ORGANIC NUTRITION IN TARO
(*Colocasia esculenta* (L.) Schott)

by

LIMISHA N. P.
(2018 - 21 - 006)

THESIS

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DECLARATION

I, hereby declare that this thesis **"ORGANIC NUTRITION IN TARO (*Colocasia esculenta* (L.) Schott)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"ORGANIC NUTRITION IN TARO (*Colocasia esculenta* (L.) Schott)"** is a record of research work done independently by Ms. Limisha N. P. (2018-21-006) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Limisha N P

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LIST OF ABBREVIATIONS

Al	Aluminium
Al^{3+}	Aluminium cation (charge of +3)
ANOVA	Analysis of variance
B	Boron
BCR	Benefit cost ratio
BR	Bulking rate
C	Carbon
Ca	Calcium
CD	Critical difference
Cl	Chlorine
cm	Centimetre
cm^2	Square centimetre
C:N	Carbon : Nitrogen
CRD	Completely randomized design
CTCRI	Central Tuber Crops Research Institute
Cu	Copper
DAS	Days after sowing
DMP	Dry matter production
dS m^{-1}	deci Seimens per metre
EC	Electrical conductivity
EPS	Extracellular polymeric substances
et al.	Co-workers/ Co-authors
Fig.	Figure
Fe	Iron
FYM	Farmyard manure
g	Gram
ha	Hectare
ha^{-1}	Per hectare
IAA	Indole-3- acetic acid
ICAR	Indian Council of Agricultural Research
INM	Integrated nutrient management
i.e.	That is

K	Potassium
K_2O	Potassium oxide
KAU	Kerala Agricultural University
kg	Kilogram
kg ha^{-1}	Kilogram per hectare
L	Litre
log cfu g^{-1}	Logarithm of colony forming unit per gram
LAI	Leaf area index
MAP	Month after planting
Mg	Magnesium
mg g^{-1}	Milligram per gram
mg kg^{-1}	Milligram per kilogram
mm	Millimetre
µg TPF $24h^{-1}$ g^{-1}	Microgram of triphenyl formazan formed per gram of soil per 24 hours
Mn	Manganese
Mo	Molybdenum
MOP	Muriate of Potash
N	Nitrogen
Na	Sodium
NO_3^-	Nitrate ion
NS	Not significant
OH^-	Hydroxide
P	Phosphorus
pH	Potenz Hydrogen
PGPR	Plant growth promoting rhizobacteria
PM	Poultry manure
PoP	Package of Practices
PSB	Phosphorus solubilizing bacteria
P_2O_5	Phosphorus pentoxide
RBD	Randomized block design
S	Significant
S	Sulphur

Si	Silicon
₹ ha^{-1}	Rupees per ha
SEm	Standard error of means
t	Tonnes
t ha^{-1}	Tonnes per hectare
viz.	Namely
Vs.	Versus
Zn	Zinc

LIST OF SYMBOLS

%	Percent
@	At the rate
^{o}C	Degree Celsius
µ	Micro
₹	Rupees
^{0}E	Degree East
^{0}N	Degree North
±	Plus-minus sign

INTRODUCTION

1. INTRODUCTION

Taro (*Colocasia esculenta* L. Schott), belonging to the family Araceae, is an important staple food crop grown in many Pacific Island countries, parts of Africa, Asia and the Caribbean islands for its edible starchy corms and nutritious leaves. The crop is adapted to a wide range of agroclimatic situations including marginal soil and unfavourable climatic conditions. Globally taro is cultivated in an area of 1.96 m ha with a production of 10.54 m t and the average productivity is 5.39 t ha^{-1} (FAO, 2021). In India, taro is mostly cultivated in Uttar Pradesh, Madhya Pradesh, Odisha, Andhra Pradesh, West Bengal and Kerala and is an integral component of different farming systems adopted in Kerala.

Taro is a perennial herb with thick tuberous underground stem and simple broad leaves with long petioles and is cultivated mostly as an annual crop. All parts of the colocasia *viz.*, the leaves, petioles, corm and cormels are consumed as vegetable and a number of food products are prepared from tubers, leaves and petioles. Taro chips prepared from the tubers are used as snacks, starch used in baby foods and there is considerable potential for the use of taro silage as animal feed. Raw tubers are also exported, mainly to the Gulf countries.

Taro corm is a good source of carbohydrate, mostly starch comprising amylase and amylopectin. It is rich in minerals such as potassium and phosphorus and contains higher amount of vitamin B-complex. The corm is low in fat and protein, however, the protein content is slightly higher than that of yam, cassava and sweet potato. Opara (2001) reported that taro leaf is an excellent source of carotene, phosphorous, potassium, calcium, iron, vitamin A, riboflavin, thiamine, niacin, vitamin C and dietary fibre.

Alternative soil management practices like organic farming assume significance in the context of climate change, for safe food production all over the world. Conventional agriculture using chemical inputs results in higher yield, but it is ecologically unfriendly as it has negative impacts on food, soil, water and environmental quality. Intensive use of chemical fertilizers and pesticides leads to deterioration of soil health, contamination of the food chain and water, reduced nutrient content and flavour in addition to potential health hazards. Indiscriminate use of chemical fertilizers for decades has lowered the organic carbon status of soils to less than one per cent (Suja, 2008). Increasing concerns about environment conservation and health hazards has indeed led to the growing interest in organic farming. It is a valid alternate approach for sustainable and safe food production, especially of tuber crops, and maintains the soil health and offers environmental protection by avoiding the use of synthetic chemicals, with maximum use of on-farm resources.

Organic manures are effective for maintaining adequate organic matter content in soils with improvement in physical, chemical and biological properties of soil favoring better crop performance. Traditionally tuber crops, the third most important group of food crops after cereals and legumes, are produced with low external inputs. Like other tuber crops, taro is also highly responsive to organic manures and has fewer pest and disease problems as compared to other vegetables. Recently there has been a great demand for organically produced tuberous vegetables in Europe, USA and Middle East and there is premium price for organically produced cocoyams (taro and tannia) both nationally and internationally. Different organic materials in large quantities are easily available and are effective sources of nutrients for tuber crops like taro. The potential organic sources of plant nutrients for tropical tuber crops include farmyard manure (FYM), poultry manure, composts, green manures, crop residues, ash, oil cakes like neem cake *etc.* Farm yard manure is the most common traditional organic manure and poultry manure is the commonly used organic manure by the farmers of Southern Kerala, having higher content of mineralizable N. There are many reports suggesting the use of poultry manure as an alternative for FYM in tuber crops. Wood ash is an indigenous source of potassium. Biofertilizer, a promising component of organic production system, offer a cheap and easily available source of nutrients and enhance the efficiency of native and applied nutrients in the soil. PGPR mix I is a talc based compatible consortium of efficient strains of micro organisms which can enhance the availability of nutrients in the rhizosphere. Vermiwash is a very good liquid manure that favourably influence the growth and productivity of crops through foliar application. It contains several enzymes, plant growth hormones like cytokinins, gibberellins and vitamins along with macro and micro nutrients and has a great potential for enhancing yield performance of taro under organic nutrition. Green manuring *in situ* is an age old practice for improving soil fertility and supplying a part of N requirement of crops. Cowpea is the commonly used green manure crop in Kerala, and the possibility of using green manure crops like daincha are to be explored for raising tuber crops, while formulating the organic production strategy.

One of the researchable issues in organic production of tuber crops is the scientific use of available organic sources to enhance crop productivity while maintaining the soil health. However, the current knowledge of the effect of organic nutrition on performance of taro crop and its influence on soil health is limited. In this back drop, the present study was undertaken with the following objectives;

- To investigate the effect of organic nutrition on growth, yield, quality, soil organic carbon build up and economics of cultivation of taro
- To study the rooting and tuberisation pattern of taro under organic nutrition

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Taro (*Colocasia esculenta* (L.) Schott) is an underexploited crop, cultivated throughout the tropics especially in the warmer regions for its edible cormels, leaves and petioles. The crop is mainly used as vegetable in the State and has good keeping quality compared to other vegetables. Taro is adapted to a wide variety of soil and climatic conditions and is an integral component of different farming systems adopted in Kerala. Growing concerns regarding food safety, environmental degradation and human health have currently generated interest in adopting alternative agricultural systems like organic farming. Organic farming has great potential for reducing some of the negative impacts caused by conventional agriculture to the environment and is an option to restore the productivity of degraded soils. Taro is highly responsive to organic manures and has fewer pest and disease problems as compared to other vegetables. Hence the present study is undertaken to investigate the effect of organic nutrition on growth, yield, quality, soil organic carbon build up and economics of cultivation of taro and to study the rooting and tuberisation pattern of taro under organic nutrition. The relevant literature on organic nutrition in taro and related crops are reviewed in this chapter.

2.1 EFFECT OF ORGANIC AND BIOLOGICAL SOURCES OF NUTRIENTS

Tuber crops have a high production potential and respond well to the organic farming practices. Organic farming is an eco-friendly alternative to conventional farming in taro for stable yield and quality cormels as well as for maintaining soil health (Suja *et al*., 2017). The potential organic sources of plant nutrients for tuber crops include FYM, poultry manure, different types of composts, crop residues, wood ash, vermiwash, oil cakes and biofertilizers *etc*. In the present study, FYM, poultry manure, wood ash, vermiwash and biofertilizer PGPR mix I were used as the organic sources of nutrients.

2.1.1 Effect of Organic and Biological Sources of Nutrients on Rooting Pattern and Tuberisation

Kumar and Tofinga (2007) conducted a study to find out the effect of poultry manure on root distribution in taro and reported that the addition of poultry manure (10 t ha^{-1}) resulted in significantly the highest root weight (0.22 g per plant) and number of roots per plant (37) compared to the root weight (0.14 g per plant) and number of roots per plant (29) in the treatment without poultry manure application. The poultry manure treated plants also produced longer roots than that of plants without poultry manure application. Ansari *et al*. (2015) reported that taro plants grown in aquaponic solution with vermiwash excelled in root growth compared to plants grown in the commercial hydroponic solution. Among the different nutrient management practices adopted in taro, the inoculation of fungal biofertilizer along with FYM, lime and half NPK had a greater impact on tuberisation and enhanced root length density and volume with root hairs over that of inorganic fertilizers (Laxminarayana, 2016).

In a study conducted to evaluate the effect of organic and inorganic sources of nutrients on yield and yield contributing characters of Bilashi variety of *Colocasia*, Hossain *et al.* (2009) found that the organic sources of nutrients (cowdung 5000 kg ha-1and mustard oil cake 100 kg ha-1) produced higher fresh weight of roots at all stages of observation (90, 120, 150 and 180 DAP) than the recommended dose of fertilizers for the soils of Bangladesh.

2.1.2 Effect of Organic and Biological Sources of Nutrients on Growth and Growth Attributes

2.1.2.1 Effect of Organic Sources of Nutrients on Growth and Growth Attributes

2.1.2.1.1 Effect of FYM

Farm yard manure (FYM) is the most commonly available organic source that can be included in the organic production of tuber crops. It provides both major and minor nutrients as well as improves the physical, chemical and biological properties of soil.

Among the different organic and inorganic nutrient management practices in taro, application of FYM 10 t ha^{-1} along with neem cake produced higher plant height (Jurri, 2008). The effectiveness of cow dung in improving the productivity of cocoyam (*Colocasia esculenta)* was studied by Iwuagwu *et al*. (2016), who reported that application of cow dung at the highest rate (30 t ha^{-1}) significantly enhanced number of suckers per plant, plant height, number of leaves and leaf area index in comparison with the lower rates and the control. In a study conducted to compare the organic and conventional farming in taro, Suja *et al*. (2017) reported that the organic management practice containing application of FYM at the rate 15 t ha^{-1} along with green manuring, ash and biofertilizers significantly enhanced the plant height at harvest. The total biomass production and its partitioning to the vegetative plant parts were also higher under organic management containing FYM as the major source of nutrients. The performance of cocoyam (*Colocasia esculenta)* to varying levels of cow dung (0, 10, 20 and 30 t ha^{-1}) was investigated by Adegbe *et al.* (2017) and found that application of cow dung at the highest rate of 30 t ha^{-1} significantly enhanced plant height, number of leaves, leaf area index and number of suckers relative to the lower rates and the control. Among different organic and inorganic nutrient combinations in colocasia, Mandavi *et al.* (2018) obtained the highest average plant height (72.60 cm) by the application of FYM 10 t ha^{-1} with neem cake 1 t ha^{-1}.

Suja *et al*. (2009) reported that among the various nutrient management practices adopted, application 12.5 t ha^{-1} of FYM along with ash favoured the plant height and leaf production in tannia.

Hore *et al*. (2003) reported that the length and girth of pseudostem and crop canopy in elephant foot yam were the highest in treatments with the highest level of FYM. Organic nutrition package standardized in elephant foot yam comprising FYM (36 t ha^{-1}) along with green manuring, neem cake and wood ash showed luxuriant growth of plants, resulting in significantly greater plant height and leaf spread over conventional (integrated nutrient management) practice (Suja *et al.*, 2012). According to Sahoo *et al*. (2015), application of 25 t ha $^{-1}$ of FYM resulted in the highest leaf area per plant in elephant foot yam and it was on a par with the treatment following integrated nutrient management.

Pamila (2003) reported that among the different organic manures, FYM produced significantly greater number of leaves and greater plant height in cassava. Compared to poultry manure and coir pith compost, FYM application resulted in maximum vine length in sweet potato (Dhanya, 2011). Jayapal *et al*. (2013) reported that the leaf area index in Chinese potato increased with increase in the level of FYM application from 3 t ha^{-1} to 6 t ha^{-1} along with coir pith compost and wood ash.

2.1.2.1.2 Effect of Poultry Manure

Poultry manure is a bulky organic manure having higher content of mineralizable nitrogen due to its narrow C: N ratio. Singh *et al*. (1973) attributed the higher efficiency of poultry manure to its narrow C: N ratio and comparatively higher content of mineralizable nitrogen. In poultry manure 60 per cent N is present as uric acid, 30 per cent present as more stable organic form and the balance as mineral nitrogen and when entire quantity of poultry manure is applied as basal, more than 60 per cent of its N present as uric acid rapidly changes to ammoniacal form (Srivastava, 1988).

The response of cocoyam *(Colocasia esculenta)* to various rates of application of poultry manure (0, 5, 10 and 15 t ha^{-1}) and potassium fertilizer was studied for two consecutive years by Uwah *et al.* (2011). The results of the study indicated that the application of poultry manure at the highest rates produced significantly taller plants with higher leaf area index compared to the other treatments. According to Hamma *et al.* (2014), among the different organic manures, poultry manure produced significantly greater plant height, and number of leaves per plants in cocoyam. Adekiya *et al*. (2016) conducted a three year study with five levels of poultry manure (0, 2.5, 5.0, 7.5, 10.0 t ha^{-1}) to evaluate the effect of poultry manure on growth and yield of cocoyam. In this study, the growth parameters (plant height and leaf area) of cocoyam increased with increase in poultry manure level up to 7.5 t ha^{-1}. Application of 4 t poultry manure per hectare resulted in greater plant height in taro than 60 kg P ha^{-1} and combined application of 40 kg P ha^{-1} + 2 t poultry manure ha^{-1} (Ansah, 2016).

Adeleye *et al*. (2010) conducted an experiment with poultry manure at the rate of 0 t ha^{-1} and 10 t ha^{-1} in yam and the data obtained indicated that poultry manure application increased the vine length, vine girth, leaves per plant, branches per plant, leaf area significantly. Agbede *et al*. (2013) reported that poultry manure application (10 t ha^{-1}) along with oil palm bunch ash increased the vine length, number of leaves and leaf area of yam by 25, 21 and 52 per cent respectively, compared with inorganic fertilizer (NPK). Agbede *et al.* (2020) conducted a study on poultry manure (0 and 7.5 t ha^{-1}) with biochar application and found that the growth of *Xanthosoma* was improved by application of 7.5 t ha^{-1} of poultry manure.

2.1.2.1.3 Effect of Wood Ash

Wood ash is the residue left after the combustion of wood, such as burning of wood in a home fireplace or in an industrial power plant. Household wood ash is used as a source of potassium in the present study. Household wood ash contains 0.5 to 1.9 per cent N, 1.6 to 4.2 per cent P_2O_5 and 2.3 to 12 per cent K_2O (Sharma, 2005).

According to Suja *et al*. (2017), application of ash 2 t ha^{-1} along with FYM, green manuring, and biofertilizers significantly enhanced the plant height at later stages of plant growth over conventional practices in taro. Application of 2 t ha^{-1} was found to be an optimal dose of oil palm bunch ash for the enhancement of cocoyam vegetative growth (leaf area index, number of leaves, stem girth and plant height) in the field experiments conducted by Omeje *et al.* (2018).

Suja *et al*. (2009) reported that among the various nutrient management practices, application of ash 3 t ha^{-1} along with FYM increased the plant height and leaf production in tannia. Organic nutrition package standardized in elephant foot yam comprising wood ash (3 t ha^{-1}) along with FYM, green manuring, and neem cake resulted in luxuriant growth of plants, greater plant height and leaf spread over conventional practice (Suja *et al.*, 2012). Kolambe *et al.* (2013) reported that the organic treatment including ash 5 t ha^{-1} along with FYM and biofertilizers were on a par with chemical based farming with respect to the growth parameters like plant height, pseudostem girth and canopy spread of elephant foot yam. Agbede *et al*. (2013), observed the effect of wood ash on growth attributes of yam under organic cultivation. In their study, oil palm bunch ash + poultry manure treatment increased the vine length, number of leaves and leaf area of yam by 22, 19 and 44 per cent respectively, compared with application of poultry manure alone.

2.1.2.1.4 Effect of Vermiwash

Vermiwash, a liquid extract obtained from vermicomposting beds, has been used as an organic fertilizer for crop plants. Ansari *et al*. (2015) reported that vermiwash is an effective treatment in hydroponics to grow colocasia (taro) plants and the plants grown in aquaponic solution with vermiwash excelled in growth parameters compared to plants grown in the commercial hydroponic solution. All the plants grown on vermiwash had produced significant shoot growth, number of leaves and number of nodes.

2.1.2.2 Effect of Biological Sources of Nutrients on Growth and Growth Attributes

The biofertilizers like Plant Growth Promoting Rhizobacteria (PGPR) can be included in the organic production system to supplement the plant nutrition. Vacheron *et al*. (2013) pointed out that PGPR can produce phytohormones and promote enzymatic activities, which in turn may improve growth of the whole plant. The PGPR mix I contains component cultures, *viz., Azospirillum lipoferum, Azotobacter chroococcum, Bacillus megaterium* and *Bacillus sporothermodurans* which is a microbial consortium for supplementing all the major nutrients as reported by Gopi *et al.* (2020).

Suja *et al*. (2017) reported that the organic management practice containing application of biofertilizers (*Azospirillum* at the rate 3 kg ha^{-1}, mycorrhiza at the rate 5 kg ha^{-1} and phosphobacteria at the rate 3 kg ha^{-1}) along with FYM, green manuring and ash significantly enhanced the plant height in taro. The application of biofertilizers also resulted in higher total biomass production and its partitioning to the vegetative plant parts. In a study conducted to evaluate the response of taro to biofertilizers, Soubeih Kh and Mahmoud (2019) reported that the plant height, number of leaves, leaf area, canopy area, leaf area index as well as number of suckers were the highest with the application of mixture of *Azotobacter chrococcum* (nitrogen fixing bacteria), *Bacillus megaterium* var. *Phosphaticum* (phosphate dissolving bacteria) and *Bacillus subtilis* and *Bacillus mucilaginosus* (potassium dissolving bacteria).

Application of PGPR mix I produced significant effects on number of leaves at one month after planting and leaf area index during initial and final stages of crop growth under organic production of chinese potato (Jayapal *et al.*, 2013). According to Kolambe *et al.* (2013), the organic treatment including *Azospirillum* at the rate 5 kg ha^{-1} + phosphorus solubilising bacteria (PSB) at the rate 5 kg ha^{-1} along with FYM and ash were on a par with chemical based farming with respect to the growth parameters like plant height, pseudo stem girth and canopy spread of elephant foot yam.

2.1.3 Effect of Organic and Biological Sources of Nutrients on Yield Attributes and Yield

2.1.3.1 Effect of Organic Sources of Nutrients on Yield Attributes and Yield

2.1.3.1.1 Effect of FYM

While comparing the organic and conventional production systems of taro, Suja *et al*. (2017) reported that the organic production system involving application of FYM (15 t ha^{-1}) along with green manuring, ash and biofertilizers could produce comparable yields as that of conventional system. The results of the experiments conducted for five consecutive seasons indicated similar yield performance of taro under organic (10.61 t ha^{-1}) and conventional (11.12 t ha^{-1}) practices but with slight yield reduction (−5%) under organic practice. In contrast to this result, in the on-farm trials, the yields under organic management were 29 per cent higher over conventional system.

Verma *et al*. (2013) reported that application of FYM (10 t ha^{-1}) along with neem cake (1 t ha^{-1}) improved yield of taro in organic production system. Yebo and Dange (2015) found that higher yield of taro was obtained with combined application of FYM and inorganic fertilizers as compared to application of inorganic fertilizers alone. Within combined fertilizer application, yield of taro increased with increasing rates of FYM. In a study conducted to evaluate the performance of cocoyam to varying levels of cow dung and potassium fertilizer, it was observed that application of cow dung at 30 t ha^{-1} produced average corm yield of 24.8 t ha^{-1} and this was higher than the yield obtained with the application of cow dung at 0, 10 and 20 t ha^{-1} by 116, 40 and 16 per cent respectively (Iwuagwu *et al*., 2016; Iwuagwu *et al.*, 2017). The performance of cocoyam (*Colocasia esculenta)* to varying levels of cow dung (0, 10, 20 and 30 t ha^{-1}) and potassium fertilizer was investigated by Adegbe *et al.* (2017) and it was reported that the application of cow dung at the highest rate (30 t ha^{-1}) significantly enhanced the yield of cocoyam (23.6 t ha^{-1}) compared to the lower rates of application and the control.

In elephant foot yam, Hore *et al*. (2003) observed that the corm diameter and corm weight were the highest with the highest FYM level and there was an yield increase from 28.92 to 32.34 t ha^{-1} by increasing the FYM level from 15 to 20 t ha^{-1}. According to Suja *et al*. (2010), application of FYM at the rate 36 t ha^{-1} along with green manuring and neem cake resulted in higher corm yield (34.6 t ha^{-1}) over conventional farming in elephant foot yam. Sahoo *et al*. (2015) reported that application of FYM at the rate 25 t ha^{-1} resulted in 97.1 per cent higher corm yield over control in elephant foot yam.

Suja *et al*. (2009) reported that application of FYM (2.5 t ha^{-1}) along with ash favoured the number of cormels, cormel yield and mother corm yield in tannia Among the different organic manures applied, the number of tubers per plant and tuber weight per plant were significantly higher in FYM treated plants under organic cultivation of sweet potato (Dhanya, 2011). Swadija *et al.* (2011) reported that application of FYM at the rate 15 t ha^{-1} along with biofertilizers was sufficient for higher rhizome yield of arrowroot intercropped in homesteads. According to Suja (2013), organic management involving FYM (15 t ha^{-1}) along with green manure, neem cake, ash and biofertilizers produced significantly higher yield in all the three species of yams. In arrowroot, application of even lower dose of FYM (10 t ha^{-1}) produced 46 per cent higher rhizome yield over control as reported by Swadija *et al*. (2013). Application of 6 t ha^{-1} FYM along with coir pith compost and wood ash and the recommended basal dose of FYM at the rate 10 t ha^{-1} was required for getting higher yields of organic coleus (Jayapal *et al*., 2013).

2.1.3.1.2 Effect of Poultry Manure

Obasi *et al*. (2005) found that poultry manure applied to supply 120 kg N ha^{-1} increased the corm plus cormel yield from 8.4 to 18.7 t ha^{-1} and above this rate, the yield of cocoyam was found to decrease. The response of cocoyam (*Colocasia esculenta*) to various rates of application of poultry manure (0, 5, 10 and 15 t ha^{-1}) and potassium fertilizer was studied for two consecutive years by Uwah *et al.* (2011) and found that the application of poultry manure at the highest rate produced the highest corms and cormels number (40 % more), weight of corms and cormels and total yield (t ha^{-1}) compared to other treatments in both the years. In a study with five levels of poultry manure (0, 2.5, 5.0, 7.5 and 10 t ha^{-1}), Ojeniyi *et al.* (2013) observed that the cormel and corm yield increased up to 7.5 t ha^{-1} in cocoyam. Application of 4 t poultry manure per hectare resulted in greater cormel weight, cormel number and yield of taro compared to the application of 60 kg P ha^{-1} or combined application of 40 kg P ha^{-1} + 2 t poultry manure ha^{-1} (Ansah, 2016).

In a study conducted on different fertilizer types in taro, poultry manure plus composted refuse at 10 t ha^{-1} increased the cormel yield by 65 per cent (Osundare, 2004). According to Hamma *et al*. (2014), poultry manure produced the highest corm yield per plot and corm yield per hectare in cocoyam. Adekiya *et al*. (2016) conducted a three year study in cocoyam with five levels of poultry manure (0, 2.5, 5.0, 7.5, 10.0 t ha^{-1}). In this study, overall mean corm yield and mean cormel yield increased with increase in poultry manure level up to 7.5 t ha^{-1}. In another study, the application of chicken manure (5 t ha^{-1}) with rice husk charcoal enhanced the number of tubers, tuber wet weight, marketable yield weight, and productivity of colocasia plants (Zulbeni *et al.,* 2020).

Adeleye *et al*. (2010) conducted an experiment with poultry manure at 0 t ha^{-1} and 10 t ha^{-1} in yam and found that the poultry manure application increased the tuber length, tuber girth, tuber weight and tuber yield significantly. Agbede *et al*. (2013)

reported that poultry manure application (10 t ha^{-1}) along with oil palm bunch ash increased tuber weight of yam by 66 per cent compared to inorganic fertilizer (NPK). Agbede *et al.* (2020) conducted a study on two levels of poultry manure (0 and 7.5 t ha^{-1}) and biochar application in *Xanthosoma* and reported that application of 7.5 t ha^{-1} poultry manure improved corm and cormel yields.

2.1.3.1.3 Effect of Wood Ash

Suja *et al.* (2017) observed that organic system involving ash at the rate 2.0 t ha^{-1} along with FYM, green manuring, and biofertilizers performed similar to that of conventional system with slight yield reduction in taro (−5%).

Application of ash 3 t ha^{-1} along with FYM favoured number of cormels, cormel yield, mother corm yield and dry biomass yield of corms and cormels in tannia (Suja *et al.*, 2009). Agbede *et al.* (2013) observed the effect of wood ash on growth attributes of yam under organic cultivation. The oil palm bunch ash + poultry manure treatment increased tuber weight of yam by 37 per cent compared to poultry manure alone. According to Suja (2013), organic management involving ash at the rate 1.5 t ha^{-1} along with FYM, green manure, neem cake, and biofertilizers produced significantly higher yield in all the three species of yams. In a study conducted to investigate the impact of wood ash as a fertilizing material on sweet potato with three levels (30, 50 and 70 g of wood ash per plant), the highest fresh tuber weight and tuber yield were obtained with 70 g per plant (Mvuni *et al.*, 2018).

According to Suja *et al.* (2010), application of 3 t ha^{-1} of ash along with FYM, green manuring and neem cake resulted in higher corm yield (34.6 t ha^{-1}) over conventional farming in elephant foot yam. Sowley *et al.* (2015) observed that the plots treated with poultry manure had more tubers than NPK applied plots in sweet potato.

2.1.3.1.4 Effect of Vermiwash

In a field trial conducted by ICAR-CTCRI (2015) in elephant foot yam, the highest yield (36.60 t ha^{-1}) was obtained with seed treatment and drenching with vermiwash (10 %) and with incorporation of vermi compost.

2.1.3.2 Effect of Biological Sources of Nutrients on Yield Attributes and Yield

Suja *et al.* (2017) observed that organic system involving application of *Azospirillum* at the rate 3 kg ha^{-1}, mycorrhiza at the rate 5 kg ha^{-1} and phosphobacteria at the rate 3 kg ha^{-1} along with FYM, green manuring and ash in taro produced similar yield (10.61 t ha^{-1}) to that of conventional (11.12 t ha^{-1}) with slight reduction in yield. In a study conducted to evaluate the response of taro to biofertilizers by Soubeih Kh and Mahmoud (2019), the highest fresh weight of cormels was recorded with application of mixture of *Azotobacter chrococcum* (nitrogen fixing bacteria), *Bacillus megaterium* var. *Phosphaticum* (phosphate dissolving bacteria) and *Bacillus subtilis* and *Bacillus mucilaginosus* (potassium dissolving bacteria).

Mukhopadhyay and Sen (1999) reported that application of *Azotobacter* along with N in soil increased the corm yield in elephant foot yam. According to Kolambe *et al.* (2013), the tuber yield produced by elephant foot yam from organic management including *Azospirillum* at the rate 5 kg ha^{-1} + phosphorus solubilising bacteria (PSB) at the rate 5 kg ha^{-1} along with FYM and ash were on a par with the tuber yield of chemical based farming.

According to Suja (2013), organic management involving biofertilizers (*Azospirillum* at the rate 3 kg ha^{-1}, mycorrhiza at the rate 5 kg $ha^{-1}$and phospho-bacteria at the rate 3 kg ha^{-1}) along with FYM, green manure, neem cake, and ash produced significantly higher yield in yams. The highest rhizome yield (18.62 t ha^{-1}) of arrowroot was obtained by the application biofertilizers along with FYM (Swadija *et al.*, 2013). Application of PGPR mix I produced higher percentage weight of marketable tuber per plant, tuber yield, number of tubers and number of marketable tubers under organic production of Chinese potato (Jayapal *et al.*, 2013).

2.1.4. Effect of Organic and Biological Sources of Nutrients on Physiological Attributes

2.1.4.1 Effect of Organic Sources of Nutrients on Physiological Attributes

2.1.4.1.1 Effect of FYM

Hota *et al*. (2014) recorded significantly higher dry matter production in C*olocasia* with the application of FYM, ½ NPK along with VAM compared to the application of 150 per cent of NPK.

According to Archana and Swadija (2000), coleus produced higher dry matter production when FYM was applied as organic manure. Suja *et al*. (2009) reported that application of FYM at the rate 12.5 t ha^{-1} along with ash produced higher dry matter yield of corms and cormels in tannia. Application of higher level of FYM (6 t ha^{-1}) along with coir pith compost and wood ash produced higher utilization index and dry matter production in Chinese potato (Jayapal *et al.*, 2013). Boru *et al.* (2017) recorded the highest harvest index in sweet potato with higher level of FYM application.

2.1.4.1.2 Effect of Poultry Manure

While studying the response of cocoyam *(Colocasia esculenta)* to various rates of poultry manure (0, 5, 10 and 15 t ha^{-1}) and potassium fertilizer for two consecutive years, Uwah *et al*. (2011) reported that the application of poultry manure at the highest rates produced the highest shoot dry matter compared to the other treatments in both years. Poultry manure rates from zero to 15 t ha^{-1} increased the shoot dry matter by 51 per cent.

Among different sources of organic manure, poultry manure 2.5 t ha^{-1} along with green manuring produced significantly higher total dry matter production in cassava (Pooja, 2018).

2.1.4.1.3 Effect of Wood Ash

In a study conducted to investigate the impact of wood ash as a fertilizing material in sweet potato with three levels of wood ash (30, 50 and 70 g per plant), the highest dry matter content of tuber and vine was produced with wood ash application at the rate of 50 g per plant (Mvuni *et al.,* 2018).

2.1.4.1.4 Effect of Vermiwash

According to Ansari *et al.* (2015), vermiwash can be used for hydroponic cultivation of taro, the nutrients available in vermiwash contributed to healthier plants and they observed that the plants grown with vermiwash resulted in greater chlorophyll content over the plants grown in standard hydroponic solution and the control.

2.1.4.2 Effect of Biological Sources of Nutrients on Physiological Attributes

Application of biofertilizers like *Azotobacter* or VAM in combination with phosphate solubilising bacteria could minimize the need of inorganic fertilizers and ensure better dry matter production in taro. In a study conducted to investigate the effect of biofertilizer application on the dry matter content and harvest index of taro, it was found that the treatment containing *Azotobacter* + PSB along with vermi compost resulted in maximum dry matter content in Gurdaspuri Local variety and higher harvest index in Desi Arvi variety (Singh *et al*., 2018).

Application of PGPR mix I produced higher utilization index and higher dry matter production under organic production of Chinese potato (Jayapal *et al.*, 2013).

2.1.5 Effect of Organic and Biological Sources of Nutrients on Tuber Quality

2.1.5.1 Effect of Organic Sources of Nutrients on Tuber Quality

2.1.5.1.1 Effect of FYM

In an investigation carried out to evaluate the effect of different organic manures on growth, yield and quality attributes in taro, the organic treatment {FYM (10 t ha^{-1}) along with neem cake (1 t ha^{-1})} resulted in the highest starch content (17.06 %) than the other integrated nutrient management practices (Verma *et al.*, 2013). According to Suja *et al*. (2017), the cormel quality (higher dry matter, starch, sugars, P, K, Ca and Mg contents) of taro was better under organic management involving application of FYM at the rate 15 t ha^{-1} along with green manuring, ash and biofertilizers than the conventional system.

Sankar *et al*. (1999) observed that application of FYM at the rate 25 t ha^{-1} resulted in the highest cooking quality, highest starch content (38 %) and organoleptic scores in elephant foot yam. Organic farming in elephant foot yam improved the tuber quality with significantly higher dry matter, starch, crude protein, K, Ca and Mg contents and lower oxalate content (Suja *et al.*, 2010 and 2012; Suja , 2013) with the application of FYM at the rate 36 t ha^{-1} along with green manuring and neem cake.

Dhanya (2011) obtained higher starch content of tubers in sweet potato when 100 per cent of recommended dose of nutrients was substituted with FYM. In arrowroot, quality characters of rhizome such as dry matter, starch, crude protein, and crude fibre increased with the application of even 10 t ha^{-1} of FYM alone over control (Swadija *et al*., 2013). In yams, organic tubers produced with FYM (15 t ha^{-1}) along with green manure, ash and biofertilizers had slightly higher dry matter and crude protein contents and considerably higher Mg (35 %) and Mn (45 %) contents over conventional practice (Suja, 2013). When 100 per cent, 75 per cent and 50 per cent substitution of recommended dose of nutrients with organic manures such as FYM and wood ash were applied in coleus, Jayapal *et al*. (2016) obtained increased starch and protein contents of tubers with increase in the level of FYM.

2.1.5.1.2 Effect of Poultry Manure

Among the different organic manures applied, poultry manure resulted in the highest protein content and lowest HCN content in cassava tubers (Pamila, 2003). According to Ezeocha *et al*. (2014) poultry manure application significantly increased the starch content in aerial yam (*Dioscorea bulbifera*). The highest starch content (13.50 %) was observed with poultry manure application at the rate of 4 t ha^{-1}. Crude fibre, ash and crude protein contents were also significantly affected by poultry manure application. The ash content ranged from 3.41 – 4.68 per cent with 4 t ha^{-1} of poultry manure. The highest crude protein content was produced with the application 3 t ha^{-1} of poultry manure.

2.1.5.1.3 Effect of Wood Ash

Suja *et al.* (2017) reported that organic cormels of taro produced by application of ash 2 t ha^{-1} along with FYM, green manuring, and biofertilizers had higher dry matter (+7.29 %), starch (+10.78 %), total sugars (+31.55 %) and reducing sugars (+9.37 %) over conventional cormels. Organically produced cormels also had higher P (+3.22 %), K (+1.77 %), Ca (+5.52 %) and Mg (+20.80 %) contents than conventionally produced cormels.

Application of ash at the rate 3 t ha^{-1} along with FYM, green manuring, and neem cake improved the tuber quality with significantly higher dry matter, starch, crude protein, K, Ca and Mg contents and lower oxalate content in elephant foot yam (Suja *et al.*, 2010 and 2012; Suja, 2013). Significantly higher starch and sugar contents and improvement in protein content of corm of elephant foot yam were observed by Kolambe *et al*. (2013) due to organic management including application of ash at the rate 5 t ha^{-1} along with vermi compost and biofertilizers.

Kurian *et al*. (1976) observed the effect of wood ash to reduce the bitterness and cyanogen content in cassava. He reported an increase in bitterness and cyanogen content in cassava due to application of cowdung alone and a reduction in cyanogen content by application of mixture of cowdung and ash. John *et al*. (2005) reported that the substitution of ash (7 to 8 % K_2O) for K fertilizers improved the quality of cassava tubers.

2.1.5.1.4 Effect of Vermiwash

In trial on spraying of bioregulants in turmeric, Sathish and Paramaguru (2009) reported an improvement in the qualitative aspects like curcumin, oleoresin and essential oil contents due to the application of 10 per cent and 20 per cent vermiwash over the control. Perez-Gomez *et al*. (2017) reported that in potato application of vermiwash significantly favoured the total soluble solids and pH value of the tuber.

2.1.5.2 Effect of Biological Sources of Nutrients on Tuber Quality

Among the different organic and inorganic nutrient management practices in taro, the quality parameter like reducing and total sugar were higher with the treatment PSB at the rate 5 kg ha^{-1} + *Azospirillum* at the rate 5 kg ha^{-1} (Jurri, 2008). According to Suja *et al*. (2017), the cormel quality of taro was better under organic management, involving application of *Azospirillum* at the rate 3 kg ha^{-1}, mycorrhiza at the rate 5 kg ha^{-1} and phosphobacteria at the rate 3 kg ha^{-1} along with FYM, green manuring and ash with higher dry matter, starch, sugars, P, K, Ca and Mg contents than the conventional system.

Total sugar and reducing sugar contents of elephant foot yam corms from biofertilizer applied plots were significantly higher than that of corms from conventional practice (Suja *et al.*, 2012). Significantly higher starch and sugar contents and improvement in protein content of corm of elephant foot yam were observed by Kolambe *et al*. (2013) due to organic management including application of *Azospirillum* at the rate 5 kg ha^{-1} + phosphorus solubilising bacteria (PSB) at the rate 5 kg ha^{-1} along with FYM and ash. In yams, organic tubers produced with the application of *Azospirillum* at the rate 3 kg ha^{-1}, mycorrhiza at the rate 5 kg ha^{-1} and phosphobacteria at the rate 3 kg ha^{-1} along with FYM, green manure and ash had slightly higher dry matter and crude protein contents and considerable improvement in the Mg and Mn contents of tubers of yams by 35 per cent and 45 per cent, respectively over conventional practice (Suja, 2013). Swadija *et al*. (2013) revealed the sufficiency of biofertilizer application along with FYM at the rate 15 t ha^{-1} for improved rhizome quality (dry matter, starch, crude protein and crude fibre contents) of arrowroot intercropped in coconut.

2.1.6. Effect of Organic and Biological Sources of Nutrients on Nutrient Uptake

2.1.6.1 Effect of Organic Sources of Nutrients on Nutrient Uptake

2.1.6.1.1 Effect of FYM

According to Majumdar *et al.* (2002), application of FYM (25 t ha^{-1}) significantly increased the NPK uptake in sweet potato. Higher uptake of NPK in sweet potato was recorded by supplying 100 per cent of recommended nutrients through FYM than supplying 75 per cent of recommended nutrients through FYM (Dhanya, 2011). Application of higher level of FYM (6 t ha^{-1}) along with coir pith compost and wood ash produced higher uptake of P and K in Chinese potato (Jayapal *et al.,* 2013).

2.1.6.1.2 Effect of Poultry Manure

In a study with five levels of poultry manure (0, 2.5, 5.0, 7.5 and 10 t ha^{-1}), Ojeniyi *et al.* (2013) observed that leaf N and P increased with rate of poultry manure up to 10 t ha^{-1} and leaf K, Ca and Mg increased up to 7.5 t ha^{-1} in cocoyam. According to Adekiya *et al*. (2016), poultry manure application enhanced the uptake of N, P, K, Ca and Mg in cocoyam. The leaf N and P increased with increase in the level of poultry manure from 0 to 10 t ha^{-1} and leaf K, Ca and Mg increased up to the level of 7.5 t ha^{-1} poultry manure and it dropped with further increase in the level of poultry manure (10 t ha^{-1}).

Adeleye *et al.* (2010) conducted an experiment with poultry manure in yams and it was found that poultry manure application increased leaf N, P, K, Ca and Mg concentration by 25, 27, 18, 20 and 21 per cent respectively over plots without poultry manure application. In a study conducted by Agbede *et al*. (2013), the organic fertilizers containing poultry manure (10 t ha^{-1}) with oil palm bunch ash significantly increased leaf N, P, K, Ca and Mg, compared to the natural soil fertility (control) in yam.

In sweet potato, higher uptake of NPK was registered by supplying 100 per cent of recommended nutrients through poultry manure than supplying 75 per cent of recommended nutrients through poultry manure (Dhanya, 2011). Odedina *et al*. (2011) also observed that poultry manure increased the leaf N, K and Mg in cassava.

2.1.6.1.3 Effect of Wood Ash

Among the various combinations of ash and MOP as sources of K, the highest uptake of K in the potato tuber was obtained from the treatment containing 50 per cent K from ash + 50 per cent from MOP (Rahman *et al.,* 2014).

2.1.6.1.4 Effect of Vermiwash

Vermiwash promotes plant growth by physical amelioration of substrate and influencing nutrient uptake mechanism (Alvarez and Grigera, 2005). According to Moridi *et al*. (2019), PGPR enriched vermiwash was more effective in enhancing the nutrient uptake in maize than the non enriched one.

2.1.6.2 Effect of Biological Sources of Nutrients on Nutrient Uptake

In a study conducted to evaluate the response of taro to biofertilizers by Soubeih Kh and Mahmoud (2019), it was observed that the biofertilizers had significant influence on nutrient uptake and the highest uptake of N, P and K were attained with the application of *Azotobacter chrococcum*, *Bacillus megaterium* var. *Phosphaticum* and *Bacillus subtilis* and *Bacillus mucilaginosus* respectively.

Yasmin *et al*. (2007) studied the effect of PGPR treatment on sweet potato and found that PGPR inoculated plants had higher nutrient content (N, P and K) in plant and storage roots. Application of PGPR mix I enhanced the uptake of nutrients, N, P and K, under organic production of Chinese potato (Jayapal *et al.*, 2013).

2.1.7 Effect of Organic and Biological Sources of Nutrients on Soil Properties

2.1.7.1 Effect of Organic Sources of Nutrients on Soil Properties

2.1.7.1.1 Effect of FYM

Based on the results of the experiments conducted for five consecutive seasons on organic vs conventional farming in taro, Suja *et al*. (2017) reported that organic management involving application of FYM at the rate 15 t ha^{-1} along with green manuring, ash and biofertilizers lowered the bulk density and improved the water holding capacity (+19 %) and porosity (+3 %) of soil. The organic plots showed significantly higher pH and available P (+59.44 %) and higher soil organic carbon (+39 %), exchangeable Ca (49.14 %), Mg (+25.74 %), Fe (16.60), Mn (10.45), Zn (21.76) and Cu (14.39 %) status over conventional system. Available N was also favoured slightly (+1.45 %) under organic management. There was an improvement in soil pH (+0.58 unit) along with significantly higher organic carbon (+47.89 %) and available K (+86.97 %) status under organic management in the onfarm trial.

Significant increase in the organic carbon, available P and K contents and improvement in available N content of soil was noticed with incremental level of FYM application from 3 to 6 t ha^{-1} along with coir pith compost and wood ash in coleus (Jayapal *et al*., 2014).

After five years of farming with elephant foot yam, the organic plots applied with FYM at the rate 36 t ha^{-1} along with green manuring, ash and neem cake showed significantly higher pH, organic carbon, exchangeable Mg, available Cu, Fe and Mn. Organic management also lowered the bulk density by 2.3 per cent, improved the porosity of soil by 16.5 per cent and the water-holding capacity by 28.4 per cent (Suja *et al.,* 2012). Slight improvement in bulk density, water holding capacity and porosity of the soil was observed under organic management involving FYM 15 t ha^{-1} along with green manure, ash and biofertilizers in yams (Suja, 2013).

Patil *et al*. (2003) observed that with each increment in FYM, the soil pH decreased from 7.99 to 7.65. Electrical conductivity of soil was found to decrease with application of FYM (Rathod *et al.*, 2003). Kumar *et al*. (2015) reported that in elephant foot yam, soil pH, EC and nutrient status increased with increasing levels of FYM while the soil bulk density got lowered due to application of FYM over control.

2.1.7.1.2 Effect of Poultry Manure

General increase in soil nutrient content with addition of poultry manure is consistent with the fact that poultry manure is a natural and effective organic source of nutrients. It has liming effect also and its presence increases the cation exchange capacity of soil (Odedina *et al.,* 2011). In a study with five levels of poultry manure (0, 2.5, 5.0, 7.5 and 10 t ha^{-1}), Ojeniyi *et al.* (2013) observed that the soil temperature and bulk density were reduced as application rate of poultry manure was increased from 0 to 10 t ha^{-1}, while porosity and moisture content showed an increasing trend under cocoyam cultivation. Adekiya *et al*. (2016) conducted a three year study with five levels of poultry manure (0, 2.5, 5.0, 7.5, 10 t ha^{-1}) to evaluate the effect of site, tillage and poultry manure treatments on soil composition and yield of cocoyam. In this study, the soil pH, organic carbon, soil and plant N, P, K, Ca and Mg increased with increase in poultry manure levels from 0 to 10 t ha^{-1}. In a study with different rates of application of chicken manure (0 t ha^{-1}, 5 t ha^{-1}, and 10 t ha^{-1}), the application of 10 t ha^{-1} of chicken manure with rice husk charcoal increased the exchangeable K in soil under *Colocasia* cultivation (Zulbeni *et al.*, 2020).

Adeleye *et al*. (2010) conducted an experiment with poultry manure at 0 t ha^{-1} and 10 t ha^{-1} in yam and it was found that poultry manure application improved the soil physical properties, reduced soil bulk density and temperature and also increased total porosity and soil moisture retention capacity. It also improved soil organic matter, total N, available P, exchangeable Mg, Ca, K and lowered the exchangeable acidity. According to Agbede *et al*. (2013), the use of poultry manure at 10 t ha^{-1} along with oil palm bunch ash was most effective for improving soil physical conditions. In their trial, the soil N, P, K, Ca and Mg, soil pH and organic carbon concentrations were significantly increased by addition of organic fertilizers in comparison to the native soil fertility (control).

According to Agbede (2010), poultry manure was effective in improving soil pH, soil organic carbon, N, Ca and Mg in comparison to NPK fertilizer in sweet potato. Soil organic carbon, N, P, K, Ca, Mg and water content increased with the increase in quantity of poultry manure from 5 to 15 t ha^{-1}, while soil pH, bulk density and temperature reduced (Agbede and Adekiya, 2011) in sweet potato. Dhanya (2011) observed higher available N status in soil under sweet potato cultivation when poultry manure has applied as a source of organic manure.

Ayoola (2010) observed that the soil K, Ca, Mg, organic carbon contents in organic plots applied with poultry manure and urban refuse in cassava was the highest when compared to plots wherein chemical fertilizers were applied and integrated nutrient management was practiced. Odedina *et al*. (2011) reported that poultry manure increased the soil K, Ca and Mg under cassava cultivation. According to Kolambe *et al*. (2013), among the different organic treatments, higher status of P was observed in treatment with application of poultry manure at the rate 5 t ha^{-1} along with biofertilizers and ash in elephant foot yam. Agbede *et al.* (2020) conducted a study on poultry manure (0 and 7.5 t ha^{-1}) and biochar application in *Xanthosoma* and reported that application of poultry manure (7.5 t ha^{-1}) improved the soil physical and chemical properties.

2.1.7.1.3 Effect of Wood Ash

Wood ash can be used as a source of calcium carbonate and potassium in organic farming to improve soil fertility. It also acts as a liming material to neutralize acidic soils. Suja *et al*. (2017) reported that the organic management lowered the bulk density, improved the water holding capacity and porosity of soil when ash was added at the rate 1.5 t ha^{-1} along with FYM and green manures in taro. This treatment also resulted in higher pH, available N, P, K, soil organic carbon and exchangeable Ca, Mg, Fe, Mn, Zn and Cu status over conventional system.

Kabeerathumma *et al.* (1993) observed higher Ca and Mg levels in soil due to the application of wood ash in cassava. Organic management comprising the application of ash at the rate 2 or 3 t ha^{-1} along with FYM and green manures in elephant foot yam lowered the bulk density, improved the water holding capacity and porosity of soil (Suja *et al.,* 2012). In this trial, the pH, available N, P, K, soil organic carbon and exchangeable Ca, Mg, Fe, Mn, Zn and Cu status were also higher over the conventional system. The above treatment was effective in improving soil physical properties in yam cultivation also (Suja, 2013). According to Kolambe *et al*. (2013), continuous application of ash 5 t ha^{-1} along with biofertilizers and vermicompost lowered the bulk density of soil and improved the overall soil physico-chemical properties in elephant foot yam cultivation.

2.1.7.1.4 Effect of Vermiwash

According to Tisdale and Oades (1982), vermi wash and vermicompost promote humification, increase microbial activity and enzyme production, which, in turn, result better aggregate stability and aeration of soil. Ansari (2008) found that application of vermiwash with vermi compost enhanced soil properties like organic carbon content and available nitrogen and also reduced the soil sodicity.

2.1.7.2 Effect of Biological Sources of Nutrients on Soil Properties

Application of *Azospirillum* at the rate 3 kg ha^{-1}, mycorrhiza at the rate 5 kg ha^{-1} and phosphobacteria at the rate 3 kg ha^{-1} along with FYM, green manure and wood ash lowered the bulk density, improved the water holding capacity and porosity of soil in taro cultivation (Suja *et al*., 2017) and also resulted in higher pH, available N, P, K, soil organic carbon and exchangeable Ca, Mg, Fe, Mn, Zn and Cu status over conventional system.

Application of PGPR mix I improved the status of available P and K in soil under organic production of Chinese potato (Jayapal *et al.*, 2013). There was an overall improvement in soil physico-chemical properties under the influence of continuous application *Azospirillum* at the rate 5 kg ha^{-1} + phosphorus solublizing bacteria at the rate 5 kg ha^{-1} along with ash and vermicompost for elephant foot yam (Kolambe *et al*., 2013). Application of *Azospirillum* at the rate 3 kg ha^{-1}, mycorrhiza at the rate 5 kg ha^{-1} and phosphobacteria at the rate 3 kg ha^{-1} along with FYM, green manure and wood ash lowered the bulk density, improved the water holding capacity and porosity of soil in yam cultivation (Suja, 2013).

2.1.8 Effect of Organic and Biological Sources of Nutrients on Soil Organic Carbon Build up

Ayoola (2010) reported that incorporation of organic fertilizer into the soil could be an efficient way of maintaining desired soil organic matter status and soil organic carbon. He observed the low depletion of organic carbon in organic plots than the plots under chemical fertilizers and integrated nutrient management.

Goyal *et al*. (1993) reported that application of FYM continuously in tropical area improved organic carbon and microbial biomass carbon in soil with balanced fertilization. According to Benbi *et al*. (1998), application of FYM increased the soil organic carbon content. Mastol (2006) also reported an increase in soil organic carbon with the application of FYM.

Agbede *et al*. (2013) has reported an increase in organic carbon status of soils under yam cultivation when poultry manure was applied along with oil palm bunch ash. Kolambe *et al*. (2013) observed significant increase in soil organic carbon content due to the continuous application of organic manures in elephant foot yam. Suja (2013) observed an increase of 19 per cent and 15 per cent in soil organic carbon in organic plots over conventional plots in elephant foot yam and yams respectively.

2.1.9 Effect of Organic and Biological Sources of Nutrients on Soil Microbial Status

Suja *et al.* (2017) observed an improvement in soil microbial population, especially the bacterial and fungal counts, under organic practice by +16.21 and +18.46 per cent respectively over chemical system in taro.

Mastol (2006) reported an increase in soil microbial biomass and microbial coefficient with the application of FYM. According to Suja (2013), the population of bacteria was considerably higher in organic plots than in conventional plots and there was an increase of 41 per cent and 23 per cent bacterial population in elephant foot yam and yams respectively. The N fixers in organically managed soils was higher by 10 per cent over conventional management under elephant foot yam, and P solubilizers was 22 per cent higher in organic management of yams over conventional management. In this trial, the dehydrogenase enzyme activity was also higher in organic plots in both the crops (elephant foot yam and yams) tested.

2.1.10 Effect of Organic and Biological Sources of Nutrients on Pest and Disease Incidence

Soil application of vermicompost and seed treatment with vermiwash (10 %) + drenching and spraying of vermiwash (10 %) at 60 and 90 days after planting showed least percentage of disease incidence of taro leaf blight. (ICAR-CTCRI, 2015). The bio priming of taro cormels with *Bacillus licheniformis, Bacillus subtilis* and *Bacillus amyloliquefaciens* at the rate 10^8 cfu ml^{-1} suspension reduced the leaf blight incidence in taro (ICAR-CTCRI, 2015). The field experiments conducted by Omeje *et al.* (2018) to determine the effect of oil palm bunch ash on control of leaf blight disease of cocoyam indicated that cocoyam leaf blight severity was suppressed in plots which received ash at the rate 2 t ha^{-1} and 3 t ha^{-1}.

The organic farming strategy wherein FYM at the rate of 36 t ha^{-1} (cowdung+neem cake mixture in 10:1, inoculated with *Trichoderma harzianum*), green manure cowpea to yield 20–25 t ha^{-1} of green matter, 3 t ha^{-1} of ash and 1 t ha^{-1} of neem cake were applied lowered the collar rot disease in elephant foot yam and resulted in a healthy crop stand (Suja *et al.*, 2012). Soil application of vermicompost and seed treatment and soil drenching with vermiwash (10 %) showed least collar rot incidence in elephant foot yam (ICAR-CTCRI, 2015). Sowley *et al.* (2015) reported that poultry manure applied soils resulted in the lowest tuber rots than unfertilized plots in sweet potato.

2.1.11 Effect of Organic and Biological Sources of Nutrients on Economics of Cultivation

Saikia *et al.* (2010) reported that application of VAM and *Azospirillum* could reduce 50 per cent N and P fertilizer for *Colocasia* and thus reduced the cost of cultivation and resulted in higher net income and benefit-cost ratio.

Of the various production systems tested, organic farming generated the highest net income of ₹ 215,776 ha^{-1} as against ₹168,060 ha^{-1} in the conventional system in elephant foot yam (Suja *et al*., 2012). Kolambe *et al*. (2013) reported that among different organic treatments, the organic treatments, application of vermicompost at the rate 5 t ha^{-1} + *Azospirillum* at the rate 5 kg ha^{-1} + Phosphate solubilizing bacteria at the rate 5 kg ha^{-1} + ash at the rate 5 t ha^{-1} resulted in the highest net income of ₹ 2,56,000 ha^{-1} and benefit-cost ratio of 2.6 in elephant foot yam.

Saikia and Borah (2007) reported that when *Azospirillum* was given at the rate of 2 kg ha^{-1} as vine dipping and 10 kg ha^{-1} as soil application, it could save 1/3rd of N and P fertilizer in sweet potato and could give higher net returns and benefit-cost ratio. According to Dhanya (2011), substitution of 100 per cent recommended dose of nutrients with poultry manure was the best treatment which fetched a benefit: cost ratio of 2.03 under organic production of sweet potato. The highest net income (₹ 74,450 ha^{-1}) and benefit-cost ratio (1.99) could be obtained by the application of FYM at the rate of 15 t ha^{-1} + biofertilizers in organic nutrition of arrow root (Swadija *et al*., 2013). Higher net income and benefit-cost ratio could be obtained by application of 100 per cent recommended dose of NPK (60:60:100 kg ha^{-1}) through organic manures (6 t FYM + 3 t coir pith compost + 3 t wood ash ha^{-1}) along with PGPR mix 1 in organic cultivation of coleus (Jayapal *et al*., 2016).

2.2 EFFECT OF GREEN MANURING

The practice of green manuring improves the soil fertility and supply a part of N requirement of crops. About 15-20 t ha^{-1} of green matter can be obtained from green manure crops like cowpea when grown in tuber crop based systems. Green manure crops contribute about 60 – 200 kg N ha^{-1} in about 45-60 days (Nayar and Potty, 1996). Growing green manure crops help to control weeds and soil erosion. John (2006) reported that the quantity of FYM for taro can be reduced to half by raising short duration cowpea varieties as intercrops and incorporating the haulms. According to Oliveira *et al.* (2007), the use of sunhemp as green manure intercropped with taro allowed a considerable addition of nitrogen to the system. When the crop was raised, cut at soil level and incorporated, it resulted in the recycling of an average 211 kg ha^{-1} of N, 17 kg ha^{-1} of P, 85 kg ha^{-1} of K, 151 kg ha^{-1} of Ca, and 27 kg ha^{-1} of Mg.

2.2.1. Effect of Green Manuring on Growth and Growth Attributes

Escalada and Ratilla (1998) reported that the application of green manure (7.23 or 10.84 t ha^{-1}) promoted vigorous growth of taro compared to control (without green manure) and those treated only with 60: 39.6: 74.7 N, P, K kg ha^{-1}. According to Oliveira *et al.* (2007), taro height and leaf area were affected by intercropping system with green manure sunhemp. In all sunhemp intercropped systems, taro plants had higher leaf area and height superior to the monoculture. Organic management practice involving green manuring to generate 15–20 t $ha^{-1}$of green matter in 45–60 days along with FYM, neem cake, ash and biofertilizers significantly enhanced the plant height at harvest and total biomass production in taro compared to conventional farming (Suja *et al*., 2017).

Comparing the organic and conventional production systems, the organic farming involving green manuring with cowpea to generate 15-20 t ha^{-1} of green matter in 45-60 days, along with FYM, neem cake and ash profoundly favoured plant height (131.13 cm) and leaf production (8.99 leaves per plant) in tannia (Suja *et al*., 2009). Organic nutrition package standardized in elephant foot yam comprising green manuring with cowpea to yield 20–25 t ha^{-1} of green matter along with FYM, neem cake and wood ash showed luxuriant growth of plants, resulting in significantly greater plant height and leaf spread over conventional practice (Suja *et al.*, 2012).

2.2.2. Effect of Green Manuring on Yield Attributes and Yield

Escalada and Ratilla (1998) reported that application of green manure promoted significantly higher total corm yields of taro than the treatment without green manure and NPK treatment. In a study conducted by Regional Centre of Central Tuber Crops Research Institute, (ICAR-CTCRI), Bhubaneswar in taro, Hota *et al.* (2014) reported that *in situ* incorporation of green manure along with half the recommended doses of NPK and lime recorded an increase of 86 per cent of cormel yield over control which indicated the positive response of green manuring on yield parameters of taro. In another trial on taro, green manuring to generate 15-20 t $ha^{-1}$of green matter in 45-60 days along with FYM, neem cake, ash and biofertilizers resulted in similar yield performance as that of conventional farming and a 29 per cent higher yield over conventional system in the on-farm trials (Suja *et al*., 2017).

Comparing the organic and conventional production systems, the organic farming involving green manuring with cowpea to generate 15-20 t ha^{-1} of green matter in 45-60 days, along with FYM, neem cake and ash favoured number of cormels, cormel yield and mother corm yield in tannia (Suja *et al*., 2009). Organic nutrition package standardized in elephant foot yam comprising green manuring with cowpea to yield 20–25 t ha^{-1} of green matter along with FYM, neem cake and wood ash resulted in higher corm yield (34.6 t ha^{-1}) than conventional farming (Suja *et al*., 2010). According to Suja (2013), organic management involving green manuring to generate 15-20 t ha^{-1} of green matter in 45- 60 days along with FYM, neem cake, ash and biofertilizers produced significantly higher yield in all the three species of yams. The yield increase observed under organic management in white yam, greater yam and lesser yam was 9 per cent, 11 per cent and 7 per cent, respectively over chemical based farming.

2.2.3. . Effect of Green Manuring on Physiological Attributes

Nayar *et al*. (1993) reported that *in situ* green manuring promoted greater dry matter accumulation in cassava. Among different sources of organic manure, green manuring along with poultry manure application resulted in significantly higher total dry matter production in cassava (Pooja, 2018).

2.2.4 Effect of Green Manuring on Tuber Quality

According to Suja *et al*. (2017), the cormel quality of taro was better under organic management. The practice involving green manuring to generate 15-20 t $ha^{-1}$of green matter in 45-60 days along with FYM, neem cake, ash and biofertilizers resulted in higher dry matter, starch, sugars, P, K, Ca and Mg content in tuber than the conventional system.

Organic nutrition package standardized in elephant foot yam comprising green manuring with cowpea to yield 20-25 t ha^{-1} of green matter along with FYM, neem cake and wood ash resulted in significantly higher dry matter, starch, crude protein, K, Ca and Mg contents and lower oxalate content (Suja *et al.*, 2010 and 2012; Suja , 2013) .

In yams, organic tubers produced with organic management involving green manuring to generate 15-20 t ha^{-1} of green matter in 45- 60 days along with FYM, neem cake, ash and biofertilizers had slightly higher dry matter and crude protein contents with considerable improvement in the Mg and Mn contents of tubers by 35 per cent and 45 per cent, respectively over conventional practice (Suja, 2013).

2.2.5 Effect of Green Manuring on Nutrient Uptake

Nayar and potty (1996) recorded higher N and K uptake by green manuring in cassava. Among different sources of organic manure, green manuring along with poultry manure application resulted in significantly higher NPK uptake in cassava (Pooja, 2018).

2.2.6. Effect of Green Manuring on Soil Properties

According to Oliveira *et al.*(2007), the use of sunhemp as green manure intercropped with taro, contributed to a greater addition of organic matter to soil, with a deposition of 6.85 Mg ha^{-1} of sun hemp's biomass (dry substance). Regarding the physical characteristics of the soil, soil temperature was lower in the treatment in which taro was intercropped with the sunhemp. According to Suja *et al*. (2017), green manuring with cowpea (incorporation of 15-20 t $ha^{-1}$of green matter) was the most effective component among the organic manures in the organic cultivation of taro. They reported that organic management involving green manuring along with FYM, ash and biofertilizers lowered the bulk density and improved the water holding capacity and porosity of soil and the organic plots had significantly higher pH, available P and K, higher soil organic C, exchangeable Ca , Mg , Fe, Mn, Zn and Cu status over conventional system. The available N was also increased by 1.45 per cent under organic management.

Organic management comprising green manuring with cowpea to yield 20-25 t ha^{-1} of green matter along with FYM, neem cake and wood ash lowered the bulk density, improved the water holding capacity and porosity of soil in elephant foot yam. The treatment also resulted in higher pH, available N, P, K , soil organic carbon and exchangeable Ca, Mg, Fe, Mn, Zn and Cu status over conventional system (Suja *et al.*, 2012). Green manuring to generate 15-20 t ha^{-1} of green matter in 45- 60 days along with FYM, neem cake, ash and biofertilizers lowered the bulk density, improved the water holding capacity and porosity of soil in yams (Suja, 2013).

Mohankumar *et al.* (2000) suggested inter planting green manure crops in between cassava rows and incorporating after 1.5-2 months or sowing the seeds of green manure crops about 1-2 months before cassava harvest and planting the next crop after incorporation of the green manure, for maintaining soil health through supply of organic matter.

2.2.7. Effect of Green Manuring on Soil Organic Carbon Build up

Significantly higher organic carbon content in soil was recorded by addition of 15-20 t ha^{-1} of green matter of cowpea along with FYM, biofertilizers and ash in taro cultivation (Suja *et al*., 2017).

There was 19 per cent and 15 per cent increase in organic carbon content in organic plots over conventional plots in elephant foot yam and yams by addition of 20-25 t ha^{-1} and 15-20 t ha^{-1} green matter respectively along with FYM and wood ash (Suja, 2013).

2.2.8. **Effect of Green Manuring on Pest and Disease Incidence**

According to Oliveira *et al.* (2007), in treatments in which taro was intercropped with sunhemp, there was a more efficient covering of the soil, which lowered the acceleration of the weeds growth. It was also observed that sunhemp promoted the shading of taro and significantly reduced the intensity of the leaf burning caused by high intensity solar radiation.

The organic farming strategy comprising green manure cowpea to yield 20–25 t ha^{-1} of green matter along with FYM (inoculated with *Trichoderma*), ash and neem cake lowered collar rot disease and resulted in healthy crop stand in elephant foot yam (Suja *et al.*, 2012).

2.2.9 Effect of Green Manuring on Economics of Cultivation

According to Oliveira *et al.* (2007), the reduction of weeds due to soil covering by green manure crops reduced the cost of cultivation by avoiding frequent weeding. Thus the use of sunhemp as green manure crop was an adequate option to the organic taro production to increase net income.

Of the various production systems tested, organic farming involving green manure cowpea to yield 20–25 t ha^{-1} of green matter along with FYM, ash and neem cake generated the highest net income of ₹ 215,776 ha^{-1} as against ₹168,060 ha^{-1} in the conventional system in elephant foot yam (Suja *et al*., 2012).

Among the different sources of organic manures applied, cowpea green manuring along with poultry manure application resulted in the highest net income and benefit-cost ratio in cassava (Pooja, 2018).

The review of literature indicate the favourable influence of components of organic farming such as organic sources, biological sources and green manuring on growth, yield, tuber quality, soil properties, nutrient uptake, organic carbon build up and economics of cultivation of organic production of taro and other tuber crops. Even though, organic production of taro is highly profitable, the current knowledge of the effect of different organic sources on performance of taro crop and soil health is limited. Hence comparison of different organic sources and formulation of a cost effective and environmental friendly nutrition package for organic taro production is absolutely essential.

MATERIALS AND METHODS

Table 1. Mechanical composition of the soil of the experimental site

Sl. No.	Fractions	Content (%)	Method used
1	Sand	18.49	Bouyoucos hydrometer method (Bouyoucos, 1962)
2	Silt	41.22	
3	Clay	40.29	

Table 2. Chemical properties of the soil of the experimental site

Parameter	Content	Rating	Method used
pH	5.93	Moderately acidic	1:2.5 soil water suspension – pH meter (Jackson, 1973)
EC (d Sm^{-1})	0.34	Safe	Conductivity meter method (Jackson,1973)
Organic carbon (%)	1.05	High	Walkley and Black method (Jackson, 1973)
Available N (kg ha^{-1})	351.58	Medium	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P (kg ha^{-1})	76.85	High	Bray colorimeter method (Jackson, 1973)
Available K (kg ha^{-1})	393.95	High	Neutral normal ammonium acetate extractant flame photometry (Jackson, 1973)
Total organic carbon (%)	4.20	-	Weight loss on ignition CHNS analyzer (Nelson and Sommers, 1996)
Recalcitrant carbon (%)	0.92	-	Modified Walkley and Black titration (Chan *et al.*, 2001)
Labile carbon (mg kg^{-1})	241.85	-	Potassium permanganate oxidation method (Blair *et al.*,1995)
Water soluble carbon (mg kg^{-1})	32.30	-	Extraction with water followed by wet oxidation (Mc Gill *et al.*,1986)

relative humidity and total rainfall during the cropping period were collected from the Class B Agromet Observatory of Department of Agricultural Meteorology, College of Agriculture, Vellayani and are given as Appendix I and graphically presented in Fig. 1 and Fig. 2.

3.1.4 Cropping History

Previously banana was cultivated in the experimental field.

3.2 MATERIALS

3.2.1 Crop and Variety

Taro variety "Muktakeshi" released from the Indian Council of Agricultural Research (ICAR) - Central Tuber Crops Research Institute (CTCRI) Regional Centre, Bhubaneswar was used as seed material. This variety is resistant to taro leaf blight disease with an average tuber yield of 15-18 t ha^{-1} with excellent cooking quality. The duration of the variety is 6-7 months (Shil and Nath, 2015).

3.2.2 Planting Material

Planting materials were procured from Indian Council of Agricultural Research (ICAR) - Central Tuber Crops Research Institute (CTCRI), Sreekariyam, Thiruvananthapuram. Cormels (side tubers) weighing 25-35 g were used for planting.

3.2.3 Plastic Sacks for Rooting and Tuberisation Study

Plastic sacks of uniform size (50 kg capacity) were used for raising plants for rooting and tuberisation study.

3.2.4 Potting Medium for Rooting and Tuberisation Study

Soil at the experimental site was used as potting medium for filling the sacks. The chemical and microbial properties of the soil used as potting medium for the rooting and tuberisation study are given in Table 3a and Table 3b respectively.

3.2.5 Organic Sources

Well decomposed FYM, poultry manure, wood ash and vermiwash were used as the organic sources of nutrients in the experiment. Farmyard manure and poultry manure were applied on N equivalent basis (to supply 80 kg N ha^{-1}) in respective treatments and the quantities were sufficient to supply 25 kg P_2O_5 ha^{-1} during both the years, which is the recommended dose of phosphorus. Application of FYM and poultry manure supplied only a portion of the recommended dose (100 kg ha^{-1}) of K_2O (51.36 and 46.75 kg K_2O respectively through FYM and 58.55 and 48.75 kg K_2O through poultry manure in Ist and IInd year of experimentation respectively). The remaining quantities of K_2O required (100 kg ha^{-1} – the quantity supplied through FYM / poultry manure) were supplied through wood ash. The nutrient content of the organic sources are given in Tables 4a and 4b and the quantity of different organic manures applied in the experiment are given in Table 5. The treatment wise quantity of nutrient added through organic manures is given in Appendix II.

3.2.5.1 Vermiwash

Vermiwash was prepared as per KAU POP using earth worms procured from College of Agriculture, Vellayani with farm waste and kitchen waste.

3.2.6 Biofertilizers

PGPR mix I supplied from the Department of Agricultural Microbiology, College of Agriculture, Vellayani, was used as biofertilizer in the experiment. The

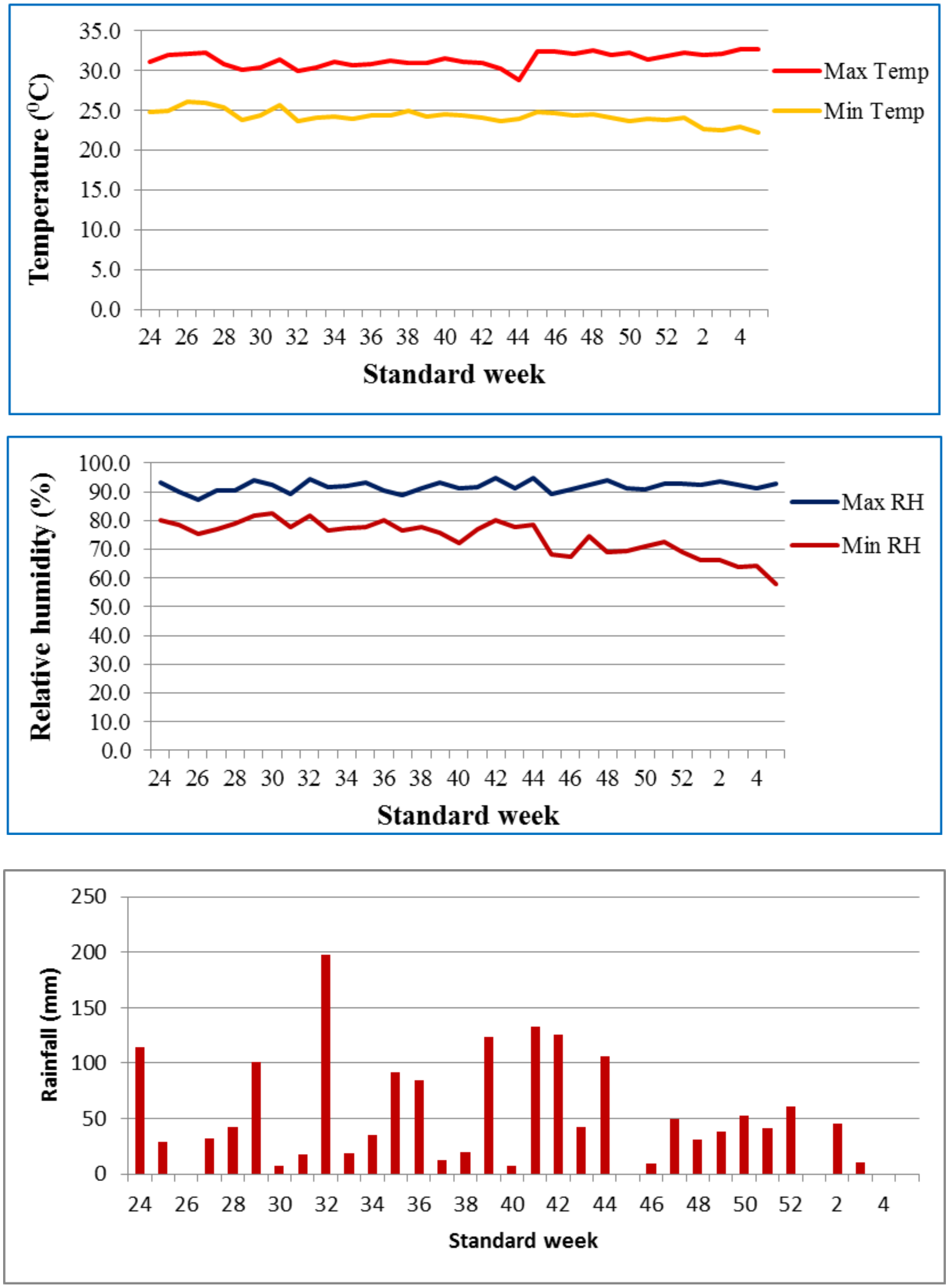


Fig. 1. Weather parameters during first year of experiment (June 2019 – January 2020)

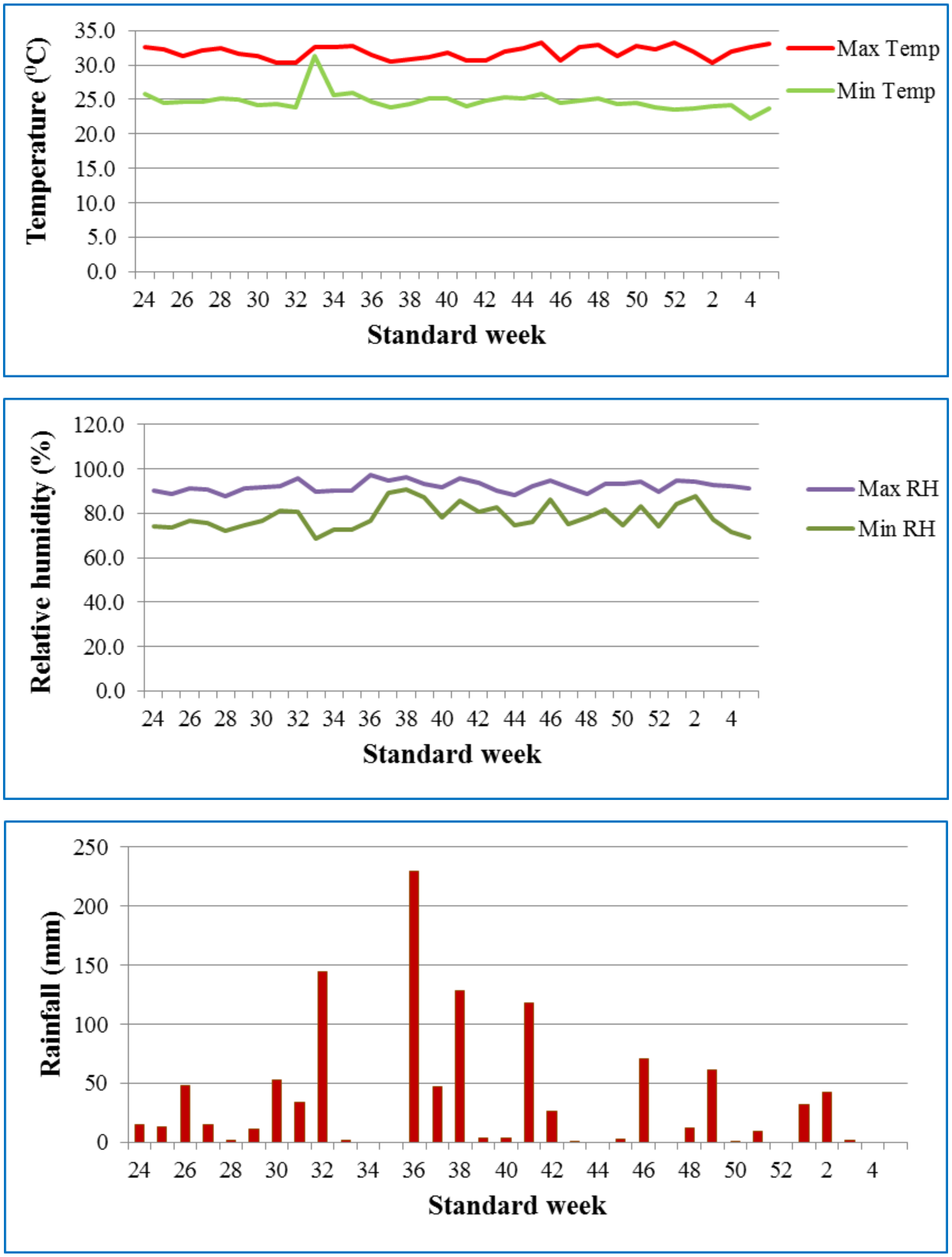


Fig. 2. Weather parameters during second year of experiment (June 2020 – January 2021)

Table 3a. Chemical properties of the soil used as potting medium

Parameter	Content	Rating	Method used
pH	5.93	Moderately acidic	1:2.5 soil water suspension – pH meter (Jackson, 1973)
EC (d Sm^{-1})	0.34	Safe	Conductivity meter method (Jackson,1973)
Organic carbon (%)	1.05	High	Walkley and Black method (Jackson, 1973)
Available N (mg kg^{-1})	156.96	Medium	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P (mg kg^{-1})	34.31	High	Bray colorimeter method (Jackson, 1973)
Available K (mg kg^{-1})	175.87	High	Neutral normal ammonium acetate extractant flamephotometry (Jackson, 1973)

Table 3b. Microbial properties of soil used as potting mixture

Microbes		**Population**	**Medium used**	**References**
Bacteria (log cfu g^{-1})		6.30	Nutrient agar	Agarwal and Hasija (1986)
Fungi (log cfu g^{-1})		4.53	Martin’s Rose Bengal agar	
Actinomycetes (log cfu g^{-1})		4.01	Kenknight and Munaier’s agar	
N- fixers (log cfu g^{-1})	Azospirillum	4.04	N-free semisolid malate medium (NFB)	
	Azotobacter	3.30	Jenson’s medium	
P solubilisers (log cfu g^{-1})		3.52	Pikovskaya’s medium	
Dehydrogenase activity (µg TPF g^{-1} 24 h^{-1})		36.08		Casida *et al*. (1964)

Table 4a. NPK content of organic sources, per cent

Organic manure	First year			Second year		
	N	P	K	N	P	K
Farmyard manure	0.95	0.72	0.61	1.06	0.68	0.62
Poultry manure	1.12	1.40	0.82	1.28	1.42	0.78
Wood ash	0.58	0.37	5.16	0.48	1.10	5.23
Vermiwash	0.08	0.06	0.07	0.08	0.06	0.06

Table 4b. Secondary and micronutrient content of organic sources, mg kg^{-1}

	First year						Second year					
	Ca	Mg	S	Zn	B	Cu	Ca	Mg	S	Zn	B	Cu
Farmyard manure	11456	5058	3834	135	16	23	6912	2346	1870	138	17	22
Poultry manure	7436	1134	2067	179	19	17	6787	1267	1578	182	21	16
Wood ash	183452	12464	5631	233	123	70	166534	13482	5204	226	128	68
Vermiwash	91	24	42	0.85	0.56	2.50	89	26	38	0.96	0.54	2.40

Table 5. Quantity of organic manures applied, t ha^{-1}

Organic manure		Quantity	
		First year	Second year
Farmyard manure		8.42	7.54
Poultry manure		7.14	6.25
Wood ash	FYM treated plots	0.94	1.02
	Poultry manure treated plots	0.80	0.98

PGPR mix I is a consortium of *Azospirillum lipoferum*, *Azotobacter chroococcum*, *Bacillus megaterium* and *Bacillus sporothermodurans* (Gopi, 2019).

