grains panicles^{-1}	1000 Grain weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest Index (HI) (%)
T_1 (Control–rice)	7.33	1.63	40.67	28.76	2858.89	3708.95	44
T_2 (Sweet potato–rice)	8.67	2.24	60.33	28.11	4202.94	5395.58	44
T_3 (Pumpkin–rice)	7.33	2.25	57.00	29.41	3690.00	4573.97	45
T_4 (Sesamum–rice)	8.00	1.93	46.67	30.01	3617.38	4698.14	44
T_5 (Amaranthus–rice)	7.33	2.11	60.67	28.03	3749.41	5054.81	43
T_6 (Cowpea–rice)	8.33	2.01	53.00	29.78	3783.51	4889.72	44
T_7 (Daincha–rice)	8.33	2.12	56.67	29.13	3846.49	4746.16	45
SEm	0.85	0.24	7.28	0.95	375.50	499.06	0.01
CD (p = 0.05)	NS	NS	NS	NS	NS	NS	NS

The grain yield was numerically higher (4202.94 kg ha^{-1}) for T_2 (Sweet potato-rice) and T_1 (Control-rice) (2858.89 kg ha^{-1}) recorded the lowest yield.

4.2.3.6. Straw yield (Table 32)

The previous season summer crops had no significant influence on the straw yield of the succeeding transplanted rice.

Treatment T_2 (Sweet potato- rice) gave higher straw yield (5395.58 kg ha^{-1}) compared to the other treatments and T_1 (Fallow - rice) recorded the lowest (3708.95 kg ha^{-1}) straw yield.

4.2.3.7. Harvest Index (Table 32)

The influence of summer crops on harvest index of the succeeding rice crop was found to be non significant and the mean values covered around 44 per cent.

4.2.4. Nutrient uptake

4.2.4.1. Nitrogen uptake (Table 33)

The previous season's summer crops exerted no significant effect on the nitrogen uptake by rice grains, straw and the total plant N uptake.

However the nitrogen uptake by the grains was numerically higher in T_2 (Sweet potato– rice) with 46.23 kg ha^{-1} followed by T_7 (Daincha–rice). The lowest nitrogen uptake (31.45 kg ha^{-1}) by the grain was recorded in T1 (Control–rice).

The total nitrogen uptake by the crop was highest in T_2 (Sweet potato– rice) with 75.37 kg ha^{-1} followed by T_5 (Amaranthus–rice) and the lowest total nitrogen uptake by the crop (51.48 kg ha^{-1}) was recorded in T_1 (Control–rice).

Table 33. Effect of summer crops on the nitrogen, phosphorus and potassium uptake by the succeeding rice crop

Treatment	N uptake (kg ha^{-1})			P uptake (kg ha^{-1})			K uptake (kg ha^{-1})		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T_1 (Control–rice)	31.45	20.03	51.48	6.29	3.15	9.44	10.01	51.18	61.19
T_2 (Sweet potato–rice)	46.23	29.14	75.37	9.25	4.59	13.83	14.71	74.46	89.17
T_3 (Pumpkin–rice)	40.59	24.70	65.29	8.12	3.89	12.01	12.92	63.12	76.04
T_4 (Sesamum–rice)	39.79	25.37	65.16	7.96	3.99	11.95	12.66	64.83	77.50
T_5 (Amaranthus–rice)	41.24	27.30	68.54	8.25	4.30	12.55	13.12	69.76	82.88
T_6 (Cowpea–rice)	41.62	26.40	68.02	8.32	4.16	12.48	13.24	67.48	80.72
T_7 (Daincha–rice)	42.31	25.63	67.94	8.46	4.03	12.50	13.46	65.50	78.96
SEm	4.13	2.69	6.55	0.83	0.42	1.20	1.31	6.89	8.02
CD ($p = 0.05$)	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.2.4.2. Phosphorus uptake (Table 33)

Effect of previous season's upland crops on the phosphorus uptake by the grain, straw and total uptake by the rice was found to be non significant.

4.2.4.3. Potassium uptake (Table 33)

The different summer crops exerted no significant effect on the uptake of potassium by grain, straw or total K uptake by rice.

The uptake of potassium by straw was markedly higher than the uptake by the grain. Numerically higher uptake of potassium by straw (74.46 kg ha^{-1}) and also the total uptake was recorded in T_2 (Sweet potato– rice). The lowest values were recorded in T_1 (Fallow–rice).

4.2.4.4. Total uptake of nitrogen, phosphorus and potassium (Table 34)

The effect of previous season crops and fallow treatment on the grand total uptake of nitrogen, phosphorus and potassium by the rice grain, straw and total plant uptake were found to be non significant during the virippu season. Among the different treatments the T_2 (Sweet potato–rice) had numerically higher grain, straw and total uptake.

4.2.4.5. Uptake of calcium (Table 35)

The uptake of calcium by rice grain, straw and total uptake by the plant during virippu season was found to be non significant.

However numerically higher grain uptake (2.27 kg ha^{-1}), straw uptake (22.66 kg ha^{-1}) and total uptake was noted in T_2 (Sweet potato–rice).

4.2.4.6. Uptake of magnesium (Table 35)

The magnesium uptake by the rice grain, straw and total uptake during virippu rice crop was not significantly affected by the preceding summer crops.

Table 34. Effect of summer crops on the total nitrogen, phosphorus and potassium uptake by the succeeding rice crop (kg ha^{-1})

Treatment	Grain	Straw	Total
T_1 (Control – rice)	47.74	74.36	122.11
T_2 (Sweet potato – rice)	70.19	108.18	178.37
T_3 (Pumpkin – rice)	61.62	91.71	153.33
T_4 (Sesamum – rice)	60.41	94.20	154.61
T_5 (Amaranthus – rice)	62.62	101.35	163.96
T_6 (Cowpea – rice)	63.18	98.04	161.22
T_7 (Daincha – rice)	64.24	95.16	159.40
SEm	6.27	10.06	15.63
CD (p = 0.05)	NS	NS	NS

However numerically higher values for magnesium uptake by rice grain, straw and total plant uptake was noted in T_2 (Sweet potato–rice).

4.2.4.7. Uptake of iron (Table 36)

The iron uptake by the grain, straw and total uptake during virippu rice crop was not significantly affected by the preceding summer crops.

However numerically higher uptake values by the grain, straw and total uptake were noted in T_2 (Sweet potato–rice).

4.2.4.8. Uptake of zinc (Table 36)

Uptake of zinc by the virippu rice crop (grain, straw and total uptake) was not significantly influenced by the preceding summer crops.

However numerically higher values were noted in T_2 (Sweet potato– rice) for grain, straw and total crop uptake of zinc. Where as it was lowest in T_1 (Control–rice).

Table 35. Effect of summer crops on the calcium and magnesium uptake by the succeeding rice crop (kg ha^{-1})

Treatment	Ca uptake (kg ha^{-1})			Mg uptake (kg ha^{-1})		
	Grain	Straw	Total	Grain	Straw	Total
T_1 (Control–rice)	1.54	15.58	17.12	4.29	10.76	15.04
T_2 (Sweet potato–rice)	2.27	22.66	24.93	6.30	15.65	21.95
T_3 (Pumpkin–rice)	1.99	19.21	21.20	5.54	13.26	18.80
T_4 (Sesamum–rice)	1.95	19.73	21.69	5.43	13.62	19.05
T_5 (Amaranthus–rice)	2.02	21.23	23.25	5.62	14.66	20.28
T_6 (Cowpea–rice)	2.04	20.54	22.58	5.68	14.18	19.86
T_7 (Daincha–rice)	2.08	19.93	22.01	5.77	13.76	19.53
SEm	0.20	2.09	2.27	0.56	3.22	1.94
CD (p = 0.05)	NS	NS	NS	NS	NS	NS

Table 36. Effect of summer crops on iron, zinc and copper uptake by the succeeding rice crop (kg ha^{-1})

Treatment	Fe uptake (kg ha^{-1})			Zn uptake (kg ha^{-1})			Cu uptake (kg ha^{-1})		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T_1 (Control–rice)	0.132	0.890	1.022	0.043	0.130	0.173	0.016	0.012	0.028
T_2 (Sweet potato–rice)	0.193	1.295	1.488	0.063	0.189	0.252	0.024	0.017	0.041
T_3 (Pumpkin–rice)	0.170	1.098	1.267	0.055	0.160	0.215	0.021	0.015	0.036
T_4 (Sesamum–rice)	0.166	1.128	1.294	0.054	0.164	0.219	0.021	0.015	0.036
T_5 (Amaranthus–rice)	0.172	1.213	1.386	0.056	0.177	0.233	0.021	0.016	0.038
T_6 (Cowpea–rice)	0.174	1.174	1.348	0.057	0.171	0.228	0.022	0.016	0.037
T_7 (Daincha–rice)	0.177	1.139	1.316	0.058	0.166	0.224	0.022	0.015	0.037
SEm	0.017	0.120	0.135	0.006	0.017	0.022	0.002	0.002	0.004
CD (p = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.2.4.9. Uptake of copper (Table 36)

The copper uptake by the grain, straw and total uptake during virippu rice crop was not significantly affected by the preceding summer crops. However higher values for grain, straw and total uptake was noted in T_2 (Sweet potato–rice).

4.2.4.10. Nutrient removal by weeds (Table 37)

The nutrient removal of nitrogen, phosphorus, potassium and total removal by the weeds at harvest time of the virippu rice were found to be not significantly influenced by the previous season's summer crops.

Table 37. Nutrient removal by weeds at harvest (kg ha^{-1}) of the virippu rice crop

Treatment	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Total (kg ha^{-1})
T_1 (Control – rice)	2.17	0.32	2.38	4.87
T_2 (Sweet potato – rice)	2.27	0.34	2.50	5.10
T_3 (Pumpkin – rice)	1.22	0.18	1.34	2.73
T_4 (Sesamum – rice)	1.49	0.22	1.64	3.35
T_5 (Amaranthus – rice)	2.81	0.42	3.09	6.32
T_6 (Cowpea – rice)	1.48	0.22	1.62	3.32
T_7 (Daincha – rice)	0.49	0.07	0.54	1.10
SEm	0.71	0.11	0.78	1.59
CD (p = 0.05)	NS	NS	NS	NS

4.2.5. Physico–chemical characters of the soil (Table 38)

4.2.5.1. Physical characters

4.2.5.1.1. Bulk density (Table 38)

Summer cropping and the incorporation of residue had no significant effect on the bulk density of the soil in the experimental site.

4.2.5.1.2. Porosity (Table 38)

The effect of previous season's summer crop and incorporation of its residues had no significant effect on the porosity of the soil at the time of rice cropping.

4.2.5.2. Chemical characters

4.2.5.2.1. Soil reaction (pH) (Table 38)

The influence of summer cropping was significant with regard to the soil reaction (pH). T3 (Pumpkin–rice) recorded significantly higher pH values (5.87) followed by T_5 (Amaranthus) (5.81) and T_7 (Daincha–rice) recorded low pH value (5.20). Treatments T_1 (Control–rice), T_2 (Sweet potato–rice), T_4 (Sesamum–rice), T_5 (Amaranthus–rice) and T_6 (Cowpea– rice) were on par.

4.2.5.2.2. Electrical conductivity (Table 38)

The influence of summer cropping on electric conductivity of pre rice soil was found to be not significant.

4.2.5.2.3. Organic carbon (Table 39)

Organic carbon status of the soil after the harvest of the virippu crop which are preceded by the summer crops and control were found to be non significant.

Table 38. Effect of summer cropping and residue incorporation on the physico chemical properties of the soil

Treatments	Bulk density (g cc^{-1})	Particle density (g cc^{-1})	Porosity (%)	pH	Electric conductivity (µsm^{-1})
T_1 (Control–rice)	1.40	2.26	37.91	5.53	145.19
T_2 (Sweet potato–rice)	1.37	2.26	39.38	5.50	138.20
T_3 (Pumpkin–rice)	1.39	2.26	38.64	5.87	125.67
T_4 (Sesamum–rice)	1.39	2.26	38.50	5.61	158.27
T_5 (Amaranthus–rice)	1.34	2.26	40.56	5.81	184.13
T_6 (Cowpea–rice)	1.36	2.26	39.82	5.61	163.85
T_7 (Daincha–rice)	1.40	2.26	37.91	5.20	158.03
SEm	0.05	-	2.09	0.16	29.03
CD (p = 0.05)	NS	-	NS	0.34	NS

Table 39. Carry over effect of summer crops on the organic carbon and available macro and micro nutrients content of the post harvest soil

Treatments	Organic carbon (%)	Nitrogen (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	Calcium (mg kg^{-1})	Magnesium (mg kg^{-1})	Iron (kg ha^{-1})	Zinc (kg ha^{-1})	Copper (kg ha^{-1})
T_1 (Control–rice)	1.11	284.33	17.52	164.96	650.17	149.40	138.88	2.93	8.15
T_2 (Sweet potato–rice)	1.06	267.61	23.15	196.59	650.17	107.90	135.88	2.10	8.08
T_3 (Pumpkin–rice)	0.80	261.33	30.15	225.55	733.17	41.50	122.33	2.47	6.91
T_4 (Sesamum–rice)	0.86	244.61	19.52	150.62	567.17	141.10	157.64	2.47	7.72
T_5 (Amaranthus–rice)	0.95	263.42	57.68	256.45	691.67	166.00	179.95	3.88	7.05
T_6 (Cowpea–rice)	0.92	263.42	28.90	151.52	581.00	157.70	158.92	3.73	7.05
T_7 (Daincha–rice)	0.98	290.60	24.27	145.86	664.00	116.20	192.88	7.19	8.44
SEm	0.152	18.787	3.574	8.35	54.92	56.18	21.60	0.72	0.70
CD (p = 0.05)	NS	NS	7.79	18.19	NS	NS	NS	1.57	NS

4.2.5.2.4. Soil available macro nutrient content of post harvest soil

4.2.5.2.4.1. Available nitrogen (Table 39)

The previous season's summer crops were failed to influence the available nitrogen status of the post rice soil. However, Among the different treatment combinations, T_7 (Daincha–rice) resulted in more available nitrogen (290.60 kg ha^{-1}) andT4 (Sesamum–rice) recorded lowest available nitrogen (244.61 kg ha^{-1}).

4.2.5.2.4.2. Available P_2O_5 (Table 39)

The available P_2O_5 content in the soil was significantly influenced by the previous season's summer crops.

The highest available P_2O_5 content (57.68 kgha^{-1}) was recorded in T_5 (Amaranthus–rice) which was statistically higher than all other treatments. Significantly lower available P_2O_5 content was recorded in T_1 (Control–rice) (17.52 kg ha^{-1}) which is statistically on par with T_2 (Sweet potato–rice), T_4 (Sesamum–rice) and T_7 (Daincha–rice).

4.2.5.2.4.3. Available K_2O (Table 39)

The results revealed a significant effect on the available potassium status of the soil. However, T_5 (Amaranthus–rice) recorded significantly higher available potassium (256.45 kg ha^{-1}) and it was lowest in T_7 (Daincha–rice) (145.86 kg ha^{-1}). Treatment T_5 (Amaranthus–rice) was significantly differ from all others.

4.2.5.2.5. Exchangeable secondary nutrient content of post harvest soil

4.2.5.2.5.1. Exchangeable calcium (Table 39)

Summer cropping of upland crops did not significantly influence the soil exchangeable calcium.

4.2.5.2.5.2. Exchangeable magnesium (Table 39)

Summer crops failed to influence the exchangeable magnesium content of post harvest soil.

4.2.5.2.6. Soil available micro nutrient content of post harvest soil

4.2.5.2.6.1. Available iron (Table 39)

Available iron status of the soil after the harvest of the virippu crop which are preceded by the summer crops and fallow (control) were found not to vary significantly.

4.2.5.2.6.2. Available zinc (Table 39)

The effect of preceding crops on the available zinc content was significant. Among the different treatments T_7 (Daincha–rice) recorded significantly higher available zinc (7.19 kg ha^{-1}) followed by T_5 (Amaranthus–rice) (3.88 kg ha^{-1}). The lowest available zinc was recorded in T_2 (Sweet potato–rice) (2.10 kg ha^{-1}) and it was on par with treatment T_1 (Control–rice), T_3 (Pumpkin–rice) and T_4 (Sesamum–rice).

4.2.5.2.6.3. Available copper (Table 39)

Summer cropping and fallowing (control) failed to influence the available copper content significantly.

4.2.6 Nutrient balance studies

4.2.6.1 Nitrogen balance (Table 40)

The post harvest soil recorded a negative balance of soil available nitrogen in all treatments.

Table 40. Balance sheet of available nitrogen in the soil as influenced by previous season's summer crops (kg ha^{-1})

Treatments	Addition of Nitrogen (kg ha^{-1})	Removal of nitrogen (kg ha^{-1})			Actual balance of N (kg ha^{-1})	Net loss or gain (kg ha^{-1})
		By weeds	By plant	Total		
T_1 (Control–rice)	405.97	2.17	51.48	53.65	284.33	-67.99
T_2 (Sweet potato– rice)	525.62	2.27	75.37	77.64	267.61	-180.37
T_3 (Pumpkin– rice)	398.37	1.22	65.29	66.51	261.33	-70.53
T_4 (Sesamum– rice)	400.47	1.49	65.16	66.65	244.61	-89.21
T_5 (Amaranthus– rice)	414.49	2.81	68.54	71.35	263.42	-79.72
T_6 (Cowpea– rice)	454.31	1.48	68.02	69.5	263.42	-121.39
T_7 (Daincha– rice)	502.85	0.49	67.94	68.43	290.6	-143.82

Addition of Nitrogen (kg ha^{-1})

Sources	T_1 (Control– rice)	T_2 (Sweet potato– rice)	T_3 (Pumpkin– rice)	T_4 (Sesamum– rice)	T_5 (Amaranthus – rice)	T_6 (Cowpea– rice)	T_7 (Daincha– rice)
Soil contribution	276.60	301.06	267.60	275.96	292.70	292.70	305.24
Crop residues/ weeds	9.37	104.56	10.77	4.51	1.79	41.61	77.61
Manures	30.00	30.00	30.00	30.00	30.00	30.00	30.00
Fertilizers	90.00	90.00	90.00	90.00	90.00	90.00	90.00
Total	405.97	525.62	398.37	400.47	414.49	454.31	502.85

The highest nutrient status of soil available nitrogen of 525.62 kg ha^{-1} was noted in the pre–cropped rice soil in T_2 (Sweet potato–rice) followed by T_7 (Daincha–rice) with 502.85 kg ha^{-1}. The least value was observed in T_3 (Pumpkin–rice). The highest depletion by the weeds and crop was noted in T_2 (Sweet potato–rice) with 77.64 kg ha^{-1} followed by T_5 (Amaranthus–rice). The post rice soil had comparatively higher nitrogen status in T_7 (Daincha–rice). The net loss of nitrogen was highest in T_2 (Sweet potato–rice) followed by T_7 (Daincha–rice). The least was noted in T_1 (Control–rice).

4.2.6.2 Phosphorus balance (Table 41)

The post harvest soil recorded a negative balance of soil available phosphorus in all treatments.

The highest nutrient status of soil available phosphorus of 218.88 kg ha^{-1} was noted in the pre–cropped rice soil in T_5 (Amaranthus–rice) followed by T_3 (Pumpkin–rice) with 197.87 kg ha^{-1}. The least value was observed in T_1 (Control–rice). The highest depletion by the weeds and crop was noted in T_2 (Sweet potato–rice) with 32.45 kg ha^{-1} followed by T_5 (Amaranthus–rice). The post rice soil had comparatively higher phosphorus status in T_5 (Amaranthus–rice). The net loss of phosphorus was highest in T_3 (Pumpkin–rice) followed by T_2 (Sweet potato–rice). The least was noted in T_1 (Control–rice).

4.2.6.3 Potassium balance (Table 42)

The post harvest soil recorded a negative balance of soil available potassium in all treatments.

The highest nutrient status of soil available potassium of 442.21 kg ha^{-1} was noted in the pre–cropped rice soil in T_3 (Pumpkin–rice) followed by T_2 (Sweet potato–rice) with 400.18 kg ha^{-1}. The least value was observed in T_4 (Sesamum–rice).

Table 41. Balance sheet of available phosphorus in the soil as influenced by previous season summer crops (kg ha^{-1})

Treatments	Addition of phosphorus (kg ha^{-1})	Removal of phosphorus (kg ha^{-1})			Actual balance of P_2O_5 (kg ha^{-1})	Net loss or gain (kg ha^{-1})
		By weeds	By plant	Total		
T_1 (Control–rice)	87.58	0.73	21.62	22.35	17.52	-47.71
T_2 (Sweet potato– rice)	191.83	0.78	31.67	32.45	23.15	-136.23
T_3 (Pumpkin– rice)	197.87	0.41	27.50	27.92	30.15	-139.80
T_4 (Sesamum– rice)	108.14	0.50	27.37	27.87	19.52	-60.76
T_5 (Amaranthus– rice)	218.88	0.96	28.74	29.70	57.68	-131.49
T_6 (Cowpea– rice)	140.25	0.50	28.58	29.08	28.9	-82.27
T_7 (Daincha– rice)	136.70	0.16	28.63	28.79	24.27	-83.64

P removal by the weeds and plant were converted to P_2O_5

Addition of P_2O_5 (kg ha^{-1})

Sources	T_1 (Control– rice)	T_2 (Sweet potato– rice)	T_3 (Pumpkin– rice)	T_4 (Sesamum– rice)	T_5 (Amaranthus – rice)	T_6 (Cowpea– rice)	T_7 (Daincha– rice)
Soil contribution	16.90	42.65	118.82	39.11	150.78	42.36	38.76
Crop residues/weed	3.18	81.68	11.55	1.53	0.60	30.39	30.44
Manures	22.50	22.50	22.50	22.50	22.50	22.50	22.50
Fertilizers	45.00	45.00	45.00	45.00	45.00	45.00	45.00
Total	87.58	191.83	197.87	108.14	218.88	140.25	136.70

Table 42. Balance sheet of available potassium in the soil as influenced by previous season summer crops (kg ha^{-1})

Treatments	Addition of potassium (kg ha^{-1})	Removal of potassium (kg ha^{-1})			Actual balance of K_2O (kg ha^{-1})	Net loss or gain (kg ha^{-1})
		By weeds	By plant	Total		
T_1 (Control–rice)	293.84	2.86	73.43	76.28	164.96	-52.60
T_2 (Sweet potato– rice)	400.18	3.00	107.00	110.00	196.59	-93.58
T_3 (Pumpkin– rice)	442.21	1.61	91.25	92.86	225.55	-123.80
T_4 (Sesamum– rice)	291.65	1.97	93.00	94.97	150.62	-46.06
T_5 (Amaranthus– rice)	510.26	3.71	99.46	103.16	256.45	-150.65
T_6 (Cowpea– rice)	321.87	1.94	96.86	98.81	151.52	-71.55
T_7 (Daincha– rice)	295.41	0.65	94.75	95.40	145.86	-54.15

K removal by the weeds and plant were converted to K_2O

Addition of K_2O (kg ha^{-1})

Sources	T_1 (Control– rice)	T_2 (Sweet potato– rice)	T_3 (Pumpkin– rice)	T_4 (Sesamum– rice)	T_5 (Amaranthus – rice)	T_6 (Cowpea– rice)	T_7 (Daincha– rice)
Soil contribution	196.48	91.85	335.10	200.70	422.91	173.38	103.20
Crop residues	12.36	223.33	22.11	5.95	2.35	63.49	107.21
Manures	40.00	40.00	40.00	40.00	40.00	40.00	40.00
Fertilizers	45.00	45.00	45.00	45.00	45.00	45.00	45.00
Total	293.84	400.18	442.21	291.65	510.26	321.87	295.41

The highest depletion by the weeds and crop was noted in T_2 (Sweet potato–rice) with 110.00 kg ha^{-1} followed by T_5 (Amaranthus–rice). The post rice soil had comparatively higher potassium status in T_5 (Amaranthus–rice). The net loss of potassium was highest in T_5 (Amaranthus–rice) followed by T_3 (Pumpkin–rice). The least was noted in T_1 (Control–rice).

DISCUSSION

5. DISCUSSION

Six different upland crops were cropped in the rice fallows during the summer season of 2008 and performance evaluated with respect to crop yield and carry over effect on the succeeding rice crop. The results of the above experiment detailed in the previous chapter are discussed in this chapter.

5.1. SUMMER CROPS

5.1.1. Studies on weeds

5.1.1.1. Weed spectrum analysis

Weeds species belonging to seven families were found to occur in the various summer crops and in the control (Table 5). The four different predominant species under the grassy weeds were *Echinochloa colona* (L.) Link, *Digitaria ciliaris* (Retz. Koel), *Isachne miliacea* (Roth.) and *Digitaria sanguinalis* (L.) Scop. The dominant species under the sedges were *Cyperus iria* (L.), *Cyperus compressus* (L.) and *Fimbristylis milliacea* (L.) Vahl. The important broad- leaved weeds consisted of *Phyllanthus niruri* (L.), *Oldenlandia affinis* (Roemer & Schultes. DC.), *Eclipta alba* (L.), *Eclipta prostrata* (L.), *Ludwigia parviflora* (Roxb.) and *Cleome viscosa* (L.). The grass weeds were comprised of four species, the sedges of three species, the broad leaved weeds were more diverse and consisted of six species belonging to five families. Such divrse weed spectrum of different summer crops and the rice fallow (control) in sweet potato was reported (Porwal, 2002 and Nedunchezhiyan and Satapathy, 2002b), Sesamum (Kavimani et al., 2001; Yadav, 2004 and Ghosh and Ghosh 2006), cowpea (Mathew and Sreenivasan, 1998; Tripathi and Govindra Singh, 2001 and Le Kwong Hoe, 2007) and rice fallow (Kuk Yongin et al., 2002).

In T_7 (Daincha) cropped field grassses and sedge weeds were totally absent (Table 6). These results are in line with the findings of Gnanavel and Kathiresen (2002), Samui and Subhendu (2006) and Nalini et al. (2008).

5.1.1.2. Weed population

All the treatment recorded a significant effect on the grasses, sedges, broad leaved and total weed population both at 40 days after planting (40DAP) and at harvest (Table 6). At both the stages T_1 (Control) recorded significantly higher sedges, broad leaved and total weed population compared to the other treatments, where as the grass weeds population was significantly higher in T_1 (Control) at 40 DAP and in T_6 (Cowpea) at harvest. The main reason for the dominance of weed flora in T_1 (Control) were the uncropped condition that eliminated the weed suppression effect by the crops. And also the absence of any weed control practices in these fallow plots compared to the other cropped fields. Yamada et al. (2007) reported that fallowing resulted in higher abundance of weeds.

Among the different summer crops the population of grasses, sedges and total weed population was significantly higher in T_4 (Sesamum) at 40 DAP (Table 6). This may be due to the slower initial growth, lesser crop canopy, poor weed suppression effect higher light penetration through the crop canopy of sesamum. The above results are in line with the findings of Krishnaprabhu and Kalyansundarm (2008).

At harvest the grasses, sedges and total weed population were significantly higher in T_6 (Cowpea) compared to the other summer crops. This might be due to the least soil cover and the highest soil exposure as the crop was trailed over the pundal that provided minimum weed suppression by the crop.

The broad leaved weed population was significantly higher in T_7 (Daincha) both at 40 DAP and at harvest, where as the grass population was absolutely nil T_7 (Daincha) both at 40 DAP and at harvest (Table 6). This may be due to the fact that the daincha was raised with minimum preparatory tillage with abundant soil clods that might have retained rain water in the depression that prevents the germination of grass and sedge weeds. Also the thick crop canopy prevented later establishment of these weeds. Only a select few broad leaved weeds got established in the crop.

Sedge population was nil in T_2 (Sweet potato) and T_7 (Daincha) both at 40 DAP and at harvest but T_3 (Pumpkin) and T_6 (Cowpea) recorded absolutely nil sedge population only at 40 DAP. Treatment T_5 (Amaranthus) recorded absolutely nil broad leaved population. These might be due to the effective weed suppression by the crops. These results are in line with the findings on weed suppression by Harrison and Peterson (1991), Roy et al. (2007), Aldesanwa and Adigun (2008) in sweet potato Olsantan (2007) in pumpkin, Ngouajio and Mc Giffin (2004) in cow pea, Gnanavel and Kathiresan (2002) in Daincha.

5.1.1.3. Weed dry matter production (WDMP) (Fig. 5)

The treatments varied significantly in WDMP at 40 DAP (Table 7). At 40 DAP treatment T_1 (Control) recorded significantly higher grasses, sedges, broad leaved and total WDMP. At harvest sedges and broad leaved WDMP was highest in T_1 (Control), where as grasses and total WDMP was highest in T_6 (cowpea).

The whole dry matter production in the T_1 (Control) was solely of weeds hence it ranked first in WDMP at 40 DAP. However with extended

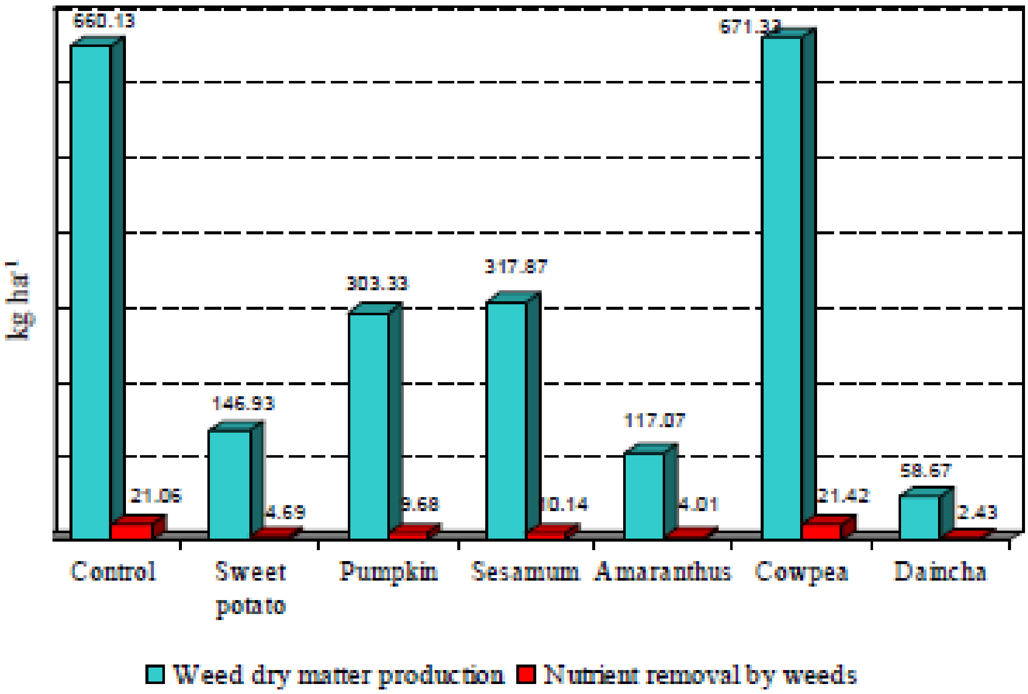

Fig. 5. Dry matter production and total nutrient removal by weeds at harvest in summer crops

period of growth, Lack of fresh nutrient supplement resulted the further increase in WDMP.

However in T_6 (Cowpea), since the crop was trailed on pandal the soil surface was totally left uncovered that facilitated the proliferation and growth of shade tolerant grasses that accounted for the highest grass WDMP and total WDMP in the treatments. These results are corroborated by the earlier reports of Nedunchezhiyan and Satapathy (2002) and Le Kwang hoe (2007).

5.1.1.4. Weed vegetation analysis

5.1.1.4.1. Relative density

The relative density of grasses, sedges, broad leaved weeds both at 40 DAT and at harvest were significantly influenced by the treatments (Table 8). Treatment T5 (Amaranthus) recorded the highest relative density of grasses both at 40 DAP and at harvest compared to other treatments. Since the weed population was dominated by the grasses which might have been facilitated by weed seed introduction through heavy application of farm yard manure. The lowest relative density of the grasses was recorded in T_1 (Control) both at 40 DAP and at harvest. Since the uncontrolled growth facilitated higher incidence of weeds of other groups as well and recorded highest relative density of sedges compared to other treatments both at 40 DAP and harvest.The relative density of the broad leaved weeds was highest in T_7 (Daincha) since broad leaved weeds solely associated for its total weed population.

5.1.1.4.2. Relative dry weight

The relative dry weight of the grasses was highest in pumpkin (T_3) at 40 DAP and Amaranthus (T_5) at harvest (Table 9). This was due to the fact that in T_3 (Pumpkin) and T_5 (Amaranthus) the grasses WDMP contributed to almost its entire total WDMP at the respective stages of observation.

The relative dry weight the sedges was highest in T_1 (Control) both at 40 DAP and at harvest because of the proportionately higher WDMP of sedges.

The relative dry weight of the broad leaved was highest in T_7 (Daincha) at 40 DAP and at harvest (Table 9). Since the entire WDMP was the contribution of broad leaved weeds.

5.1.1.4.3. Summed dominance ratio (SDR) (Fig. 6)

The summed dominance ratio of grasses was highest in T_3 (Pumpkin) at 40 DAP and T_5 (Amaranthus) at harvest (Table 10). This was due to the dominance of grass weeds in the total weed population and total WDMP in these treatments.

Treatment T_1 (Control) recorded significantly higher values for summed dominance ratio of sedges both at 40 DAP and at harvest (Table 10). Since it constitute proportionately higher fraction of total weed population and WDMP in this treatment.

The summed dominance ratio of broad leaved weed was highest in T_7 (Daincha), since both the entire weed population and total WDMP was contributed by broad leaved weeds.

5.1.2. Yield of summer crops

5.1.2.1. Economic yield (Fig. 7)

The summer crops grown in rice fallows differed significantly with respect to the economic yield. Among the different crops T_5 (Amaranthus)

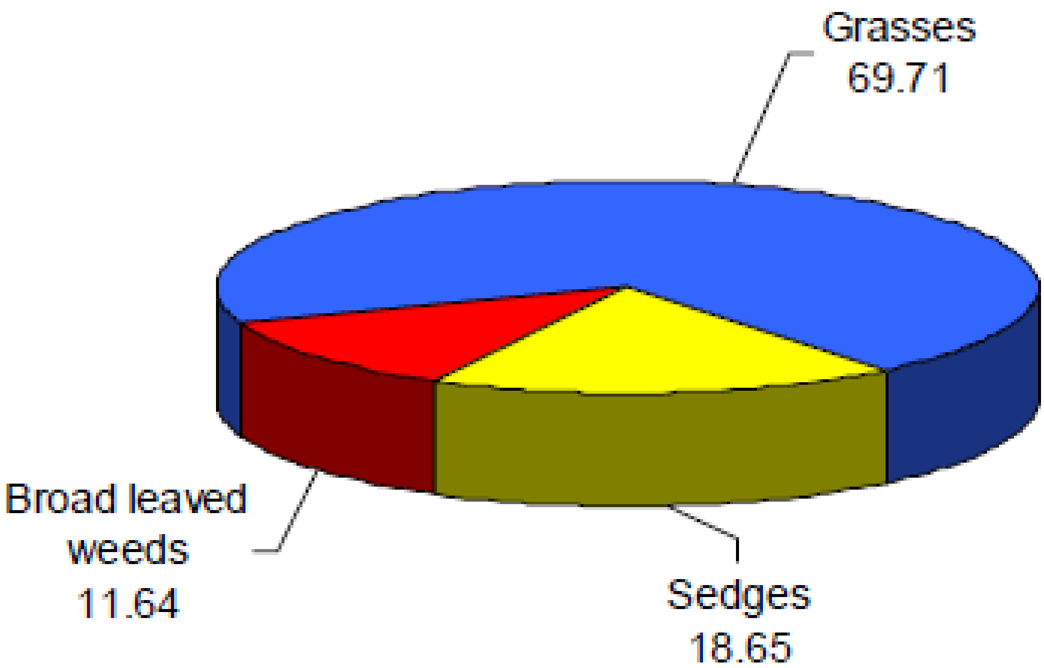

Fig. 6. Summed dominance ratio of weeds in cowpea

produced highest economic yield (33388 kg ha^{-1}) followed by T_2 (Sweet potato) with 21296 kg ha^{-1} and T_3 (Pumpkin) with 17014 kg ha^{-1} (Table 11). The lowest yield was recorded in T_4 (Sesamum). The highest yield in T_5 (Amaranthus) could attributed to the two sequential harvests made at the tender vegetative stage of the crop and its higher photosynthetic ability. The comparatively lower yields recorded in T_2 (Sweet potato) and T_3 (Pumpkin) due to the difference in the nature of the produce viz tuber and fruit respectively. The lowest yield in T_4 (Sesamum) was due to the inherent low yield potential of this high energy yielding oil seed crop. The above results are in conformity with the findings of Kumar et al. (1993), Niranjana (1998), Rajan (2000) and Pillai et al. (2007).

5.1.2.2. Total biological yield

Summer crops varied significantly in their total biological yield (Tanble 11). Treatment T_2 (Sweet potato) recorded significantly higher yield followed by T_5 (Amaranthus) and T_6 (Cowpea) which were on par, but with almost half of the yield of T_2 (Sweet potato). Significantly lower yield was recorded by T_4 (Sesamum) with only 17 per cent of the yield of T_2 (Sweet potato). The higher yield in T_2 (Sweet potato) can be attributed to the significantly higher quantity of vine yield, facilitated by the rapid spread of the crop as a full cover crop that enables higher source for photosynthesis and proportionately high sink in the tubers. The lowest yield recorded in T_4 (Sesamum) was due to comparatively lower inherent potential of sesamum crop for biological yield and lower sink compared to the source. These results are in line with the findings of Byju and Ray (2002) and Paul and Savithiri (2003).