3.2.7 Green Manuring

Green manure cowpea (var. Anaswara) and daincha (*Sesbania aculeata*) were raised in the interspaces (seed @ 30 kg ha^{-1}) as per treatments and incorporated at 50 per cent flowering stage. The nutrient content of green manure crops and the mean quantity of green matter (on dry weight basis) added are given in the Table 6.

3.2.8 Fertilizers

Urea (46 % N), Rajphos (20 % P_2O_5) and Muriate of potash (60 % K_2O) were used as sources of chemical fertilizer for N, P and K respectively in control plots managed as per KAU POP.

Table 6. Nutrient content of green manure crops and quantity of green matter added

Green manure crop	Nutrient content (%)						Mean quantity of green matter (t ha^{-1})	
	First year			Second year			First year	Second year
	N	P	K	N	P	K		
Cowpea	1.18	0.12	2.65	1.12	0.15	2.08	1.57	2.26
Daincha	1.34	0.26	1.96	1.29	0.24	1.86	4.55	3.18

3.3 METHODS

3.3.1 Design, Treatments and Layout

3.3.1.1 Experiment I - Organic Nutrition in Taro (Field Experiment)

Design : Randomised Block Design

Treatments : 12 + 3

Replications : 3

Spacing : 60 cm x 45 cm

Plot size : 4.8 m x 4.5 m

Different organic sources and biofertilizer with *in situ* green manuring were tried as organic nutrition practices.

Treatments

1. Organic sources (S)

s_1- FYM + wood ash

s_2- FYM + wood ash + PGPR mix I

s_3- FYM + wood ash + PGPR mix I + vermiwash

s_4- Poultry manure + wood ash

s_5- Poultry manure + wood ash + PGPR mix I

s_6- Poultry manure + wood ash + PGPR mix I + vermiwash

2. *In situ* green manuring (G)

g_1- Cowpea

g_2- Daincha

Control

C_1- Nutrient management through chemical fertilizers as per KAU POP (80 : 25: 100 kg ha^{-1})

C_2 - Nutrient management as per KAU organic POP (*Ad hoc*)

C_3 - Absolute control

KAU organic POP (*Ad hoc*) : Apply cattle manure or compost @ 12 t ha^{-1} as basal dressing, while preparing the ridges for planting. Sow green manure seeds (cow pea /sunhemp) @30 kg ha^{-1} at the time of planting with the receipt of pre monsoon showers. 10 kg P_2O_5 as rock phosphate has to be applied for the green manure crop at sowing time. At flowering (40-45 DAS) incorporate the plants along with 4t FYM /2t PM/ 2 t vermi compost/ 2 t coir pith compost and 1500 kg wood ash.

Treatment combinations

s_1g_1 s_2g_1 s_3g_1 s_4g_1 s_5g_1 s_6g_1

s_1g_2 s_2g_2 s_3g_2 s_4g_2 s_5g_2 s_6g_2

The layout of the field experiment is given in Fig. 3.

3.3.1.2 Experiment II- Rooting and Tuberisation Pattern Study in Taro (Pot Culture)

Pot culture study was conducted to study the rooting and tuberisation pattern of taro under organic nutrition.

Design : Completely Randomised Design

Number of treatments : 6 +3

Number of replications : 3

Number of plants per treatment per replication : 16

Treatments

T_1- FYM + wood ash

T_2- FYM + wood ash + PGPR mix I

T_3- FYM + wood ash + PGPR mix I + vermiwash

T_4- Poultry manure + wood ash

T_5- Poultry manure + wood ash + PGPR mix I

T_6- Poultry manure + wood ash + PGPR mix I + Vermiwash

<u>Control</u>

C_1- Nutrient management through chemical fertilizers as per KAU POP (80 : 25: 100 kg ha^{-1})

C_2 - Nutrient management as per KAU organic POP (*Ad hoc*)

C_3 - Absolute control

3.3.2 Crop Management

3.3.2.1 Main Field Preparation and Planting

The experimental site was initially cleared by removing weeds and ploughed using a cultivator. After levelling the field, plots were separated by taking bunds. Beds were prepared and cormels weighing 25-35 g treated with PGPR mix I as per treatments were planted at a spacing of 60 cm x 45 cm.

3.3.2.2 Preparation of Sacks and Planting in Pot Culture Study

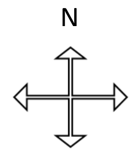
Plants were raised in plastic sacks having 50 kg capacity for pot culture study. Soil from the experimental site was used as potting medium. Uniform quantity of potting medium (25 kg) was filled in each sack and cormels weighing 25-35 g treated with PGPR mix I as per treatments were planted in each sack. The sacks were arranged at a spacing of 60 cm x 45 cm from centre to centre.

3.3.2.3 Application of Organic Sources

A uniform dose of FYM at the rate of 12 t ha^{-1} was given (except for absolute control) at the time of land preparation for field experiment and a quantity of 324 g FYM per sack was given after filling potting medium in plastic sacks for pot culture study. The recommended dose of NPK at the rate of 80: 25: 100 kg ha^{-1} were supplied through organic sources (FYM, poultry manure, wood ash) on N equivalent basis as per the treatments as basal dose, except wood ash (applied while incorporating green manure in field experiment and one half months after planting in pot culture study).

3.3.2.4 Application of Biofertilizers

Corm treatment with 5 per cent suspension of PGPR mix I was done as per treatments. Soil application of PGPR mix 1 enriched cow dung at the rate of 10 g per plant (mixture of dry cow dung and PGPR mix 1 in 50:1 proportion) were done at planting and 2 MAP as per the treatments.



Replication I	Replication II	Replication III
s_3g_2	C_2	s_6g_2
s_1g_1	s_2g_2	s_3g_2
s_5g_2	s_6g_2	s_4g_1
C_1	s_5g_2	s_2g_2
s_6g_2	s_4g_2	s_2g_1
s_2g_1	s_1g_2	s_4g_2
s_5g_1	s_6g_1	s_5g_2
C_2	s_3g_2	s_1g_2
s_3g_1	s_4g_1	s_6g_1
s_4g_1	s_1g_1	C_2
s_4g_2	C_3	s_5g_1
s_6g_1	C_1	C_3
s_2g_2	s_2g_1	s_3g_1
s_1g_2	s_3g_1	s_1g_1
C_3	s_5g_1	C_1

Fig. 3. Layout of Experiment I

Plate 1. General view of the field experiment – first year

Plate 2. General view of the field experiment – second year

Plate 3. Planting of cormels

Plate 4. *In situ* green manuring with cow pea and daincha

Plate 5. Taro plants at active growth stage

Plate 6. General view of the pot culture experiment

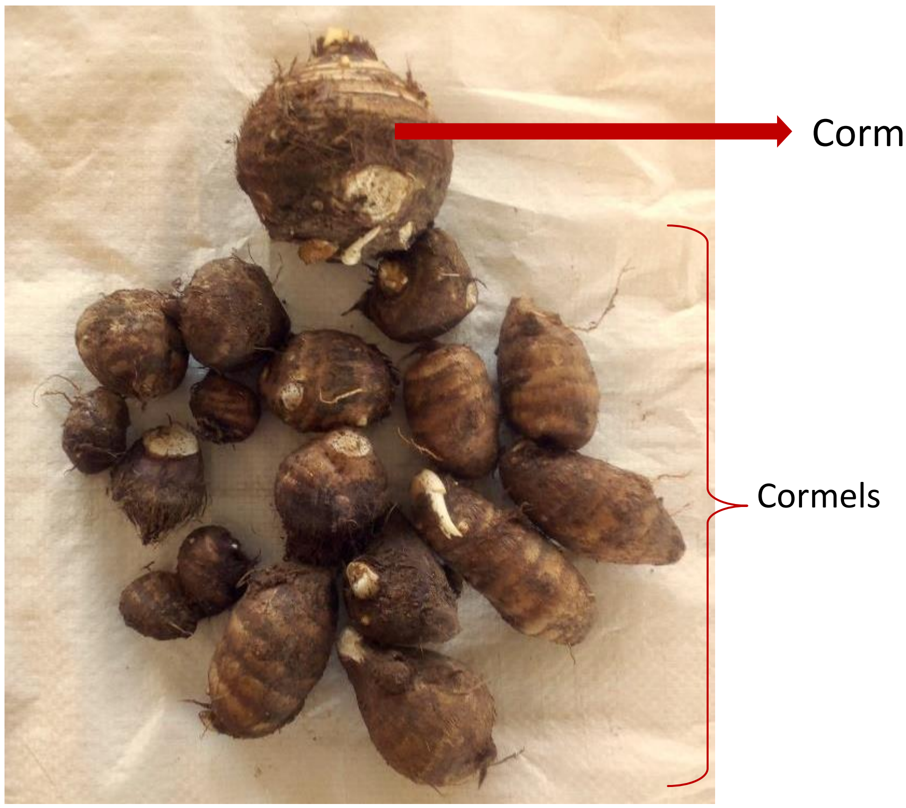


Plate 7. Corm and cormels of taro

3. MATERIALS AND METHODS

The study entitled “Organic nutrition in taro (*Colocasia esculenta* (L.) Schott)” was carried out at College of Agriculture, Vellayani to investigate the effect of organic nutrition on growth, yield, quality, soil organic carbon build up and economics of cultivation of taro and to study rooting and tuberisation pattern of taro under organic nutrition. Two separate experiments were conducted; a field experiment to investigate the effect of organic nutrition in taro, and a pot culture to study the rooting and tuberization pattern of taro.

3.1 EXPERIMENTAL SITE

3.1.1 Location

The experiment was carried out in the farmer field at Chavadinada, Peringamala, Venganoor, Thiruvananthapuram, Kerala, India. The site was located at 08º41’56” N latitude, 77º01’92” E longitude and at an altitude of 28 m above mean sea level.

3.1.2 Soil

Soil of the experimental field was silty clay in texture. Composite soil sample was collected from the experimental field before conducting the experiment and analysed for its mechanical composition and chemical properties.

The mechanical composition and chemical properties of soil are given in Table 1 and Table 2 respectively.

3.1.3 Climate and Season

The field experiment was carried out during June 2019 to January 2020 and repeated from June 2020 to January 2021 while the pot culture was conducted during June 2019 to January 2020. Tropical humid climate prevailed over the experimental site. The standard week wise weather data on minimum and maximum temperature, *3.3.2.5 Green Manuring*

Green manure crops cowpea (variety Anaswara) and daincha were raised in the interspaces (seed @ 30 kg ha^{-1}) in the field experiment as per treatments and incorporated at 50 per cent flowering stage (45 DAS) by uprooting.

3.3.2.6 Application of Vermiwash

Vermiwash (10 times dilution) prepared at the experimental site as per KAU POP was sprayed at 2nd, 3rd and 4th months after planting.

3.3.2.7 Weeding and Earthing Up

Weeding was carried out at monthly interval. Earthing up was done along with the application of wood ash one and half month after planting.

3.3.2.8 Irrigation

Irrigation was given on the day of planting and thereafter at weekly interval during non rainy periods

3.3.2.9 Harvest

The crop was harvested seven months after planting when the plants started drying and falling.

3.4 OBSERVATIONS

3.4.1 Observations in the Main Field

Four plants were selected at random and tagged from each plot as observational plants and observations were taken from these plants and the average was worked out.

3.4.1.1 Growth and Growth Attributes

3.4.1.1.1 Number of Days Taken for 50 Per Cent Sprouting of Seed Corm

The observations on days taken for 50 per cent sprouting of corms was recorded from the date of planting of taro seed corms and expressed in days.

3.4.1.1.2 Plant Height

Height of the plant was measured from the ground (base of plant) to the tip of the longest petiole at the blade joint (Mohankumar, 1986). Plant height of four observational plants was measured at 2, 4, 6 MAP and at harvest with the help of a scale and the average value was calculated and expressed in cm.

3.4.1.1.3 Number of Retained Leaves per Plant

Number of fully opened green leaves of the observational plants at the time of observations (2, 4, 6 MAP and at harvest) was counted and recorded.

3.4.1.1.4 Leaf Area per Plant

The length and breadth of each leaf was measured. The length was taken from the apex of the leaf to the sinus region, while the breadth was measured across the point of petiole attachment. The leaf area (cm^2) was estimated according to the formula put forth by Biradar *et al.* (1978).

$$\text{Leaf area} = 0.917 \times L \times B$$

(Where, L and B are the length and breadth of the leaf respectively)

The total leaf area was worked out by adding the leaf area of all the fully opened leaves at the time of observation.

3.4.1.1.5 Leaf Area Index

Leaf area index (LAI) of the plant was calculated by the formula suggested by Watson (1947).

$$\text{Leaf area index} = \frac{\text{Total leaf area of the plant}}{\text{Land area occupied by the plant}}$$

3.4.1.2 Yield Attributes and Yield

3.4.1.2.1 Number of Cormels per Plant

Number of cormels in the observational plants was counted at harvest and the average was worked out.

3.4.1.2.2 Mean Weight of Cormel

The total weight of the cormels in the observational plants was divided by the total number of cormels and expressed in grams (g).

3.4.1.2.3 Cormel to Corm Ratio

This was calculated as the ratio of the weight of cormels to the weight of corms per plant.

3.4.1.2.4 Cormel Yield ha^{-1}

Yield of cormels obtained from net plot area was noted and from this corm yield per hectare was calculated and expressed in t ha^{-1}.

3.4.1.2.5 Corm Yield ha^{-1}

Yield of corms obtained from net plot area was noted and from this, corm yield per hectare was calculated and expressed in t ha^{-1}.

3.4.1.3 Physiological Attributes

3.4.1.3.1 Leaf Chlorophyll Content (4 MAP)

Fresh leaf samples were taken from each plot and the chlorophyll content was estimated at 4 MAP (Yoshida *et al*., 1976) and expressed in mg g^{-1} of leaf tissue.

3.4.1.3.2 Dry Matter Production at Harvest

From each plot, uprooted plants containing both above and below ground portions were cleaned and plant parts were first shade dried and then kept at about 70 $\pm 5^{o}$ C in a hot air oven till constant weights were obtained. The dry weight was noted and total dry matter production at harvest was calculated in t ha^{-1}.

3.4.1.3.3 Harvest Index

It is the ratio of cormel yield to total biomass on dry weight basis. This was worked out from observational plants.

3.4.1.4 Quality Attributes of Cormel

3.4.1.4.1 Dry Matter Content

A known weight of harvested cormels was first cleaned and shade dried. The dry weight of cormel was recorded after drying in an oven at 70 ± 5^{o}C temperature till constant weights were obtained and the dry matter percentage was worked out.

3.4.1.4.2 Starch Content

The percentage starch content of the cormel was estimated using titrimetric method (Aminoff *et al*., 1970) on dry weight basis.

3.4.1.4.3 Total Sugar Content

Total sugar content of the cormel was estimated using Anthrone method following the procedure suggested by Sadasivam and Manickam (1996) and expressed in percentage.

3.4.1.4.4 Crude Protein Content

The N content of cormel estimated was multiplied with a factor 6.25 to get the crude protein content (Simpson *et al*., 1965) and expressed in percentage.

3.4.1.4.5 Crude Fibre Content

Crude fibre content of cormel was estimated using the method given by Sadasivam and Manickam (1996) and expressed in percentage.

3.4.1.4.6 Oxalic Acid Content

Oxalic acid content of cormel was estimated by a method suggested by Day and Underwood (1986) and expressed in percentage on dry weight basis.

3.4.1.5 Content and Uptake of Nutrients and Nutrient Use Efficiency

3.4.1.5.1 N, P and K Content of Plant and Tuber

The observational plants uprooted were separated into cormels, corm, blade and petiole and the sub samples were taken and oven dried at 70 ± 5^0C. The plant samples were then ground to pass through a 0.5 mm sieve and digested for the analysis of NPK contents. The N content was analysed using the modified microkjeldahl method (Jackson, 1973). Vanadomolybdate phosphoric yellow colour method was used for the estimation of P content (Piper, 1966). Potassium content was determined by flame photometry (Jackson, 1973).

3.4.1.5.2 Total N, P and K Uptake at Harvest

The N content obtained through modified microkjeldahl method in each plant part was then multiplied with the respective total DMP to obtain the uptake of N. Total N uptake was obtained by summing up the uptake values of each plant part and expressed in kg ha^{-1}.

The P uptake was calculated by multiplying the P content in each plant part obtained through Vanadomolybdate phosphoric yellow colour method with respective total DMP. Total P uptake was obtained by summing up the uptake values of each plant part and expressed in kg ha^{-1}.

The K uptake was determined by multiplying the K content in each plant part obtained through flame photometry with respective total DMP. Total K uptake was obtained by summing up the uptake values of each plant part and expressed in kg ha^{1}.

3.4.1.5.3 Nutrient Use Efficiency

The agronomic efficiency of N was calculated by using the formula and expressed as kg yield per kg nitrogen applied.

$$\text{Agronomic efficiency} = \frac{\text{Yield of N applied plot – Yield of control plot}}{\text{Amount of N applied}}$$

3.4.1.6 Soil Analysis

Soil pH, EC, organic carbon, available N, P and K were determined before and after the experiment. A composite soil sample was collected from the experimental field before conducting the experiment. Similarly, from each experimental plot, soil samples were also collected after the experiment. Samples were air dried, powdered and sieved before analysis. For the estimation of macro nutrients *viz*., available N, available P and available K, soil was passed through 2 mm sieve and for organic carbon 0.5 mm sieve was used. The analysis was conducted using appropriate methods as given in Table 2.

3.4.1.7 Soil Organic Carbon Build Up

The soil samples collected after the experiment from each treatment were analysed for different fractions of soil carbon.

3.4.1.7.1 Recalcitrant Organic Carbon

Recalcitrant organic carbon content in the soil was determined by Modified Walkley and Black titration method as described by Chan *et al.* (2001).

3.4.1.7.2 Total Organic Carbon

Total organic carbon content in the soil samples was determined by weight loss on ignition CHNS analyzer (Vario EI cube, Elementar, Germany) method as described by Nelson and Sommers (1996).

3.4.1.7.3 Labile Carbon

Labile carbon was determined by potassium permanganate oxidation method as described by Blair *et al.* (1995).

3.4.1.7.4 Water Soluble Carbon

Water soluble carbon was determined as per the method given by Mc Gill *et al.* (1986) by extracting with water followed by wet oxidation method.

3.4.1.8 Pest and Disease Incidence

Incidence of pest and disease was monitored throughout the crop period.

3.4.1.9 Nutrient Balance Sheet

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

3.4.1.10 Economic Analysis

3.4.1.10.1 Net Income

Cost of cultivation was deducted from gross returns to obtain the net income

Net income (₹ ha^{-1}) = gross returns (₹ ha^{-1}) - cost of cultivation (₹ ha^{-1})

3.4.1.10.2 Benefit : Cost Ratio

The benefit to the cost ratio was worked out as per the formula given below

$$\mathrm{BCR} = \frac{\text{Gross return}}{\text{Cost of cultivation}}$$

3.4.2 Observations in Pot Culture Study

3.4.2.1 Analysis of Potting Medium

The analysis of potting media was done at initial, 1 MAP, 4 MAP and at harvest. The collected samples were air dried and sieved before conducting analysis. The samples were analyzed for pH, EC, organic carbon, available N, available P and available K using standard procedures as presented in Table 3a.

3.4.2.2 Microbial Study of Potting Medium

Microbial study of potting media (population of bacteria, fungi, actinomycetes, N- fixers and P solubilisers) were done at the beginning of the experiment, 1 MAP, 4 MAP and harvest. The analysis was conducted using media and methods as given in Table 3b and expressed in log cfu g^{-1} of soil. The composition of media used is given in Appendix III. The dehydrogenase activity of the samples was analyzed by following the procedure outlined by Casida *et al*. (1964) and expressed in µg TPF g^{-1} 24 h^{-1}.

3.4.2.3 Rooting Pattern

Rooting pattern was studied at monthly interval from 1 MAP and also at harvest by uprooting (destructive sampling) two plants from each treatment per replication.

3.4.2.3.1 Root Apex Diameter

Root apex diameter was recorded at 10±2 cm above the root tip.

3.4.2.3.2 Number of Roots per Plant

Total number of roots in the uprooted sample plants was counted and average was worked out

3.4.2.3.3 Weight of Roots per Plant

Roots were separated from the uprooted plants and cleaned them. Fresh weight of roots was recorded and average was worked out in g plant^{-1}.

3.4.2.3.4 Root Anatomy

Collected roots from the uprooted plants of each treatment were washed and then a piece of root, 10±2 cm above the root tip was kept in distilled water. Freehand sections of about 50 μm thick were cut and the sections were selected for observation under microscope. The observations on number of late metaxylem, number of early metaxylem, stele diameter and stele diameter to root diameter ratio were taken.

3.4.2.4 Tuberisation Pattern

Tuberisation pattern was studied at monthly interval from 1 MAP and also at harvest by uprooting (destructive sampling) two plants from each treatment per replication.

3.4.2.4.1 Time of Tuber Initiation

Tuber initiation was observed from the uprooted sample plants at monthly interval from 1 MAP.

3.4.2.4.2 Corm Weight per Plant

Weight of corm in the uprooted sample plants was recorded, mean value was worked out and expressed in g plant^{-1}.

3.4.2.4.3 Cormel Weight per Plant

Weight of cormels in the uprooted sample plants was recorded, mean value was worked out and expressed in g plant^{-1}.

3.4.2.4.4 Cormel Bulking Rate

Cormel bulking rate is the rate of increase in cormel weight per unit time and was calculated from the data on cormel weight per plant at monthly interval. It was expressed as g day^{-1} plant^{-1} on dry weight basis (Kumar, 1986).

$$\text{Bulking rate (BR)} \quad = \quad \frac{w2 - w1}{t2 - t1}$$

where, w_1 – dry weight of cormel at time t_1

w_2 – dry weight of cormel at time t_2

3.5 STATISTICAL ANALYSIS

Data relating to different observations were compiled, tabulated and statistically analysed using analysis of variance technique (ANOVA), suggested by Panse and Sukhatme (1985). The significance was tested using f test (Snecdeore and Cochran, 1967) and if the treatment differences were found significant, then critical difference was worked out at 5 per cent level of probability. The significance of each treatment *Vs.* each control of factorial experiment (experiment I) was tested using contrast analysis. Correlation analysis of nutrient uptake *Vs.* root anatomical characters such as root apex diameter, late metaxylem number, early metaxylem number and stele diameter were done.

4. RESULTS

The study entitled "Organic nutrition in taro (*Colocasia esculenta* (L.) Schott)" was conducted in the farmer field at Peringamala, Thiruvananthapuram from June 2019 to January 2020 and June 2020 to January 2021 to investigate the effect of organic nutrition on growth, yield, quality, soil organic carbon build up and economics of cultivation of taro and to study rooting and tuberisation pattern of taro under organic nutrition. The first experiment was laid out in randomised block design with 12 treatment combinations involving six organic sources and two *in situ* green manuring practices along with three control treatments with three replications. The tuberization study was laid out as completely randomized design with six treatments and three control with three replications. The experimental data was statistically analysed and the results are presented in this chapter.

4.1 EXPERIMENT I - ORGANIC NUTRITION IN TARO (FIELD EXPERIMENT)

4.1.1 Growth and Growth Attributes

4.1.1.1 Number of Days Taken for 50 Per Cent Sprouting of Seed Corm

The effects of organic sources, *in situ* green manuring and their interactions on number of days taken for 50 per cent sprouting of seed corm of taro are given in Tables 7a and 7b.

The organic sources had significant influence on number of days taken for 50 per cent sprouting of seed corm during the first year. The organic source s_2 (FYM + wood ash +PGPR mix I) took less number of days (24.33 days) for 50 per cent sprouting of seed corm and it was on par with s_3 (FYM + wood ash + PGPR mix I + vermiwash) which required 24.67 days for attaining 50 per cent sprouting of seed corm. The organic source s_4 (PM+ wood ash) took the highest number of days (28.67 days) for 50 per cent sprouting of seed corm followed by s_6 - 26.50 days (PM+ wood ash + PGPR mix I + vermiwash) and s_6 was on par with s_5 (26.17 days) and s_1 (25.67

days). During the second year, the organic sources did not show any significant influence on number of days taken for 50 per cent sprouting of seed corm.

The *in situ* green manuring and S x G interaction did not influence the number of days taken for 50 per cent sprouting of seed corm during both the years.

No significant difference was found among any of the control treatments and organic treatments with respect to number of days taken for 50 per cent sprouting of seed corm during both the years.

4.1.1.2 Plant Height

The result of effect of organic sources, *in situ* green manuring and their interactions on plant height of taro at bimonthly intervals from 2 MAP are given in Table 8a and 8b.

In general, the height of plants increased up to 4 MAP during both the years after which the height reduced up to harvest.

Plant height varied significantly with different organic sources at all stages of observation during both the years. During the first year, the organic source s_6 (application of poultry manure along with wood ash, PGPR mix I and vermiwash) resulted in the tallest plants, which was significantly superior to all other organic sources at all stages of observation (156.26 cm, 129.62 cm and 107.53 cm at 4 MAP, 6 MAP and at harvest respectively), except 2 MAP (82.67 cm). At 2 MAP, s_6 was on par with s_5 (PM+ wood ash + PGPR mix I) and s_3 (FYM + wood ash + PGPR mix I + vermiwash) which had values 78.72 cm and 80.33 cm respectively. The s_6 treatment was followed by s_5 with respect to the plant height at all stages of observation (145.83 cm, 124.83 cm, and 103.47 cm at 4 MAP, 6 MAP and at harvest respectively), except 2 MAP, wherein it was statistically similar to s_6 and s_3.

During the second year also, the greatest plant height was recorded with s_6 (application of poultry manure along with wood ash, PGPR mix I and vermiwash) at

Table 7a. Effect of organic sources and *in situ* green manuring on number of days taken for 50 per cent sprouting of seed corm

Treatments	Number of days for 50 % sprouting of seed corm	
	I year	II year
Organic sources (S)		
s_1- FYM + wood ash	25.67	11.00
s_2- FYM + wood ash +PGPR mix I	24.33	10.33
s_3- FYM + wood ash + PGPR mix I + vermiwash	24.67	10.17
s_4- PM+ wood ash	28.67	11.33
s_5- PM+ wood ash + PGPR mix I	26.17	9.83
s_6- PM+ wood ash + PGPR mix I + vermiwash	26.50	11.00
SEm(±)	0.34	0.40
CD (0.05)	0.994	NS
***In situ* green manuring (G)**		
g_1- Cowpea	26.00	10.28
g_2- Daincha	26.00	10.94
SEm(±)	0.20	0.23
CD (0.05)	NS	NS

Table 7b. Effect of S x G interaction and treatments *Vs*. control on number of days taken for 50 per cent sprouting of seed corm

Treatments	Number of days for 50 % sprouting of seed corm	
S x G interaction	I year	II year
s_1g_1	25.67	10.67
s_1g_2	25.67	11.33
s_2g_1	24.33	11.00
s_2g_2	24.33	9.67
s_3g_1	24.67	9.67
s_3g_2	24.67	10.67
s_4g_1	28.00	10.33
s_4g_2	29.33	12.33
s_5g_1	26.67	9.67
s_5g_2	25.67	10.00
s_6g_1	26.67	10.33
s_6g_2	26.33	11.67
SEm(±)	0.48	0.57
CD (0.05)	NS	NS
Control		
C_1- KAU PoP	25.67	10.67
Treatments *vs.* C_1	NS	NS
C_2- KAU organic PoP	26.33	11.00
Treatments *vs.* C_2	NS	NS
C_3- Absolute control	25.67	10.33
Treatments *vs.* C_3	NS	NS

[1] significantly different from C_1; [2] significantly different from C_2;
[3] significantly different from C_3

all stages of observation (72.00 cm, 139.20 cm, and 97.56 cm at 2 MAP, 4 MAP and at harvest respectively) except 6 MAP and was comparable to s_5 (PM+ wood ash + PGPR mix I) and s_3 (FYM + wood ash + PGPR mix I + vermiwash) which recorded the values 69.33 and 68.83 cm respectively at 2 MAP and with s_5 (95.31 cm) at harvest. At 6 MAP, s_5 (PM+ wood ash + PGPR mix I) resulted in significantly taller plants (116.12 cm) and was on par with s_6 (116 cm).

In situ green manuring showed significant effect on plant height only at 4 MAP and 6 MAP during the first year. In both the stages, *in situ* green manuring with daincha produced significantly taller plants (137.31 cm at 4 MAP and 111.59 cm at 6 MAP) than cow pea. During the second year, the plant height was significantly influenced by *in situ* green manuring only at 4 MAP and *in situ* green manuring with daincha produced significantly taller plants (123.65 cm) than cow pea.

The S x G interaction showed significant response at all stages except 2 MAP during the first year. The treatment combination s_6g_2 produced the tallest plants at 4 MAP (158.18 cm) and 6 MAP (130.58 cm) which was on par with s_6g_1 at 4 MAP (154.34 cm), with s_6g_1 (128.67 cm) and s_5g_2 (126 cm) at 6 MAP. At harvest, the highest plant height (108.67 cm) was recorded with s_6g_1 and which was on par with s_6g_2 (106.39 cm) and s_5g_1 (104.51 cm). During the second year, S x G interaction was significant only at harvest, the treatment combination s_6g_1 produced more plant height (101.67 cm) which was significantly higher than all other treatments, but was on par with s_5g_2 (95.04 cm) and s_5g_1 (95.58 cm).

Regarding the treatments *vs.* control (Table 8b), the effect of organic treatments on plant height showed significant difference from C_1 (nutrient management through chemical fertilizers as per KAU POP - 80: 25: 100 kg NPK ha^{-1}) at all stages during both the years. During the first year, only s_1g_1 (71.55 cm) was found to be significantly different (lower value) from C_1 (82.78 cm) at 2 MAP and all other organic treatments were on par with nutrient management through chemical fertilizers. At 4 MAP, all treatments except s_5g_2 and s_6g_1 showed significant difference from $C_{1,}$ wherein the treatment s_6g_2 (158.18 cm) was significantly superior to C_1 (151.48). At 6 MAP, the treatment combinations s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 were statistically similar to C_1 while other treatment combinations recorded significantly lower value. At harvest the organic treatment combination s_6g_1 (108.67 cm) produced significantly taller plants than C_1 (100.78 cm) while the interactions s_3g_2, s_5g_1, s_5g_2 and s_6g_2 were on par with C_1. During the second year, all organic treatment combinations were on par with C_1 at 2 MAP except s_1g_1 and s_4g_1 which registered significantly lower plant height than C_1. At 4 MAP, $s_5g_{1,}$ s_5g_2, s_6g_1 and s_6g_2 were found to be statistically equal to $C_{1.}$ At 6 MAP and harvest, and all organic treatments were found to be on par with C_1 except $s_1g_{1,}$ $s_1g_{2,}$ s_2g_2, s_4g_1 and s_4g_2 which resulted in significantly lower value than C_1

While comparing C_2 [nutrient management as per KAU organic POP (*Ad hoc*)] with other organic treatments, it was found that, organic treatments were not significantly different from C_2 at 2 MAP during both the years. During the first year, all treatments except s_1g_1 and s_1g_2 produced significantly taller plants than C_2 at 4 MAP. At 6 MAP all other treatments except $s_1g_{2,}$ s_2g_2 and s_4g_2 were significantly different from $C_{2.}$ The treatments s_5g_1 (104.15 cm), s_5g_2 (102.79 cm), s_6g_1 (108.67 cm), s_6g_2 (106.39 cm), s_3g_1 (91.85 cm), s_3g_2 (95.84 cm) and s_2g_1 (89.33 cm) recorded significantly higher value of plant height than C_2 (75.16 cm) at harvest. During the second year, $s_4g_{2,}$ s_5g_1, $s_5g_{2,}$ $s_6g_{1,}$ $s_6g_{2,}$ s_3g_2, $s_3g_{1,}$ s_2g_2 and s_2g_1 were significantly superior to C_2 at 4 MAP. At 6 MAP and harvest s_5g_1, s_5g_2, s_6g_1, s_6g_2, s_3g_1 and s_3g_2 recorded significantly taller plants than $C_{2.}$

While comparing organic treatments with absolute control (C_3), during the first year the treatment combinations s_3g_1, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 were significantly superior to C_3 at 2 MAP. All organic treatments except s_1g_1 at 4 MAP; s_1g_1, s_1g_2 and s_4g_1 at 6 MAP; s_1g_1 and s_4g_1 at harvest were found significantly superior to C_3. During the second year, $s_2g_{2,}$ s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 recorded significantly superior plant height than C_3 at 2 MAP. All organic treatments except

Table 8a. Effect of organic sources and *in situ* green manuring on plant height, cm

Treatments	Plant height							
	I year				II year			
	2 MAP	4 MAP	6 MAP	Harvest	2 MAP	4 MAP	6 MAP	Harvest
Organic sources (S)								
s_1- FYM + wood ash	72.11	109.54	92.00	71.84	62.83	98.18	82.33	67.42
s_2- FYM + wood ash +PGPR mix I	75.50	134.72	103.67	84.08	66.17	122.64	94.33	78.47
s_3- FYM + wood ash + PGPR mix I + vermiwash	80.33	135.29	114.66	93.85	68.83	122.38	104.74	87.13
s_4- PM+ wood ash	74.11	121.76	97.31	76.62	64.33	109.38	89.31	72.66
s_5- PM+ wood ash + PGPR mix I	78.72	145.83	124.83	103.47	69.33	131.26	116.12	95.31
s_6- PM+ wood ash + PGPR mix I + vermiwash	82.67	156.26	129.62	107.53	72.00	139.20	116.00	97.56
SEm(±)	1.67	1.03	1.28	1.22	1.43	1.86	2.49	1.94
CD (0.05)	4.892	3.029	3.714	3.562	4.198	5.457	7.306	5.693
***In situ* green manuring (G)**								
g_1- Cowpea	76.05	130.49	109.11	89.01	66.06	117.36	101.32	84.19
g_2- Daincha	78.42	137.31	111.59	90.12	68.44	123.65	99.62	81.99
SEm(±)	0.96	0.60	0.73	0.70	0.83	1.07	1.44	1.12
CD (0.05)	NS	1.749	2.144	NS	NS	3.151	NS	NS

Table 8b. Effect of S x G interaction and treatment *vs*. control effect on plant height, cm

Treatments	Plant height							
	I year				II year			
S x G interaction	2 MAP	4 MAP	6 MAP	Harvest	2 MAP	4 MAP	6 MAP	Harvest
s_1g_1	71.55[1]	104.98[1]	90.32[12]	69.93[1]	61.67[1]	93.54[1]	81.00[1]	66.75[1]
s_1g_2	72.67	114.10[13]	93.67[1]	73.74[13]	64.00	102.81[13]	83.67[1]	68.08[1]
s_2g_1	74.33	128.17[123]	109.00[123]	89.33[123]	65.33	117.17[123]	101.33[3]	85.48[3]
s_2g_2	76.67	141.28[123]	98.33[13]	78.82[13]	67.00[3]	128.11[23]	87.33[1]	71.45[1]
s_3g_1	78.33[3]	133.33[123]	112.13[123]	91.85[123]	65.33	120.70[123]	104.76[23]	86.51[23]
s_3g_2	82.33[3]	137.25[123]	117.19[23]	95.84[23]	72.33[3]	124.06[123]	104.72[23]	87.75[23]
s_4g_1	73.11	118.89[123]	90.86[12]	70.11[1]	63.00[1]	104.64[13]	85.86[1]	69.14[1]
s_4g_2	75.11	124.62[123]	103.76[13]	83.12[13]	65.67	114.12[123]	92.76[1]	76.18[13]
s_5g_1	77.66[3]	143.22[123]	123.67[23]	104.15[23]	67.66[3]	130.82[23]	118.67[23]	95.58[23]
s_5g_2	79.77[3]	148.43[23]	126.00[23]	102.79[23]	71.00[3]	131.70[23]	113.58[23]	95.04[23]
s_6g_1	81.33[3]	154.34[23]	128.67[23]	108.67[123]	73.33[3]	137.27[23]	116.33[23]	101.67[23]
s_6g_2	84.00[3]	158.18[123]	130.58[23]	106.39[23]	70.67[3]	141.13[23]	115.67[23]	93.45[23]
SEm(±)	2.36	1.46	1.79	1.72	2.02	2.63	3.52	2.75
CD (0.05)	NS	4.283	5.252	5.038	NS	NS	NS	8.051
C_1- KAU PoP	82.78	151.48	126.69	100.78	72.00	136.74	113.42	96.43
Treatments *vs.* C_1	S	S	S	S	S	S	S	S
C_2- KAU organic PoP	72.33	110.46	98.55	75.16	62.78	98.05	88.65	76.64
Treatments *vs.* C_2	NS	S	S	S	NS	S	S	S
C_3- Absolute control	67.33	100.52	86.98	64.93	57.78	89.89	78.48	62.49
Treatments *vs.* C_3	S	S	S	S	S	S	S	S

[1] significantly different from C_1; [2] significantly different from C_2; [3] significantly different from C_3

s_1g_1 at 4 MAP; s_1g_1, s_1g_2, s_2g_2, s_4g_1 and s_4g_2 at 6 MAP and s_1g_1, s_1g_2, s_2g_2 and s_4g_1 at harvest were significantly superior to C_3.

4.1.1.3 Number of Retained Leaves

The effect of different organic sources and *in situ* green manuring and their interactions on number of retained leaves per plant at bimonthly intervals starting from 2 MAP are presented in Tables 9a and 9b.

During both the years, the highest number of retained leaves was recorded at 2 MAP even though smaller in size and then started to decline upto harvest.

During the first year, organic sources significantly influenced leaf number at all stages of crop growth except at harvest with the highest number being recorded by s_6 (4.94 leaves per plant at 2 MAP, 3.67 leaves per plant at 4 MAP and 2.95 leaves per plant at 6 MAP) wherein poultry manure was applied along with wood ash, PGPR mix I and vermiwash. The s_6 was however found to be on par with s_5 (PM+ wood ash + PGPR mix I) and s_2 (FYM + wood ash + PGPR mix I) at 2 MAP, with s_5 and s_3 (FYM + wood ash + PGPR mix I + vermiwash) at 4 MAP and with s_3 at 6 MAP. During the second year, number of leaves per plant was significantly influenced by organic sources only at 4 MAP and harvest. As in the case of first year, the organic source s_6 produced the highest number of leaves per plant (3.84 leaves per plant at 4 MAP and 2.73 leaves per plant at harvest) which was on par with s_3, s_2, and s_5 at 4 MAP and with s_3 and s_5 at harvest.

In situ green manuring showed significant effect on number of leaves per plant only at 4 MAP and 6 MAP during the first year and *in situ* green manuring with daincha was found superior to cowpea at both the stages for producing higher leaf number per plant (3.52 leaves per plant at 4 MAP and 2.69 leaves per plant at 6 MAP). *In situ* green manuring could not exert any significant influence on number of leaves per plant at any growth stage of the crop during the second year.

With regarding interaction effect, the SxG interaction significantly influenced the number of leaves per plant only at 2 MAP during the first year and s_1g_2 and s_6g_1 produced more leaves (4.89 leaves per plant) and was on par with, s_5g_2, s_2g_1, s_2g_2, s_3g_1 , s_6g_2, s_4g_1 and s_5g_1. The SxG interaction failed to produce any significant effect on number of leaves per plant at any stage of observation during the second year.

No significant difference was observed between organic treatments and C_1 (nutrient management through chemical fertilizers as per KAU POP - 80: 25: 100 kg NPK ha^{-1}) at all stages of crop growth during both the years with respect to number of leaves per plant. While there was significant difference between treatments and C_2 [Nutrient management as per KAU organic POP (Adhoc)] at 6 MAP during the first year. However, the C_2 (2.89 leaves per plant) was on par with all treatments except s_1g_1 (2.11 leaves per plant), s_1g_2 (2.33 leaves per plant) and s_4g_1 (2.22 leaves per plant). During the second year all treatments were on par with C_2 at all stages of observation. While comparing absolute control (C_3) with treatments, no significant difference was observed during the first year on number of leaves per plant. While during the second year, s_6g_2 produced significantly higher number of leaves (3 leaves per plant) than C_3 at 6 MAP (2.33 leaves per plant), however at all the other stages the C_3 was found to be on par with organic treatments.

4.1.1.4 Leaf Area

The main effects and the interaction effects of treatments on leaf area per plant are presented in Tables 10a and 10b.

Irrespective of treatments leaf area per plant increased from 2 MAP to 4 MAP after which it showed a declining trend upto harvest during both the years.

During the first year, organic sources significantly influenced the leaf area at all stages of crop growth with the highest number recorded in s_6 in which poultry manure along with wood ash, PGPR mix I and vermiwash were applied, at all stages (2795.05 cm^2, 1501.80 cm^2, and 872.40 cm^2 respectively at 4 MAP, 6 MAP and at

Table 9a. Effect of organic sources and *in situ* green manuring on number of retained leaves per plant

Treatments	Number of retained leaves per plant							
	I year				II year			
	2 MAP	4 MAP	6 MAP	Harvest	2 MAP	4 MAP	6 MAP	Harvest
Organic sources (S)								
s_1- FYM + wood ash	4.50	3.22	2.22	2.17	4.39	3.28	2.50	2.33
s_2- FYM + wood ash +PGPR mix I	4.78	3.39	2.66	2.55	4.50	3.61	2.77	2.50
s_3- FYM + wood ash + PGPR mix I + vermiwash	4.55	3.61	2.84	2.39	4.44	3.72	2.84	2.56
s_4- PM+ wood ash	4.33	3.33	2.33	2.33	4.22	3.22	2.67	2.50
s_5- PM+ wood ash + PGPR mix I	4.78	3.46	2.61	2.49	4.67	3.61	2.66	2.55
s_6- PM+ wood ash + PGPR mix I + vermiwash	4.94	3.67	2.95	2.45	4.83	3.84	2.95	2.73
SEm(±)	0.12	0.09	0.09	0.11	0.15	0.12	0.11	0.07
CD (0.05)	0.364	0.262	0.268	NS	NS	0.361	NS	0.217
***In situ* green manuring (G)**								
g_1- Cowpea	4.63	3.37	2.52	2.33	4.50	3.50	2.68	2.50
g_2- Daincha	4.67	3.52	2.69	2.46	4.52	3.59	2.78	2.56
SEm(±)	0.07	0.05	0.05	0.06	0.09	0.07	0.07	0.04
CD (0.05)	NS	0.151	0.155	NS	NS	NS	NS	NS

Table 9b. Effect of S x G interaction and treatment *vs*. control effect on number of retained leaves per plant

Treatments	Number of retained leaves per plant							
	I year				II year			
S x G interaction	2 MAP	4 MAP	6 MAP	Harvest	2 MAP	4 MAP	6 MAP	Harvest
s_1g_1	4.11	3.21	2.11[2]	2.11	4.22	3.22	2.44	2.22
s_1g_2	4.89	3.20	2.33[2]	2.22	4.56	3.33	2.55	2.44
s_2g_1	4.78	3.33	2.55	2.43	4.56	3.56	2.66	2.43
s_2g_2	4.78	3.44	2.78	2.67	4.44	3.67	2.89	2.56
s_3g_1	4.78	3.56	2.78	2.33	4.67	3.78	2.78	2.56
s_3g_2	4.33	3.67	2.89	2.45	4.22	3.67	2.89	2.56
s_4g_1	4.44	3.21	2.22[2]	2.22	4.33	3.11	2.67	2.56
s_4g_2	4.22	3.44	2.44	2.44	4.11	3.33	2.67	2.44
s_5g_1	4.78	3.33	2.55	2.55	4.55	3.55	2.66	2.55
s_5g_2	4.78	3.56	2.67	2.43	4.78	3.67	2.67	2.56
s_6g_1	4.89	3.56	2.89	2.33	4.67	3.78	2.89	2.67
s_6g_2	4.50	3.78	3.00	2.56	4.50	3.89	3.00[3]	2.78
SEm(±)	0.18	0.13	0.13	0.16	0.21	0.17	0.16	0.11
CD (0.05)	0.515	NS	NS	NS	NS	NS	NS	NS
C_1- KAU PoP	5.00	3.67	2.78	2.67	4.78	3.67	2.89	2.56
Treatments *vs*. C_1	NS	NS	NS	NS	NS	NS	NS	NS
C_2- KAU organic PoP	4.44	3.50	2.89	2.67	4.22	3.44	2.78	2.55
Treatments *vs*. C_2	NS	NS	S	NS	NS	NS	NS	NS
C_3- Absolute control	4.44	3.56	2.33	2.22	4.55	3.22	2.33	2.33
Treatments *vs*. C_3	NS	NS	NS	NS	NS	NS	S	NS

[1] significantly different from C_1; [2] significantly different from C_2; [3] significantly different from C_3

harvest respectively) except 2 MAP. At 2 MAP, the highest leaf area per plant (1955.86 cm^2) was recorded in s_3 (FYM + wood ash + PGPR mix I + vermiwash) and which was on par with s_6, s_2 and s_5. At 4 MAP and 6 MAP, treatment s_6 was found to be significantly superior to all the other organic source treatments. However, at harvest the s_6 was on par with s_3, s_2 and s_5. During the second year, leaf area per plant was significantly influenced by organic sources and the highest values were recorded with s_6 at 2 MAP (1668.40 cm^2), 4 MAP (3063.46 cm^2) and 6 MAP (1399.86 cm^2) and the effect was not significant at harvest stage. At 2 MAP, the s_5, s_3 and s_1 were on par with s_6 and at 6 MAP s_3, s_5 and s_2 were on par with s_6.

Regarding *in situ* green manuring at first year, significantly higher leaf area was recorded by *in situ* green manuring with daincha (g_2) at all stages of observation (2620.83 cm^2, 1392.45 cm^2 and 825.04 cm^2 at 4 MAP, 6 MAP and at harvest respectively) except 2 MAP wherein the effect was non significant. During the second year, *in situ* green manuring had significant effect only at 4 MAP and 6 MAP and higher leaf area was observed in green manuring with daincha (2662.80 cm^2 and 1293.09 cm^2 at 4 and 6 MAP respectively). The same trend was observed at 2 MAP and harvest, though the effect was not significant.

SxG interaction had significantly influenced the leaf area only at 4 MAP and 6 MAP during the first year wherein the treatment combination s_6g_2 recorded the highest value (2837.12 cm^2 and 1525.67 cm^2 at 4 and 6 MAP respectively) and was followed by s_6g_1 (2752.99 cm^2 and 1477.93 cm^2 at 4 and 6 MAP respectively). During the second year, SxG interaction significantly influenced leaf area only at 4 MAP and the highest value was recorded in s_6g_2 (3155.43 cm^2) followed by s_6g_1 (2971.49 cm^2) which in turn was on par with s_5g_1, s_5g_2 and s_3g_2.

Regarding treatments *vs.* control effect (Table 10b) on leaf area per plant, the organic treatments showed significant difference from C_1 (nutrient management through chemical fertilizers as per KAU POP) at all stages of crop growth during the first year. All organic nutrition treatments were on par with C_1, except s_1g_2, s_4g_1 and s_4g_2 at 2 MAP; s_1g_1, s_1g_2, s_2g_1, s_2g_2, s_4g_1, s_4g_2 and s_5g_1 at 4 MAP; s_1g_1, s_1g_2, s_2g_1, s_2g_2, s_4g_1, s_4g_2 and s_5g_1 at 6 MAP and s_1g_1, s_1g_2, s_2g_2 and s_4g_1 at harvest which recorded significantly lower values of leaf area per plant than C_1. During the second year, significant difference between treatments and C_1 were observed only at 4 MAP and the treatments s_6g_2, s_6g_1, s_5g_2, s_5g_1 and s_3g_2 which produced the leaf area per plant values 3155.43 cm^2, 2971.49 cm^2, 2865.50 cm^2, 2816.95 cm^2 and 2858.32 cm^2 respectively were on par with C_1, while all other treatment combinations produced significantly lower leaf area per plant.

While comparing C_2 (nutrient management as per KAU organic Adhoc POP) with treatments, significant difference was observed in case of leaf area per plant only at 4 MAP and 6 MAP during the first year and the treatments s_6g_1 and s_6g_2 at 4 MAP and s_2g_2, s_3g_1, s_3g_2, s_5g_2, s_6g_1 and s_6g_2 at 6 MAP were found to be significantly superior to C_2. During the second year significant difference was observed only at 4 MAP and s_5g_1, s_5g_2, s_6g_1, s_6g_2, s_2g_2, s_3g_1 and s_3g_2 recorded higher leaf area than C_2, while the treatments s_1g_1 and s_4g_1 recorded significantly lower leaf area per plant compared to C_2.

The absolute control (C_3) had significant variation from all organic treatments at all stages of observation during both the years. During the first year, the treatments s_3g_2 and s_6g_2 at 2 MAP; all treatments except s_1g_1 at 4 MAP; all treatments except s_1g_1, s_1g_2 and s_4g_1 at 6 MAP and the treatments s_2g_2, s_3g_1, s_3g_2, s_5g_2, s_6g_1 and s_6g_2 at harvest were found significantly superior to C_3. During the second year, s_5g_2 and s_6g_2 at 2 MAP; all treatments at 4 MAP; s_2g_2, s_3g_1, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 at 6 MAP and s_6g_2, s_5g_2 and s_6g_1 at harvest recorded higher leaf area per plant than absolute control.

Table 10a. Effect of organic sources and *in situ* green manuring on leaf area per plant, cm^2

Treatments	Leaf area per plant							
	I year				II year			
	2 MAP	4 MAP	6 MAP	Harvest	2 MAP	4 MAP	6 MAP	Harvest
Organic sources (S)								
s_1- FYM + wood ash	1348.75	2357.31	1274.04	694.07	1246.20	1925.42	974.48	622.23
s_2- FYM + wood ash +PGPR mix I	1695.12	2531.40	1361.98	810.28	1049.02	2634.94	1244.54	785.27
s_3- FYM + wood ash + PGPR mix I + vermiwash	1955.86	2658.37	1417.37	847.33	1359.07	2751.17	1362.58	884.28
s_4- PM+ wood ash	1109.67	2486.86	1284.70	735.23	849.01	2121.96	1158.08	774.97
s_5- PM+ wood ash + PGPR mix I	1664.15	2585.38	1397.51	808.61	1618.86	2866.23	1270.50	859.05
s_6- PM+ wood ash + PGPR mix I + vermiwash	1820.65	2795.05	1501.80	872.40	1668.40	3063.46	1399.86	969.65
SEm(±)	111.00	10.13	6.72	29.47	158.41	42.47	62.20	76.46
CD (0.05)	325.551	29.703	19.720	86.427	464.601	124.546	182.397	NS
***In situ* green manuring (G)**								
g_1- Cowpea	1535.39	2517.29	1353.35	764.27	1242.73	2458.26	1176.92	774.04
g_2- Daincha	1662.67	2620.83	1392.45	825.04	1354.12	2662.80	1293.09	857.78
SEm(±)	64.09	5.85	3.88	17.01	91.46	24.52	35.91	44.14
CD (0.05)	NS	17.149	11.385	49.899	NS	71.907	105.307	NS

Table 10b. Effect of S x G interaction and treatment *vs*. control effect on leaf area per plant, cm^2

Treatments	Leaf area per plant							
	I year				II year			
S x G interaction	2 MAP	4 MAP	6 MAP	Harvest	2 MAP	4 MAP	6 MAP	Harvest
s_1g_1	1492.83	2319.39[1]	1270.70[1]	661.24[1]	1155.25	1853.00[123]	921.16	554.58
s_1g_2	1204.67[1]	2395.22[13]	1277.37[1]	726.90[1]	1337.14	1997.85[13]	1027.80	689.88
s_2g_1	1782.15	2453.02[13]	1356.88[13]	774.95	1011.54	2530.49[13]	1166.22	749.84
s_2g_2	1608.09	2609.77[13]	1367.07[123]	845.61[3]	1086.50	2739.39[123]	1322.85[3]	820.69
s_3g_1	1617.89	2633.89[3]	1420.17[23]	822.12[3]	1408.35	2644.02[123]	1323.57[3]	885.22
s_3g_2	2293.83[3]	2682.86[3]	1414.57[23]	872.53[3]	1309.78	2858.32[23]	1401.59[3]	883.33
s_4g_1	1094.58[1]	2417.88[13]	1240.78[1]	703.36[1]	922.59	1883.60[123]	1126.92	774.59
s_4g_2	1124.75[1]	2555.83[13]	1328.63[13]	767.10	775.42	2360.32[13]	1189.24	775.36
s_5g_1	1584.01	2526.58[13]	1353.66[13]	799.50	1342.07	2866.95[23]	1213.83[3]	766.52
s_5g_2	1744.28	2644.17[3]	1441.37[23]	817.73[3]	1895.65[3]	2865.50[23]	1327.17[3]	951.57[3]
s_6g_1	1640.90	2752.99[23]	1477.93[23]	824.43[3]	1616.54	2971.49[23]	1309.84[3]	913.49[3]
s_6g_2	2000.39[3]	2837.12[23]	1525.67[23]	920.37[3]	1720.26[3]	3155.43[23]	1489.88[3]	1025.81[3]
SEm(±)	156.98	14.32	9.51	41.67	224.03	60.06	87.95	108.13
CD (0.05)	NS	42.006	27.888	NS	NS	176.135	NS	NS
C_1- KAU PoP	2062.98	2750.10	1520.92	951.29	1684.00	3083.91	1411.15	1012.79
Treatment *vs.* C_1	S	S	S	S	NS	S	NS	NS
C_2-KAU organic PoP	1651.38	2397.71	1281.13	801.30	1337.60	2256.33	1174.69	832.07
Treatment *vs.* C_2	NS	S	S	NS	NS	S	NS	NS
C_3-Absolute control	1153.36	2125.54	1201.00	644.40	735.44	1473.04	839.49	459.30
Treatment *vs.* C_3	S	S	S	S	S	S	S	S

[1] significantly different from C_1; [2] significantly different from C_2; [3] significantly different from C_3

4.1.1.5 Leaf Area Index (LAI)

The average values of LAI at bimonthly interval as influenced by organic sources, *in situ* green manuring and their interactions are presented in Tables 11a and 11b.

As in the case of leaf area per plant, LAI also increased from 2 MAP to 4 MAP after which it showed a declining trend upto harvest during both the years irrespective of treatments.

During the first year, organic sources significantly influenced the LAI at all stages of crop growth. At 2 MAP, the highest LAI (0.72) was recorded by s_3 (FYM + wood ash + PGPR mix I + vermiwash), which was on par with s_6 (0.67), s_2 (0.63) and s_5 (0.62). At 4 MAP, 6 MAP and harvest, the highest LAI was recorded by s_6 (1.04, 0.56 and 0.32 respectively) in which poultry manure along with wood ash, PGPR mix I and vermiwash were applied. At 4 MAP and 6 MAP, the s_6 was found significantly superior to all other organic sources. However at harvest, the s_6 was on par with s_3 (0.31), s_2 (0.30) and s_5 (0.30). During the second year, LAI was significantly influenced by organic sources at 2 MAP, 4 MAP and 6 MAP and the highest values were recorded in s_6 (0.62, 1.14, and 0.52 respectively) at these stages. At 2 MAP, s_5, s_3 and s_1 were on par with s_6 and at 6 MAP s_3, s_5 and s_2 were on par with s_6.

With respect to *in situ* green manuring, significantly higher LAI was produced by daincha (g_2) at all stages (0.97, 0.52 and 0.31 at 4 MAP, 6 MAP and at harvest respectively) except 2 MAP during the first year. During the second year *in situ* green manuring had significant effect only at 4 MAP and 6 MAP and higher value was recorded by daincha (0.99 at 4 MAP and 0.48 at 6 MAP).

SxG interaction had significant effect on LAI only at 4 MAP and 6 MAP and the treatment combination s_6g_2 recorded the highest value (1.05 at 4 MAP and 0.57 at 6 MAP) during the first year. During the second year, SxG interaction significantly influenced the LAI only at 4 MAP and the highest value was recorded by s_6g_2 (1.17) followed by s_6g_1 (1.10). The s_6g_1 was however on par with s_5g_1, s_5g_2 and s_3g_2.

Regarding treatments *vs.* control effect on LAI (Table 11b), the organic treatments resulted in significant variation when compared with nutrient management through chemical fertilizers as per KAU POP (C_1) at all stages of crop growth during the first year. All organic treatments were on par with C_1 except s_1g_2, s_4g_1 and s_4g_2 at 2 MAP; s_1g_1, s_1g_2, s_2g_1, s_2g_2, s_4g_1, s_4g_2 and s_5g_1 at 4 MAP; s_1g_1, s_1g_2, s_2g_1, s_2g_2, s_4g_1, s_4g_2 and s_5g_1 at 6 MAP and s_1g_1, s_1g_2, s_2g_2 and s_4g_1 at harvest, which recorded significantly lower values of LAI than C_1.

During the second year, the significant difference between treatments and C_1 were observed only at 4 MAP and the treatments s_6g_2, s_6g_1, s_5g_2, s_5g_1 and s_3g_2 which produced the LAI values 1.17, 1.10, 1.06, 1.06 and 1.06 respectively were on par with C_1 (1.14) while all other treatment combinations produced significantly lower LAI.

While comparing C_2 [nutrient management as per KAU organic POP (Adhoc)] with treatments with respect to LAI, significant difference was observed only at 4 MAP and 6 MAP during the first year and the treatments s_6g_1 and s_6g_2 at 4 MAP and s_2g_2, s_3g_1, s_3g_2, s_5g_2, s_6g_1 and s_6g_2 at 6 MAP were found significantly superior to C_2. During the second year significant difference was observed only at 4 MAP and s_5g_1, s_5g_2, s_6g_1, s_6g_2, s_2g_2, s_3g_1 and s_3g_2 recorded higher LAI than C_2, while the treatments s_1g_1 and s_4g_1 recorded significantly lower values of LAI than C_2.

The absolute control (C_3) significantly differed from all organic treatments at all stages of observation during both the years with respect to LAI. During the first year, the treatments s_3g_2 and s_6g_2 at 2 MAP; all treatments except s_1g_1 at 4 Map; all treatments except s_1g_1, s_1g_2 and s_4g_1 at 6 MAP and the treatments s_2g_2, s_3g_1, s_3g_2, s_5g_2, s_6g_1 and s_6g_2 at harvest were recorded significantly higher values of LAI compared to absolute control. During the second year, s_5g_2 and s_6g_2 at 2 MAP; all treatments at 4

Table 11a. Effect of organic sources and *in situ* green manuring on leaf area index

Treatments	Leaf area index							
	I year				II year			
	2 MAP	4 MAP	6 MAP	Harvest	2 MAP	4 MAP	6 MAP	Harvest
Organic sources (S)								
s_1- FYM + wood ash	0.50	0.87	0.48	0.26	0.46	0.71	0.36	0.23
s_2- FYM + wood ash +PGPR mix I	0.63	0.94	0.50	0.30	0.39	0.98	0.46	0.29
s_3- FYM + wood ash + PGPR mix I + vermiwash	0.72	0.99	0.53	0.31	0.50	1.02	0.51	0.33
s_4- PM+ wood ash	0.41	0.92	0.47	0.27	0.31	0.79	0.43	0.29
s_5- PM+ wood ash + PGPR mix I	0.62	0.96	0.52	0.30	0.60	1.06	0.47	0.32
s_6- PM+ wood ash + PGPR mix I + vermiwash	0.67	1.04	0.56	0.32	0.62	1.14	0.52	0.36
SEm(±)	0.04	0.004	0.002	0.01	0.06	0.02	0.02	0.03
CD (0.05)	0.121	0.011	0.007	0.032	0.172	0.046	0.068	NS
***In situ* green manuring (G)**								
g_1- Cowpea	0.57	0.93	0.50	0.28	0.46	0.91	0.44	0.29
g_2- Daincha	0.62	0.97	0.52	0.31	0.50	0.99	0.48	0.32
SEm(±)	0.02	0.002	0.001	0.01	0.03	0.01	0.01	0.02
CD (0.05)	NS	0.006	0.004	0.018	NS	0.027	0.039	NS

Table 11b. Effect of S x G interaction and treatment *Vs*. control effect on leaf area index

Treatments	Leaf area index							
	I year				II year			
S x G interaction	2 MAP	4 MAP	6 MAP	Harvest	2 MAP	4 MAP	6 MAP	Harvest
s_1g_1	0.55	0.86[1]	0.46[1]	0.25[1]	0.43	0.69[123]	0.34	0.21
s_1g_2	0.45[1]	0.89[13]	0.49[1]	0.27[1]	0.50	0.74[13]	0.38	0.26
s_2g_1	0.66	0.91[13]	0.50[13]	0.29	0.38	0.94[13]	0.43	0.28
s_2g_2	0.60	0.97[13]	0.51[123]	0.31[3]	0.40	1.02[123]	0.49[3]	0.30
s_3g_1	0.60	0.98[3]	0.53[23]	0.30[3]	0.52	0.98[123]	0.49[3]	0.33
s_3g_2	0.85[3]	0.99[3]	0.52[23]	0.32[3]	0.49	1.06[23]	0.52[3]	0.33
s_4g_1	0.41[1]	0.90[13]	0.47[1]	0.26[1]	0.34	0.70[123]	0.42	0.29
s_4g_2	0.42[1]	0.95[13]	0.47[13]	0.28	0.29	0.87[13]	0.44	0.29
s_5g_1	0.59	0.94[13]	0.50[13]	0.30	0.50	1.06[23]	0.45[3]	0.28
s_5g_2	0.65	0.98[3]	0.53[23]	0.30[3]	0.70[3]	1.06[23]	0.49[3]	0.35[3]
s_6g_1	0.61	1.02[23]	0.55[23]	0.31[3]	0.60	1.10[23]	0.49[3]	0.34[3]
s_6g_2	0.74[3]	1.05[23]	0.57[23]	0.34[3]	0.64[3]	1.17[23]	0.55[3]	0.38[3]
SEm(±)	0.06	0.01	0.004	0.02	0.08	0.02	0.03	0.04
CD (0.05)	NS	0.016	0.010	NS	NS	0.065	NS	NS
C_1- KAU PoP	0.76	1.02	0.56	0.35	0.62	1.14	0.52	0.38
Treatment *vs.* C_1	S	S	S	S	NS	S	NS	NS
C_2- KAU organic PoP	0.61	0.89	0.47	0.30	0.50	0.84	0.44	0.31
Treatment *vs.* C_2	NS	S	S	NS	NS	S	NS	NS
C_3-Absolute control	0.43	0.79	0.45	0.24	0.27	0.55	0.31	0.17
Treatment *vs.* C_3	S	S	S	S	S	S	S	S

[1] significantly different from C_1; [2] significantly different from C_2; [3] significantly different from C_3

MAP; s_2g_2, s_3g_1, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 at 6 MAP and s_6g_2, s_5g_2 and s_6g_1 at harvest were found significantly superior to C_3.

4.1.2 Yield Attributes and Yield

4.1.2.1 Number of Cormels per Plant

The data on number of cormels per plant during both the years as influenced by the treatments are summarized in Tables 12a and 12b.

The organic sources had significant effect on number of cormels per plant during both the years. During the first year, the organic source s_1 in which FYM and wood ash were applied recorded the highest value (23.50 cormels per plant) and it was on par with s_5 (PM+ wood ash + PGPR mix I) and s_2 (FYM + wood ash +PGPR mix I) producing 23.00 cormels per plant and 20.67 cormels per plant respctively. The s_2 was in turn on par with s_4 (PM+ wood ash). During the second year, among the organic sources the s_4 in which PM and wood ash were applied was found to be significantly superior to all the other organic sources for producing more number of cormels per plant (23.50 cormels).

The *in situ* green manuring and S x G interaction did not show any significant influence on number of cormels per plant during both the years.

While comparing the treatments with C_1 (nutrient management through chemical fertilizers as per KAU POP), it was observed that there was significant difference between treatments and C_1 with respect to number of cormels per plant during both the years. During the first year, the organic treatments s_1g_1, s_1g_2, s_2g_2, s_4g_1, s_5g_1 and s_5g_2 were on par with C_1 (27.33 cormels per plant), while the organic treatment combinations s_2g_1, s_3g_1, s_3g_2, s_4g_2, s_6g_1 and s_6g_2 recorded significantly lower number of cormels per plant than C_1. During the second year, all treatments except s_2g_1 and s_3g_2 were on par with C_1 (21.33 cormels per plant).

The control nutrient management as per KAU organic POP (C_2) showed significant difference from the organic nutrition treatments only during the first year, wherein the treatment combinations s_1g_1, s_1g_2, s_2g_2, s_4g_1, s_5g_1 and s_5g_2 were on par with C_2 (26.00 cormels per plant), while s_2g_1, s_3g_1, s_3g_2, s_4g_2, s_6g_1 and s_6g_2 recorded significantly lower number of cormels per plant than C_2.

The treatments *vs*. absolute control effect was not significant in case of number of cormels per plant during both the years.

4.1.2.2 Mean Weight of Cormel

A perusal of the data in Tables 12a and 12b indicated that mean weight of cormel was significantly influenced by organic sources, *in situ* green manuring and their interaction during both the years of experimentation.

During the first year, the application of poultry manure along with wood ash, PGPR mix I and vermiwash (s_6) recorded the highest mean weight of cormel (34.86 g) and was on par with s_3 (34.17 g) in which FYM along with wood ash, PGPR mix I and vermiwash were applied. The lowest mean cormel weight (19.75 g) was recorded with s_1 in which only FYM and wood ash were applied. During the second year, s_3 (FYM along with wood ash, PGPR mix I and vermiwash) registered the highest value (26.01 g), however it was statistically on par with s_5 (25.02 g), s_6 (24.57 g) and s_2 (23.93 g). The organic source containing only poultry manure and wood ash recorded the lowest value of cormel weight (14.83 g).

In situ green manuring with daincha (g_2) recorded the highest mean cormel weight of 29.51 g (first year) and 24.48 g (second year), which was significantly superior to g_1 (*in situ* green manuring with cowpea) during both the years.

While analysing the interaction effect, mean weight of cormel was found to be significantly influenced by S x G interaction during both the years and the treatment combination s_3g_2 recorded the highest value (41.26g and 31.47g during first and second year respectively). During the first year s_3g_2 was on par with s_6g_2 (37.52 g) only, while during the second year s_3g_2 was on par with s_5g_2 (27.73 g) and s_6g_2 (26.74 g). The lowest mean cormel weight was recorded by s_1g_1 and s_4g_2 during first and second years respectively.

Significant difference was observed between treatments and C_1 (nutrient management through chemical fertilizers as per KAU POP) during the first year wherein s_3g_2 (41.26g), s_6g_1 (32.20g) and s_6g_2 (37.52g) recorded significantly higher mean weight of cormel than C_1 (20.85g). During the second year there was no significant difference between organic treatments and C_1 with respect to mean weight of cormel.

Mean weight of cormel showed significant difference between treatments and C_2 during both the years. The treatment combinations s_3g_1, s_3g_2, s_4g_2, s_6g_1 and s_6g_2 during the first year and s_3g_2, s_5g_2 and s_6g_2 during the second year registered significantly higher mean weight of cormels than C_2 (17.07 g during the first year and 19.00 g during the second year).

The organic treatments resulted in significant variation in case of mean weight of cormels, compared to absolute control (C_3) during both the years. The organic treatment combinations s_3g_2, s_4g_2, s_6g_1 and s_6g_2 during the first year and s_3g_2, s_5g_2 and s_6g_2 during the second year recorded significantly higher mean weight of cormel than absolute control (18.74 g during the first year and 18.09 g during the second year).

4.1.2.3 Cormel to Corm Ratio

The data presented in Table 12a indicated that variation in cormel to corm ratio due to organic sources was significant only during the second year. The organic treatment s_5 (application of poultry manure, wood ash and PGPR mix I) recorded the highest value (1.80) and was on par with s_6 (1.56), s_4 (1.69), s_2 (1.70) and s_1 (1.56).

In situ green manuring with cowpea or daincha failed to produce any significant effect on cormel to corm ratio during both the years. Though not significant, *in situ* green manuring with cow pea recorded higher value for cormel to corm ratio during both the years.

The interaction effects shown in Table 12b revealed that the effect was significant on cormel to corm ratio only during the second year. The treatment combination s_5g_1 registered the highest value (2.12) which was on par with s_2g_2 (1.95) and s_4g_1 (1.97) Among the treatment combinations, the lowest value for cormel to corm ratio was recorded with s_3g_1 (1.15).

The organic nutrition treatments did not significantly vary from the control treatments during both the years, with respect to the cormel to corm ratio.

4.1.2.4 Cormel Yield ha^{-1}

It is evident from Table 13a that organic sources and *in situ* green manuring had significant influence on cormel yield during both the years.

Cormel yield was the highest for the organic source in which poultry manure along with wood ash, PGPR mix I and vermiwash were applied (s_6) during both the years (20.89 t ha^{-1} during the first year and 16.47 t ha^{-1} during the second year). During the first year s_6 was on par with s_5 (20.28 t ha^{-1}) wherein poultry manure along with wood ash and PGPR mix I were applied which in turn was on par with s_3 (19.45 t ha^{-1}) in which FYM along with wood ash, PGPR mix I and vermiwash were applied. Application of FYM and wood ash alone (s_1) recorded the lowest value (17.20 t ha^{-1}). During the second year s_6 (poultry manure along with wood ash, PGPR mix I and vermiwash were applied) was found to be on par with s_5 (15.72 t ha^{-1}) and s_3 (14.55 t ha^{-1}) and the effects of s_5, s_3 and s_2 were on par each other. The lowest value was recorded with the organic source s_1 (12.63 t ha^{-1}) and was on par with s_4 (12.74 t ha^{-1}). Pooled data also indicated the same trend. The organic source s_6 recorded the highest cormel yield (18.68 t ha^{-1}) and was on par with s_5 (18.00 t ha^{-1}),

Table 12a. Effect of organic sources and *in situ* green manuring on number of cormels per plant, mean weight of cormel and cormel to corm ratio

Treatments	I year			II year		
	Number of cormels per plant	Mean weight of cormel (g)	Cormel to corm ratio	Number of cormels per plant	Mean weight of cormel (g)	Cormel to corm ratio
Organic sources (S)						
s_1- FYM + wood ash	23.50	19.75	1.62	16.67	21.87	1.56
s_2- FYM + wood ash +PGPR mix I	20.67	25.36	1.64	15.83	23.93	1.70
s_3- FYM + wood ash + PGPR mix I + vermiwash	16.00	34.17	1.66	14.83	26.01	1.23
s_4- PM+ wood ash	19.67	25.16	1.63	23.50	14.83	1.69
s_5- PM+ wood ash + PGPR mix I	23.00	24.25	1.58	17.33	25.02	1.80
s_6- PM+ wood ash + PGPR mix I + vermiwash	16.67	34.86	1.55	18.33	24.57	1.56
SEm(±)	1.00	1.46	0.04	1.18	1.15	0.12
CD (0.05)	2.942	4.277	NS	3.458	3.375	0.340
***In situ* green manuring (G)**						
g_1- Cowpea	20.72	25.00	1.62	18.22	20.92	1.63
g_2- Daincha	19.11	29.51	1.60	17.28	24.48	1.55
SEm(±)	0.58	0.84	0.02	0.68	0.66	0.07
CD (0.05)	NS	2.469	NS	NS	1.948	NS

Table 12b. Effect of S x G interaction and treatments *Vs*. control effect on number of cormels per plant, mean weight of cormel and cormel to corm ratio

Treatments	I year			II year		
	Number of cormels per plant	Mean weight of cormel (g)	Cormel to corm ratio	Number of cormels per plant	Mean weight of cormel (g)	Cormel to corm ratio
S x G interaction						
s_1g_1	23.00	19.29	1.63	16.33	21.63	1.56
s_1g_2	24.00	20.20	1.61	17.00	22.11	1.57
s_2g_1	19.67[12]	24.93	1.70	13.33[1]	23.05	1.44
s_2g_2	21.67	25.79	1.57	18.33	24.81	1.95
s_3g_1	18.67[12]	27.08[2]	1.66	15.67	20.54	1.15
s_3g_2	13.33[12]	41.26[123]	1.66	14.00[1]	31.47[23]	1.32
s_4g_1	22.00	22.57	1.61	24.00	15.61	1.97
s_4g_2	17.33[12]	27.76[23]	1.66	23.00	14.05	1.42
s_5g_1	23.00	23.95	1.57	20.33	22.30	2.12
s_5g_2	23.00	24.55	1.58	14.33	27.73[23]	1.49
s_6g_1	18.00[12]	32.20[123]	1.58	19.67	22.39	1.55
s_6g_2	15.33[12]	37.52[123]	1.53	17.00	26.74[23]	1.56
SEm(±)	1.42	2.06	0.05	1.67	1.63	0.16
CD (0.05)	NS	6.048	NS	NS	4.773	0.480
C_1- KAU PoP	27.33	20.85	1.56	21.33	22.85	1.65
Treatments *vs.* C_1	S	S	NS	S	NS	NS
C_2- KAU organic PoP	26.00	17.07	1.61	16.33	19.00	1.31
Treatments *vs.* C_2	S	S	NS	NS	S	NS
C_3- Absolute control	19.00	18.74	1.70	14.33	18.09	1.51
Treatments *vs.* C_3	NS	S	NS	NS	S	NS

[1] significantly different from C_1; [2] significantly different from C_2;

[3] significantly different from C_3

which in turn was on par with s_3 (17.00 t ha^{-1}) and s_2 (16.64 t ha^{-1}). Application of FYM and wood ash alone (s_1) resulted in the lowest cormel yield of 14.91 t ha^{-1}.

Cormel yield during both the years and also the pooled mean significantly increased under *in situ* green manuring with daincha over cowpea. Cormel yield recorded by *in situ* green manuring with daincha was 19.57 t ha^{-1}, 14.99 t ha^{-1} and 17.28 t ha^{-1} during the first year, second year and for pooled mean respectively.

Interaction effects of organic sources and *in situ* green manuring on cormel yield are furnished in Table 13b.

Treatment combinations significantly influenced the cormel yield ha^{-1} during both the years, reflecting same trend in pooled analysis. The treatment combination s_6g_2 (application of poultry manure along with wood ash, PGPR mix I and vermiwash + *in situ* green manuring with daincha) recorded the highest cormel yield of 21.27 t ha^{-1}, 16.77 t ha^{-1} and 19.02 t ha^{-1} during the first year, second year and in the pooled analysis respectively. However the s_6g_2 was on par with s_6g_1 (20.51 t ha^{-1}), s_5g_2 (20.15 t ha^{-1}), s_5g_1 (20.40 t ha^{-1}), s_3g_2 (20.31 t ha^{-1}) and s_2g_2 (20.26 t ha^{-1}) during the first year; with s_6g_1 (16.17 t ha^{-1}), s_5g_2 (14.71 t ha^{-1}), s_5g_1 (16.74 t ha^{-1}), s_3g_2 (16.20 t ha^{-1}), s_2g_2 (16.64 t ha^{-1}), and s_1g_2 (13.91 t ha^{-1}) during the second year and with s_6g_1 (18.35 t ha^{-1}), s_5g_2 (17.43 t ha^{-1}), s_5g_1 (18.57 t ha^{-1}), s_3g_2 (18.26 t ha^{-1}) and s_2g_2 (18.45 t ha^{-1}) for pooled analysis. The s_1g_1 (application of FYM and wood ash + *in situ* green manuring with cow pea) recorded the lowest cormel yield ha^{-1} during the first year, second year and in the pooled analysis also.

Regarding the treatments *vs.* C_1 (nutrient management through chemical fertilizers) effect, there was significant difference between organic treatments and C_1 during both the years and also for pooled mean with respect to cormel yield t ha^{-1} (Table 13b). The organic treatments s_2g_2, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 during the first year and s_1g_2, s_2g_2, s_3g_2, s_4g_1, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 during the second year were found to be on par with C_1 (21.08 t ha^{-1} during the first year and 18.03 t ha^{-1} during the second year). As in the case of first year, the organic treatments s_2g_2, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 were found to be on par with C_1 (19.55 t ha^{-1}) under pooled analysis also. However the treatment s_6g_2 recorded a 0.90 percentage increase of cormel yield over chemical nutrient management during the first year. The treatment combinations s_1g_1, s_1g_2, s_2g_1, s_3g_1, s_4g_1 and s_4g_2 during the first year and their pooled mean, recorded significantly lower cormel yield than C_1, while the treatment combinations s_1g_1, s_2g_1, s_3g_1 and s_4g_2 recorded significantly lower cormel yield than C_1 during the second year.

The significance difference was observed between treatments and control C_2 [nutrient management as per KAU organic POP (*Ad hoc*)] during both the years and also for the pooled mean. The treatment combinations s_2g_2, s_3g_1, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 during the first year; s_2g_2, s_3g_2, s_5g_1, s_6g_1 and s_6g_2 during the second year and s_2g_2, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 for pooled mean recorded significantly higher cormel yield than C_2 (16.25 t ha^{-1} during the first year; 11.35 t ha^{-1} during the second year and 13.80 t ha^{-1} for pooled mean) and all other treatments were on par with C_2. The treatment s_6g_2 recorded a 37.83 percentage increase of cormel yield over KAU organic POP for pooled mean.

All the organic treatments during the first year; all organic treatments except s_1g_1, s_2g_1, s_3g_1 and s_4g_2 during the second year and all treatments except s_1g_1 for pooled mean recorded significantly higher cormel yield ha^{-1} than C_3 (absolute control).

4.1.2.5 Corm Yield ha^{-1}

A clear scrutiny of the data in Table 13a indicated the significant influence of organic sources and *in situ* green manuring on corm yield ha^{-1} during both the years and also in the pooled analysis.

As in the case of cormel yield, the organic source s_6 (PM+ wood ash + PGPR mix I + vermiwash) registered the highest corm yield during the first year (13.48 t ha$^-$

^{1}) and for pooled analysis (12.21 t ha^{-1}), while during the second year, the highest corm yield (12.07 t ha^{-1}) was recorded with the organic source s_3 (FYM + wood ash + PGPR mix I + vermiwash). During the first year, the organic source s_6 was on par with s_5 (PM+ wood ash + PGPR mix I), while, the organic sources s_3 and s_6 were on par each other during the second year with same trend for pooled analysis. The lowest corm yield was recorded with s_1 (10.66 t ha^{-1}) during the first year and s_4 during the second year (7.71t ha^{-1}) and also for pooled analysis (9.35 t ha^{-1}).

During both the years, significantly higher corm yield was obtained by *in situ* green manuring with daincha (g_2) than with cow pea (g_1). Pooled analysis revealed the same trend which produced a corm yield of 11.14 t ha^{-1} with g_2 and 10.16 t ha^{-1} with g_1.

The data on interaction effect of organic sources and *in situ* green manuring on corm yield ha^{-1} are given in Table 13b.

The SxG interaction was significant only during the first year of experimentation. The treatment combination s_6g_2 (application of poultry manure along with wood ash, PGPR mix I and vermiwash + *in situ* green manuring with daincha) recorded higher corm yield (13.94 t ha^{-1}), which was on par with treatment combinations s_6g_1 (13.01 t ha^{-1}), s_5g_1 (12.96 t ha^{-1}), and s_2g_2 (12.92 t ha^{-1}).

As shown in Table 13b, the corm yield ha^{-1} was significantly influenced by treatment *vs*. control (C_1) effect during both the years and for pooled mean also. The organic treatment combinations s_2g_2, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 during the first year; s_1g_2, s_2g_1, s_2g_2, s_3g_1, s_3g_2, s_4g_2, s_5g_2, s_6g_1, and s_6g_2 during the second year and s_3g_1, s_3g_2, s_5g_2, s_6g_1, and s_6g_2 for pooled mean were on par with nutrient management through chemical fertilizers as per KAU POP (80: 25: 100 kg NPK ha^{-1}). Meanwhile the treatment combinations s_1g_1, s_1g_2, s_2g_1, s_3g_1, s_4g_1 and s_4g_2 during the first year; s_1g_1, s_4g_1 and s_5g_1 during the second year and s_1g_1, s_1g_2, s_2g_1, s_2g_2, s_4g_1, s_4g_2 and s_5g_1 for pooled mean recorded significantly lower corm yield than C_1 (13.54 t ha^{-1} during

Table 13a. Effect of organic sources and *in situ* green manuring on cormel and corm yield, t ha^{-1}

Treatments	Cormel yield			Corm yield		
	I year	II year	Pooled mean	I year	II year	Pooled mean
Organic sources (S)						
s_1- FYM + wood ash	17.20	12.63	14.91	10.66	8.13	9.40
s_2- FYM + wood ash +PGPR mix I	19.14	14.14	16.64	11.81	8.43	10.12
s_3- FYM + wood ash + PGPR mix I + vermiwash	19.45	14.55	17.00	11.73	12.07	11.90
s_4- PM+ wood ash	17.91	12.74	15.33	11.00	7.71	9.35
s_5- PM+ wood ash + PGPR mix I	20.28	15.72	18.00	12.85	8.96	10.91
s_6- PM+ wood ash + PGPR mix I + vermiwash	20.89	16.47	18.68	13.48	10.94	12.21
SEm(±)	0.36	0.71	0.53	0.28	0.46	0.23
CD (0.05)	1.066	2.093	1.565	0.824	1.349	0.684
***In situ* green manuring (G)**						
g_1- Cowpea	18.72	13.76	16.24	11.57	8.74	10.16
g_2- Daincha	19.57	14.99	17.28	12.27	10.01	11.14
SEm(±)	0.21	0.41	0.31	0.16	0.27	0.14
CD (0.05)	0.615	1.208	0.903	0.476	0.779	0.395

Table 13b. Effect of S x G interaction and treatments *Vs*. control effect on cormel and corm yield, t ha^{-1}

Treatments	Cormel yield			Corm yield		
	I year	II year	Pooled mean	I year	II year	Pooled mean
S x G interaction						
s_1g_1	16.43[13]	11.34[1]	13.88[1]	10.13[13]	7.37[1]	8.750[13]
s_1g_2	17.96[13]	13.91[3]	15.94[13]	11.19[13]	8.90	10.041[13]
s_2g_1	18.03[13]	11.63[1]	14.83[13]	10.69[13]	8.26	9.472[13]
s_2g_2	20.26[23]	16.64[23]	18.45[23]	12.92[23]	8.60	10.764[13]
s_3g_1	18.59[123]	12.90[1]	15.74[13]	11.20[13]	11.35[3]	11.275[3]
s_3g_2	20.31[23]	16.20[23]	18.26[23]	12.26[23]	12.78[3]	12.524[3]
s_4g_1	18.34[13]	13.77[3]	16.05[13]	11.45[13]	7.11[1]	9.281[13]
s_4g_2	17.49[13]	11.72[1]	14.60[13]	10.54[13]	8.31	9.424[13]
s_5g_1	20.40[23]	16.74[23]	18.57[23]	12.96[23]	7.90[1]	10.430[13]
s_5g_2	20.15[23]	14.71[3]	17.43[23]	12.75[23]	10.02[3]	11.38[3]
s_6g_1	20.51[23]	16.17[23]	18.35[23]	13.01[23]	10.46[3]	11.74[3]
s_6g_2	21.27[23]	16.77[23]	19.02[23]	13.94[23]	11.42[3]	12.68[3]
SEm(±)	0.51	1.01	0.75	0.40	0.65	0.33
CD (0.05)	1.508	2.959	2.213	1.166	NS	NS
C_1- KAU PoP	21.08	18.03	19.55	13.54	11.16	12.35
Treatments *vs.* C_1	S	S	S	S	S	S
C_2- KAU organic PoP	16.25	11.35	13.80	10.12	9.72	9.92
Treatments *vs.* C_2	S	S	S	S	NS	NS
C_3- Absolute control	13.15	9.60	11.37	7.75	6.37	7.06
Treatments *vs.* C_3	S	S	S	S	S	S

[1] significantly different from C_1; [2] significantly different from C_2;

[3] significantly different from C_3

the first year, 11.16 t ha^{-1} during the second year and 12.35 t ha^{-1} in case of pooled mean). The treatment s_6g_2 recorded a 2.67 percentage increase of corm yield over chemical nutrient management for pooled mean.

While comparing treatments with control C_2 (nutrient management as per KAU organic POP), the treatments s_2g_2, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 during the first year recorded significantly higher corm yield than C_2 (10.12 t ha^{-1}). However, there was no significant difference between C_2 and treatments during the second year in case of corm yield. The pooled mean data of corm yield was also statistically non significant. However, the treatment s_6g_2 recorded a 27.82 percentage increase of corm yield over KAU organic POP for pooled mean.

All treatments during the first year and the pooled mean data recorded significantly higher values of corm yield than C_3 (absolute control). While during the second year only s_3g_1, s_3g_2, s_5g_2, s_6g_1 and s_6g_2 recorded significantly higher corm yield than C_3 (6.37 t ha^{-1}).

4.1.3 Physiological Attributes

4.1.3.1 Leaf Chlorophyll Content (4 MAP)

The data on leaf chlorophyll content at 4 MAP during both the years are summarized in Table 14a and 14b.

Neither the main effects, nor the interaction effects of organic sources and *in situ* green manuring did exert any significant influence on the leaf chlorophyll content. The treatments *vs.* control effect were also not significant to influence the leaf chlorophyll content during both the years.

4.1.3.2 Dry Matter Production at Harvest

The data in Table 14a and 14b revealed the significant influence of treatments on dry matter production of crop at harvest stage, during both the years.

Among the organic sources, poultry manure application along with wood ash, PGPR mix I and vermiwash (s_6) recorded the highest dry matter production at harvest during both the years. During the first year, s_6 (8.08 t ha^{-1}) was on par with s_5 (7.75 t ha^{-1}) in which poultry manure along with wood ash and PGPR mix I were applied, while during the second year s_6 (6.12 t ha^{-1}) was on par with s_3 (5.95 t ha^{-1}), in which FYM along with wood ash, PGPR mix I and vermiwash were applied.

In situ green manuring with daincha registered significantly higher dry matter production at harvest (7.43 t ha^{-1} during the first year and 5.67 t ha^{-1} during the second year) than *in situ* green manuring with cowpea during both the years.

The interaction had significant effect on dry matter production at harvest during both the years. During the first year, treatment combination s_6g_2 (application of poultry manure along with wood ash, PGPR mix I and vermiwash + *in situ* green manuring with daincha) recorded the highest dry matter production at harvest (8.37 t ha^{-1}) followed by s_5g_2 (application of poultry manure along with wood ash and PGPR mix I + *in situ* green manuring with daincha) with 7.90 t ha^{-1} of dry matter production and the treatment s_5g_2 was on par with s_6g_1, s_2g_2, s_3g_2 and s_5g_1. The lowest value of dry matter production (5.99 t ha^{-1}) was recorded with s_1g_1. During the second year, s_3g_2 (application of FYM along with wood ash, PGPR mix I and vermiwash + *in situ* green manuring with daincha) recorded the highest dry matter production (6.55 t ha^{-1}) at harvest and was on par with s_6g_2 (6.42 t ha^{-1}). As in the case of first year, the lowest value of dry matter production (4.30 t ha^{-1}) was recorded by s_1g_1.

As shown in Table 14b, significant difference was observed between organic treatments and C_1 (Nutrient management through chemical fertilizers as per KAU POP - 80: 25: 100 kg NPK ha^{-1}) during both the years. During the first year, the treatment combinations s_2g_2 (7.74 t ha^{-1}), s_3g_1 (7.16 t ha^{-1}), s_3g_2 (7.64 t ha^{-1}), s_5g_1 (7.60 t ha^{-1}), s_5g_2 (7.90 t ha^{-1}), s_6g_1 (7.79 t ha^{-1}) and s_6g_2 (8.37 t ha^{-1}) were on par with C_1 (7.85 t ha^{-1}) while s_1g_1, s_1g_2, s_2g_1, s_4g_1 and s_4g_2 recorded significantly lower values than C_1. During the second year, the treatment combinations s_2g_2 (5.77 t ha^{-1}), s_3g_2 (6.55 t ha^{-}

^{1}), s_5g_1 (5.47 t ha^{-1}), s_5g_2 (5.59 t ha^{-1}), s_6g_1 (5.81 t ha^{-1}) and s_6g_2 (6.42 t ha^{-1}) were on par with nutrient management through chemical fertilizers (6.18 t ha^{-1}) and s_1g_1, s_1g_2, s_2g_1, s_3g_1, s_4g_1 and s_4g_2 recorded significantly lower values than C_1 in case of dry matter production at harvest.

Regarding treatments *vs.* nutrient management as per KAU organic POP-Adhoc (C_2), there was significant difference only during the first year. Except s_1g_1, s_1g_2 and s_4g_2, all the other treatment combinations resulted in significantly higher value of dry matter production compared to C_2 (5.99 t ha^{-1}). Even though not significant, s_1g_2, s_2g_2, s_3g_1, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 recorded higher values of dry matter production than C_2 during the second year.

All organic treatments were significantly superior to absolute control (4.69 t ha^{-1} during the first year and 3.50 t ha^{-1} during the second year) with respect to dry matter production during both the years.

4.1.3.3 Harvest Index

The data on harvest index as influenced by the treatments are presented in Table 14a and 14b.

Organic sources and *in situ* green manuring failed to produce significant influence on harvest index during both the years.

The S x G interaction also could not exert any significant influence on harvest index during the first year. However during the second year, there was significant effect on harvest index and the treatment combinations s_5g_1 and s_2g_2 recorded the highest harvest index (same value of 0.60) and these treatments were on par with s_1g_1 (0.53), s_1g_2 (0.54), s_4g_1 (0.58), s_5g_2 (0.53), s_6g_1 (0.54) and s_6g_2 (0.53).

There was no significant difference between treatments and control C_1 during both the years in case of harvest index. However the control C_2 showed significant variation from treatments during the second year, wherein s_2g_2 (0.60) and s_5g_1 (0.60) were significantly superior to C_2 (0.47). The absolute control (C_3) also did not show significant difference from treatments with respect to harvest index.

Table 14a. Effect of organic sources and *in situ* green manuring on leaf chlorophyll content at 4 MAP, dry matter production at harvest and harvest index

Treatments	I year			II year		
	Leaf chlorophyll content (mg g^{-1})	Dry matter production (t ha^{-1})	Harvest index	Leaf chlorophyll content (mg g^{-1})	Dry matter production (t ha^{-1})	Harvest index
Organic sources (S)						
s_1- FYM + wood ash	2.26	6.25	0.55	2.18	4.72	0.53
s_2- FYM + wood ash +PGPR mix I	2.11	7.20	0.54	2.33	5.16	0.56
s_3- FYM + wood ash + PGPR mix I + vermiwash	2.08	7.40	0.54	2.40	5.95	0.50
s_4- PM+ wood ash	2.17	6.57	0.55	2.22	4.65	0.54
s_5- PM+ wood ash + PGPR mix I	2.26	7.75	0.54	2.30	5.53	0.57
s_6- PM+ wood ash + PGPR mix I + vermiwash	2.02	8.08	0.53	2.51	6.12	0.54
SEm(±)	0.15	0.11	0.01	0.08	0.13	0.02
CD (0.05)	NS	0.328	NS	NS	0.388	NS
***In situ* green manuring (G)**						
g_1- Cowpea	2.07	6.99	0.54	2.28	5.04	0.54
g_2- Daincha	2.23	7.43	0.54	2.37	5.67	0.54
SEm(±)	0.08	0.07	0.003	0.05	0.08	0.01
CD (0.05)	NS	0.189	NS	NS	0.224	NS

Table 14b. Effect of S x G interaction and treatments *Vs*. control effect on leaf chlorophyll content at 4 MAP, dry matter production at harvest and harvest index

Treatments	I year			II year		
	Leaf chlorophyll content (mg g^{-1})	Dry matter production (t ha^{-1})	Harvest index	Leaf chlorophyll content (mg g^{-1})	Dry matter production (t ha^{-1})	Harvest index
S x G interaction						
s_1g_1	2.04	5.99[13]	0.55	2.13	4.30[13]	0.53
s_1g_2	2.48	6.52[13]	0.54	2.23	5.13[13]	0.54
s_2g_1	2.08	6.67[123]	0.54	2.31	4.55[13]	0.51
s_2g_2	2.13	7.74[23]	0.54	2.35	5.77[3]	0.60[2]
s_3g_1	2.11	7.16[23]	0.54	2.40	5.36[13]	0.49
s_3g_2	2.06	7.64[23]	0.55	2.39	6.55[3]	0.51
s_4g_1	2.23	6.71[123]	0.55	2.18	4.74[13]	0.58
s_4g_2	2.11	6.43[13]	0.55	2.26	4.57[13]	0.51
s_5g_1	2.21	7.60[23]	0.54	2.15	5.47[3]	0.60[2]
s_5g_2	2.31	7.90[23]	0.53	2.45	5.59[3]	0.53
s_6g_1	1.74	7.79[23]	0.53	2.51	5.81[3]	0.54
s_6g_2	2.30	8.37[23]	0.53	2.51	6.42[3]	0.53
SEm(±)	0.21	0.16	0.01	0.11	0.19	0.03
CD (0.05)	NS	0.464	NS	NS	0.549	0.072
C_1- KAU PoP	2.19	7.85	0.52	2.09	6.18	0.54
Treatments *vs.* C_1	NS	S	NS	NS	S	NS
C_2- KAU organic PoP	2.20	5.99	0.53	2.13	4.86	0.47
Treatments *vs.* C_2	NS	S	NS	NS	NS	S
C_3- Absolute control	2.48	4.69	0.53	2.24	3.50	0.50
Treatments *vs.* C_3	NS	S	NS	NS	S	NS

[1] significantly different from C_1; [2] significantly different from C_2;

[3] significantly different from C_3

4.1.4 Quality Attributes of Cormel

4.1.4.1 Dry Matter Content

The dry matter content of the cormel on dry weight basis as influenced by the treatments is given in Table 15a and 15b.

Neither the main effects nor the interaction effects of organic sources and *in situ* green manuring did exert any significant influence on the dry matter content of the cormel during both the years.

Significant difference was observed between organic treatments and C_1 (Nutrient management through chemical fertilizers as per KAU POP - 80: 25: 100 kg NPK ha^{-1}) with respect to dry matter content during both the years. The organic treatments s_2g_2 (20.51 %), s_3g_1 (20.61 %), s_3g_2 (20.59 %), s_5g_2 (20.71 %) and s_6g_2 (20.73 %) recorded significantly higher dry matter content of cormel during the first year while s_2g_1 (20.10 %), s_2g_2 (20.75 %), s_3g_1(20.28 %), s_3g_2 (20.42 %), s_5g_2 (20.10 %) and s_6g_2 (20.16 %) recorded significantly more cormel dry matter content during the second year compared to C_1 (19.15 % during the first year and 18.60 % during the second year). All other treatments were found to be on par with C_1 during both the years.

There was no significant difference between treatments and control C_2 during both the years in case of cormel dry matter content. However the absolute control showed significant difference from organic treatments during both the years. The organic treatments s_2g_2 (20.51 %), s_3g_1 (20.61 %), s_3g_2 (20.59 %), s_5g_2 (20.71 %) and s_6g_2 (20.73 %) during the first year and s_2g_2 (20.75 %) and s_3g_2 (20.42 %) during the second year recorded significantly higher values of dry matter content of cormel than absolute control and all other treatments were on par with C_3 (19.03 % during the first year and 18.5 per cent during the second year).

4.1.4.2 Starch Content

The data on starch content of cormel on dry weight basis as influenced by the treatments are presented in Table 15a and 15b.

Different organic sources had significant influence on starch content of cormel during both the years. Poultry manure application along with wood ash, PGPR mix I and vermiwash (s_6) recorded the highest starch content of cormel during both the years. During the first year, the organic sources s_3 (62.88 %), s_5 (62.15 %) and s_2 (62.06 %) were on par with s_6 (63.72 %) and during the second year, the s_6 (60.44 %) was on par with s_3 (59.13 %) and s_5 (58.82 %).

In situ green manuring had significant effect on starch content of cormel during both the years and *in situ* green manuring with daincha (63.26 % during the first year and 59.18 % during the second year) registered significantly higher starch content of cormel compared to *in situ* green manuring with cowpea during both the years.

The SxG interaction (Table 15b) failed to produce any significant effect on starch content during both the years.

While comparing the treatments with C_1 (nutrient management through chemical fertilizers as per KAU POP), it was observed that there was significant difference between treatments and C_1 with respect to starch content of cormel during both the years. During the first year, all organic treatments except s_1g_1 and s_4g_1 were found to be significantly superior to C_1 (57.09 %), wherein s_1g_1 and s_4g_1 were on par with C_1. During the second year, s_3g_2 (59.85 %) and s_6g_2 (61.64 %) recorded significantly superior values of starch content than C_1 and all other treatments were on par with C_1.

The control nutrient management as per KAU organic POP (C_2) showed significant difference from the organic nutrition treatments only during the first year, wherein the treatment combinations s_3g_2 and s_6g_2 recorded significantly higher starch content of cormel (63.93 % and 64.91 % respectively) compared to C_2, and all other treatments except s_3g_2 and s_6g_2 were on par with C_2 (59.16 %).

All organic nutrition treatments during the first year and all treatments except s_1g_1, s_1g_2, s_2g_1 and s_4g_1 during the second year recorded significantly superior values of dry matter content than C_3 (52.23 % during the first year and 52.98 % during the second year).

4.1.4.3 Total Sugar Content

As presented in Table 15a, the organic sources had significant effect on total sugar content of cormel during both the years. During the first year, the organic source s_3 (FYM + wood ash + PGPR mix I + vermiwash) recorded the highest total sugar content of 4.02 per cent, however it was on par with s_2 (3.63 %), s_5 (3.76 %) and s_6 (3.74 %). The lowest total sugar content of 3.02 per cent was recorded by organic source s_4 in which PM and wood ash were applied. During the second year, the organic source s_6 (PM + wood ash + PGPR mix I + vermiwash) recorded the highest total sugar content of 3.97 per cent and it was on par with s_3 (3.92 %) and s_5 (3.82 %).

As in the case of starch content, *in situ* green manuring with daincha resulted in significantly higher total sugar content of cormel during both the years (3.78 % during the first year and 3.79 % during the second year) compared to *in situ* green manuring with cow pea.

The SxG interaction had significant influence on total sugar content of cormel only during the first year. The treatment combination s_3g_2 (application of FYM along with wood ash, PGPR mix I and vermiwash + *in situ* green manuring with daincha) recorded the highest total sugar content of 4.50 per cent and was on par with s_2g_2 (3.65 %), s_5g_2 (4.17 %), s_1g_2 (3.67 %) and s_6g_2 (4.08 %).

The control C_1 (nutrient management through chemical fertilizers as per KAU POP), showed significant difference from treatments with respect to total sugar content of cormel only during the second year, wherein s_5g_2 (4.15 %) and s_6g_2 (4.23

Table 15a. Effect of organic sources and *in situ* green manuring on dry matter content, starch and total sugar content of cormel on dry weight basis, per cent

Treatments	I year			II year		
	Dry matter content	Starch	Total sugar	Dry matter content	Starch	Total sugar
Organic sources (S)						
s_1- FYM + wood ash	19.82	60.80	3.03	20.00	56.54	3.45
s_2- FYM + wood ash +PGPR mix I	20.19	62.06	3.63	20.42	57.19	3.28
s_3- FYM + wood ash + PGPR mix I + vermiwash	20.60	62.88	4.02	20.35	59.13	3.92
s_4- PM+ wood ash	20.02	60.91	3.02	19.85	57.36	3.47
s_5- PM+ wood ash + PGPR mix I	20.44	62.15	3.76	19.93	58.82	3.82
s_6- PM+ wood ash + PGPR mix I + vermiwash	20.37	63.72	3.74	19.81	60.44	3.97
SEm(±)	0.18	0.69	0.21	0.21	0.79	0.16
CD (0.05)	NS	2.013	0.610	NS	2.319	0.480
***In situ* green manuring (G)**						
g_1- Cowpea	20.10	60.91	3.29	19.90	57.31	3.51
g_2- Daincha	20.39	63.26	3.78	20.22	59.18	3.79
SEm(±)	0.10	0.39	0.12	0.12	0.46	0.09
CD (0.05)	NS	1.162	0.352	NS	1.339	0.277

Table 15b. Effect of S x G interaction and treatments *Vs*. control effect on dry matter content, starch and total sugar content of cormel on dry weight basis, per cent

Treatments	I year			II year		
	Dry matter content	Starch	Total sugar	Dry matter content	Starch	Total sugar
S x G interaction						
s_1g_1	19.95	58.76[3]	2.39	20.03	56.15	3.17
s_1g_2	19.69	62.85[13]	3.67	19.97	56.92	3.72
s_2g_1	19.87	61.61[13]	3.61	20.10[1]	55.57	3.11
s_2g_2	20.51[13]	62.52[13]	3.65	20.75[13]	58.82[3]	3.45
s_3g_1	20.61[13]	61.83[13]	3.54	20.28[1]	58.40[3]	3.90
s_3g_2	20.59[13]	63.93[123]	4.50[3]	20.42[13]	59.85[13]	3.94
s_4g_1	19.96	58.61[3]	3.45	19.79	56.31	3.70
s_4g_2	20.08	63.21[13]	2.59	19.92	58.42[3]	3.23
s_5g_1	20.18	62.16[13]	3.35	19.76	58.20[3]	3.49
s_5g_2	20.71[13]	62.14[13]	4.17[3]	20.10[1]	59.45[3]	4.15[13]
s_6g_1	20.02	62.52[13]	3.41	19.46	59.25[3]	3.70
s_6g_2	20.73[13]	64.91[123]	4.08	20.16[1]	61.64[13]	4.23[13]
SEm(±)	0.25	0.97	0.29	0.30	1.12	0.23
CD (0.05)	NS	NS	0.862	NS	NS	NS
C_1- KAU PoP	19.15	57.09	2.88	18.60	54.65	2.98
Treatments *vs.* C_1	S	S	NS	S	S	S
C_2- KAU organic PoP	19.63	59.16	3.90	19.80	58.22	3.70
Treatments *vs.* C_2	NS	S	NS	NS	NS	NS
C_3- Absolute control	19.03	52.23	2.73	18.50	52.98	3.14
Treatments *vs.* C_3	S	S	S	S	S	S

[1] significantly different from C_1; [2] significantly different from C_2;

[3] significantly different from C_3

%) were significantly superior to C1 (2.98 %) and all other treatments were on par with C1.

The treatments vs. control C2 (nutrient management as per KAU organic POP) effect was not significant in case of total sugar content of cormel during both the years.

The organic treatments resulted in significant variation in total sugar content of cormel, compared to absolute control (C3) during both the years. The organic treatment combinations s_3g_2 (4.50 %) and s_5g_2 (4.17 %) during the first year and s_5g_2 (4.15 %) and s_6g_2 (4.23 %) during the second year recorded significantly higher total sugar content of cormel than absolute control (2.73 % during the first year and 3.14 % during the second year).

4.1.4.4 Crude Protein Content

The main effects and interaction effects of treatments on crude protein content of cormel on dry weight basis are presented in Tables 16a and 16b.

The crude protein content of cormel was significantly influenced by organic sources only during the second year. The organic source s_6 (application of PM along with wood ash, PGPR mix I and vermiwash) recorded the highest value of 13.91 per cent of crude protein and was on par with the organic sources s_4 (13.65 %) and s_2 (13.39 %).

In situ green manuring did not produce any significant variation in the crude protein content of cormels during both the years.

As in the case of organic sources, the SxG interaction also had significant effect on crude protein content of cormel only during the second year. The treatment combination s_6g_1 (14. 53 %) recorded the highest value, however it was on par with s_6g_2, s_4g_2, s_4g_1, s_3g_1, s_2g_2 and s_2g_1.

The organic nutrition treatments did not vary significantly from the control C_1, C_2 and C_3 during both the years, with respect to crude protein content of cormel.

4.1.4.5 Crude Fibre Content

The data on crude fibre content of cormel on dry weight basis as influenced by the treatments are presented in Tables 16a and 16b.

The organic sources had significant influence on crude fibre content of cormel only during the second year. The lowest crude fibre content of 1.24 per cent was recorded by s_6 (PM+ wood ash + PGPR mix I + vermiwash). The organic source s_1 (FYM + wood ash) recorded the highest crude fibre content (1.88 %) and was on par with s_4 (1.75 %).

Crude fibre content of cormel was not significantly influenced by *in situ* green manuring and SxG interaction during both the years.

Regarding the treatments *vs.* C_1 (nutrient management through chemical fertilizers) effect, there was significant difference between organic treatments and C_1 during both the years. The organic treatments s_4g_1, s_4g_2 and s_5g_1 during the first year and s_1g_1, s_1g_2, s_3g_1, s_4g_1 and s_4g_2 during the second year were found to be on par with C_1 and the organic treatments s_1g_1, s_1g_2, s_2g_1, s_2g_2, s_3g_1, s_3g_2, , s_5g_2, s_6g_1 and s_6g_2 during the first year and s_2g_1, s_2g_2, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 during the second year recorded significantly lower values of crude fibre content of cormel compared to C_1 (2.12 % during the first year and 1.98 % during the second year).

Significant difference was observed between treatments and control C_2 [nutrient management as per KAU organic POP (Adhoc)] during both the years. All the treatments except, s_3g_2 and s_6g_2 during the first year and s_2g_2, s_3g_2, s_5g_1, s_6g_1 and s_6g_2 during the second year were on par with C_2. The treatment combinations s_3g_2 and s_6g_2 during the first year and s_2g_2, s_3g_2, s_5g_1, s_6g_1 and s_6g_2 during the second year recorded significantly lower values of crude fibre content of cormel than C_2 (1.90 % during the first year and 1.83 % during the second year).

All the organic treatments except, s_3g_2 and s_6g_2 during the first year and s_2g_1, s_2g_2, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 during the second year were on par with absolute control, while s_3g_2 and s_6g_2 during the first year and s_2g_1, s_2g_2, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and

s_6g_2 during the second year recorded significantly lower values of crude fibre content of cormel than C_3 (1.90 % during the first year and 1.93 % during the second year).

4.1.4.6 Oxalic Acid Content

The data on the main effects and interaction effects of treatments on oxalic acid content of cormel on dry weight basis are presented in Tables 16a and 16b.

During the first year, the organic sources s_3 and s_6 recorded the lowest oxalic acid content of 0.25 per cent wherein s_3 (0.25 %) and s_6 (0.25 %) were on par each other and also did not differ from s_2 (0.31 %) and s_5 (0.30 %). During the second year, the oxalic acid content of cormel was not significantly influenced by the organic sources.

The *in situ* green manuring had no significant effect on oxalic acid content during the first year, while the content was significantly influenced by *in situ* green manuring during the second year. *In situ* green manuring with daincha resulted in lower oxalic acid content of 0.24 per cent compared to 0.29 per cent of *in situ* green manuring with cow pea.

The SxG interaction had no significant influence on oxalic acid content of cormel during both the years.

As shown in Table 16b, significant difference was observed between organic treatments and C_1 (Nutrient management through chemical fertilizers as per KAU POP - 80: 25: 100 kg NPK ha^{-1}) with respect to oxalic acid content in cormels during both the years. During the first year, the treatments s_2g_2 (0.24 %), s_3g_1 (0.20 %) and s_6g_2 (0.23 %) recorded significantly lower oxalate content than C_1, and all the remaining treatments were on par with C_1 (0.49 %). During the second year, s_3g_2 (0.20 %), s_5g_2 (0.21 %) and s_6g_2 (0.19 %) recorded significantly lower oxalate content than C_1 and the remaining treatments were on par with C_1 (0.49 %).

The nutrient management as per KAU organic POP- *Ad hoc* (C_2) did not show significant difference from treatments with respect to oxalic acid content of cormels. However the organic treatments had significant variation from absolute control C_3

Table 16a. Effect of organic sources and *in situ* green manuring on crude protein, crude fibre and oxalic acid content of cormel on dry weight basis, per cent

Treatments	I year			II year		
	Crude protein	Crude fibre	Oxalic acid	Crude protein	Crude fibre	Oxalic acid
Organic sources (S)						
s_1- FYM + wood ash	12.19	1.53	0.40	11.43	1.88	0.32
s_2- FYM + wood ash +PGPR mix I	15.63	1.48	0.31	13.39	1.43	0.28
s_3- FYM + wood ash + PGPR mix I + vermiwash	15.69	1.39	0.25	12.69	1.49	0.25
s_4- PM+ wood ash	16.22	1.68	0.38	13.65	1.75	0.29
s_5- PM+ wood ash + PGPR mix I	14.47	1.63	0.30	12.16	1.45	0.21
s_6- PM+ wood ash + PGPR mix I + vermiwash	15.11	1.31	0.25	13.91	1.24	0.25
SEm(±)	1.18	0.09	0.04	0.35	0.07	0.03
CD (0.05)	NS	NS	0.113	1.020	0.197	NS
***In situ* green manuring (G)**						
g_1- Cowpea	14.04	1.55	0.34	13.03	1.59	0.29
g_2- Daincha	15.73	1.45	0.29	12.72	1.49	0.24
SEm(±)	0.68	0.05	0.02	0.20	0.04	0.02
CD (0.05)	NS	NS	NS	NS	NS	0.051

Table 16b. Effect of S x G interaction and treatments *Vs*. control effect on crude protein, crude fibre and oxalic acid content of cormel on dry weight basis, per cent

Treatments	I year			II year		
	Crude protein	Crude fibre	Oxalic acid	Crude protein	Crude fibre	Oxalic acid
S x G interaction						
s_1g_1	9.10	1.58[1]	0.44	10.62	1.90	0.33
s_1g_2	15.28	1.48[1]	0.36	12.25	1.87	0.31
s_2g_1	15.52	1.45[1]	0.37	13.30	1.47[13]	0.31
s_2g_2	15.75	1.50[1]	0.24[1]	13.48	1.40[123]	0.25
s_3g_1	15.52	1.55[1]	0.20[1]	13.65	1.70	0.29
s_3g_2	15.87	1.23[123]	0.29	11.73	1.28[123]	0.20[1]
s_4g_1	15.17	1.70	0.40	13.13	1.90	0.30
s_4g_2	17.27	1.65	0.37	14.18	1.60	0.29
s_5g_1	14.00	1.65	0.34	12.95	1.40[123]	0.22
s_5g_2	14.93	1.60[1]	0.26	11.38	1.50[13]	0.21[1]
s_6g_1	14.93	1.40[1]	0.27	14.53	1.20[123]	0.30
s_6g_2	15.28	1.23[123]	0.23[1]	13.30	1.28[123]	0.19[13]
SEm(±)	1.67	0.12	0.05	0.49	0.10	0.04
CD (0.05)	NS	NS	NS	1.442	NS	NS
C_1- KAU PoP	15.28	2.12	0.49	13.30	1.98	0.39
Treatments *vs.* C_1	NS	S	S	NS	S	S
C_2- KAU organic PoP	16.92	1.90	0.25	11.90	1.83	0.28
Treatments *vs.* C_2	NS	S	NS	NS	S	NS
C_3- Absolute control	14.81	1.90	0.39	12.09	1.93	0.37
Treatments *vs.* C_3	NS	S	NS	NS	S	S

[1] significantly different from C_1; [2] significantly different from C_2;

[3] significantly different from C_3

during the second year, wherein s_6g_2 (0.19 %) recorded significantly lower oxalate content than C_3 and all the remaining treatments were on par with C_3 (0.37 %).

4.1.5 Uptake of Nutrients

4.1.5.1 N, P and K Content of Plant and Tuber

4.1.5.1.1 N Content of Plant

The main effects and interaction effects of treatments on N content of plant during both the years are presented in Tables 17a and 17b respectively.

The N content of plant was significantly affected by different organic sources only during the second year and the organic source s_6 (PM+ wood ash + PGPR mix I + vermiwash) recorded the highest N content of 2.27 per cent, which was on par with s_2 (2.18 %), s_3 (2.07 %) and s_5 (2.07 %).

In situ green manuring with daincha recorded significantly higher N content of plant (2.03 %) during the first year than *in situ* green manuring with cowpea (1.85 %),while during the second year, the N content of plant was not significantly influenced by *in situ* green manuring.

No significant variation in plant N content was observed due to interaction effects of organic source and *in situ* green manuring during both the years.

While comparing treatments *vs*. control effect, the control C_1 and C_2 were not significantly different from treatments during both the years with respect to N content of plant. The C_3 (absolute control) showed significant difference from treatments during the first year and the treatment combinations s_5g_2 (2.15 %) and s_6g_2 (2.18 %) recorded significantly higher plant N content than absolute control (1.55 %). During the second year, treatment *vs.* C_3 was not significant in case of N content in plant.

4.1.5.1.2 P Content of Plant

It is observed from Table 17a that the organic sources had no profound influence on P content of plant during both the years.

Table 17a. Effect of organic sources and *in situ* green manuring on N, P and K content of plant, per cent

Treatments	I year			II year		
	N content	P content	K content	N content	P content	K content
Organic sources (S)						
s_1- FYM + wood ash	1.84	0.32	4.59	2.02	0.29	4.32
s_2- FYM + wood ash +PGPR mix I	1.96	0.47	4.78	2.18	0.18	3.61
s_3- FYM + wood ash + PGPR mix I + vermiwash	1.89	0.37	4.61	2.07	0.50	4.43
s_4- PM+ wood ash	1.87	0.43	4.28	1.75	0.39	3.40
s_5- PM+ wood ash + PGPR mix I	2.07	0.30	4.05	2.07	0.37	3.15
s_6- PM+ wood ash + PGPR mix I + vermiwash	2.00	0.30	4.73	2.27	0.29	4.01
SEm(±)	0.09	0.05	0.19	0.10	0.07	0.38
CD (0.05)	NS	NS	NS	0.291	NS	NS
***In situ* green manuring (G)**						
g_1- Cowpea	1.85	0.31	4.55	2.05	0.31	4.08
g_2- Daincha	2.03	0.42	4.46	2.07	0.37	3.57
SEm(±)	0.05	0.03	0.11	0.06	0.04	0.22
CD (0.05)	0.159	0.090	NS	NS	NS	NS

Table 17b. Effect of S x G interaction and treatments *Vs*. control effect on N, P and K content of plant, per cent

Treatments	I year			II year		
	N content	P content	K content	N content	P content	K content
S x G interaction						
s_1g_1	1.70	0.20	4.99	1.96	0.31	4.19
s_1g_2	1.98	0.44	4.20	2.07	0.27	4.44
s_2g_1	1.85	0.50	4.88	2.16	0.10	4.33
s_2g_2	2.07	0.44	4.68	2.21	0.26	2.90
s_3g_1	1.92	0.34	4.28	2.15	0.38	5.10
s_3g_2	1.85	0.41	4.94	2.00	0.63	3.77
s_4g_1	1.79	0.43	4.11	1.74	0.33	4.17
s_4g_2	1.94	0.44	4.44	1.76	0.45	2.62
s_5g_1	2.00	0.24	4.16	2.13	0.46	2.96
s_5g_2	2.15[3]	0.36	3.95	2.02	0.29	3.35
s_6g_1	1.81	0.17	4.89	2.16	0.28	3.70
s_6g_2	2.18[3]	0.43	4.58	2.38	0.31	4.32
SEm(±)	0.13	0.08	0.27	0.14	0.10	0.54
CD (0.05)	NS	NS	NS	NS	NS	NS
C_1- KAU PoP	2.09	0.52	4.78	2.10	0.39	4.14
Treatments *vs.* C_1	NS	NS	NS	NS	NS	NS
C_2- KAU organic PoP	1.83	0.36	4.26	1.85	0.28	3.48
Treatments *vs.* C_2	NS	NS	NS	NS	NS	NS
C_3- Absolute control	1.55	0.20	4.04	1.79	0.22	3.28
Treatments *vs.* C_3	S	NS	NS	NS	NS	NS

[1] significantly different from C_1; [2] significantly different from C_2;

[3] significantly different from C_3

In situ green manuring had significant influence on P content of plant only during the first year, wherein *in situ* green manuring with daincha registered higher content of plant P (0.42 %) than with cowpea (0.31%).

No marked variation in plant P content was observed due to interaction effects during both the years. The treatments *vs.* control (C_1 or C_2 or C_3) were also not significant with respect to plant P content during both the years.

4.1.5.1.3 K Content of Plant

The effects of organic sources, *in situ* green manuring and their interactions on K content of plant are presented in Table 17a and 17b respectively.

Both the main factors and their interactions were found to be non significant in case of plant K content during both the years. The treatments *vs.* control (C_1 or C_2 or C_3) also was non significant with respect to plant K content during both the years.

4.1.5.1.4 N Content of Tuber

The results of the influence of main effects and their interaction effects on N content of taro tuber are given in Table 18a and 18b.

The organic sources, *in situ* green manuring and their interactions could not exert any significant influence on N content of tuber during both the years.

The organic treatments did not show any significant variation from any of control treatments during both years in case of N content of tuber.

4.1.5.1.5 P Content of Tuber

The data pertaining to P content of taro tuber are furnished in Table 18a and 18b.

Organic sources had no profound influence on phosphorus content of tuber during both the years. However, green manuring exerted significant effect on P content of tuber during the first year, wherein *in situ* green manuring with daincha resulted in higher tuber P content of 0.33 per cent than *in situ* green manuring with cow pea (0.27 %). During the second year, P content of tuber was however not affected by *in situ* green manuring.

Regarding the interaction effect, during the first year, the treatment combination s_3g_2 (application of FYM along with wood ash, PGPR mix I and vermiwash + *in situ* green manuring with daincha) recorded the highest tuber P content of 0.46 per cent, which was on par with s_6g_2 (0.37 %), s_2g_1 (0.37 %) and s_4g_2 (0.36 %). During the second year, P content of tuber was not affected by interaction effect.

The effect of treatments *vs.* C_1 and treatments *vs.* C_2 were not significant with respect to P content of tuber, while control C_3 showed significant difference from treatments during the first year and the treatment combination s_3g_2 (0.46 %) recorded higher content of tuber phosphorus than absolute control (0.18 %). During the second year, C_3 was not significantly different from the treatments in case of P content of tuber.

4.1.5.1.6 K Content of Tuber

As shown in Table 18a, K content of taro tuber was significantly influenced by organic sources during both the years. The highest K content (3.37 % during the first year and 3.22 % during the second year) was observed with the application of organic source s_6 (PM+ wood ash + PGPR mix I + vermiwash) followed by s_5 (PM+ wood ash + PGPR mix I) during both the years. During the first year, s_6 was significantly superior to all other organic sources, while the effects of s_5 (3.10 %), s_4 (3.02 %), s_3 (2.99 %) and s_2 (2.98 %) were on par. During the second year, s_6 was found to be on par with s_5 (3.07 %).

No significant variation in K content of tuber was observed due to *in situ* green manuring and S x G interaction (Table 18b) during both the years.

Comparison of treatments with C_1 (nutrient management through chemical fertilizers as per KAU POP - 80: 25: 100 kg NPK ha^{-1}) indicated that there was no

Table 18a. Effect of organic sources and *in situ* green manuring on N, P and K content of tuber, per cent

Treatments	I year			II year		
	N content	P content	K content	N content	P content	K content
Organic sources (S)						
s_1- FYM + wood ash	1.60	0.31	2.89	2.00	0.26	2.64
s_2- FYM + wood ash +PGPR mix I	1.91	0.29	2.98	2.26	0.27	2.78
s_3- FYM + wood ash + PGPR mix I + vermiwash	1.91	0.37	2.99	2.16	0.24	2.84
s_4- PM+ wood ash	1.99	0.29	3.02	2.33	0.27	2.89
s_5- PM+ wood ash + PGPR mix I	1.92	0.23	3.10	2.32	0.20	3.07
s_6- PM+ wood ash + PGPR mix I + vermiwash	1.88	0.31	3.37	2.34	0.26	3.22
SEm(±)	0.11	0.03	0.07	0.08	0.03	0.06
CD (0.05)	NS	NS	0.206	NS	NS	0.180
***In situ* green manuring (G)**						
g_1- Cowpea	1.81	0.27	3.07	2.27	0.25	2.86
g_2- Daincha	1.93	0.33	3.05	2.20	0.25	2.96
SEm(±)	0.06	0.02	0.04	0.05	0.02	0.04
CD (0.05)	NS	0.054	NS	NS	NS	NS

Table 18b. Effect of S x G interaction and treatments *Vs*. control effect on N, P and K content of tuber, per cent

Treatments	I year			II year		
	N content	P content	K content	N content	P content	K content
S x G interaction						
s_1g_1	1.40	0.31	2.84	1.93	0.28	2.60
s_1g_2	1.79	0.31	2.95	2.07	0.24	2.68
s_2g_1	1.91	0.37	3.08[3]	2.27	0.30	2.74
s_2g_2	1.91	0.21	2.88	2.25	0.23	2.82
s_3g_1	1.88	0.28	3.01	2.26	0.21	2.81
s_3g_2	1.93	0.46[3]	2.96	2.06	0.27	2.87[3]
s_4g_1	1.91	0.22	2.97	2.29	0.23	2.87[3]
s_4g_2	2.08	0.36	3.06[3]	2.38	0.30	2.91[3]
s_5g_1	1.91	0.19	3.05	2.53	0.20	3.12[23]
s_5g_2	1.92	0.28	3.15[3]	2.11	0.21	3.02[3]
s_6g_1	1.82	0.26	3.44[23]	2.33	0.30	3.00[3]
s_6g_2	1.93	0.37	3.31[23]	2.35	0.23	3.45[23]
SEm(±)	0.16	0.05	0.10	0.12	0.04	0.09
CD (0.05)	NS	0.132	NS	NS	NS	NS
C_1- KAU PoP	1.92	0.31	3.01	2.25	0.34	3.08
Treatments *vs.* C_1	NS	NS	NS	NS	NS	NS
C_2- KAU organic PoP	2.02	0.24	2.82	2.19	0.21	2.69
Treatments *vs.* C_2	NS	NS	S	NS	NS	S
C_3- Absolute control	1.71	0.18	2.64	2.07	0.17	2.50
Treatments *vs.* C_3	NS	S	S	NS	NS	S

[1] significantly different from C_1; [2] significantly different from C_2;

[3] significantly different from C_3

significant difference between treatments and C_1 with respect to the K content of tuber.

Significant difference was observed between the treatments and C_2 (nutrient management as per KAU organic Adhoc POP), wherein the treatment combination s_6g_1 (3.44 %) and s_6g_2 (3.31 %) during the first year and s_5g_1 (3.12 %) and s_6g_2 (3.45 %) during the second year recorded higher K content of tuber than C_2 (2.82 % during the first year and 2.69 % during the second year).

While comparing treatments with C_3 it was found that the treatment combinations s_2g_1, s_4g_2, s_5g_2, s_6g_1 and s_6g_2 during the first year and s_3g_2 , s_4g_1, s_4g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 during the second year recorded significantly higher K content of tuber than C_3 (2.64 % during the first year and 2.50 % during the second year).

4.1.5.2 Total N, P and K Uptake at Harvest

4.1.5.2.1 N Uptake

The data in Table 19a revealed the significant influence of organic sources and *in situ* green manuring on the uptake of N during both the years.

The organic source in which poultry manure along with wood ash, PGPR mix I and vermiwash were applied (s_6) registered the highest uptake of N during both the years (161.93 kg ha^{-1} and 141.43 kg ha^{-1} during I and II year respectively). During the first year, s_5 (157.07 kg ha^{-1}), s_3 (152.07 kg ha^{-1}), s_2 (148.34 kg ha^{-1}) and s_4 (138.90 kg ha^{-1}) were found to be on par with s_6, while during the second year s_6 was significantly superior to all other treatments.

The significantly higher uptake of N was recorded by in situ green manuring with daincha (154.39 kg ha^{-1} during the first year and 122.39 kg ha^{-1} during the second year) when compared to *in situ* green manuring with cow pea (134.21 kg ha^{-1} during the first year and 110.99 kg ha^{-1} during the second year).

The S x G interaction (Table 19b) significantly influenced the N uptake only during the second year and the highest N uptake was recorded with treatment combination s_6g_2 (149.03 kg ha^{-1}) which was on par with s_3g_2 (133.94 kg ha^{-1}) and s_6g_1 (133.84 kg ha^{-1}). The lowest N uptake was registered by s_1g_1 with a value of 80.90 kg ha^{-1}.

The treatments and control C_1 (Nutrient management through chemical fertilizers as per KAU POP - 80: 25: 100 kg NPK ha^{-1}) did not vary significantly in the case of N uptake during the first year, while during the second year, there was significant difference between treatments and control C_1. The treatment combinations s_2g_2 (127.59 kg ha^{-1}), s_3g_1 (121.10 kg ha^{-1}), s_3g_2 (133.94 kg ha^{-1}), s_5g_1 (127.46 kg ha^{-1}), s_5g_2 (114.43 kg ha^{-1}), s_6g_1 (133.84 kg ha^{-1}) and s_6g_2 (149.03 kg ha^{-1}) were found to be at par with C_1 (135.87 kg ha^{-1}). However, C_1 was significantly superior to $s_1g_{1,}$ $s_1g_{2,}$ s_2g_1, s_4g_1 and s_4g_2.

The treatments and control C_2 (nutrient management as per KAU organic Adhoc POP) were not significantly different in the case of N uptake during both the years. The treatments were significantly different from absolute control during both the years. All the treatments except s_1g_1, s_1g_2, s_2g_1 and s_4g_1 during the first year and all the treatments except s_1g_1 during the second year were significantly superior to C_3 (86.08 kg ha^{-1} during the first year and 70.08 kg ha^{-1} during the second year) with respect to N uptake by the crop.

4.1.5.2.2 P Uptake

The effect of organic sources, *in situ* green manuring and their interactions on P uptake of crop at harvest are presented in Tables 19a and 19b.

The P uptake varied with the different organic sources during the first year. The application of FYM along with wood ash, PGPR mix I and vermiwash (s_3) recorded the highest uptake of P (28.29 kg ha^{-1}), which was on par with s_6 (25.95 kg ha^{-1}) and s_2 (23.94 kg ha^{-1}). During the second year, uptake of P was unaffected by different organic sources.

In situ green manuring with daincha (g2) resulted in significantly higher uptake of P during the first year (26.27 kg ha^{-1}) compared to *in situ* green manuring with cow pea (20.09 kg ha^{-1}). Uptake of P was not influenced by *in situ* green manuring during the second year.

Phosphorus uptake by crop was significantly influenced by SxG interaction only during the first year. The treatment combination s_3g_2 recorded higher uptake (35.12 kg ha^{-1}) and was on par with s_6g_2 (30.94 kg ha^{-1}) and s_2g_1 (28.32 kg ha^{-1}).

The difference between phosphorus uptake by treatments and control C_1 (nutrient management through chemical fertilizers as per KAU POP - 80: 25: 100 kg NPK ha^{-1}) was not significant during the first year. During the second year, there was significant difference between treatments and control with respect to P uptake and all the treatments except s_4g_1 were found to be on par with C_1 (21.29 kg ha^{-1}).

Regarding treatments *vs.* C_2 (nutrient management as per KAU organic *Ad hoc* POP), the treatment combinations s_2g_1 (28.32 kg ha^{-1}), s_3g_2 (35.12 kg ha^{-1}) and s_6g_2 (30.94 kg ha^{-1}) during the first year were found to be significantly superior to C_2 (15.21 kg ha^{-1}). During the second year, treatments were however not significantly different from C_2 in case of P uptake.

The treatments were significantly different from absolute control during both the years. The organic treatment combinations s_1g_2, s_2g_1, s_3g_1, s_3g_2, s_4g_2, s_5g_2 and s_6g_2 during the first year and s_3g_2, s_4g_2, s_6g_1 and s_6g_2 during the second year recorded significantly higher values of P uptake than absolute control (9.23 kg ha^{-1} during the first year and 6.31 kg ha^{-1} during the second year).

4.1.5.2.3 K Uptake

The significant effect of organic sources and *in situ* green manuring on K uptake is evident from Table 19a.

Application of poultry manure along with wood ash, PGPR mix I and vermiwash (s_6) resulted in significantly the highest uptake of K (292.96 kg ha^{-1} during the first year and 208.61 kg ha^{-1} during the second year) and was followed by s_5 (257.05 kg ha^{-1}) during the first year and s_3 (182.56 kg ha^{-1}) during the second year.

During both the years, *in situ* green manuring with daincha (g_2) recorded significantly higher uptake of K (248.54 kg ha^{-1} during the first year and 177.91 kg ha^{-1} during the second year) than *in situ* green manuring with cowpea (g_1).

Interaction effects (Table 19b) were significant with respect to K uptake only during the second year. The treatment combination s_6g_2 (application of PM along with wood ash, PGPR mix I and vermiwash + *in situ* green manuring with daincha) resulted in the highest uptake (232.80 kg ha^{-1}) of K by crop, which was significantly superior to all the other treatments, followed by s_3g_2 in (199.95 kg ha^{-1}) which application of FYM, wood ash, PGPR mix I and vermiwash were applied along with *in situ* green manuring with daincha. The lowest uptake of 125.34 kg ha^{-1} was recorded by s_1g_1 in which FYM and wood ash were applied along with *in situ* green manuring with cow pea.

The organic treatment combination s_6g_2 (297.68 kg ha^{-1}) was significantly superior to chemical nutrient management (C_1) in K uptake during the first year. The organic treatment combinations s_2g_1, s_2g_2, s_3g_1 s_3g_2, s_5g_1, s_5g_2 and s_6g_1 during the first year and s_2g_2, s_3g_1, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 during the second year were found to be on par with C_1 (261.80 kg ha^{-1} during the first year and 202. 61 kg ha^{-1} during the second year).

While comparing treatments with nutrient management as per KAU organic Adhoc POP (C_2), the treatment combinations s_2g_1, s_2g_2, s_3g_1, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 during the first year and s_3g_2 and s_6g_2 during the second year were superior to C_2 (187.91 kg ha^{-1} during the first year and 138.72 kg ha^{-1} during the second year) in case of K uptake.

Regarding treatment *vs.* absolute control, all treatments during the first year and all treatments except s_1g_1 during the second year were significantly superior to C_3 (137.14 kg ha^{-1} during the first year and 94.40 kg ha^{-1} during the second year).

4.1.5.2 Nutrient Use Efficiency

Nutrient management through chemical fertilizers resulted in higher agronomic efficiency (Table 19c) during both the years (40.88 kg kg^{-1} during the first year and 40.69 kg kg^{-1} during the second year) followed by s_6g_1 (33.71 kg kg^{-1}) during the first year and s_5g_1 (30.11 kg kg^{-1}) during the second year.

4.1.6 Soil Analysis After the Experiment

4.1.6.1 pH

The data on pH of the soil after the experiment as influenced by the treatments is given in Tables 20a and 20b.

A decrease in pH of soil was observed after the experiment irrespective of treatments compared to the initial values. However, neither the main effects nor the interaction effects of organic sources and *in situ* green manuring did have any significant influence on the pH of soil after the experiment.

Even though not significant, organic nutrition treatments in general resulted in higher values of pH than C_1 during the first year. Significant variation was however observed between organic treatments and C_1 (Nutrient management through chemical fertilizers as per KAU POP - 80: 25: 100 kg NPK ha^{-1}) with respect to soil pH during second year. The organic treatments s_3g_1 (5.93) and s_5g_2 (5.91) resulted in significantly higher values of pH than C_1 (5.46).

While comparing treatments vs. control C_2, there was no significant difference between treatments and control during both the years. The absolute control (C_3) however, had significant variation from treatments during the second year. The organic treatment combinations s_3g_1 (5.93) and s_5g_2 (5.91) resulted in significantly higher values of pH than C_3 (5.39). During the first year, treatments *vs.* C_3 was not significant in case of pH of soil.

Table 19a. Effect of organic sources and *in situ* green manuring on N, P and K uptake, kg ha^{-1}

Treatments	I year			II year		
	N uptake	P uptake	K uptake	N uptake	P uptake	K uptake
Organic sources (S)						
s_1- FYM + wood ash	107.51	20.59	200.86	93.27	12.78	139.76
s_2- FYM + wood ash +PGPR mix I	148.34	23.94	238.63	114.30	13.78	154.19
s_3- FYM + wood ash + PGPR mix I + vermiwash	152.07	28.29	246.45	127.52	15.61	182.56
s_4- PM+ wood ash	138.90	20.44	213.66	102.69	13.35	142.23
s_5- PM+ wood ash + PGPR mix I	157.07	19.87	257.05	120.95	12.77	177.18
s_6- PM+ wood ash + PGPR mix I + vermiwash	161.93	25.95	292.96	141.43	16.47	208.61
SEm(±)	9.11	1.98	5.07	4.55	1.46	7.26
CD (0.05)	26.728	5.792	14.867	13.342	NS	21.304
***In situ* green manuring (G)**						
g_1- Cowpea	134.21	20.09	234.67	110.99	13.36	156.93
g_2- Daincha	154.39	26.27	248.55	122.39	14.90	177.91
SEm(±)	5.26	1.14	2.93	2.63	0.84	4.19
CD (0.05)	15.432	3.344	8.583	7.703	NS	12.300

Table 19b. Effect of S x G interaction and treatments *Vs*. control effect on N, P and K uptake, kg ha^{-1}

Treatments	I year			II year		
	N uptake	P uptake	K uptake	N uptake	P uptake	K uptake
S x G interaction						
s_1g_1	87.31	17.83	193.20[13]	80.90[1]	13.15	125.34[1]
s_1g_2	127.72	23.36[3]	208.52[13]	105.63[13]	12.40	154.17[13]
s_2g_1	135.94	28.32[23]	231.37[23]	101.02[13]	13.10	137.48[13]
s_2g_2	160.74[3]	19.56	245.92[23]	127.59[3]	14.46	170.90[3]
s_3g_1	145.23[3]	21.46[3]	235.88[23]	121.10[3]	12.13	165.17[3]
s_3g_2	158.92[3]	35.12[23]	257.02[23]	133.94[3]	19.10[3]	199.95[23]
s_4g_1	135.00	16.82	213.57[13]	101.66[13]	11.67[1]	150.66[13]
s_4g_2	142.79[3]	24.05[3]	213.75[13]	103.72[13]	15.04[3]	133.80[13]
s_5g_1	151.45[3]	15.17	245.73[23]	127.46[3]	12.77	178.53[3]
s_5g_2	162.70[3]	24.57[3]	268.38[23]	114.43[3]	12.78	175.83[3]
s_6g_1	150.37[3]	20.95	288.24[23]	133.84[3]	17.33[3]	184.42[3]
s_6g_2	173.49[3]	30.94[23]	297.68[123]	149.03[3]	15.61[3]	232.80[23]
SEm(±)	12.89	2.79	7.17	6.43	2.06	10.27
CD (0.05)	NS	8.191	NS	18.868	NS	30.129
C_1- KAU PoP	159.73	28.53	261.80	135.87	21.29	202.61
Treatments *vs.* C_1	NS	NS	S	S	S	S
C_2- KAU organic PoP	127.26	15.21	187.91	102.21	10.84	138.72
Treatments *vs.* C_2	NS	S	S	NS	NS	S
C_3- Absolute control	86.08	9.23	137.14	70.08	6.31	94.40
Treatments *vs.* C_3	S	S	S	S	S	S

[1] significantly different from C_1; [2] significantly different from C_2;

[3] significantly different from C_3

Table 19c. Effect of treatments on agronomic efficiency, kg kg^{-1}

Treatments	Agronomic efficiency	
	I year	II year
s_1g_1	15.05	7.33
s_1g_2	18.48	17.04
s_2g_1	22.39	8.55
s_2g_2	27.31	27.82
s_3g_1	24.83	13.83
s_3g_2	27.38	25.96
s_4g_1	23.90	17.59
s_4g_2	16.72	8.39
s_5g_1	33.39	30.11
s_5g_2	26.97	20.22
s_6g_1	33.71	27.57
s_6g_2	31.14	28.22
C_1	40.88	40.69
C_2	17.30	8.66
C_3	-	-

4.1.6.2 Electrical Conductivity

The main effects and interaction effects of treatments on EC of soil after the experiment are presented in Table 20a and 20b.

There was an increase in the EC values of the soil after the experiment compared to initial values. The EC value of the soil after the experiment was significantly influenced by organic sources only during the second year. The organic source s_5 (application of PM along with wood ash and PGPR mix I) resulted in the lowest value of 0.40 dS m^{-1} and was on par with the organic sources s_1 (0.41 dS m^{-1}), s_3 (0.42 dS m^{-1}) and s_4 (0.41 dS m^{-1}).

In situ green manuring did not produce any significant variation in the EC of soil after the experiment during both the years.

The SxG interaction and treatments *vs.* control effect were also not significant to influence the EC of soil after experiment during both the years.

4.1.6.3 Organic Carbon

The organic carbon content of the soil after the experiment as influenced by the treatments are given in Tables 20a and 20b.

Compared to the initial values, organic carbon content of soil increased after the experiment.

Organic sources had significant influence on organic carbon content of soil after the experiment during both the years. Poultry manure application along with wood ash, PGPR mix I and vermiwash (s_6) resulted in the highest organic carbon content (1.57 %) of soil after the experiment during the first year and was on par with s_4 (1.44 %) and s_5 (1.32 %). During the second year, s_5 (Poultry manure application along with wood ash and PGPR mix I) resulted in the highest organic carbon content (1.55 %) of soil after the experiment and was on a par with s_2 (1.39 %), s_3 (1.29 %), s_4 (1.39 %) and s_6 (1.40 %).

Table 20a. Effect of organic sources and *in situ* green manuring on pH, EC and organic carbon content of soil after the experiment

Treatments	pH		EC (dS m^{-1})		Organic carbon (%)	
	I year	II year	I year	II year	I year	II year
Organic sources (S)						
s_1- FYM + wood ash	5.74	5.79	0.46	0.41	1.19	1.08
s_2- FYM + wood ash +PGPR mix I	5.71	5.68	0.51	0.45	1.06	1.39
s_3- FYM + wood ash + PGPR mix I + vermiwash	5.82	5.80	0.52	0.42	1.15	1.29
s_4- PM+ wood ash	5.68	5.77	0.48	0.41	1.44	1.39
s_5- PM+ wood ash + PGPR mix I	5.66	5.78	0.62	0.40	1.32	1.55
s_6- PM+ wood ash + PGPR mix I + vermiwash	5.66	5.79	0.58	0.45	1.57	1.40
SEm(±)	0.08	0.08	0.07	0.01	0.12	0.09
CD (0.05)	NS	NS	NS	0.030	0.337	0.275
***In situ* green manuring (G)**						
g_1- Cowpea	5.68	5.75	0.52	0.41	1.19	1.28
g_2- Daincha	5.73	5.78	0.54	0.43	1.39	1.42
SEm(±)	0.05	0.04	0.04	0.01	0.07	0.05
CD (0.05)	NS	NS	NS	NS	0.195	NS

Table 20b. Effect of S x G interaction and treatments *Vs*. control on pH, EC and organic carbon of soil after the experiment

Treatments	pH		EC (dS m^{-1})		Organic carbon (%)	
S x G interaction	I year	II year	I year	II year	I year	II year
s_1g_1	5.65	5.76	0.42	0.40	1.11	1.07
s_1g_2	5.83	5.83	0.50	0.41	1.26	1.08
s_2g_1	5.62	5.62	0.50	0.45	0.93	1.25
s_2g_2	5.79	5.73	0.52	0.45	1.18	1.53
s_3g_1	5.80	5.93[13]	0.62	0.39	1.01	1.24
s_3g_2	5.83	5.67	0.41	0.44	1.29	1.34
s_4g_1	5.75	5.81	0.33	0.41	1.33	1.34
s_4g_2	5.60	5.73	0.64	0.41	1.56	1.44
s_5g_1	5.66	5.65	0.63	0.40	1.36	1.42
s_5g_2	5.68	5.91[13]	0.62	0.41	1.28	1.67[3]
s_6g_1	5.65	5.76	0.62	0.44	1.38	1.37
s_6g_2	5.67	5.82	0.54	0.46	1.76[3]	1.43
SEm(±)	0.11	0.11	0.09	0.01	0.16	0.13
CD (0.05)	NS	NS	NS	NS	NS	NS
C_1- KAU PoP	5.59	5.46	0.29	0.40	1.06	1.19
Treatments *vs.* C_1	NS	S	NS	NS	NS	NS
C_2- KAU organic PoP	5.68	5.69	0.48	0.34	1.08	1.29
Treatments *vs.* C_2	NS	NS	NS	NS	NS	NS
C_3- Absolute control	5.60	5.39	0.35	0.40	0.89	1.00
Treatments *vs.* C_3	NS	S	NS	NS	S	S

[1] significantly different from C_1; [2] significantly different from C_2; [3] significantly different from C_3

In situ green manuring with daincha registered significantly higher organic carbon content of soil after the experiment (1.39 %) during the first year than *in situ* green manuring with cowpea. During the second year, organic carbon content of soil after the experiment was not however influenced by *in situ* green manuring.

No significant variation in organic carbon content of the soil after the experiment was observed due to SxG interaction during both the years.

The treatments did not show any significant difference from control C_1 (nutrient management through chemical fertilizers as per KAU POP) and C_2 (nutrient management as per KAU organic POP) during both the years, while significant difference was observed between treatments and absolute control during both the years. The treatment s_6g_2 (1.76 %) during the first year and s_5g_2 (1.67 %) during the second year resulted in significantly higher values of organic carbon content of soil after the experiment than absolute control (0.89 % during the first year and 1.00 % during the second year).

4.1.6.4 Available N

As presented in Table 21a, the main effects of treatments on available N status of the soil after the experiment were significant during both the years. There was a decrease (13.17 % - 63.13 %) in the available N status of the soil after the experiment.

During the first year, the organic source s_5 (PM+ wood ash + PGPR mix I) resulted in the highest available N content in soil (303.15 kg ha^{-1}) and it was on par with s_6 (PM+ wood ash + PGPR mix I + vermiwash) with an available N content of 286.42 kg ha^{-1}. During the second year, s_6 (PM+ wood ash + PGPR mix I + vermiwash) recoded the highest available N content in soil (233.11 kg ha^{-1}) and it was on par with s_5 (232.07 kg ha^{-1}), s_2 (219.52 kg ha^{-1}) and s_4 (211.16 kg ha^{-1}).

In situ green manuring with daincha (g_2) resulted in the highest available soil N content of 284.33 kg ha^{-1} (first year) and 224.40 kg ha^{-1} (second year), which was significantly superior to g_1 (*in situ* green manuring with cow pea) during both the years.

Regarding interaction effect, available N content in soil was significantly influenced by S x G interaction only during the first year and the treatment combination s_6g_2 (application of PM along with wood ash, PGPR mix I and vermiwash + *in situ* green manuring with daincha) resulted in the highest value (326.14 kg ha^{-1}) which was on par with s_5g_2 (321.96 kg ha^{-1}) and s_2g_2 (309.42 kg ha^{-1}).

The treatments did not show any significant difference from control C_1 (nutrient management through chemical fertilizers as per KAU POP) and C_2 (nutrient management as per KAU organic POP) during both the years, while significant difference was observed between treatments and absolute control during both the years. All organic nutrition treatments recorded significantly higher values of available N content of soil after the experiment during both the years than absolute control (175.62 kg ha^{-1} during the first year and 129.62 kg ha^{-1} during the second year).

4.1.6.5 Available P

The data on available P content of soil after the experiment as influenced by the treatments are presented in Table 21a and 21b.

Different organic sources had significant influence on available P content of soil during both the years. FYM application along with wood ash, PGPR mix I and vermiwash (s_3) resulted in the highest available P content (78.87 kg ha^{-1} during the first year and 72.46 kg ha^{-1} during the second year) of soil during both the years, which was on par with s_2 (77.07 kg ha^{-1} during the first year and 68.79 kg ha^{-1} during the second year), s_5 (76.41 kg ha^{-1} during the first year and 66.75 kg ha^{-1} during the second year) and s_6 (74.18 kg ha^{-1} during the first year and 67.20 kg ha^{-1} during the second year) during both the years.

In situ green manuring had significant effect on available P content of soil only during the second year, and *in situ* green manuring with daincha (68.88 kg ha^{-1}) registered significantly higher available P content of soil compared to *in situ* green manuring with cowpea.

The SxG interaction failed to produce any significant effect on available P content of soil after the experiment during both the years.

While comparing the treatments with C_1 (nutrient management through chemical fertilizers as per KAU POP) and C_2 (nutrient management as per KAU organic POP), it was observed that there was significant difference between treatments and control with respect to available P content of soil after the experiment only during the second year. The organic treatments s_2g_2 (73.65 kg ha^{-1}) and s_3g_2 (75.19 kg ha^{-1}) were found to be significantly superior to C_1 (55.47 kg ha^{-1}) and C_2 (54.07 kg ha^{-1}).

All organic nutrition treatments except s_1g_1, s_1g_2, s_4g_1, s_4g_2 and s_6g_1 during the first year and all treatments except s_1g_1, s_4g_1 and s_4g_2 during the second year resulted in significantly higher values of available P content of soil than C_3 (53.56 kg ha^{-1} during the first year and 45.16 kg ha^{-1} during the second year).

4.1.6.6 Available K

The data on available K content of soil after the experiment during both the years are summarized in Table 21a and 21b.

There was a decrease (14.81 % - 68.17 %) in the available K status of the soil after the experiment compared to initial value.

Neither the main effects nor the interaction effects of organic sources and *in situ* green manuring did exert any significant influence on the available K content of soil.

Table 21a. Effect of organic sources and *in situ* green manuring on soil nutrient status after the experiment, kg ha^{-1}

Treatments	Available N		Available P		Available K	
	I year	II year	I year	II year	I year	II year
Organic sources (S)						
s_1- FYM + wood ash	217.43	199.66	64.41	58.30	307.00	253.63
s_2- FYM + wood ash +PGPR mix I	275.97	219.52	77.07	68.79	356.02	298.32
s_3- FYM + wood ash + PGPR mix I + vermiwash	257.15	206.98	78.87	72.46	384.85	333.90
s_4- PM+ wood ash	225.79	211.16	64.39	56.75	328.07	260.29
s_5- PM+ wood ash + PGPR mix I	303.15	232.07	76.41	66.75	367.80	323.60
s_6- PM+ wood ash + PGPR mix I + vermiwash	286.42	233.11	74.18	67.20	374.71	320.44
SEm(±)	5.94	7.69	3.46	3.05	22.53	27.26
CD (0.05)	17.425	22.555	10.217	8.930	NS	NS
***In situ* green manuring (G)**						
g_1- Cowpea	237.64	209.77	70.75	61.20	354.83	299.38
g_2- Daincha	284.33	224.40	74.36	68.88	351.32	297.35
SEm(±)	3.43	4.44	2.00	1.76	13.01	15.74
CD (0.05)	10.060	13.022	NS	5.156	NS	NS

Table 21b. Effect of S x G interaction and treatments *Vs*. control effect on soil nutrient status after the experiment, kg ha^{-1}

Treatments	Available N		Available P		Available K	
S x G interaction	I year	II year	I year	II year	I year	II year
s_1g_1	213.25[3]	194.44[3]	63.34	48.59	309.22	250.79
s_1g_2	221.61[3]	204.89[3]	65.47	68.00[3]	304.78	256.48
s_2g_1	242.52[3]	213.25[3]	75.97[3]	63.93[3]	347.99	295.26[3]
s_2g_2	309.42[3]	225.80[3]	78.17[3]	73.65[123]	364.06	301.37[3]
s_3g_1	217.43[3]	200.71[3]	78.16[3]	69.73[3]	390.72[3]	332.19[3]
s_3g_2	296.88[3]	213.25[3]	79.58[3]	75.19[123]	378.99	335.61[3]
s_4g_1	221.61[3]	204.89[3]	62.81	55.66	334.19	274.14
s_4g_2	229.97[3]	217.43[3]	65.98	57.85	321.95	246.44
s_5g_1	284.33[3]	225.80[3]	73.70[3]	63.74[3]	364.72	328.38[3]
s_5g_2	321.96[3]	238.34[3]	79.12[3]	69.76[3]	370.88	318.82[3]
s_6g_1	246.70[3]	219.52[3]	70.51	65.56[3]	382.14[3]	315.52[3]
s_6g_2	326.14[3]	246.70[3]	77.85[3]	68.84[3]	367.28	325.37[3]
SEm(±)	8.40	10.88	4.90	4.31	31.87	38.55
CD (0.05)	24.643	NS	NS	NS	NS	NS
C_1- KAU PoP	259.24	209.07	62.51	55.47	364.06	307.02
Treatments *vs.* C_1	NS	NS	NS	S	NS	NS
C_2- KAU organic PoP	265.52	200.71	60.82	54.07	341.47	221.00
Treatments *vs.* C_2	NS	NS	NS	S	NS	NS
C_3- Absolute control	175.62	129.62	53.56	45.16	238.53	125.38
Treatments *vs.* C_3	S	S	S	S	S	S

[1] significantly different from C_1; [2] significantly different from C_2; [3] significantly different from C_3

The treatments did not vary significantly from control C_1 (nutrient management through chemical fertilizers as per KAU POP) and C_2 (nutrient management as per KAU organic POP) during both the years, while significant difference was observed between treatments and absolute control during both the years. The organic nutrition treatments s_3g_1 and s_6g_1 during the first year and all treatments except s_1g_1, s_1g_2, s_4g_1 and s_4g_2 during the second year resulted in significantly higher values of available soil K content after the experiment than absolute control (238.53 kg ha^{-1} during the first year and 125.38 kg ha^{-1} during the second year).

4.1.7 Soil Organic Carbon Build Up

4.1.7.1 Recalcitrant Carbon

Perusal of the data in Table 22a indicated that the recalcitrant carbon content of soil after the experiment was significantly influenced by the organic sources.

The highest recalcitrant carbon content (1.08 %) was recorded by the organic source s_5 (PM+ wood ash + PGPR mix I) during the first year and was on par with s_2 (0.90 %), s_3 (1.04 %) and s_6 (1.07 %). During the second year, the highest recalcitrant carbon content (1.25 %) was recorded by the organic source s_3 (FYM + wood ash + PGPR mix I + vermiwash), which was on par with s_6 (1.05 %), s_5 (1.14 %) and s_2 (1.02 %).

In situ green manuring did not have any significant influence on recalcitrant carbon content of soil after the experiment during both the years.

The SxG interaction also failed to show any significant effect on recalcitrant carbon content of soil after the experiment during both the years.

While comparing treatments *vs*. control, the control C_1 and C_2 were not significantly different from treatments during both the years with respect to recalcitrant carbon content of soil after the experiment, however C_3 (absolute control) showed significant difference from treatments during both the years. The treatments s_3g_1 (1.20 %), s_5g_1 (1.15 %) and s_6g_2 (1.21 %) during the first year and the treatments s_3g_1 (1.41 %) during the second year recorded significantly higher value than C_3 (0.63 % during the first year and 0.77 % during the second year).

4.1.7.2 Total Organic Carbon

The main effects and interaction effects of treatments on total organic carbon content of soil after the experiment during both the years are presented in Table 22a and 22b.

Total organic carbon content of soil after the experiment was significantly influenced by organic sources only during the first year. The organic source application of poultry manure along with wood ash and PGPR mix I (s_5) recorded the highest value of total organic carbon content (4.79 %), which was on par with s_2 (4.70 %) wherein FYM was applied along with wood ash and PGPR mix I.

In situ green manuring with daincha recorded higher value of total organic carbon content (4.73 %) compared to *in situ* green manuring with cowpea during the first year. During the second year, total organic carbon content of soil was however not influenced by *in situ* green manuring.

SxG interaction failed to produce any significant effect on total organic carbon content of soil after the experiment during both the years.

All organic nutrition treatments during both the years recorded significantly higher values of total organic carbon content than control treatments C_1 (3.87 % during

Table 22a. Effect of organic sources and *in situ* green manuring on recalcitrant carbon and total organic carbon, per cent

Treatments	I year		II year	
	Recalcitrant carbon	Total organic carbon	Recalcitrant carbon	Total organic carbon
Organic sources (S)				
s_1- FYM + wood ash	0.70	4.60	0.82	5.36
s_2- FYM + wood ash +PGPR mix I	0.90	4.70	1.02	5.45
s_3- FYM + wood ash + PGPR mix I + vermiwash	1.04	4.59	1.25	5.32
s_4- PM+ wood ash	0.77	4.53	0.90	5.58
s_5- PM+ wood ash + PGPR mix I	1.08	4.79	1.14	5.45
s_6- PM+ wood ash + PGPR mix I + vermiwash	1.07	4.58	1.05	5.44
SEm(±)	0.08	0.05	0.09	0.07
CD (0.05)	0.248	0.138	0.256	NS
***In situ* green manuring (G)**				
g_1- Cowpea	0.96	4.54	1.01	5.41
g_2- Daincha	0.89	4.73	1.05	5.46
SEm(±)	0.05	0.03	0.05	0.04
CD (0.05)	NS	0.080	NS	NS

Table 22b. Effect of S x G interaction and treatments *Vs*. control effect on recalcitrant carbon and total organic carbon, per cent

Treatments	I year		II year	
	Recalcitrant carbon	Total organic carbon	Recalcitrant carbon	Total organic carbon
S x G interaction				
s_1g_1	0.80	4.52[123]	0.93	5.27[123]
s_1g_2	0.60	4.68[123]	0.71	5.45[123]
s_2g_1	0.84	4.62[123]	0.94	5.37[123]
s_2g_2	0.96	4.78[123]	1.09	5.54[123]
s_3g_1	1.20[3]	4.56[123]	1.41[3]	5.31[123]
s_3g_2	0.88	4.61[123]	1.09	5.33[123]
s_4g_1	0.81	4.42[123]	0.83	5.57[123]
s_4g_2	0.72	4.64[123]	0.97	5.59[123]
s_5g_1	1.15[3]	4.60[123]	1.13	5.57[123]
s_5g_2	1.00	4.99[123]	1.16	5.34[123]
s_6g_1	0.94	4.51[123]	0.83	5.39[123]
s_6g_2	1.21[3]	4.66[123]	1.27	5.48[123]
SEm(±)	0.12	0.07	0.12	0.10
CD (0.05)	NS	NS	NS	NS
C_1- KAU PoP	0.92	3.87	0.99	4.17
Treatments *vs.* C_1	NS	S	NS	S
C_2- KAU organic PoP	0.85	4.06	0.86	4.39
Treatments *vs.* C_2	NS	S	NS	S
C_3- Absolute control	0.63	3.61	0.77	3.76
Treatments *vs.* C_3	S	S	S	S

[1] significantly different from C_1; [2] significantly different from C_2;

[3] significantly different from C_3

first year and 4.17 % during the second year), C_2 (4.06 % during the first year and 4.39 % during the second year) and C_3 (3.61 % during the first year and 3.76 % during the second year).

4.1.7.3 Labile Carbon

The data on labile carbon content of soil after the experiment as influenced by organic sources, *in situ* green manuring and SxG interaction are given in Table 23a and 23b.

The organic sources had significant effect on labile carbon content of the soil after the experiment only during the second year. Application of poultry manure along with wood ash, PGPR mix I and vermiwash (s_6) recorded the highest labile carbon content of 694.00 mg kg^{-1}, which was on par with s_3 (658. 11 mg kg^{-1}).

In situ green manuring with daincha (g2) resulted in significantly higher labile carbon content of soil during both years (662.15 mg kg^{-1} and 648.50 mg kg^{-1} during the first year and second year respectively) compared to *in situ* green manuring with cow pea (611.29 mg kg^{-1} and 590.39 mg kg^{-1} during the first year and second year respectively).

Labile carbon content of soil was not significantly influenced by SxG interaction during both years.

The treatments and control C_1 (nutrient management through chemical fertilizers as per KAU POP) were significantly different in the case of labile carbon content of soil during both the years. During the first year, the treatments s_1g_2 (633.46 mg kg^{-1}), s_2g_2 (718.11 mg kg^{-1}), s_3g_1 (657.65 mg kg^{-1}), s_3g_2 (651.14 mg kg^{-1}), s_4g_2 (617.65 mg kg^{-1}), s_5g_1 (670.67 mg kg^{-1}), s_5g_2 (662.30 mg kg^{-1}), s_6g_1 (698.58 mg kg^{-1}) s_6g_2 (690.21 mg kg^{-1}) were found to be significantly superior to C_1 (457.66 mg kg^{-1}). During the second year, s_3g_2 (693.00 mg kg^{-1}), s_4g_2 (634.39 mg kg^{-1}), s_5g_2 (656.72 mg kg^{-1}), s_6g_1 (672.69 mg kg^{-1}) and s_6g_2 (715.32 mg kg^{-1}) recorded significantly higher values than C_1 (511.61 mg kg^{-1}).

The treatments and control C_2 (nutrient management as per KAU *Ad hoc* organic POP) were not significantly different during the first year, while s_3g_2 (693.00 mg kg^{-1}), s_5g_2 (656.72 mg kg^{-1}), s_6g_1 (672.69 mg kg^{-1}) and s_6g_2 (715.32 mg kg^{-1}) during the second year were found significantly superior to C_2 (533.00 mg kg^{-1}) in the case of labile carbon content of soil after the experiment.

The treatments were significantly different from absolute control during both the years. All treatments except s_1g_1 and s_2g_1 during the first year and all treatments except s_1g_1, s_1g_2, s_2g_1, s_4g_1 and s_5g_1 during the second year were significantly superior to C_3 (394.40 mg kg^{-1} during the first year and 471.61 mg kg^{-1} during the second year) in case of labile carbon content of soil after the experiment.

4.1.7.4 Water Soluble Carbon

The significant effect of organic sources and *in situ* green manuring on water soluble carbon content of soil after the experiment is evident from Table 23a.

Application of FYM along with wood ash, PGPR mix I and vermiwash (s_3) resulted in the highest water soluble carbon content of soil of 47.48 mg kg^{-1} during the first year and which was on par with s_6 (46.73 mg kg^{-1}). During the second year, s_6 (application of poultry manure along with wood ash, PGPR mix I and vermiwash) recorded the highest value of water soluble carbon content (45.60 mg kg^{-1}).

During both the years, in situ green manuring with daincha (g_2) recorded significantly higher water soluble carbon (41.98 mg kg^{-1} during the first year and 41.15 mg kg^{-1} during the second year) than in situ green manuring with cow pea (g_1).

Interaction effects (Table 23b) were significant with respect to water soluble carbon content of soil during both the years. The treatment combination s_3g_2 (application of FYM along with wood ash, PGPR mix I and vermiwash + *in situ* green manuring with daincha) and s_6g_2 (application of PM along with wood ash, PGPR mix I and vermiwash + *in situ* green manuring with daincha) resulted in the highest water soluble carbon content (47.85 mg kg^{-1}) of soil during the first year, which was on par with s_4g_2 (47.25 mg kg^{-1}), s_3g_1 (47.10 mg kg^{-1}), s_2g_2 (46.50 mg kg^{-1}), s_5g_1 (45.90 mg kg^{-1}) and s_6g_1 (45.60 mg kg^{-1}). During the second year, s_6g_2 recorded the highest water soluble carbon content (47.40 mg kg^{-1}) of soil and which was on par with s_5g_2 (47.25 mg kg^{-1}).

Regarding the treatments *vs.* C_1 (nutrient management through chemical fertilizers) effect, there was significant difference between organic treatments and C_1 during both the years. All the organic treatments except s_1g_1, s_1g_2, s_2g_1, s_4g_1 and s_5g_2 during the first year and except s_1g_1, s_1g_2, s_3g_1 and s_4g_1 during the second year were found to be significantly superior to C_1 (31.20 mg kg^{-1} during the first year and 31.95 mg kg^{-1} during the second year) in case of water soluble carbon content of soil after the experiment.