5.1.2.3. Rice yield equivalent (Kg ha^{-1}) (Fig. 7)

The rice yield equivalent of the summer crops grown in rice fallows varied significantly. Among the different summer crops T_5 (Amaranthus)

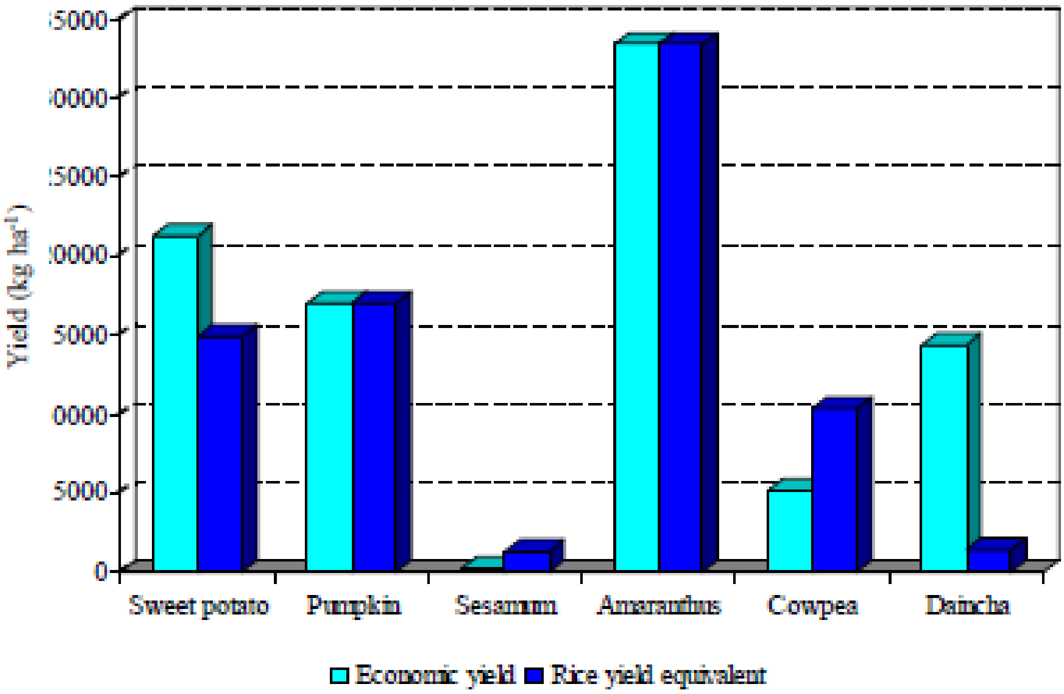

Fig. 7. Economic yield and rice yield equivalent of summer crops

produced significantly higher rice yield equivalent (Table 11) followed by T_3 (Pumpkin) and T_2 (Sweet potato). The higher quantity of economic produce resulted in higher rice yield equivalent in these treatments.

Though T_4 (Sesamum) had the highest unit price for economic produce its lower productivity resulted in the lowest rice yield equivalent values for the cop. These results are in line with the findings of Thakur et al. (1999) and Varughese (2006).

5.1.2.4. Per day production

The summer crops grow in rice fallows varied significantly on the per day production. Treatment T_5 (Amaranthus) recorded significantly higher per day production (Table 11). This is mainly because of Amaranthus (T_5) was short duration crop and at the same time produced the highest yield compared to other crops. This result was is in conformity with the findings of Niranjana (1998).

The lowest per day production was noticed in T_4 (Sesamum) because the economic produce by the nature was seed, accounted on dry weight basis and at the same time recorded lowest economic yield with considerably longer duration. Similar results were obtained by Pillai (1998) and Rajan (2000).

5.1.2.5. Energy yield m^{-2}

Among the treatments T_2 (Sweet potato) recorded the highest energy yield of 2555 cal m^{-2} followed by T_5 (Amaranthus) with 1502 cal m^{-2} (Table 13). The lowest energy yield was recorded in T_4 (Sesamum). The combination of higher calorific value (120 cal $100g^{-1}$) and high tuber yield resulted in the highest energy value for T_2 (Sweet potato). Similarly the highest economic yield and comparatively lower calorific value (45 $100g^{-1}$) resulted in the second highest energy value in T_5 (Amaranthus).

Though T_4 (Sesamum) had the highest calorific value for unit produce, its lowest yield placed it on the lowest energy yielding crop per unit area.The above results are in line with the findings of Gopalan et al. (1990).

5.1.3. Water productivity (Fig. 8)

The water productivity was significantly influenced by the treatments, with T_5 (Amaranthus) leading the list (Table 12). The least water productivity was noted in T_4 (Sesamum). Among the edible crops, it being of shortest duration utilized the minimum quantity of water, at the same time produced the highest economic yield that resulted in its higher water productivity. Treatment T_4 (Sesamum) was raised with higher quantity of water, its duration being longer compared to other treatments except T_2 (Sweet potato) and yielded the least economic yield that resulted in least water productivity.

5.1.3.1 Water productivity on rice yield equivalent

The highest water productivity on rice yield equivalent basis was retained by T_5 (Amaranthus) followed by T_3 (Pumpkin). But values increased six times for T_4 (Sesamum) and two times for T_6 (Cowpea). The values for T_7 (Daincha) fall on ten per cent of its actual values.

Since the yield of the crop was compared on common value base for the economic yield, the water productivity for T_4 (Sesamum) increased many fold and that of T_7 (Daincha) cropped drastically.

5.1.4. Nutrient uptake

5.1.4.1. Nitrogen uptake (Fig. 9)

Among the edible crops T_5 (Amaranthus) recorded the highest uptake of N by the economic parts and T_2 (Sweet potato) recorded the highest

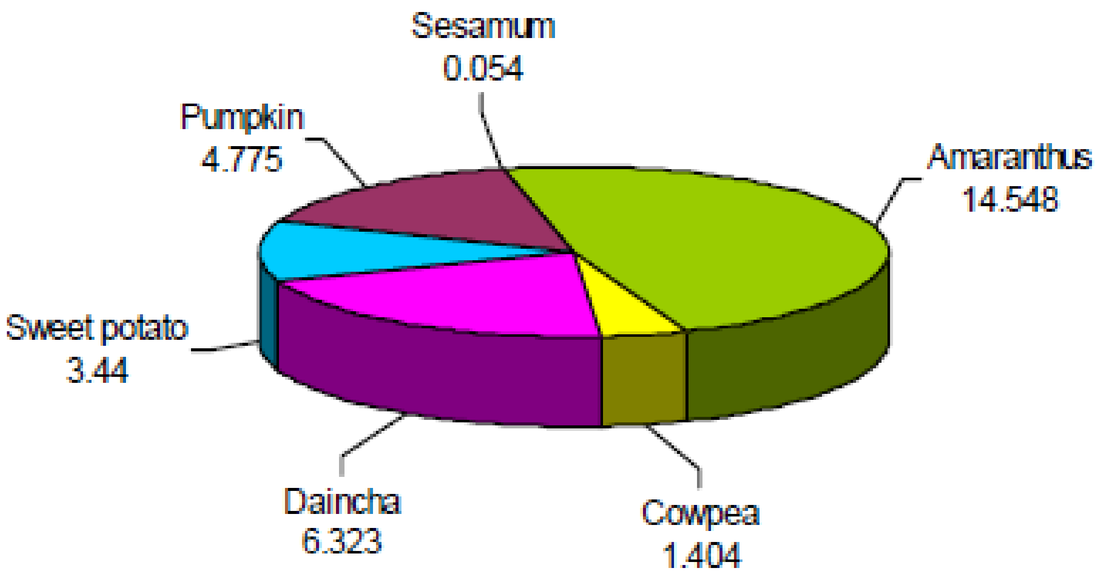

Fig. 8. Water productivity (kg m^{-3}) of summer crops

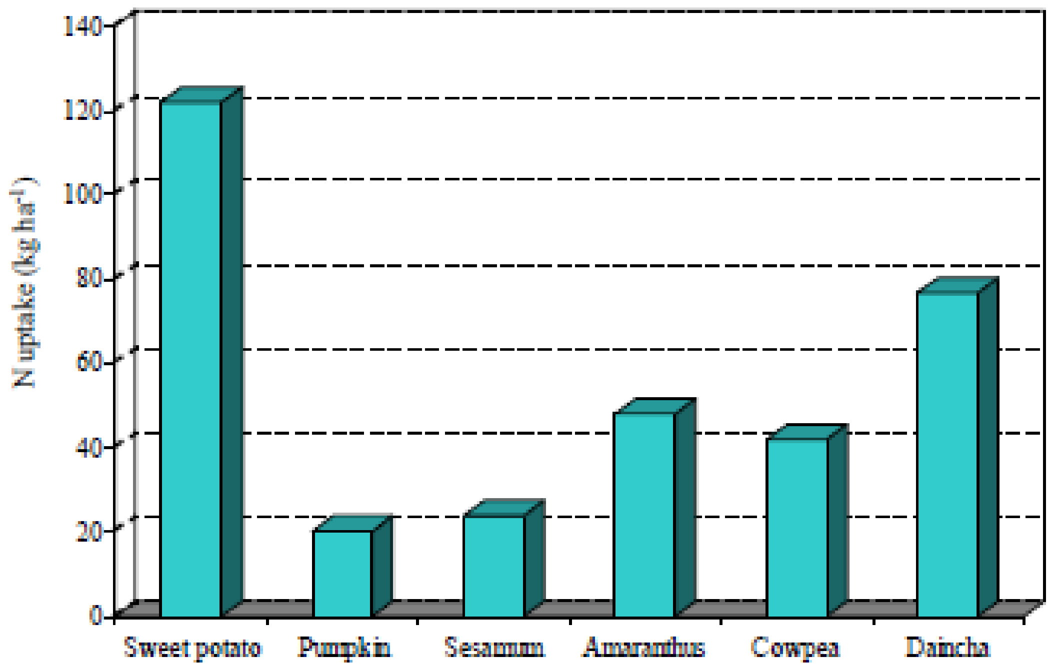

Fig. 9. Nitrogen uptake by the summer crops

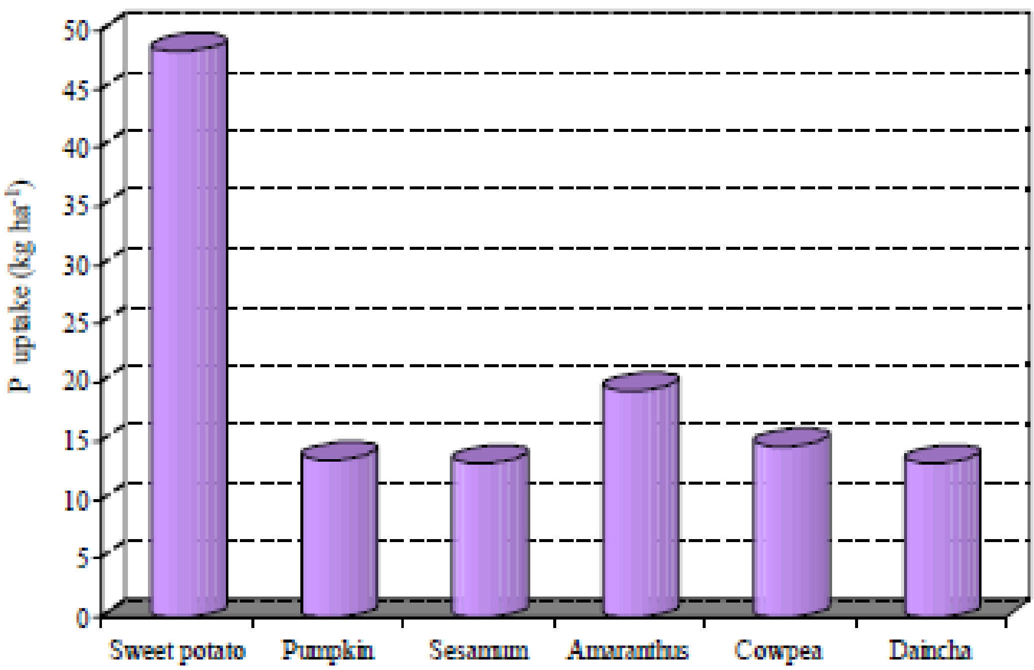

Fig. 10. Phosphorus uptake by the summer crops

uptake by both vegetative and total uptake of nitrogen (Table 14). The higher productivity of T_5 (Amaranthus) resulted in the highest uptake of N by economic part. Where as the highest biomass production of vegetative parts resulted in the highest uptake of nitrogen both by vegetative parts and the total uptake by the crop.

The lowest uptake by the economic part was in T_4 (Sesamum) a reflection of its lower yield and nitrogen content of the seed.

The total uptake was lowest in T_3 (Pumpkin) mainly due to the lower biological yield and lower content of the nutrient in the produce.These results are in conformity with the findings of Suresh (1998) and Olsanten (2007).

5.1.4.2. Phosphorus uptake (Fig. 10)

Among the treatments T_5 (Amaranthus) had the highest uptake of Phosphorus by economic parts due to its higher yield (Table 14). The phosphorus uptake both by the vegetative part and the total uptake by the crop was highest in T_2 (Sweet potato) a reflection of its higher biological yield and resultant dry matter production.

The lowest phosphorus uptake was noted in T_7 (Daincha). This might be due to its lower dry matter production compared to the other crops. These results are in conformity with the findings of Suresh (1998) and Paikaray et al. (2002).

5.1.4.3. Potassium uptake (Fig. 11)

Significantly higher uptake of potassium has noted in T_7 (Daincha) a reflection of its higher potassium content.

Treatment T_2 (Sweet potato) recorded significantly higher potassium uptake (Table 14) both by vegetative parts and total crop uptake compared

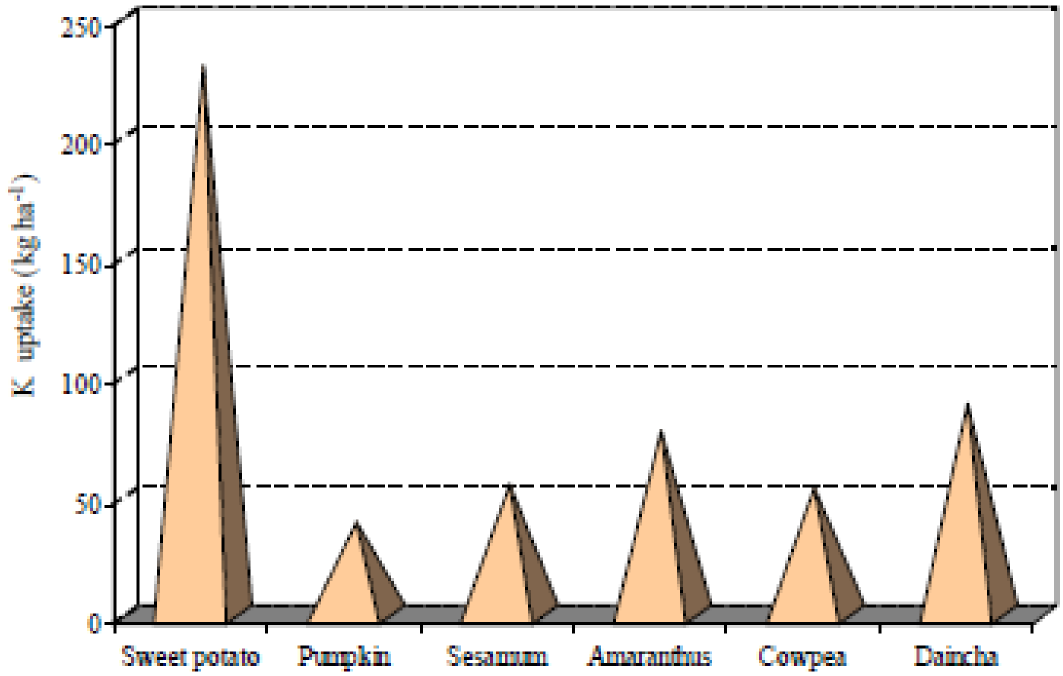

Fig. 11. Potassium uptake by the summer crops

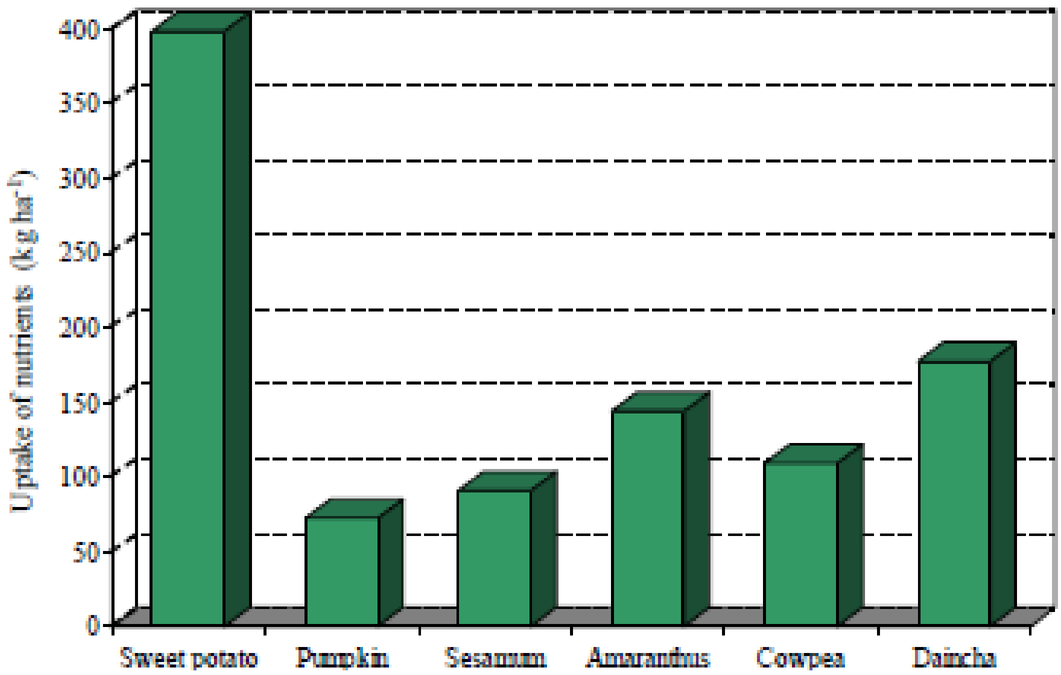

Fig. 12. Grand total uptake of nutrients (N + P + K) by the summer crops

to other treatments a reflection of its higher dry matter production. The least potassium uptake was noted in T_3 (Pumpkin) mainly due to its lower vegetative dry matter production. These results are in conformity with the findings of Padmaja and Raju (1999) and Byju and George (2005).

5.1.4.4. Total uptake of N, P and K (Fig. 12)

Significantly higher N, P and K uptake was records in T_2 (Sweet potato), followed by T_7 (Daincha). The least uptake was noted in T_3 (Pumpkin). These were the reflection of higher dry matter production in T_2 (Sweet potato) and comparatively higher content in T_7 (Daincha), and the lowest nutrient content of plant part in T_3 (Pumpkin).

5.1.4.5. Calcium and Magnesium uptake

The summer crops recorded significant variation with regard to calcium and magnesium uptake (Table 15). Treatment T_2 (Sweet potato) recorded significantly higher uptake of calcium and magnesium compared to other crops. This was due to the higher dry matter production and nutrient content. The lowest Ca and Mg uptake was recorded in T_3 (Pumpkin). This might be due to higher moisture content in pumpkin which results in lower dry matter production combined with low nutrient content.