Significant difference was observed between treatments and control C_2 [nutrient management as per KAU organic POP (Adhoc)] during both the years. All treatments except s_1g_1, s_1g_2, s_2g_1, s_4g_1 and s_5g_2 during the first year were on par with C_2 (46.20 mg kg^{-1}). During the second year, the treatments s_2g_1, s_2g_2, s_3g_2, s_4g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 were recorded significantly higher values of water soluble carbon, while the other treatments recorded significantly lower values than C_2 (33.45 mg kg^{-1}).

All the organic treatments except s_1g_1, s_1g_2, s_2g_1 and s_4g_1 during the first year and all treatments during the second year recorded significantly higher values of water soluble carbon than absolute control (27.00 mg kg^{-1}during the first year and 18.90 mg kg^{-1} during the second year).

4.1.8 Pest and Disease Incidence

Incidence of pests were absent in the present study, while mild incidence of taro leaf blight disease was noticed on few plants. The timely precautionary measures taken and the resistant nature of this variety ‘Muktakeshi’ to leaf blight disease reduced the further spread of disease without reaching the economic threshold level.

Table 23a. Effect of organic sources and *in situ* green manuring on labile carbon and water soluble carbon, mg kg^{-1}

Treatments	I year		II year	
	Labile carbon	Water soluble carbon	Labile carbon	Water soluble carbon
Organic sources (S)				
s_1- FYM + wood ash	567.89	29.33	527.42	29.93
s_2- FYM + wood ash +PGPR mix I	626.02	39.53	613.00	38.40
s_3- FYM + wood ash + PGPR mix I + vermiwash	654.39	47.48	658.11	36.68
s_4- PM+ wood ash	611.14	36.83	605.56	35.78
s_5- PM+ wood ash + PGPR mix I	666.49	40.80	618.58	41.93
s_6- PM+ wood ash + PGPR mix I + vermiwash	694.39	46.73	694.00	45.60
SEm(±)	27.67	1.24	19.23	0.34
CD (0.05)	NS	3.630	56.390	0.999
***In situ* green manuring (G)**				
g_1- Cowpea	611.29	38.25	590.39	34.95
g_2- Daincha	662.15	41.98	648.50	41.15
SEm(±)	15.97	0.72	11.10	0.20
CD (0.05)	46.851	2.096	32.557	0.577

Table 23b. Effect of S x G interaction and treatments *Vs*. control effect on labile carbon and water soluble carbon, mg kg^{-1}

Treatments	I year		II year	
	Labile carbon	Water soluble carbon	Labile carbon	Water soluble carbon
S x G interaction				
s_1g_1	502.31	31.95[2]	487.42	30.00[23]
s_1g_2	633.46[13]	26.70[2]	567.42	29.85[23]
s_2g_1	533.93	32.55[2]	601.84	37.35[123]
s_2g_2	718.11[13]	46.50[13]	624.16[3]	39.45[123]
s_3g_1	657.65[13]	47.10[13]	623.23[3]	30.60[23]
s_3g_2	651.14[13]	47.85[13]	693.00[123]	42.75[123]
s_4g_1	604.63[3]	26.40[2]	576.72	31.35[23]
s_4g_2	617.65[13]	47.25[13]	634.39[13]	40.20[123]
s_5g_1	670.67[13]	45.90[13]	580.44	36.60[123]
s_5g_2	662.30[13]	35.70[23]	656.72[123]	47.25[123]
s_6g_1	698.58[13]	45.60[13]	672.69[123]	43.80[123]
s_6g_2	690.21[13]	47.85[13]	715.32[123]	47.40[123]
SEm(±)	39.13	1.75	27.19	0.48
CD (0.05)	NS	5.134	NS	1.414
C_1- KAU PoP	457.66	31.20	511.61	31.95
Treatments *vs.* C_1	S	S	S	S
C_2- KAU organic PoP	649.28	46.20	533.00	33.45
Treatments *vs.* C_2	NS	S	S	S
C_3- Absolute control	394.40	27.00	471.61	18.90
Treatments *vs.* C_3	S	S	S	S

[1] significantly different from C_1; [2] significantly different from C_2;

[3] significantly different from C_3

4.1.9 Nutrient Balance Sheet

4.1.9.1 Nitrogen

The data on balance sheet of N after first and second year of experiment are presented in Table 24a and 24b respectively.

The N balance of soil was negative for all treatments after first year of experiment. The highest balance of N was observed in absolute control (-89.88 kg ha^{-1}) followed by s_6g_2 (-112.76 kg ha^{-1}) in which application of poultry manure, wood ash, PGPR mix I and vermiwash were done along with *in situ* green manuring with daincha. After second year, the N balance was positive for absolute control (24.08 kg ha^{-1}). For all the other treatments, the balance sheet was negative. The absolute control was followed by C_1 (-121.5 kg ha^{-1}), s_6g_1 (-131.75 kg ha^{-1}) and s_3g_1 (-134.23 kg ha^{-1}).

4.1.9.2 Phosphorus

The data on balance sheet of P after first and second year of experiment are presented in Table 24c and 24d respectively.

The balance sheet of P was negative for all treatments during both the years. However, the highest balance was recorded in absolute control during both the years (-14.06 kg ha^{-1} after first year and -2.09 kg ha^{-1} after second year of experiment), followed by C_1 (-97.21 kg ha^{-1} after first year and -92.35 kg ha^{-1} after second year) in which chemical fertilizer application was followed according to KAU POP.

4.1.9.2 Potassium

The data on balance sheet of K after first and second year of experiment are presented in Table 24e and 24f respectively.

The balance sheet of K was positive for s_3g_1 (16.93 kg ha^{-1}), s_5g_1 (1.86 kg ha^{-1}), s_6g_1 (60.74 kg ha^{-1}), s_6g_2 (7.75 kg ha^{-1}) and C_1 (58.71 kg ha^{-1}) after first year of experiment. For all the other treatments the balance sheet was negative. After second year of experiment, the balance sheet was negative for all the treatments. However the loss of potassium was lower in absolute control (-18.75 kg ha^{-1}) followed by C_1(-28.83 kg ha^{-1}) and s_6g_2 (-43.56 kg ha^{-1}).

4.1.9 Economic Analysis

The economics of cultivation was worked out in terms of net income and BCR considering the cost of inputs and price of produce during the cropping periods as given in Appendix IV. The treatment wise cost of cultivation is given in Appendix V. The effect of treatments on net income and BCR are presented in Tables 25a and 25b.

4.1.9.1 Net Income

Among the organic sources, application of poultry manure along with wood ash, PGPR mix I and vermiwash (s_6) registered the highest net income during both the years and for mean also (₹ 846714 ha^{-1} during the first year, ₹ 584157 ha^{-1} during the second year and ₹ 715435 ha^{-1} for mean) followed by s_5 (PM+ wood ash + PGPR mix I) recording a net income of ₹ 812235 ha^{-1} during the first year, ₹ 541710 ha^{-1} during the second year and ₹ 676972 ha^{-1} for mean. The s_5 was followed by s_3 (₹ 739461 ha^{-1} during the first year, ₹ 449748 ha^{-1} during the second year and ₹ 594604 ha^{-1} for mean), The s_3 was followed by s_4 during the first year (₹ 725069 ha^{-1}) and s_2 during the second year (₹ 427232 ha^{-1}) and for mean (₹ 575345 ha^{-1}). During the first year s_4 was followed by s_2 (₹ 723459 ha^{-1}). During the second year and for mean, s_2 was followed by s_4 (₹ 417588 ha^{-1} during the second year and ₹ 571328 ha^{-1} for mean). The lowest net income (₹ 661129 ha^{-1} during the first year, ₹ 391413 ha^{-1} during the second year and ₹ 526271 ha^{-1} for mean) was recorded by s_1 in which only FYM and wood ash were applied.

Table 24a. Balance sheet of N after first year of experiment, kg ha^{-1}

Treatments	Nitrogen added			Crop uptake	Balance		
	Soil contribution	Added through manures and fertilizers	Total input		Computed balance	Actual balance	Net gain/ loss
s_1g_1	351.58	217.98	569.56	87.31	482.25	213.25	-269.00
s_1g_2	351.58	260.42	612.00	127.72	484.28	221.61	-262.67
s_2g_1	351.58	217.98	569.56	135.94	433.62	242.52	-191.10
s_2g_2	351.58	260.42	612.00	160.74	451.26	309.42	-141.84
s_3g_1	351.58	219.18	570.76	145.23	425.53	217.43	-208.10
s_3g_2	351.58	261.62	613.20	158.92	454.28	296.88	-157.40
s_4g_1	351.58	217.17	568.75	135.00	433.75	221.61	-212.14
s_4g_2	351.58	259.61	611.19	142.79	468.40	229.97	-238.43
s_5g_1	351.58	217.17	568.75	151.45	417.30	284.33	-132.97
s_5g_2	351.58	259.61	611.19	162.70	448.49	321.96	-126.53
s_6g_1	351.58	218.37	569.95	150.37	419.58	246.70	-172.88
s_6g_2	351.58	260.81	612.39	173.49	438.90	326.14	-112.76
C_1	351.58	194.00	545.58	159.73	385.85	259.24	-126.61
C_2	351.58	179.23	530.81	127.26	403.55	265.52	-138.03
C_3	351.58	-	351.58	86.08	265.50	175.62	-89.88

Table 24b. Balance sheet of N after second year of experiment, kg ha^{-1}

Treatments	Nitrogen added			Crop uptake	Balance		
	Soil contribution	Added through manures and fertilizers	Total input		Computed balance	Actual balance	Net gain/ loss
s_1g_1	213.25	237.41	450.66	80.90	369.76	194.44	-175.32
s_1g_2	221.61	253.12	474.73	105.63	369.10	204.89	-164.21
s_2g_1	242.52	237.41	479.93	101.02	378.91	213.25	-165.66
s_2g_2	309.42	253.12	562.54	127.59	434.95	225.80	-209.15
s_3g_1	217.43	238.61	456.04	121.10	334.94	200.71	-134.23
s_3g_2	296.88	254.32	551.20	133.94	417.26	213.25	-204.01
s_4g_1	221.61	237.21	458.82	101.66	357.16	204.89	-152.27
s_4g_2	229.97	252.92	482.89	103.72	379.17	217.43	-161.74
s_5g_1	284.33	237.21	521.54	127.46	394.08	225.80	-168.28
s_5g_2	321.96	252.92	574.88	114.43	460.45	238.34	-222.11
s_6g_1	246.70	238.41	485.11	133.84	351.27	219.52	-131.75
s_6g_2	326.14	254.12	580.26	149.03	431.23	246.70	-184.53
C_1	259.24	207.20	466.44	135.87	330.57	209.07	-121.50
C_2	265.52	202.11	467.63	102.21	365.42	200.71	-164.71
C_3	175.62	-	175.62	70.08	105.54	129.62	24.08

Table 24c. Balance sheet of P after first year of experiment, kg ha^{-1}

Treatments	Phosphorus added			Crop uptake	Balance		
	Soil contribution	Added through manures and fertilizers	Total input		Computed balance	Actual balance	Net gain/ loss
s_1g_1	76.85	152.38	229.23	17.83	211.40	63.34	-148.06
s_1g_2	76.85	162.33	239.18	23.36	215.82	65.47	-150.35
s_2g_1	76.85	152.38	229.23	28.32	200.91	75.97	-124.94
s_2g_2	76.85	162.33	239.18	19.56	219.62	78.17	-141.45
s_3g_1	76.85	153.28	230.13	21.46	208.67	78.16	-130.51
s_3g_2	76.85	163.23	240.08	35.12	204.96	79.58	-125.38
s_4g_1	76.85	191.20	268.05	16.82	251.23	62.81	-188.42
s_4g_2	76.85	201.15	278.00	24.05	253.95	65.98	-187.97
s_5g_1	76.85	191.20	268.05	15.17	252.88	73.70	-179.18
s_5g_2	76.85	201.15	278.00	24.57	253.43	79.12	-174.31
s_6g_1	76.85	192.10	268.95	20.95	248.00	70.51	-177.49
s_6g_2	76.85	202.05	278.90	30.94	247.96	77.85	-170.11
C_1	76.85	111.40	188.25	28.53	159.72	62.51	-97.21
C_2	76.85	132.63	209.48	15.21	194.27	60.82	-133.45
C_3	76.85	-	76.85	9.23	67.62	53.56	-14.06

Table 24d. Balance sheet of P after second year of experiment, kg ha^{-1}

Treatments	Phosphorus added			Crop uptake	Balance		
	Soil contribution	Added through manures and fertilizers	Total input		Computed balance	Actual balance	Net gain/ loss
s_1g_1	63.34	147.48	210.82	13.15	197.67	48.59	-149.08
s_1g_2	65.47	151.72	217.19	12.40	204.79	68.00	-136.79
s_2g_1	75.97	147.48	223.45	13.10	210.35	63.93	-146.42
s_2g_2	78.17	151.72	229.89	14.46	215.43	73.65	-141.78
s_3g_1	78.16	148.38	226.54	12.13	214.41	69.73	-144.68
s_3g_2	79.58	152.62	232.20	19.10	213.10	75.19	-137.91
s_4g_1	62.81	184.52	247.33	11.67	235.66	55.66	-180.00
s_4g_2	65.98	188.76	254.74	15.04	239.70	57.85	-181.85
s_5g_1	73.70	184.52	258.22	12.77	245.45	63.74	-181.71
s_5g_2	79.12	188.76	267.88	12.78	255.10	69.76	-185.34
s_6g_1	70.51	185.42	255.93	17.33	238.60	65.56	-173.04
s_6g_2	77.85	189.66	267.51	15.61	251.90	68.84	-183.06
C_1	62.51	106.60	169.11	21.29	147.82	55.47	-92.35
C_2	60.82	138.69	199.51	10.84	188.67	54.07	-134.60
C_3	53.56	-	53.56	6.31	47.25	45.16	-2.09

Table 24e. Balance sheet of K after first year of experiment, kg ha^{-1}

Treatments	Potassium added			Crop uptake	Balance		
	Soil contribution	Added through manures and fertilizers	Total input		Computed balance	Actual balance	Net gain/ loss
s_1g_1	393.95	214.67	608.62	193.20	415.42	309.22	-106.20
s_1g_2	393.95	262.24	656.19	208.52	447.67	304.78	-142.89
s_2g_1	393.95	214.67	608.62	231.37	377.25	347.99	-29.26
s_2g_2	393.95	262.24	656.19	245.92	410.27	364.06	-46.21
s_3g_1	393.95	215.72	609.67	235.88	373.79	390.72	16.93
s_3g_2	393.95	263.29	657.24	257.02	400.22	378.99	-21.23
s_4g_1	393.95	214.64	608.59	213.57	395.02	334.19	-60.83
s_4g_2	393.95	262.21	656.16	213.75	442.41	321.95	-120.46
s_5g_1	393.95	214.64	608.59	245.73	362.86	364.72	1.86
s_5g_2	393.95	262.21	656.16	268.38	387.78	370.88	-16.90
s_6g_1	393.95	215.69	609.64	288.24	321.40	382.14	60.74
s_6g_2	393.95	263.26	657.21	297.68	359.53	367.28	7.75
C_1	393.95	173.20	567.15	261.80	305.35	364.06	58.71
C_2	393.95	216.61	610.56	187.91	422.65	341.47	-81.18
C_3	393.95	-	393.95	137.14	256.81	238.53	-18.28

Table 24f. Balance sheet of K after second year of experiment, kg ha^{-1}

Treatments	Potassium added			Crop uptake	Balance		
	Soil contribution	Added through manures and fertilizers	Total input		Computed balance	Actual balance	Net gain/ loss
s_1g_1	309.22	221.51	530.73	125.34	405.39	250.79	-154.60
s_1g_2	304.78	233.65	538.43	154.17	384.26	256.48	-127.78
s_2g_1	347.99	221.51	569.50	137.48	432.02	295.26	-136.76
s_2g_2	364.06	233.65	597.71	170.90	426.81	301.37	-125.44
s_3g_1	390.72	222.41	613.13	165.17	447.96	332.19	-115.77
s_3g_2	378.99	234.55	613.54	199.95	413.59	335.61	-77.98
s_4g_1	334.19	221.41	555.60	150.66	404.94	274.14	-130.80
s_4g_2	321.95	233.55	555.50	133.80	421.70	246.44	-175.26
s_5g_1	364.72	221.41	586.13	178.53	407.60	328.38	-79.22
s_5g_2	370.88	233.55	604.43	175.83	428.60	318.82	-109.78
s_6g_1	382.14	222.31	604.45	184.42	420.03	315.52	-104.51
s_6g_2	367.28	234.45	601.73	232.80	368.93	325.37	-43.56
C_1	364.06	174.40	538.46	202.61	335.85	307.02	-28.83
C_2	341.47	224.66	566.13	138.72	427.41	221.00	-206.41
C_3	238.53	-	238.53	94.40	144.13	125.38	-18.75

In situ green manuring with daincha (g_2) resulted in higher net income during both the years and for mean also (₹ 778699 ha^{-1} during the first year, ₹ 507417 ha^{-1} during second year and ₹ 643058 ha^{-1} for mean) over *in situ* green manuring with cowpea (₹ 723990 ha^{-1} during the first year, ₹ 429865 ha^{-1} during the second year and ₹ 576928 ha^{-1} for mean).

Regarding SxG interaction, the treatment combination, s_6g_2 (application of poultry manure along with wood ash, PGPR mix I and vermiwash + i*n situ* green manuring with daincha) registered the highest net income during both the years and for mean (₹ 870813 ha^{-1} during the first year, ₹ 603670 ha^{-1} during the second year and ₹ 737241 ha^{-1} for mean) followed by s_6g_1 during the first year (₹ 822615 ha^{-1}) and s_5g_1 during the second year (₹ 601217 ha^{-1}) and in mean value also (₹ 709647 ha^{-1}). The lowest net income was recorded by s_1g_1 during the first year (₹ 613855 ha^{-1}) and for mean (₹ 463222 ha^{-1}) and s_2g_1 during the second year (₹ 274146 ha^{-1}).

While comparing the treatments with C_1 (nutrient management through chemical fertilizers as per KAU POP), it was observed that all the treatments during the first year and all treatments except s_1g_1, s_2g_1, s_3g_1 and s_4g_2 during the second year and except s_1g_1 and s_2g_1 for mean recorded higher net income than C_1 (₹ 576139 ha^{-1} during the first year, ₹ 448095 ha^{-1} during the second year and ₹ 512117 ha^{-1} for mean). The treatment s_6g_2 recorded a 43.96 percentage increase of net income over chemical nutrient management for mean. The added profit of s_6g_2 over chemical nutrient management for mean was ₹ 225124 ha^{-1}.

Regarding treatments *vs.* nutrient management as per KAU organic POP (C_2), all treatments except s_1g_1 during the first year, except s_1g_1 and s_2g_1 during the second year and for mean recorded higher net income compared to C_2 (₹ 623714 ha^{-1} during the first year, ₹ 329363 ha^{-1} during the second year and ₹ 476538 ha^{-1} for mean). The treatment s_6g_2 recorded a 54.71 percentage increase of net income over KAU organic

POP for mean. The added profit of s_6g_2 over KAU organic POP for mean was ₹ 260703 ha^{-1}.

All organic nutrition treatments recorded higher net income compared to absolute control (₹ 335865 ha^{-1} during the first year, ₹ 186397 ha^{-1} during the second year and ₹ 261131 ha^{-1} for mean) during both the years and for mean also. The added profit of s_6g_2 over absolute control for mean was ₹ 476110 ha^{-1}.

4.1.9.2 Benefit : Cost Ratio

As in the case of net income, application of poultry manure along with wood ash, PGPR mix I and vermiwash (s_6) registered the highest BCR during both the years and for mean (3.08 during the first year, 2.45 during the second year and 2.76 for mean) followed by s_4 during the first year (3.07) and s_5 during the second year (2.35) and for mean (2.68). During the first year, s_4 was followed by s_5 (3.01), s_1 (2.79) and s_3 (2.73). During the second year and for mean s_5 was followed by s_4 (2.20 during the second year and 2.64 for mean), s_1 (2.07 during the second year and 2.43 for mean) and s_3 (2.06 during the second year and 2.40 for mean). The lowest BCR (2.70 during the first year, 2.02 during the second year and 2.36 for mean) was recorded by the organic source s_2.

BCR values during both the years and for mean were the highest with *in situ* green manuring with daincha over cowpea. BCR recorded by *in situ* green manuring with daincha was 2.97, 2.29 and 2.63 during the first year, second year and for mean respectively. The *in situ* green manuring with cowpea recorded the BCR values of 2.82, 2.10 and 2.46 during the first year, second year and for mean respectively.

Regarding the interaction effect, the treatment combination s_6g_2 (application of PM along with wood ash, PGPR mix I and vermiwash + *in situ* green manuring with daincha) recorded the highest BCR during both years and in mean also (3.15 during the first year, 2.50 during the second year and 2.82 for mean) followed by s_4g_1 during the first year (3.13); s_5g_1 during the second year (2.49); s_4g_1 and s_5g_1 for mean

(2.75). The lowest BCR was recorded by s_2g_1 (2.53 during the first year, 1.65 during the second year and 2.09 for mean).

While comparing the treatments with C_1 (nutrient management through chemical fertilizers as per KAU POP), it was observed that all the treatments except s_1g_1, s_2g_1, s_3g_1 and s_3g_2 during the first year and treatments s_5g_1 and s_6g_2 during the second year s_4g_1, s_5g_1, s_6g_1 and s_6g_2 for mean recorded higher BCR than C_1 (2.86 during the first year, 2.45 during the second year and 2.66 for mean). Regarding treatments *vs.* nutrient management as per KAU organic POP (C_2), all treatments except s_1g_1, s_2g_1 and s_3g_1 during both the years and for mean recorded higher BCR compared to C_2 (2.77 during the first year, 1.94 during the second year and 2.36 for mean). All organic nutrition treatments except s_2g_1 during the first year, except s_1g_1, s_2g_1 and s_3g_1 during the second year and except s_2g_1 and s_3g_1 for mean recorded higher BCR compared to absolute control (2.55 during the first year, 1.86 during the second year and 2.21 for mean).

Table 25a. Effect of organic sources and *in situ* green manuring on economics of cultivation

Treatments	Net income (₹ ha^{-1})			BCR		
	I year	II year	Mean	I year	II year	Mean
Organic sources (S)						
s_1- FYM + wood ash	661129	391413	526271	2.79	2.07	2.43
s_2- FYM + wood ash +PGPR mix I	723459	427232	575345	2.70	2.02	2.36
s_3- FYM + wood ash + PGPR mix I + vermiwash	739461	449748	594604	2.73	2.06	2.40
s_4- PM+ wood ash	725069	417588	571328	3.07	2.20	2.64
s_5- PM+ wood ash + PGPR mix I	812235	541710	676972	3.01	2.35	2.68
s_6- PM+ wood ash + PGPR mix I + vermiwash	846714	584157	715435	3.08	2.45	2.76
***In situ* green manuring (G)**						
g_1- Cowpea	723990	429865	576928	2.82	2.10	2.46
g_2- Daincha	778699	507417	643058	2.97	2.29	2.63

Table 25b. Effect of S x G interaction and treatments *Vs*. control effect on economics of cultivation

Treatments	Net income (₹ ha^{-1})			BCR		
	I year	II year	Mean	I year	II year	Mean
S x G interaction						
s_1g_1	613855	312589	463222	2.65	1.85	2.25
s_1g_2	708403	470236	589320	2.92	2.29	2.61
s_2g_1	654167	274146	464156	2.53	1.65	2.09
s_2g_2	792752	580317	686534	2.88	2.39	2.63
s_3g_1	686209	349090	517649	2.60	1.82	2.21
s_3g_2	792713	550406	671559	2.86	2.31	2.58
s_4g_1	749019	477505	613262	3.13	2.37	2.75
s_4g_2	701120	357671	529395	3.01	2.04	2.53
s_5g_1	818078	601217	709647	3.02	2.49	2.75
s_5g_2	806392	482203	644297	3.00	2.21	2.60
s_6g_1	822615	564645	693630	3.01	2.39	2.70
s_6g_2	870813	603670	737241	3.15	2.50	2.82
C_1- KAU PoP	576139	448095	512117	2.86	2.45	2.66
C_2- KAU organic PoP	623714	329363	476538	2.77	1.94	2.36
C_3- Absolute control	335865	186397	261131	2.55	1.86	2.21

4.2 EXPERIMENT II - POT CULTURE STUDY

4.2.1 Analysis of Potting Medium

4.2.1.1 pH

The effect of organic sources on pH of potting medium at 1 MAP, 4 MAP and harvest is detailed in Table 26.

An increase in pH was noticed (except for T_1 and C_3) compared to initial status (5.93) at harvest. The pH was the highest at 4 MAP in all treatments except in C_1 (nutrient management through chemical fertilizers). In $C_{1,}$ the highest pH was recorded at 1 MAP.

At 1 MAP, the highest pH of 6.97 was recorded in the treatment T_6 (poultry manure + wood ash + PGPR mix I + vermiwash) and was on par with T_2 (6.84), T_5 (6.93) and C_2 (6.74). At 4 MAP, T_6 and T_5 recorded the highest pH value of 7.07 and it was on par with T_2 (7.02), T_3 (6.72) and C_2 (7.02). The organic source treatment T_5 (poultry manure + wood ash + PGPR mix I) recorded the highest pH of 6.84 at harvest and was on par with T_3 (6.35) and T_6 (6.60). At 1 MAP and harvest, the lowest pH (5.70 at 1 MAP and 5.81 at harvest) was recorded in the absolute control while at 4 MAP, nutrient management through chemical fertilizers recorded the lowest pH (5.81).

4.2.1.2 Electrical conductivity

The effect of treatments on EC of potting medium at 1 MAP, 4 MAP and harvest is given in Table 27.

Increase in EC was noticed from initial (0.34 dS m^{-1}) to harvest stage in all treatments. The absolute control (C_3) recorded the lowest value of EC at all stages of observation (0.29 dS m^{-1} at 1 MAP, 0.33 dS m^{-1} at 4 MAP and 0.44 dS m^{-1} at harvest). However, EC was significantly influenced by the treatments only at 1 MAP and m^{-1})

harvest. At 1 MAP, C_3 which recorded the lowest EC (0.29 dS m^{-1}) was on par with T_1 (0.30 dS m^{-1}), T_2 (0.33 dS m^{-1}), T_3 (0.41 dS m^{-1}), T_4 (0 38 dS m^{-1}), C_1 (0. 31 dS and C_2 (0. 32 dS m^{-1}). At harvest, C_3 which recorded the lowest EC of 0.44 dS m^{-1} was on par with T_1 (FYM + wood ash) recording a value of 0.53 dS m^{-1}. At 4 MAP, EC was not significantly affected by the treatments.

4.2.1.3 Organic Carbon

The effect of treatments on organic carbon content of potting medium at 1 MAP, 4 MAP and harvest is presented in Table 28.

Increase in organic carbon content was noticed compared to initial value (1.05 %). The highest organic carbon content was noticed at harvest in all treatments.

At 1 MAP, the highest organic carbon content (1.38 %) was recorded with T_2 (FYM + wood ash + PGPR mix I) and was on par with T_1 (1.19 %), T_3 (1.28 %), T_5 (1.35 %) and T_6 (1.30 %). At 4 MAP also, the highest organic carbon content (1.45 %) of potting medium was recorded in $T_{2,}$ which was on par with T_1 (1.37 %), T_3 (1.38 %), T_5 (1.39 %) and T_6 (1.43 %). At harvest, T_2 and T_3 resulted in the highest organic carbon content of 1.58 per cent in the potting medium and these treatments were on par with T_1 (1.39 %), T_4 (1.44 %), T_5 (1.55 %), T_6 (1.57 %) and C_2 (1.35 %). At all stages, the lowest organic carbon content of potting medium was recorded in absolute control (1.09 %, 1.11 % and 1.12 % at 1MAP, 4 MAP and harvest respectively).

4.2.1.4 Available N

The effect of treatments on available N content in potting medium at 1 MAP, 4 MAP and harvest is presented in Table 29.

A decrease (32.21 % - 53.62 %) in available N content of potting medium was noticed compared to initial status (156.96 mg kg^{-1}).

Table 26. Effect of organic sources on pH of potting medium

Treatments	pH of potting medium		
	1 MAP	4 MAP	Harvest
T_1 - FYM + wood ash	6.40	6.41	5.92
T_2 - FYM + wood ash +PGPR mix I	6.84	7.02	5.96
T_3 - FYM + wood ash + PGPR mix I + Vermiwash	6.45	6.72	6.35
T_4 - Poultry manure + wood ash	6.40	6.53	5.96
T_5 - Poultry manure + wood ash + PGPR mix I	6.93	7.07	6.84
T_6 - Poultry manure + wood ash + PGPR mix I + Vermiwash	6.97	7.07	6.60
C_1 - Chemical fertilizers as per KAU POP	6.29	5.81	5.95
C_2 - KAU organic POP	6.74	7.02	6.22
C_3 - Absolute control	5.70	6.40	5.81
SEm±	0.14	0.12	0.19
CD (0.05)	0.429	0.367	0.577
Initial	5.93		

Table 27. Effect of organic sources on EC of potting medium, dS m^{-1}

Treatments	Electrical conductivity (EC)		
	1 MAP	4 MAP	Harvest
T_1 - FYM + wood ash	0.30	0.34	0.53
T_2 - FYM + wood ash +PGPR mix I	0.33	0.58	0.67
T_3 - FYM + wood ash + PGPR mix I + vermiwash	0.41	0.64	0.65
T_4 - Poultry manure + wood ash	0.38	0.52	0.59
T_5 - Poultry manure + wood ash + PGPR mix I	0.57	0.64	0.69
T_6 - Poultry manure + wood ash + PGPR mix I + Vermiwash	0.49	0.56	0.66
C_1 - Chemical fertilizers as per KAU POP	0.31	0.38	0.59
C_2 - KAU organic POP	0.32	0.61	0.63
C_3 - Absolute control	0.29	0.33	0.44
SEm±	0.05	0.10	0.03
CD (0.05)	0.159	NS	0.091
Initial	0.34		

Table 28. Effect of organic sources on organic carbon content of potting medium, per cent

Treatments	Organic carbon		
	1 MAP	4 MAP	Harvest
T_1 - FYM + wood ash	1.19	1.37	1.39
T_2 - FYM + wood ash +PGPR mix I	1.38	1.45	1.58
T_3 - FYM + wood ash + PGPR mix I + Vermiwash	1.28	1.38	1.58
T_4 - Poultry manure + wood ash	1.14	1.20	1.44
T_5 - Poultry manure + wood ash + PGPR mix I	1.35	1.39	1.55
T_6 - Poultry manure + wood ash + PGPR mix I + Vermiwash	1.30	1.43	1.57
C_1 - Chemical fertilizers as per KAU POP	1.11	1.18	1.21
C_2 - KAU organic POP	1.15	1.26	1.35
C_3 - Absolute control	1.09	1.11	1.12
SEm±	0.07	0.06	0.09
CD (0.05)	0.201	0.186	0.259
Initial	1.05		

In all organic nutrition treatments and absolute control, higher available N content was noticed during 1 MAP and then decreased, while in C_1 and C_2, available N content of potting medium increased from 1 MAP to 4 MAP.

The organic source T_6 (PM + wood ash + PGPR mix I + vermiwash) recorded the highest available N status of 122.27 mg kg^{-1} at 1 MAP and was on par with T_2 (117.60 mg kg^{-1}), T_3 (117.60 mg kg^{-1}), T_4 (108.27 mg kg^{-1}) and T_5 (120.40 mg kg^{-1}). At 4 MAP, C_1 (nutrient management through chemical fertilizers) recorded the highest available N content of 112.00 mg kg^{-1}, and was on par with T_2 (102.67 mg kg^{-1}), T_3 (102.67 mg kg^{-1}), T_5 (106.40 mg kg^{-1}), T_6 (108.27 mg kg^{-1}) and C_2 (102.67 mg kg^{-1}). At harvest, T_6 recorded the highest available N content of 106.40 mg kg^{-1} and was on par with T_2 (97.07 mg kg^{-1}), T_3 (97.07 mg kg^{-1}), T_5 (100.80 mg kg^{-1}), C_1 (102. 67 mg kg^{-1}) and C_2 (97.07 mg kg^{-1}). At all stages of observation, available N content was the lowest in absolute control (85.87 mg kg^{-1}, 78.40 mg kg^{-1} and 72.80 mg kg^{-1} at 1 MAP, 4 MAP and harvest respectively).

4.2.1.5 Available P

The effect of treatments on available P content in potting medium at 1 MAP, 4 MAP and harvest is presented in Table 30.

In all treatments except absolute control, the highest available P content was noticed at 4 MAP, while absolute control had higher available P content at 1 MAP which showed a decreasing trend at further stages of observation.

The organic source T_3 (FYM + wood ash + PGPR mix I + vermiwash) recorded the highest available P content of 38.04 mg kg^{-1} at 1 MAP and was on par with T_1 (35.37 mg kg^{-1}), T_2 (37.90 mg kg^{-1}), T_4 (35.24 mg kg^{-1}), T_5 (37.49 mg kg^{-1}), T_6 (36.88 mg kg^{-1}) and C_2 (34.66 mg kg^{-1}). At 4 MAP, T_2 (FYM + wood ash + PGPR mix I) recorded the highest available P status of 40.07 mg kg^{-1}, and was on par with all treatments except absolute control. At harvest, T_3 recorded the highest available P content of 35. 10 mg kg^{-1} which was on par with T_2 (32.91 mg kg^{-1}), T_5 (32.35 mg kg^{-1}) and T_6 (31.85mg kg^{-1}). At all stages, the lowest available P content was recorded in absolute control (30.64 mg kg^{-1}, 26.27 mg kg^{-1} and 23.19 mg kg^{-1} at 1 MAP, 4 MAP and harvest respectively).

4.2.1.6 Available K

The effect of treatments on available K content of potting medium at 1 MAP, 4 MAP and harvest is presented in Table 31.

A decrease (0.98 % - 41.18 %) in available K content in potting medium (except for T_6) was noticed from initial status (175.87 mg kg^{-1}) to harvest stage, while at 1 MAP and 4 MAP, the content was higher compared to initial status in all treatments except absolute control.

In general, higher available K content was noticed at 4 MAP except absolute control. The absolute control had higher available K content at 1 MAP and the K content then decreased at 4 MAP and at harvest.

The organic source T_6 (PM + wood ash + PGPR mix I + vermiwash) recorded the highest available K content of 202.44 mg kg^{-1} at 1 MAP and was on par with T_1 (188.22 mg kg^{-1}), T_2 (195.10 mg kg^{-1}), T_3 (196.91 mg kg^{-1}), T_4 (193.51 mg kg^{-1}), T_5 (202.38 mg kg^{-1}) and C_2 (183.44 mg kg^{-1}). At 4 MAP, C_1 (nutrient management through chemical fertilizers) recorded the highest available K content of 219.20 mg kg^{-1}, and was on par with all treatments except absolute control. At harvest, T_6 recorded the highest available K content of 180.48 mg kg^{-1} and which was on par with T_2 (153.38 mg kg^{-1}), T_3 (161.95 mg kg^{-1}), T_4 (153.75 mg kg^{-1}), T_5 (174.15 mg kg^{-1}), C_1 (171.90 mg kg^{-1}) and C_2 (151.50 mg kg^{-1}). At all stages the lowest available K content was recorded in absolute control (151.13 mg kg^{-1}, 118.62 mg kg^{-1} and 103.45 mg kg^{-1} at 1 MAP, 4 MAP and harvest respectively).

Table 29. Effect of organic sources on available N content of potting medium, mg kg^{-1}

Treatments	Available N content of potting medium		
	1 MAP	4 MAP	Harvest
T_1 - FYM + wood ash	106.40	87.73	82.13
T_2 - FYM + wood ash +PGPR mix I	117.60	102.67	97.07
T_3 - FYM + wood ash + PGPR mix I + Vermiwash	117.60	102.67	97.07
T_4 - Poultry manure + wood ash	108.27	91.47	81.51
T_5 - Poultry manure + wood ash + PGPR mix I	120.40	106.40	100.80
T_6 - Poultry manure + wood ash + PGPR mix I + Vermiwash	122.27	108.27	106.40
C_1 - Chemical fertilizers as per KAU POP	98.93	112.00	102.67
C_2 - KAU organic POP	97.07	102.67	97.07
C_3 - Absolute control	85.87	78.40	72.80
SEm±	5.24	5.90	6.06
CD (0.05)	15.698	17.674	18.137
Initial	156.96		

Table 30. Effect of organic sources on available P content of potting medium, mg kg^{-1}

Treatments	Available P content of potting medium		
	1 MAP	4 MAP	Harvest
T_1 - FYM + wood ash	35.37	35.53	30.22
T_2 - FYM + wood ash +PGPR mix I	37.90	40.07	32.91
T_3 - FYM + wood ash + PGPR mix I + Vermiwash	38.04	38.23	35.10
T_4 - Poultry manure + wood ash	35.24	35.42	29.83
T_5 - Poultry manure + wood ash + PGPR mix I	37.49	39.04	32.35
T_6 - Poultry manure + wood ash + PGPR mix I + Vermiwash	36.88	38.02	31.85
C_1 - Chemical fertilizers as per KAU POP	34.17	37.68	27.37
C_2 - KAU organic POP	34.66	35.15	29.16
C_3 - Absolute control	30.64	26.27	23.19
SEm±	1.24	1.96	1.10
CD (0.05)	3.697	5.870	3.291
Initial	34.31		

Table 31. Effect of organic sources on available K content of potting medium, mg kg^{-1}

Treatments	Available K content of potting medium		
	1 MAP	4 MAP	Harvest
T_1 - FYM + wood ash	188.22	200.07	138.53
T_2 - FYM + wood ash +PGPR mix I	195.10	210.73	153.38
T_3 - FYM + wood ash + PGPR mix I + vermiwash	196.91	211.56	161.95
T_4 - Poultry manure + wood ash	193.51	206.32	153.75
T_5 - Poultry manure + wood ash + PGPR mix I	202.38	215.96	174.15
T_6 - Poultry manure + wood ash + PGPR mix I + Vermiwash	202.44	215.24	180.48
C_1 - Chemical fertilizers as per KAU POP	176.47	219.20	171.90
C_2 - KAU organic POP	183.44	208.92	151.50
C_3 - Absolute control	151.13	118.62	103.45
SEm±	7.07	10.11	9.96
CD (0.05)	21.165	30.279	29.830
Initial	175.87		

4.2.2 Microbial Study of the Potting Medium

4.2.2.1 Population of Bacteria

The effect of organic sources on bacterial population of potting medium at 1 MAP, 4 MAP and harvest is detailed in Table 32.

The bacterial population was the highest at 1 MAP and then decreased to harvest in all treatments.

At 1 MAP, the organic source T_5 (poultry manure + wood ash + PGPR mix I) recorded the highest bacterial population of 6.68 log cfu g^{-1} soil followed by T_2 (FYM + wood ash + PGPR mix I) with a bacterial population of 6.49 log cfu g^{-1} soil, which was on par with T_3 (FYM + wood ash + PGPR mix I + vermiwash) with a bacterial population of 6.41 log cfu g^{-1} soil. At 4 MAP and harvest also, the highest bacterial population was recorded in T_5 (6.40 log cfu g^{-1} soil and 6.00 log cfu g^{-1} soil respectively at 4 MAP and at harvest). The T_5 was on par, with T_2 (6.18 log cfu g^{-1} soil), T_3 (6.31 log cfu g^{-1} soil), T_6 (6.16 log cfu g^{-1} soil) and C_2 (6.07 log cfu g^{-1} soil) at 4 MAP and with T_2 (5.69 log cfu g^{-1} soil), T_3 (5.74 log cfu g^{-1} soil), T_4 (5.65 log cfu g^{-1} soil) and T_6 (5.84 log cfu g^{-1} soil) at harvest. The lowest bacterial population was recorded in absolute control at all stages of observation (6.16 log cfu g^{-1} soil, 5.90 log cfu g^{-1} soil and 5.38 log cfu g^{-1} soil at 1 MAP, 4 MAP and harvest respectively).

4.2.2.2 Population of Fungi

The effect of organic sources on fungal population of potting medium at 1 MAP, 4 MAP and harvest is given in Table 32.

The organic source T_6 (PM + wood ash + PGPR mix I + vermiwash) recorded the highest fungal population of 4.48 log cfu g^{-1} soil at 1 MAP, which was on par with T_2 (FYM + wood ash +PGPR mix I), T_3 (FYM + wood ash + PGPR mix I + vermiwash), T_4 (Poultry manure + wood ash) and T_5 (Poultry manure + wood ash + PGPR mix I) recording a fungal population of 4.12 log cfu g^{-1} soil, 4.38 log cfu g^{-1}

soil, 4.07 log cfu g^{-1} soil and 4.15 log cfu g^{-1} soil respectively. At 4 MAP, T_3 (FYM + wood ash + PGPR mix I + vermiwash) recorded the highest fungal population (4.42 log cfu g^{-1} soil) and was on par with T_1 (4.28 log cfu g^{-1} soil), T_2 (4.29 log cfu g^{-1} soil), T_4 (4.13 log cfu g^{-1} soil), T_5 (4.29 log cfu g^{-1} soil) and T_6 (4.34 log cfu g^{-1} soil). At harvest stage, T_2 (FYM + wood ash + PGPR mix I) recorded the highest fungal population of 4.39 log cfu g^{-1} soil and was on par with T_3 (4.23 log cfu g^{-1} soil), T_5 (4.35 log cfu g^{-1} soil), T_6 (4.29 log cfu g^{-1} soil) and C_1 (4.21 log cfu g^{-1} soil). As in the case of bacteria, the lowest fungal population was also recorded by absolute control at all stages of observation (3.65 log cfu g^{-1} soil, 3.65 log cfu g^{-1} soil and 3.63 log cfu g^{-1} soil at 1 MAP, 4 MAP and harvest respectively).

4.2.2.3 Population of Actinomycetes

The effect of organic sources on actinomycetes population of potting medium at 1 MAP, 4 MAP and harvest is presented in Table 32.

The organic source T_2 (FYM + wood ash +PGPR mix I) recorded the highest actinomycetes population of 4.19 log cfu g^{-1} soil at 1 MAP, and was on par with T_6 (Poultry manure + wood ash + PGPR mix I + vermiwash) recording an actinomycetes population of 4.12 log cfu g^{-1} soil. At 4 MAP, significantly the highest actinomycetes population of 4.35 log cfu g^{-1} soil was recorded in the organic source T_5 (Poultry manure + wood ash + PGPR mix I). The treatments T_2 (FYM + wood ash +PGPR mix I) and T_3 (FYM + wood ash + PGPR mix I + vermiwash) recorded the highest value of actinomycetes population (3.79 log cfu g^{-1} soil) at harvest and the treatments T_1 (3.77 log cfu g^{-1} soil), T_4 (3.77 log cfu g^{-1} soil), T_5 (3.77 log cfu g^{-1} soil), T_6 (3.77 log cfu g^{-1} soil) and C_2 (3.74 log cfu g^{-1} soil) were on par with T_2 and $T_{3.}$ The lowest actinomycetes population of 3.94 log cfu g^{-1} soil at 1 MAP, 3.74 log cfu g^{-1} soil at 4 MAP and 3.66 log cfu g^{-1} soil at harvest was recorded by the absolute control.

Table 32. Effect of organic sources on population of bacteria, fungi and actinomycetes of potting medium, log cfu g^{-1}

Treatments	Bacteria			Fungi			Actinomycetes		
	1MAP	4 MAP	Harvest	1MAP	4 MAP	Harvest	1 MAP	4 MAP	Harvest
T_1 - FYM + wood ash	6.27	5.92	5.50	3.87	4.28	3.93	4.00	3.91	3.77
T_2 - FYM + wood ash +PGPR mix I	6.49	6.18	5.69	4.12	4.29	4.39	4.19	4.02	3.79
T_3 - FYM + wood ash + PGPR mix I + vermiwash	6.41	6.31	5.74	4.38	4.42	4.23	4.11	4.10	3.79
T_4 - Poultry manure + wood ash	6.31	5.95	5.65	4.07	4.13	3.90	4.00	3.94	3.77
T_5 - Poultry manure + wood ash + PGPR mix I	6.68	6.40	6.00	4.15	4.29	4.35	4.05	4.35	3.77
T_6 - Poultry manure + wood ash + PGPR mix I + Vermiwash	6.39	6.16	5.84	4.48	4.34	4.29	4.12	4.03	3.77
C_1 - Chemical fertilizers as per KAU POP	6.20	6.00	5.40	3.93	3.88	4.21	3.97	3.96	3.71
C_2 - KAU organic POP	6.36	6.07	5.45	3.91	3.80	3.84	4.06	3.90	3.74
C_3 - Absolute control	6.16	5.90	5.38	3.65	3.65	3.63	3.94	3.74	3.66
SEm±	0.03	0.11	0.13	0.14	0.16	0.09	0.03	0.07	0.02
CD(0.05)	0.084	0.334	0.391	0.412	0.480	0.271	0.078	0.204	0.053

4.2.2.4 Population of N- Fixers

4.2.2.4.1 Population of Azospirillum

The effect of organic sources on population of *Azospirillum* of potting medium at 1 MAP, 4 MAP and harvest is presented in Table 33.

Among the three observation stages, the highest population of *Azospirillum* was recorded at 4 MAP in all treatments.

The organic sources did not show any significant influence on population of *Azospirillum* at 1 MAP, while at 4 MAP and harvest, the organic source T_6 (PM + wood ash + PGPR mix I + vermiwash) recorded the highest population of *Azospirillum* (4.73 log cfu g^{-1} soil and 4.45 log cfu g^{-1} soil respectively). At 4 MAP, T_6 was on par with all treatments except absolute control. At harvest T_6 was on par with T_2 (FYM + wood ash +PGPR mix I), T_3 (FYM + wood ash + PGPR mix I + vermiwash) and T_5 (PM + wood ash +PGPR mix I) recording a population of 4.39 log cfu g^{-1} soil, 4.36 log cfu g^{-1} soil and 4.38 log cfu g^{-1} soil respectively. The lowest population of *Azospirillum* at 4 MAP (4.25 log cfu g^{-1} soil) and harvest (3.97 log cfu g^{-1} soil at) was recorded by the absolute control.

4.2.2.4.1 Population of Azotobacter

The effect of organic sources on *Azotobacter* population of potting medium at 1 MAP, 4 MAP and harvest is presented in Table 33.

Among the three observation stages, the highest population of *Azotobacter* was recorded at 4 MAP in all treatments.

The organic source T_2 (FYM + wood ash + PGPR mix I) recorded the highest population of *Azotobacter* (4.25 log cfu g^{-1} soil) at 1 MAP, which was on par with T_3 (FYM + wood ash + PGPR mix I + vermiwash), T_5 (Poultry manure + wood ash + PGPR mix I), T_6 (PM + wood ash + PGPR mix I + vermiwash) and C_2 (nutrient

Table 33. Effect of organic sources on population of nitrogen fixers of potting medium, log cfu g^{-1}

Treatments	Azospirillum			Azotobacter		
	1 MAP	4 MAP	Harvest	1 MAP	4 MAP	Harvest
T_1 - FYM + wood ash	4.32	4.52	4.24	3.72	4.18	3.54
T_2 - FYM + wood ash +PGPR mix I	4.39	4.67	4.39	4.25	4.49	3.72
T_3 - FYM + wood ash + PGPR mix I + vermiwash	4.34	4.70	4.36	3.94	4.22	3.72
T_4 - Poultry manure + wood ash	4.12	4.48	4.32	3.83	4.11	3.54
T_5 - Poultry manure + wood ash + PGPR mix I	4.37	4.72	4.38	3.89	4.69	3.63
T_6 - Poultry manure + wood ash + PGPR mix I + Vermiwash	4.32	4.73	4.45	3.90	4.87	3.87
C_1 - Chemical fertilizers as per KAU POP	4.25	4.60	4.18	3.63	4.22	3.39
C_2 - KAU organic POP	4.28	4.65	4.31	3.87	4.07	3.54
C_3 - Absolute control	4.22	4.25	3.97	3.45	3.88	3.30
SEm±	0.07	0.08	0.04	0.13	0.11	0.10
CD(0.05)	NS	0.252	0.118	0.389	0.340	0.299

management as per KAU adhoc organic POP) recording a population of 3.94 log cfu g^{-1} soil, 3.89 log cfu g^{-1} soil, 3.90 log cfu g^{-1} soil and 3.87 log cfu g^{-1} soil respectively. At 4 MAP, T_6 (PM + wood ash + PGPR mix I+ vermiwash) recorded the highest population of *Azotobacter* (4.87 log cfu g^{-1} soil) and was on par with T_5 (4.69 log cfu g^{-1} soil). At harvest stage also, the highest population of *Azotobacter* (3.87 log cfu g^{-1} soil) was recorded by T_6 (PM + wood ash + PGPR mix I+ vermiwash), which was on par with T_2 (3.72 log cfu g^{-1} soil), T_3 (3.72 log cfu g^{-1} soil) and T_5 (3.63 log cfu g^{-1} soil). As in the case of *Azospirillum*, the lowest *Azotobacter* population was also recorded in the absolute control at all stages of observation (3.45 log cfu g^{-1} soil, 3.88 log cfu g^{-1} soil and 3.30 log cfu g^{-1} soil at 1 MAP, 4 MAP and harvest respectively).

4.2.2.5 Population of P Solubilisers

The effect of organic sources on population of P solubilisers of potting medium at 1 MAP, 4 MAP and harvest is presented in Table 34.

The organic source T_3 (FYM + wood ash + PGPR mix I + vermiwash) recorded the highest population of P solubilisers of 4.25 log cfu g^{-1} soil and 4.10 log cfu g^{-1} soil at 1 MAP and 4 MAP respectively and was on par with T_6 (PM + wood ash +PGPR mix I+ vermiwash) at both the stages recording a population of 4.20 log cfu g^{-1} soil at 1 MAP and 4.06 log cfu g^{-1} soil at 4 MAP. The lowest population of P solubilisers (3.81 log cfu g^{-1} soil at 1 MAP and 3.56 log cfu g^{-1} soil at 4 MAP) was recorded in absolute control. The organic source did not show any significant effect on population of P solubilisers at harvest.

4.2.2.6 Dehydrogenase Activity

The effect of organic sources on dehydrogenase activity of potting medium at 1 MAP, 4 MAP and harvest is presented in Table 35.

In all treatments except absolute control, the highest dehydrogenase activity was observed during 4 MAP.

Table 34. Effect of organic sources on P solubilisers of potting medium, log cfu g^{-1}

Treatments	P solubilisers		
	1 MAP	4 MAP	Harvest
T_1 - FYM + wood ash	3.92	3.93	3.24
T_2 - FYM + wood ash +PGPR mix I	4.14	3.96	3.41
T_3 - FYM + wood ash + PGPR mix I + vermiwash	4.25	4.10	3.31
T_4 - Poultry manure + wood ash	4.00	3.78	3.29
T_5 - Poultry manure + wood ash + PGPR mix I	4.11	3.82	3.31
T_6 - Poultry manure + wood ash + PGPR mix I + Vermiwash	4.20	4.06	3.30
C_1 - Chemical fertilizers as per KAU POP	3.97	3.91	3.30
C_2 - KAU organic POP	3.97	3.66	3.23
C_3 - Absolute control	3.81	3.56	3.22
SEm±	0.02	0.03	0.04
CD(0.05)	0.066	0.101	NS

Table 35. Effect of organic sources on dehydrogenase activity of potting medium, µg TPF $24h^{-1}$ g^{-1}

Treatments	Dehydrogenase activity		
	1 MAP	4 MAP	Harvest
T_1 - FYM + wood ash	39.35	52.21	24.38
T_2 - FYM + wood ash +PGPR mix I	55.47	78.70	35.51
T_3 - FYM + wood ash + PGPR mix I + vermiwash	61.87	99.62	33.91
T_4 - Poultry manure + wood ash	36.34	51.06	26.30
T_5 - Poultry manure + wood ash + PGPR mix I	63.60	84.84	42.29
T_6 - Poultry manure + wood ash + PGPR mix I + Vermiwash	52.21	73.90	33.21
C_1 - Chemical fertilizers as per KAU POP	27.26	33.21	22.39
C_2 - KAU organic POP	32.57	55.66	25.91
C_3 - Absolute control	16.12	14.08	13.72
SEm±	6.43	11.59	3.37
CD(0.05)	19.260	34.709	10.083

The organic source T_5 (PM + wood ash + PGPR mix I) recorded the highest dehydrogenase activity of 63.60 µg TPF $24h^{-1}$ g^{-1} at 1 MAP, and was on par with T_2 (FYM + wood ash + PGPR mix I), T_3 (FYM + wood ash + PGPR mix I + vermiwash), and T_6 (PM + wood ash + PGPR mix I + vermiwash) recording a dehydrogenase activity of 55.47 µg TPF $24h^{-1}$ g^{-1}, 61.87 µg TPF $24h^{-1}$ g^{-1} and 52.21 µg TPF $24h^{-1}$ g^{-1} respectively. At 4 MAP, T_3 (FYM + wood ash + PGPR mix I+ vermiwash) recorded the highest dehydrogenase activity (99.62 µg TPF $24h^{-1}$ g^{-1}) and was on par with T_2 (78.70 µg TPF $24h^{-1}$ g^{-1}), T_5 (84.84 µg TPF $24h^{-1}$ g^{-1}) and T_6 (73.90 µg TPF $24h^{-1}$ g^{-1}). At harvest stage, the highest dehydrogenase activity of 42.29 µg TPF $24h^{-1}$ g^{-1} was recorded in T_5 (PM + wood ash + PGPR mix I), which was on par with T_2 (35.51 µg TPF $24h^{-1}$ g^{-1}), T_3 (33.91 µg TPF $24h^{-1}$ g^{-1}) and T_6 (33.21 µg TPF $24h^{-1}$ g^{-1}). The dehydrogenase activity of the control C_1 - nutrient management through chemical fertilizers as per KAU POP (27.26 µg TPF $24h^{-1}$ g^{-1}, 33.21 µg TPF $24h^{-1}$ g^{-1} and 22.39 µg TPF $24h^{-1}$ g^{-1} at 1 MAP, 4 MAP and harvest respectively) was lower when compared to all other organic nutrition treatments. The absolute control recorded the lowest dehydrogenase activity at all stages of observation (16.12 µg TPF $24h^{-1}$ g^{-1}, 14.08 µg TPF $24h^{-1}$ g^{-1} and 13.72 µg TPF $24h^{-1}$ g^{-1} at 1 MAP, 4 MAP and harvest respectively).

4.2.3 Rooting Pattern (Monthly Interval from 1MAP)

Two plants were uprooted from each treatment per replication at monthly intervals in order to study the effect of organic sources on rooting pattern of taro.

4.2.3.1 Root Apex Diameter

Root apex diameter recorded at 10±2 cm above the root tip from sample plants at monthly interval up to 7 MAP is given in Table 36.

The root apex diameter showed an increasing trend from 1 MAP up to 3-4 MAP and then started declining afterwards in all the treatments.

Root apex diameter was significantly influenced by the treatments at all stages of observation. At 1 MAP, the highest root apex diameter (2.39 mm) was recorded by the treatment T_6 (poultry manure + wood ash + PGPR mix I + vermiwash) and it was on par with T_5 (poultry manure + wood ash + PGPR mix I) which recorded a root apex diameter of 2.31 mm. At 2 MAP, the control nutrient management through chemical fertilizer application as per KAU POP recorded the highest root apex diameter of 3.03 mm, which was significantly superior to all other treatments. While at 3 MAP, the highest root apex diameter of 3.11 mm was recorded by the treatment T_5 (poultry manure + wood ash + PGPR mix I), which was on par with T_2 (2.79 mm), T_3 (2.80 mm), T_4 (2.91 mm), T_6 (3.03 mm) and C_1 (3.09 mm). The treatment T_6 recorded the highest root apex diameter during the later stages of crop growth, from 4 MAP to 7 MAP. At 4 MAP, T_6 (3.12 mm) was on par with T_2 (2.90 mm) and T_5 (2.83 mm) and at 5 MAP, T_6 (2.98 mm) was on par with T_5 (2.71 mm) and control C_1 (2.68 mm). The T_6 (2.90 mm) was found to be on par with C_1 (2.56 mm) at 6 MAP, while T_6 (2.83 mm) was significantly superior to all treatments at 7 MAP. The absolute control C_3 recorded the lowest value for root apex diameter at all stages of crop growth except 1 MAP (2.15 mm, 2.47 mm, 2.07 mm, 1.82 mm, 1.77 mm and 1.77 mm at 2, 3, 4, 5, 6 and 7 MAP respectively).

4.2.3.2 Number of Roots per Plant

Number of roots produced per plant at monthly intervals up to 7 MAP as influenced by different organic sources is presented in Table 37.

The number of roots produced per plant showed an increasing trend from 1 MAP up to 4 to 5 MAP and then started declining afterwards in all the treatments except $C_{1.}$ In $C_{1,}$ the highest number roots was observed at 3 MAP and then started to decline. At all stages of observation, root number per plant showed significant variation among the treatments except at 1MAP. At 2 MAP, the highest root number per plant (101.67 roots per plant) was recorded in the control treatment (C_1) that followed the nutrient management through chemical fertilizer application as per KAU

POP and was on par with organic treatment T_6 (98.33 roots per plant) and T_5 (93 roots per plant). At 3 MAP also the highest root number per plant was recorded in the control treatment C_1 (152 roots per plant), which was significantly superior to all the treatments. However, from 4 MAP onwards organic treatments recorded the significantly higher root number per plant than the chemical fertilizer application. At 4 MAP and 5 MAP significantly higher root number per plant (128 roots per plant and 145.67 roots per plant at 4 MAP and 5 MAP respectively) was recorded in T_6 (PM + wood ash+ PGPR mix I+ vermiwash), which was on par with T_3 (120.67 numbers per plant) and T_5 (118.33 numbers per plant) at 4 MAP and with T_4 (124.67 numbers per plant) and T_5 (138 numbers per plant) at 5 MAP. During the later stages of crop growth (6 MAP and 7 MAP), the higher root number per plant was recorded with the treatment T_3 (91 roots per plant and 38 roots per plant at 6 MAP and 7 MAP respectively) wherein application of FYM along with wood ash and PGPR mix I application and vermiwash spraying was carried out. The T_3 was however on a par with T_6 (90.67 numbers per plant) and T_5 (87 numbers per plant) at 6 MAP and with T_6 (31.50 numbers per plant) at 7 MAP. Absolute control recorded the lowest number of roots per plant at all stages of observation except 2 MAP and 5 MAP.

4.2.3.3 Weight of Roots per Plant

The data on fresh weight of roots per plant at monthly intervals up to 7 MAP as influenced by the treatments are given in Table 38.

The weight of roots per plant showed an increasing trend from 1 MAP up to 4 to 5 MAP and then started declining afterwards in all the treatments except $C_{1.}$ In $C_{1,}$ the highest root weight was observed at 3 MAP and then started to decline. The fresh weight of roots per plant showed a significant difference among the treatments at all stages of observation. The treatment T_6 (Poultry manure + wood ash+ PGPR mix I+ vermiwash) recorded the highest root weight per plant at all

Table 36. Effect of organic sources on root apex diameter, mm

Treatments	Root apex diameter						
	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
T_1 - FYM + wood ash	1.35	2.40	2.71	2.13	2.12	2.02	1.89
T_2 - FYM + wood ash +PGPR mix I	1.78	2.74	2.79	2.90	2.28	2.21	2.02
T_3 - FYM + wood ash + PGPR mix I + Vermiwash	2.07	2.63	2.80	2.48	2.40	2.40	2.29
T_4 - Poultry manure + wood ash	1.37	2.39	2.91	2.42	2.34	2.05	2.04
T_5 - Poultry manure + wood ash + PGPR mix I	2.31	2.48	3.11	2.83	2.71	2.52	2.32
T_6 - Poultry manure + wood ash + PGPR mix I + vermiwash	2.39	2.52	3.03	3.12	2.98	2.90	2.83
C_1 - Chemical fertilizers as per KAU POP	1.75	3.03	3.09	2.80	2.68	2.56	2.48
C_2 - KAU organic POP	1.39	2.34	2.56	2.40	2.25	2.15	1.94
C_3 - Absolute control	1.75	2.15	2.47	2.07	1.82	1.77	1.77
SEm±	0.10	0.07	0.12	0.10	0.13	0.13	0.09
CD(0.05)	0.312	0.210	0.353	0.293	0.378	0.377	0.269

Table 37. Effect of organic sources on number of roots per plant

Treatments	Number of roots per plant						
	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
T_1 - FYM + wood ash	23.33	45.00	94.67	101.00	70.00	39.00	26.67
T_2 - FYM + wood ash +PGPR mix I	25.67	74.00	101.00	112.00	93.00	51.00	30.67
T_3 - FYM + wood ash + PGPR mix I + Vermiwash	30.00	63.00	116.00	120.67	103.00	91.00	38.00
T_4 - Poultry manure + wood ash	18.67	68.33	86.67	109.00	124.67	68.00	25.00
T_5 - Poultry manure + wood ash + PGPR mix I	26.00	93.00	98.00	118.33	138.00	87.00	29.00
T_6 - Poultry manure + wood ash + PGPR mix I + vermiwash	24.67	98.33	107.00	128.00	145.67	90.67	31.50
C_1 - Chemical fertilizers as per KAU POP	21.67	101.67	152.00	90.33	88.00	40.00	14.00
C_2 - KAU organic POP	18.00	82.00	114.33	70.67	51.67	28.67	13.33
C_3 - Absolute control	13.67	59.00	83.00	56.67	74.67	28.00	9.33
SEm±	3.41	6.08	9.24	3.43	13.88	7.62	2.33
CD(0.05)	NS	13.241	27.653	10.254	41.546	22.808	6.976

Table 38. Effect of organic sources on root weight per plant, g

Treatments	Root weight per plant						
	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
T_1 - FYM + wood ash	3.73	41.62	75.00	88.43	69.00	33.25	20.99
T_2 - FYM + wood ash +PGPR mix I	5.33	53.13	95.70	121.31	94.88	42.30	25.16
T_3 - FYM + wood ash + PGPR mix I + Vermiwash	5.23	54.27	121.41	131.03	141.01	72.16	33.33
T_4 - Poultry manure + wood ash	3.33	46.90	76.72	117.07	108.37	54.90	19.44
T_5 - Poultry manure + wood ash + PGPR mix I	7.43	58.72	88.70	127.85	126.58	71.45	22.95
T_6 - Poultry manure + wood ash + PGPR mix I + vermiwash	8.30	72.48	133.40	140.37	161.44	73.85	24.30
C_1 - Chemical fertilizers as per KAU POP	3.57	63.32	123.39	99.29	46.72	31.80	11.55
C_2 - KAU organic POP	3.10	65.92	93.08	77.02	43.34	22.80	10.20
C_3 - Absolute control	2.43	51.06	58.50	61.94	63.89	22.50	7.33
SEm±	0.54	4.29	7.82	3.19	11.49	6.55	2.05
CD(0.05)	1.614	12.841	23.400	9.559	34.390	19.616	6.138

stages of observation (8.30 g, 72.48 g, 133.40 g, 140.37 g, 161.44 g and 73.85 g at 1,2,3,4,5 and 6 MAP respectively) except 7 MAP, wherein T_3 (FYM + wood ash+ PGPR mix I+ vermiwash) recorded the highest root weight per plant (33.33 g). At 1 MAP, the T_6 (8.30 g per plant) was on par with the treatment T_5 (7.43 g per plant). The treatment T_6 was on par with C_1 (63.32 g per plant) and C_2 (65.92 g per plant) at 2 MAP. At 3 MAP, T_6 was on par with T_3 (121.41 g per plant) and C_1 (123.39 g per plant). At 4 MAP and 5 MAP, it was also on par with T_3 (131.03 g per plant and 141.01 g per plant at 4 MAP and 5 MAP respectively). At 6 MAP, the T_6 was on par with the organic treatments T_3 (72.16 g per plant), T_4 (54.90 g per plant) and T_5 (71.45 g per plant). At 7 MAP, T_3 (33.33 g per plant) was significantly superior to all treatments with respect to fresh weight of roots. As in the case of number of roots per plant, absolute control recorded the lowest weight of roots per plant at all stages of observation except 2 MAP and 5 MAP.

4.2.3.4 Root Anatomy

4.2.3.4.1 Number of Late Metaxylem

The data on number of late metaxylem of taro roots as influenced by treatments at monthly intervals up to 7 MAP are given in Table 39.

The number of late metaxylem showed significant difference among treatments only at 1 MAP, 2 MAP and 6 MAP. At 1 MAP, the treatments T_1, T_3, and T_5 recorded the highest value of 6.67 and these treatments were on par with T_2 (6.50), T_4 (6.50) and T_6 (6.17). At 2 MAP, the highest number of late metaxylem (7.83) was recorded in the treatment T_6 (poultry manure + wood ash+ PGPR mix I+ vermiwash) and was on par with T_2 (7.67) and T_4 (7.17). At 6 MAP, T_3 and T_6 recorded the highest number of late metaxylem (8.17) and these treatments were on par with T_1 (7.83), T_2 (8), and C_1 (8).

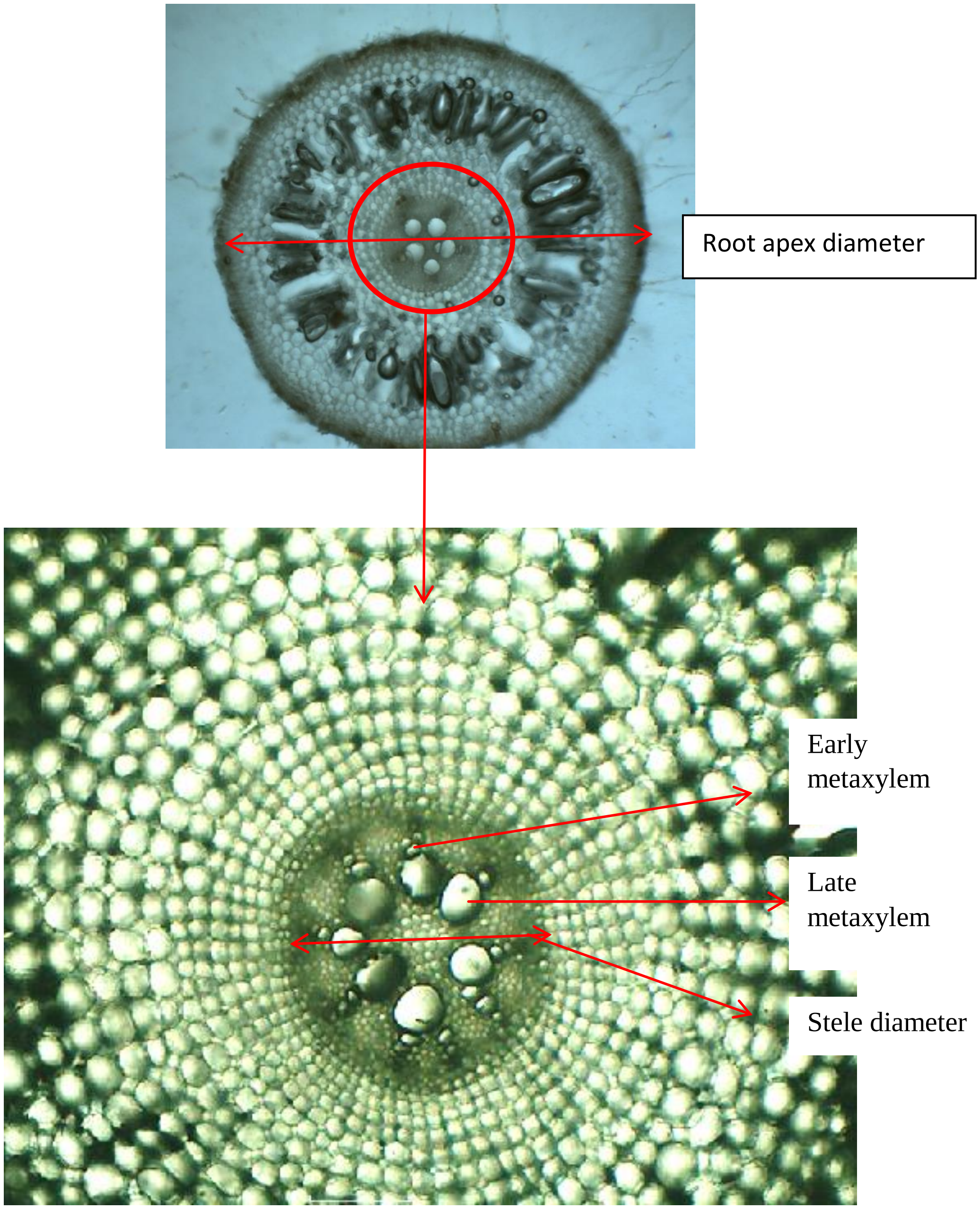


Plate 8. Observations on root anatomy

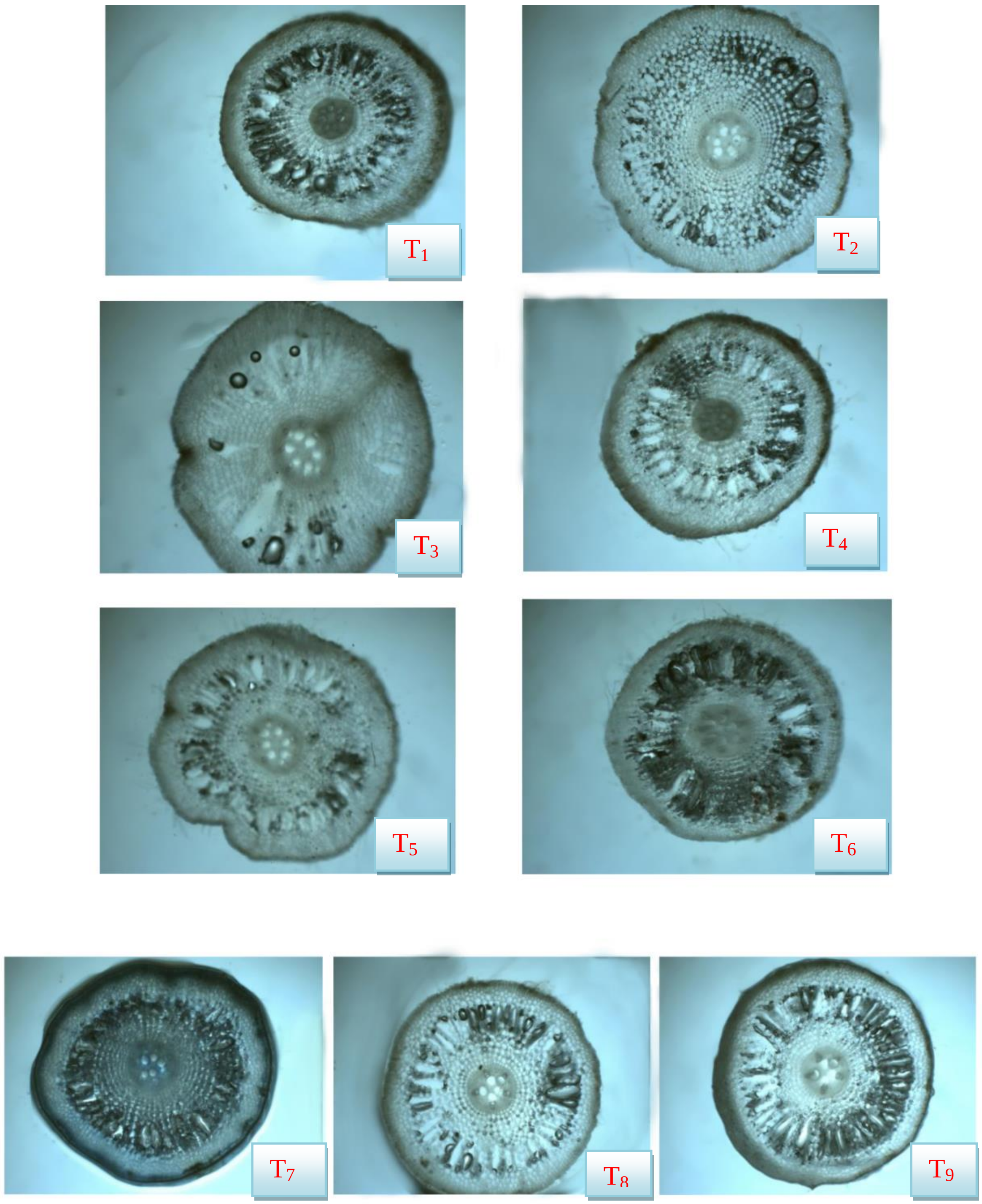


Plate 9. Root anatomy at 1 MAP

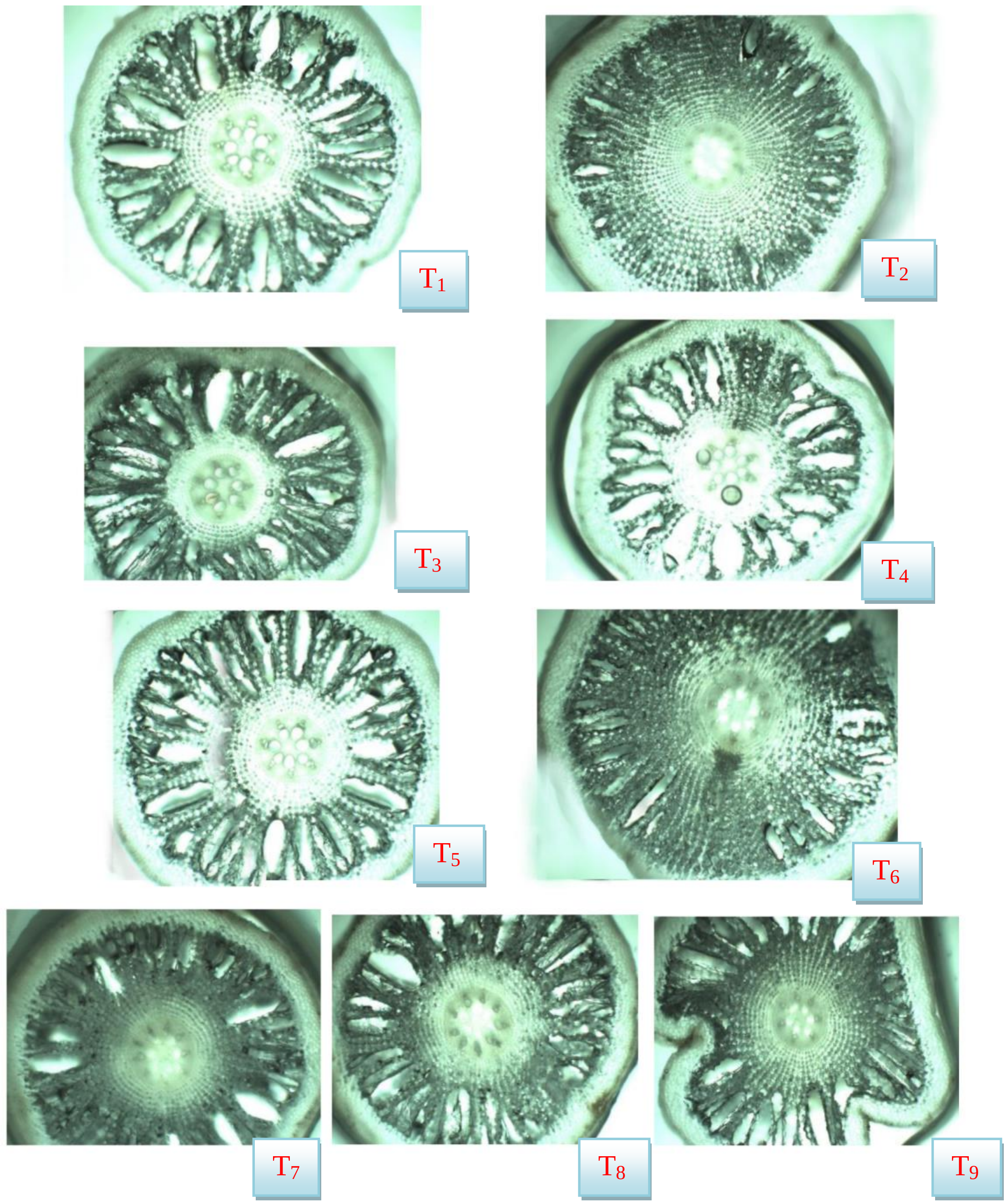


Plate 10. Root anatomy at 2 MAP

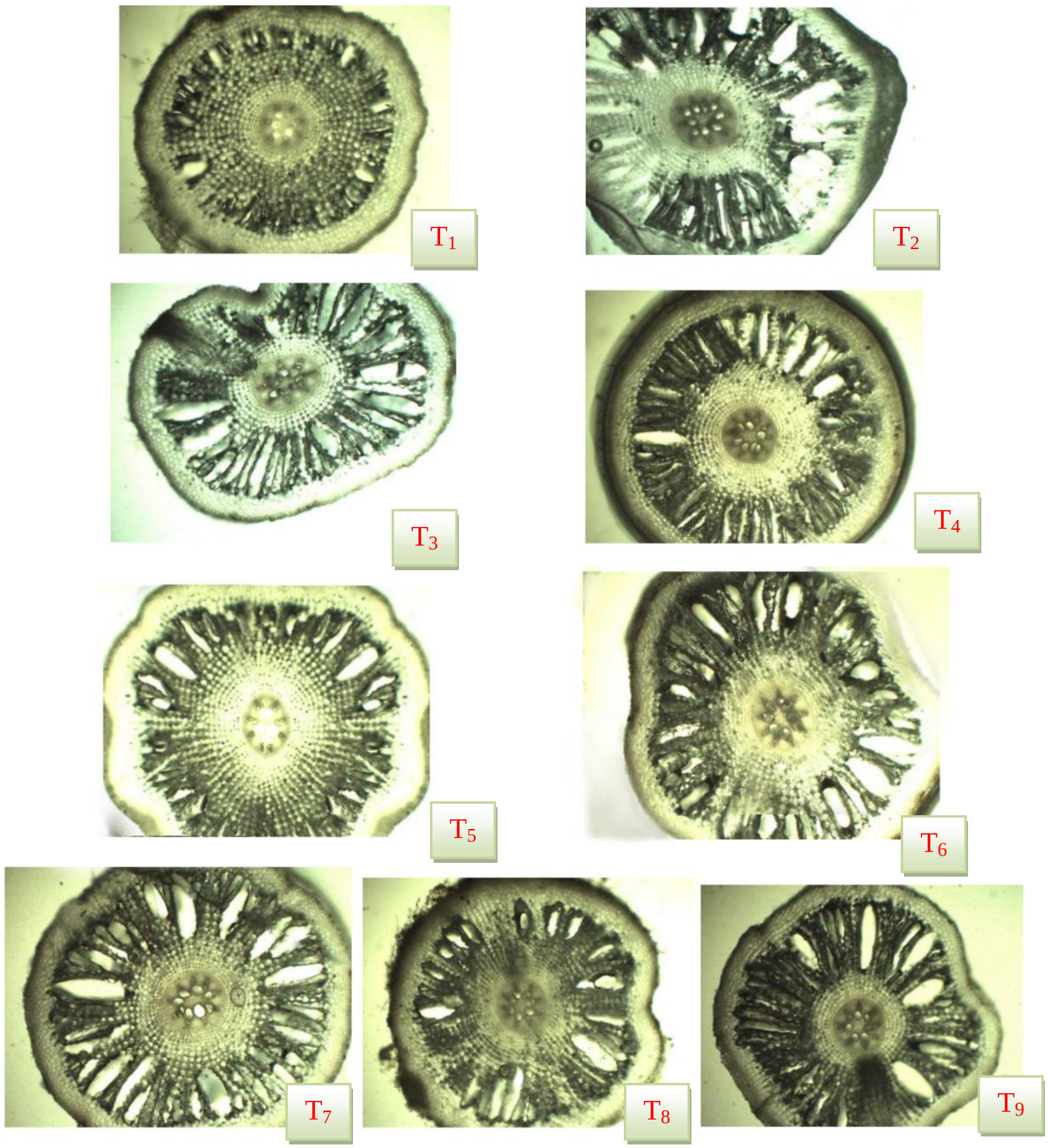


Plate 11. Root anatomy at 3 MAP

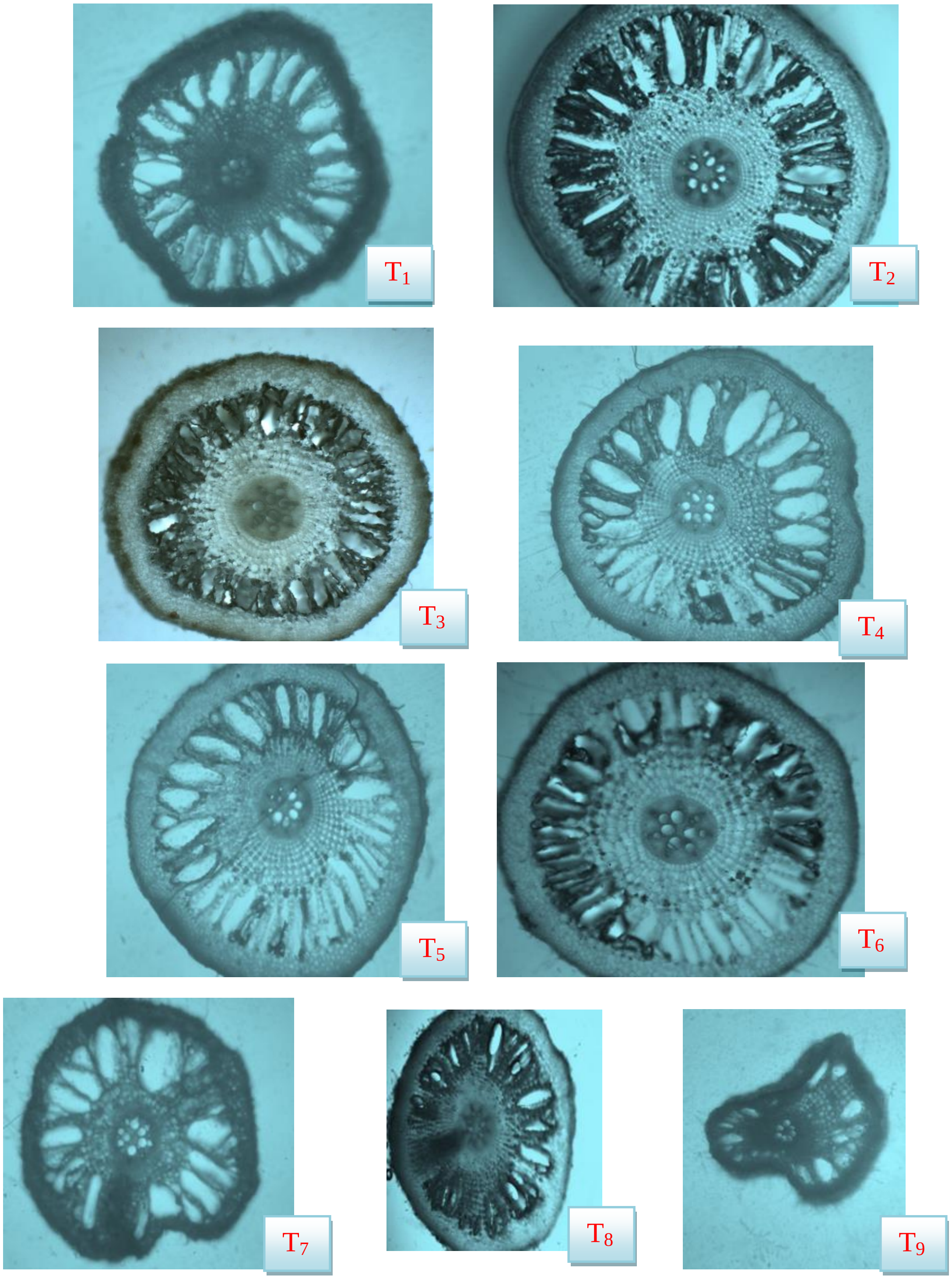


Plate 12. Root anatomy at 6 MAP

4.2.3.4.2 Number of Early Metaxylem

The data on number of early metaxylem of colocasia roots as influenced by treatments at monthly intervals are given in Table 40.