In general nutrient uptake values were related to the crop yield levels. As the dry matter accumulation increased, nutrient uptake was also observed to increase. This is in accordance with the findings of Fageria and Baligar (2005).

5.1.4.6. Micro nutrient uptake

The micro nutrient uptake *viz.,* Fe, Zn and Cu varied significantly by the summer crops. The uptake of Fe, Zn and Cu was significantly higher in

T_2 (Sweet potato) compared to others (Table 16). Where as the micro nutrient uptake was lowest in T_7 (Daincha). It was mainly due to the concentration of nutrients in these crops as well as dry matter production. The relationship of uptake of nutrients, nutrient accumulation and dry matter production of plants was earlier reported by Fageria and Baligar (2005).

5.1.5. Nutrient removal by weeds at harvest

The nitrogen, phosphorus, potassium and total nutrients (N+P+K) removal by the weeds at harvest of summer crops varied significantly between the treatments. Weeds in treatment T_6 (Cowpea) recorded significantly higher removal of N, P, K and total removal (Table 17). This is mainly because of higher total weed dry matter production recorded by this treatment. Where as the lowest removal of these nutrients were recorded in T_7 (Daincha) because it recorded the lowest used dry weight compared to other crops. These results are in line up with the findings of Osten et al. (2006).

5.1.6. Effect of summer crops on physico- chemical characters of the post harvest soil

5.1.6.1. Physical characters

5.1.6.1.1. Bulk density

Treatments did not influence the bulk density of the soil significantly (Table 18). This was due to the gradual compaction of tilled soil with passage of time, finally equalizing the values for tilled and non tilled soil at harvest of the crop.

5.1.6.1.2. Porosity

Summer crops and rice following had no significant effect on the prosperity of the soil due to the gradual field compaction reached by the harvest time of the crop.

5.1.6.2. Chemical characters

5.1.6.2.1. Soil pH

Summer crops markedly influence the pH values of post harvest rice soil. Treatment T_5 (Amaranthus) recorded significantly higher pH values than all other treatments (Table 19). This is due to the high content exchangeable Ca and Mg and comparatively lower quantity of available Fe in the post harvest soil and also might be due to buffering action of the large quantity farm yard manure incorporated in to the soil as earlier reported by Lund and Dass (1980). These results are in conformity with the findings of Thakur et al. (1999) and Phogat et al. (2004).

5.1.6.2.2. Electrical conductivity

The effect of summer crops were found to be non significant on the electrical conductivity of the soil (Table 19). Since the soil was inherently devoid of any saline compounds. Also integrated nutrient management did not result in charges in soil electrical conductivity (Singh et al., 2001).

5.1.6.2.3. Organic carbon

The different treatments had no significant effect on the organic carbon content of the post harvest soil (Table 20). However T_5 (Amaranthus) recorded numerically higher content of organic carbon compared to other treatments. This might be due to the heavy application of farm yard manure @ 50 t ha^{-1} to Amaranthus. Similar increase in the organic carbon content due to the application of farm yard manure has been reported by Nambiar (1994).

5.1.6.2.4. Available nitrogen

Effect of summer crops on the soil available nitrogen was found to be non significant (Table 20), though among the different treatments T_7

(Daincha) recorded numerically highest quantity of available nitrogen. The daincha cropped soil might have been enriched with nitrogen through nitrogen fixation in their root nodules and the latent possible diffusion to the root zone. This result was in conformity with the findings of Subhash Chandra Gautam (1997), Mahapatra et al. (2002) and Saha et al. (2007).

Treatment T_1 (Control) recorded lower quantity of nitrogen compared to the initial status of the soil. This might be due to the non supplement of nitrogen under uncropped condition and another main reason was nitrogen depletion through removal by weeds. Nitrogen accretion by mineralization and nitrification might have been negligible during the rice fallow period due to the dry conditions and low organic matter content. This result is in line with the findings of Singh et al. (1999).

5.1.6.2.5. Available P_2O_5

Available phosphorous status of the soil was significantly influenced by the different summer crops (Table 20). The highest quantity of available P_2O_5 was recorded in T_5 (Amaranthus). This might be due to the supplement of the nutrient through the application of large quantity of farm yard manure @ 50 t ha^{-1}. Similar results of increase in the available phosphorous content of the soil through the addition of organic manures have been reported by Padmaja et al. (1993), Madhu et al. (1996) and Sharma et al. (2001).

Among the different treatments T_1 (Control) recorded lowest P_2O_5 content. Lack of nutrient supplement through manures and fertilizers and also P_2O_5 depletion through weeds removal might have lowered the P_2O_5 content of the soil. Similar results were earlier reported by Varughese (2006) in rice-rice-fallow cropping system.

5.1.6.2.6. Available K_2O

Summer cropping significantly influenced the available K_2O content of the soil (Table 20). Treatment T_5 (Amaranthus) cropped soil recorded highest K_2O content of the soil. This could be due to the nutrient enrichment through the application large quantity (50 t ha^{-1}) of farm yard manure. This result is in line with the findings of Nambiar (1994) and Madhu et al. (1996).

Treatment T_7 (Daincha) recorded the lowest quantity of K_2O compared to other treatments. It might be due to the fact that daincha crop was raised without any nutrient supplement through manures or fertilizers and at the same time it had significantly higher uptake of K_2O compared to all other crops except T_2 (Sweet potato), thereby heavily depleted the soil reserves of potassium that resulted in this low available potassium status of post harvest soil.

5.1.6.2.7. Exchangeable calcium

The exchangeable calcium content of the post harvest soil was not significantly affected by the different summer crops (Table 20). This result is in expected line as no differential supplementation of calcium was done in any treatment.

5.1.6.2.8. Exchangeable magnesium

Summer crops showed a significant influence on the exchangeable magnesium (Table 20). Among the treatment T_5 (Amaranthus) recorded significantly higher exchangeable magnesium. This might be due to the higher application of farm yard manure @ 50 t ha^{-1} combined with moderate uptake of magnesium by the crop that lead to enrichment of soil with regard to this nutrient. The lower exchangeable magnesium was recorded in T_1 (Control).

This could be due nutrient removal by weeds on the one hand and lack of nutrient supplementation in this treatment. These results are in conformity with the findings of Olsen et al. (1970) and Selvi and Selvaseelan (2003).

5.1.6.2.9. Available iron

The available iron content varied significantly between the treatments (Table 20). Treatment T_7 (Daincha) cropped soil recorded significantly higher available iron. This is because of the significantly lower iron uptake by T_7 (Daincha) crop (Table 16). Also various biochemical reactions triggered in the root zone of the crop might have released unavailable iron locked up as organo-chemical complexes in the soil that finally enriched the soil iron status. The lowest quantity of available iron was noted in the control plot. Probably due to weed removal and probable conversion of soil iron to unavailable form.

5.1.6.2.10. Available zinc

The available zinc content after the harvest of the summer crop varied significantly (Table 20). Among the treatment T_7 (Daincha) cropped soil recorded significantly higher available zinc. This might be because of lower uptake of zinc by the daincha crop compared to other crops (Table 16). The lowest available zinc was recorded in T_2 (Sweet potato) cropped soil. This could be due to the higher uptake of zinc by sweet potato (Table 16).

5.1.6.2.11. Available copper

The available copper content varied significantly between the treatments (Table 20). Among the treatments T_7 (Daincha) cropped soil recorded highest copper content. This could be due to the lower copper uptake by daincha crop (Table 16). The lowest copper content was noted in T_4 (Sesamum).

5.1.7. Economics of summer cropping in rice fallows (Fig.13)

Among the treatments highest net return of Rs. 290556 ha^{-1} was recorded in T_5 (Amaranthus). This was due to the highest gross return earned by the treatment with moderate cost of cultivation. The B:C ratio was highest (7.71) in T_5 (Amaranthus) also due to the above reasons (Table 21).

5.1.8. Post summer crop nutrient balance sheet

5.1.8.1 Balance sheet of available nitrogen (Fig.14)

The post summer crop soil recorded negative balance of soil nitrogen except for T_2 (Sweet potato) and T_7 (Daincha). In T_2 (Sweet potato) there was a nominal accretion (1.38 kg ha^{-1}) where as in T_7 (Daincha) it was appreciable (+94.33 kg ha^{-1}). The nominal accretion observed in T_2 (Sweet potato) might be due to the extra supplementation of nutrients through leaf fall during the growth period of the crop.

The appreciable positive nitrogen balance noted in T_7 (Daincha) treatment might be due to the nitrogen enrichment due to the possible diffusion of nitrogen from the root nodules of the crop. The negative balance noted in other treatments are due to the loss of nitrogen from the soil through various processes like nitrification, leaching and run off losses etc. These results are in conformity with the findings of Subhash Chandra Gautam (1997), Sharma et al. (2000), Mahapathra et al. (2002), Paikaray et al. (2002) and Pillai et al. (2007).

5.1.8.2. Balance sheet of available phosphorous (Fig.15)

The nutrient balance sheet of post summer crop soil recorded a general negative balance except for T_2 (Sweet potato) and T_7 (Daincha) (Table 23). This might be due to the fact that when the computed values of soil available P in T_2 (Sweet potato) with 34.02 kg ha^{-1} and T_7 (Daincha)

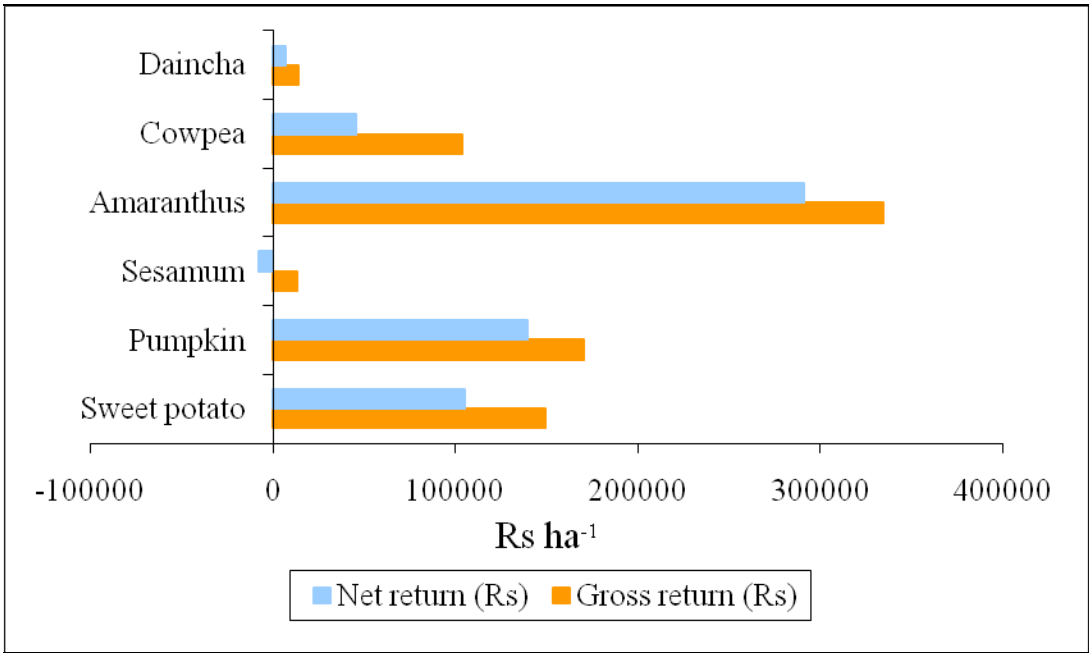

Fig. 13. Gross and net return of the summer crops

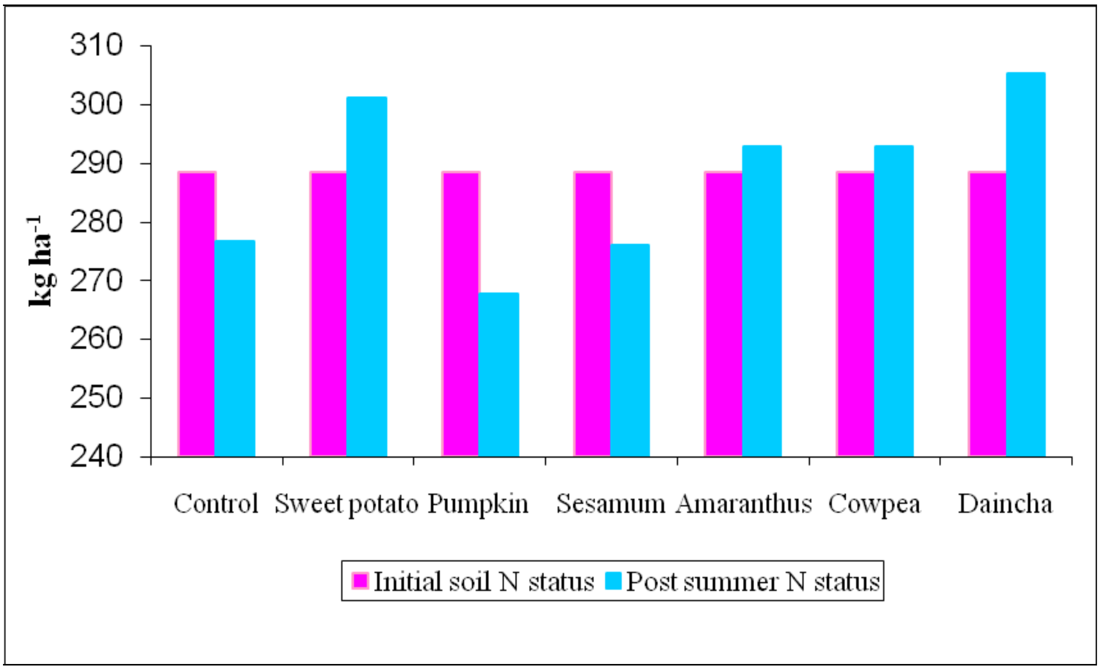

Fig. 14. Nitrogen balance of post summer crop soil

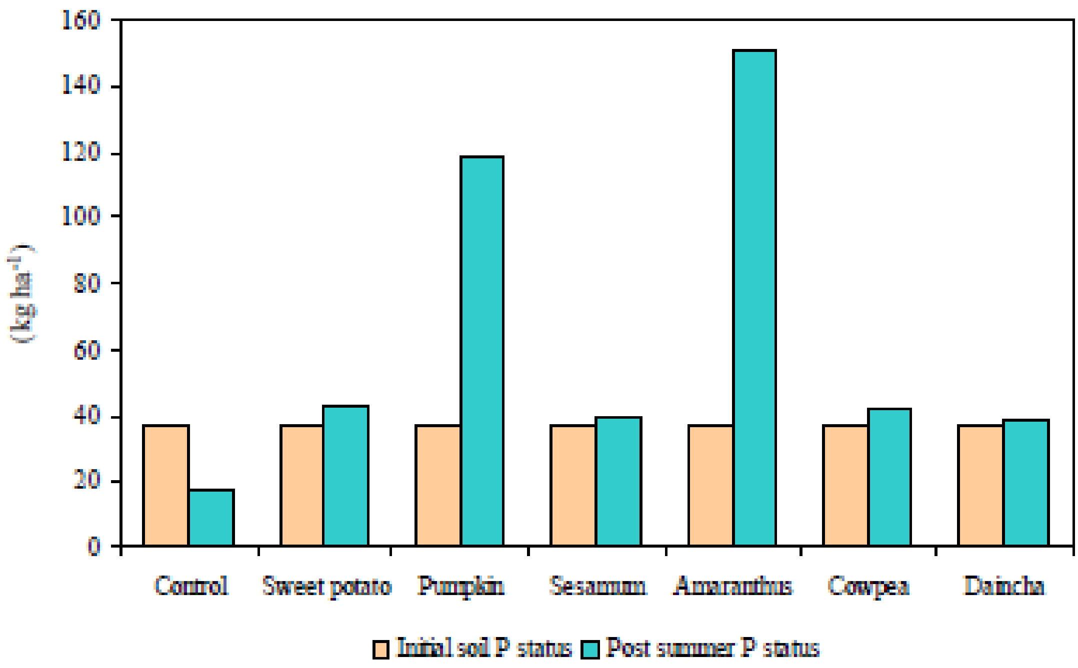

Fig. 15. Phosphorus balance of post summer crop soil

with 6.75 kg ha^{-1} falls below the inherent soil P availability level (37.19 kg ha^{-1}) more of unavailable P is converted into available form, accounting for an increase in the actual available balance in their treatments. Whereas when the computed soil available P was considerably higher than the inherent soil available P level more of available P sets converted into unavailable form thus accounting for a negative balance of P in the other treatments. These results are in conformity with the findings of Sharma et al. (2001), Paikaray et al. (2002), Kharub et al. (2004) and Bhargavi et al. (2007).

5.1.1.8.3. Balance sheet of available potassium (Fig.16)

The post summer crop soil recorded a general negative balance of potassium for all treatments (Table 24). This might be due to the fact that potassium being highly water soluble nutrient. It is subjected to dissolution and loss through leaching and surface run off from the soil at times of heavy rainfall. These results are in line with the findings of Prasad et al. (1997) and Chander Pal et al. (2007).

5.2. SUCCEEDING RICE (VIRIPPU) CROP

5.2.1. Studies on weeds

5.2.1.1. Weed spectrum

Observation on weed species revealed a drastic reduction in the number of grass weed species and increase in number of broad leaved weed species. Out of the six broad leaved weed species in the weed flora of the summer crop five were totally replaced in the weed flora of rice. The shift might be due to changes brought about in the soil aeration, moisture regime and stimulus for weed seed germination. Similar observation on weed spectrum of rice field were reported earlier by Verma et al. (1987), Thirumurugan et al. (1992), Dhiman Mukherjee (2005) and Natarajan (2007).

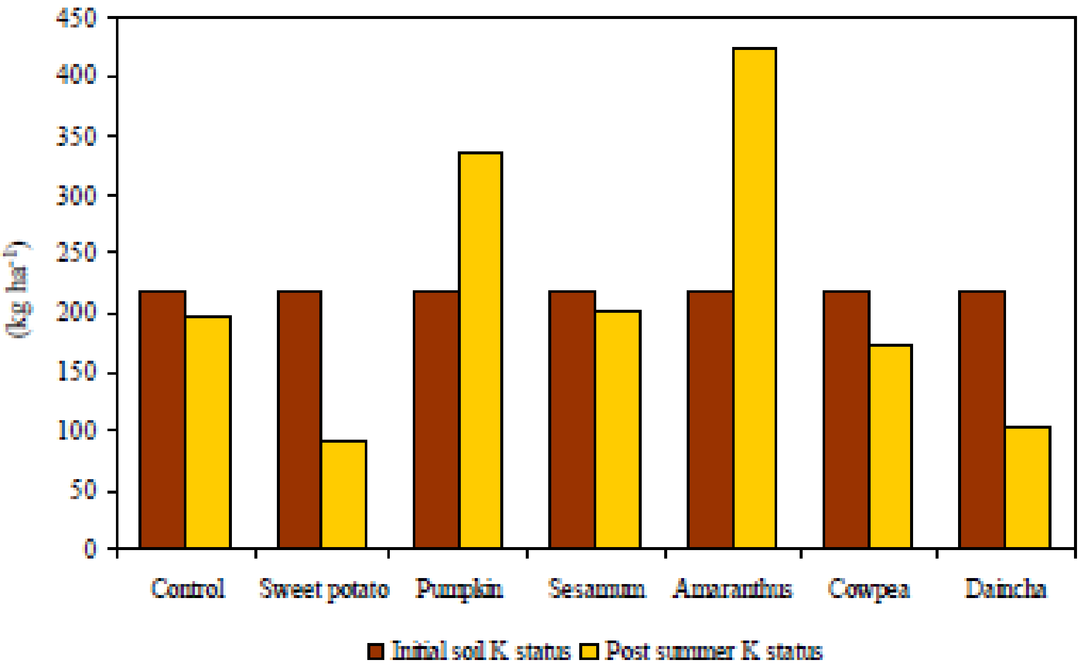

Fig. 16. Potassium balance of post summer crop soil

5.2.1.2. Weed population

5.2.1.2.1. Population of grass weeds

The grass weed population was sparse in all the treatments both at 40 DAT and at harvest. This could could be due to the lower population of grassy weeds in summer crops and their better control that reduced the soil grass weed seed bank. Also the previous season's upland cropping period might have lead to the loss of seed viability of many seasonal grass weed species as evidenced by the total absence of *Isachne miliacea* in the cropped treatments (Table 25).

5.2.1.2.2. Population of sedge weeds

The significant variation was noticed between the treatments on the sedge population at 40 DAT (Table 26). Treatment T_2 (Sweet potato-rice) recorded significantly higher population of sedges. This could be due to the fact that most of the sedge weed seeds in the sweet potato cropped soil remained dormant throughout summer crop period (Table 6) which added to the sedge weed seed bank that promoted more sedge weed germination and growth.

The sedge weed population was significantly lower in T_6 (Cowpea-rice) at 40 DAT and in T_7 (Daincha-rice) at harvest. This was due to the fact that the sedge weed population was nil at 40DAT but by the harvest stage it was significantly higher than all other treatments, which means that almost all the sedge weed in the soil germinated and considerably depleted the sedge weed seed bank. But they could not have produced the mature seeds or that produced seed remained dormant through the major part of the duration of rice that reduced the population of sedge weeds in the T_6 (Cowpea-rice) treatment. Where as in T_7 (Daincha-rice) during the summer crop period all the sedge weed seed remained dormant and majority might have lost viability and viable seeds germinated during the early growth phase of rice but had lesser weed population from the left over weed seeds towards the harvest stage.

5.2.1.2.3. Population of broad leaved weed

The population of broad leaved weed varied significantly between the treatments both at 40 DAT and at harvest (Table 26). Treatment T_2 (Sweet potato-rice) recorded significantly higher broad leaved weed population at 40DAT. This might be due to the addition of large quality of vegetative residue (Table 11) of summer crop of T_2 (Sweet potato) and the resultant soil environment might have triggered the germination of higher number of broad leaved weed seeds that resulted in the higher broad leaved weed population in T_2 (Sweet potato-rice). Where as at the harvest time the weed population was highest in T_5 (Amaranthus-rice). This could be due to the fact that lot of weed seeds might have been introduced through the high quantity (50 t ha^{-1}) of farm yard manure and these seeds might have remained dormant, where as the native seeds germinated during the early stage of the rice growth. The weed seeds added through farm yard manure broke their dormancy and resulted in the highest weed population at harvest time.

The broad leaved weed population was lowest in T_7 (Daincha-rice) at both 40 DAT and at harvest. This could be due to the fact that the entire weed flora of the summer crop daincha was constituted by broad leaved weeds which might have depleted the soil weed seed bank and resulted in lesser plant population.

5.2.1.2.4. Total weed population

The total weed population varied significantly both at 40 DAT and at harvest (Table 26). Treatment T_2 (Sweet potato-rice) recorded significantly higher total weed population at 40DAT, resultant to the significant increased in the population of broad leaved weeds, discussed in 5.2.1.2.3. The lowest total weed population was recorded in T_7 (Daincha-rice) both at 40DAT and at harvest due to the absence of grass weeds and the lowest population of broad leaved weeds discussed in 5.2.1.2.3.

At harvest treatment T_5 (Amaranthus-rice) recorded significantly higher total weed population, resultant to the significant higher population of broad leaved weeds discussed in 5.2.1.2.3.

5.2.1.3. Weed dry matter production (WDMP)

The grasses, broad leaved weed and total WDMP did not vary significantly between the treatments both at 40 DAT and at harvest. Where as WDMP of sedges varied significantly between the treatments at 40DAT but not at harvest (Table 27).

Among the treatments T_2 (Sweet potato-rice) recorded significantly higher WDMP of sedges at 40 DAT. This was due to the higher sedge weed population in T_2 (Sweet potato-rice) discussed in 5.2.1.2.2.

5.2.1.4. Weed vegetation analysis

5.2.1.4.1. Relative density

The relative density per cent of grasses and sedges varied significantly at 40 DAT but not at harvest the significant variation was noticed for grasses only (Table 28) and followed the pattern of dominance of grasses, sedges and broad leaved weed population among the treatment as discussed in population of grasses, sedges and broad leaved weeds.

5.2.1.4.2. Relative dry weight

The relative dry weight of grasses and broad leaved weeds did not vary significantly both at 40DAT and at harvest. The relative dry weight of sedges varied significantly only at 40 DAT and not at harvest (Table 29). Generally the relative dry weight followed the pattern of WDMP of the treatment as discussed in 5.2.1.3.

5.2.1.4.3. Summed dominance ratio

Summed dominance ratio (per cent) of grasses and sedges varied significantly 40DAT (Table 30) and followed the pattern of relative density and relative dry weight of weeds in the different treatments as discussed in 5.2.1.4.1 and 5.2.1.4.2.

5.2.2. Studies on growth attributes

5.2.2.1. Plant height

Plant height did not vary significantly among the treatments at maximum tillering stage but varied at harvest (Table 31). Among the various treatments T_5 (Amaranthus-rice) produced significantly taller plants compared to other treatments. This could be due to the residual effect of the large quantity of farm yard manure applied to T_5 (Amaranthus) in the previous summer season. Plant height at the maximum tillering stage was mainly influenced by the fertilizer nutrients which was applied uniformly to all the treatments and was present in quite sufficient quantity. However its effects waned towards fag end of crop duration where in the presence of residual quantity of farm yard manure sustained better growth of the plant in T_5 (Amaranthus-rice) for it to attain significantly higher plant height at harvest stage. The lowest plant height was recorded in T_1 (Control-rice). This might be due to the poor fertility status of the soil as there was no addition of manures and fertilizes to this treatment in the previous season and also there was no crop residue incorporation prior to the transplanting of rice crop. The above results are in conformity with the findings of Singh et al. (2002).

5.2.2.2. Tiller No. hill^{-1}

The treatments did not show any significant variation in number of tillers hill^{-1} at the maximum tillering stage (Table 31). This might be due to the application of uniform package of practices for rice in all the treatments. Similar results were earlier reported by Singh et al. (2003b).

5.2.2.3. Days to 50 per cent flowering

The days to 50 per cent flowering did not vary significantly between the treatments (Table 31). Since the flowering character is more of genetic character when growth environment is not limiting factor.

5.2.2.4. SPAD value

SPAD reading varied significantly at maximum tillering stage but not at flowering stage (Table 31). The treatment T_7 (Daincha-rice) recorded significantly higher SPAD value compared to other treatments. This might be due to the higher leaf nitrogen concentration of plant in this treatment facilitated by the significantly higher nitrogen status of the post summer crop soil (Table 20). This result is in confirmly with the findings of Johnkutty et al. (2000).

5.2.2.5. Leaf area index (LAI)

The previous season upland crop did not significantly influence the leaf area index of the succeeding rice crop at flowering stage (Table 31). This might be due to the uniform application of recommended package of practices to all the treatments that lead to the masking of all residual effect of the previous season’s upland crop. The result is in line with the findings of Singh et al. (2003b).

5.2.3. Yield attributes

5.2.3.1. Panicle No. hill^{-1}

There was no significant variation in the number of panicles hill^{-1} due to the previous season's summer crop (Table 32). This might be due to the adoption of uniform package of practices to all the treatments. The above results are in conformity with the findings of Singh et al. (2003b) and Tulasi (2007).

5.2.3.2. Mean panicle weight

The mean panicle weight did not significantly vary between the treatments (Table 32). This might be due to the uniform application of nutrients to all the treatments which had the same effect on mean panicle weight. Similar findings were reported by Pillai (1998), Thakur et al. (1999) and Singh et al. (2003b).

5.2.3.3. Thousand grain weight

The treatment did not differ significantly in the thousand grain weight as this character is more influenced by genetic make up of the rice variety that is grown under good management. The above result is as reported by Yoshida (1981).

5.2.4. Grain yield (Fig. 11)

The previous season's upland crops did not significantly influence the grain yield of the succeeding rice crop (Table 32). This might be due to the adoption of uniform recommended package of practices in all the treatments that masked the carry over effect of previous season's summer crops. This result is in line with the findings of Kumar et al. (1993) and Singh et al. (2003b).

5.2.5. Straw yield (Fig. 11)

Straw yield was not significantly influenced by the previous season's summer crops (Table 32) due to the reasons discussed in 5.2.4.

5.2.6. Harvest index

The previous season's upland crops failed to have any significant impact on harvest index of the succeeding rice crop (Table 32), since the rice crop was grown under uniform package of practices recommendations as discussed in 5.2.4 and 5.2.5.

5.2.7. Nutrient uptake

5.2.7.1. Macronutrient uptake (Fig. 12)

The previous season's upland crops did not vary significantly with regards to nitrogen, phosphorous and potassium uptake by the grain, straw and total rice crop uptake (Table 33). Since the rice crop was raised under uniform package of crop management that resulted in non significant variations in yield of rice grain and straw. These results are corroborated by the findings of Fageria and Baligar (2005).

5.2.7.2 Uptake of secondary nutrients

The treatments did not vary significantly in the uptake of calcium and magnesium by grain, straw and also in the total uptake (Table 35) which is a reflection of the non significant variation in the yield of grain and straw of the rice crop.

5.2.7.3 Uptake of micronutrients

The proceeding summer crops had no significant effect on the uptake of iron, zinc and copper by both the grain, straw and total uptake (Table 36), which was discussed in 5.2.7.2. is a reflection of the non significant variation in the yield of grain, straw of the rice crop.

5.2.8. Nutrient removal by weeds at harvest of the virippu rice crop

The nitrogen, phosphorus, potassium and the total (N+P+K) nutrient removal by the harvest of succeeding rice crop did not vary significantly (Table 37). This might be due to the fact that the total weed dry matter production at harvest of the crop did not vary significantly.

5.2.9. Physico-chemical characters of soil

5.2.9.1. Physical properties of soil

Summer cropping and incorporation of the crop residues had no significant effect on the bulk density and porosity of the soil (Table 38). This could be due to uniform application of farm yard manure to all the treatments that resulted in uniform effect on the physical properties of the soil. Similar results were observed by Newaj and Yadav (1994).

5.2.9.2. Chemical properties

5.2.9.2.1. Soil pH

The influence of summer cropping was significant with regard to the soil pH (Table 38). Treatment T_3 (Pumpkin-rice) recorded significantly higher pH values followed by T_5 (Amaranthus-rice). This might be due to the changes in the soil biochemical reaction brought about by the residual effect of large quantity of organic matter carried over from the summer cropping. Also T_3 (Pumpkin-rice) had the lowest uptake of calcium (Table 35) and highest quantity of calcium in the post harvest soil (Table 39) that resulted in higher soil pH values. This result is in line with the findings of Puste et al. (2001).

5.2.9.2.2. Electrical conductivity

The influence of summer cropping on electrical conductivity of rice soil was not significant (Table 38). Since the inputs used up for the crop contained salty materials. Similar result was obtained by Singh et al. (2001).

5.2.9.2.3. Organic carbon

The organic carbon status of the soil did not vary significantly among the various treatments (Table 39). This could be due to the uniform integrated nutrient management practices adopted for rice crop. Similar results were obtained by Singh et al. (2001) and Varughese (2006).

5.2.9.2.4. Soil available nitrogen

The nitrogen status of the soil immediately after the harvest of rice crop was not found to vary significantly (Table 39), though T_7 (Daincha-rice) recorded numerically higher value compared to the other treatments. The increase in the soil available nitrogen due to the incorporation of daincha was earlier reported by Alok kumar (2003), Kharub et al. (2004) and Saha et al. (2007).

5.2.9.2.5. Available phosphorus (P_2O_5)

The available P_2O_5 status of the soil after the harvest of rice crop varied significantly (Table 39). Treatment T_5 (Amaranthus-rice) recorded significantly higher values. This might be due to the fact the post summer crop soil had significantly higher amount of P_2O_5 in the T_5 (Amaranthus-rice) treatment. At the same time the phosphorus uptake by the rice crop was almost uniform with no significant difference which resulted in higher quantities of phosphorus in the post harvest rice soil.

Significantly lower amount of P_2O_5 was recorded in T_1 (Control-rice). This might be due to the fact that post summer season soil in the fallow plot contained significantly lower amount of P_2O_5 since there was no nutrient supplementation. These results are in line with the findings of Badanur et al. (1990), Sharma and Mittra (1990), Padmaja et al. (1993) and Madhu et al. (1996).

5.2.9.2.6. Available potassium (K_2O)

The available potassium status of the post harvest soil varied significantly (Table 39). The highest amount of potassium was recorded in T_5 (Amaranthus-rice) and lowest in T_7 (Daincha-rice). This might be due to the fact that the T_5 (Amaranthus-rice) had significantly higher quantity of K_2O in the post summer crop soil to begin with and there was no significant variation in the uptake of nutrient among the treatments that resulted in the higher availability of K_2O in the post harvest soil.

In T_1 (Fallow-rice) the post summer crop soil had only lower quantity of K_2O to begin with and the uptake of succeeding rice crop was on par with other treatments, that resulted in more depletion of the nutrient and lesser availability in soil.

5.2.9.2.7. Exchangeable calcium and magnesium.

Summer cropping of upland crops did not significantly influence the exchangeable calcium and magnesium content of the post harvest rice soil (Table 39). This might be due to the fact that the post summer crop soil did not significantly vary in status of calcium and also the uptake by the treatments was also not significantly different that lead to more uniform status of calcium and magnesium of the post harvest rice soil.

5.2.9.2.8. Available iron

The iron status of the soil after the harvest of the summer crop did not vary significantly (Table 39). This might be due to the fact that significant difference noted in the iron status of the post summer crop soil. This difference was buffered through the possible forms of organo-chemical soil complexes that left a good amount of iron to the unavailable form and resulted in the more uniform status of iron in the post rice soil.

5.2.9.2.9. Available zinc

The effect of preceding upland crops on the available zinc content was significant (Table 39). Treatment T_7 (Daincha-rice) recorded significantly higher available zinc. This might be due to the fact that to begin with the post summer crop soil had significantly higher content of zinc in T_7 (Daincha-rice) and there was no significant variation in the uptake of zinc by the rice crop in the different treatments that resulted in significantly higher quantity of zinc in the post harvest rice soil in T_7 (Daincha-rice).

5.2.9.2.10. Available copper

The available copper content of the soil did not vary significantly between the treatments (Table 39). Though the initial post summer crop soil had significant variation in the status of copper, the subsequent addition of copper residues and organic manures might have converted a portion of the available copper into unavailable form through the addition of organo-chemical soil complexes. Moreover there was no significant difference in the uptake of copper by rice crop. Hence a sort of buffering occurred in the available status of copper.

5.2.10. Nutrient balance studies

5.2.10.1. Nitrogen balance (Fig. 13)

The treatment in general had a negative balance for soil available nitrogen in the post harvest rice soil (Table 40). The magnitude of rice nitrogen loss was highest (180.37 kg ha^{-1}) in T_2 (Sweet potato-rice) followed by T_7 (Daincha-rice). The least nitogen lost was noticed in T_1 (Control- rice). The highest soil available nitrogen was observed in T_2 (Sweet potato-rice) might be due to the fact that it had the highest computed pre-rice soil nitrogen status considering the full rotation of all mineralized nitrogen in soil but, the soil depletion by plant absorption was comparatively very low. This might have left higher quantities of mineralized nitrogen in the soil unutilized which was subjected to dissolution and loss by leaching and runoff from the root zone of rice. Hence the actual quantity of nitrogen in the post rice soil was lesser than what was computed and that lead to negative balance of the soil available nitrogen in T_2 (Sweet potato-rice) and other treatments.

5.2.10.2. Phosphorous balance (Fig. 14)

All the treatments were negatively balanced in soil available phosphorous (Table 41). The highest depletion of phosphorous was noticed in T_3 (Pumpkin-rice) and the least in T_1 (Fallow-rice). Considering the pre rice soil status of phosphorous and the actual plant absorption, the computed balance were higher for T_5 (Amaranthus-rice) and T_3 (Pumpkin-rice). Since the whole of the mineralized phosphorous was not absorbed by the crop and weeds what was left unutilized got converted to unavailable form in the soil. The actual quantity of mineralized phosphorous that got converted to unavailable form varied with soil mineral constitution that lead to the above results.

5.2.10.3. Potassium balance (Fig. 15)

All the treatments ended up with a negative balance for available potassium (Table 42). The highest loss was computed for T_5 (Amaranthus-rice) and least for T_4 (Sesamum-rice).

The pre rice soil status of the potassium was the highest for T_5 (Amaranthus-rice) and lowest for T_4 (Sesamum-rice) that lead to highest computed balance of potassium for T_5 (Amaranthus-rice) and lowest for T_4 (Sesamum-rice). Since the plant absorption was vary moderate large quantities of mineralized potassium was left unutilized in the soil which was lost through water by leaching and runoff. This lead to negative balance of potassium in all the treatments.

Summary

6. SUMMARY

A field experiment was entitled "Performance of summer crops in rice fallows and its effect on succeeding transplanted rice" was taken up at the Cropping systems research station, Karamana, Thiruvananthapuram during February 2008 to October 2008 that covered the summer (third crop) and virippu (the first crop) seasons of rice cultivation. The main objectives of the experiment was study the performance of different upland crops in the summer rice fallows of southern Kerala in terms of resource utilisation, yield, soil health and carry over effect on succeeding rice crop, and to arrive at a sound practice of summer rice fallow utilization. The experiment was laid out in a randomised block design with three replication and seven treatments (T_1 - Control or summer rice fallow, T_2 - Sweet potato, T_3 - Pumpkin, T_4 - Sesamum, T_5 - Amaranthus, T_6 – Cowpea and T_7 - Daincha) which were followed by rice crop in the virippu season. All the crops were raised as par the KAU package of practices recommendations. The salient findings of this study are summarised below.

Weeds species belonging to seven families were found to occur in the various summer crops and in the control. The predominant species under the grassy weeds were *Echinochloa colona* (L.) Link, *Digitaria ciliaris* (Retz. Koel), *Isachne miliacea* (Roth.) and *Digitaria sanguinalis* (L.) Scop. The dominant species under the sedges were *Cyperus iria* (L.), *Cyperus compressus* (L.) and *Fimbristylis milliacea* (L.) Vahl. The important broad-leaved weeds consisted of *Phyllanthus niruri* (L.), *Oldenlandia affinis* (Roemer & Schultes. DC.), *Eclipta alba* (L.), *Eclipta prostrata* (L.), *Ludwigia parviflora* (Roxb.) and *Cleome viscosa* (L.).