The number of early metaxylem showed significant difference among treatments only at 1 MAP and 3 MAP. At 1 MAP, T_6 (poultry manure + wood ash+ PGPR mix I+ vermiwash) recorded the highest early metaxylem number of 14 and was on par with T_3 (12.33). The treatment T_3 (FYM + wood ash + PGPR mix I + vermiwash) recorded the highest early metaxylem number of 22.67 at 3 MAP and it was on par with T_1 (20), T_2 (21.33), T_6 (19.67), C_1 (21.33) and C_2 (20.33).

4.2.3.4.3 Stele Diameter

The data on stele diameter of colocasia roots as influenced by treatments at monthly interval are given in Table 41.

Significant difference was found among treatments in case of stele diameter of taro root at all stages of observation. At 1 MAP, the highest stele diameter of 0.52 mm was recorded in T_5 (poultry manure + wood ash + PGPR mix I) and was on par with T_6 (0.51 mm) and T_3 (0.45 mm). At 2 MAP, T_2 (FYM + wood ash +PGPR mix I) recorded the highest stele diameter of 0.67 mm and was on par with T_3 (0.63 mm), T_5 (0.62 mm), T_6 (0.63 mm) and C_1 (0.64 mm). At 3 MAP, T_5 (Poultry manure + wood ash + PGPR mix I) recorded the highest stele diameter of 0.65 mm, which was on par with T_2 (0.63 mm), T_4 (0.61 mm), T_6 (0.63 mm) and C_1 (0.64 mm). At 4 MAP, T_5 recorded the highest stele diameter of 0.60 mm and was on par with T_6 (0.59 mm) and C_1 (0.54 mm). The treatment T_6 recorded the highest stele diameter of 0.58 mm, 0.53 mm and 0.47 mm at 5, 6 and 7 MAP respectively and was on par with T_3 (0.47 mm), T_5 (0.51 mm) and C_1 (0.48 mm) at 5 MAP; with T_3 (0.46 mm) and C_1 (0.47 mm) at 6 MAP and with T_3 (0.46 mm), T_4 (0.41 mm), T_5 (0.41 mm) and C_1 (0.45 mm) at 7 MAP.

4.2.3.4.4 Stele Diameter to Root Diameter Ratio

The data on stele diameter to root diameter ratio of taro root as influenced by treatments at monthly intervals are given in Table 42.

The ratio of stele diameter to root diameter showed significant difference among treatments only at 1 MAP, 3 MAP and 7 MAP. At 1 MAP, T_5 and C_2 recorded the highest value (0.23) and was on par with all treatments except T_2, T_4 and T_6. At 3 MAP, T_2 recorded the highest value of 0.23 and was on par with T_4 (0.21), T_5 (0.21), T_6 (0.21), C_1 (0.21) and C_3 (0.21). At 7 MAP, T_1, T_3 and T_4 recorded the highest value of 0.20 as ratio of stele diameter to root diameter and was on par with T_5 (0.18) and C_1 (0.18).

4.2.4 Tuberisation Pattern (Monthly Interval from 1 MAP)

Two plants were uprooted from each treatment per replication at monthly interval in order to study the effect of organic sources on tuberisation pattern of taro.

4.2.4.1 Time of Tuber Initiation

When samples plants were uprooted from all the treatments at 1 MAP, no corm initiation was observed. While at 2 MAP, corm development was observed in the treatment T_6 (Poultry manure + wood ash + PGPR mix I + vermiwash) and C_1 (chemical fertilizers as per KAU POP). But no corm initiation was observed in the other treatments (Table 43). Hence corm initiation has occurred between 1 MAP and 2 MAP in the treatments C_1 and T_6 and between 2 MAP and 3 MAP in all the other trearments (T_1, T_2, T_3, T_4, T_5, C_2 and C_3).

4.2.4.2 Corm Weight per Plant

Weight of corm per plant at monthly intervals as influenced by the organic sources are presented in Table 43.

Table 39. Effect of organic sources on number of late metaxylem in taro root

Treatments	Number of late metaxylem						
	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
T_1 - FYM + wood ash	6.67	6.67	7.00	7.67	7.50	7.83	7.50
T_2 - FYM + wood ash +PGPR mix I	6.50	7.67	8.00	7.83	7.50	8.00	8.00
T_3 - FYM + wood ash + PGPR mix I + Vermiwash	6.67	7.00	7.50	7.83	7.50	8.17	8.00
T_4 - Poultry manure + wood ash	6.50	7.17	7.00	7.33	7.33	7.33	6.67
T_5 - Poultry manure + wood ash + PGPR mix I	6.67	6.50	8.00	7.67	7.50	7.50	7.67
T_6 - Poultry manure + wood ash + PGPR mix I + vermiwash	6.17	7.83	7.00	7.67	7.83	8.17	8.33
C_1 - Chemical fertilizers as per KAU POP	5.00	6.50	7.67	7.67	7.67	8.00	8.00
C_2 - KAU organic POP	5.50	6.50	7.00	7.33	7.33	7.33	7.67
C_3 - Absolute control	5.00	6.50	6.33	7.00	7.00	7.17	7.33
SEm±	0.36	0.26	0.38	0.31	0.28	0.22	0.33
CD(0.05)	1.091	0.780	NS	NS	NS	0.644	NS

Table 40. Effect of organic sources on number of early metaxylem in taro root

Treatments	Number of early metaxylem						
	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
T_1 - FYM + wood ash	10.33	17.67	20.00	21.17	19.83	20.17	20.33
T_2 - FYM + wood ash +PGPR mix I	9.67	17.67	21.33	20.67	19.83	20.67	20.33
T_3 - FYM + wood ash + PGPR mix I + Vermiwash	12.33	21.67	22.67	21.17	20.00	21.17	18.83
T_4 - Poultry manure + wood ash	9.67	19.00	16.33	19.67	19.33	18.67	16.33
T_5 - Poultry manure + wood ash + PGPR mix I	11.67	19.33	18.33	20.67	20.00	19.17	19.33
T_6 - Poultry manure + wood ash + PGPR mix I + vermiwash	14.00	19.00	19.67	20.67	20.83	21.17	21.33
C_1 - Chemical fertilizers as per KAU POP	10.00	19.33	21.33	20.67	20.67	20.67	20.33
C_2 - KAU organic POP	10.00	20.00	20.33	19.67	19.67	18.67	19.33
C_3 - Absolute control	10.00	18.67	19.33	18.67	18.67	18.17	18.33
SEm±	0.60	0.82	1.01	1.25	2.49	0.76	1.03
CD(0.05)	1.792	NS	3.031	NS	NS	NS	NS

Table 41. Effect of organic sources on stele diameter of taro root, mm

Treatments	Stele diameter of taro root						
	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
T_1 - FYM + wood ash	0.30	0.53	0.55	0.42	0.42	0.40	0.37
T_2 - FYM + wood ash +PGPR mix I	0.37	0.67	0.63	0.44	0.44	0.41	0.35
T_3 - FYM + wood ash + PGPR mix I + Vermiwash	0.45	0.63	0.56	0.51	0.47	0.46	0.46
T_4 - Poultry manure + wood ash	0.27	0.50	0.61	0.45	0.44	0.42	0.41
T_5 - Poultry manure + wood ash + PGPR mix I	0.52	0.62	0.65	0.60	0.51	0.42	0.41
T_6 - Poultry manure + wood ash + PGPR mix I + vermiwash	0.51	0.63	0.63	0.59	0.58	0.53	0.47
C_1 - Chemical fertilizers as per KAU POP	0.39	0.64	0.64	0.54	0.48	0.47	0.45
C_2 - KAU organic POP	0.32	0.51	0.47	0.46	0.44	0.39	0.34
C_3 - Absolute control	0.39	0.52	0.52	0.33	0.32	0.31	0.30
SEm±	0.03	0.03	0.02	0.03	0.05	0.03	0.03
CD(0.05)	0.076	0.096	0.073	0.072	0.137	0.074	0.080

Table 42. Effect of organic sources on stele diameter to root diameter ratio of taro root

Treatments	Stele diameter to root diameter ratio						
	1 MAP	2MAP	3MAP	4MAP	5MAP	6MAP	7MAP
T_1 - FYM + wood ash	0.22	0.22	0.20	0.20	0.20	0.20	0.20
T_2 - FYM + wood ash +PGPR mix I	0.21	0.25	0.23	0.16	0.19	0.19	0.17
T_3 - FYM + wood ash + PGPR mix I + Vermiwash	0.22	0.24	0.20	0.20	0.20	0.19	0.20
T_4 - Poultry manure + wood ash	0.19	0.21	0.21	0.19	0.19	0.20	0.20
T_5 - Poultry manure + wood ash + PGPR mix I	0.23	0.25	0.21	0.21	0.19	0.17	0.18
T_6 - Poultry manure + wood ash + PGPR mix I + vermiwash	0.21	0.25	0.21	0.19	0.20	0.18	0.16
C_1 - Chemical fertilizers as per KAU POP	0.22	0.21	0.21	0.19	0.18	0.18	0.18
C_2 - KAU organic POP	0.23	0.22	0.18	0.19	0.19	0.19	0.17
C_3 - Absolute control	0.22	0.24	0.21	0.16	0.18	0.18	0.17
SEm±	0.01	0.02	0.01	0.01	0.02	0.01	0.01
CD(0.05)	0.015	NS	0.023	NS	NS	NS	0.024

The corm weight per plant was significantly influenced by the treatments at all stages of observation. During the early stages of crop growth *ie,* at 3 MAP and 4 MAP, the highest corm weight per plant (68.41 g and 140.96 g at 3 MAP and 4 MAP respectively) was recorded in the control C_1 (Chemical fertilizers as per KAU POP).

At 3 MAP C_1 was on par with the treatment T_6 (Poultry manure + wood ash + PGPR mix I + vermiwash), while at 4 MAP C_1 was significantly superior to all other treatments. During the later stages of plant growth *ie,* from 5 MAP onwards the highest corm weight per plant was recorded by the organic nutrition treatment T_6 (Poultry manure + wood ash + PGPR mix I + vermiwash). At 5 MAP, T_6 (249.71 g per plant) was on par with T_5 (220.02 g per plant) while at 6 MAP, T_6 (289.30 g per plant) was significantly superior to all other treatments. At 7 MAP, T_6 (301.88 g per plant) was on par with T_2 (260.87 g per plant), T_5 (251.90 g per plant) and C_1 (275.09 g per plant). At all stages of observation, the lowest corm weight per plant was recorded in the absolute control (37.18 g per plant, 51.96 g per plant, 91.42 g per plant, 100.24 g per plant and 116.08 g per plant at 3, 4, 5, 6 and 7 MAP respectively).

4.2.4.3 Cormel Weight per Plant

The data on the effects of treatments on cormel weight per plant at monthly intervals are presented in Table 44.

The cormel weight per plant was significantly influenced by the treatments at all stages of observation. Nutrient management through chemical fertilizers as per KAU POP (C_1) recorded the highest cormel weight per plant at 3 MAP, 4 MAP and 5 MAP. At 3 MAP, C_1 (182.36 g per plant) was significantly superior to all treatments, while at 4 MAP, C_1 (346.80 g per plant) was on par with T_6 (291.89 g per plant) and at 5 MAP, C_1 (420.34 g per plant) was on par with T_3 (350.13 g per plant), T_5 (340.33 g per plant) and T_6 (410.49 g per plant). Application of poultry manure along with wood ash, PGPR mix I and vermiwash (T_6) recorded the highest cormel weight at 6 MAP (465.23 g per plant) and 7 MAP (507.04 g per plant) and was on par with T_2

(410.23 g per plant and 468.71 g per plant at 6 MAP and 7 MAP respectively) , T_3 (400.13 g per plant and 440.24 g per plant at 6 MAP and 7 MAP respectively), T_5 (398.61 g per plant and 432.88 g per plant at 6 MAP and 7 MAP respectively) and C_1 (460.42 g per plant and 486.90 g per plant at 6 MAP and 7 MAP respectively) at both the stages. At all stages of observation, the lowest cormel weight per plant was recorded in absolute control except 3 MAP (100.13 g per plant, 140.12 g per plant, 173.61 g per plant and 206.13 g per plant at 4, 5, 6 and 7 MAP respectively). At 3 MAP, the lowest cormel weight (39.96 g per plant) was recorded in T_1 in which only FYM and wood ash were applied.

4.2.4.4 Cormel Bulking Rate

The calculated values of bulking rate of cormel as influenced by the treatments are shown in Table 45.

The highest values of cormel bulking rate were observed between 3 MAP and 4 MAP and after that a decreasing trend of bulking rate was noticed towards harvest in all the treatments.

The treatment T_6 (Poultry manure + wood ash + PGPR mix I + vermiwash) recorded the highest bulking rate of 1.23 g per day per plant during 3-4 MAP and was on par with all the other treatments (0.76 g per day per plant, 0.80 g per day per plant, 0.92 g per day per plant, 0.82 g per day per plant, 0.95 g per day per plant, 1.10 g per day per plant and 1.01 g per day per plant for T_1, T_2, T_3, T_4, T_5, C_1 and C_2 respectively) except absolute control. During 4-5 MAP, the treatments T_3 and T_5 recorded the highest bulking rate of 0.87 g per day per plant and were on par with T_1 (0.60 g per day per plant), T_2 (0.71 g per day per plant), T_4 (0.80 g per day per plant) and T_6 (0.79 g per day per plant). The highest bulking rate of 0.63 g per day per plant was recorded by T_2 (FYM + wood ash +PGPR mix I) during 5-6 MAP. During 6-7 MAP, bulking rate of cormel was not significantly influenced by treatments. At all stages of observation, the lowest cormel bulking rate (0.32, 0.27, 0.22 and 0.22 g per

Table 43. Effect of organic sources on corm weight per plant, g

Treatments	Corm weight per plant						
	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
T_1 - FYM + wood ash	-	-	38.21	86.50	105.89	132.36	153.04
T_2 - FYM + wood ash +PGPR mix I	-	-	55.93	120.73	163.80	195.94	260.87
T_3 - FYM + wood ash + PGPR mix I + vermiwash	-	-	45.26	111.66	141.84	161.16	210.64
T_4 - Poultry manure + wood ash	-	-	42.92	94.14	124.80	131.28	141.56
T_5 - Poultry manure + wood ash + PGPR mix I	-	-	46.49	115.18	220.02	231.60	251.90
T_6 - Poultry manure + wood ash + PGPR mix I + vermiwash	-	-	61.58	116.86	249.71	289.30	301.88
C_1 - Chemical fertilizers as per KAU POP	-	-	68.41	140.96	180.75	175.55	275.09
C_2 - KAU organic POP	-	-	44.67	85.25	110.13	137.91	150.61
C_3 - Absolute control	-	-	37.18	51.96	91.42	100.24	116.08
SEm±			2.93	5.90	15.74	17.79	26.16
CD(0.05)			8.785	17.673	47.137	53.260	78.330

Table 44. Effect of organic sources on cormel weight per plant, g

Treatments	Cormel weight per plant						
	1 MAP	2MAP	3MAP	4MAP	5MAP	6MAP	7MAP
T_1 - FYM + wood ash	-	-	39.96	153.65	243.89	305.21	358.51
T_2 - FYM + wood ash +PGPR mix I	-	-	88.01	208.50	315.54	410.23	468.71
T_3 - FYM + wood ash + PGPR mix I + Vermiwash	-	-	82.39	220.13	350.13	400.13	440.24
T_4 - Poultry manure + wood ash	-	-	37.91	160.34	280.24	336.79	386.91
T_5 - Poultry manure + wood ash + PGPR mix I	-	-	67.89	210.47	340.33	398.61	432.88
T_6 - Poultry manure + wood ash + PGPR mix I + vermiwash	-	-	107.60	291.89	410.49	465.23	507.04
C_1 - Chemical fertilizers as per KAU POP	-	-	182.36	346.80	420.34	460.42	486.90
C_2 - KAU organic POP	-	-	58.37	210.18	283.60	337.08	373.74
C_3 - Absolute control	-	-	51.45	100.13	140.12	173.61	206.13
SEm±			11.09	21.19	32.84	26.66	28.11
CD(0.05)			33.206	63.454	98.317	79.828	84.170

Table 45. Effect of organic sources on cormel bulking rate per day per plant, g

Treatments	Cormel bulking rate			
	3-4 MAP	4-5 MAP	5-6 MAP	6-7 MAP
T_1 - FYM + wood ash	0.76	0.60	0.41	0.36
T_2 - FYM + wood ash +PGPR mix I	0.80	0.71	0.63	0.39
T_3 - FYM + wood ash + PGPR mix I + vermiwash	0.92	0.87	0.33	0.27
T_4 - Poultry manure + wood ash	0.82	0.80	0.38	0.33
T_5 - Poultry manure + wood ash + PGPR mix I	0.95	0.87	0.39	0.23
T_6 - Poultry manure + wood ash + PGPR mix I + vermiwash	1.23	0.79	0.37	0.28
C_1 - Chemical fertilizers as per KAU POP	1.10	0.49	0.27	0.18
C_2 - KAU organic POP	1.01	0.49	0.36	0.24
C_3 - Absolute control	0.32	0.27	0.22	0.22
SEm±	0.16	0.12	0.07	0.13
CD(0.05)	0.471	0.347	0.215	NS

day per plant during 3-4, 4-5, 5-6 and 6-7 MAP respectively) was recorded by absolute control (C_3).

4.3 CORRELATION STUDY ON ROOT ANATOMY AND NUTRIENT UPTAKE

Correlation analysis of nutrient uptake *Vs.* root apex diameter, late metaxylem number, early metaxylem number and stele diameter were done and the correlation coefficients are given in Tables 46a, 46b and 46c.

4.3.1 Nitrogen Uptake *Vs.* Root Anatomical Characters

The correlation studies (Table 46a) indicated that N uptake during both the years was significantly and positively correlated with root apex diameter at 2, 3, 4, 5, 6 and 7 MAP. N uptake during the first year was significantly and positively correlated with late metaxylem number at 3 MAP, while late metaxylem number at 4 and 5 MAP and early metaxylem number at 5 MAP were significantly and positively correlated with N uptake during both the years. The late metaxylem number at 6 and 7 MAP and early metaxylem number at 4 and 6 MAP were significantly and positively correlated with N uptake recorded during the second year. N uptake during both years was significantly and positively correlated with stele diameter at 2, 4, 5, 6 and 7 MAP, while stele diameter at 3 MAP was found significantly correlated with only the N uptake recorded during the first year.

4.3.2 Phosphorus Uptake *Vs.* Root Anatomical Characters

The results presented in Table 46b revealed that P uptake during both the years was significantly and positively correlated with root apex diameter at 2, 3, 5, 6 and 7 MAP; late and early metaxylem number at 4, 5 and 6 MAP and with stele diameter at 5, 6 and 7 MAP. The stele diameter at 2 MAP was significantly and positively correlated with P uptake during the first year, while stele diameter at 4 MAP was significantly and positively correlated with P uptake during the second year.

4.3.3 Potassium Uptake *Vs.* Root Anatomical Characters

Correlation coefficients presented in Table 46c showed that K uptake during both the years was significantly and positively correlated with root apex diameter at 2, 3, 4, 5, 6 and 7 MAP; late and early metaxylem number at 4, 5 and 6 MAP and with stele diameter at 2, 4, 5, 6 and 7 MAP. The late metaxylem at 7 MAP was significantly and positively correlated only with K uptake during the second year and the stele diameter at 3 MAP was significantly and positively correlated only with K uptake during the first year.

Table 46a. Correlation analysis of N uptake *Vs*. root apex diameter, late metaxylem number, early metaxylem number and stele diameter

Variables correlated	Correlation coefficients (r)	
	I year	II year
N uptake x root apex diameter at 2 MAP	0.727*	0.754*
N uptake x root apex diameter at 3 MAP	0.850**	0.814**
N uptake x root apex diameter at 4 MAP	0.883**	0.861**
N uptake x root apex diameter at 5 MAP	0.893**	0.925**
N uptake x root apex diameter at 6 MAP	0.869**	0.951**
N uptake x root apex diameter at 7 MAP	0.817**	0.920**
N uptake x late metaxylem number at 3 MAP	0.749*	0.625
N uptake x late metaxylem number at 4 MAP	0.721*	0.744*
N uptake x late metaxylem number at 5 MAP	0.805**	0.903**
N uptake x late metaxylem number at 6 MAP	0.622	0.766*
N uptake x late metaxylem number at 7 MAP	0.520	0.689*
N uptake x early metaxylem number at 4 MAP	0.603	0.670*
N uptake x early metaxylem number at 5 MAP	0.807**	0.926 **
N uptake x early metaxylem number at 6 MAP	0.623	0.766*
N uptake x stele diameter at 2 MAP	0.734*	0.765*
N uptake x stele diameter at 3 MAP	0.714*	0.643
N uptake x stele diameter at 4 MAP	0.887**	0.897**
N uptake x stele diameter at 5 MAP	0.875**	0.910**
N uptake x stele diameter at 6 MAP	0.853**	0.939**
N uptake x stele diameter at 7 MAP	0.811**	0.883**

** Significant at 1% level

* Significant at 5% level

Table 46b. Correlation analysis of P uptake *Vs*. root apex diameter, late metaxylem number, early metaxylem number and stele diameter

Variables correlated	Correlation coefficients (r)	
	I year	II year
P uptake x root apex diameter at 2 MAP	0.845**	0.902**
P uptake x root apex diameter at 3 MAP	0.710*	0.771*
P uptake x root apex diameter at 4 MAP	0.642	0.640
P uptake x root apex diameter at 5 MAP	0.694*	0.742*
P uptake x root apex diameter at 6 MAP	0.729*	0.742*
P uptake x root apex diameter at 7 MAP	0.717*	0.746*
P uptake x late metaxylem number at 3 MAP	0.630	0.562
P uptake x late metaxylem number at 4 MAP	0.864**	0.702*
P uptake x late metaxylem number at 5 MAP	0.855**	0.847**
P uptake x late metaxylem number at 6 MAP	0.893**	0.755*
P uptake x late metaxylem number at 7 MAP	0.559	0.502
P uptake x early metaxylem number at 4 MAP	0.824**	0.681*
P uptake x early metaxylem number at 5 MAP	0.829**	0.873**
P uptake x early metaxylem number at 6 MAP	0.894**	0.757*
P uptake x stele diameter at 2 MAP	0.731*	0.632
P uptake x stele diameter at 3 MAP	0.620	0.622
P uptake x stele diameter at 4 MAP	0.661	0.684*
P uptake x stele diameter at 5 MAP	0.709*	0.691*
P uptake x stele diameter at 6 MAP	0.867**	0.844**
P uptake x stele diameter at 7 MAP	0.856**	0.832**

** Significant at 1% level
* Significant at 5% level

Table 46c. Correlation analysis of K uptake *Vs*. root apex diameter, late metaxylem number, early metaxylem number and stele diameter

Variables correlated	Correlation coefficients (r)	
	I year	II year
K uptake x root apex diameter at 2 MAP	0.695*	0.744*
K uptake x root apex diameter at 3 MAP	0.880**	0.845**
K uptake x root apex diameter at 4 MAP	0.888**	0.816**
K uptake x root apex diameter at 5 MAP	0.940**	0.935**
K uptake x root apex diameter at 6 MAP	0.940**	0.957**
K uptake x root apex diameter at 7 MAP	0.906**	0.932**
K uptake x late metaxylem number at 3 MAP	0.661	0.592
K uptake x late metaxylem number at 4 MAP	0.795*	0.747*
K uptake x late metaxylem number at 5 MAP	0.936**	0.931**
K uptake x late metaxylem number at 6 MAP	0.764*	0.772*
K uptake x late metaxylem number at 7 MAP	0.624	0.673*
K uptake x early metaxylem number at 4 MAP	0.732*	0.714*
K uptake x early metaxylem number at 5 MAP	0.912**	0.954**
K uptake x early metaxylem number at 6 MAP	0.764*	0.772*
K uptake x stele diameter at 2 MAP	0.768*	0.731*
K uptake x stele diameter at 3 MAP	0.762*	0.652
K uptake x stele diameter at 4 MAP	0.907**	0.912**
K uptake x stele diameter at 5 MAP	0.940**	0.915**
K uptake x stele diameter at 6 MAP	0.936**	0.947**
K uptake x stele diameter at 7 MAP	0.868**	0.911**

** Significant at 1% level
* Significant at 5% level

DISCUSSION

5. DISCUSSION

The study entitled “Organic nutrition in taro (*Colocasia esculenta* (L.) Schott)” was carried out during 2018 – 2021 at College of Agriculture, Vellayani, Thiruvananthapuram and farmer’s field, Peringamala, Thiruvananthapuram to investigate the effect of organic nutrition on growth, yield, quality, soil organic carbon build up and economics of cultivation of taro and to study rooting and tuberisation pattern of taro under organic nutrition. The results of the study are discussed in this chapter.

5.1 EXPERIMENT I - ORGANIC NUTRITION IN TARO (FIELD EXPERIMENT)

5.1.1 Growth and Growth Attributes

The organic source application of FYM + wood ash +PGPR mix I took less number of days for 50 per cent sprouting of seed corm during the first year and it was on par with application of FYM + wood ash + PGPR mix I + vermiwash (Fig. 4). The comparatively early sprouting of seed corm in these treatments may be due to the effect of PGPR mix I. The PGPR mix I is a microbial consortium for supplementing all the major nutrients which contains components cultures, *viz.*, *Azospirillum lipoferum, Azotobacter chroococcum, Bacillus megaterium* and *Bacillus sporothermodurans* as reported by Gopi *et al. (*2020). Bakonyi *et al.* (2013) reported the positive effect of biofertilizers containing *Azotobacter chroococcum and Bacillus megaterium var. phosphaticum* on seed germination. The bacteria can excrete phytohormones such as auxins and gibberellin *etc* thereby improving seed germination and early development. The combined effect of PGPR mix I with the production of large amount of heat and organic compounds as a result of the decomposition of large quantity of FYM might have contributed to the early sprouting of seed corm. Effect of heat stress on genetic expression resulting an earliness in sprouting has been recently reported by Zhang *et al*. (2021) in potato.

Growth characters like plant height, number of leaves per plant, leaf area per plant and LAI were recorded from 2 MAP onwards at bimonthly interval. The plant height (Fig. 5c and 5d), leaf area per plant (Fig. 7c and 7d) and LAI (Fig. 8c and 8d) increased upto 4 MAP irrespective of treatments and after which there was a declining trend upto harvest during both the years. This clearly indicated that the rapid vegetative growth in taro extends upto 4 or 5 MAP and during later stages of tuber development and bulking, the vegetative growth reduces. As explained by Thokchom *et al*. (2018), the corm and cormel development in taro start 90 days after planting, demanding more diversion of assimilates for the development of tuber. Thus photosynthates produced are mostly used for the tuber development in the expense of growth of the plant and thereby the plant height is found to be decreasing after 150 days after planting. This is in agreement with the findings of Sivan (1982) who identified the three growth stages of taro *viz.* a period of establishment up to 6-8 weeks (phase I), grand growth period up to 20 weeks (Phase II) and a growth declining period with continuing corm growth (Phase III). This is also in conformity with the findings of Rajasree (1993) who observed that the plant height and LAI of taro increased progressively up to 120 days after planting and then declined. During both the years, the highest number of leaves per plant was recorded at 2 MAP even though smaller in size and then started to decline upto harvest. The reduction in leaf number at later stages of taro was also reported by Rajasree (1993) which could have been due to drying out of existing leaves.

Among organic sources, application of poultry manure along with wood ash, PGPR mix I and vermiwash (s_6) produced taller plants during both the years except at 6 MAP during the second year (Fig 5a and 5b). At 6 MAP during the second year, application of poultry manure along with wood ash and PGPR mix I (s_5) produced the tallest plants. The s_5 (PM+ wood ash + PGPR mix I) and s_3 (FYM + wood ash + PGPR mix I + vermiwash) was found to be equally effective as s_6 during the second

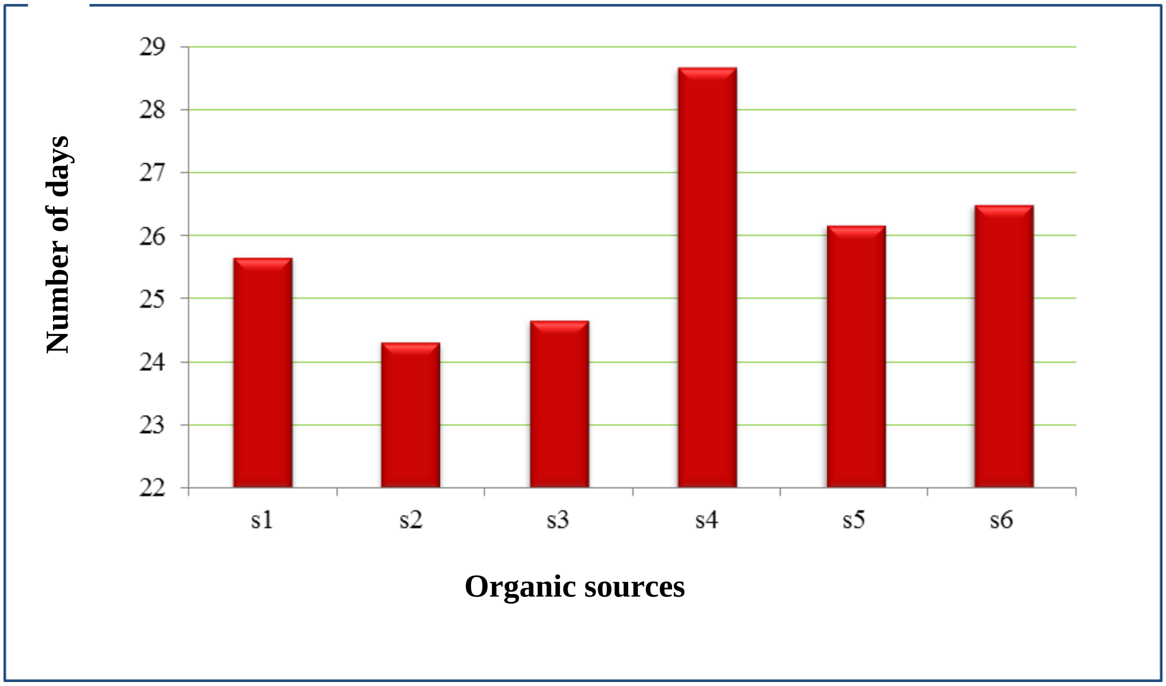


Fig. 4. Effect of organic sources on number of days taken for 50 per cent sprouting of seed corm

year with respect to plant height. The highest number of leaves per plant was recorded with poultry manure

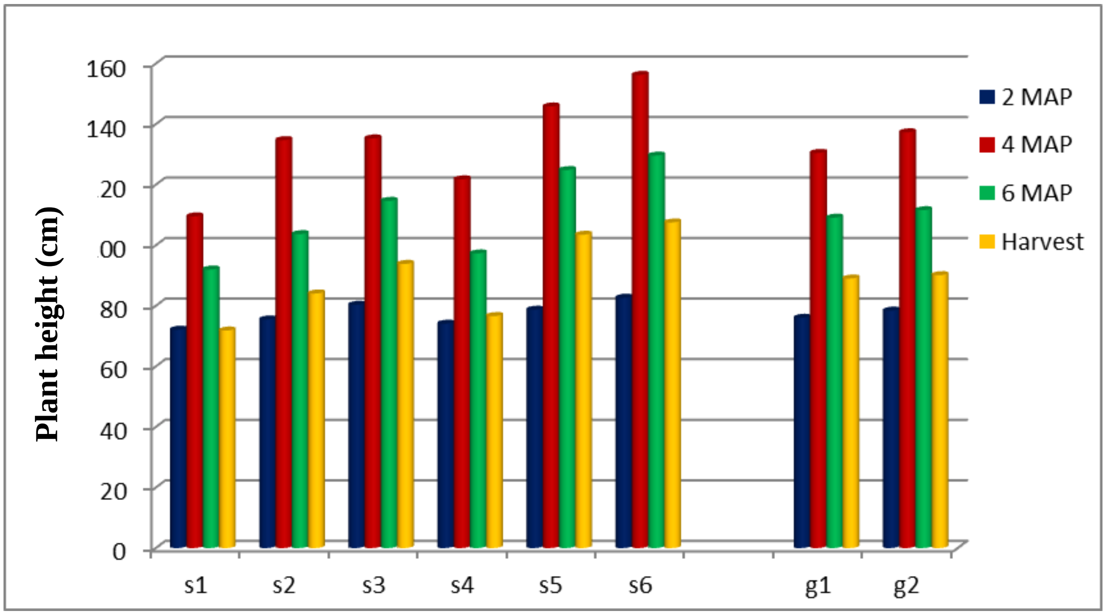
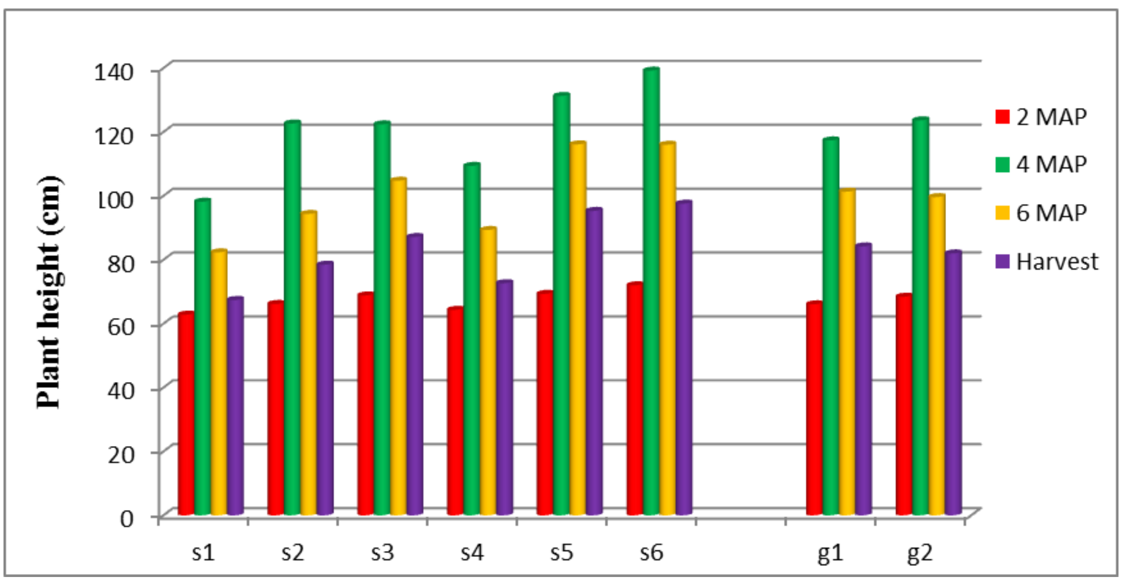


Fig. 5a. Effect of organic sources and *in situ* green manuring on plant height during the first year, cm



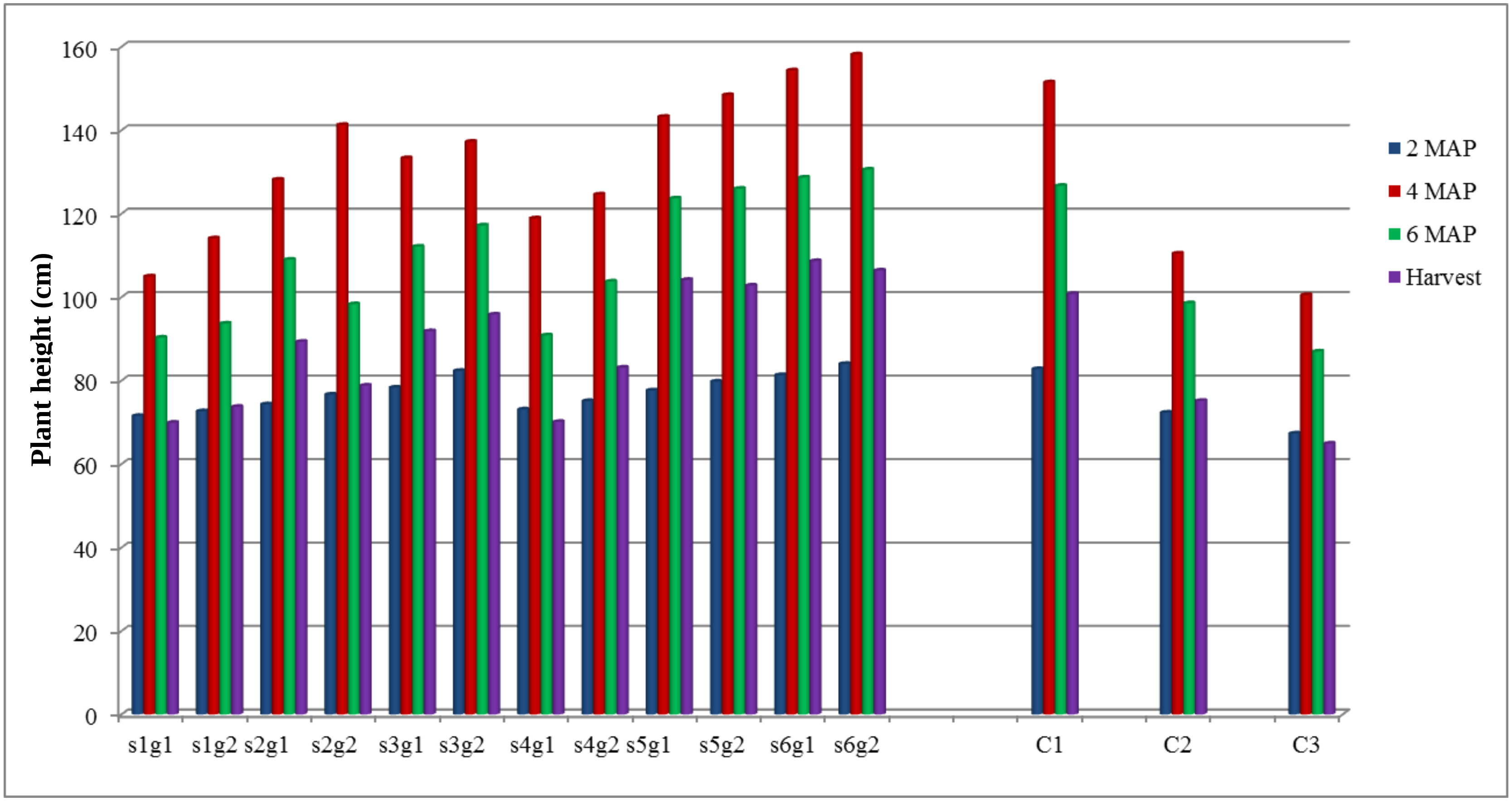


Fig. 5c. Effect of S x G interaction and treatment *vs*. control effect on plant height during the first year, cm

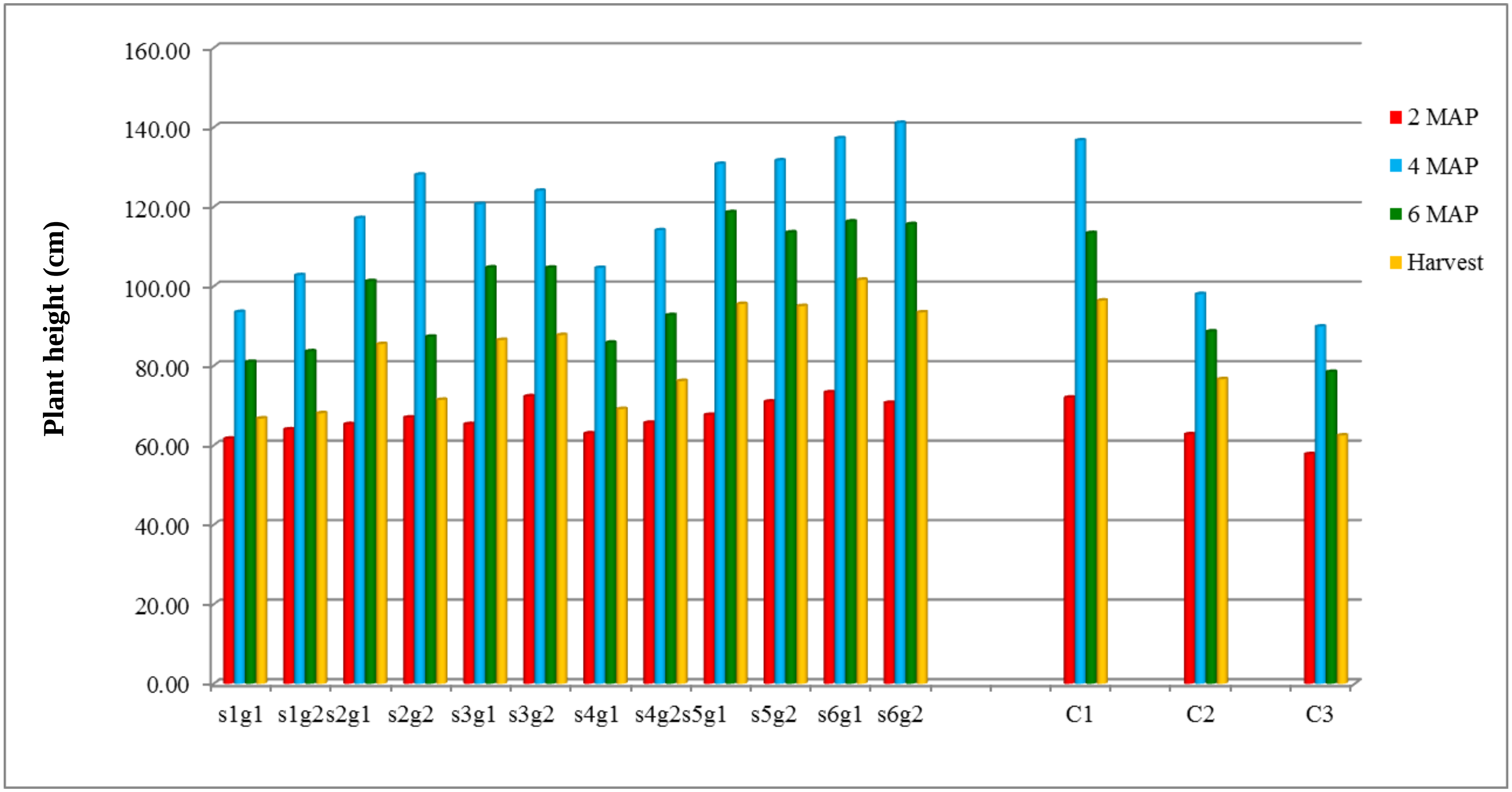


Fig. 5d. Effect of S x G interaction and treatment *vs*. control effect on plant height during the second year, cm

application along with wood ash, PGPR mix I and vermiwash (s_6) at all stages of observation except at harvest during the first year (Fig 6a) and at 4 MAP and harvest during the second year (Fig 6b). The organic sources s_5 (PM+ wood ash + PGPR mix I), s_2 (FYM + wood ash + PGPR mix I) and s_3 (FYM + wood ash + PGPR mix I + vermiwash) also was equally effective as s_6 in producing more number of leaves per plant. During the first year, the highest leaf area per plant and LAI (Fig. 7a and 8a) were recorded by application of poultry manure along with wood ash, PGPR mix I and vermiwash (s_6) at 4 MAP, 6 MAP and harvest, while at 2 MAP, application of FYM along with wood ash, PGPR mix I and vermiwash (s_3) recorded the highest leaf area per plant and LAI. During the second year also the highest leaf area per plant and LAI (Fig. 7b and 8b) were recorded by application of poultry manure along with wood ash, PGPR mix I and vermiwash (s_6) at 2 MAP, 4 MAP and 6 MAP. The organic sources s_5, s_2 and s_3 were found to be equally effective as s_6 at harvest during the first year and at 6 MAP during the second year. During the second year $s_{5,}$ s_3 and s_1 were equally effective as s_6 in case of leaf area per plant and LAI at 2 MAP.

The superiority of application of poultry manure along with wood ash, PGPR mix I and vermiwash with respect to growth parameters of taro may be due to the combined favourable effect of the organic sources. The mineralization pattern of poultry manure has indicated that nearly 60 per cent of N in this manure is present as uric acid which quickly changes to ammoniacal form that can be easily utilized by crop (Smith, 1950). The initial immobilization of nutrients on applying large quantity of FYM compared to continuous availability of nutrients from poultry manure may be the reason for higher growth parameters recorded with poultry manure containing treatments. Poultry manure can provide all thirteen essential plants nutrients *i.e.* N (N), phosphorous (P), K (K), calcium (Ca), magnesium (Mg), sulfur (S), manganese (Mn), copper (Cu), zinc (Zn), chlorine (Cl), boron (B), iron (Fe), and molybdenum (Mo) in good amount (Chastain *et al*., 2001). As reported by Roy and Kashem (2014), the organic C and total N content of poultry manure is higher in comparison

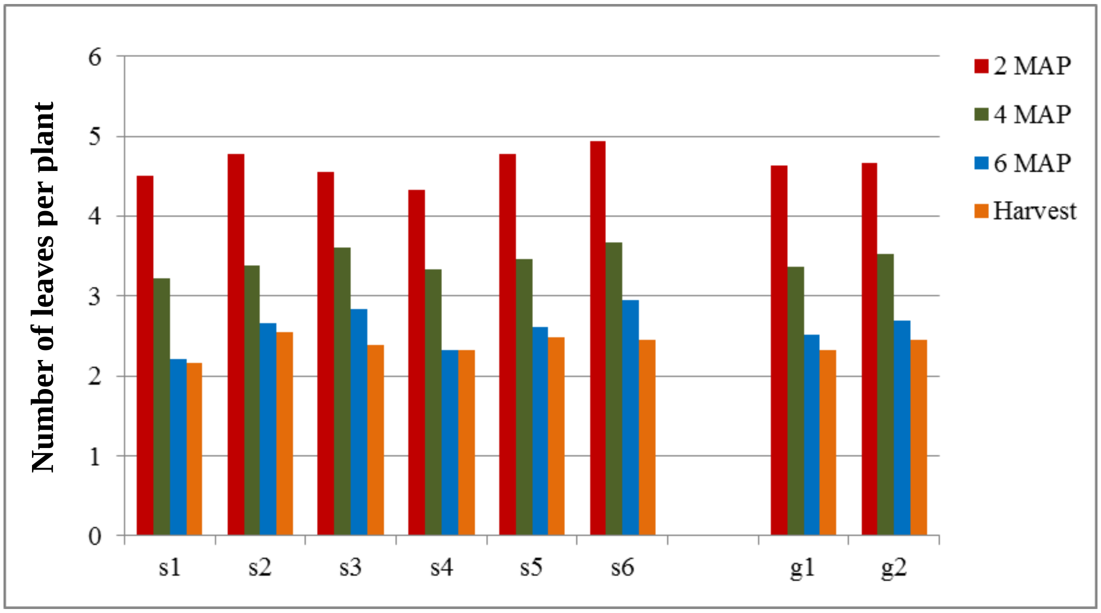


Fig. 6a. Effect of organic sources and *in situ* green manuring on number of leaves per plant during the first year

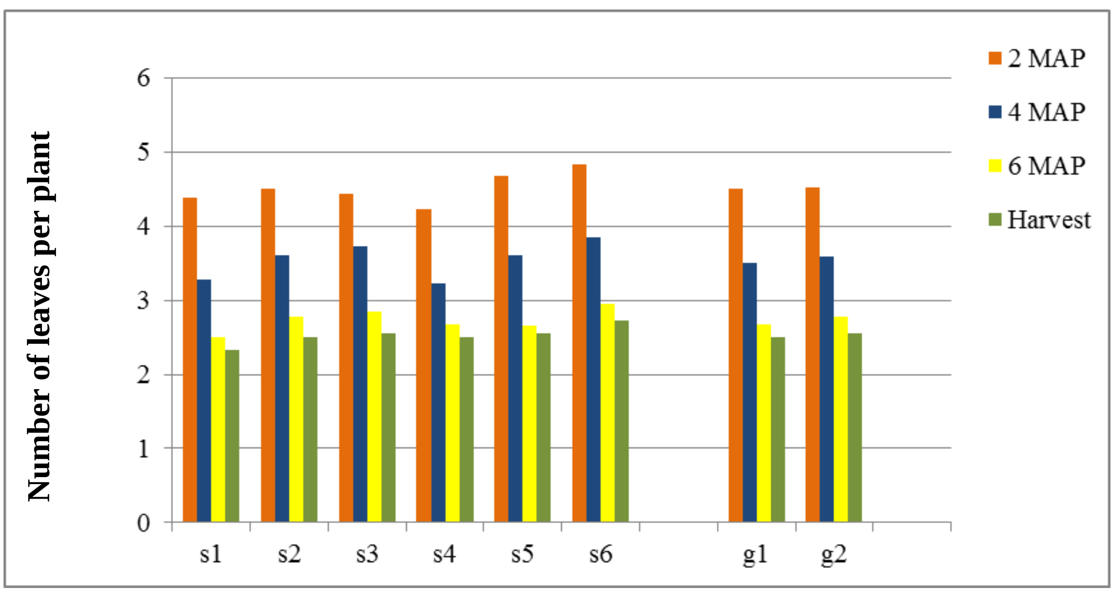


Fig. 6b. Effect of organic sources and *in situ* green manuring on number of leaves per plant during the second year

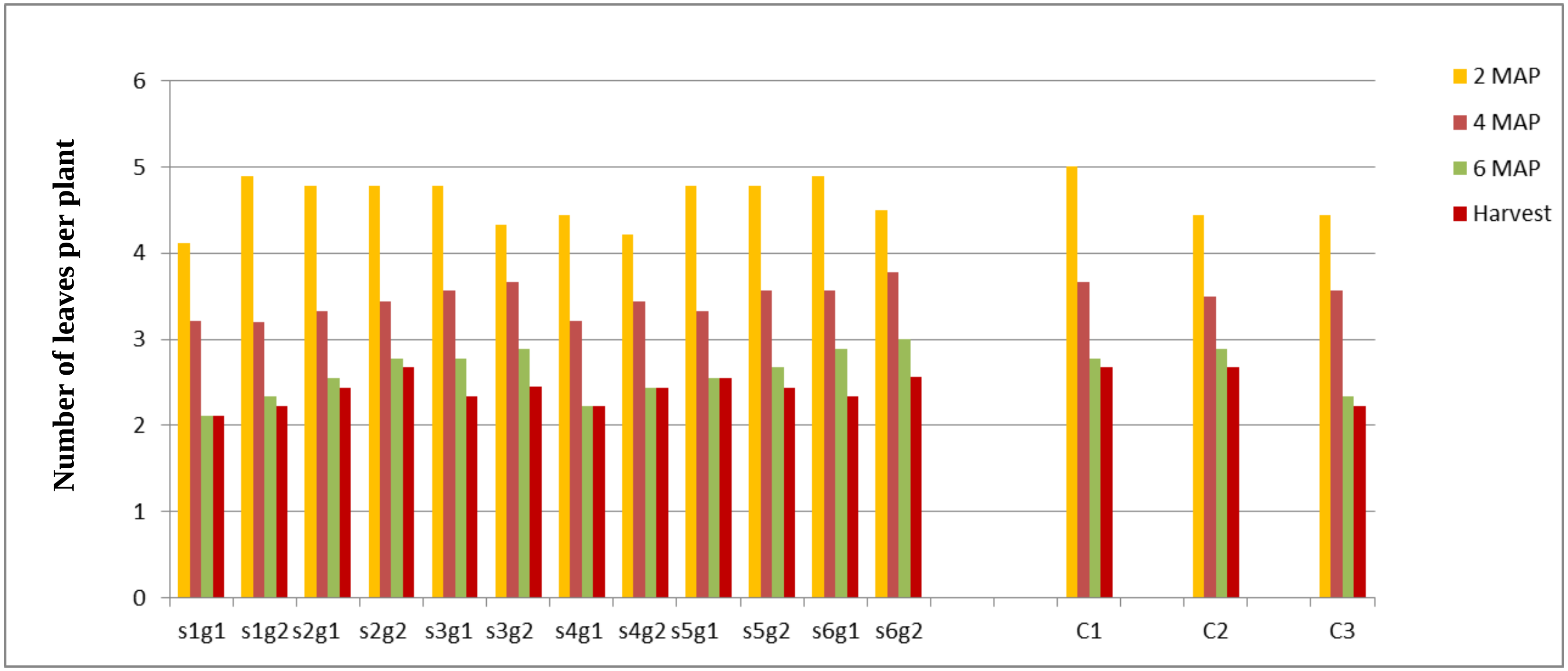


Fig. 6c. Effect of S x G interaction and treatment *vs*. control effect on number of leaves per plant during the first year

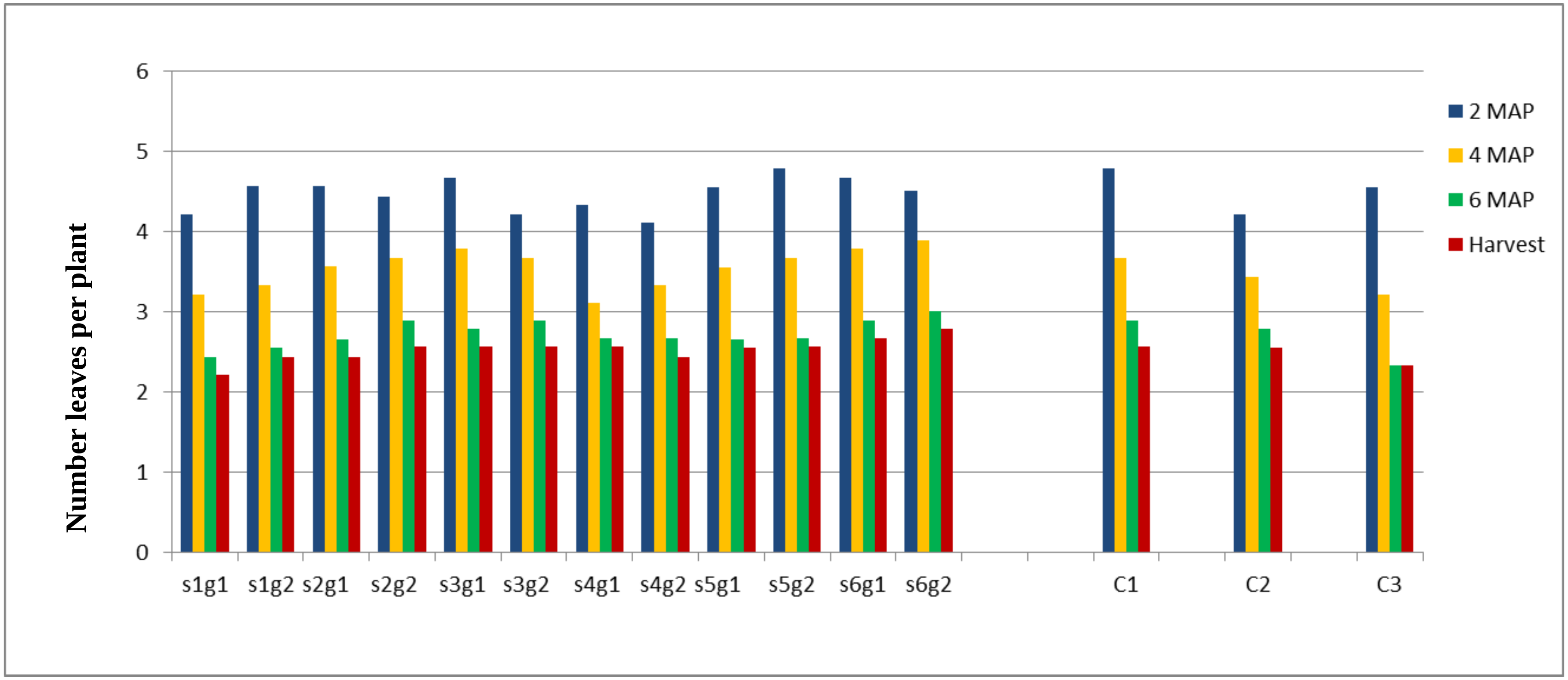


Fig. 6d. Effect of S x G interaction and treatment *vs*. control effect on number of leaves per plant during the second year

with FYM. The PGPR mix I is a microbial consortium, supplementing all the major nutrients which contains component cultures, *viz.*, *Azospirillum lipoferum, Azotobacter chroococcum, Bacillus megaterium* and *Bacillus sporothermodurans* as reported by Gopi *et al. (*2020). Vacheron *et al*. (2013) pointed out that PGPR can produce phytohormones and promote enzymatic activities which in turn may improve the root growth, uptake of minerals and water, and growth of the whole plant. Suja *et al*. (2017) and Soubeih Kh and Mahmoud (2019) also reported the enhanced plant height in taro by the application of biofertilizers. Vermiwash is coelomic fluid extract containing several enzymes and plant growth hormones like cytokinins, gibberlines and vitamins along with major and minor nutrients (Buckerfield *et al*., 1999). Vermiwash can favourably affect the growth and productivity of crop when applied as foliar spray (Verma *et al*., 2018). The favourable influence of vermiwash could be attributed to the presence of N in easily available form of mucus along with Nous excretory substances of worms, growth stimulating hormones and enzyme as reported by Tripathi and Bhardwaj (2004). In this context, Ansari *et al*. (2015) reported the excelled shoot growth and number of leaves of colocasia plants with vermiwash hydroponic solution.

In situ green manuring with daincha produced significantly taller plants, higher number of leaves per plant at 4 MAP and 6 MAP during the first year (Fig 5a and 6a) and significantly taller plants at 4 MAP during the second year (Fig. 5b) than *in situ* green manuring with cowpea. Significantly higher leaf area and LAI were also recorded by *in situ* green manuring with daincha at all stages of observation except at 2 MAP during the first year (Fig. 7a and 8a) and at 4 MAP and 6 MAP during the second year (Fig 7b and 8b). The green manure applied to soil undergoes a series of chemical changes wherein the carbon compounds are converted to carbon dioxide and water, the Nitrogenous compounds like protein are finally converted to nitrate and mineral constituents like P, K, calcium, magnesium *etc* present in the organic form or to some extent in the inorganic form are converted to more soluble forms and they become

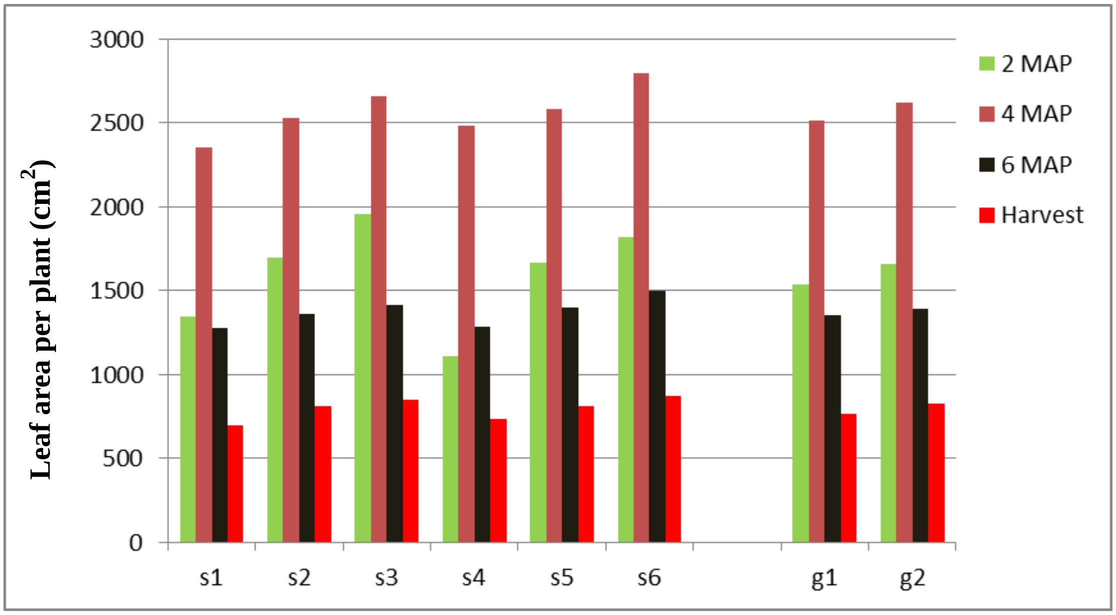
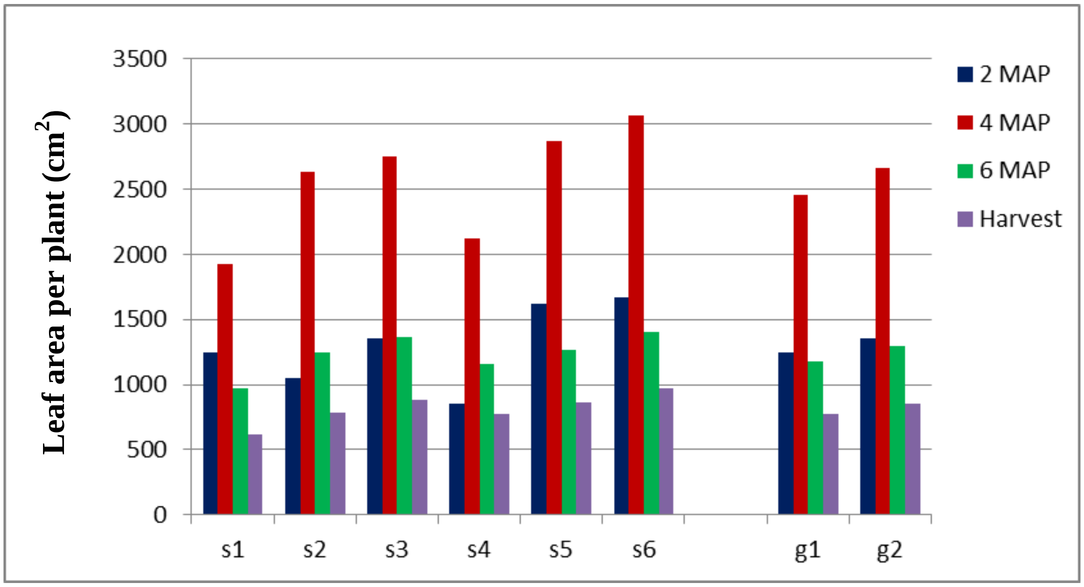


Fig. 7a. Effect of organic sources and *in situ* green manuring on leaf area per plant during the first year, cm^2



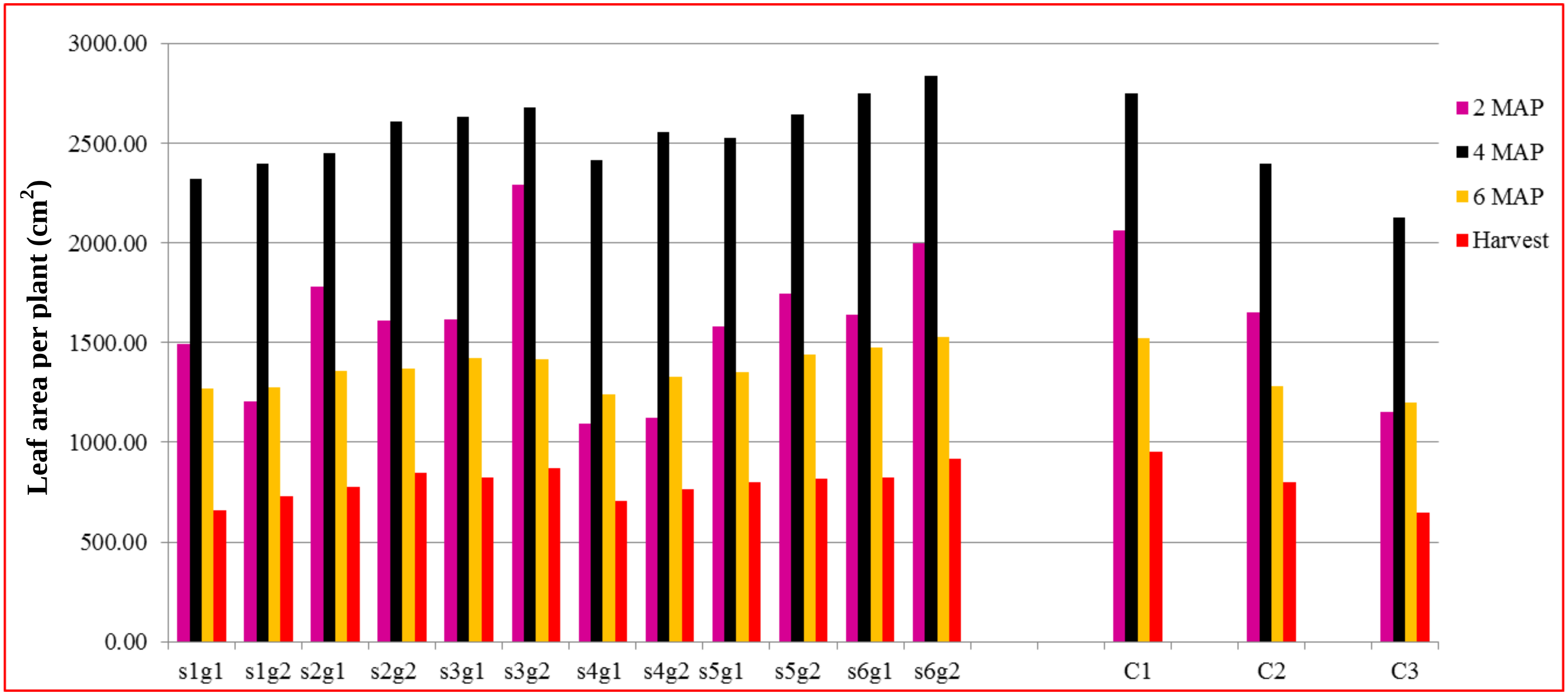


Fig. 7c. Effect of S x G interaction and treatment *vs*. control effect on leaf area per plant during the first year, cm^2

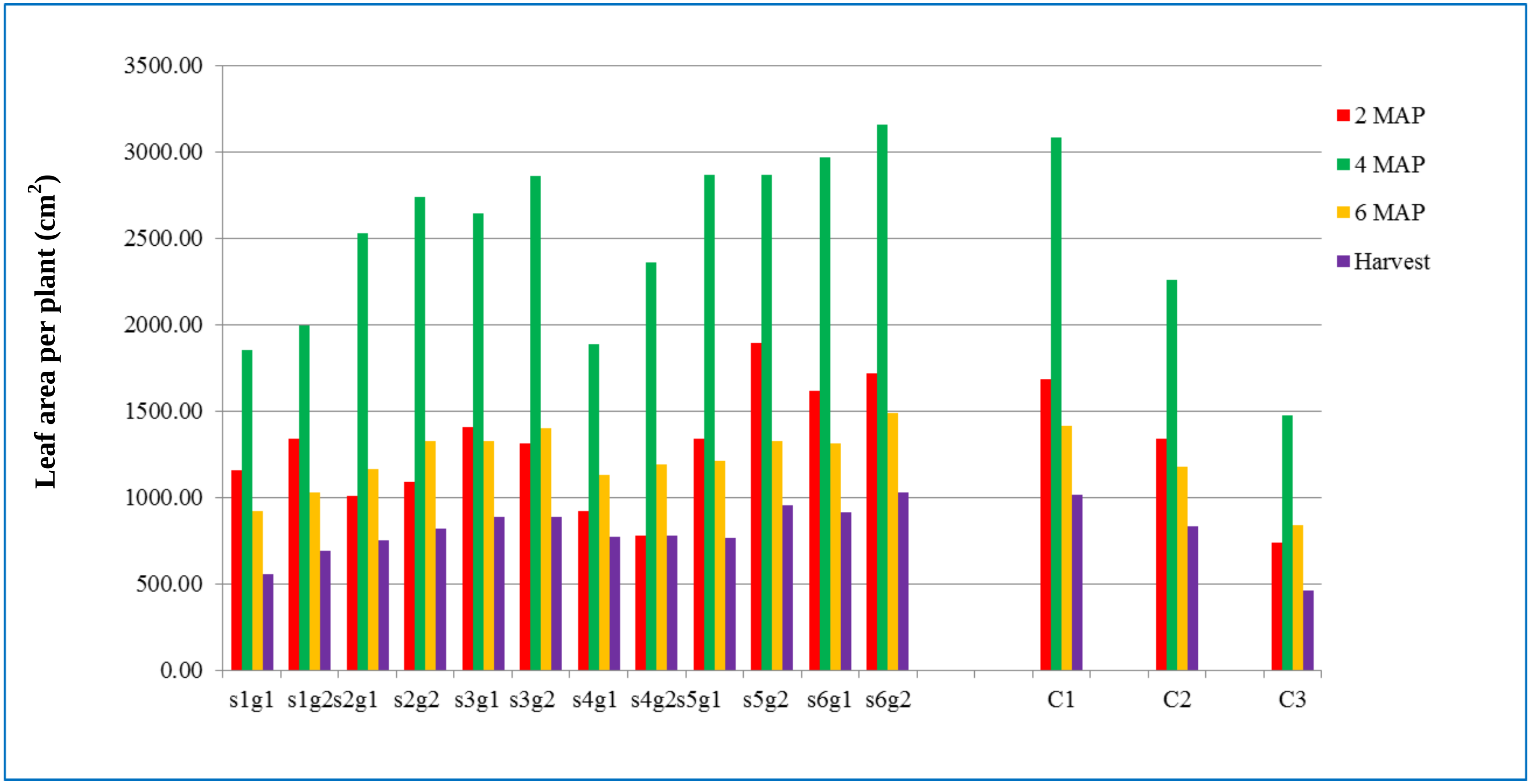


Fig. 7d. Effect of S x G interaction and treatment *vs*. control effect on leaf area per plant during the second year, cm^2

Fig. 5b. Effect of organic sources and *in situ* green manuring on plant height during the second year, cm

RESULTS

Fig. 7b. Effect of organic sources and *in situ* green manuring on leaf area per plant during the second year, cm^2

readily available to the succeeding cop (Palaniappan and Annadurai, 1999). The superiority of *in situ* green manuring with diancha over cow pea in producing higher growth parameters may be due to the higher biomass production and higher N and P content of daincha compared to cowpea (Table 6) and higher mineralization of daincha than cowpea (Dey and Jain, 1997). Irin *et al.* (2019) reported the higher biomass production of daincha compared to cow pea. This combined with higher nutrient content might have improved the available soil nutrient content and uptake upon decomposition which in turn would have resulted in higher growth parameters. In agreement with this, several researchers have reported their findings on higher biomass production and nutrient accumulation in daincha. Khind *et al.* (1987) opined that, daincha could produce 21.1 t ha^{-1} of green biomass and accumulate about 133 kg N ha^{-1}. Singh and Shivay (2014) stated that the increased of biomass accumulation of sesbania might be due to its fast and determinate growth habit leading to enhanced biomass incorporation and nutrient availability in soil. Sanjay *et al*. (2015) reported that among the summer green manuring crops, daincha recorded significantly higher fresh and dry matter accumulation than cowpea .