The changes in the cropping environment from low land to upland situation resulted in variation of the weed flora associated with the summer crops composition, density and dominance of weed species. Among the upland crops grassy weeds were totally absent in T_7 (Daincha), Sedges weeds totally absent in T_2 (Sweet potato) and T_7 (Daincha) and broad leaved weeds were totally absent in T_5 (Amaranthus) at harvest time. The weed population was highest in T_6 (cowpea) and the lowest in Amaranthus at harvest.

Among the crops at harvest stage the weed dry matter production (WDMP) of grasses and sedges were highest in T_6 (cowpea) and WDMP of broad leaved weeds highest in T_4 (Sesamum). The total WDMP was highest (671.33 kg ha^{-1}) in T_6 (cowpea) and the lowest (58-67 kg ha^{-1}) in T_7 (Daincha). Among the summer crops the relative density of grasses was in general higher (60.12 to 96.30 per cent) except in T_7 (Daincha) which had cent per cent value for broad leaved weeds. The relative dry weight and summed dominance ratio also followed same trend. The nutrient removal by weeds varied significantly with the summer crops. The highest removal of nitrogen (9.53 kg ha^{-1}), phosphorus (1.41 kg ha^{-1}) and potassium (10.47 kg ha^{-1}) and total (N+P+K) nutrient removal was recorded in T_6 (cowpea).

The economic yield was highest (33388 kg ha^{-1}) in T_5 (Amaranthus) and biological yield (62778 kg ha^{-1}) in T_2 (Sweet potato). The rice yield equivalent (33388 kg ha^{-1}), per day production (722.83 kg ha^{-1}) and water productivity (14.548 kg m^{-3}) were highest in T_5 (Amaranthus). However, the energy yield was highest (2555 calories m^{-2}) in T_2 (Sweet potato) and the lowest (124 calories m^{-2}) in T_4 (Sesamum). The highest net return was obtained in T_5 (Amaranthus) that gave Rs. 290556 ha^{-1} with the highest B:C ratio of 7.71.

The uptake of nitrogen (121.75 kg ha^{-1}), phosphorus (48.24 kg ha^{-1}) and potassium (229.40 kg ha^{-1}) was highest in T_2 (Sweet potato).The lowest uptake of nitrogen (20.13 kg ha^{-1}) and potassium (38.52 kg ha^{-1}) was recorded in T_3 (Pumpkin). The total phosphorus uptake was lowest (13.13 kg ha^{-1}) in T_7 (Daincha). The total plant uptake of (N+P+K) was higher (399.39 kg ha^{-1}) in T_2 (Sweet potato) and lowest (72.09 kg ha^{-1}) in T_3 (Pumpkin). Treatment T_2 (Sweet potato) recorded the highest plant uptake of secondary nutrients (Ca and Mg) and also micro nutrients (Fe, Zn and Cu).

The treatments significantly influenced the post summer crop soil acidity, with T_7 (Daincha) recording the lowest pH of 5.26 and T_3 (Pumpkin) recording the highest pH of 5.73.

The nutrient balance sheet of the post summer crop soil revealed a general negative balance of N in all the treatments except T_2 (Sweet potato) and T_7 (Daincha) with a positive balance of +1.38 and +94.33 kg ha^{-1} respectively.

The phosphorus balance sheet of summer crops revealed a general negative balance for except T_2 (Sweet potato) and T_7 (Daincha) which recorded a positive balance with +21.64 and +32.01 kg ha^{-1} respectively.

The potassium balance sheet of the summer crops revealed a negative balance of the nutrients for all the treatments.

The weed spectrum analysis of the succeeding rice crop revealed significant changes in the weed species composition. The grass weeds got drastically reduced and the species of broad leaved weeds changed totally. Of the 5 species of broad leaved weeds present in the summer crops only one species occurred in the rice crop, where additionally 6 more species were noted.

The weed population was dominated by broad leaved weeds. The relative weed density, relative weed dry weight and the summed dominance ratio were highest for broad leaved weeds and lowest for grassy weeds.

The growth attributes and yield attributes of the succeeding rice crop did not vary significantly between the treatments except the plant height at harvest.

The uptake of both macro and micro nutrients by rice was not significantly influenced by the treatments. There was no significant variation among the treatments in the nutrient removal by weeds.

The post rice soil varied significantly in the soil acidity between the treatments. The soil was more acidic in T_7 (Daincha - rice) with a pH of 5.20 and least acidic in T_3 (Pumpkin - rice) with a pH of 5.87.

The post rice soil varied significantly in the available phosphorus, potassium and zinc. The highest values for P and K were recorded by T_5 (Amaranthus - rice) and the highest value for Zn by T_7 (Daincha - rice).

The balance sheet analysis of nutrients revealed a general negative balance for nitrogen, phosphorus and potassium.

Conclusion

Where ever water, the key deciding resource is limited, the leafy vegetable crop Amaranthus being of shortest duration should be included in the cropping sequence.

Amaranthus gave the highest quantity of economic produce and the produce being a preferred vegetable fetched the highest net profit and BC ratio. Also it improved the rhizosphere environment by reducing the soil acidity. The second best was the fruit vegetable pumpkin in all the above aspects. However, under situation where priority is for meeting the human calorie requirement sweet potato is to be preferred.

Under situation where the former is constrained of capital, the best preference is for green manuring with Daincha.

Under situation where the summer crops and the succeeding rice crop are grown adopting the recommended integrated nutrient management practice, there will not be any deleterious carry over effect of summer crops on the succeeding rice crop.

Hence, the ideal crop sequence will be summer crop of Amaranthus followed by rice with respect to productivity and profitability.

References

REFERENCES

Aladesanwa, R. D. and Adigun. A. W. 2008. Evaluation of sweet potato (*Ipomoea batatas*) live mulch at different spacings for weed suppression and yield response of maize (*zea mays* L.) In South western Nigeria. Crop Protection. 27(6) : 968-975.

Alavez, C. G., Barrales, D. J. S., Bolanos, E. A and Revista. C. 1998. Biological efficacy of clomazone in the control of weeds in amaranth (*Amaranthus hypochondriacus* L.). Serie. Ingenieria. Agropecuaria. 1(1): 33-36.

Ali, M. 1993. Effect of summer legumes on the productivity and nitrogen economy of succeeding rice (*Oryza sativa*) in sequential cropping. Indian J. agric. Sci. 62(7): 466-467.

Alok Kumar, Y. D. S. 2003. Long term nutrient management for sustainability in rice-wheat cropping system. Fert. News. 48(8): 27-28, 31-34.

Anbumani, S., Rajendran, K. and Kuppuswamy, G. 2000. Effect of planting methods and NPK levels on rice and rice fallow crops in single rice based cropping system. J. Ecobiol. 12(4): 313-315.

Ansary, S. H., Ghanti, P. and Thapa, U. 2003. Effect of irrigation and nitrogen fertilization on growth, development and yield of pumpkin (*Cucurbita moschata* Poir). Environ and Ecol. 21(4): 947-950.

Argenta, G., Silva, P. R. F. da and Bortolini, C. G. 2001. Leaf chlorophyll as an index of nitrogen status in cereals. Ciencia. Rural. 31(4): 715-722.

Aulakh, M. S., Khera, T. S., Doran, J. W., Singh. K. and Singh. B. 2000. Yields and nitrogen dynamics in a rice-wheat system using green manure and inorganic fertilizer. Soil. Sci. Soc. America. J. 64(5): 1867-1876.

Badanur, V. P., Poleshi, C. M., and Balachandra, K. 1990. Effect of organic matter on crop yield and physical and chemical properties of vertisol. J. Indian Soc. Soil Sci. 38(3):426-429.

Basavaraj, B., Shetty, R.A. and Hunshal, C.S. 2000. Response of sesame varieties to fertilizer and population levels in paddy lands of Tungabhadra Project area during summer. Karnataka J. Agric. Sci. 13(1): 138-140.

Bazejczak, D. and Dawidowski, J.B. 1999. The influence of cropping systems on the physical properties of soil. [Journal article] Prace Przemysowego Instytutu Maszyn Rolniczych. 44(4): 46-50.

Beaulah, A., Ramaswamy, N. and Rajadurai, K.R. 2001. The effect of different planting systems and nutrient management on the nutrient uptake of rice fallow pumpkin (*Cucurbita moschata*). J. Ecotoxic & Environ. Monitor. 11(3/4): 181-184.

Bhandari, D.C. 1981. Weed vegetation analysis. In: Cropping system Training Programmes, IRRI, Los Banos, Philippines.

Bhargavi, K., Reddy, C.R., Reddy, T.Y. and Reddy, D.S. 2007. The productivity and residual soil fertility status under different of rice based cropping systems in scarce rain fall zone of Andhra Pradesh, India. International. J. Agric. Sci. 3(2): 26-31.

Bhuiyan, N.I. 1988. Daincha green manure: A potential N source for rain fed lowland rice – Work shop IRRI. 108 p.

Black, C.A.1965. Methods of soil analysis Vol.1.Am.Soc Agron. Madison, Wisconsin, U.S.A.

Boparai, B.S. and Yadvinder Singh, S.B.D. 1992. Effect of green manure (*Sesbania aculeata*) on physical properties of soil and growth of wheat in rice-wheat and maize-wheat cropping systems. International Agrophysics. 6(1-2): 95-101.

Bouman, B.A.M. and Tuong, T.P. 2001. Field water management to save water and increase its productivity in irrigated low land rice. Agric. Water Manag., 49 : 11 – 30.

Bronson, K.F., Cassman, K.G., Wassmann, R., Olk, D.C. , Van Noordwijk, M. and Garrity, D.P. 1997. Soil carbon dynamics in different cropping systems in principal eco regions of Asia. (eds., Lal , R., Kimble, J. Follet, R.F. and Stewart. B.A.). *Management of carbon sequestriation in soil.* Boca Raton, Fla (USA): Lewis Publishers. pp. 35 – 57.

Bruun, T. B., Mertz, O. and Elberling, B. 2006. Linking yields of upland rice in shifting cultivation to fallow length and soil properties. Agric. Ecos & Environ. 113(1/4): 139-149.

Byju, G. and George, J. 2005. Potassium nutrition of sweet potato. Adv. Hort. Sci. 19(4): 221-239.

Byju, G. and Ray, R.C. 2002. Effect of graded levels of potassium on yield and yield compnents of sweet potato. Orissa. J. Hort. 30 (2):91-93.

Chander Pal, S., Ram, H.N. and Nand Ram. S. 2007. Response to potassium fractions and their relationship with physico-chemical properties under different nutrient management systems in long-term fertilizer experiment on a Mollisol. Pantnagar J. Res. 5(1): 81-87.

Chandra. R. and Pareek, R.P. 1998. Effect of different green manure crops on growth, yield and N uptake by rice. Oryza. 35 (3): 256 – 259.

Chandrasekhar, C. N., Manian, K. and Kandasamy, O. S. 1998. Studies on allelopathic potential of sesame haulm on physiology and growth of purple nutsedge (*Cyperus rotundus*) and bermuda grass (*Cynodon dactylon*). Indian. J. Weed. Sci. 30 (1/2): 94-95.

Channabasavanna, A.S., Itnal, C.J. and Patil, S.G. 2002. Productivity, economic analysis and changes in physico-chemical properties of soil as influenced by integrated rice (*Oryza sativa*)-based farming systems. Indian. J. Agron. 47(1): 1-5.

Channal, H.T and Kandaswamy, P. 1998. Direct and residual effect of amendments and zinc levels on the utilisation of applied zinc by rice-cowpea cropping system in sodic soil. J. Nuclear. Agric. and Bio. 27(2): 102-107.

Choubey, N. K., Tripathy, R.S., Ghosh, B.C. and Kolhe, S.S. 1998. Effect of water and weed management practices on weed growth and performance of transplanted rice. 35 (3): 252-255.

Danso, S.K.A. and Papastylianou, I.1992. Evaluation of nitrogen contribution of legumes to subsequent cereals. J. Agric. Sci. (Camb.) 119:13-18.

Darshan, P.Y.S.K. and Manju, G.K.N. 2004. Nutrient composition of amaranth (*Amaranthus tricolor*) and kondhara (*Digera arvensis*) leaves and their products. J. Food. Sci and Tech. (Mysore). 41(5): 563-566.

Das, K., Medhi, D. N., Guha, B. and Baruah, B. K. 2002. Direct and residual effects of recycling of crop residues along with chemical fertilizers in rice-wheat cropping system. Ann. Agric. Res. 23(3): 415-418.

Das, N.R. and Datta, B. 1995. Weed flora in rainfed rice-based 3-crop system under biofertilizers and N-levels in West Bengal. World Weeds. 2(1): 11-18.

Debabrata. A.M, S.S. and Saha, M. 2008. Production potential and profitability of different rice (*Oryza sativa*)-based cropping system under integrated nutrient management in Indo-Gangetic plains of West Bengal. Indian J. Agric. Sci. 78(6): 569-572.

Denich, M., Vlek, P.L.G., Sa, T.D., de A., Vielhauer, K. and Lucke, W. 2005. A concept for the development of fire-free fallow management in the Eastern Amazon, Brazil. (Special Issue: Fallow management in the tropics). Agric. Ecosyst & Environ. 110(1/2): 43-58.

Dhiman Mukherjee, S.R.P. 2005. Effect of low doses of herbicides on weeds, nutrient uptake and yield of transplanted rice (*Oryza sativa*). Indian J. Agron. 50(3): 194-196.

Dogbe, S.Y. 1998. Lowlands soil fertility management in Togo through a rice-based cropping system. [Conference paper] Soil fertility management in West African land use systems. *Proceedings of the Regional Workshop*, University of Hohenheim, ICRISAT Sahelian Centre and INRAN, Niamey, Niger, 4-8 March 1997. 147-154.

Donald, C.M. and Humblin. 1976. The biological yield and harvest index of cereals as agronomic and plant breeding criteria. Adv. Agron., 28: 361-405.

Dwivedi, B. S., Shukla, A.K., Singh, V.K. and Yadav, R.L. 2003. Improving nitrogen and phosphorus use efficiencies through inclusion of forage cowpea in the rice-wheat systems in the Indo-Gangetic Plains of India. Field Crop Res. 80(3): 167-193.

Fageria, N.K. 2004. Dry matter yield and nutrient uptake by lowland rice at different growth stages. J. Pl. Nutrit. 27(6): 947-958.

Fageria, N.K. and Baligar, V.C. 2005. Enhancing nitrogen use efficiency in crop plants. Adv. Agron., 88 : 97-185.

FAO/UNESCO.1974. Soil map of the world 1, legend sheet memories. Food and Agricultural Organisation, Paris. p. 59

Farm Guide 2008. Farm Information Bureau, Government of Kerala, Thiruvananthapuram, Kerala, India, 104p.

Gangwar, B., Katyal, V. and Anand, K.V. 2006. Stability and efficiency of different cropping system in Western Himalayan region. Indian J.Agric.Sci., 76 (2): 125 – 135.

Geetha, V. and Varughese, K. 2001. Response of vegetable cowpea to nitrogen and potassium under varying methods of irrigation. J. Trop. Agric. 39 : 111-113.

Ghosh, R.G. and Ghosh, S.K. 2006. Impact of integrated weed management on soil micro-flora in sesame (*Sesamum indicum* L.). J. Crop and Weed. 2 (1): 15-19.

Gnanavel, I. and Kathiresan, R.M. 2002. Sustainable weed management in rice-rice cropping system. Indian J. Weed. Sci. 34(3/4): 192-196.

Gomez, K.A. and A.A. Gomez. 1983. Statistical procedures for Agricultural Research. 2nd edn. John Wiley and Sons, New York. pp. 108-130& 304-308.

Gopalan, C., Rama, S.B.V. and Balasubramanian. S.C. 1990. Nutritive value of Indian foods. National institute of nutrition (NIN). *Indian Council of Medical Research (ICMR).* Hyderabad. 156 p.

Goswami, S.B. 2004. Crop water productivity of crop sequences involving rice (*Oryza sativa*), jute (*Corchorus species*) and vegetables in deep and shallow tube-well commands of lower Gangetic plains region. *Indian J. Agron*., 49 (2) : 89-93.

Gupta, R.P. and Dakshinmoorthy, C. 1980. Procedure for physical analysis of soil and collection of agro meteorological data. IARI, New Delhi.

Gurusamy, L., Hattab, K.O., Vijayakumar, P.S., Suganya, S. and Muthukumar, V. B. 2007c. Nutrient uptake and efficiency of rice under different soil conditions. Asian J. Agric. Res. 1(2): 59-66.

Gurusamy, L., Hattab, K.O., Thavaprakaash, N., Gunasekhar, N. and Vijayakumar, P.S. 2007 a. Impact of sesame (*Sesamum indicum* L.) on succeeding rice and optimization of N to rice (*Oryza sativa* L.). International J. Soil. Sci. 2(3): 224-229.

Gurusamy, L., Hattab, K.O., Gunasekhar, N., Vijayakumar, P.S. and Muthukumar, V. B. 2007 b. Dry matter production, nutrient uptake and yield of rice crop influenced by previous season sesame crop. International J. Agric. Res. 2(8): 704-711.

Harrison, H.I. Jr and Peterson, J. K.1991.Evidence that sweet potato allelopathic to yellow nut sedge *Cyperus esculentus*. Weed. Sci. 39. 308-312.

Hegade, D.M. and Dwivedi, B.S. 1993. Integrated nutrient supply and management as a strategy to meet nutrient demand. Fert. News. 38(12): 49-59.

Hesse, P. R. 1971. A text book of soil chemical analysis. John Murray publishers ltd., London, p. 513

Howeler, R. H. 1990. Phosphorus requirements and management of tropical root and tuber crops. [Conference paper] Phosphorus requirements for sustainable agriculture in Asia and Oceania. *Proceedings of a symposium*, 6-10 March 1989. 427-444.

Humphrey, W. D. 1996. Mineral depletion of a Typic Udivitrand through continuous cropping with sweet potato. [Conference paper] Mineral nutrient disorders of root crops in the Pacific: *Proceedings of a workshop*, Nuku'alofa, Kingdom of Tonga, 65-69.

Ila'ava, V. P., Asher, C. J. and Blamey, F. P. C. 1995. Growth of sweet potato (*Ipomoea batatas* L.) as affected by pH in solution culture. [Conference paper] Plant-soil interactions at low pH: principles and management. *Proceedings of the 3rd International Symposium on Plant-Soil Interactions at Low pH*, Brisbane, Queensland, Australia. 627-630.

Jackson, M.L. 1973. Soil chemical analysis. Prentice Hall of India Inc., New Delhi. p.170.

Jacob, B., George, M. and John, P. S. 1999. Ammonium and nitrate release pattern from residue incorporated rice soils. J. Trop. Agric. 37(1/2): 75-78.

Janiya, J.D. and K. Moody. 1989. Effect of continuous herbicides application on weed growth and yield of transplanted rice (*Oryza sativa*). Philippines J. Weed. Sci., 14: 62-69

Johnkutty, I., Mathew, G., Thiyagarajan, T. M. and Balasubramanian, V. 2000. Relationship among leaf nitrogen content, SPAD and LCC values in rice. J. Trop. Agric. 38(1/2): 97-99.