Considering SxG interaction, application of poultry manure along with wood ash, PGPR mix I and vermiwash combined with *in situ* green manuring with daincha (s_6g_2) produced the tallest plants at 4 MAP and 6 MAP during the first year (Fig. 5c) which was comparable with s_6g_1 (application of poultry manure along with wood ash, PGPR mix I and vermiwash combined with *in situ* green manuring with cowpea) at 4 MAP and with s_6g_1 and s_5g_2 (application of poultry manure along with wood ash and PGPR mix I with or without vermiwash combined with *in situ* green manuring with cowpea or daincha) at 6 MAP. At harvest, the highest plant height was recorded with application of poultry manure along with wood ash, PGPR mix I and vermiwash combined with *in situ* green manuring with cowpea and was equally effective as s_6g_2 and s_5g_1. During the second year, S x G interaction was significant only at harvest, the

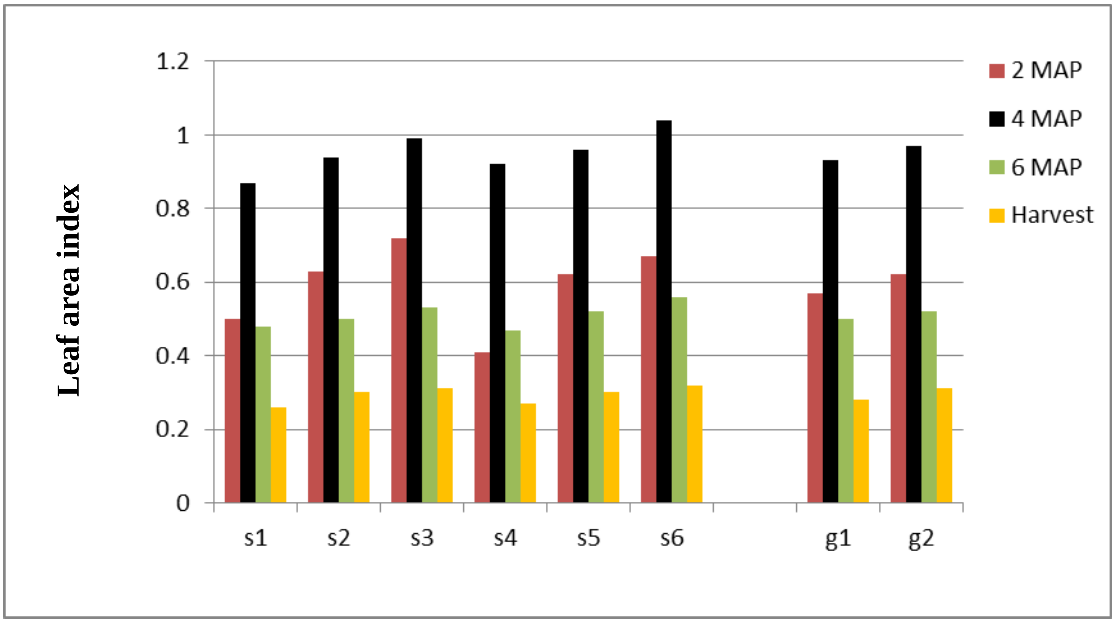


Fig. 8a. Effect of organic sources and *in situ* green manuring on leaf area index during the first year

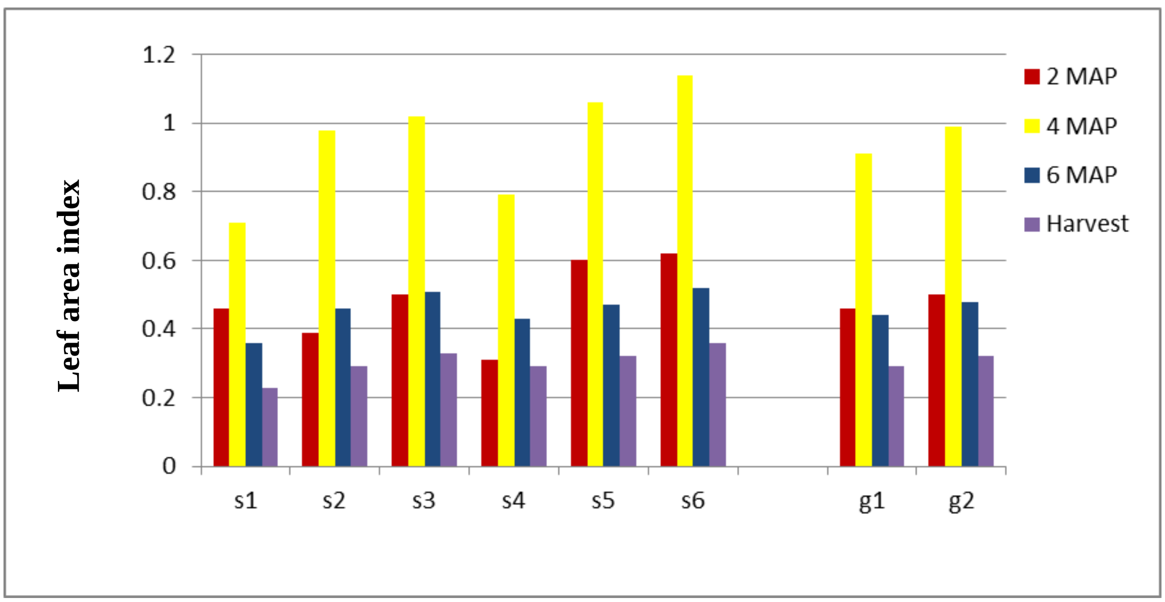


Fig. 8b. Effect of organic sources and *in situ* green manuring on leaf area index during the second year

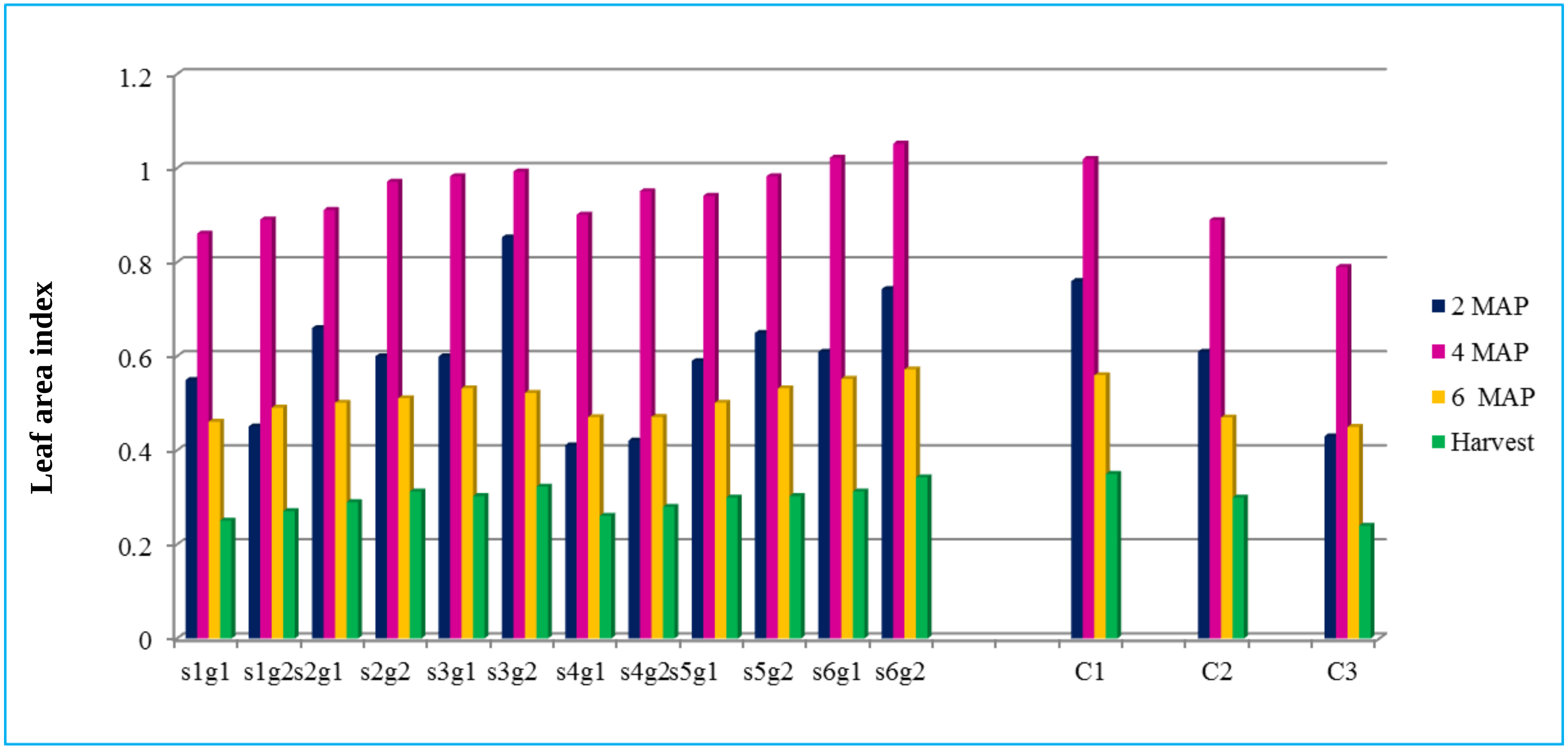


Fig. 8c. Effect of S x G interaction and treatment *vs*. control effect on leaf area index during the first year

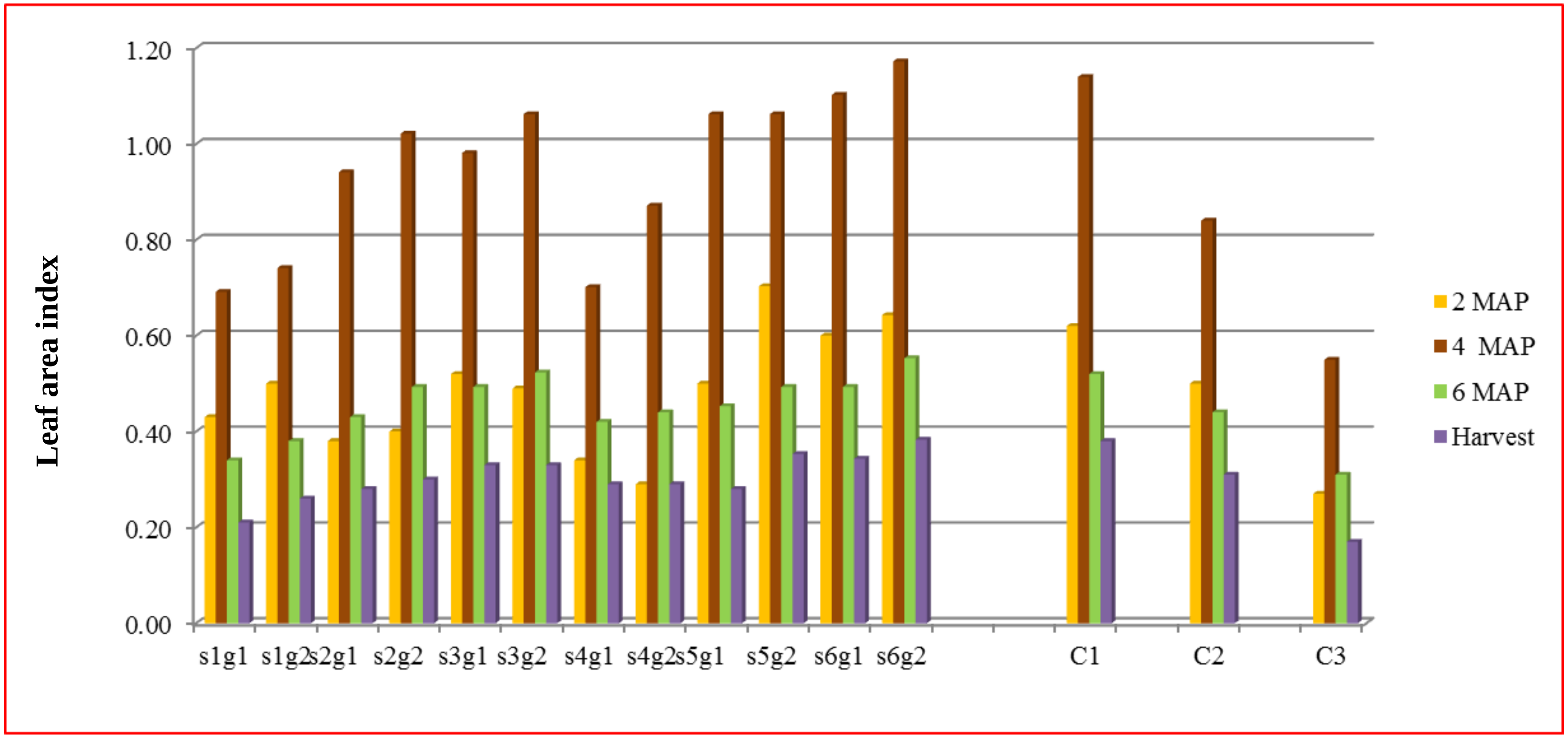


Fig. 8d. Effect of S x G interaction and treatment *vs*. control effect on leaf area index during the second year

treatment combination s_6g_1 produced more plant height (Fig. 5d), but was on par with s_5g_2 and s_5g_1. The number of leaves per plant was significantly influenced by SxG interaction only at 2 MAP during the first year and s_1g_2 and s_6g_1 produced the more leaves (Fig. 6c) and was on par with, s_5g_2, s_2g_1, s_2g_2, s_3g_1, s_5g_2, s_4g_1 and s_5g_1. Application of poultry manure along with wood ash, PGPR mix I and vermiwash combined with *in situ* green manuring with daincha (s_6g_2) recorded significantly the highest leaf area per plant and LAI at 4 MAP and 6 MAP during the first year (Fig. 7c and 8c) and at 4 MAP during the second year (Fig. 7d and 8d). The results pointed out the favourable influence of application of poultry manure along with wood ash, PGPR mix I and vermiwash on vegetative growth of taro. The effect of *in situ* green manuring with daincha or cow pea was equally effective when it was combined with application of poultry manure along with wood ash, PGPR mix I and vermiwash in case of plant height, while *in situ* green manuring with daincha had superior effect than cowpea in case of leaf area per plant and LAI. Favourable effects of main effects of treatments comprising poultry manure, wood ash, PGPR mix I and vermiwash as discussed earlier would have also reflected on plant height when combined with the effect of green manure. The rate of leaf expansion is an important determinant of the leaf area and leaf size. However when the above organic sources were combined with *in situ* green manuring with daincha it promoted the leaf area compared to cowpea. The relationship between the N supply and rate of leaf expansion probably due to the stimulation of rate of cell division has been suggested by Vos and Biemond (1992). The higher biomass production and subsequent accumulation of relatively higher quantity of N in daincha would have therefore contributed to the higher rate of leaf expansion and greater leaf area.

While comparing the organic nutrition treatments with nutrient management through chemical fertilizers as per KAU POP, it was found that, in general the treatments s_6g_2, s_6g_1, s_5g_2, s_5g_1 and s_3g_2 were equally effective as chemical nutrient management in all growth parameters *viz*. plant height (Fig. 5c and 5d), number of leaves per plant (Fig. 6c and 6d), leaf area (Fig. 7c and 7d) and LAI (Fig. 8c and 8d) during both years. In case of plant height, s_6g_2 at 4 MAP and s_6g_1 at harvest were significantly superior to C_1. The on par effect of these treatments with the C_1 indicates the efficiency of organic treatments as that of chemical nutrient management in the growth of taro. Jayapal (2017) observed that the vegetative characters like plant height, leaf number per plant and LAI of tannia were higher under organic nutrition compared to INM at all growth stages. Suja *et al.* (2017) also noted similar observations that the organic management significantly enhanced the plant height at harvest stage compared to conventional management in taro. This could be due to gradual availability of nutrients by decomposition of organic manures throughout the growth period and reduced loss of nutrients compared to readily available nutrients from chemical fertilizers. The inorganic source of nutrients was subjected to various losses after application (Nedunchezhiyan *et al*., 2017) and when inorganic fertilizers are applied at an early growth period, availability of nutrients is reduced during the later growth stages of long duration crops like taro.

While comparing C_2 (nutrient management as per KAU organic Adhoc POP) with treatments, in general, s_5g_1, s_5g_2, s_6g_1, s_6g_2, s_3g_1 and s_3g_2 were recorded significantly higher plant height than C_2 at all stages from 4 MAP onwards (Fig. 5c and 5d). The treatments s_6g_1 and s_6g_2 at 4 MAP and s_2g_2, s_3g_1, s_3g_2, s_5g_2, s_6g_1 and s_6g_2 at 6 MAP during the first year and s_5g_1, s_5g_2, s_6g_1, s_6g_2, s_2g_2, s_3g_1 and s_3g_2 at 4 MAP during the second year recorded significantly higher leaf area and LAI compared to C_2 (Fig. 7c, 7d, 8c and 8d). Regarding number of leaves per plant, all treatments during both years except s_1g_1, s_1g_2 and s_4g_1 at 6 MAP during the first year were produced statistically equal number of leaves as that of C_2 (Fig. 6c and 6d). The superiority of organic treatments in growth parameters compared to KAU organic POP indicated the higher growth promoting effect of treatments especially s_5g_1, s_5g_2, s_6g_1, s_6g_2, s_3g_2 and s_3g_1 compared to the existing organic management practice. This points out the additional benefits of like PGPR mix I and vermiwash over and above the organic adhoc POP. In the case of s_5g_1, s_5g_2, s_6g_1 and s_6g_2 quick nutrient release of poultry manure compared to FYM (used in KAU Adhoc organic POP) also might have enhanced the plant growth. Studies conducted by Dey *et al*. (2019) on nutrient release kinetics of organic manures pointed out that the poultry manure releases more P than FYM and the total concentration of P in organic amendments was signifcantly and positively correlated to fulvic and humic acid concentrations present in organic amendment. The plant growth promoting effect of humic and fulvic acid has been previously described by Suh *et al*. (2014) in potato and Hita *et al*. (2020) in cucumber.

While comparing organic treatments with absolute control (C_3), in general organic treatments performed better than absolute control in all growth parameters. Taro is a crop which develops large leaf area and accumulates substantial amount of dry matter and hence it requires sufficient quantity of nutrients especially N (Manrique, 1994). Therefore the poor growth performance of the crop under absolute control without any application of nutrients could be due to the nutrient stress.

The effect of organic sources and *in situ* green manuring in general reflected in the superiority of organic treatments in growth parameters compared to absolute control.

5.1.2 Yield Attributes and Yield

The organic sources varied in their influence on number of cormels per plant and mean weight of cormel during both the years (Fig. 9a and 9b). An inverse relationship was found between number and mean weight of cormels as usually noticed in the case of tuber crops. During the first year, the application of poultry manure along with wood ash, PGPR mix I and vermiwash (s_6) recorded the highest mean weight of cormel and was equally effective as s_3 in which FYM along with wood ash, PGPR mix I and vermiwash were applied. The lowest mean cormel weight was recorded with s_1 in which only FYM and wood ash were applied, while it recorded the highest number of cormels per plant. During the second year, FYM application along with wood ash, PGPR mix I and vermiwash registered the highest mean cormel weight, however it was equally effective as application of poultry manure or FYM along with wood ash and PGPR mix I with or without vermiwash. The organic source containing only poultry manure and wood ash recorded the lowest value of mean cormel weight, but the highest number of cormels per plant. Variation in cormel to corm ratio due to organic sources was significant only during the second year and the organic source s_5 (application of poultry manure, wood ash and PGPR mix I) recorded the highest value while all organic sources were equally effective as s_5 except s_3.

Cormel yield was the highest when poultry manure, wood ash, PGPR mix I and vermiwash were applied (s_6) during both the years (Fig. 10a). The s_6 also registered the highest corm yield during the first year with the same trend under pooled analysis (Fig. 10b). During the second year, the highest corm yield was recorded with the organic source s_3 (FYM + wood ash + PGPR mix I + vermiwash). During the first year the s_5 wherein poultry manure along with wood ash and PGPR mix I were applied was equally effective as s_6 in respect to both corm and cormel yield. During the second year s_6 was found to be on par with s_5 and s_3 in case of cormel yield. While pooled data followed the same trend noticed during the first year in case of cormel yield. The organic sources s_3 and s_6 were on par each other during the second year and for pooled analysis in case of corm yield.

The combined effect of poultry manure, PGPR mix I and vermiwash might have resulted in the higher yield of taro under these treatments. Poultry manure is a bulky organic manure having higher content of all essential nutrients including micro nutrients. Poultry manure helps to improve soil condition, increase water holding capacity of soil and provide more macro as well as micro nutrients than FYM (Subedi *et al*., 2018). A study on periodic release of nutrients from poultry manure by Dey *et al*. (2019) indicated that there was a higher release of Zn and B from poultry manure and in case of B, the percentage of release was upto 97.70 per cent. The physiological effect of Zn and B on tuberization was studied by Puzina (2004) in potato wherein the supply of both these nutrients resulted a shift in hormonal response of the plant. The zinc treatment was found to stop the apical dominance and increase the weight of tuber due to increased number of phellem (cork) cell layers. The boric acid treatment in turn increased cell diameter in the tuber perimedullary zone resulting in tuber growth and an increase in tuber weight per plant. The favourable effect of poultry manure in particular on tuber yield and yield attributes could be therefore considered as a direct influence of Zn and B on tuberization. Increased cormel yield of taro with poultry manure application was previously reported by Osundare (2004) and Hamma *et al*. (2014).

The nutrient supplementing ability and growth promoting effect of PGPR mix I as explained earlier also might have contributed the higher yield when used in conjunction with poultry manure with these treatments. Jayapal *et al.* (2013) reported the higher tuber yield by application of PGPR mix I in Chinese potato. Ranjan *et al.* (2013) concluded that PGPR produce biologically active substances like vitamins, gibberellin, nicotinic acid and indole acetic acid which have a growth promoting effect on crops. These findings are in agreement with that of Soubeih Kh and Mahmoud (2019), who reported the higher fresh weight of cormels in taro by the application of mixture of *Azotobacter chrococcum* (N Fixing Bacteria), *Bacillus megaterium* var. *phosphaticum* (Phosphate Dissolving Bacteria) and *Bacillus subtilis* and *Bacillus mucilaginosus* (K Dissolving Bacteria).

Use of vermiwash might have further accentuated the beneficial effect of poultry manure. Vermiwash is very good liquid manure which favourably affect the growth and productivity of crop when applied as foliar spray (Verma *et al*., 2018). The highest yield obtained by vermiwash (10 %) along with vermi compost application in elephant foot yam as reported by ICAR-CTCRI (2015) is in agreement with this.

In situ green manuring with daincha (g_2) resulted in higher mean cormel weight, cormel yield and corm yield during both the years (Fig. 9a, 9b, 10a and 10b) compared to g_1 (*in situ* green manuring with cowpea). As explained earlier, the higher biomass production of daincha compared to cowpea resulted in the higher soil nutrient availability and it might have resulted in higher yield.

The treatment combination s_3g_2 recorded the highest mean cormel weight during both the years (Fig. 9c and 9d). During the first year s_3g_2 was on par with s_6g_2 only, while during the second year s_3g_2 was on par with s_5g_2 and s_6g_2. The significant effect of interaction on cormel to corm ratio was noticed only during the second year. The treatment combination s_5g_1 registered the highest value which was on par with s_2g_2 and s_4g_1. The treatment combination s_6g_2 (application of poultry manure along with wood ash, PGPR mix I and vermiwash + *in situ* green manuring with daincha) recorded the highest cormel yield during both the years (Fig. 10c). Corm yield varied significantly by SxG interaction only during the first year (Fig. 10d) and the treatment combination s_6g_2 recorded higher corm yield. The treatment combinations s_6g_1, s_5g_2, s_5g_1, s_3g_2 and s_2g_2 was found equally effective as s_6g_2 in case of yield parameters of taro under organic nutrition. These results followed the same trend as that of the main effects of treatments on corm and cormel yield of taro. Improvement in growth characters coupled with favourable physiological effects on tuberization due to the application of poultry manure, PGPR mix I and vermiwash along with *in situ* green manuring with daincha might have resulted in higher cormel as well as corm yields under these treatments.

Significant difference was observed between organic treatments and C_1 (nutrient management through chemical fertilizers as per KAU POP) in case of yield parameters such as mean weight of cormel (Fig. 9c and 9d), corm (Fig. 10d) and cormel yield (Fig.10c). The treatments s_3g_2, s_6g_1 and s_6g_2 recorded significantly higher mean weight of cormel than C_1 during the first year. In general, the organic treatments s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 were found to be equally effective as C_1 in

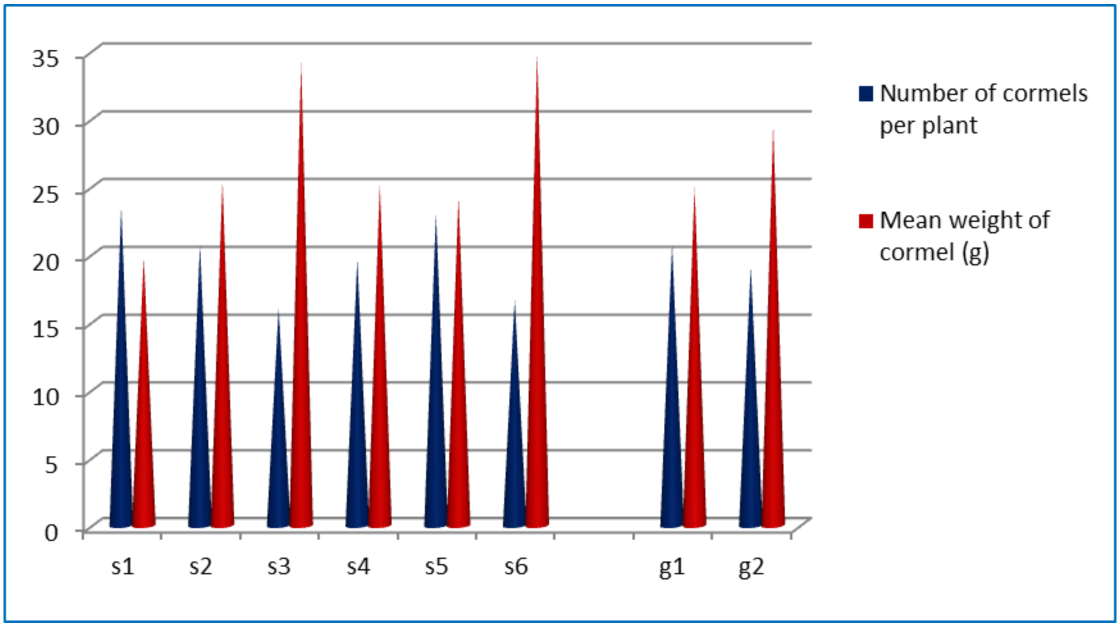


Fig. 9a. Effect of organic sources and *in situ* green manuring on number of cormels per plant and mean weight of cormel during the first year

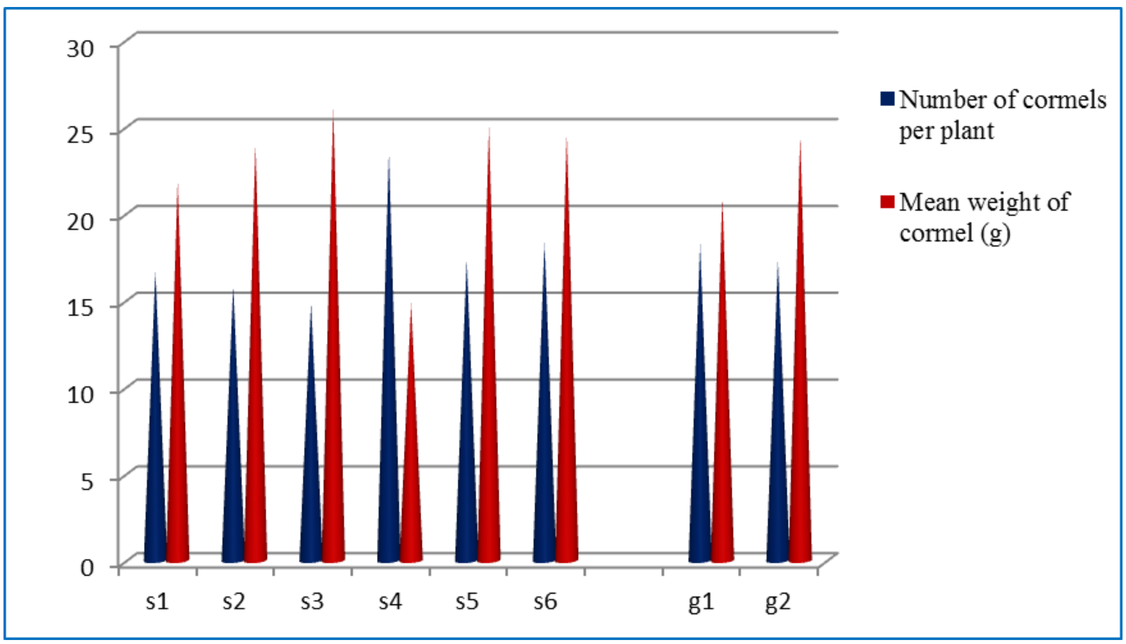


Fig. 9b. Effect of organic sources and *in situ* green manuring on number of cormels per plant and mean weight of cormel during the second year

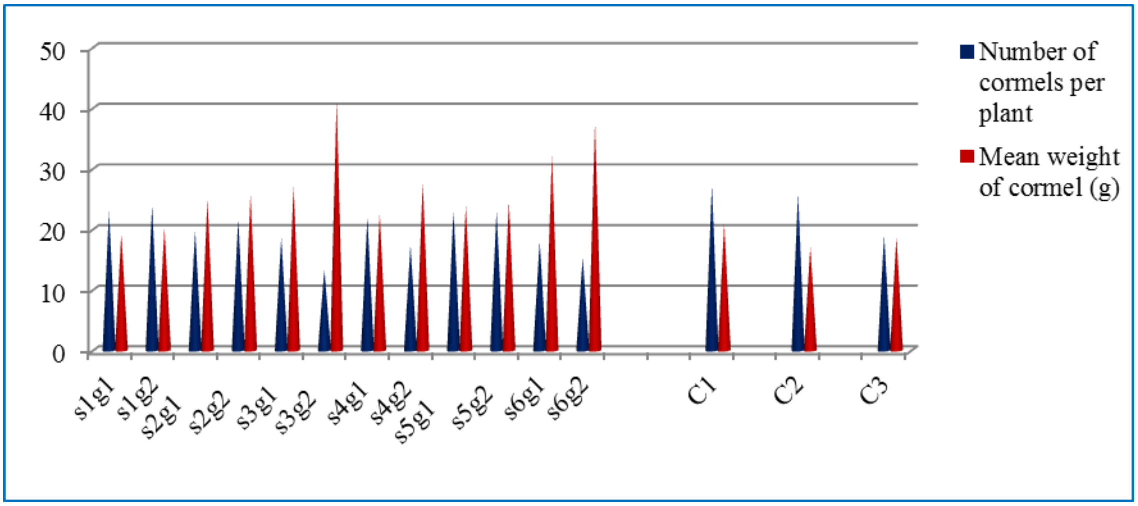


Fig. 9c. Effect of S x G interaction and treatments *Vs*. control effect on number of cormels per plant and mean weight of cormel during the first year

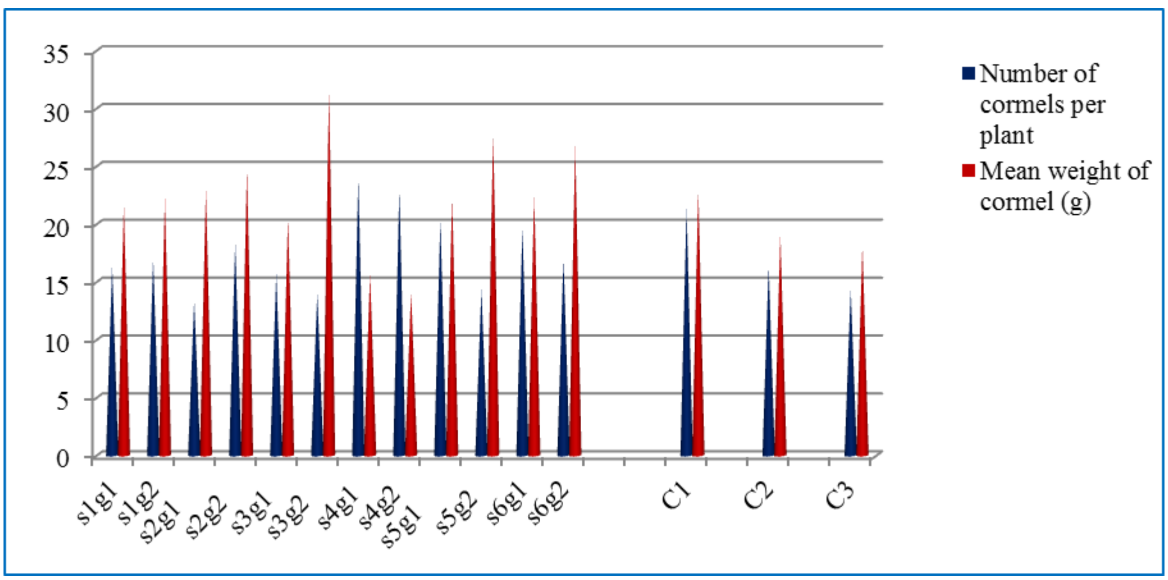


Fig. 9d. Effect of S x G interaction and treatments *Vs*. control effect on number of cormels per plant and mean weight of cormel during the second year

corm and cormel yield of taro. The treatment s_6g_2 recorded a 0.90 percentage increase of cormel yield over chemical nutrient management during the first year and a 2.67 percentage increase of corm yield over chemical nutrient management for pooled mean. As in the case of growth characters, some of the organic treatments were found to be as effective as nutrient management through chemical fertilizers in case of yield parameters also. Chastain *et al*. (1999) stated that poultry manure produce better results than pure inorganic fertilizer treatment, as it can provide all the 13 micronutrients in considerable amount which inorganic fertilizer cannot provide. The result is also in agreement with the findings of Suja *et al.* (2017) who reported similar performance of organic system to that of conventional with slight yield reduction (−5%) at on station trial and 29 per cent higher yield at farm level over chemical based farming. The findings of Suja *et al*. (2009) in tannia, Suja (2013) in yams and Suja *et al*. (2010) in elephant foot yam also corroborates the result of present study.

Mean weight of cormel showed significant difference between treatments and C_2 [nutrient management as per KAU organic POP (Adhoc)] during both the years. The treatment combinations s_3g_1, s_3g_2, s_4g_2, s_6g_1 and s_6g_2 during the first year and s_3g_2, s_5g_2 and s_6g_2 during the second year registered significantly higher mean weight of cormels than C_2 (Fig. 9c and 9d). Significant difference was observed between treatments and control C_2 during both the years in case of cormel yield (Fig. 10c), and the treatments s_2g_2, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 recorded significantly higher cormel yield than C_2. The corm yield showed significant difference only during the first year and the treatments s_2g_2, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 recorded significantly higher corm yield than C_2 (Fig. 10d). The treatment s_6g_2 recorded a 37.83 percentage and 27.82 percentage increase of cormel yield and corm yield respectively over KAU organic POP for pooled mean. The enhancement of growth parameters by the organic treatments over Adhoc organic KAU POP reflected in the cormel yield also.

The organic treatment combinations s_3g_2, s_4g_2, s_6g_1 and s_6g_2 during the first year and s_3g_2, s_5g_2 and s_6g_2 during the second year recorded significantly higher mean weight

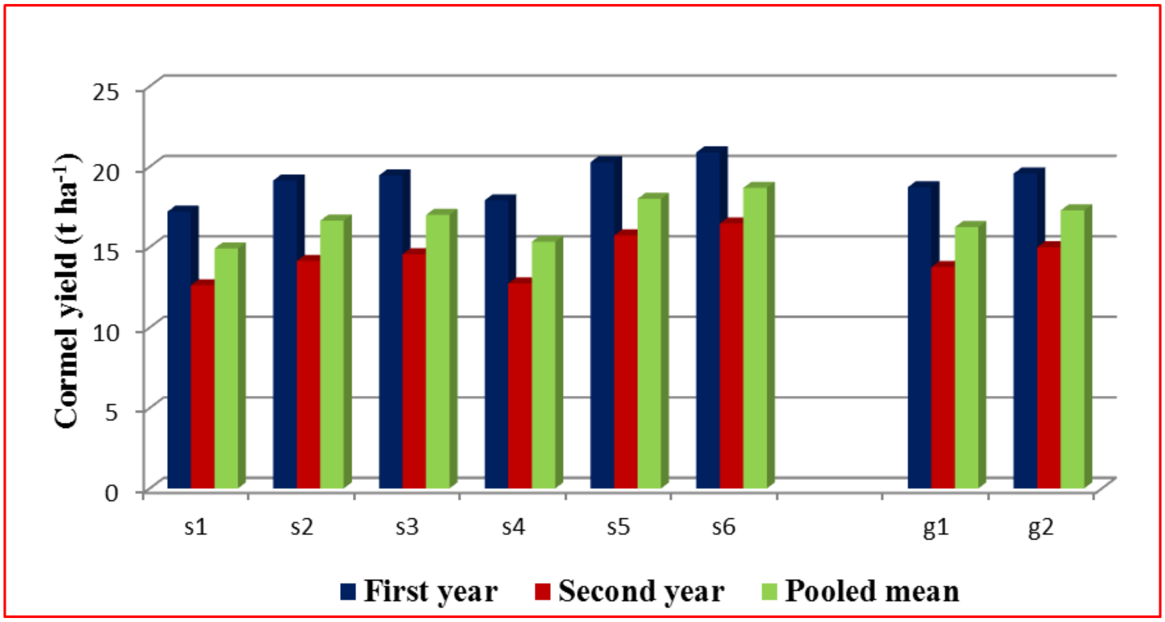


Fig. 10a. Effect of organic sources and *in situ* green manuring on cormel yield, t ha^{-1}

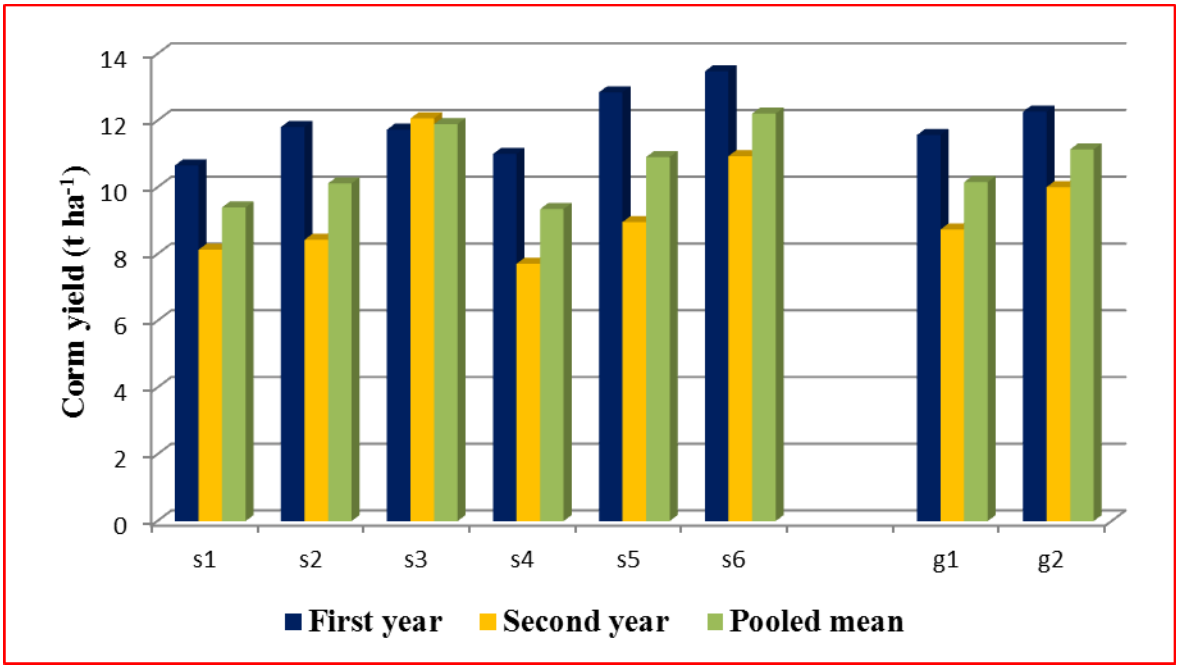


Fig. 10b. Effect of organic sources and *in situ* green manuring on corm yield, t ha^{-1}

of cormel than absolute control (Fig. 9c and 9d). Both cormel yield (Fig. 10c) and corm yield (Fig. 10d) showed significant variation between treatments and C_3 during both the years. All treatments except s_1g_1 in case of cormel yield and all treatments in case of corm yield for pooled mean recorded significantly higher value than C_3 (absolute control). Tuber crops are nutrient exhausting crops (Suja *et al.*, 2016) and the soil nutrients are to replenished to get a higher yield. In contrast to the application of chemical sources of fertilizers which quickly release nutrients to the soil, the organic sources slowly release nutrients to the soil. As observed in the case of growth attributes, the higher yield of organic treatments over absolute control is undoubtedly due to the effect of applied organic sources and *in situ* green manuring which enhanced soil nutrient status and coupled with direct feeding of nutrients through vermiwash spraying. Similar trends were reported earlier by Stockdale *et al*. (2001)

5.1.3 Physiological Attributes

The treatments exerted profound influence on dry matter production during both the years. Among the organic sources, poultry manure application along with wood ash, PGPR mix I and vermiwash (s_6) recorded the highest dry matter production at harvest during both the years (Fig. 11a). During the first year, poultry manure application along with wood ash, PGPR mix I and vermiwash was found equally effective as poultry manure application along with wood ash and PGPR mix I without vermiwash. While during the second year poultry manure application along with wood ash, PGPR mix I and vermiwash was found equally effective as FYM application along with wood ash, PGPR mix I and vermiwash. *In situ* green manuring with daincha registered significantly higher dry matter production at harvest than *in situ* green manuring with cowpea during both the years (Fig. 11a). The higher plant height, number of leaves, leaf area, LAI and yield produced due to organic source poultry manure application along with wood ash, PGPR mix I and vermiwash and *in situ* green manuring with daincha could be considered responsible for higher dry

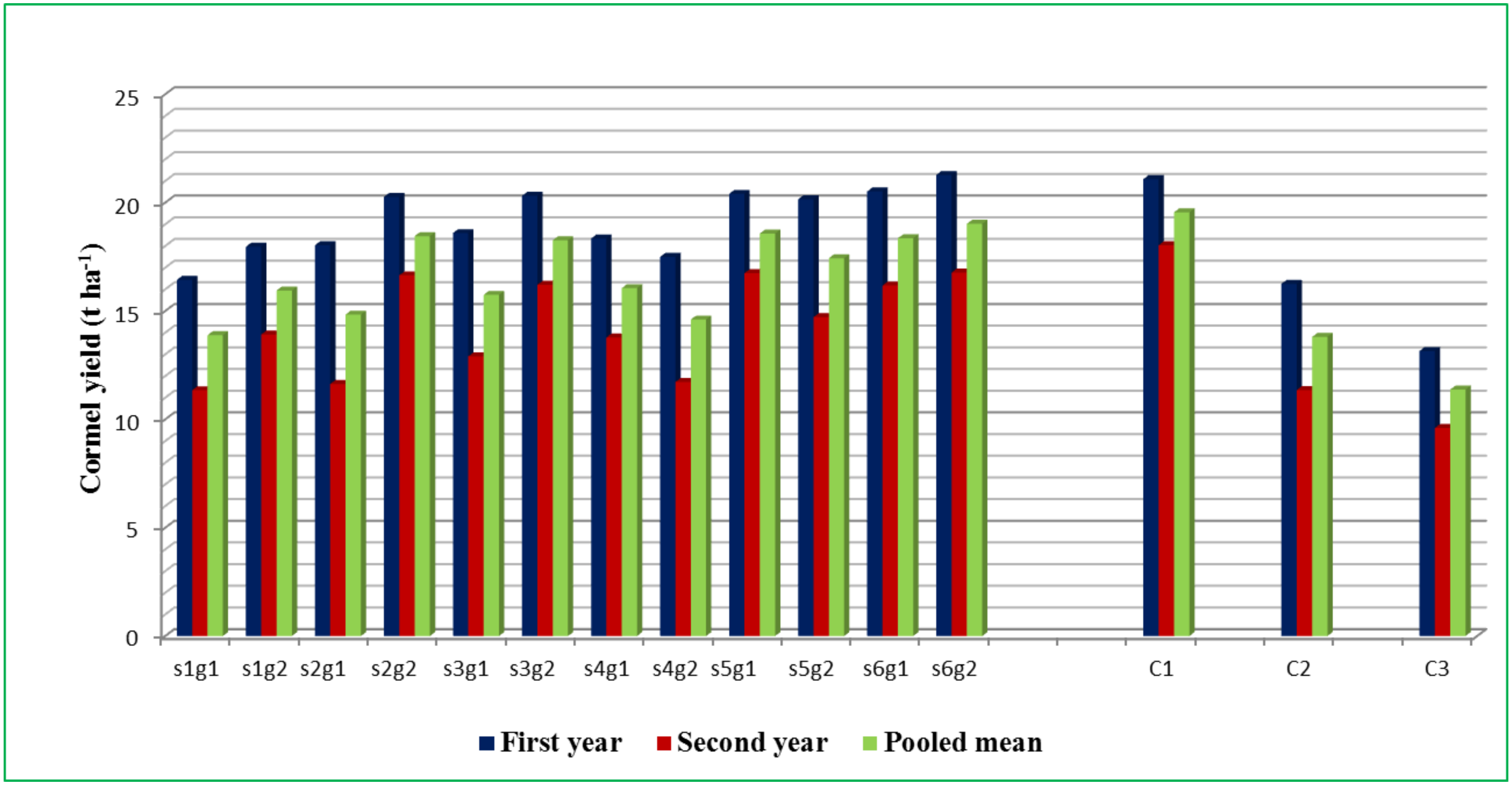


Fig. 10c. Effect of S x G interaction and treatments *Vs*. control effect on cormel yield, t ha^{-1}

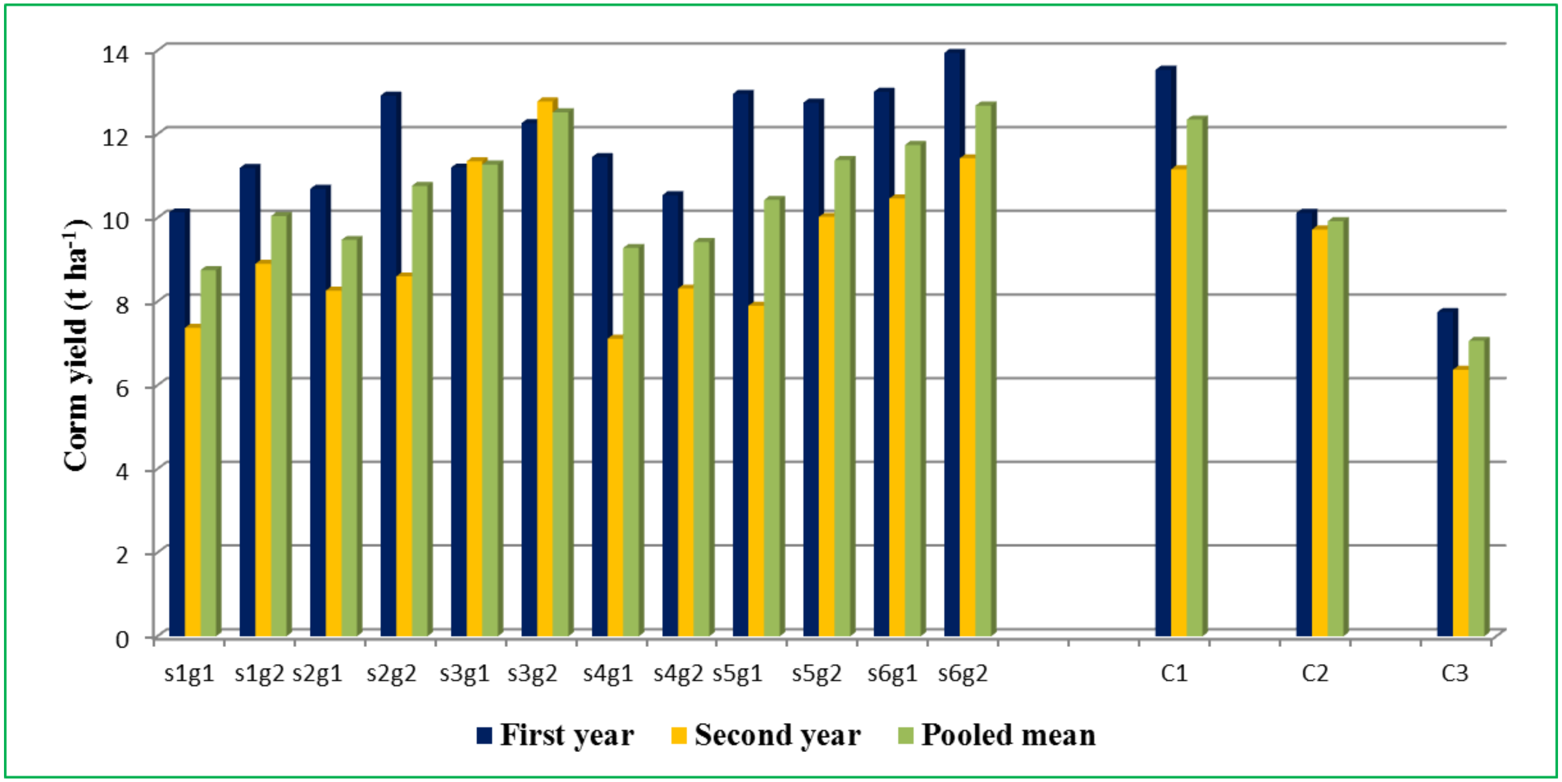


Fig. 10d. Effect of S x G interaction and treatments *Vs*. control effect on corm yield, t ha^{-1}

matter production under these treatments. The higher leaf area produced due to these treatments would have improved the production of assimilates and resulted in higher dry matter production. Similar observation was made by Roychoudhury (1995) who reported that high LAI and associated high dry matter production are two major physiological attributes for better yield in Colocasia.

The interaction had significant effect on dry matter production at harvest during both the years (Fig.11b). During the first year, treatment combination s_6g_2 (application of poultry manure along with wood ash, PGPR mix I and vermiwash + *in situ* green manuring with daincha) recorded significantly the highest dry matter production at harvest. During the second year, s_3g_2 (application of FYM along with wood ash, PGPR mix I and vermiwash + *in situ* green manuring with daincha) and s_6g_2 (application of poultry manure along with wood ash, PGPR mix I and vermiwash + *in situ* green manuring with daincha) was equally effective in dry matter production at harvest. The impact of these treatments on growth and yield of taro might have resulted in higher dry matter production. Higher leaf area recorded by the treatments intercepted more light and produced more photosynthates resulting in higher dry matter production by the treatments. According to Goenaga (1995) absence of an optimum LAI for longer period of time can prevent the realization of higher dry matter yield in *Colocasia esculenta*. Harvest index was significantly influenced by SxG interaction during the second year and the treatment combinations s_5g_1 and s_2g_2 recorded the highest harvest index, however these treatments were on par with s_1g_1, s_1g_2, s_4g_1, s_5g_2, s_6g_1 and s_6g_2.

In general, the organic treatment combinations s_2g_2, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 were on par with nutrient management through chemical fertilizers (C_1) in dry matter production at harvest (Fig. 11b). As in the case of growth and yield of taro, these organic treatments were equally effective as nutrient management through chemical fertilizers with respect to the dry matter production also. Significant difference was observed during the first year between organic treatments and nutrient management as per KAU organic POP- Adhoc (C_2). Except s_1g_1, s_1g_2 and s_4g_2, all

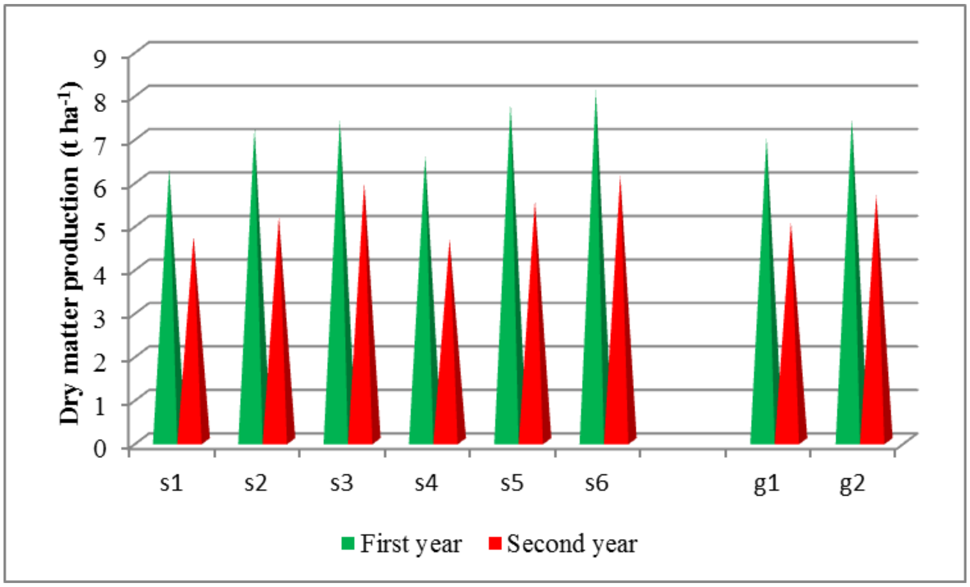


Fig. 11a. Effect of organic sources and *in situ* green manuring on dry matter production, t ha^{-1}

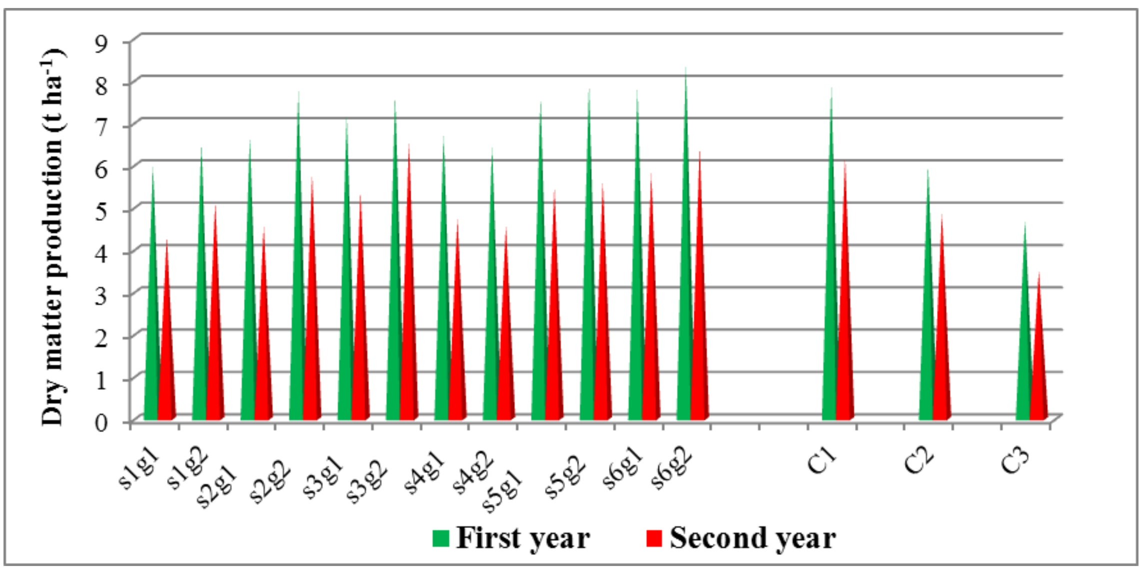


Fig. 11b. Effect of S x G interaction and treatments *Vs*. control effect on dry matter production, t ha^{-1}

other treatment combinations resulted in significantly higher value of dry matter production compared to C_2 (Fig. 11b). Harvest index also showed significant variation between treatments and control C_2 during the second year, wherein s_2g_2 and s_5g_1 were significantly superior to C_2. All organic treatments were significantly superior to absolute control with respect to dry matter production during both the years (Fig. 11b). The higher growth and yield produced under the organic nutrition treatments compared to absolute control invariably resulted in higher total dry matter production of the crop. The organic system of cultivation producing higher dry matter yield in taro compared to the conventional method was previously reported by Suja *et al* (2017).

5.1.4 Quality Attributes

Quality characters of cormel such as starch content and total sugar were significantly influenced by organic sources during both the years. The crude protein and crude fibre showed significant variation only during the second year and oxalic acid content varied significantly only during the first year. Poultry manure application along with wood ash, PGPR mix I and vermiwash (s_6) recorded the highest starch content (Fig. 12) during both the years and the highest total sugar content (Fig.13), the highest crude protein and the lowest crude fibre content (Fig.16) during the second year. While the highest total sugar content during the first year was recorded by organic source s_3 (FYM + wood ash + PGPR mix I + vermiwash). Application of FYM or poultry manure along with wood ash, PGPR mix I and vermiwash (s_3 or s_6) recorded the lowest oxalic acid content during the first year (Fig.15).

The nutrients play an important role in the quality parameters of crops. Yossif and Ibrahim (2013) stated that N plays a great role in synthesis of protein and P plays an important role in starch synthesis. The organic sources FYM or poultry manure in presence of PGPR mix I was found to promote the protein, starch and sugar content of the cormels while reducing the fibre content in the present study. The N and P

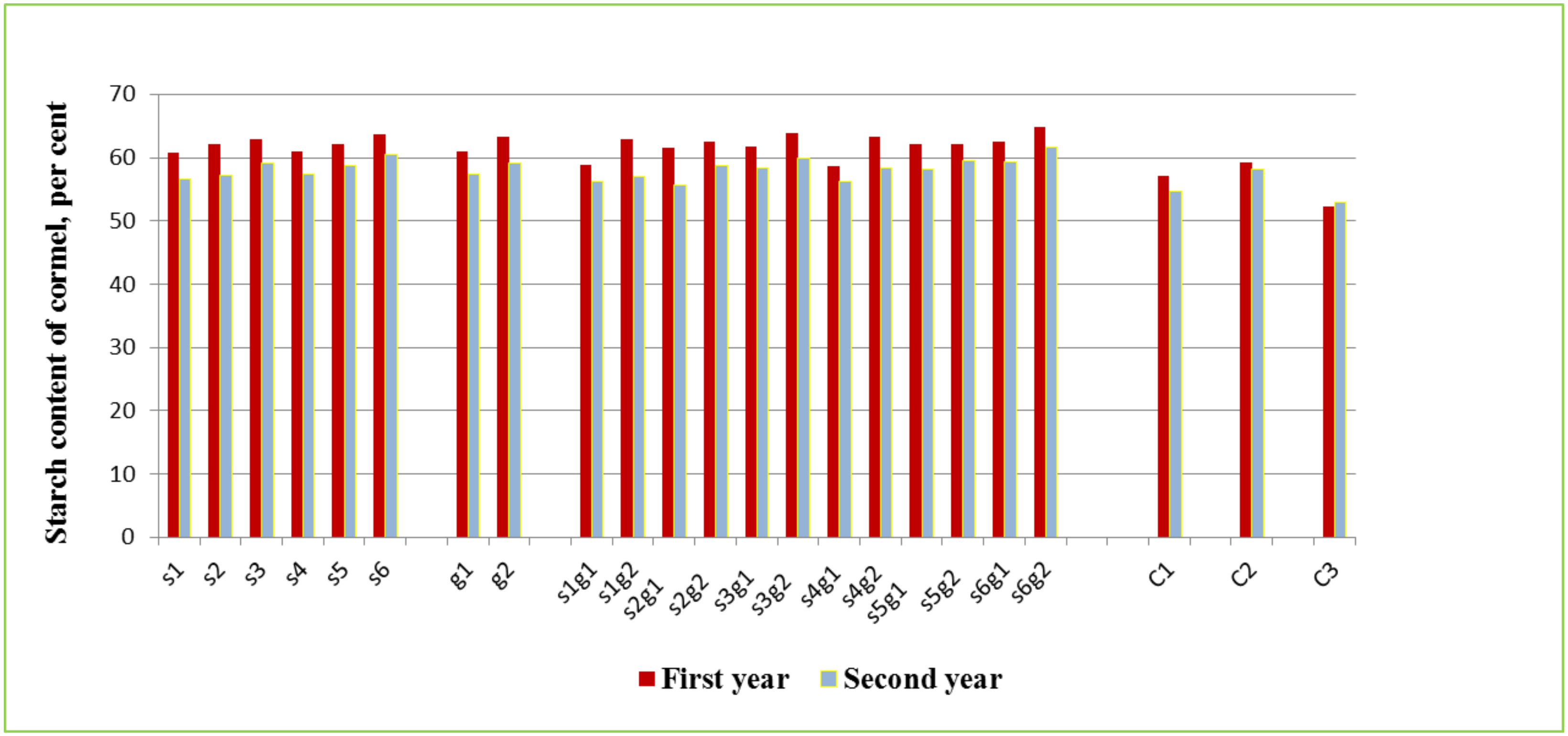


Fig. 12. Effect of organic sources, *in situ* green manuring, S x G interaction and treatments *Vs*. control effect on starch content of cormel on dry weight basis, per cent

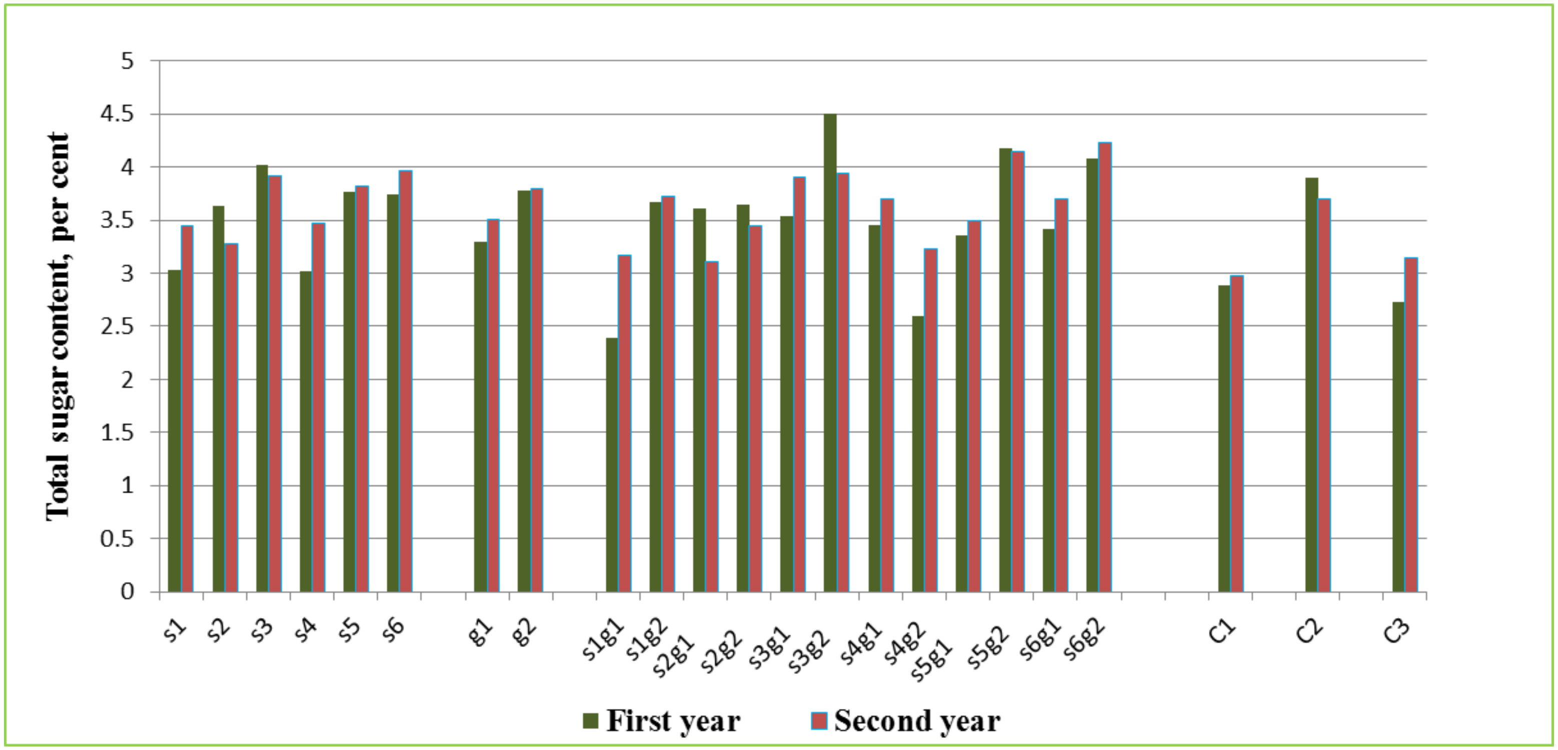


Fig. 13. Effect of organic sources, *in situ* green manuring, S x G interaction and treatments *Vs*. control effect on total sugar content of cormel on dry weight basis, per cent

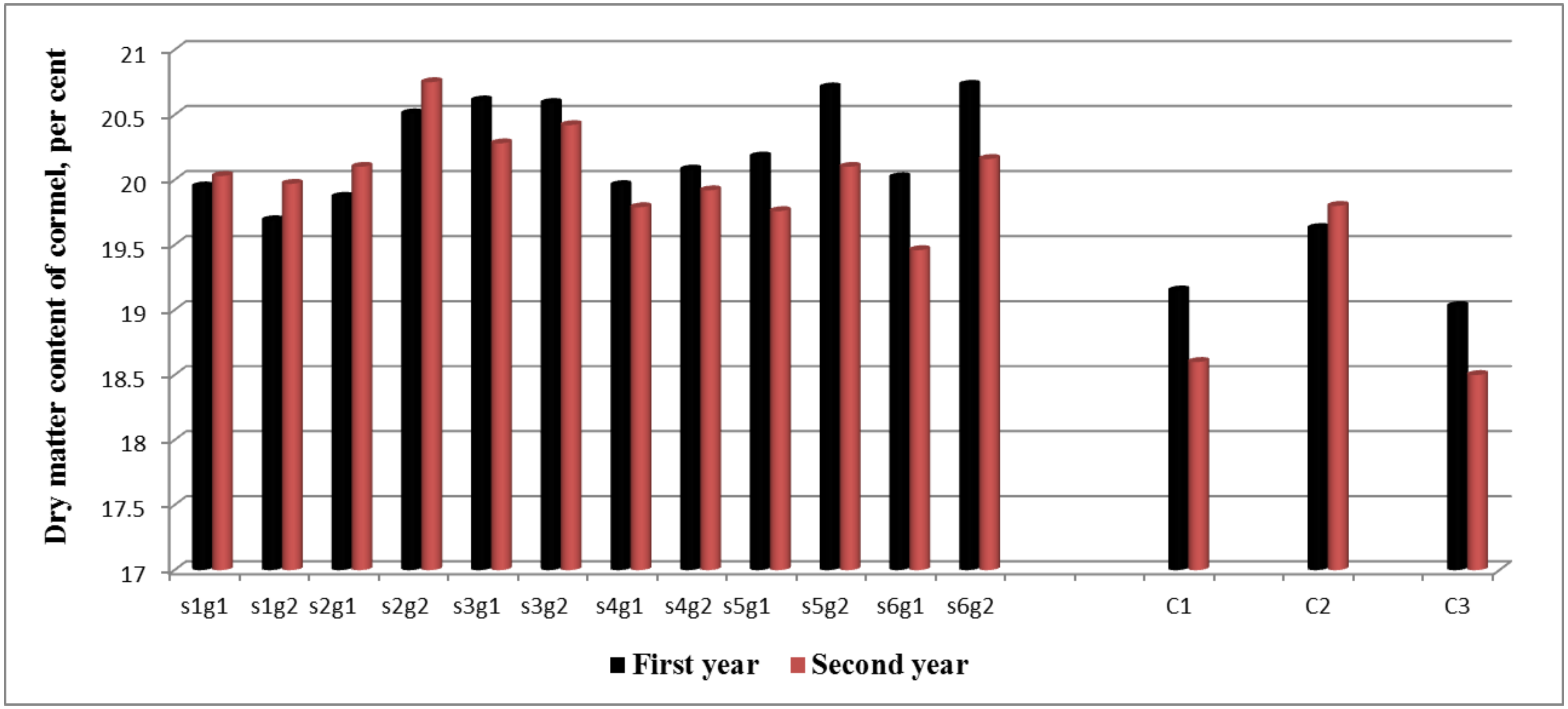


Fig. 14. Effect of S x G interaction and treatments *Vs*. control effect on dry matter content of cormel on dry weight basis, per cent

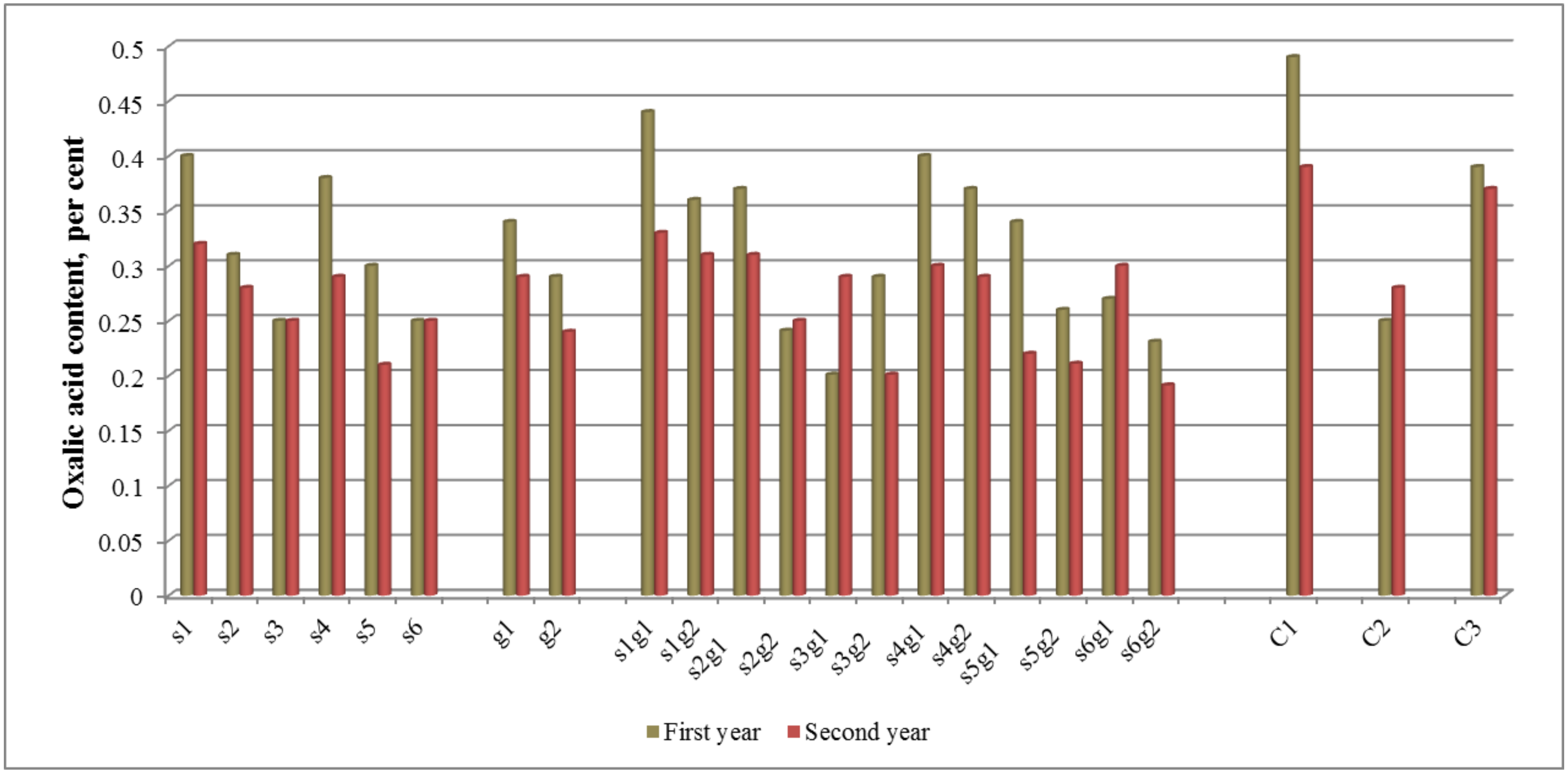


Fig. 15. Effect of organic sources, *in situ* green manuring, S x G interaction and treatments *Vs*. control effect on oxalic acid content of cormel on dry weight basis, per cent

content of poultry manure was found to be higher than other organic sources during both the years compared to that of other organic sources.

The mineralization pattern of poultry manure has indicated that nearly 60 per cent of N in this manure is present as uric acid which quickly changes to ammoniacal form that can be easily utilized by crop (Smith, 1950). According to Amanullah *et al*. (2010) the C:N ratio of poultry manure is narrow (9:1) and this would have further favoured its quick mineralization and release of N which is an structural component of protein. The N released by the poultry manure in a relatively faster pace would have facilitated its uptake promoting the synthesis of crude protein. This also would have reduced the fibre content in tuber as suggested by Gasim (2001) as another effect of increased availability of N. Pamila (2003) also reported that among different organic manures, poultry manure resulted in the highest protein content of cassava tuber. Kareem *et al.* (2020) also stated that the highest crude protein in tubers of plants treated with organic fertilizer might be due to the better N supply to the tubers which also reduced the crude fiber content of tuber.

As reported by Heldt and Flugge (1987), the exchange of cytosolic P with triose phosphates from the chloroplast is thought to be a key component in the regulation of starch and sucrose synthesis. The higher P content of poultry manure would have resulted in increased uptake thereby enhancing the starch and sugar content of the tuber through bio mediation of respective enzymes taking part in starch and sugar synthesis. This result is in agreement with that of Ezeocha *et al*. (2014) who reported increased starch content in aerial yam by application of poultry manure. Furthermore, the PGPR mix I is a consortium for supplementing all the major nutrients as reported by Gopi *et al.* (2020). The use of organic sources in conjunction with PGPR mix I would have therefore further accentuated the availability of nutrients which could have reflected on the qualitative aspects positively. Improvement in quality of

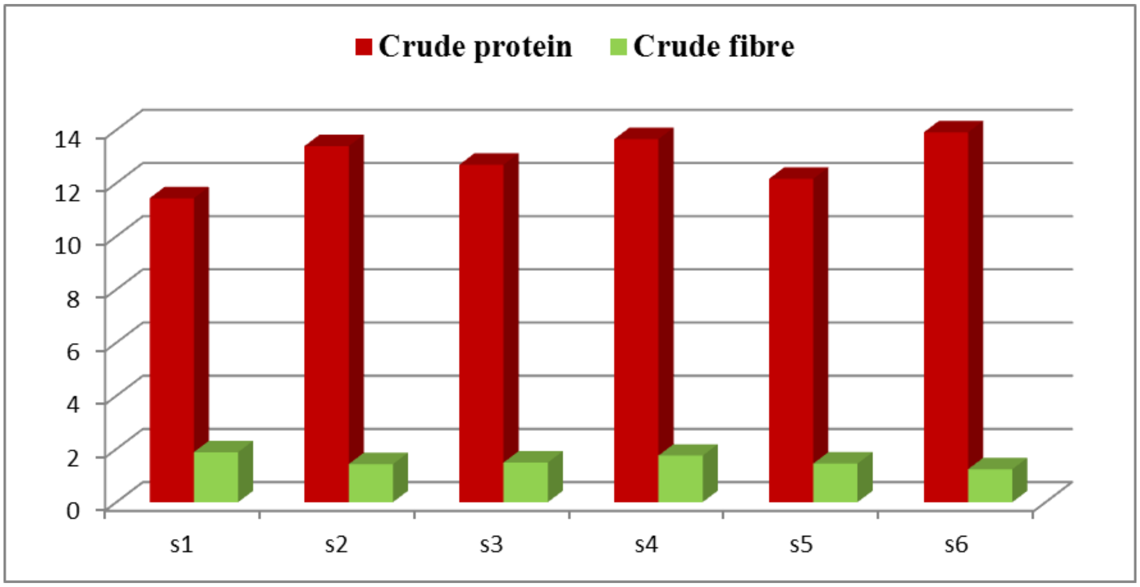


Fig. 16. Effect of organic sources on crude protein and crude fibre content of cormel on dry weight basis during the second year, per cent

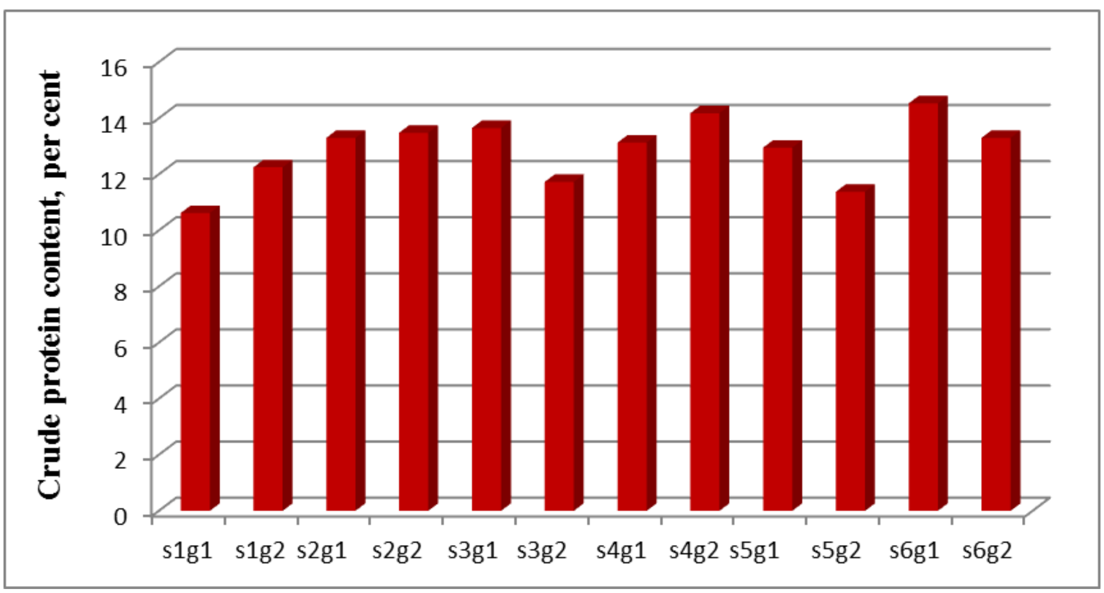


Fig. 17. Effect of S x G interaction on crude protein content of cormel on dry weight basis during the second year, per cent

cormels by application of biofertilizers in taro was reported by Jurri (2008), in elephant foot yam by Kolambe *et al*. (2013) and in arrowroot by Swadija *et al*. (2013).

Application of FYM or poultry manure along with wood ash and PGPR mix I and vermiwash lowered the oxalic acid content in taro cormels. Oxalic acid is a naturally occurring organic compound present in tropical tuber crops and many vegetables and is considered as an anti nutritional factor. The oxalate concentrations in plants are influenced by environmental and biological factors, light intensity, fertilizer application, genotype and plant variety (Shellikeri *et al.*, 2019). It was also observed that as the level of potash increased, the starch content of corms increased, while the oxalic acid content in the corms decreased (Sahoo *et al.*, 2019).

The form of N is also considered to have a role in deciding the oxalic content of plants. As reported by Palaniswamy *et al*. (2004), the oxalic acid content in plants is influenced by the form in which N is supplied and there exists a strong negative correlation between ammoniacal form of N and oxalic acid content. Agreeing with this Zhang *et al*. (2005) demonstrated that oxalate accumulation was positively correlated with increase in N levels especially NO_3^- N in spinach. Very recently Joshi *et al*. (2021) suggested the N management as a strategy for regulating the oxalic acid content in vegetables. Vermiwash was used a foliar organic fertilizer in the above treatments and according to Nayak *et al*. (2019), vermiwash releases 45 per cent of its N in the ammoniacal form, 25 per cent in the nitrate form, 3 per cent as organic soluble compound and remaining 27 per cent as other uncalculated forms. This further strengthens the above argument and the low oxalic acid content could have been resulted from the augmented effect of ammoniacal form of N present in the vermiwash which was applied as a foliar spray. The effect of vermiwash on improvement of quality parameters of tubers also were reported by Perez-Gomez *et al*. (2017) in potato and Sathish and Paramaguru (2009) in turmeric.

Regarding *in situ* green manuring, significantly higher starch content (Fig.12) and total sugar content (Fig.13) during both the years and significantly lower oxalic acid content (Fig. 15) during the second year were recorded with *in situ* green manuring with daincha. The higher starch content with *in situ* green manuring with daincha may be due to the greater production and translocation of photosynthates as observed from the higher tuber yield in this treatment which might have led to the synthesis of storage starch. It is generally observed that if the supply of N is adequate, the carbohydrates synthesized will be stored in the sink as storage starch. Under conditions photosynthesis at a maximum, formation of sugar occurs faster than it can be utilized to form new tissues. The higher K content in tubers during the second year with *in situ* green manuring with daincha might have lowered the oxalic acid content in tubers as the inverse relationship of K nutrition and oxalic acid content as explained by Sahoo *et al.* (2019).

The SxG interaction had significant influence on total sugar content of cormel only during the first year. The treatment combination s_3g_2 (application of FYM along with wood ash, PGPR mix I and vermiwash + *in situ* green manuring with daincha) recorded the highest total sugar content (Fig.13) and was on par with s_2g_2, s_5g_2, s_1g_2 and s_6g_2 which reflected the main effects of the treatments as explained before. The SxG interaction also had significant effect on crude protein content (Fig. 17) of cormel only during the second year and the treatment combination s_6g_1 recorded the highest value which might have been due to the increased availability of N from the poultry manure along with augmented supply of nutrients by the rhizosphere effect of PGPR mix I application.

Significant difference was observed between organic treatments and C_1 (Nutrient management through chemical fertilizers as per KAU POP - 80: 25: 100 kg NPK ha^{-1}) with respect to quality characters of cormel. In general, the organic treatments s_2g_2, s_3g_1, s_3g_2, s_5g_2 and s_6g_2 recorded significantly higher dry matter content of cormel than C_1 (Fig.14). During the first year, all organic treatments except s_1g_1 and s_4g_1 were found to be significantly superior to C_1 in case of starch content. During the second year, s_3g_2 and s_6g_2 recorded significantly superior values of starch content than $C_{1.}$ The treatments s_5g_2 and s_6g_2 were significantly superior to C_1 during the second year with respect to total sugar content of cormel. Improvement in cormel quality (higher dry matter, starch, sugars, P, K, Ca and Mg contents) of colocaisa under organic management than the conventional system has been reported by Suja *et al*. (2017). Similar results of improved tuber quality with organic nutrition were reported in yams by Suja (2013) and Kaswala *et al*. (2013), in elephant foot yam by Suja *et al.* (2010), Suja *et al.* (2012) and Kolambe *et al*. (2013). Addition of organic manure ensures a continuous supply of minerals and helps to make soil nutrients available to plants. The quality of tubers has a direct relation with the availability of nutrients as explained earlier. Singh *et al.* (2018) stated that the greater dry matter content of colocasia corms in organic treatments might be associated with greater accumulation of photosynthates in corms in the presence of biofertilizers. Hota *et al.* (2014) also reported the highest content of dry matter in colocasia due to the application of VAM. Similarly the effect of wood ash improving the quality of tuber was reported by Kurian *et al*. (1976) and John *et al*. (2005) in cassava.