Kalidurai, M. 1998. Nitrogen fixation and mineralization of *Sesbania rostrata* in rice soil ecosystem. Ann. Agric. Res. 19 (4): 365-369.

Kalpana, R., Palaniappan, S. P. and Rajendran. P. 2000.Effect of preceding grain legume and green manure and rates of N application on rice. Oryza. 37 (3): 248-250.

Kang, B. T. 1993. Changes in soil chemical properties and crop performance with continuous cropping on an Entisol in the humid tropics. [Conference paper] Soil organic matter dynamics and the sustainability of tropical agriculture: *proceedings of an International Symposium*, Leuven, Belgium, 4-6 November 1991. 297-305.

KAU. 2007. Package of Practice Recommendations-Crops, 13th edn., Directorate of Extension, Kerala Agrl. Univ., Thrissur, Kerala. p. 333

Kavimani, R., Vijayabaskaran, S. and Annadurai, K.2001. Nutrient uptake by sesame (*Sesamum indicum* L.) and associated weeds under different methods of sowing and weed management. Madras Agric. J. 87(10-12): 709-711.

Kharub, A. S., Sharma, R. K., Mongia, A. D., Chhokar, R. S., Tripathi, S. C. and Sharma, V. K.2004. Effect of rice (*Oryza sativa*) straw removal, burning and incorporation on soil properties and crop productivity under rice – wheat (*Triticum aestivum*) system. J. Agric. Sci. 74 (6) : 295 -299.

Krishnaprabu, S and Kalyanasundaram, D. 2008. Studies on nutrient management practices on yield attributes and nutrient uptake of sesame in rice fallow. Plt. Arc.8 (2):717-718.

Krishnaprabu, S. and Kalyanasundaram, D. 2007. Influence of chemical and mechanical methods on weed control and productivity of sesame in rice fallow. Pl. Arc. 7 (2): 787-789.

Kuk Yongin., Park, T. D and Kwon, O. D. 2002. Changes of ecological traits of weed species as affected by fallow period in paddy fields. Korean. J. Weed. Sci. 22 (2): 137-146.

Kumar, V. Jayakrishna., Ushakumari, K., Nair, C., Sundaresan., Pusphakumari, R., Nair, V. and Ramachandran. 1993. Economics of high intensity of crop sequences in rice based cropping system. Oryza 30: 302-304.

Kumari, S. M. S. and Ushakumari, K. 2002. Effect of vermicompost enriched with rock phosphate on the yield and uptake of nutrients in cowpea (Vigna unguiculata L. Walp). J. Trop. Agric. 40: 27-30.

Lee Kwang Hoe. 2007. Comparison of weed occurrence and growth of some leguminous plants for green manure cover crop during summer fallow. Korean. J. Crop. Sci. 52(2): 169-175.

Lindsay, W. L. and Norvell, W. A.1978. Development of a DTPA soil test for zinc, copper, iron and manganese. Soil. Sci. Soc. Am. J. 42: 421-428

Lugo, T. M. L. and Diaz, M. 2007. Weed control in sweet potato [*Ipomoea batatas* (L.) Lam.]. J. Agric. University. Puerto Rico. 91 (¾): 161-167.

Lund, J. F. and Dass, B. D. 1980. Residual effect on dairy, cattle manure on the plant growth and soil properties. Agron. J. 71: 121-130.

Madhu, M., Sheshachalam, N,. Nalatwadmath, S. K. and Nimje, P. M. 1996. Effect of organic and inorganic fertilizers on the yield of the crops and physico chemical properties of the soil in the high hills of Nilgiris. Paper presented at the *National seminar on organic faming and sustainable agriculture,* 9-11 October, 1996, Bangalore.

Mahapatra, B. S., Kandpal, B. K. and Sharma, G. L. 2002. Summer legumes in relation to productivity and fertility in rice-wheat cropping system. Ann. Agric. Res. 23(3): 365-370.

Mandal, U. K., Sharma, S. N. and Gurcharan Singh Das, D. K. 1999. Effect of Sesbania green manuring and greengram (*Phaseolus radiatus*) residue incorporation on physical properties of soil under rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system. J. Agric. Sci. 69(9): 615-620.

Mathew, G. and Sreenivasan, E. 1998. Effect of weed control methods on yield and economics of rainfed and rice fallow summer cowpea. Madras. Agric. J. 85(1): 50-52.

Mathew, J., Mathew, R., Varughese, K., Santhakumari, G. and Pillai, G. R. 1996. Influence of summer cropping and fallowing on fertilizer use efficiency and productivity of rice. J. Trop. Agric. 34:(2): 142-144.

Meena, M. M. and Hameed, S. M. 2002.Effect of microbial inoculants and phosphorus levels on growth and phosphorus nutrition of vegetable cowpea. J. Trop. Agric. 40 : 74 -77.

Menon, M. V. and Nair, M. A. 1993.Performance of some fodder legumes in rice fallows. J. Trop. Agric. 31(2): 246-248.

Menon, M. V., Nair, M. A. and Potty, N. N. 1999 a. Effect of summer cropping and fallowing on the productivity of rice lands. J. Trop. Agric. 37(1/2): 83-84.

Menon, M. V., Nair, M. A. and Potty, N. N. 1999 b. Effect of preceding fodder crops and fallow on productivity mechanics in first crop season rice. J. Trop. Agric. 37(1/2): 85-86.

Mishra, B. N., Prasad, R. and Gangaiah, B. 2004. Organic manures for increased rice productivity and sustained supply of Fe to rice. Acta Agronomica Hungarica. 52(4): 391-397.

Mishra, B. N., Prasad, R., Gangaiah, B. and Shivakumar, B. G. 2006. Organic manures for increased productivity and sustained supply of micronutrients Zn and Cu in a rice-wheat cropping system. J. Sustain. Agric. 28(1): 55-66.

Misra, P. N., Tewari, S. K. and Dheer Singh. 1993. Studies on the critical stages of crop weed competition in grain amaranth (*Amaranthus hypochondriacus*). Integrated weed management for sustainable agriculture. *Proceedings of an Indian Society of Weed Science International Symposium*, Hisar, India. Vol. II : 33-35.

Mondal, S. S. and Chettri, M. 1998. Integrated nutrient management for sustaining productivity and fertility under rice (*Oryza sativa*)-based cropping system. Indian J. Agric. Sci. 68(7): 337-340.

Mortimer, M. and Hill, J.E.. 1999. Weed species shifts in response to broad spectrum herbicides in sub tropical and tropical crops. Brighton Crop Protection Conference: Weeds. 2: 425 – 437.

Mythili, S., Natarajan, K., Palaniappan, S.P. and Pushpavalli,R. 1993. Influence of green manures (GM) *Sesbania acculata* on Zn and S translocation in rice. International Rice Research Institute, Philiphines Newsl. 18:27.

Nagalikar, V. P., Setty, R. A and Channabasavanna, A. S. 1999. Economic analysis of rice (*Oryza sativa*)-based cropping system for Tungabhadra project area. Indian J. Agron. 44(3): 456-458.

Nalini, K., Jayanthi, C. and Vennila, C. 2008. Dual cropping in semidry rice - a review. Agric. Reviews. 29(2): 151-156.

Nambiar, K. K. M. 1994. Soil fertility and crop productivity under long term fertilizer in india. Publication and information division, ICAR, Pusa, New Delhi.

Nanda, S. S., Patro, G. K., Alim, M. A. and Mohananda, N. 1999. Efficiency of rice (*Oryza sativa*)-based crop sequences under coastal ecosystem. Indian J. Agron. 44(3): 452-455.

Narang, R. S., Cheema, S.S., Grewal, D.S., Grewal, H.S., Sharma,B.D. and Dev. G.1990. Yield nutrient removals and changes in soil fertility under intensive rice - wheat cropping system. Indian J. Agron. 35(1 and 2): 113-119.

Natarajan, S. 2007. Major weed flora of transplanted rice and rice fallow blackgram fields at Annamalainagar, Tamil Nadu. J. Ecobiol. 19(1): 77-80.

Nedunchezhiyan, M. and Satapathy, B. S. 2002 b. Effect of weed management practices on weed dynamics in sweet potato. J. Root. Crops. 28 (2): 73-77.

Nedunchezhiyan, M. 1996. Ecological studies on weed flora associated with sweet potato. Orissa. J. Hort. 24 (½): 69-73.

Nedunchezhiyan, M. and Satapathy, B. S. 2002 a. The effect of weed management practices on nutrient uptake of weeds in sweet potato. Orissa. J. Hort. 30(2): 110-112.

Newaj, R. and Yadav, D.S. 1994.Changes in the physico - chemical properties of the soil under intensive cropping system. Indian J. Agron. 39(3): 373-378.

Ngouajio, M. and McGiffen, M. E. 2004. Sustainable vegetable production: effects of cropping systems on weed and insect population dynamics. Acta. Hort. 638: 77-83.

Niranjana, N. S. 1998. Bio farming in vegetables – effect of bio fertilizers on amaranth (Amaranthus tricolor). M.Sc. Thesis, Vellanikkara, Thrissure, Kerala Agricultural University.182 p.

Olasantan, F. O. 2007. Effect of population density and sowing date of pumpkin on soil hydrothermal regime, weed control and crop growth in a yam-pumpkin intercrop. Exp. Agric. 43(3): 365-380.

Olekar, J. N., Venkatraman Naik, A. D., Kerur, N. M. and Hiremath, G. M. 2000. An economic analysis of rice based crop sequences. Karnataka. J. Agric. Sci. 13(4): 897-900.

Olsen, R. J., Henslar, R. F. and Alloe, O. J. 1970. Effect of manure application, aeration and soil pH on Soil N transformations and on certain soil test values. Soil. Sci. Agric. Proc. 34: 222-225

Onyango, C. M., Shibairo, S. I., Imungi, J. K. and Harbinson, J. 2008. The physico-chemical characteristics and some nutritional values of vegetable amaranth sold in Nairobi-Kenya. Ecol. Food. Nutrit. 47(4): 382-398.

Osten, V., Hashem, A., Koetz, E., Lemerle, D., Pathan, S. and Wright, G. 2006. Impacts of summer fallow weeds on soil nitrogen and wheat in the southern, western and northern Australian grain regions. 15th *Australian Weeds Conference, Papers and Proceedings,* Adelaide, South Australia, 24-28 September 2006: Managing weeds in a changing climate. 395-398.

Padhi, A. K. 1993. Productivity and economics of rice (*Oryza sativa*) – based cropping sequences. Indian J. Agron. 38(3): 351-356.

Padmaja, G. and Raju, A. S. 1999. Response of sweet potato (*Ipomoea batatas* L.) to potassium fertilization. J. Res. ANGRAU. 27(1/2): 24-29.

Padmaja, P., Menon, P. K. G., Rao, G. S. L. V., Chinnamma, N. P., Geethakumari, V. L., George, K. C. and Kumari, P. S. 1993. *Sustaining rice productivity through integrated nutrient management,* Kerala Agricultural University, Vellanikkara, Thrissur, Kerala, India.

Paikaray, R. K., Mahapatra, B. S. and Sharma, G. L. 2002. Effect of organic and inorganic sources of nitrogen on productivity and soil fertlity under rice (*Oryza sativa*) – wheat (*Triticum aestivum*) crop sequence.

Palaniappan, S. P. 1985. Cropping system in the tropics – principles and management. Willey Eastern Ltd., New Delhi

Palanisamy, K.H. and K.A. Gomez. 1974. Length width method for estimating leaf area of rice. Agron. J., 66: 430-433.

Panda, S. C., Mohanthy, K., Sahoo, H. K. and Sahoo, B. C.1999.Effect of continuous manuring in rice – rice cropping system. Oryza.36 (2): 139-142.

Pathak, A. K. and Ghose, T.J. 1996. Nutrient management in rice – rice cropping system. Fert. News 41(8): 55-58.

Patro, H., Mahapatra, B. S., Sharma, G. L. and Kumar.A. 2005. Total productivity, nitrogen, phosphorus and potassium removal and economics of rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system with integrated nitrogen management in rice. Indian J. Agron., 50(2): 94-97.

Paul, I. K. and Savithri, K. E. 2003. Effect of biofertilizers vs perfected chemical fertilization for sesame grown in summer rice fallow. J. Trop. Agric. 41(1/2): 47-49.

Phogat, S. B., Dahiya, I. S., Hooda, R. S., Sangwan, N. K. and Solanki, Y. P. S. 2004. Studies on residual effect of green manuring and farm yard manure for sustained productivity of rice-wheat cropping sequence and on soil health under shallow groundwater table conditions. Ann. Biol. 20(2): 161-165.

Pillai, P. S., Geethakumari, V. L. and Issac, S. R. 2007. Balance-sheet of soil nitrogen in rice (*Oryza sativa*)-based cropping systems under integrated nutrient management. Indian. J. Agron. 52(1): 16-20.

Pillai, S. P. 1998. Integrated nutrient management for rice based cropping systems of Onattukara tract. Ph.D. Thesis, Vellanikkara, Thrissure, Kerala Agricultural University.340 p.

Piper, C. S. 1950. Soil and plant analysis second edn. University of Adilaide, Australia

Porwal, M. K. 2002. Relative economics of weed management systems in winter sweet potato (*Ipomoea batatus* L.) in command area of Southern Rajasthan. Indian. J. Weed. Sci. 34 (½): 88-91.

Prasad, U. K., Prasad, T. N., Narayan, S. and Kumar, A. 1997. Effect of soil moisture regimes on sweet potato yield, potassium balance and water use efficiency. J. Potassium. Res. 13(3/4): 283-289.

Preetha, D., Sushama, P.K. and Marykutty, K.C. 2005. Vermicompost + inorganic fertilizers promote yield and nutrient uptake of amaranth (*Amaranthus tricolor* L.). J. Trop. Agric. 43 (1-2): 87-89.

Premasthira, C. and Zungsontiporn, S. 1999. Allelopathic effects of sesame (*Sesamum indicum* L.) residues on crop growth. [Conference paper] Biodiversity and allelopathy: from organisms to ecosystems in the Pacific. *Proceedings of PSA Symposium*, Taipei, Taiwan. 281-288.

Punia, S. S., Mayank, R. A. and Yadav, M. R. K. 2001. Bioefficacy of dinitroaniline herbicides against weeds in sesame (*Sesamum indicum* L.). Indian. J. Weed. Sci. 33 (¾): 143-146.

Pushpakumari.R., Vijayraghavkumar., Shahul Hameed,S.M. and Ramachandran.N. 1991. Maximisation of profit through high intensity cropping sequences in rice based cropping system.Proc. 3rd Kerala Sci Cong. 28th Feb – 3rd March. State committee on science and technology and environment, Government of Kerala, Trivandrum pp 132-133.

Puste, A. M., Bandyopadhyay, S. and Das, D. K. 2001. Economy of fertilizer nitrogen through organic sources in rain-fed rice-legume cropping systems in West Bengal, India. The ScientificWorld. 1: tsw.2001.456, 722-727.

Quayyum, M. A. and Maniruzzaman, A. F. M. 1996. Effect of preceding crops on yield of succeeding transplanted aman rice (*Oryza sativa*). Indian. J. Agron 41(3): 349-353.

Rahman, M. A., Gaffer, M. A., Hossain. S. M. A. and Tareque, A. M. M. 1998. Nitrogen balance sheet under forage cropping system in the old Brahmaputra flood plain soils. Indian J. Agron. 43(2): 269-272.

Raj, S. M., Pramanik, S. C. and Sagar, R. L. 1999.Productivity and profitability of lowland rainfed rice (*Oryza sativa*)-based cropping sequences in Andaman. Indian. J. Agric. Sci. 69(8): 543-546.

Rajan, S. 2000. Integrated weed management for rice based cropping system of Onattukara tract. Ph.D. Thesis, Vellanikkara, Thrissure, Kerala Agricultural University.254 p.

Ramamoorthy, K. 1991. Effect of integrated weed management on nutrient uptake by upland rice and associated weeds. Indian. J. Agron. 36 (2): 213-217.

Ramanathan, S. P., Nagarajan, R. and Balasubramanian, V. 2000. Assessment of chlorophyll meter-based N application at critical growth stages of irrigated transplanted rice. International. Rice. Res. Notes. 25(2): 34-35.

Ramesh, K. and Chandrashekharan, B. 2004. Soil organic carbon build up and dynamics in rice – rice cropping system. J. Agron. and Crop Sci.,190 (1): 21 – 27.

Ramesh, K., Chandrasekaran, B., Balasubramanian, T. N., Bangarusamy, U., Sivasamy, R. and Sankaran, N. 2002. Chlorophyll dynamics in rice (*Oryza sativa*) before and after flowering based on SPAD (chlorophyll) meter monitoring and its relation with grain yield. J. Agron. and. Crop. Sci. 188(2): 102-105.

Rana,S. S. and Angiras, N. N. 1999. Influence of integrated weed management practices on weed competition for nutrients in puddle-sown rice. Indian J. Weed. Sci. 31(3/4): 161-163.

Reddy, K.C., Visser, P. and Buckner, P. 1992. Pearl millet and cow pea yields in sole and inter crop systems, and their after effects on soil and crop productivity. Field Crops Res. 28:315-326.

Reddy, M. N,. Sitaramayya,M., Narayan swamy, S,. Sairam, A. and Krishna kanth, G.1999. Productivity and soil fertility changes under continuous fertilization of rice (Oryza sativa) – rice cropping system.Indian. J. Agric. Sci. 69 (6): 395-398.

Reddy, N. S., Reddy, G. P. and Reddy, T. Y. 1995. Nutrient uptake and yield of semi-dry rice (*Oryza sativa*) as influenced by preceding crops. J. Res. APAU. 23(3/4): 97-99.

Regy, V.J. 1996. Improving fertilizer use efficiency in sesamum (*Sesamum indicum* L.) in Onattukara tract. M.Sc. (Ag.) Thesis. Kerala Agricultural University, Vellanikkara, Thrissur p 132.

Renault, D. and Wallender, W .W . 2000. Nutritional water productivity and diets. Agric. Water Mgmt, 45 (3): 275-296.

Roy, C. S., Kannan, K. and Ashwanti, K. 2007.Suppression of weed growth in sweet potato (*Ipomea batatus* L) field under different irrigation regimes. Orissa. J. Hort. 35 (1):109-111.

Roy, D. K. 1997. Production potential of rice (*Oryza sativa*)-based cropping systems under deep water ecosystem of north Bihar. Indian J. Agron. 42(4): 570-572.

Saha, P. K., Ishaque, M., Saleque, M. A., Miah, M. A. M., Panaullah, G. M. and Bhuiyan, N. I. 2007. Long-term integrated nutrient management for rice-based cropping pattern: effect on growth, yield, nutrient uptake, nutrient balance sheet, and soil fertility. Communications in Soil Science and Plant Analysis. 38(5/6): 579-610.

Samui, R. C. and Subhendu. M. D. D. 2006. Effect of diversification of rice-wheat cropping system on weed population and weed dry weight. *In*: 15^{th} *Australian Weeds Conference, Papers and Proceedings,* Adelaide, South Australia, 24-28 September 2006: Managing weeds in a changing climate: 414-416.