The organic treatments in general produced low fibre content compared to application of nutrients through chemical fertilizers. Crude fibre, is a part of organic material that contains cellulose and other carbohydrates which are insoluble in either weak acid or alkali. Higher crude fibre content implies low digestibility of the food material and low energy and total digestible nutrient. The increase in crude fibre by inorganic fertilizer implies that the tuber produced will have low quality. So, the mechanism of tuber bulking from application of chemical fertilizer is through increase in fibre content and water which are disadvantages because they result in low shelf life, low dry matter content and low digestibility (kareem *et al.*, 2020). The organic treatments $s_1g_{1,}$ $s_1g_{2,}$ $s_2g_{1,}$ $s_2g_{2,}$ $s_3g_{1,}$ $s_3g_{2,,}$ $s_5g_{2,}$ s_6g_1 and s_6g_2 during the first year and $s_2g_{1,}$ $s_2g_{2,}$ $s_3g_{2,}$ $s_5g_{1,}$ $s_5g_{2,}$ s_6g_1 and s_6g_2 during the second year recorded significantly lower values of crude fibre content of cormel compared to C_1 (Fig. 18). Kareem *et al.* (2020) also reported the similar results in which the highest crude fibre production was from the inorganic fertilizer treated plants followed by the control (zero fertilizer) while organic treated plots had the lowest percentage. During the first year, the treatments s_2g_2, s_3g_1 and s_6g_2 recorded significantly lower oxalate content than C_1. During the second year, s_3g_2, s_5g_2 and s_6g_2 recorded significantly lower oxalate content than C_1. Lower calcium oxalate content in elephant foot yam corms due to organic source of nutrients compared to inorganic fertilizer were reported by Nedunchezhiyan *et al*. (2017). Suja *et al.* (2012) also reported that oxalate content in elephant foot yam was lowered by 21 per cent due to the application of organic source of nutrients.

The treatment combination s_3g_2 and s_6g_2 recorded significantly higher starch content of cormel than control nutrient management as per KAU organic POP (C_2) during the first year. The treatment combination s_3g_2 and s_6g_2 during the first year and s_2g_2, s_3g_2, s_5g_1, s_6g_1 and s_6g_2 during the second year recorded significantly lower values of crude fibre content of cormel than C_2. In general, improvement in quality parameters was observed due to organic nutrition treatments compared to absolute control. The higher nutrient availability through the organic sources such as poultry manure, FYM, wood ash, PGPR mix I, and *in situ* green manuring might have improved the cormel quality under organic nutrition compared to KAU organic POP and absolute control.

5.1.5 Uptake of Nutrients

The N content of plant was significantly influenced by different organic sources during the second year. The K content of tuber and uptake of N and K were significantly affected by organic sources during both the years. The organic source s_6 (PM+ wood ash + PGPR mix I + vermiwash) recorded the highest N content of plant, the highest K content of tuber and the highest N (Fig.19) and K (Fig. 21) uptake. The s_6 was on par with s_2, s_3 and s_5 in case of N content. The treatments s_5, s_3, s_2 and s_4 were

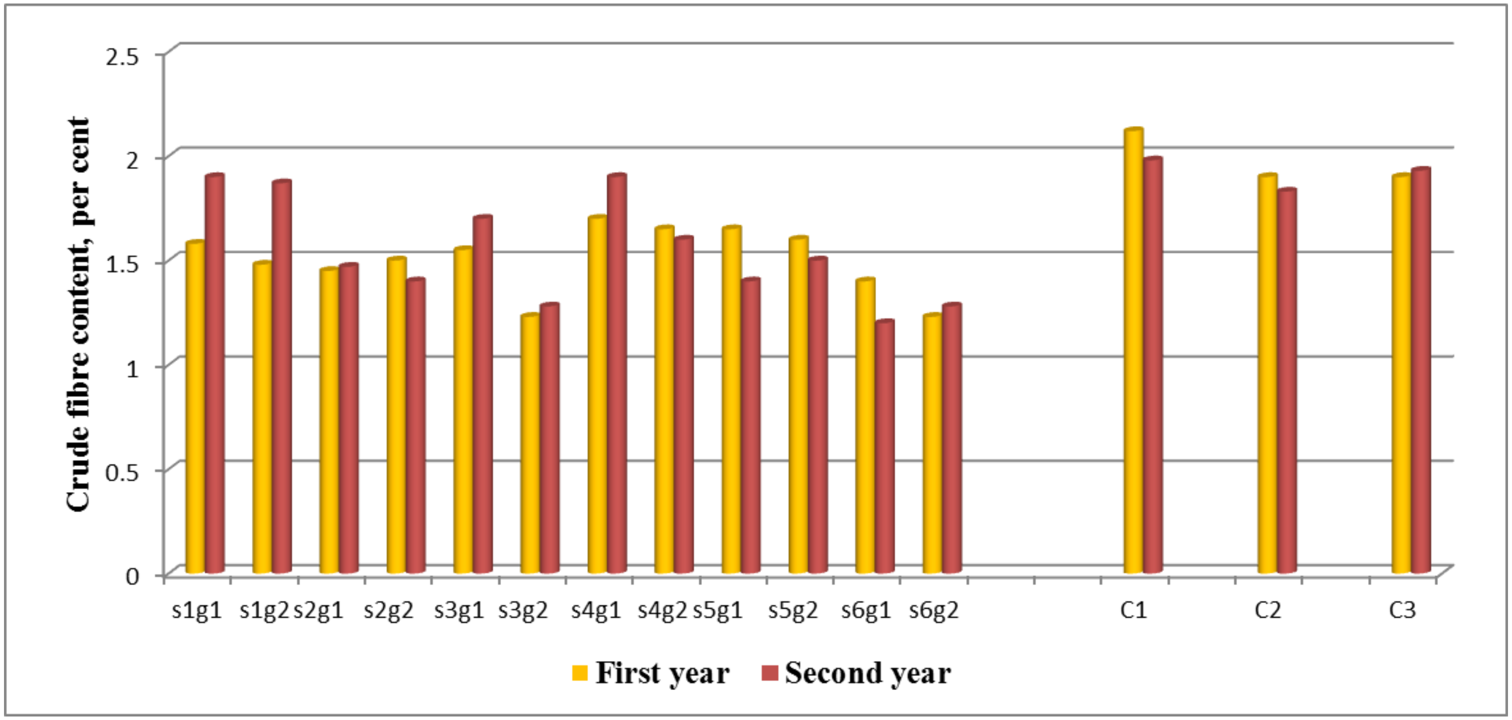


Fig. 18. Effect of S x G interaction and treatments *Vs*. control effect on crude fibre content of cormel on dry weight basis, per cent

found to be on par with s_6 in case of N uptake during the first year. The s_6 was found to be on par with s_5 in case of K content of tuber during the second year. As discussed before, the N content of poultry manure was higher and this coupled with the faster release of N through the conversion of uric acid in the manure would have improved the available N status of soil and increased uptake of N by crop. The comparatively higher K content of poultry manure and higher dry matter production in s_6 might have culminated in higher uptake of K by s_6. Ojeniyi *et al.* (2013) and Adekiya *et al*. (2016) reported the similar results of increased nutrient uptake by higher rate of poultry manure application in cocoyam. The highest uptake of P (Fig. 20) was recorded with application of FYM along with wood ash, PGPR mix I and vermiwash (s_3) during the first year which was on par with s_6 and s_2. The highest P uptake by s_3 may be due to the higher quantity of FYM added compared to poultry manure, to equalize N recommendation might have enhanced available P content in soil. Application of PGPR mix I along with FYM would have further accelerated the release and uptake of P. Gunes *et al.* (2015) reported that apart from N fixing, PGPR can affect plant growth directly by the synthesis of vitamins and phytohormones (auxins, cytokinins, gibberellins), enhanced stress resistance, inhibition of plant ethylene synthesis and improved nutrient uptake. Plants take up most mineral nutrients from the rhizosphere where microorganisms interact with plant products in root exudates and also render the insoluble organic fractions into plant available form and thus changing the mineral status of the rhizosphere. The increased nutrient uptake by biofertilizers was reported by Soubeih Kh and Mahmoud (2019) in taro. Similar results were obtained by Yasmin *et al*. (2007) in sweet potato and Jayapal *et al.* (2013) in chinese potato. Influence of vermiwash on nutrient uptake mechanism was reported by Alvarez and Grigera (2005).

In situ green manuring with daincha recorded significantly higher N and P content of plant and P content of tuber during the first year and significantly higher uptake of N (Fig. 19) and K (Fig. 21) during both the years and higher uptake of P

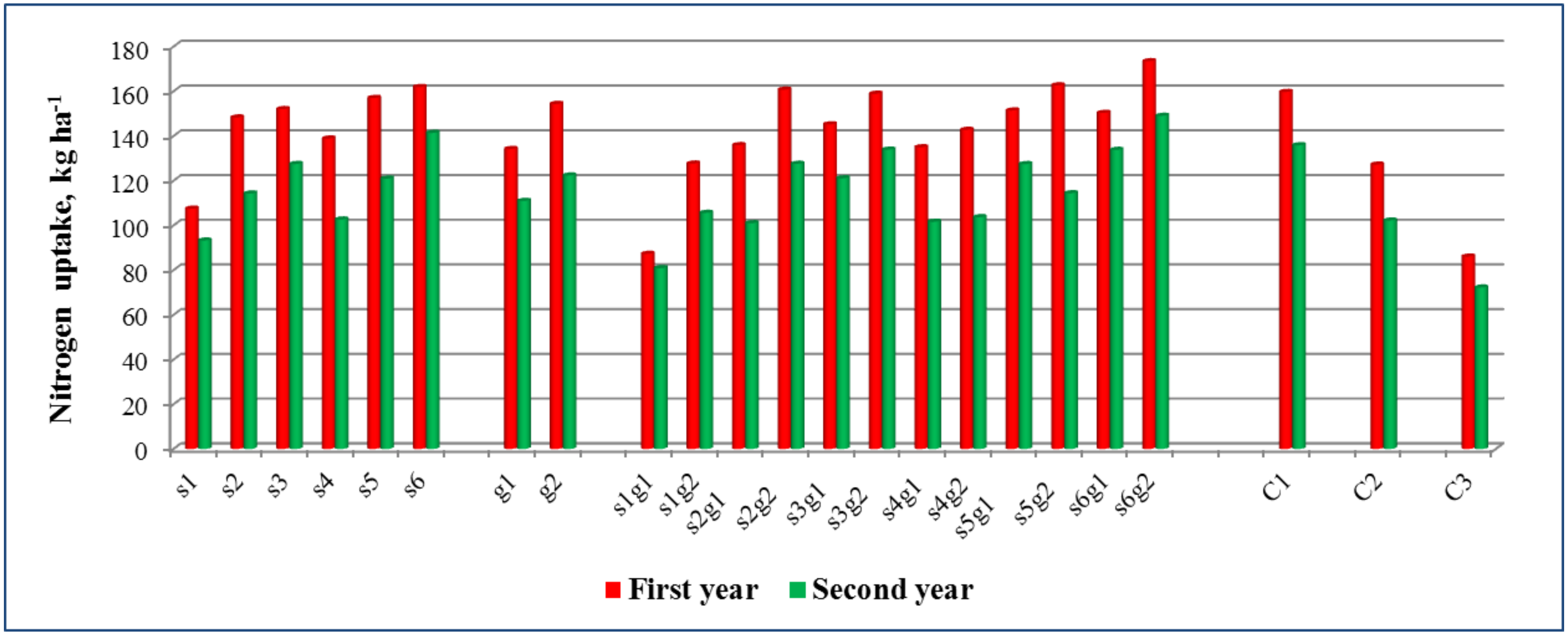


Fig. 19. Effect of organic sources, *in situ* green manuring, S x G interaction and treatments *Vs*. control effect on nitrogen uptake, kg ha^{-1}

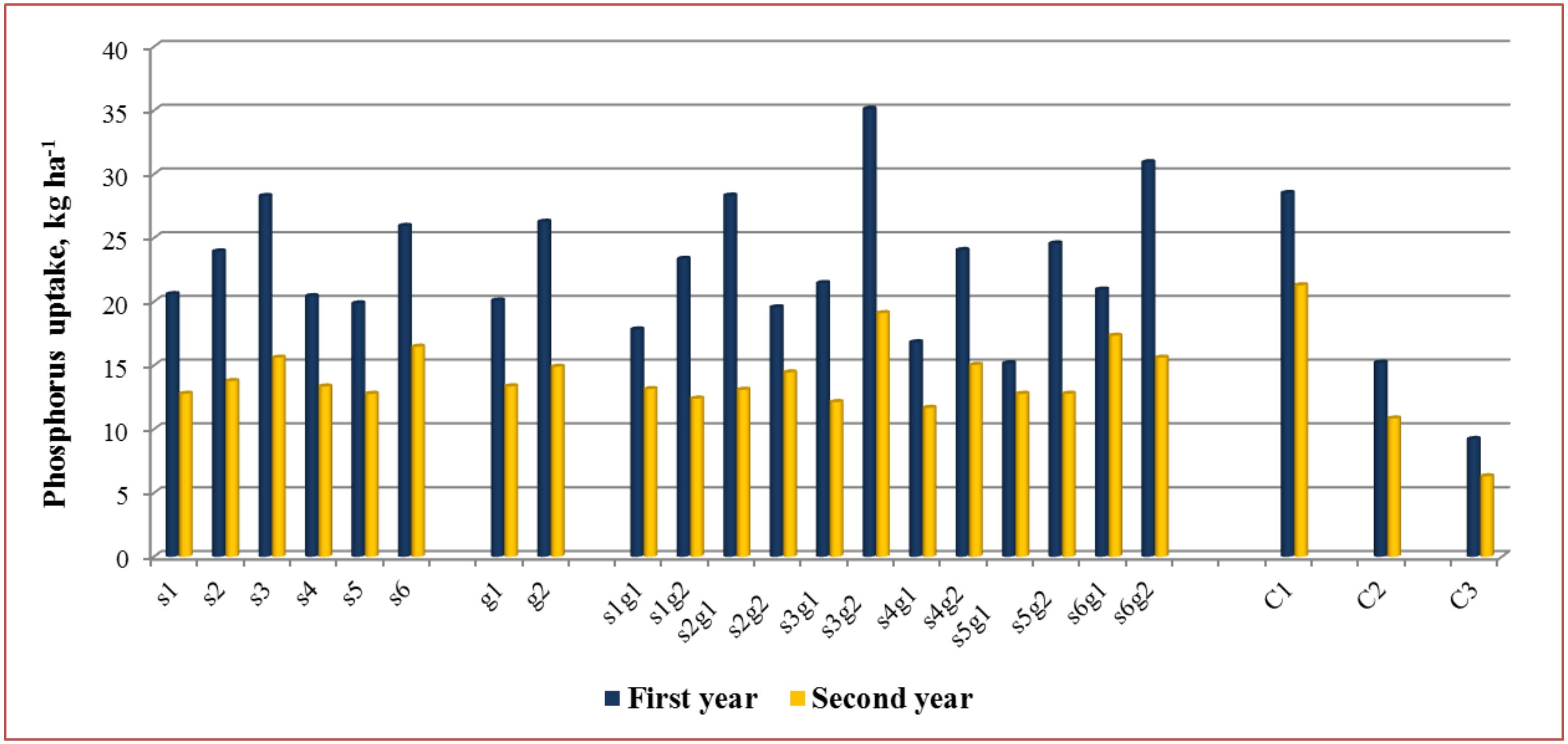


Fig. 20. Effect of organic sources, *in situ* green manuring, S x G interaction and treatments *Vs*. control effect on phosphorus uptake, kg ha^{-1}

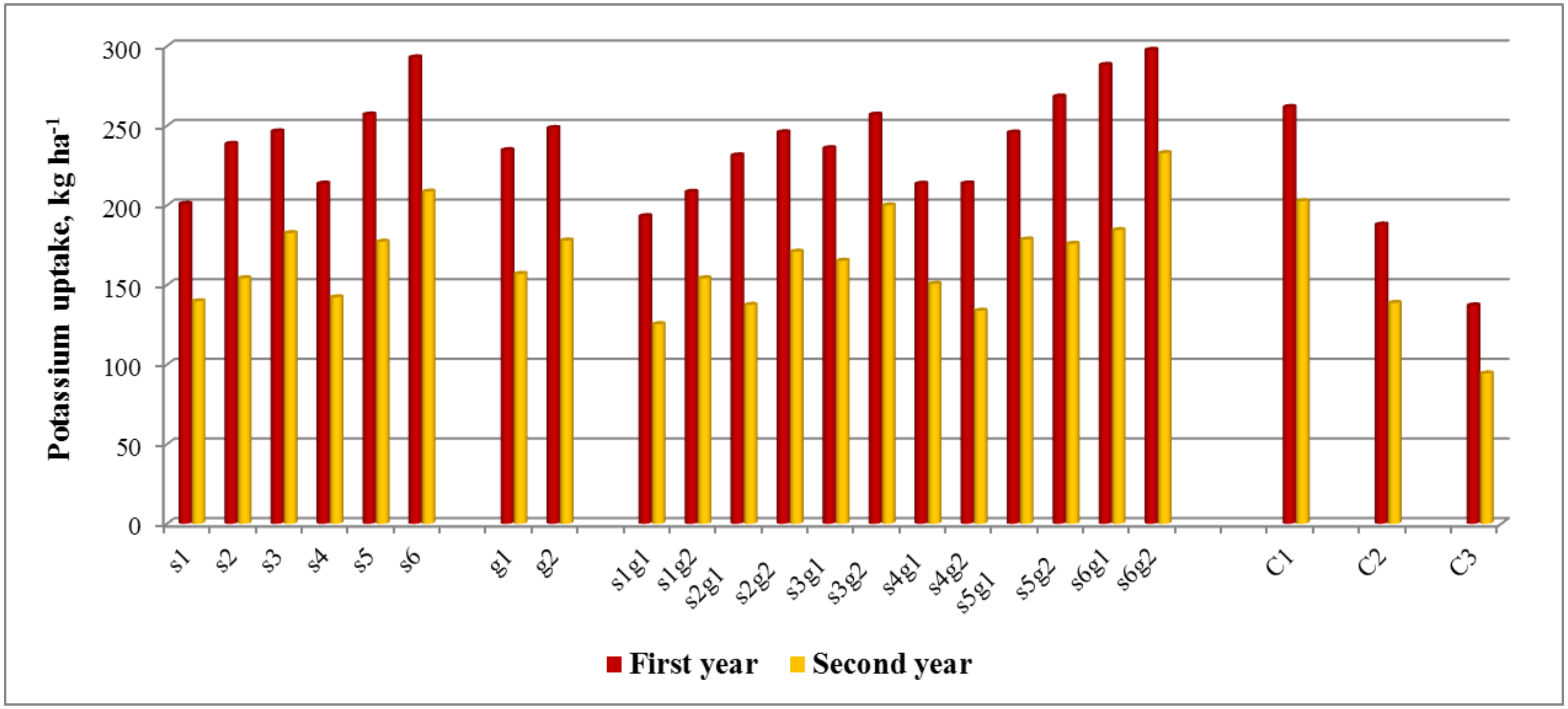


Fig. 21. Effect of organic sources, *in situ* green manuring, S x G interaction and treatments *Vs*. control effect on potassium uptake, kg ha^{-1}

(Fig. 20) during the first year. The higher content of N and P and higher biomass production of diancha compared to cow pea might have added more nutrients to soil on decomposition and thus resulting in higher content of N and P under its incorporation. Since uptake is a function of nutrient content and dry matter production, the positive effects of these treatments on dry matter production had reflected in higher uptake of nutrients.

The main effects of the treatments were found to reflect on SxG interaction. The interaction effect significantly influenced the N and K uptake only during the second year and the highest N and K uptake (Fig. 19 and 21) was recorded with treatment combination s_6g_2, which was on par with s_3g_2 and s_6g_1 in case of N uptake. During the first year, the treatment combination s_3g_2 (application of FYM along with wood ash, PGPR mix I and vermiwash + *in situ* green manuring with daincha) recorded the highest tuber P content and higher P uptake (Fig. 20). The favourable influence of PGPR on nutrient release and uptake was pronounced in case of interaction effects too.

During the second year, there was significant difference between treatments and control C_1 in case of N and P uptake. The treatment combinations s_2g_2, s_3g_1, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 were found to be at par with C_1 in case of N uptake. All the treatments except s_4g_1 were found to be on par with C_1 in case of P uptake. The organic treatment combination s_6g_2 was found to be significantly superior to chemical nutrient management (C_1) in case of K uptake during the first year and treatment combinations s_2g_1, s_2g_2, s_3g_1 s_3g_2, s_5g_1, s_5g_2 and s_6g_1 during the first year and s_2g_2, s_3g_1, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 during the second year were found to be on par with $C_{1.}$ Improvement in soil physical and chemical properties due to organic manures might have culminated in higher uptake of nutrients and on par performance with the chemical sources of nutrients resulting in higher dry matter production and tuber yield.

While comparing treatments with nutrient management as per KAU organic Adhoc POP (C_2), the treatment combination s_6g_1 and s_6g_2 during the first year and s_5g_1 and s_6g_2 during the second year recorded higher K content of tuber than C_2. The treatment combinations s_2g_1, s_3g_2 and s_6g_2 during the first year were found to be significantly superior to C_2 in case of P uptake. The treatment combinations s_2g_1, s_2g_2, s_3g_1, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 during the first year and s_3g_2 and s_6g_2 during the second year were superior to C_2 in case of K uptake. The C_3 (absolute control) showed significant difference from treatments during the first year and the treatment combinations s_5g_2 and s_6g_2 recorded significantly higher plant N content and the treatment combination s_3g_2 recorded higher content of tuber P than absolute control. While comparing treatments with C_3 in case of K content of tuber, it was found that the treatment combinations s_2g_1, s_4g_2, s_5g_2, s_6g_1 and s_6g_2 during the first year and s_3g_2 , s_4g_1, s_4g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 during the second year recorded significantly higher K content of tuber than C_3. All treatments except s_1g_1, s_1g_2, s_2g_1 and s_4g_1 during the first year and all treatments except s_1g_1 during the second year were significantly superior to C_3 with respect to N uptake by the crop. The organic treatment combinations s_1g_2, s_2g_1, s_3g_1, s_3g_2, s_4g_2, s_5g_2 and s_6g_2 during the first year and s_3g_2, s_4g_2, s_6g_1 and s_6g_2 during the second year recorded significantly higher values of P uptake than absolute control. All treatments during the first year and all treatments except s_1g_1 during the second year were significantly superior to C_3 in case of K uptake. The addition of large quantities of FYM and poultry manure on N equivalent basis along with the application of PGPR mix I might have improved soil physical and chemical properties and higher nutrient uptake in organic treatments in comparison with the KAU organic A*d hoc* POP and absolute control. Similar effects of PGPR was previously reported by Patten and Glick (2002) who observed that PGPR enhance nutrient uptake by increase of root elongation and growth due to IAA production and other plant growth promoting activities.

5.1.6 Soil Properties

A decrease in pH of soil was observed after the experiment than the initial values. Being strongly acidic, a higher concentration of hydroxides of iron and aluminium could be expected in the soil. There is a possibility of ion exchange reaction with the terminal OH^- ion of Fe and Al with that of the organic anions from the decaying organic sources. This might have enhanced the hydroxyl content in the rhizosphere which caused the reduction in the acidity of soil (Jacob, 2018). In agreement with this, Wakene *et al*. (2005) reported that the decrease in pH may be due to the release of organic acids from the organic manures on decomposition. Similar result was reported earlier by Leno *et al.* (2017).

With regard to soil properties, pH of the soil was not affected by the organic nutrition treatments after the experiment. However, significant difference was observed between organic treatments and C_1 (Nutrient management through chemical fertilizers as per KAU POP - 80: 25: 100 kg NPK ha^{-1}) during the second year. The organic treatments s_3g_1 and s_5g_2 recorded significantly higher values of pH than C_1. Even though not significant, all other organic nutrition treatments recorded higher values of pH than C_1 during both the years. The increase in pH under organic nutrition may be due to the presence of basic cations produced from the mineralization of organic matter that are rich in Ca, Mg and K. Increase in pH of soil under organic system compared to conventional farming were reported by Suja *et al.* (2012) in elephant foot yam, Suja (2013) in yam and Suja *et al*. (2017) in taro cultivation. Absolute control showed significant difference from treatments during the second year and s_3g_1 and s_5g_2 recorded significantly higher values of pH than absolute control (C_3). All organic nutrition treatments lowered soil acidity even though not significant than absolute control in both the years. The moderation of acidity and higher pH under organic management in the present study was apparently due to the addition of wood ash and organic manures especially, green manure as part of the treatment. Wood ash is alkaline in nature and its calcium carbonate equivalence ranged from 26 to 59 per cent, indicating that the acid-neutralizing power and hence could be suggested as an alternative liming agent (Ohno and Erich, 1990). Adding green manure in the organic system may provide extra cations possibly from lower soil depths, that are released at the soil surface through leaching and decomposition of organic sources. The observed increase in soil pH in organically managed soil could also be attributed to decrease in the activity of exchangeable Al^{3+} ions in soil solution due to chelation by organic molecules. The increase in pH of soil due to application of plant residues, FYM and poultry manure in acid soil was noticed by Naramabuye *et al*. (2006).

The EC values of the soil increased after the experiment compared to initial values. The increase in EC might have been due to the release of nutrient elements from organic manures a result of mineralization and due to the specific effect of wood ash used in all the organic treatments. Glaser *et al.* (2015) reported that cationic and anionic nutrients are produced due to mineralization of organic manures thereby increasing the EC of soil. Significant increase in EC with application of different types of organic manures had been reported by Moran – Salazar *et al.* (2016). Wood ash particles are highly reactive in soil and alters several physio-chemical properties of the soil. Hence, addition of wood ash leads to an increase in soil pH and pore water EC and increases the concentrations of elements such as K, S, B, Na, Ca, Mg, Si, Fe, and P as reported by Demeyer *et al*. (2001).

The EC of soil after the experiment was significantly influenced by organic sources only during the second year. The organic source s_5 (application of PM along with wood ash and PGPR mix I) recorded the lowest value of EC. PGPR mediates biophysical changes in the rhizospheric soil through the production of extracellular polymeric substances (EPS). These substances are potentially responsible for the changes in hydraulic properties and soil evaporation through alteration in the connectivity of pore spaces (Zheng *et al*., 2018). Electrical conductivity of the soil is associated with the physical properties such as particle size distribution, porosity, pore size distribution and connectivity (Bai *et al*., 2013). Hence the low EC observed under s_5 could be assumed to be due to the specific effect of PGPR used in the organic treatment, which would have modified the soil matrix by enhancing the connectivity of pore spaces, resulting in leaching down of soluble salts, lowering the electrical conductivity.

However the EC was not affected by any of treatments during the first year and by *in situ* green manuring and SxG interaction during the second year. The treatments *vs.* control effects were also not significant to influence the EC of soil after experiment during both the years.

The organic carbon content of soil increased after the experiment compared to the initial values. This might be due to the addition of large quantities of organic manures with higher carbon content and *in situ* green manuring. Organic sources had significant influence on organic carbon content of soil after the experiment during both the years (Fig. 22). Poultry manure application along with wood ash, PGPR mix I and vermiwash (s_6) recorded the highest organic carbon content of soil after the experiment during the first year and the organic sources s_4 and s_5 were found as equally effective as s_6. During the second year, s_5 (Poultry manure application along with wood ash and PGPR mix I) recorded the highest organic carbon content of soil after the experiment and was on a par with s_2, s_3, s_4 and s_6. Poultry manure had higher organic carbon content of 27.80 per cent and its application in higher rates might have improved the organic carbon content of the soil as suggested by Adeyemo *et al*. (2019). The similar result of increased in organic carbon content of soil with addition of PM compared to FYM was reported by Pooja (2018) in cassava.

In situ green manuring with daincha registered significantly higher organic carbon content of soil after the experiment during the first year than *in situ* green manuring with cow pea. This might be due to higher biomass production of daincha compared to cow pea in the present experiment. Significant difference was observed between treatments and absolute control during both the years (Fig.22). The treatment s_6g_2 during the first year and s_5g_2 during the second year recorded significantly higher

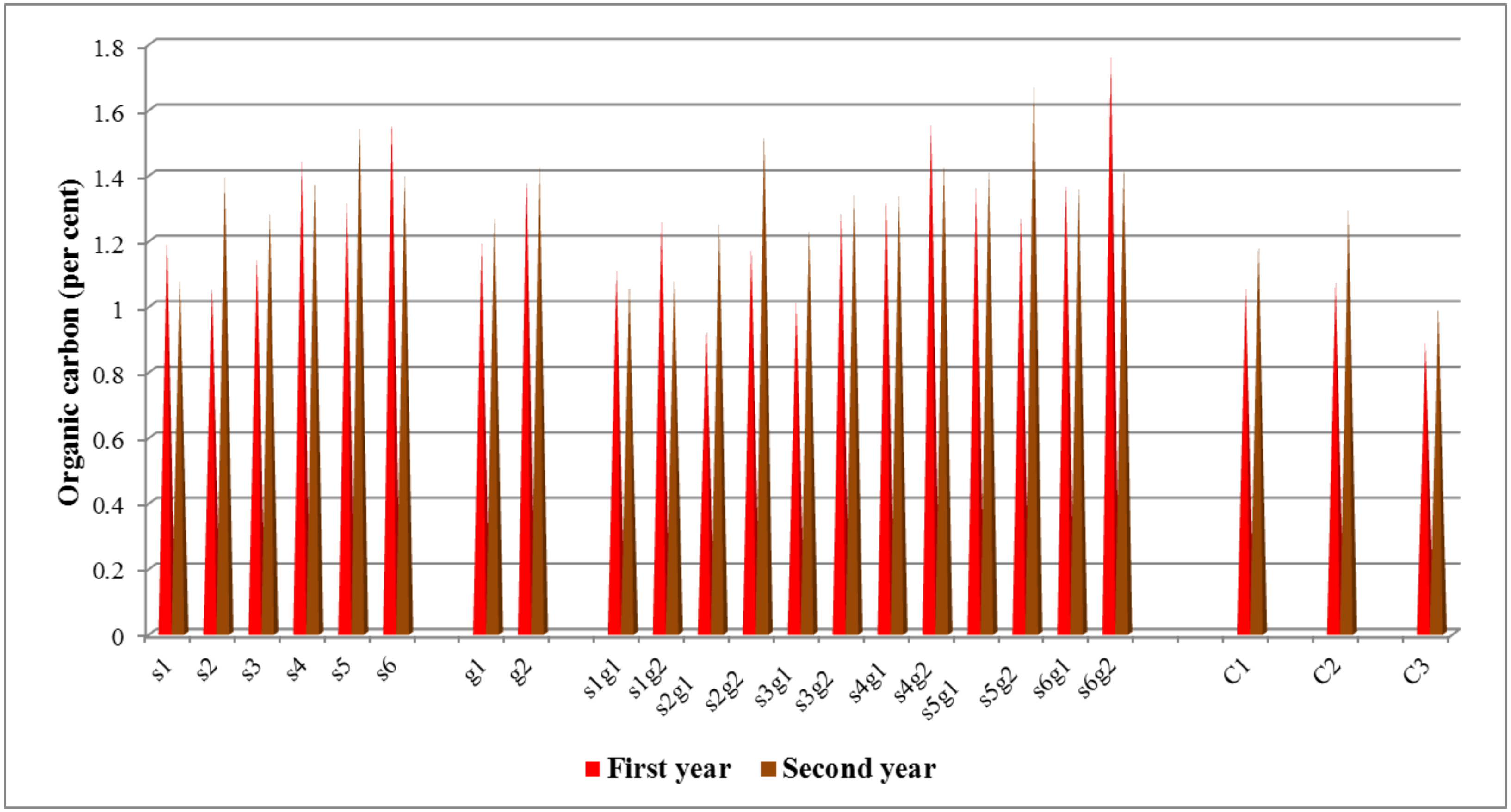


Fig. 22. Effect of organic sources, *in situ* green manuring, S x G interaction and treatments *Vs*. control on organic carbon content of soil after the experiment, per cent

values of organic carbon content of soil after the experiment than absolute control. Higher organic carbon content of organic plots was expected from addition of organic manures, particularly green manures. The increase in organic carbon content of soil under organic farming is quite obvious since the carbonaceous materials contribute to soil organic carbon after their decomposition.

During the first year, the organic source s_5 (PM+ wood ash + PGPR mix I) recoded the highest available N content in soil and it was on par with s_6 (PM+ wood ash + PGPR mix I + vermiwash (Fig.23). During the second year, s_6 (PM+ wood ash + PGPR mix I + vermiwash) recoded the highest available N content in soil and it was on par with s_5, s_2 and s_4 (Fig.23). Moderately higher content and quick release of N from poultry manure would have improved the available N status of soil after the experiment. Dhanya (2011) observed higher available N status in soil under sweet potato cultivation when poultry manure applied as a source of organic manure. Pooja (2018) also reported the similar result under cassava cultivation. The application of PGPR mix I also might have contributed to increased available N status under these treatments as PGPR mix I is a consortium of microorganisms including N fixing organisms such as *Azospirillum* and *Azotobacter*. *In situ* green manuring with daincha (g_2) recorded significantly the highest available N content in soil during both the years (Fig.23). The higher biomass production of daincha would have added more N to the soil through the decomposition of proteinous substances in the legume, thus enriching the available N status of soil. Regarding interaction effect, the treatment combination s_6g_2 (application of PM along with wood ash, PGPR mix I and vermiwash + *in situ* green manuring with daincha) recorded the highest value during the first year, which reflected the trend of main effects of treatments. Significant difference was observed between treatments and absolute control during both the years (Fig.23). All organic nutrition treatments recorded significantly higher values of available N content of soil after the experiment during both the years than absolute

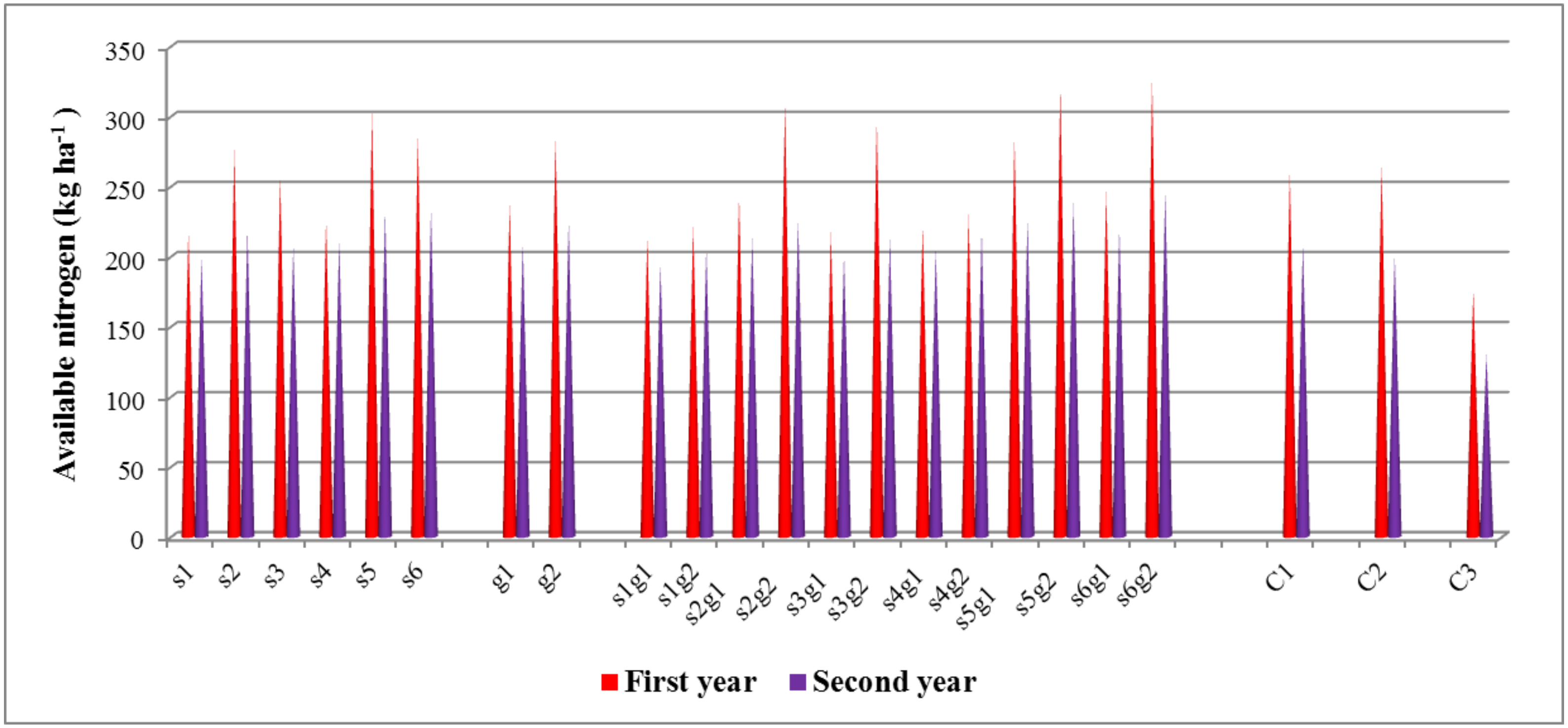


Fig. 23. Effect of organic sources, *in situ* green manuring, S x G interaction and treatments *Vs*. control on available nitrogen content of soil after the experiment, kg ha^{-1}

control. Adekiya *et al*. (2016) reported the increased soil N with poultry manure application compared to control in cocoyam. Similar results were reported by Adeleye *et al*. (2010) and Agbede *et al*. (2013). The available N status of organic plots compared to absolute control could have resulted from addition of organic manures (either FYM or PM) and green manures. The slow decomposition and slow release of nutrients from organic manures might have contributed to the higher status of available N in the soil.

Different organic sources had significant influence on available P content of soil during both the years (Fig.24). FYM application along with wood ash, PGPR mix I and vermiwash (s_3) recorded the highest available P content of soil during both the years and which was on par with s_2, s_5 and s_6 during both the years. FYM used as an organic source in the treatment had a moderate P content (Table 4a). Studies on P characterization of FYM have indicated that both organic and inorganic fractions of P constitute its total P content. According to Braos *et al*. (2015), proportion of inorganic P fraction which mainly contribute to the available pool is nearly two times that of the organic P in the cattle manure. On the other hand though the poultry manure contains relatively higher content of P, its fractionalization studies have shown that a large portion of P in poultry manure is acid soluble indicating its low bioavailability (Bolan *et al*., 2010). The higher quantity of FYM compared to poultry manure used in the present study might have added more P to soil owing to the bioavailable nature of its P content. The favourable effect of PGPR on rhizosphere modification is well known and this together with increased phosphatase activity (Gunes *et al.*, 2015) would have further improved the available P status of the soil.

The improved available P status in soil by application of PGPR mix I under organic production of chinese potato was reported by Jayapal *et al.* (2013). *In situ* green manuring had significant effect on available P content of soil only during the second year and *in situ* green manuring with daincha registered significantly higher available P content of soil compared to *in situ* green manuring with cowpea (Fig.24).

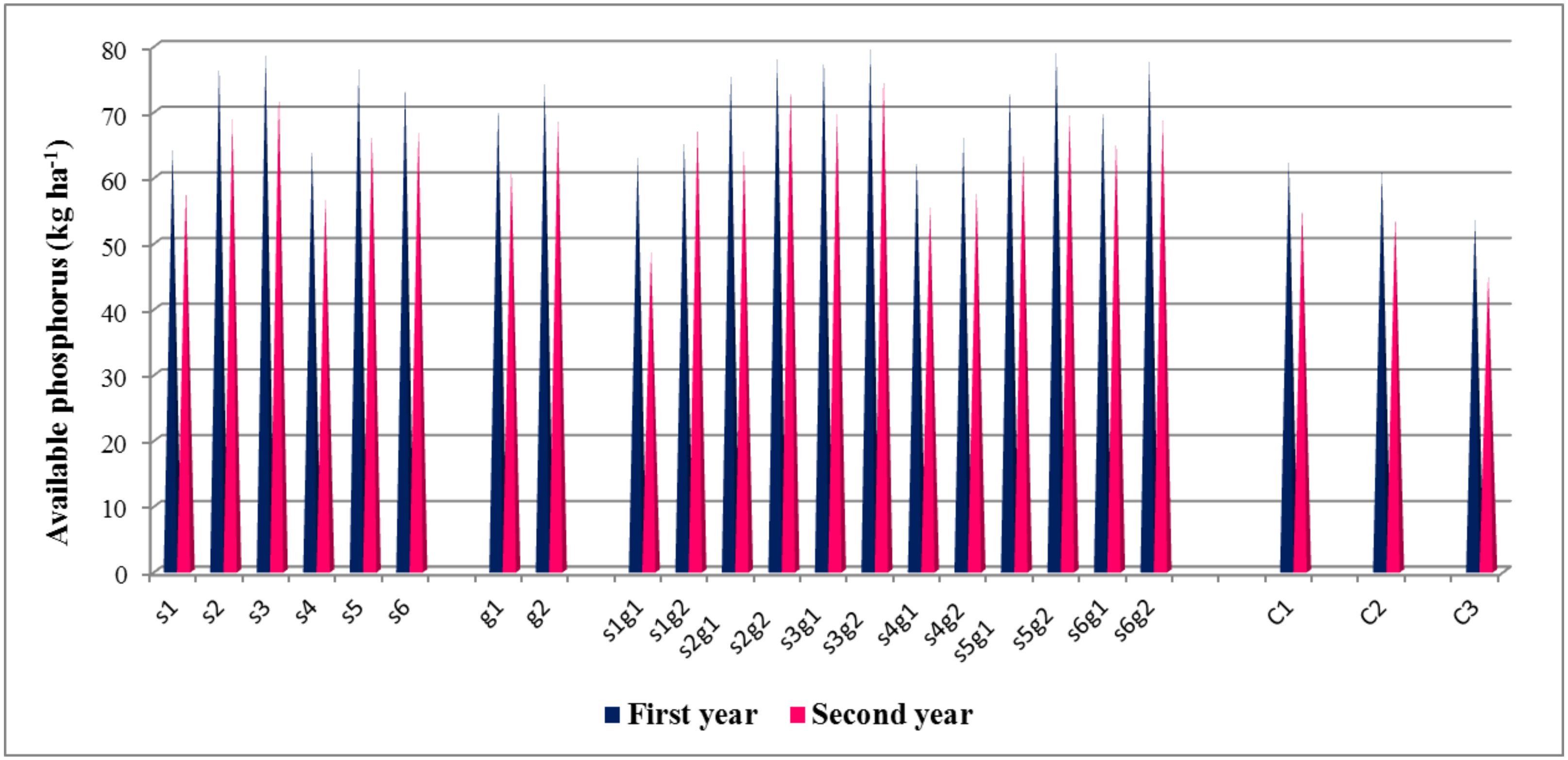


Fig. 24. Effect of organic sources, *in situ* green manuring, S x G interaction and treatments *Vs*. control on available phosphorus content of soil after the experiment, kg ha^{-1}

The higher P content and higher biomass production of daincha might have added more P to the soil on decomposition.

The organic treatments s_2g_2 and s_3g_2 were found to be significantly superior to C_1 (nutrient management through chemical fertilizers as per KAU POP) and C_2 (nutrient management as per KAU organic POP) during the second year (Fig.24). Solubilization of native P by organic acids during decomposition of organic manures and increased mineralization of P from the added organic manures with the increased activity of P solubilizers from PGPR mix I might have led to a higher available P in organic plots. Organic nutrition resulting in higher status of available P, is in agreement with the findings of Suja *et al*. (2017) in taro. Similar results were reported by Srivastava (1985) and More (1994). It is well known that organic matter reduces P fixation and enhance P availability. Also organic acids produced during the decomposition of organic matter might have increased the solubility of native P (Singh *et al*., 2008). All organic nutrition treatments except s_1g_1, s_1g_2, s_4g_1, s_4g_2 and s_6g_1 during the first year and all treatments except s_1g_1, s_4g_1 and s_4g_2 during the second year recorded significantly superior values of available P content of soil than absolute control (C_3). The available P status of organic plots compared to absolute control is evidently resulted from addition of organic manures, PGPR mix I and green manures.

The available K status was not significantly influenced by main effects, interaction effects and treatments *vs.* C_1 and C_2, while significant difference was observed between treatments and absolute control during both the years. The organic nutrition treatments s_3g_1 and s_6g_1 during the first year and all treatments except s_1g_1, s_1g_2, s_4g_1 and s_4g_2 during the second year recorded significantly higher values of available K content of soil after the experiment than absolute control. The addition of organic manures and green manuring along with PGPR would have released more plant available K to the soil since PGPR is a consortium of microorganisms including K solubilizing bacteria. The improved status of available K in soil under organic production of chinese potato by application of PGPR mix I was reported by Jayapal *et al.* (2013). Increased availability of K on decomposition of organic manures, reduction of K fixation and leaching loss by organic manures might be the reasons for the higher status of available K in plots given organic nutrition. Zulbeni *et al.* (2020) reported the similar result of the increased exchangeable K in soil under colocasia cultivation by chicken manure application compared to without application. Adekiya *et al*. (2016), Adeleye *et al*. (2010) and Agbede *et al*. (2013) also reported similar results.

5.1.7 Soil Organic Carbon Build Up

Soil carbon is an important soil quality component, which plays important role in controlling soil fertility, crop production, hydrology, drainage, greenhouse gas emissions and other several ecosystem functions on earth (Bhardwaj *et al*., 2019). Shrestha *et al*. (2007) reported that carbon dynamics is greatly influenced by land use and management practices. The management practices that returns greater amounts of carbon to soil causes a net buildup of the total organic carbon stock in soil (Singh and Benbi, 2020). Total organic carbon is a measure of the carbon contained in soil organic matter. Application of poultry manure along with wood ash and PGPR mix I (s_5) recorded the highest total organic carbon content during the first year (Fig. 26), which was on par with s_2 wherein FYM applied along with wood ash and PGPR mix I. The total organic carbon is constituted by two fractions such as recalcitrant carbon and labile carbon. Recalcitrant organic carbon is the fraction that is resistant to microbial decomposition or protected by soil mineral particles (Fang *et al.*, 2005). The highest recalcitrant carbon content was recorded by the organic source s_5 (PM+ wood ash + PGPR mix I) during the first year and which was on par with s_2, s_3 and s_6. During the second year, the highest recalcitrant carbon content was recorded by the organic source s_3 (FYM + wood ash + PGPR mix I + vermiwash), which was on par with s_6, s_5 and s_2 (Fig. 25). Labile carbon fractions are the active carbon pools and higher level of labile carbon indicates greater turnover rate of organic matter and higher availability of nutrients. Labile carbon pool is readily decomposable, easily oxidizable and is sensitive to attack by microorganisms and is more prone to management induced changes in soil organic carbon. Water soluble

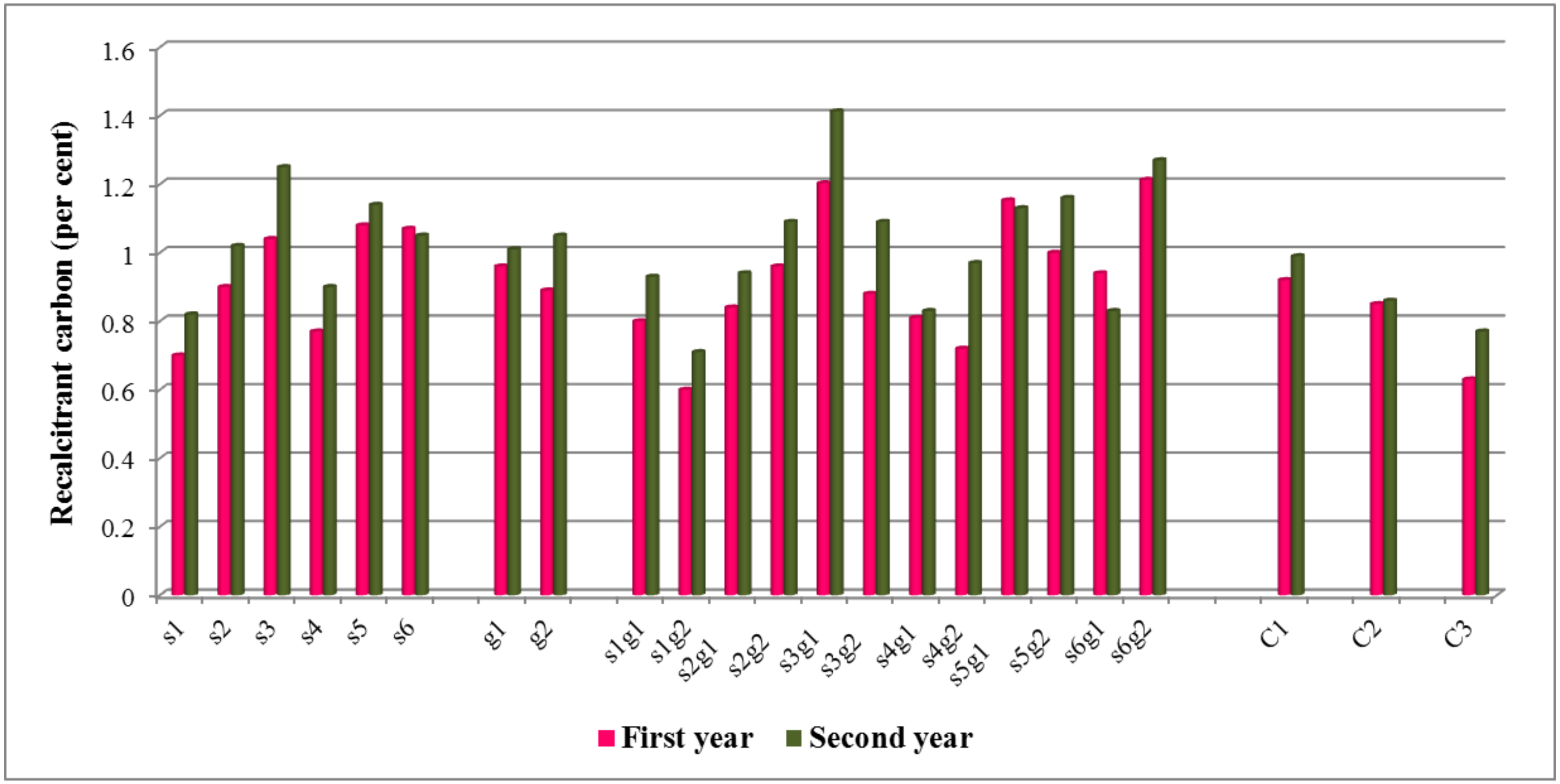


Fig. 25. Effect of organic sources, *in situ* green manuring, S x G interaction and treatments *Vs*. control on recalcitrant carbon of soil after the experiment, per cent

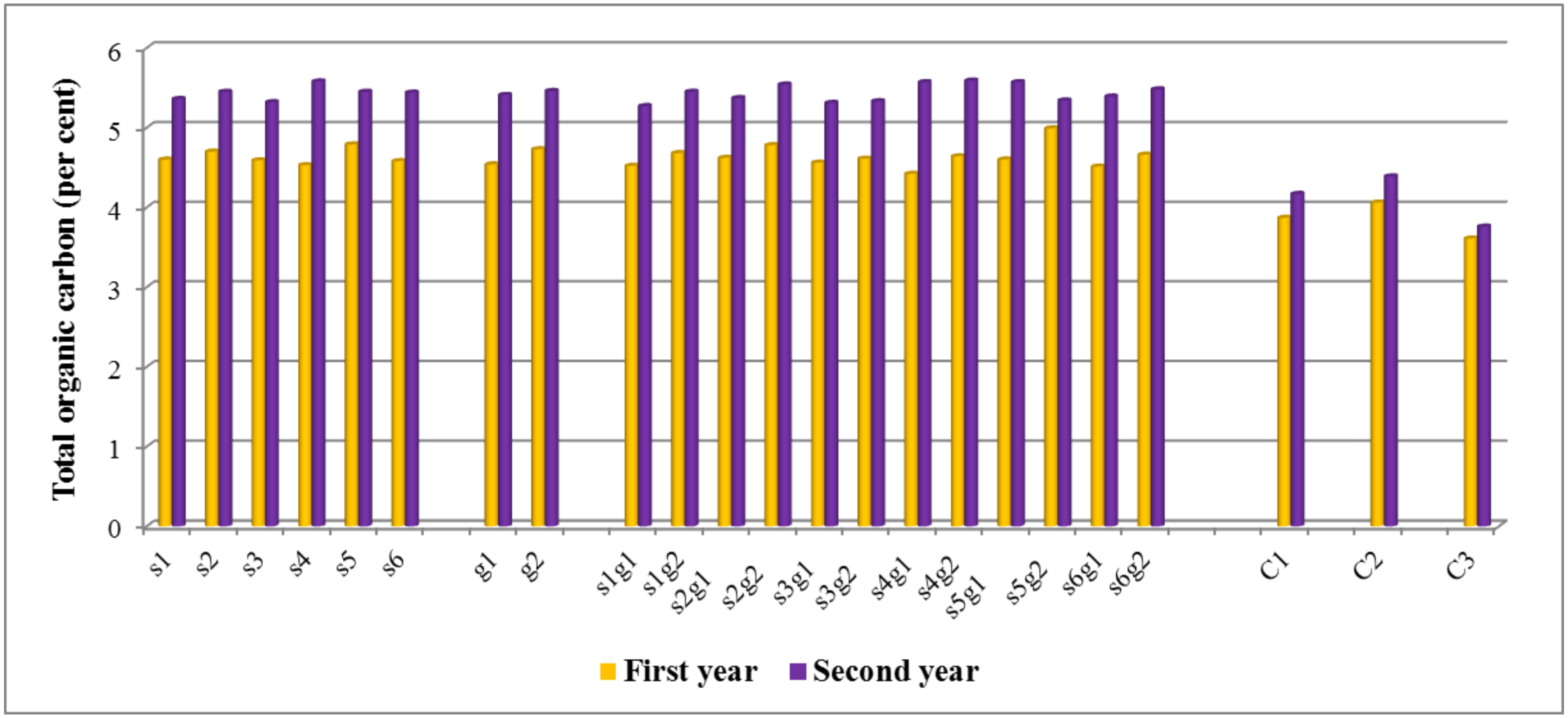


Fig. 26. Effect of organic sources, *in situ* green manuring, S x G interaction and treatments *Vs*. control on total organic carbon of soil after the experiment, per cent

carbon is the mobile and reactive soil carbon source and it is the sensible indicator of soil organic matter quality. These pools are vigorously cycled and easily decomposed by microorganisms and serve as energy source. Application of FYM along with wood ash, PGPR mix I and vermiwash (s_3) and application of poultry manure along with wood ash, PGPR mix I and vermiwash (s_6) resulted in higher labile carbon during the second year (Fig.27) and water soluble carbon content during both the years (Fig.28). The water soluble carbon results from an increased microbial activity and contributing to labile pool of soil carbon.

Carbon fluxes are critical determinants of rhizosphere function. It is reported that approximately 5–21 per cent of photosynthetically fixed carbon is transported to the rhizosphere through root exudation (Marschner, 1995) and the PGPR play a major role in the carbon build up through colonization, promoting root exudation and other growth promoting activities in the rhizosphere. The increased carbon fractions in the organic treatments could be therefore attributed to the application of PGPR mix I as microorganisms play a pivotal role in carbon mineralization.

In situ green manuring with daincha recorded significantly higher value of total organic carbon content (Fig. 26) compared to *in situ* green manuring with cow pea during the first year, and higher labile carbon (Fig.27) and water soluble carbon content (Fig. 28) of soil during both the years owing to the higher biomass production of diancha compared to cow pea. The higher green matter incorporation and resultant decomposition might have increased the amount of carbon and mineralization. The study of Bhardwaj *et al*. (2019) corroborates this results who reported green manuring with *Sesbania aculeata* accumulated the maximum labile carbon fraction at the surface soil and the maximum carbon assimilation and maximum input of C into soil compared to green manuring with other legumes and other residue incorporation. The interaction effects were significant with respect to water soluble carbon content of soil during both the years and which reflected the main effects of treatments. The treatment

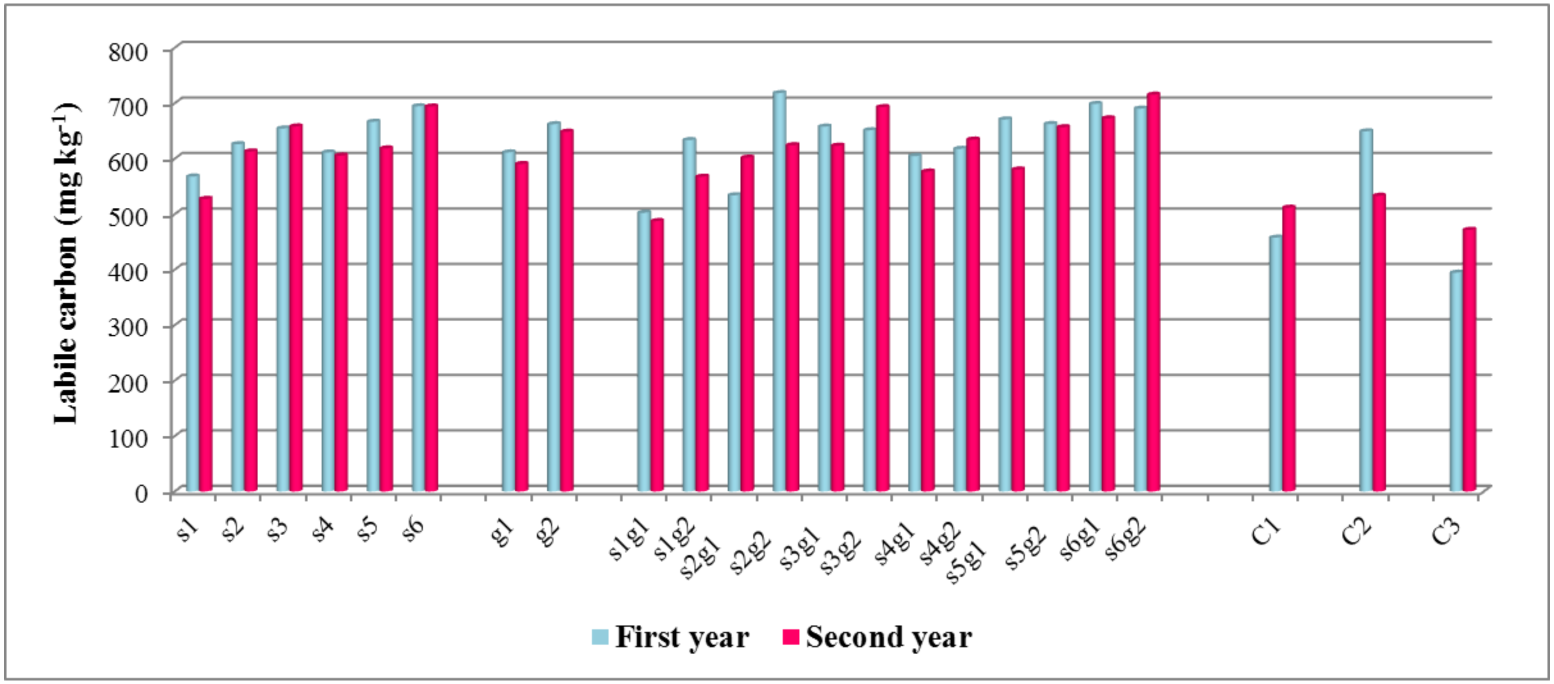


Fig. 27. Effect of organic sources, *in situ* green manuring, S x G interaction and treatments *Vs*. control on labile carbon of soil after the experiment, mg kg^{-1}

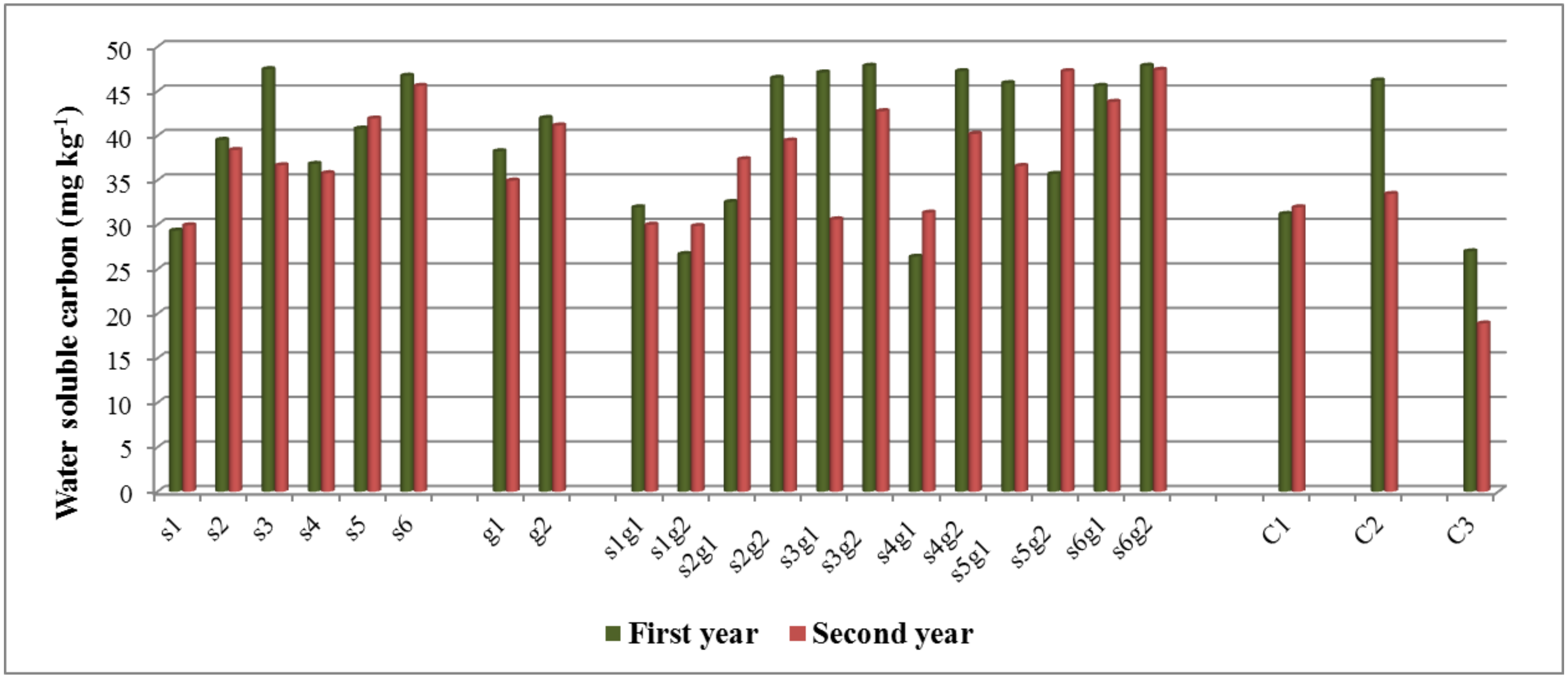


Fig. 28. Effect of organic sources, *in situ* green manuring, S x G interaction and treatments *Vs*. control on water soluble carbon of soil after the experiment, mg kg^{-1}

combination s_3g_2 (application of FYM along with wood ash, PGPR mix I and vermiwash + *in situ* green manuring with daincha) and s_6g_2 (application of PM along with wood ash, PGPR mix I and vermiwash + *in situ* green manuring with daincha) resulted in the highest water soluble carbon content of soil.

The role of organic farming in carbon sequestration is a known fact. Soil carbon sequestration is the process of capturing or sequestering carbon dioxide and storing it in soils. At global scale increasing soil C has been recognized as a major strategy for curtailing increased carbon dioxide. Carbon is stored in soil as soil organic matter. Carbon contained within the soil organic matter is measured as total organic carbon. Recalcitrant organic carbon accounts for the long term C storage (Yang *et al.*, 2011). All organic nutrition treatments during both the years recorded significantly higher values of total organic carbon content than control treatments C_1, C_2 and C_3 (Fig.26). The treatments s_3g_1, s_5g_1 and s_6g_2 during the first year and the treatments s_3g_1 during the second year recorded significantly higher recalcitrant carbon than C_3 (Fig.25). The addition of large quantities of organic manures and *in situ* green manuring practiced in organic nutrition might have contributed to increased organic carbon fractions in soil. The treatments and control C_1 were significantly different in the case of labile carbon and water soluble carbon content of soil during both the years (Fig. 27 and 28). The treatments s_1g_2, s_2g_2, s_3g_1, s_3g_2, s_4g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 during the first year and s_3g_2, s_4g_2, s_5g_2, s_6g_1 and s_6g_2 during the second year recorded significantly higher labile carbon than C_1. The organic treatments s_2g_2, s_3g_1, s_3g_2, s_4g_2, s_5g_1, s_6g_1 and s_6g_2 during the first year and s_2g_1, s_2g_2, s_3g_2, s_4g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 during the second year were found to be significantly superior to C_1 in case of water soluble carbon content. The treatments s_3g_2, s_5g_2, s_6g_1 and s_6g_2 in the case of labile carbon content and the treatments s_2g_1, s_2g_2, s_3g_2, s_4g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 in case of water soluble carbon during the second year were found significantly superior to C_2. All treatments except s_1g_1 and s_2g_1 during the first year and all treatments except s_1g_1, s_1g_2, s_2g_1, s_4g_1 and s_5g_1 during the second year were significantly superior to C_3 in case of labile carbon content of soil after the experiment. All the organic treatments except s_1g_1, s_1g_2, s_2g_1 and s_4g_1 during the first year and all treatments during the second year recorded significantly higher values of water soluble carbon than absolute control. Guo *et al*. (2019) reported the increased content of soil organic carbon and its fractions with organic fertilization. On an average 2.2 percentage increase in soil carbon content (soil organic carbon) in organic systems was reported by Leifeld and Fuhrer (2010). The maximum C input to soil and its direct effect on soil C fractions with green manuring as reported by Bhardwaj *et al*. (2019) validates the result obtained in the present study.

5.1.8 Nutrient Balance Sheet

The N balance of soil was negative for all treatments after first year of experiment (Fig.29a). In organic manures, N is present in available and unavailable forms. Hence the N applied through organic manures may not be completely available to the crop, but only available fraction of soil N was computed for preparing balance sheet and this might be the reason for negative balance sheet of N. Only a portion of nutrients (30 % of N from FYM and nearly 60 % from poultry manure) would have been available from organic manures in the corresponding season as the release from organic manures was very slow as it needs mineralization. Apart from that, the leaching loss of available N from soil as the season was having higher rainfall also might have contributed to negative balance sheet of N. The highest balance of N was observed in absolute control followed by s_6g_2 in which application of poultry manure, wood ash, PGPR mix I and vermiwash were done along with *in situ* green manuring with daincha after first year of experiment. The treatment combinations with PGPR in general were found to produce higher N balance in soil. The higher uptake coupled with higher nutrient balance observed in s_6g_2 compared to other treatments could be due to the beneficial effect of PGPR used in the combination. The direct mechanisms of PGPR on nutrient dynamics operate through the production of plant growth promoting substances like phytohormones and enhanced availability and uptake of nutrients in soil through biological N fixation, solubilization of fixed form of nutrients to plant available form, chelation of nutrients through siderophore production etc as suggested by Goswamy *et al*. (2016). According to Lonhienne *et al*. (2019), PGPR confer a very effective mechanism of plant nutrient uptake, and reduce nutrient leaching risks. In their study, application of PGPR along with organic fertilizers decreased the N leaching by 95 per cent. After second year, the N balance was positive for absolute control. For all other treatments the balance sheet was negative. The absolute control was followed by C_1, s_6g_1 and s_3g_1. The input of N was zero in absolute control, and the nutrient uptake was also reduced to a greater extent and this might have eventually led to a positive balance in soil as the soil had a moderately higher N status initially.

The balance sheet of P was negative for all treatments during both the years (Fig.29b). The soil was acidic in reaction and the negative balance of P observed after both the years of experiment irrespective of treatments might be due to fixation of P under acidic conditions. The similar cases of fixation of P as iron and aluminium phosphate was reported by Huck *et al.* (2014). Besides that, the release of P from organic manures is slow and as a result only a part of it would have been made available in the soil in corresponding season (60-70 % of P from FYM), while the other portion contained in the manures as unavailable form. However, the highest balance was recorded with absolute control during both the years followed by C_1 in which chemical fertilizer application was followed according to KAU POP. The addition of P was less in these treatments (no addition of P in absolute control and only 25 kg ha^{-1} in C_1) and the crop uptake was also minimal in absolute control. Furthermore, the initial P status of soil was very high and this would have left more P in soil unutilized by the crop.

The balance sheet of K was positive (net gain) for s_6g_2, s_6g_1, s_3g_1, s_5g_1 and C_1 after first year of experiment and for all other treatments the balance sheet was negative (Fig. 29c). It could be seen that the organic treatment combinations

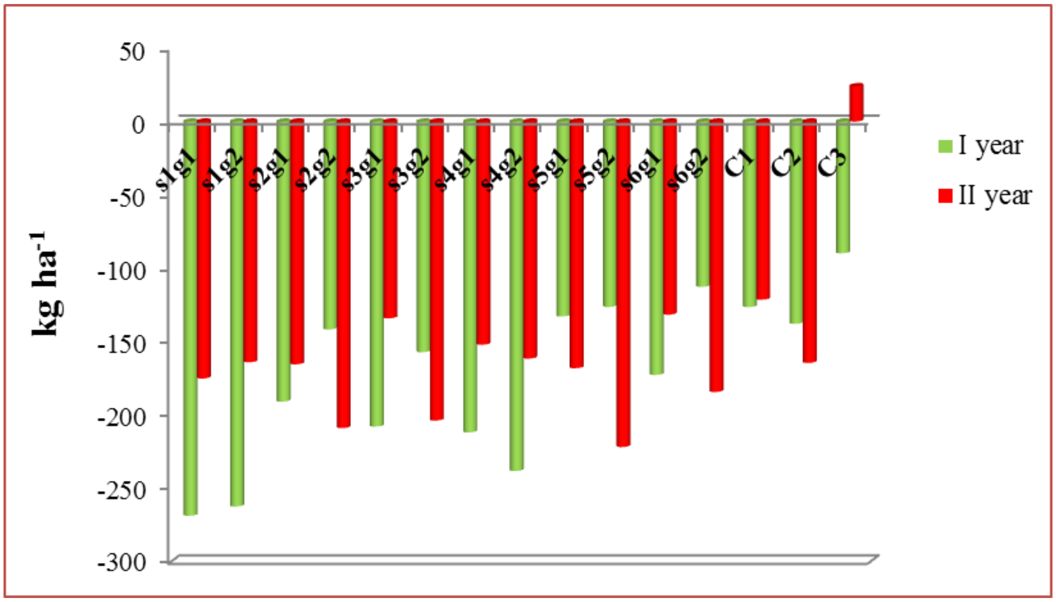


Fig. 29a. Balance sheet of N, kg ha^{-1}

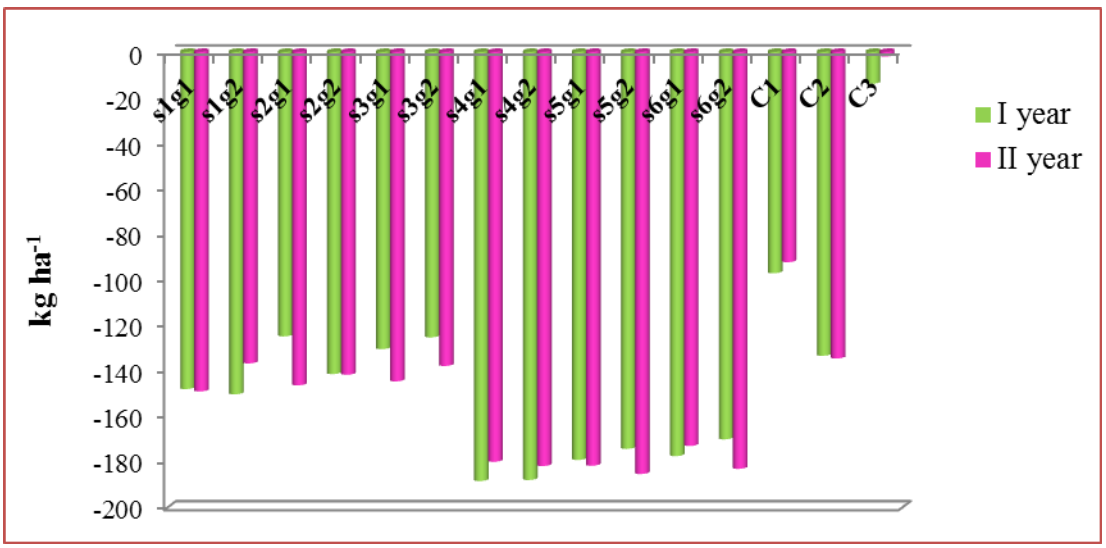


Fig. 29b. Balance sheet of P, kg ha^{-1}

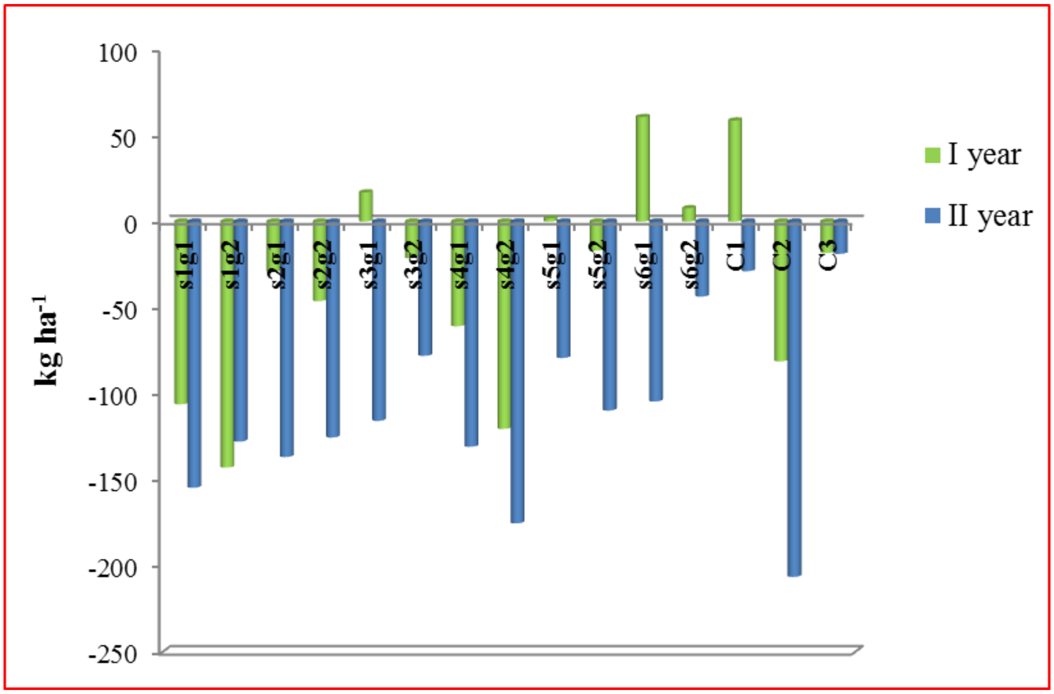


Fig. 29c. Balance sheet of K, kg ha^{-1}

containing PGPR was found to result in positive balance of K along with control treatment containing the application of chemical fertilizers. PGPR is a consortium of microorganisms including the K solubilizing bacteria and the beneficial effect of PGPR on nutrient availability through mechanisms as explained by Lonhienne *et al.* (2019), would have resulted in a positive balance of K in the soil which had a higher K content initially. After second year of experiment the balance sheet was negative for all the treatments. The similar result of negative balance sheet of available K was reported by Veeresha *et al.* (2014) in organic manure applied treatments. Only a portion of K would have been available from organic manures during corresponding season (70 % of K from FYM for first crop).The leaching loss of available K from soil as the season was having higher rainfall also might have contributed to negative balance sheet of K. The negative balance was however lower in absolute control followed by C_1 and s_6g_2. The input of K in absolute control was zero and crop uptake was the lowest. However the initial K status of soil was high and this coupled with minimal uptake would have left a major portion of it unutilized in the soil. Meanwhile it could be remembered that the owing to the high rainfall received during the season, some portion of the K^+ left unutilized in the soil would have been leached out which otherwise would have resulted in a positive balance in case of absolute control.

5.1.9 Economic Analysis

Among organic sources, application of poultry manure along with wood ash, PGPR mix I and vermiwash (s_6) registered the highest net income and BCR during both the years and for mean also (Fig. 30a and 30b). The higher quantity of FYM applied compared to poultry manure to equalize the N requirement resulted in higher cost of cultivation in FYM applied treatments. The higher yield produced in poultry manure applied treatments with lower cost of cultivation might have resulted in higher net income and BCR in poultry manure applied treatments over FYM applied treatments. *In situ* green manuring with daincha (g_2) resulted in higher net income and BCR during

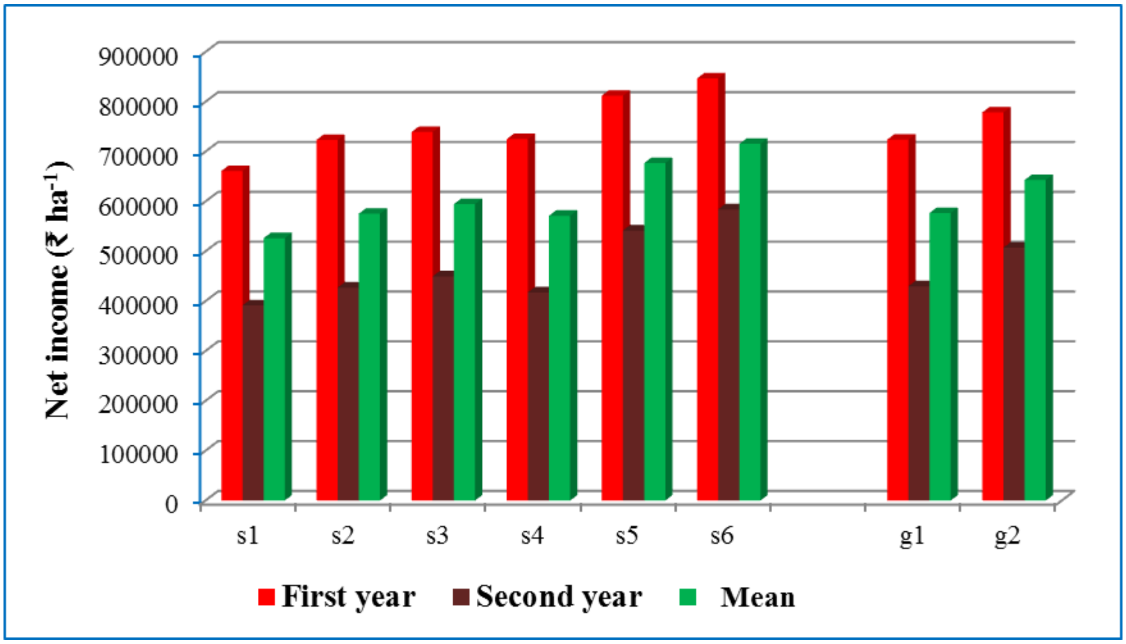


Fig. 30a. Effect of organic sources and *in situ* green manuring on net income (₹ ha^{-1})

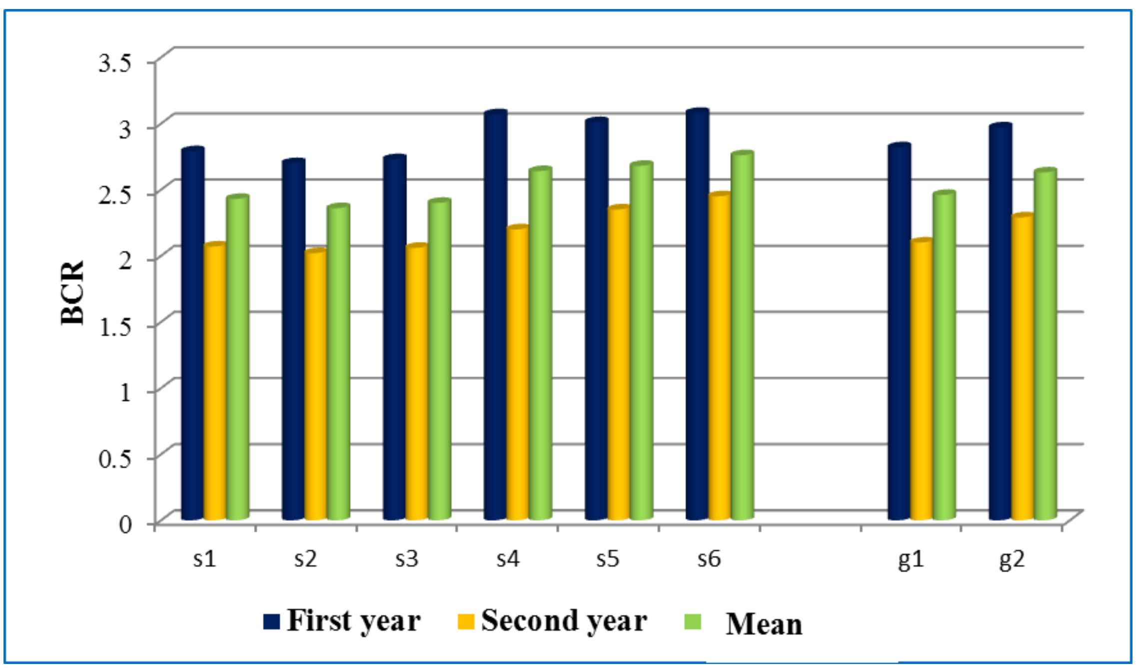


Fig. 30b. Effect of organic sources and *in situ* green manuring on BCR

both the years and for mean also over *in situ* green manuring with cow pea. *In situ* green manuring with daincha resulted in higher yields than *in situ* green manuring with cow pea, which was reflected in the economics also. Regarding SxG interaction (Fig. 31a and 31b), the treatment combination, s_6g_2 (application of poultry manure along with wood ash, PGPR mix I and vermiwash + i*n situ* green manuring with daincha) registered the highest net income and BCR during both the years and for mean also which reflects the main effects of treatments. The same treatments have resulted in better growth and yield of the crop resulting in profitable taro cultivation.