Samui, R. C., Hazarika, B., Maity, S. and Roy, A. 1995. Fertilizer management in rice-based crop sequences for sustained production in sub-humid zones. [Conference paper] *Proceedings national symposium on sustainable agriculture in sub-humid zone*. 130-132.

Sasidhar.V. K.1978.Studies on the effect of multiple cropping on the soil fertility and crop yield in wet lands. Ph.D. Thesis Kerala Agricultural University. pp 40-50.

Sathyamoorthy, N. K., Mahendran, S., Babu, R. and Ragavan, T. 2004. Effect of integrated weed management practices on total weed dry weight, nutrient removal of weeds in rice-rice wet seeded system. J. Agron. 3(4): 263-267.

Savithri, P., Poongothai, S., Biju, J. and Vennila. R. K. 1999.Non conventional souces of micronutrients for sustaining soil health and yield of rice-green gram cropping system. Oryza. 36 (3): 219 – 222.

Schulz, S., Keatinge, J. D. H. and Wells, G. J. 1999. Productivity and residual effects of legumes in rice-based cropping systems in a warm-temperate environment. II. Residual effects on rice. Field. Crops. Res. 61(1): 37-49.

Selvi, D. and Selvaseelan, A. 2003. Effect of mushroom spent rice straw compost on nutrient availability on laterite soils of Niligris during potato crop growth. Int. J. Trop. Agri. 21 (1-4): 99-107.

Sharma, A. R. and Das, K. C. 1994. Effect of green manuring with dhaincha (*Sesbania aculeata*) on growth and yield of direct-sown and transplanted rice under intermediate deepwater conditions (0-50 cm). J. Agric. Sci. 122(3): 359-364.

Sharma, A. R. and Mitra, B. N. 1990.Complementary effect of organic materials and phosphorus fertilizer in rice (*Oryza sativa*) – based cropping system. Indian. J. Agron. 36 (3): 297-302.

Sharma, M. P., Bali, S. V. and Gupta, D. K. 2001. Soil fertility and productivity of rice (*Oryza sativa*) - wheat (*Triticum aestivum*) cropping system in an Inceptisol as influenced by integrated nutrient management. Indian J. Agric. Sci. 71(2): 82-86.

Sharma, S. N., Prasad, R. and Singh, R. K. 2000. Influence of summer legumes in rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system on soil fertility. Indian J. Agric. Sci. 70(6): 357-359.

Sheeba, S. and Kumarasamy, K. 2002. Influence of continuous cropping and fertilization on physical properties of rice soil. Madras. Agric. J. 88(10/12): 728-730.

Shrikant C., Narendra P and Urkurkar, J. S. 2007. Effect of planting method, tillage and weed management on productivity and physico-chemical properties of rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system. Indian. J. Agron. 52(4): 283-288.

Siddeswaran, K. 1992. Integrated nitrogen management with green manure and grain legume in rice - based cropping systems. Ph.D Thesis. Tamil Nadu Agricultural University, Coimbatore p 158.

Singh, B. P., Prakash, O.M. and Singh, P.K.2003 a.Dry matter accumulation in weeds and qualitative character of sesame (*Sesamum indicum*) as influenced by nitrogen levels and weed control measures. Indian. J. Agron. 48 (2): 120-123.

Singh, G., Kumar, T., Kumar, V., Singh, R.G. and Sharma, R.B. 2002. Effect of INM on transplanted rice (*Oryza sativa*) and its residual effect on succeeding wheat (*Triticum aestivum*) crop in rainfed low lands. Indian J. Agron., 47 : 311-317.

Singh, L. N., Singh, T. R. and Bhanisana, R. K. 2008. Production potential and economics of a few rice-based cropping systems with fodder crops under upland rainfed condition of Manipur. J. Interacademicia. 12(1): 27-31.

Singh, N. B. and Verma, K. K. 1999. Impact of selected rabi crops on productivity and nitrogen economy in rice based cropping system. *Oryza*. 36(1): 89-91.

Singh, U., Patil, S. K., Das, R. O., Padilla, J. L., Singh, V. P. and Pal, A. R. 1999. Nitrogen dynamics and crop growth on an alfisol and a vertisol under rainfed lowland rice-based cropping system. Field. Crops. Res. 61(3): 237-252.

Singh, V. K. and Sharma, B. B. 2002. Economic evaluation of rice (*Oryza sativa*)-based cropping sequences in the foothills of Himalayas. Indian J. Agron.47(1): 12-19.

Singh, V. K., Dwivedi, B. S., Shukla, A. K. and Yadav, R. L. 2003 b. Effects of nitrogen and phosphorus fertilization on the growth and yield of rice (*Oryza sativa*) and wheat (*Triticum aestivum*) as influenced by the inclusion of forage cowpea (*Vigna unguiculata*) in rice-wheat system. Indian J. Agric. Sci. 73(9): 482-489.

Singh, V.K., Varma, S. C. and Singh, R. P. 2001. Effect of integrated nutrient supply on growth, yield, nutrient uptake, economics and soil fertility in irrigated rice. *Oryza*. 28 (1&2): 56-60.

Singh, Y., Chaudhary, D. C., Singh, S.P., Bharadwaj, A. K. and Singh, D. 1996. Sustainability of rice-wheat sequential cropping through the introduction of legume crops and green manure crop in the system. Indian J. Agron. 41(4): 510-514.

Singh, Y., Khind, C.S.and Singh, B.1991.Efficient management of leguminous green manures in wet land rice. Adv. Agron. 45:135-189.

Singha, D.D., Sarma, N.N. and Sarma, A.1993. Effect of rice (*Oryza sativa*) based cropping sequences on soil chemical properties and available nutrients. Indian J. agric. Sci. 63(10): 644-646.

Sriramachandrasekharan, M. V., Bhuvaneswari, R. and Ravichandran, M. 2004. Integrated use of organics and sulphur on the rice yield and sustainable soil health in sulphur deficient soil. Pl. Arch. 4(2): 281-286.

Subbaiah, B.V. and G. Asija. 1956. A rapid procedure for the estimation of available nitrogen in soils. Curr. Sci., 25: 259-260.

Subhash Chandra Gautam, R. C. 1997.Effect of preceding crops and nitrogen rates on N-uptake by rice and soil fertility. Ann. Agric. Res. 18(4): 460-464.

Subramanyam, D., Raghav reddy. C. and Srinivasulu reddy, D.2007.Effect of puddling, water and weed management on yield and nutrient uptake in transplanted rice and associate weeds. J. Res. ANGRAU. 35 (2): 9 - 15.

Sudhir, S., Atul Bhargava, C. A., Srivastava, J., Singh, N. and Singh, S. P. 2006. Mineral profile and variability in vegetable amaranth (*Amaranthus tricolor*). Plant Foods for Human Nutrition. 61(1): 23-28.

Suresh. K S. N. 1998. Vermicompost as a potential organic source and partial substitution for inorganic fertilizer in sweet potato (*Ipomoea batatus* (L.) Lam.) 117 p.

Ten Hare, R. 1977. Outlines for filling out the coding forms. All India Coordinated Rice Improvement Project, Rajendranagar, Hyderabad, India.

Thakur, A. K. S. 2005.Effect of sowing method and weed control practices on production potential of sesamum (*Sesamum indicum*)-based intercropping system under rainfed condition. Indian. J. Weed. Sci. 37 (1/2): 133-134.

Thakur, R. B., Chaudhary, S. K. and Jha, G. 1999. Effect of combined use of green-manure crop and nitrogen on productivity of rice (*Oryza sativa*)-wheat (*Triticum aestivum*) system under lowland rice. Indian J. Agron. 44(4): 664-668.

Thirumurugan, V., Venkataraman, N.S. and Veerbadran, V. 1992. Effect of summer ploghing and puddling implements on weeds and grain yield of low land rice. *In*: *Annual weed science conference,* March 3-4, Haryana Agriculture University, Hissar. P. 44.

Thomas, C.G and Abraham,C.T. 1998. Common weeds in rice ecosystems of Kerala and their management. Kerala Agricultural University, Thrissur.80.P

Tomar, S.S. 1991. Agronomic and economic evaluation of herbicides in transplanted rice. IRRN. 16(2): 24.

Tran, Q., Tuyen, C. V., Phung, T. and Kim, T. 2006. Influence of long term application of N, P, K fertilizer on soil pH, organic matter, CEC, exchangeable cations and some trace elements. Omonrice. 14: 144-148.

Tripathi, S. S. and Govindra Singh. 2001. Critical period of weed competition in summer cowpea [*Vigna unguiculata* (L.) Walp.]. Indian. J. Weed. Sci. 33 (½): 67-68.

Tulasi,T. 2007. Integrated nutrient management for basmati rice (*oryza sativa* l.) production. M.Sc. Thesis, Vellanikkara, Thrissure, Kerala Agricultural University.153 p.

Urkurkar, J. S., Chitale, S., Tiwari, A., Savu, R. M., and Tomar, H. S. 2008. Identification of promising rice (*Oryza sativa*) based cropping system for increasing productivity and sustainability for Chhattisgarh plains. J. Farming Syst. Res. and Developt. 14(1): 50-55.

Usman, A., Bala, A., Tiamiyu, S. A. and Alabi, M. O. 2006. Use of legumes for maintenance of rice yield in lowland rice-based cropping systems in Nigeria. J. Sust. Agric. 29(1): 43-51.

Varughese, K. 2006. Production potential of high value cropping system in coastal ecosystem.Indian. J. Agron. 51 (1): 21-23.

Venkatakrishnan, A. S. and Gnanamurthy, P. 1998. Influence of varying period of crop-weed competition in sesame. Indian J. Weed. Sci. 30(3/4): 209-210.

Verma, K. P. and Warsi, A. S. 1999. Evaluation of suitable rice-based (*Oryza sativa*) cropping system for central plain zone of Uttar Pradesh. Indian J. Agron. 44(3): 444-447.

Verma, O.P.S., Katyal, S.K. and Bhavan, V.M. 1987. Studies on relative efficiency of promising herbicides in transplanted rice. Indian J. Agron. 32: 374-377.

Walkley, A. and I.A. Black. 1934. An examination of the effect of degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci., 37: 29-38.

Wang, E. C. H. and Yu Qiang, V. K. 2008. Summer forage cropping as an effective way to control deep drainage in south-eastern Australia - a simulation study. Agric. Ecosyst & Environ. 125(1/4): 127-136.

Wassmann,R., .Lantin, R.S and H.U.Neue (eds.). 2000. Methane emission from major rice ecosystem in Asia. Developments in plant and soil sciences, Volume 91. Dordrecht (the Netherlands.), Kluwer Academic Publishers, 395 p.

Wu, J. H. and Yan, C. 1992.Multiple cropping patterns in the single rice cropping area. Zhejiang Nongye Kexue. 1: 7-9.

Yadav, D.S., Kumar, A. Singh, R.M. and Ram, A.1991. Yield, economics and nutrient balance in cropping systems based on rice (*Oryza sativa*). Indian J. agric. Sci. 61(12):872-876.

Yadav, S. S. 2004. Integrated weed management in sesame (Sesamum indicum L.) under rainfed conditions of Rajasthan. Haryana. J. Agron. 20 (½): 120-121.

Yamada, S., Okubo, S., Kitagawa, Y. and Takeuchi, K. 2007. Restoration of weed communities in abandoned rice paddy fields in the Tama Hills, central Japan. Agric, Ecos & Environ. 119(1/2): 88-102.

Yoshida, S. 1981. Effect of mineral nutrition on tillering of rice. Soil Sci. Plant Nutr., 16 : 186-191.

Yoshida,S., D.A. Farno, J.H. Cook and K.A. Gomez. 1976. Laboratory manual for physiological studies of rice. 3rd edn., IRRI, Philippines. pp. 7-76.

Zamir, M. S. I., Ahmad, R. and Haq, A. U. 2005. Performance of rice in different rice-based cropping systems sown after different legume and non legume crops. J. Animal and Pl. Sci. 15(3/4): 79-81.

Appendices

APPENDIX – I a

Meteorological information (week wise) for entire summer season during 2008

Month	Standard week from	Standard week	Temperature ^{0}C		RH (%)	Rainfall (mm)	Evaporation (mm)
			Max.	Min.			
Feb 08	12-18	7	32.06	23.09	82.50	17.60	3.9
	19-25	8	32.43	22.59	83.29	0.00	4
Mar 08	26-3 Mar	9	32.71	23.19	84.15	3.10	4
	4-10	10	32.21	22.54	76.29	6.20	5.4
	11-17	11	31.34	24.18	91.19	77.60	3.4
	18-24	12	29.34	23.43	94.29	9.80	0.9
April 08	25-31 Mar	13	32.03	24.34	86.07	9.20	4
	1-7 Apr	14	32.14	24.63	83.57	13.80	4.1
	8-14	15	31.29	24.06	87.22	59.80	3.3
	15-21	16	32.74	24.90	81.72	14.40	4.4
	22-28	17	32.73	25.96	84.57	3.00	4.1
May 08	29-5May	18	32.63	26.03	84.65	12.40	4.1
	6-12 May	19	32.57	25.83	81.15	0.00	4.2
	13-19 May	20	32.31	25.66	84.07	32.00	4.5
	20-26 May	21	32.23	25.20	83.65	63.20	3.9
June 08	27-2 June	22	30.6	24.1	86.20	86.80	3.1
	3-9	23	31.9	23.2	85.85	30.20	3.7
	10-16	24	31.0	23.4	85.90	0.50	3.4
	17-23	25	30.6	23.1	86.30	16.40	3.5

APPENDIX – I b

Meteorological information (week wise) for entire virippu season during 2008

Month	Standard week from	Standard week	Temperature ^{0}C		RH (%)	Rainfall (mm)	Evaporation (mm)
			Max.	Min.			
June 08	24-30	26	30.6	23.4	87.55	38.10	3.2
July 08	1-7	27	31.1	23.5	84.95	30.00	3.5
	8-14	28	30.9	23.5	85.30	28.20	3.6
	15-21	29	29.40	22.36	78.96	63.40	2.91
	22-28	30	27.2	22.2	84.30	99.80	2.1
	29- Aug 4	31	28.9	22.3	86.80	19.80	2.7
Aug 08	5-11	32	29.7	23.1	87.15	41.20	3.1
	12-18	33	29.7	23.0	87.30	15.20	3.1
	19-25	34	31.5	23.1	88.20	0.00	3.7
Sept 08	26- Sep1	35	29.7	22.4	89.65	264.00	3.2
	2-8	36	29.7	22.3	89.40	275.80	3.2
	9-15	37	29.70	22.00	86.29	60.60	3.40
	16-22	38	30.40	22.94	85.07	14.80	3.94
	23-29	39	30.91	22.91	76.57	0.00	3.97
Oct 08	30- Oct 5	40	31.70	23.27	81.34	0.00	4.20

APPENDIX – II

BASIC DATA

Basic data used for calculating the cost of cultivation and net returns (Rs. ha^{-1}) are furnished below.

A. Cost of labour

1. Hire charge for tiller - Rs. 275 hr^{-1}
2. Man labour - Rs. 225 hr^{-1}
3. Woman labour - Rs. 200 hr^{-1}

B. Cost of manures, fertilizers

1. Farmyard manure - Rs. 300 t^{-1}
2. Nitrogen - Rs. 5 kg^{-1}
3. Phosphorus - Rs. 4.70 kg^{-1}
4. Potassium - Rs 4.80 kg^{-1}

C. Cost of seeds or vines

1. Sweet potato - Rs. 0.10 $vine^{-1}$
2. Pumpkin - Rs. 1500 kg^{-1}
3. Sesamum - Rs. 75 kg^{-1}
4. Amaranthus - Rs. 1000 kg^{-1}
5. Cowpea - Rs. 1200 kg^{-1}
6. Daincha - Rs. 50 kg^{-1}

D. Cost of economic produce

1. Sweet potato - Rs. 7 kg^{-1}
2. Pumpkin - Rs. 10 kg^{-1}
3. Sesamum - Rs. 60 kg^{-1}
4. Amaranthus - Rs. 10 kg^{-1}
5. Cowpea - Rs. 20 kg^{-1}
6. Daincha - Rs. 1 kg^{-1}
7. Paddy - Rs. 10 kg^{-1}

APPENDIX – III

YIELD SUMMER CROPS

Treatments	Crop	Fresh weight (Kg ha^{-1})	Moisture %	Dry weight (Kg ha^{-1})
T1	Fallow	0	0	0
T2	Sweet potato (tuber)	21296	77.00	4898
T2	Sweet potato (vine)	41482	71.00	12030
T3	Pumpkin (fruit)	17014	91.50	1446
T3	Pumpkin (vine)	6090	93.54	393
T3	Pumpkin (Leaves)	3076	90.74	285
T4	Sesamum (seed)	234	4.81	222
T4	Sesamum (vegetative matter)	10390	60.00	4156
T5	Amaranthus	33388	90.00	3339
T6	vegetable cowpea(pods)	5191	86.00	727
T6	vegetable cowpea(vines)	13003	87.26	1656
T6	vegetable cowpea(Leaves)	12493	89.58	1301
T7	Daincha	14386	65.00	5035

PERFORMANCE OF SUMMER CROPS IN RICE FALLOWS AND ITS EFFECT ON SUCCEEDING TRANSPLANTED RICE

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ABSTRACT

A field experiment entitled "Performance of summer crops in rice fallows and its effect on succeeding transplanted rice" was taken up at the Cropping systems research station, Karamana, Thiruvananthapuram during February 2008 to October 2008 that covered the summer (third crop) and virippu (the first crop) seasons of rice cultivation. The main objectives of the experiment was study the performance of different upland crops in the summer rice fallows of southern Kerala in terms of resource utilisation, yield, soil health and carry over effect on succeeding rice crop, and to arrive at a sound practice of summer rice fallow utilization. The experiment was laid out in a randomised block design with three replication and seven treatments (T_1 - Control or summer rice fallow, T_2 - Sweet potato, T_3 - Pumpkin, T_4 - Sesamum, T_5 - Amaranthus, T_6 – Cowpea and T_7 - Daincha) which were followed by rice crop in the virippu season. Al the crops were raised as par the KAU package of practices recommendations.

Results of the study revealed that there was a significant variation in the composition of weed flora of summer crops and the succeeding rice crop. The associated weed species of summer crop also varied significantly. Cowpea (T_6) being grown on pandal had no weed separation effect and hence had the higher WDMP and SDR. Amaranthus (T_5) recorded the highest economic yield and rice yield equivalent, water productivity, net profit and B:C ratio. However, sweet potato (T_2) recorded the highest energy yield per unit area and highest nutrient uptake of macro and micro nutrients. The nutrient balance sheet showed a general negative balance for N and P except for sweet potato (T_2) and Daincha (T_7) where as K showed a negative balance for all treatments.

The succeeding rice crop was not significantly influenced by the summer crops with respect to yield and yield attributes. The post rice soil was left less acidic by pumpkin-rice sequence, where as Daincha-rice significantly increased the soil acidity. The post rice soil significantly varied in the available P and K with the highest value noted in Amaranthus-rice (T_5). Significantly higher quantity of Zn was recorded in Daincha-rice (T_7).