All the treatments during the first year and all treatments except s_1g_1, s_2g_1, s_3g_1 and s_4g_2 during the second year and except s_1g_1 and s_2g_1 for mean recorded higher net income than C_1. While all the treatments except s_1g_1, s_2g_1, s_3g_1 and s_3g_2 during the first year and treatments s_5g_1 and s_6g_2 during the second year s_4g_1, s_5g_1, s_6g_1 and s_6g_2 for mean recorded higher BCR than C_1. The treatment s_6g_2 recorded a 43.96 percentage and 6.02 percentage increase of net income and BCR respectively over chemical nutrient management for mean. Though the cost of cultivation was lower for chemical nutrient management, the premium price of organic produce in the market resulted in the higher net income and BCR for organic nutrition treatments.

The treatments except s_1g_1 during the first year, except s_1g_1 and s_2g_1 during the second year and for mean recorded higher net income compared to C_2. The treatments except s_1g_1, s_2g_1 and s_3g_1 during both the years and for mean recorded higher BCR compared to C_2. The treatment s_6g_2 recorded a 54.71 percentage and 19.49 percentage increase of net income and BCR respectively over KAU organic POP for mean. All organic nutrition treatments recorded higher net income compared to absolute control during both the years and for mean also. The organic nutrition treatments except s_2g_1 during the first year, except s_1g_1, s_2g_1 and s_3g_1 during the second year and except s_2g_1 and s_3g_1 for mean recorded higher BCR compared to absolute control. Even though the cost of cultivation was less in the control

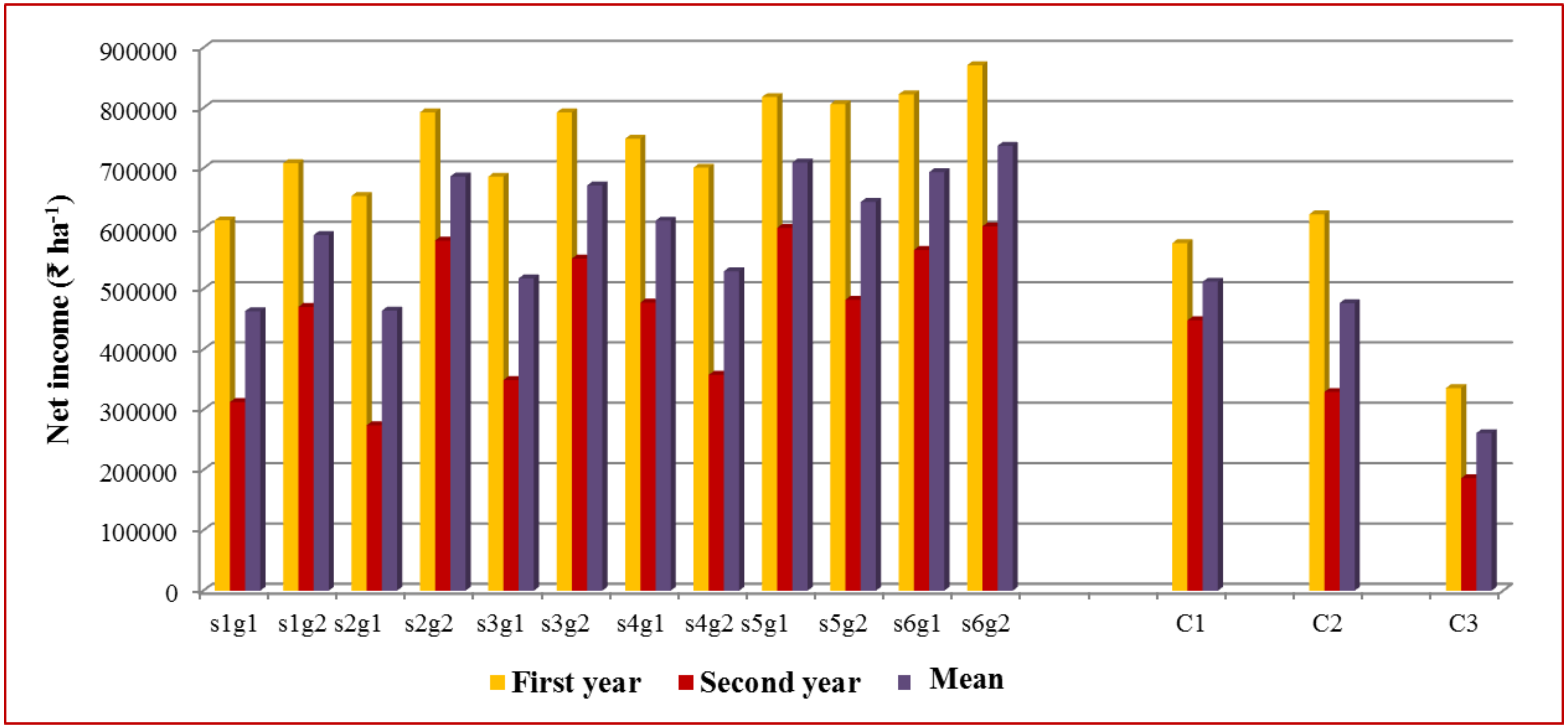


Fig. 31a. Effect of S x G interaction and treatments *Vs*. control effect on net income (₹ ha^{-1})

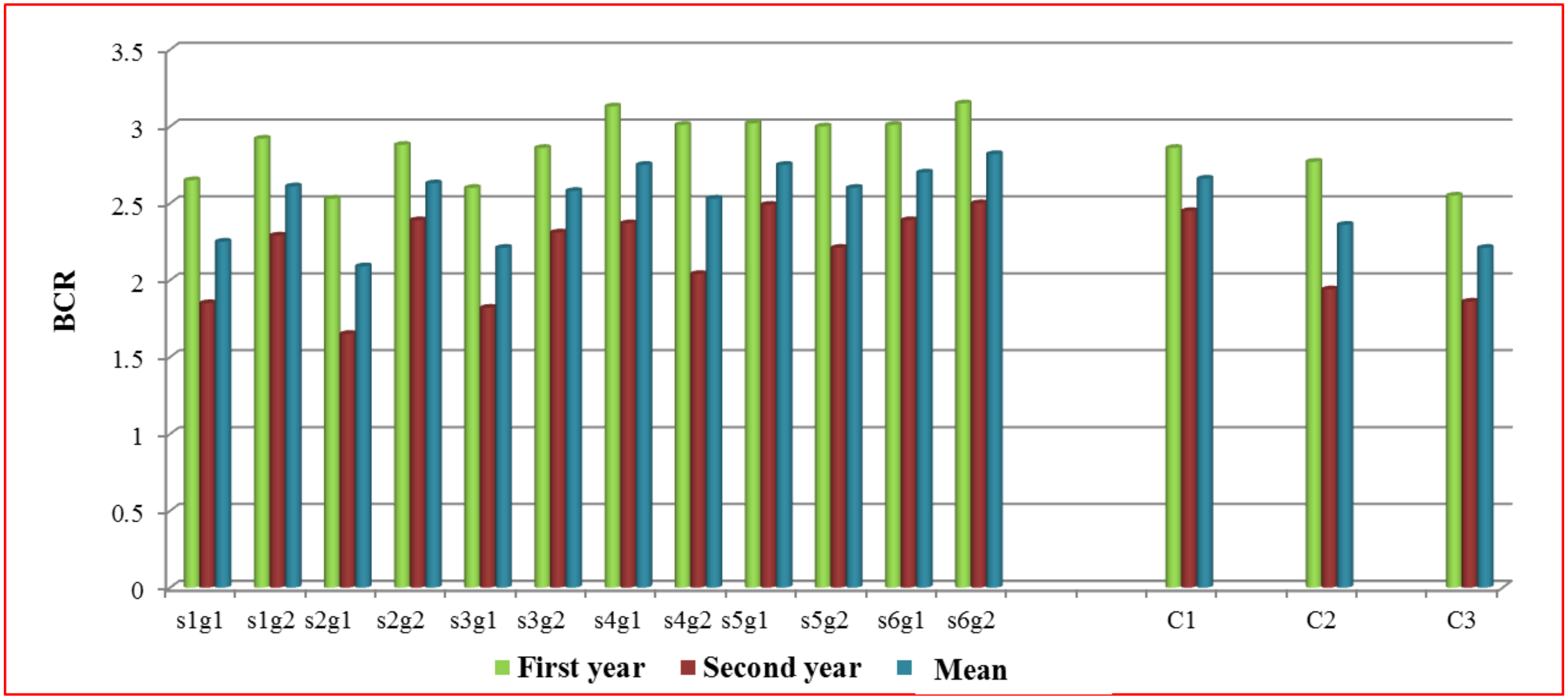


Fig. 31b. Effect of S x G interaction and treatments *Vs*. control effect on BCR

treatments, the higher yield produced in the organic treatments resulted in the higher net income and BCR in organic treatments compared to control treatments.

Taro is used as a vegetable and is also preferred for making a wide array of food products which have great demand and market abroad. The organic nutrition is highly relevant for the export oriented production of taro and the health conscious urban consumers of overseas market will not compromise the quality and would prefer a high quality produce even at premium price.

The discussion of the results of this investigation indicated that the organic nutrition involving combined application of organic manures along with other organic sources of nutrition such as *in situ* green manuring or use of biofertilizer (PGPR mix I) was superior or equally effective as inorganic fertilizer application in improving the yield attributes and yield and was found to be beneficial economically.

5.2 EXPERIMENT II - POT CULTURE STUDY

5.2.1 Analysis of Potting Medium

Increase in pH was noticed (except for T_1 and C_3) compared to initial status in all treatments except at 4 MAP in C_1 and at 1MAP and harvest in absolute control. The increase in pH under organic nutrition may be due to the presence of basic cations produced from the mineralization of organic matter that are rich in Ca, Mg and K. The highest pH was recorded at 4 MAP (Fig. 32) in all treatments except in C_1 (nutrient management through chemical fertilizers). In $C_{1,}$ the highest pH was recorded at 1 MAP. The decrease in pH of C_1 from 1 MAP to 4 MAP may be due to the application of chemical fertilizers after 1 MAP.

At 1 MAP, the highest pH was recorded by the treatment T_6 (poultry manure + wood ash + PGPR mix I + vermiwash) and was on par with T_2, T_5 and C_2. The higher pH in poultry manure applied treatments during the 1 MAP possibly due to the faster mineralization of poultry manure and release of entrapped cations compared to FYM. At 4 MAP, T_6 and T_5 (poultry manure + wood ash + PGPR mix I) recorded the highest value for pH and were on par with T_2, T_3 and $C_{2.}$ The organic source T_5 recorded the highest pH at harvest and was on par with T_3 and T_6. Even though the highest pH was recorded with poultry manure applied treatments during later stages, it was statistically comparable with treatments containing FYM owing to mineralization of FYM during later stages. Further more in all the organic nutrition treatments, wood ash was used as a source of K and as reported by (Ohno and Erich, 1990) wood ash is alkaline in nature and has got an acidity moderation effect.

The application of PGPR also might have enhanced the mineralization of organic manure leading to the release of organic acids and hence the higher pH in PGPR applied treatments compared to without application. At 1 MAP and harvest, the lowest pH was recorded by absolute control while at 4 MAP, nutrient management through chemical fertilizers recorded the lowest pH. The higher pH of organic nutrition treatments compared to C_1 and C_3 may be as a result of basic cations produced from the mineralization of organic matter combined with the basic nature of wood ash used as a common component in all the organic nutrition treatments. Brar *et al.* (2015) reported the increase in pH due to production of basic cations by mineralization of C and production of OH^- ions by ligand exchange.

An increase in EC was noticed from initial to harvest stage in all treatments. The increase in EC might have been due to the release of nutrient elements from organic manures a result of mineralization as explained earlier. Glaser *et al.* (2015) reported that cationic and anionic nutrients are produced due to mineralization of organic manures thereby increasing the electrical conductivity of soil. The activity of wood ash which modifies the soil physical properties and release nutrients including sodium (Demeyer *et al*., 2001) would have further contributed to elevated EC after the organic nutrition treatments.

The absolute control (C_3) recorded the lowest value of EC at all stages of observation (Fig.33). The higher EC in organic treatments might be due to the release of more soluble salts by wood ash and decomposition of organic manures as explained before. However EC was significantly influenced by the treatments only at 1 MAP and harvest. At 1 MAP, C_3 was on par with T_1, T_2, T_3, T_4, C_1 and C_2. The significantly higher EC in T_5 and T_6 might be due to faster mineralization of PM

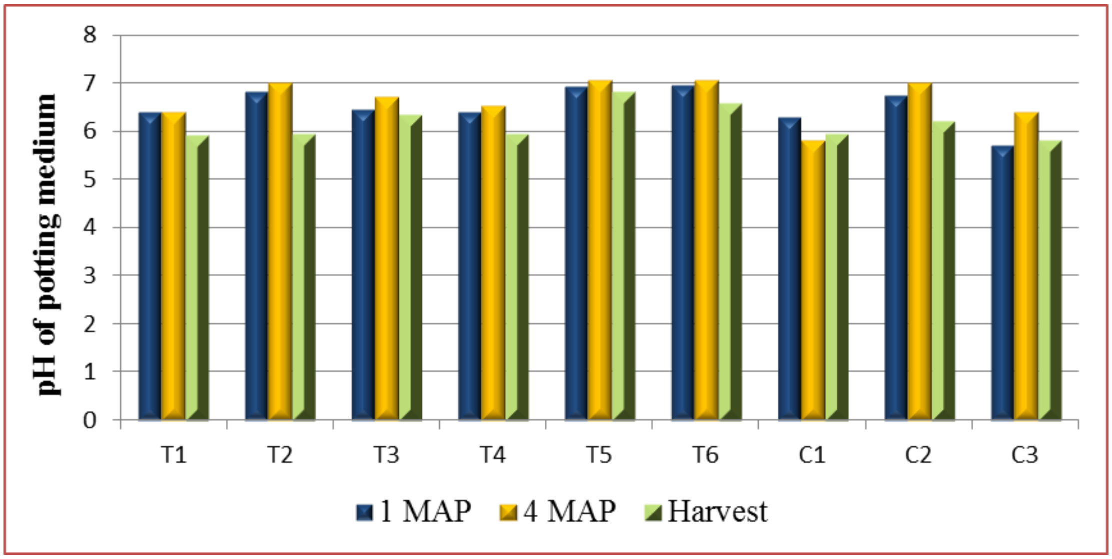


Fig. 32. Effect of organic sources on pH of potting medium

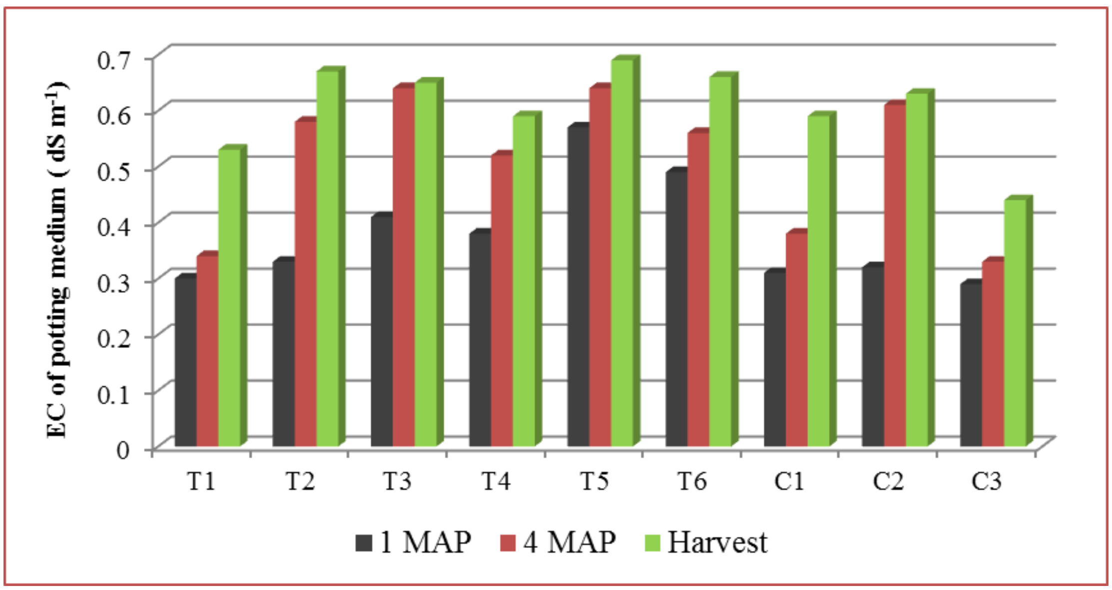


Fig. 33. Effect of organic sources on EC of potting medium, dS m^{-1}

along with the effect of PGPR leading to the release of nutrients to the soil. This effect would have been further augmented by the specific characteristic of wood ash releasing minerals including sodium into the soil. At harvest, C_3 was on par with only T_1 (FYM + wood ash) and all other organic treatments resulted in significantly higher EC which could be due to greater extent of decomposition of organic sources during later stages and resultant release of soluble salts.

Increase in organic carbon content was noticed in organic treatments compared to initial value. The increase organic carbon content of potting medium receiving organic nutrition might be due to the addition of organic manures having higher organic carbon content. The highest organic carbon content was noticed at harvest in all treatments (Fig. 34).

At 1 MAP, the highest organic carbon content was recorded with T_2 (FYM + wood ash + PGPR mix I) and was on par with T_1, T_3, T_5 and T_6. At 4 MAP also, the highest organic carbon content of potting medium was recorded with $T_{2,}$ which was on par with T_1, T_3, T_5 and T_6. At harvest, T_2 and T_3 recorded the highest organic carbon content of potting medium and these treatments were on par with T_1, T_4, $T_{5,}$ T_6 and C_2. This results shows that all the organic treatments were equally effective in enhancing the carbon content of potting medium. While all the organic treatments recorded higher organic carbon than that of C_1 and $C_{3,}$ at all stages, the lowest organic carbon content of potting medium was recorded with absolute control which emphasises the need for addition of organic sources for maintaining the organic matter content of the potting medium.

A decrease (32.21 % - 53.62 %) in available N content of potting medium was noticed compared to initial available N status. In all organic nutrition treatments and absolute control, higher available N content was noticed during 1 MAP and then decreased, while in C_1 and C_2, available N was increased from 1 MAP to 4 MAP (Fig. 35). The basal application of organic manures might have increased the N content at 1 MAP in organic nutrition treatments and thereafter the uptake by crop

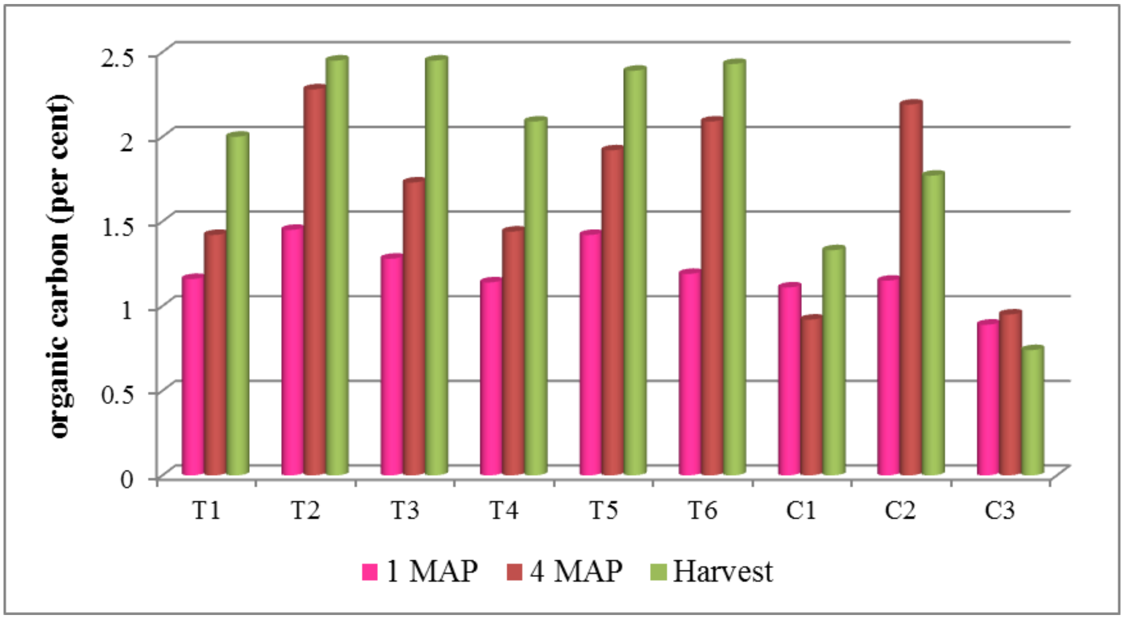


Fig. 34. Effect of organic sources on organic carbon content of potting medium, per cent

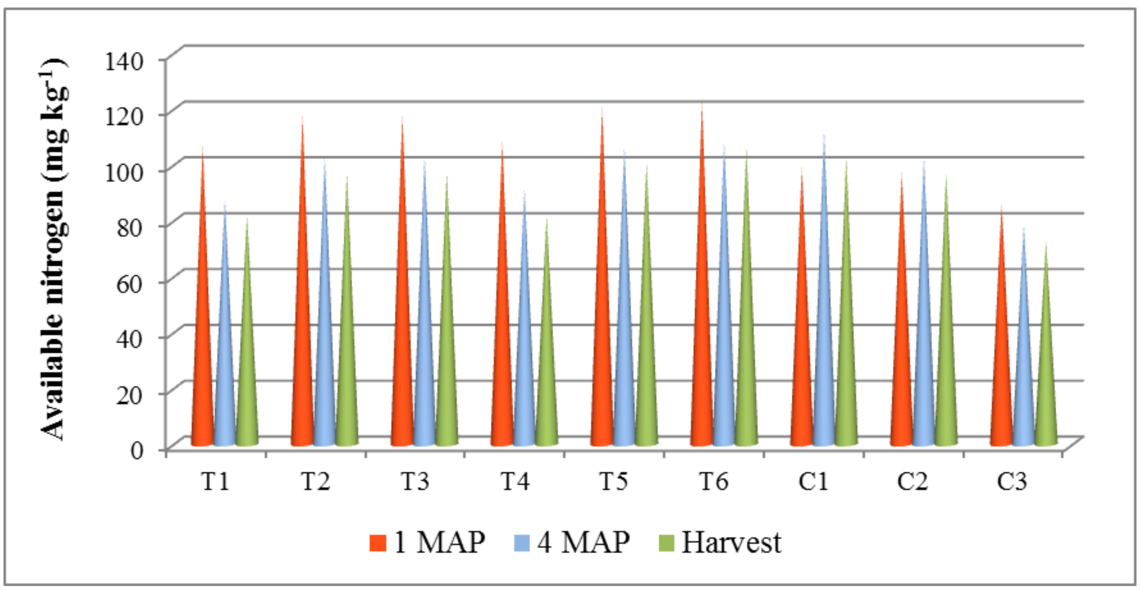


Fig. 35. Effect of organic sources on available nitrogen content of potting medium, mg kg^{-1}

which is raised under pot culture might have reduced the available N content towards harvest. In absolute control also the continuous decrease in available N might be due to the nutrient uptake by crops without any further manure application. Application of fertilisers in C_1 and organic manures in C_2 after 1 MAP might have enhanced available N status and led to a higher content at 4 MAP than at 1 MAP. The organic source T_6 (PM + wood ash + PGPR mix I + vermiwash) recorded the highest available N status at 1 MAP and was on par with T_2, T_3, T_4 and T_5. The basal application of organic manures might have enhanced the available N status at 1 MAP in organic treatments. The higher N status in PM applied treatments may be due to the quick release of N from poultry manure to soil as more than 60 per cent of its total N is present as uric acid which is easily converted to ammonia. Similar results were reported by Dhanya (2011) in sweet potato and Pooja (2018) in cassava. The application of PGPR mix I also might have contributed to increased available N status under these treatments as PGPR mix I is a consortium of microorganisms including N fixing organisms such as *Azospirillum* and *Azotobacter*. At 4 MAP, C_1 (nutrient management through chemical fertilizers) recorded the highest available N status, and was on par with T_2, T_3, $T_{5,}$ T_6 and C_2. The application of urea as sources of N in C_1 contributed to higher available N at 4 MAP in $C_{1.}$ However the organic nutrition treatments also were equally effective as chemical fertilizers in maintaining available N status. At harvest, T_6 recorded the highest available N status and was on par with T_2, T_3, T_5 and C_1. The slow release and continuous availability of nutrients from organic manures have contributed to higher available N at harvest stage compared to chemical fertilizers, however C_1 showed on par effect with the organic treatments. At all stages the lowest available N status was recorded with absolute control, this definitely would have resulted from the no nutrient application strategy under absolute control. Adekiya *et al*. (2016) reported the increased soil N with poultry manure compared to control in cocoyam. Similar results were reported by Adeleye *et al*. (2010) and Agbede *et al*. (2013).

In all treatments except absolute control, the highest available P content was noticed at 4 MAP, while in absolute control, higher available P status was noticed at 1 MAP and then decreased to harvest (Fig. 36). The organic source T_3 (FYM + wood ash + PGPR mix I + vermiwash) recorded the highest available P status at 1 MAP and was on par with T_1, T_2, T_4, T_5, T_6 and C_2. At 4 MAP, T_2 (FYM + wood ash + PGPR mix I) recorded the highest available P status and was on par with all treatments except absolute control. The result shows that the organic treatments were equally effective in case of available P content of potting medium. However the higher P content in T_3 might be due to the moderate P content of FYM, higher quantity of FYM added compared to PM and its greater proportion of bioavailable fraction of inorganic P suggested by Braos *et al*. (2015). The application of PGPR also could have contributed to higher available P status as it includes P solubilizes. The similar result of improved available P status in soil by application of PGPR mix I under organic production of chinese potato was reported by Jayapal *et al.* (2013). At harvest, T_3 recorded the highest available P status and was on par with T_2, T_5 and T_6. At all stages, the lowest available P status was recorded with absolute control. The higher available P in other treatments compared to absolute control was definitely on account of addition of organic manures in organic treatments and application of P fertilizers in chemical nutrient management. It is well known that organic matter reduces P fixation and enhances P availability. The organic acids produced during the decomposition of organic matter might have also increased the solubility of native P (Singh *et al*., 2008).

A decrease (0.98 % - 41.18 %) in available K content of potting medium (except for T_6) was noticed from initial status to harvest stage, while at 1 MAP and 4 MAP, the available K content was higher compared to initial status in all treatments except absolute control (Fig. 37). The decrease in available K status during later stages of crop growth compared to early stages might be due to the higher uptake of K during later stages of crop growth than vegetative periods as K plays an important role in tuber development. In general, higher available K content was noticed at 4

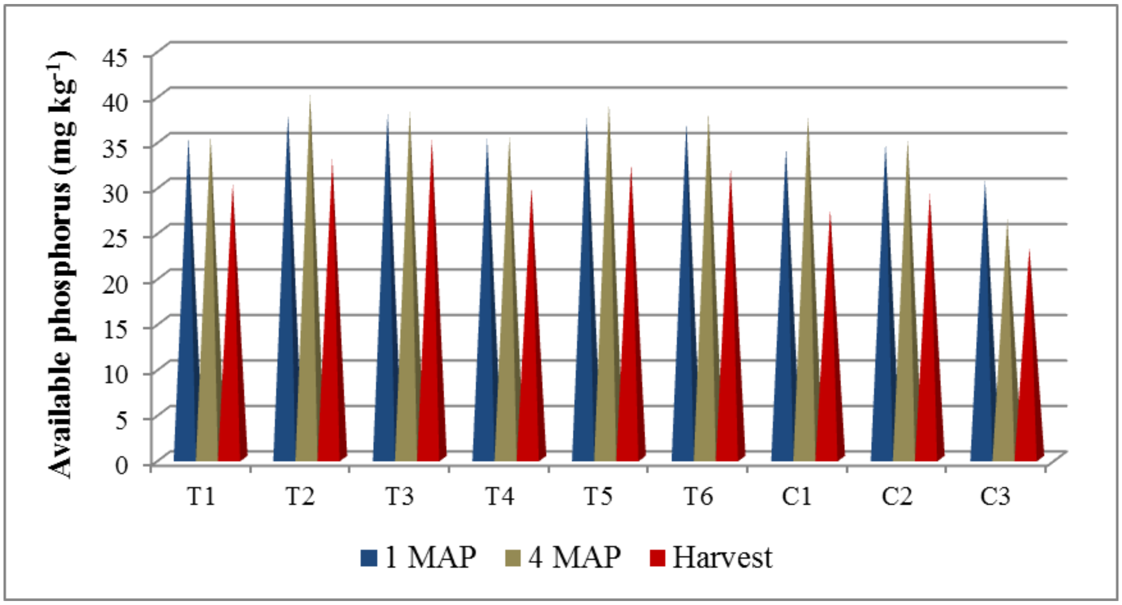


Fig. 36. Effect of organic sources on available phosphorus content of potting medium, mg kg^{-1}

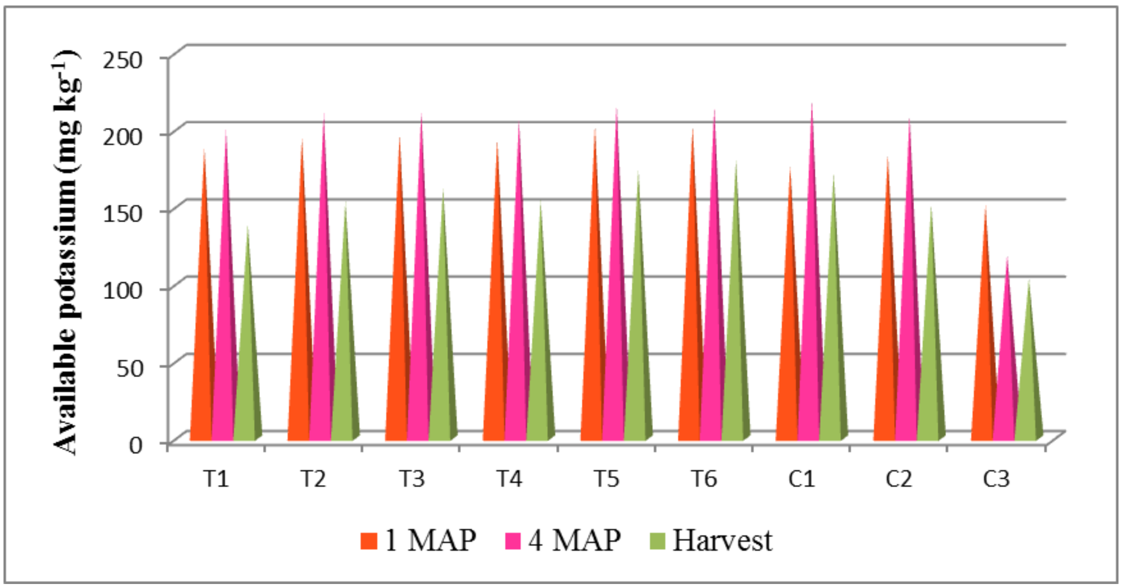


Fig. 37. Effect of organic sources on available potassium content of potting medium, mg kg^{-1}

MAP except in absolute control. In absolute control higher available K content was noticed at 1 MAP and then decreased to harvest. The organic source T_6 (PM + wood ash + PGPR mix I + vermiwash) recorded the highest available K status at 1 MAP and was on par with T_1, T_2, T_3, T_4, T_5 and C_2. At 4 MAP, C_1 (nutrient management through chemical fertilizers) recorded the highest available K status, and was on par with all treatments except absolute control. At harvest, T_6 recorded the highest available K content in potting medium and was on par with T_2, T_3, T_4, T_5, C_1 and C_2. The result shows that the organic treatments were equally effective in case of available K status of potting medium. The difference was however noticed between treatments and absolute control and at all stages, the lowest available K status was recorded with absolute control. Addition of organic manures containing K in organic treatments and application of MOP as source of K in C_1 might have improved the available K status of potting medium in comparison with absolute control. Increased availability of K on decomposition of organic manures, reduction of K fixation and leaching loss by organic manures might be the reasons for improved status of available K in pots treated under organic nutrition. Zulbeni *et al.* (2020) reported increased exchangeable K in soil under colocasia cultivation by chicken manure application compared to without application treatment. Adekiya *et al*. (2016), Adeleye *et al*. (2010) and Agbede *et al*. (2013) also reported the similar results.

5.2.2 Microbial Study of the Potting Medium

The bacterial population was the highest at 1 MAP and then decreased to harvest in all treatments (Fig. 38). This may be due to the application organic manures, a source of food for microorganisms as basal dose.

The highest population of bacteria was obtained by organic source T_5 wherein poultry manure applied along with wood ash and PGPR mix I. The T_5 was on par with $T_{2,}$ $T_{3,}$ T_6 and C_2 at 4 MAP and with $T_{2,}$ $T_{3,}$ T_4 and T_6 at harvest. The highest fungal population (Fig. 39) was recorded by organic source T_6 (PM + wood ash + PGPR mix I + vermiwash) at 1 MAP; T_3 (FYM + wood ash + PGPR mix I + vermiwash) at 4 MAP, T_2 (FYM + wood ash + PGPR mix I) at harvest. However, in

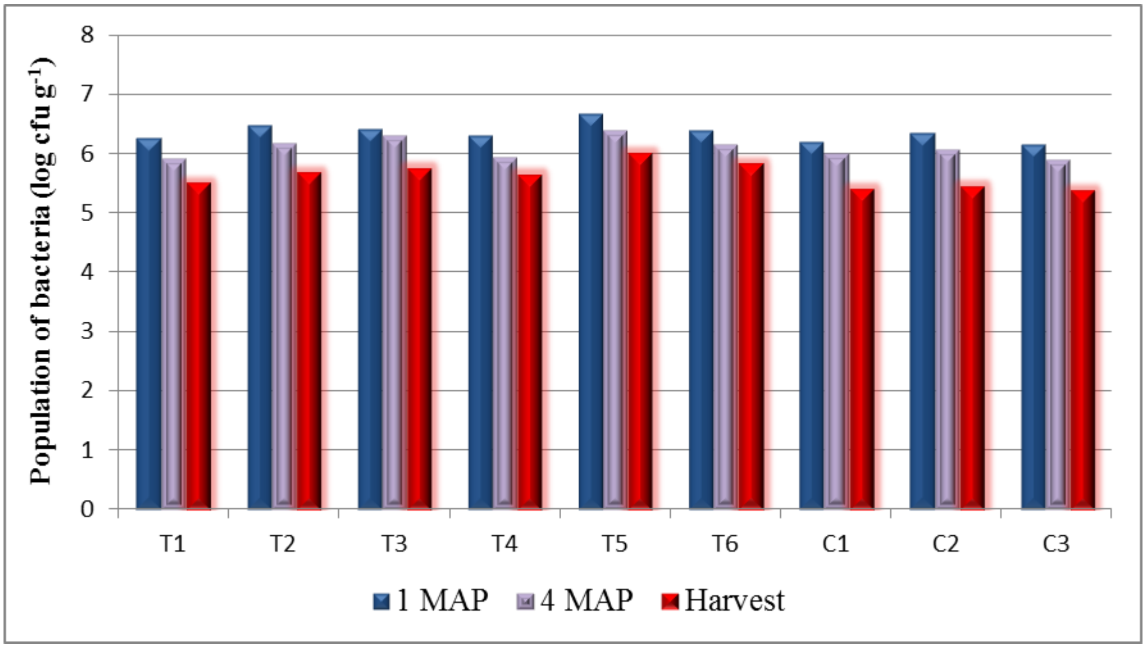


Fig. 38. Effect of organic sources on population of bacteria of potting medium, log cfu g^{-1}

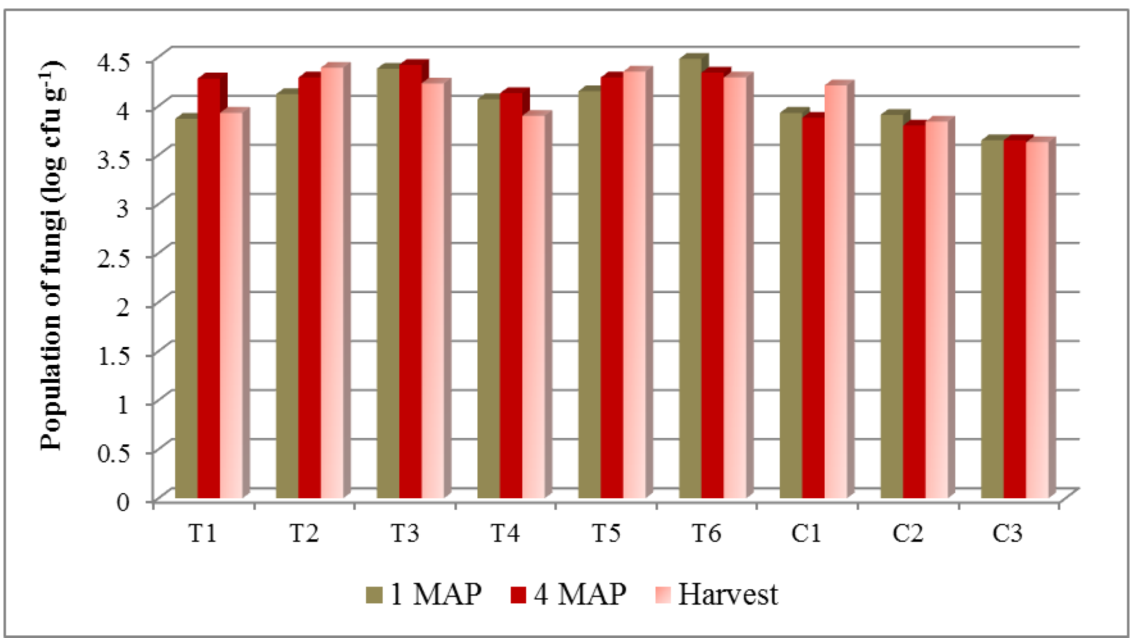


Fig. 39. Effect of organic sources on population of fungi of potting medium, log cfu g^{-1}

general, the treatments T_2, T_3, T_5 and T_6 were found equally effective in case of fungal population. The highest actinomycetes population (Fig. 40) was recorded by T_2 (FYM + wood ash +PGPR mix I) at 1 MAP; T_5 (Poultry manure + wood ash + PGPR mix I) at 4 MAP and T_2 (FYM + wood ash +PGPR mix I) and T_3 (FYM + wood ash + PGPR mix I + vermiwash) at harvest.

Among the three observation stages, the highest population of *Azospirillum* and *Azotobacter* were recorded at 4 MAP in all treatments (Fig. 41 and 42). The organic source application of PM along with wood ash, PGPR mix I and vermiwash (T_6) recorded the highest population of *Azospirillum.* At 4 MAP, T_6 was on par with all treatments except absolute control. At harvest T_6 was on par with T_2, T_3 and T_5. The highest population of *Azotobacter* was recorded by organic source application of FYM along with wood ash and PGPR mix I (T_2) at 1 MAP which was on par with T_3, T_5, T_6 and C_2. At 4 MAP and harvest, PM application along with wood ash, PGPR mix I and vermiwash (T_6) recorded the highest population of *Azotobacter* and was on par with T_5 at 4 MAP and with T_2, T_3 and T_5 at harvest. The organic source T_3 (FYM + wood ash + PGPR mix I + vermiwash) recorded the highest population of P solubilisers (Fig.43) at 1 MAP and 4 MAP and was on par with T_6 (PM + wood ash +PGPR mix I+ vermiwash) at both the stages. The above result shows that the treatments T_2 (FYM + wood ash + PGPR mix I + vermiwash), T_3 (FYM + wood ash + PGPR mix I), T_5 (PM+ wood ash + PGPR mix I) and T_6 (PM+ wood ash + PGPR mix I + vermiwash) were equally effective in maintaining microbial population of potting medium. Application of organic sources of nutrients improving the microbial counts and soil microbial biomass carbon has been previously reported by Nakhro and Dkhar (2010). As reported by Pujiastuti *et al.* (2018), application of poultry manure has several benefits including the soil organic matter enrichment. The soil organic matter serves as a source of food for the microorganisms in the soil which could be responsible for the higher microbial population with the application of poultry manure. The significant improvement of microbial population by FYM application

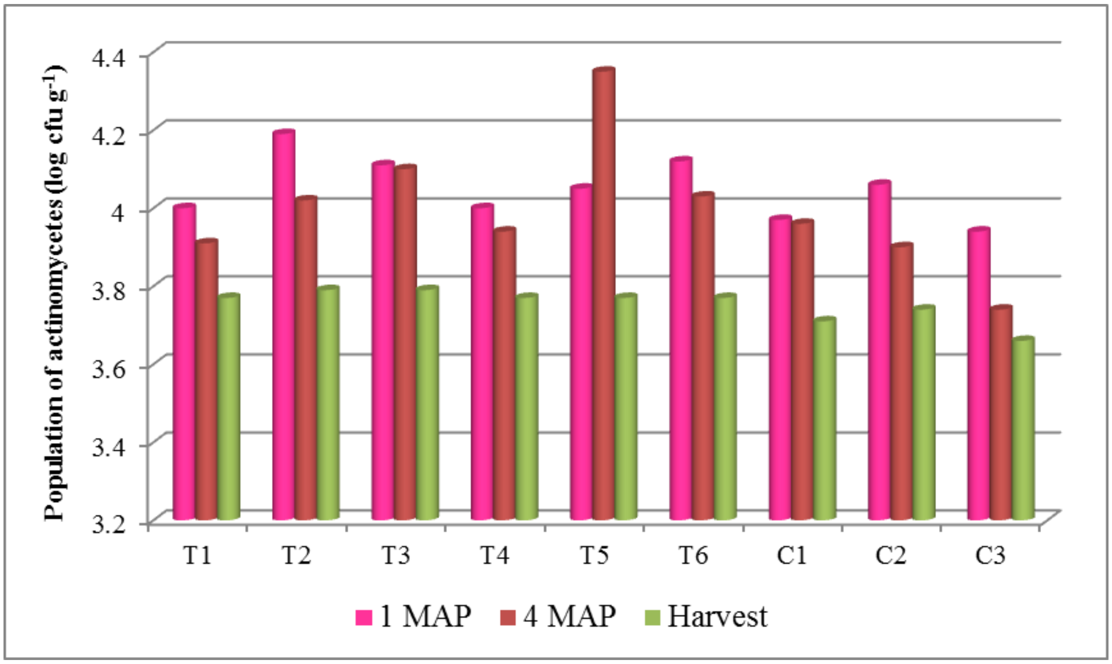


Fig. 40. Effect of organic sources on population of actinomycetes of potting medium, log cfu g^{-1}

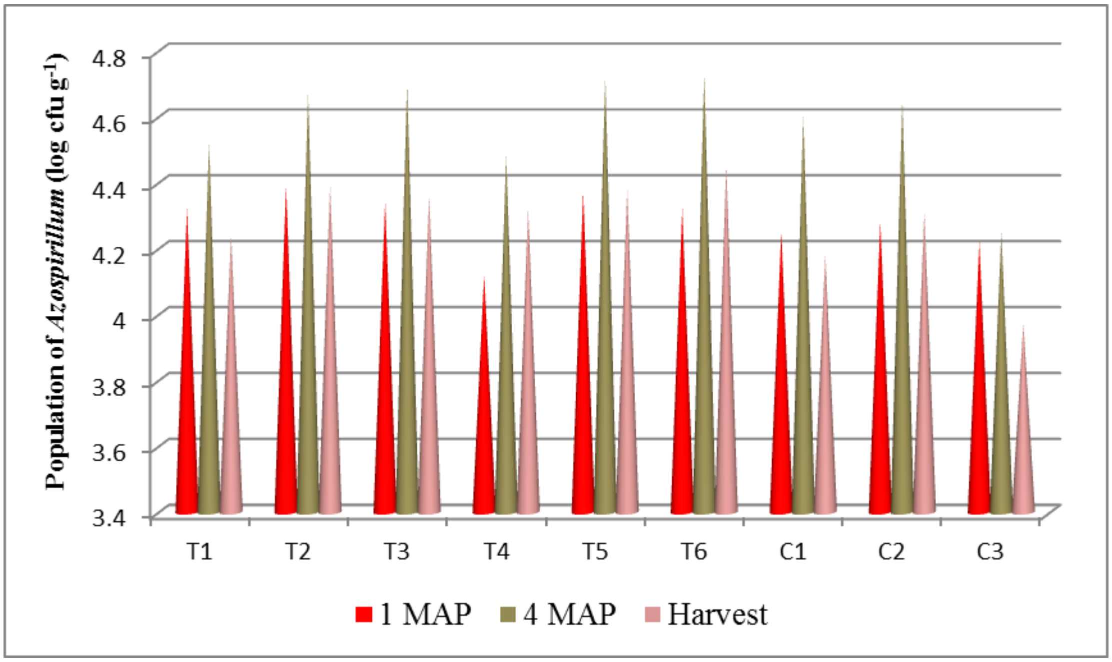


Fig. 41. Effect of organic sources on population of *Azospirillum* of potting medium, log cfu g^{-1}

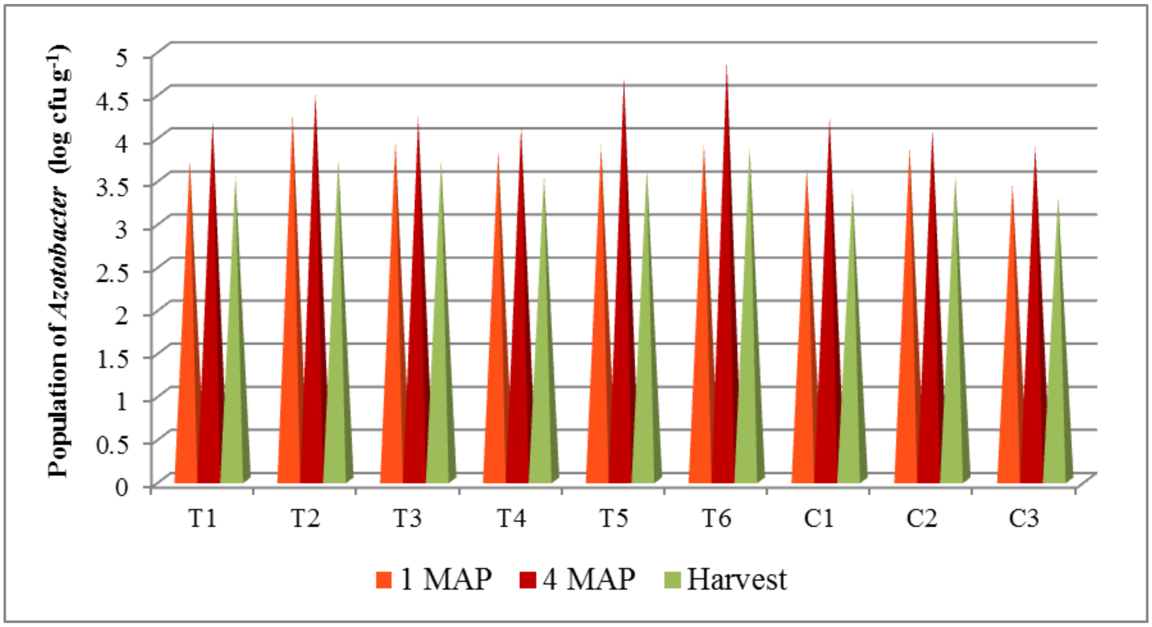


Fig. 42. Effect of organic sources on population of *Azotobacter* of potting medium, log cfu g^{-1}

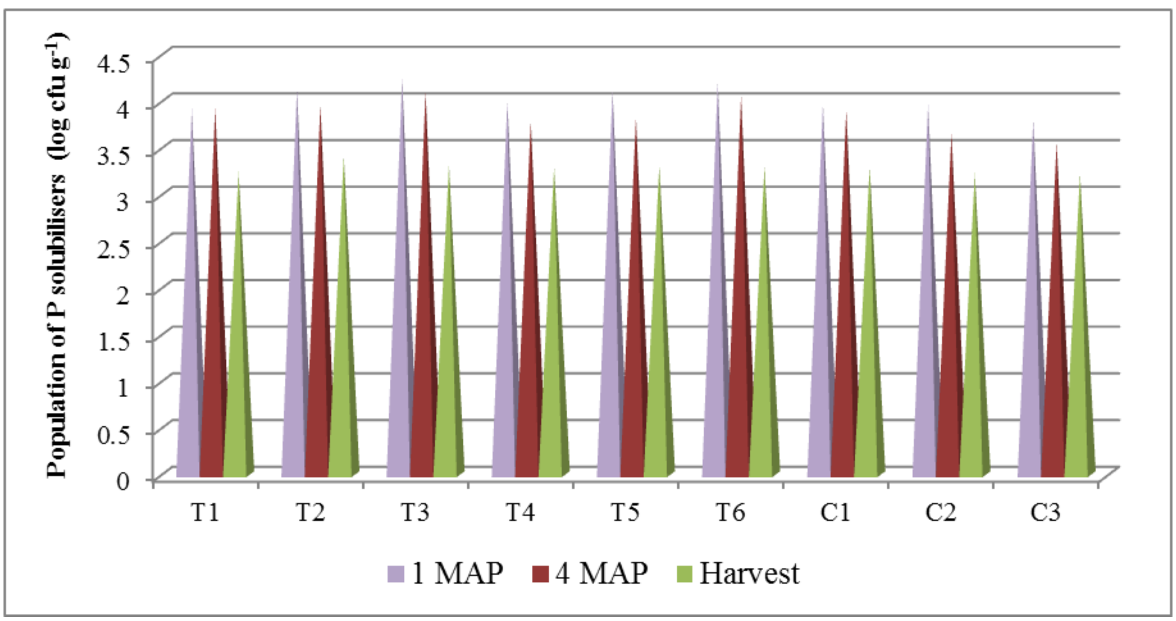


Fig. 43. Effect of organic sources on population of P solubilisers of potting medium, log cfu g^{-1}

was reported by Parewa *et al.* (2014). The PGPR mix I is a microbial consortium for supplementing all the major nutrients as reported by Gopi *et al. (*2020). The PGPR application modifies the mineral status of the crop rhizosphere through the secretion of amino acids, organic acids and other compounds which are also having a stimulatory effect on soil microbial activity.

Generally microbial population was lower in control treatment nutrient management through chemical fertilizers. This may be due to the suppressing effect of fertilizer sources on microbial community as suggested by Staley *et al.* (2018) who reported the decreased microbial diversity in agricultural soils with urea amendment. The lowest microbial population was recorded by absolute control in all cases, the scarcity of food sources as absolute control contains no organic matter might have decreased the population of microbes.

Dehydrogenase enzyme activity is an indicator of the biological activity in the soil (Gu *et al*., 2009; Salazar *et al*., 2011), as these occur intracellular in all living microbial cell (Moeskops *et al.*, 2010) while all other soil enzymes are mostly extra cellular. In all treatments except absolute control, the highest dehydrogenase activity was observed during 4 MAP (Fig. 44). The organic source T_5 (PM + wood ash + PGPR mix I) recorded the highest dehydrogenase activity at 1 MAP, which was on par with T_2 (FYM + wood ash + PGPR mix I), T_3 (FYM + wood ash + PGPR mix I+ vermiwash), and T_6 (PM + wood ash + PGPR mix I + vermiwash). At 4 MAP, T_3 recorded the highest dehydrogenase activity and was on par with T_2, T_5 and T_6. At harvest stage, the highest dehydrogenase activity was recorded by T_5, which was on par with T_2, T_3 and T_6. From the result, it was observed that the treatments T_2, $T_{3,}$ T_5 and T_6 were equally effective with respect to dehydrogenase activity. The application of PGPR mix I in these treatments might have enhanced the dehydrogenase activity as the enzymes are produced by proliferating microorganisms in soil. The variation of

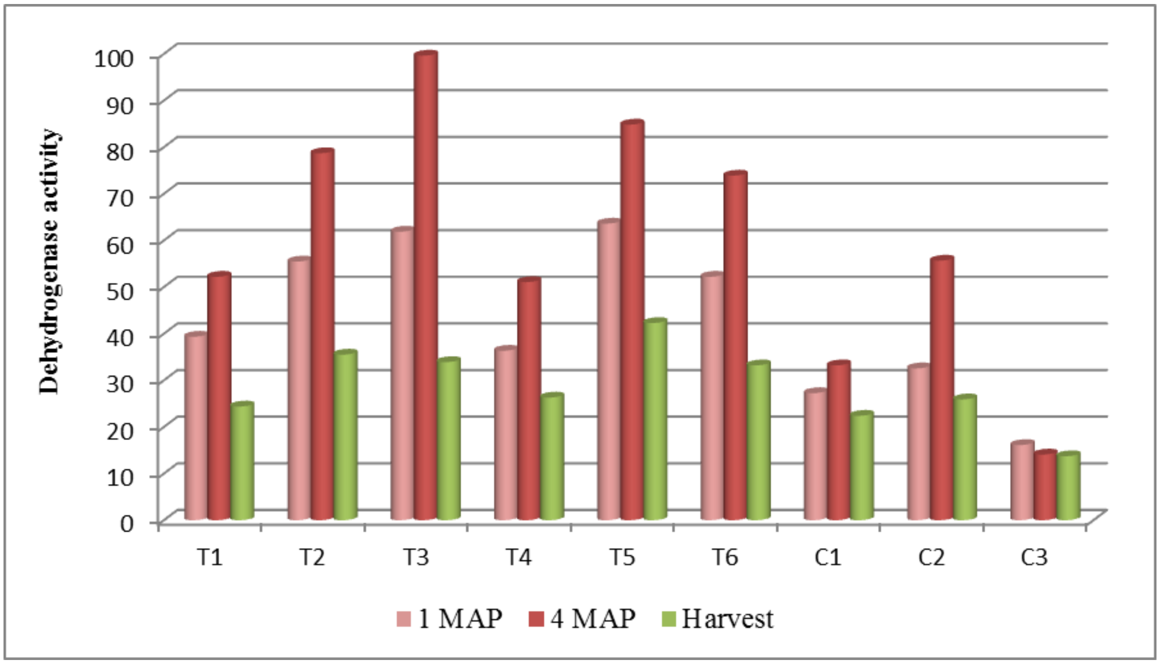


Fig. 44. Effect of organic sources on dehydrogenase activity of potting medium, µg TPF $24h^{-1}$ g^{-1}

the microbial population in soil might result in an alteration of enzyme activity in soil. No difference was found in between FYM and poultry manure with respect to the enzyme activity. The dehydrogenase activity of the control C_1 - nutrient management through chemical fertilizers as per KAU POP was lower when compared to all other organic nutrition treatments. The absolute control recorded the lowest dehydrogenase activity at all stages of observation. Microbial activity reported was also lower in chemical nutrient management and absolute control compared to organic nutrition treatments this might have resulted in lower dehydrogenase activity as dehydrogenase activity is an indicator of biological activity.

5.2.3 Rooting Pattern of Taro

The root apex diameter showed an increasing trend up to 3-4 MAP, while number and root weight per plant showed an increasing trend up to 4 - 5 MAP and then started declining towards harvest (Fig. 45, 46 and 47). This might be due to the fact that the grand growth period of taro occurs between 8 to 20 weeks as explained by Sivan (1982). The treatment T_6 (poultry manure + wood ash + PGPR mix I + vermiwash) recorded the highest root apex diameter at 1, 4, 5, 6 and 7 MAP. At 2 MAP, the control nutrient management through chemical fertilizer application as per KAU POP recorded the highest root apex diameter. While at 3 MAP, the highest root apex diameter was recorded by the treatment T_5 (poultry manure + wood ash + PGPR mix I). The control treatment (C_1) that followed the nutrient management through chemical fertilizer application as per KAU POP recorded the highest root number per plant at 2 and 3 MAP. However, from 4 MAP onwards organic treatments recorded the significantly higher root number per plant than the chemical fertilizer application. At 4 MAP and 5 MAP significantly higher root number per plant was recorded with T_6 (PM + wood ash+ PGPR mix I+ vermiwash). During the later stages of crop growth (6MAP and 7 MAP), the higher root number per plant was recorded with the treatment $T_{3.}$ The treatment T_6 (Poultry manure + wood ash+ PGPR mix I+ vermiwash) recorded the highest root weight per plant at all stages of observation

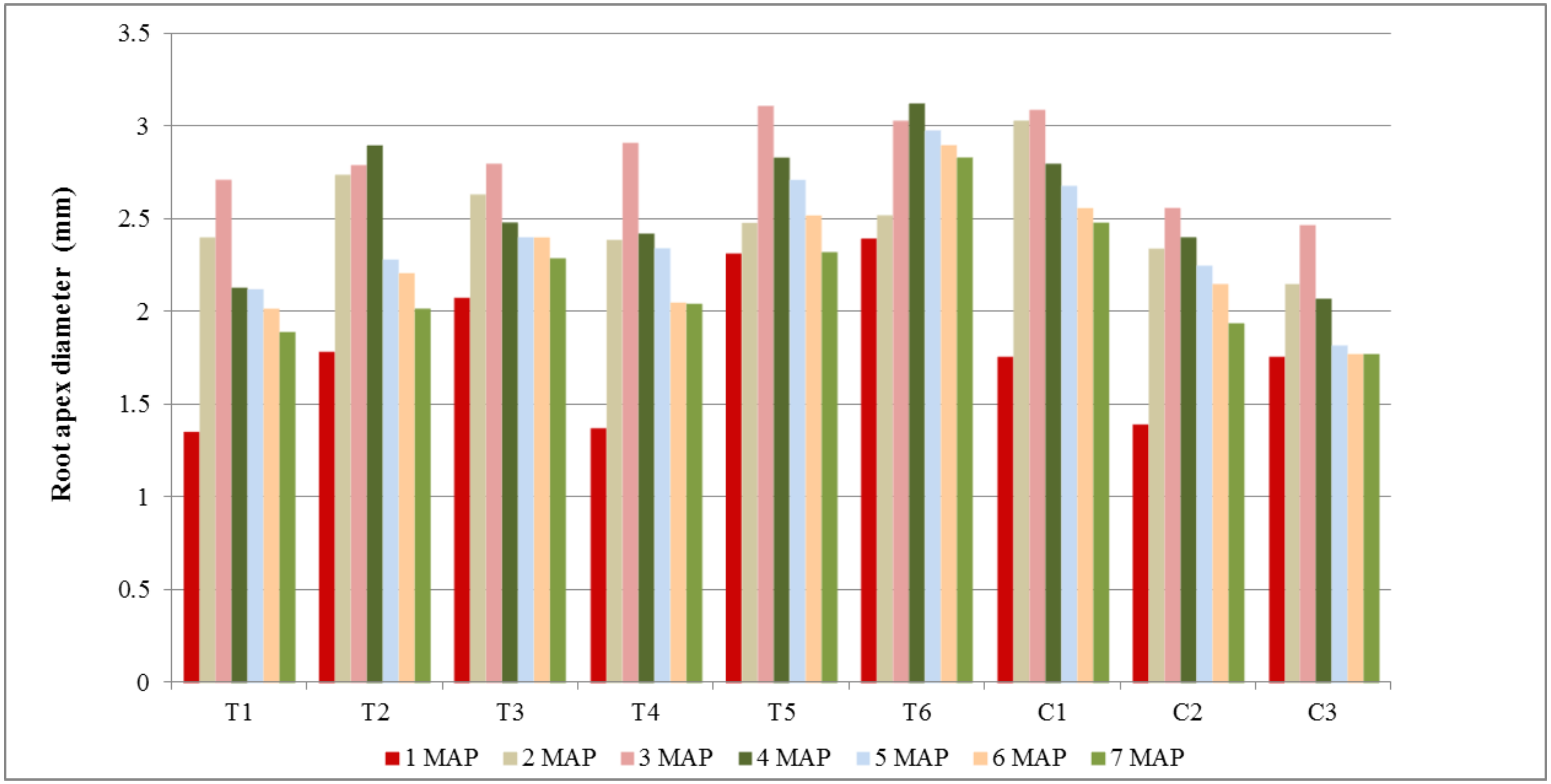


Fig. 45. Effect of organic sources on root apex diameter, mm

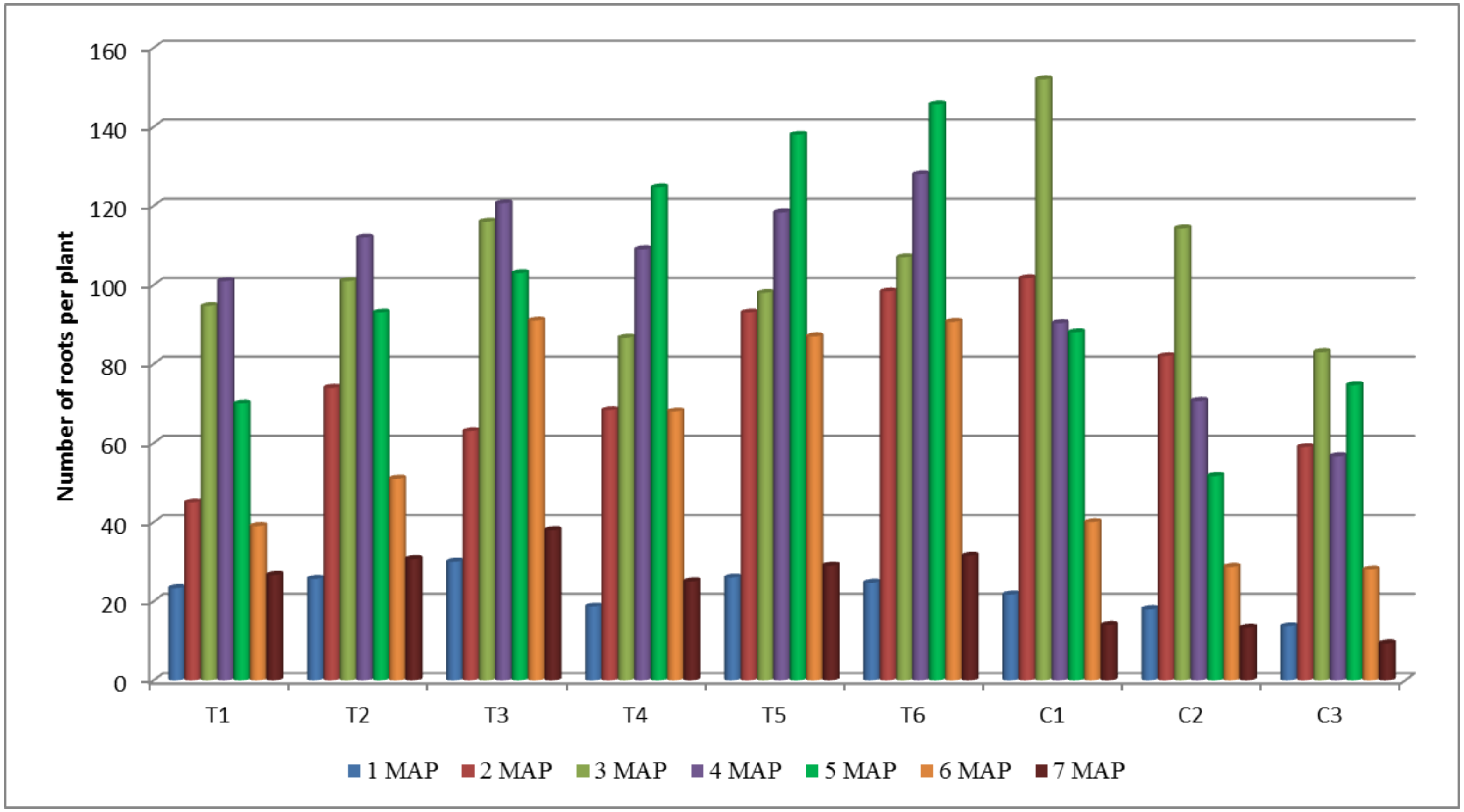


Fig. 46. Effect of organic sources on number of roots per plant

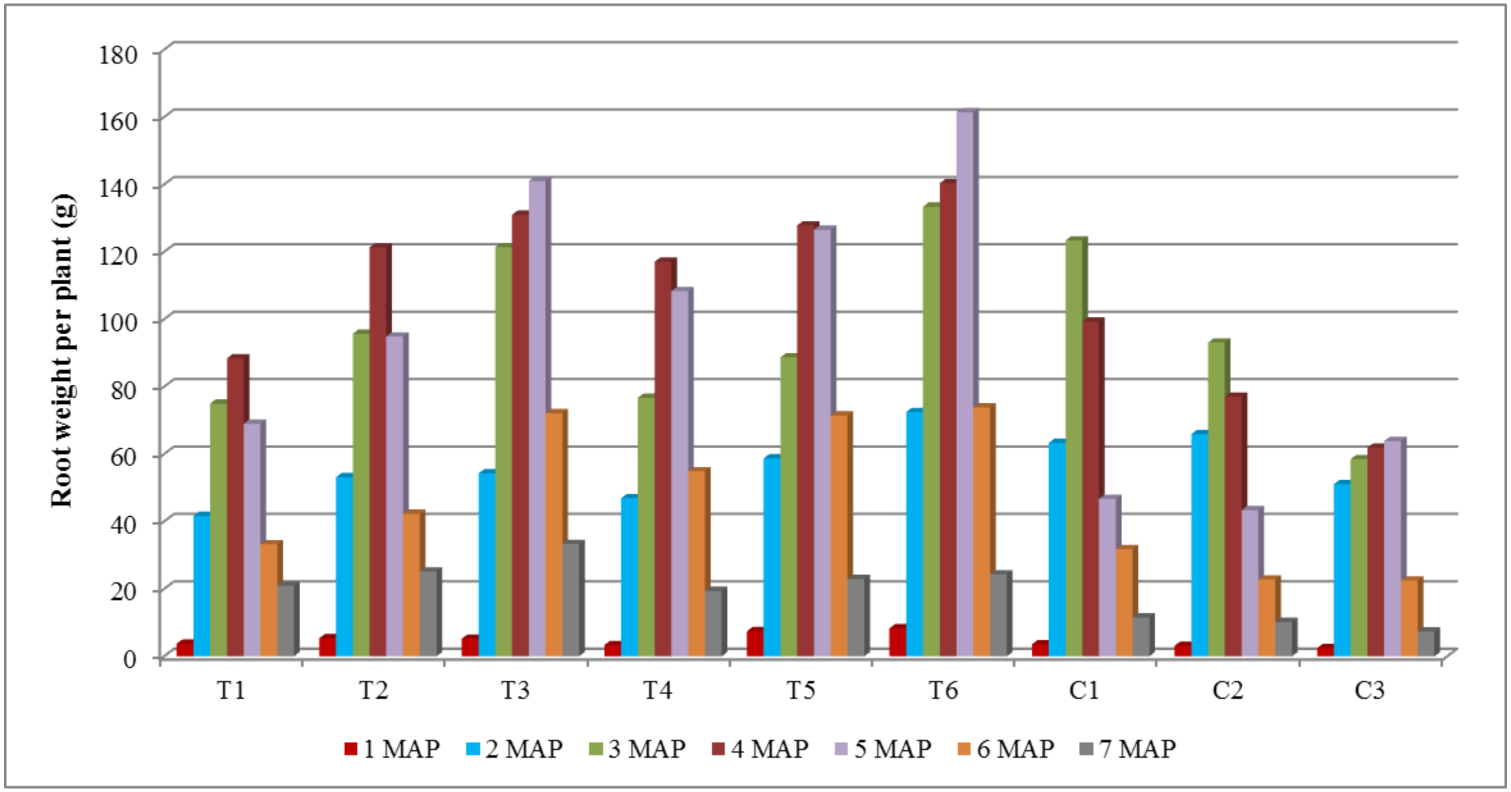


Fig. 47. Effect of organic sources on root weight per plant, g

except 7 MAP, wherein T_3 (FYM + wood ash+ PGPR mix I+ vermiwash) recorded the highest root weight per plant. The higher roots parameters with chemical fertilizers during initial stages indicate the rapid availability of nutrients to the plants through chemical fertilizers. The higher value of root parameters with the treatment T_6, and it's on par performance with chemical fertilizers may be due to the combined effect of quick release of N from poultry manure and crop growth augmenting effect of PGPR and vermiwash. The mineralization pattern of poultry manure has indicated that nearly 60 per cent of N in this manure is present as uric acid which quickly changes to ammoniacal form that can be easily utilized by crop (Smith, 1950). The PGPR mix I is a microbial consortium for supplementing all the major nutrients as reported by Gopi *et al. (*2020). Vacheron *et al*. (2013) pointed out that PGPR can produce phytohormones and promote enzymatic activities which in turn may improve the root growth, uptake of minerals and water, and growth of the whole plant. Yasmin *et al*. (2007) studied the effect of PGPR treatment on sweet potato (vine inoculation) and found that PGPR inoculated plants had higher storage root dry weight and nutrient content (N, P and K) in plant and storage roots. Vermiwash is very good liquid manure which favourably affect the growth and productivity of crop when applied as foliar spray (Verma *et al.,* 2018). The favourable influence of vermiwash could be attributed to the presence of N in easily available form of mucus along with Nous excretory substances of worms, growth stimulating hormones and enzyme as reported by Tripathi and Bhardwaj (2004).

Depending upon the time of development and structural differences, the xylem is of two types - protoxylem and metaxylem. The late formed xylem is called metaxylem. The late metaxylem begins development in the centre of stele after lignification of early metaxylem. The number of late metaxylem showed significant difference among treatments only at 1 MAP, 2 MAP and 6 MAP (Fig. 48). The

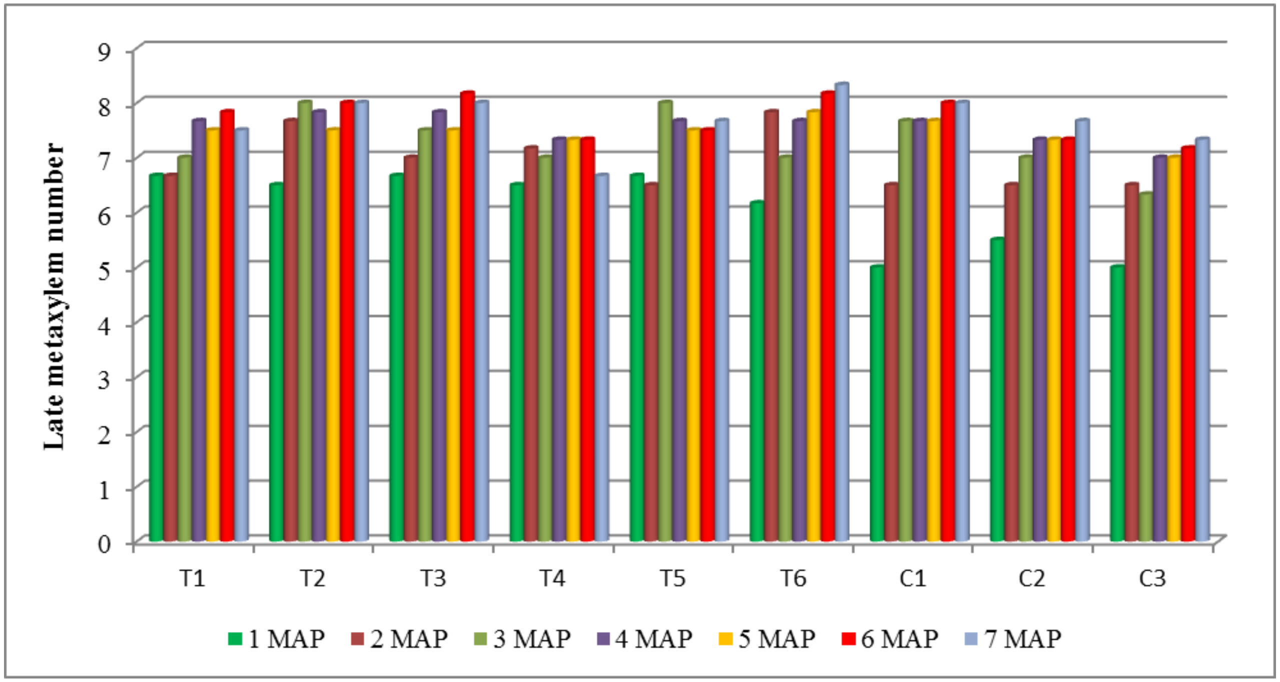


Fig. 48. Effect of organic sources on number of late metaxylem in taro root

highest number of late metaxylem was recorded by T_1 (FYM + wood ash), T_3 (FYM + wood ash + PGPR mix I + vermiwash) and T_5 (PM+ wood ash + PGPR mix I + vermiwash) at 1 MAP, T_6 (Poultry manure + wood ash+ PGPR mix I+ vermiwash) at 2 MAP and T_3 and T_6 at 6 MAP. The number of early metaxylem showed significant difference among treatments only at 1 MAP and 3 MAP (Fig. 49). At 1 MAP, T_6 (Poultry manure + wood ash+ PGPR mix I+ vermiwash) recorded the highest early metaxylem number. The treatment T_3 (FYM + wood ash + PGPR mix I + vermiwash) recorded the highest early metaxylem number at 3 MAP. The increased availability of nutrient from these treatments (T_3 and T_6) with the application of PGPR mix I and vermiwash might have enhanced the number of xylem vessels. This result is in agreement with that of Speights *et al.* (1967), who observed that the roots which grew in the presence of high levels of N with high rates of K had an increased number of secondary xylem vessels associated with the continuous combial zone in sweet potato.

Stele is the central portion of the root having conducting tissues xylem and phloem. Chimungu *et al.* (2015) reported that stele diameter as the better indicator of root penetration ability compared with root diameter. Significant difference was found among treatments in case of stele diameter of taro root at all stages of observation (Fig. 50). The highest stele diameter was recorded by T_5 (Poultry manure + wood ash + PGPR mix I) at 1 MAP, 3 MAP and 4 MAP, T_2 (FYM + wood ash +PGPR mix I) at 2 MAP and T_6 at 5, 6 and 7 MAP. The ratio of stele diameter to root diameter showed significant difference among treatments only at 1 MAP, 3 MAP and 7 MAP. At 1 MAP, T_5 and C_2 recorded the highest value and was on par with all treatments except T_2, T_4 and T_6. At 3 MAP, T_2 recorded the highest value and was on par with T_4, T_5, T_6, C_1 and C_3. At 7 MAP, T_1, T_3 and T_4 recorded the highest value and were on par with T_5 and C_1. From this result it is can be seen that there was no much difference among the organic treatments on root anatomy, however PGPR applied treatments ($T_{2,}$ T_3, T_5 and T_6) had shown a better performance on rooting

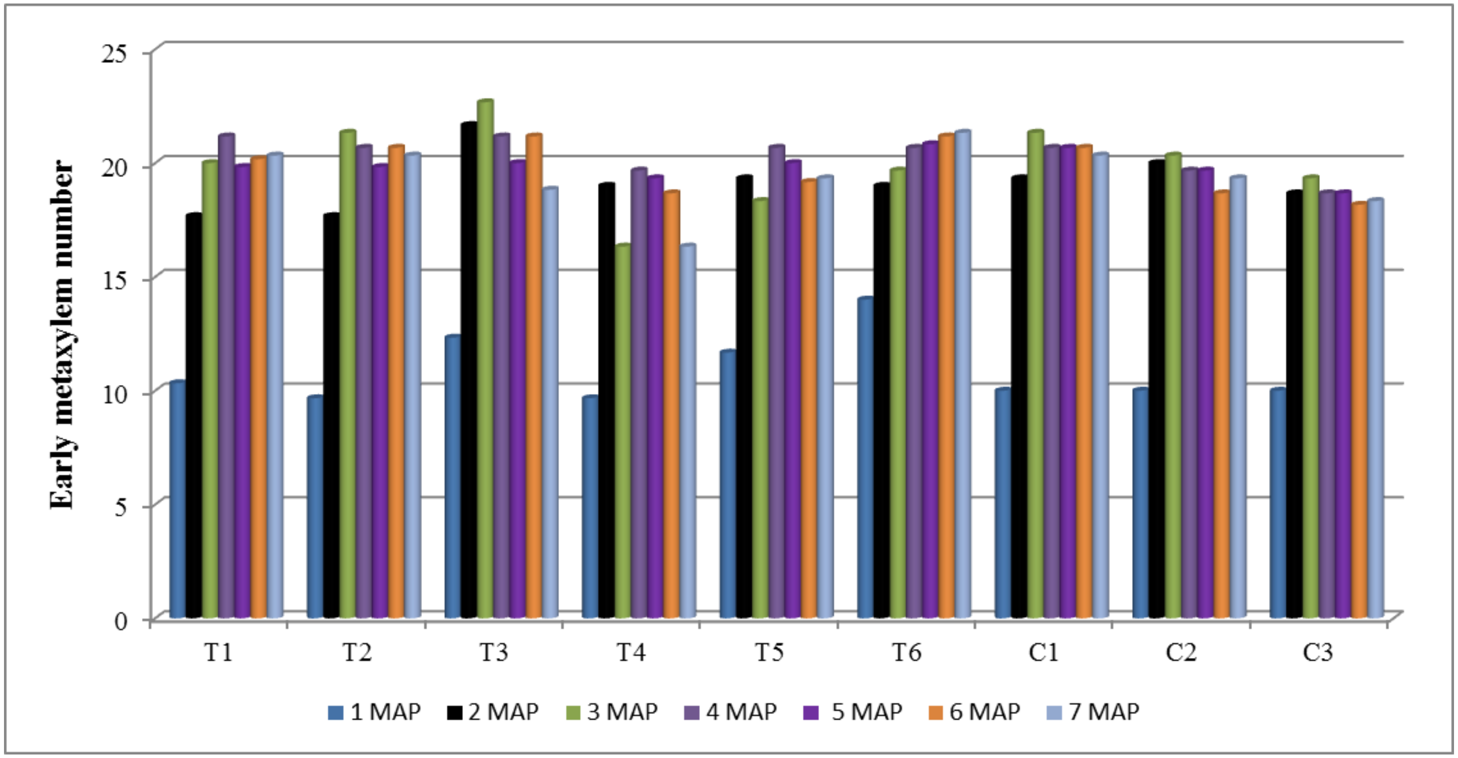


Fig. 49. Effect of organic sources on number of early metaxylem in taro root

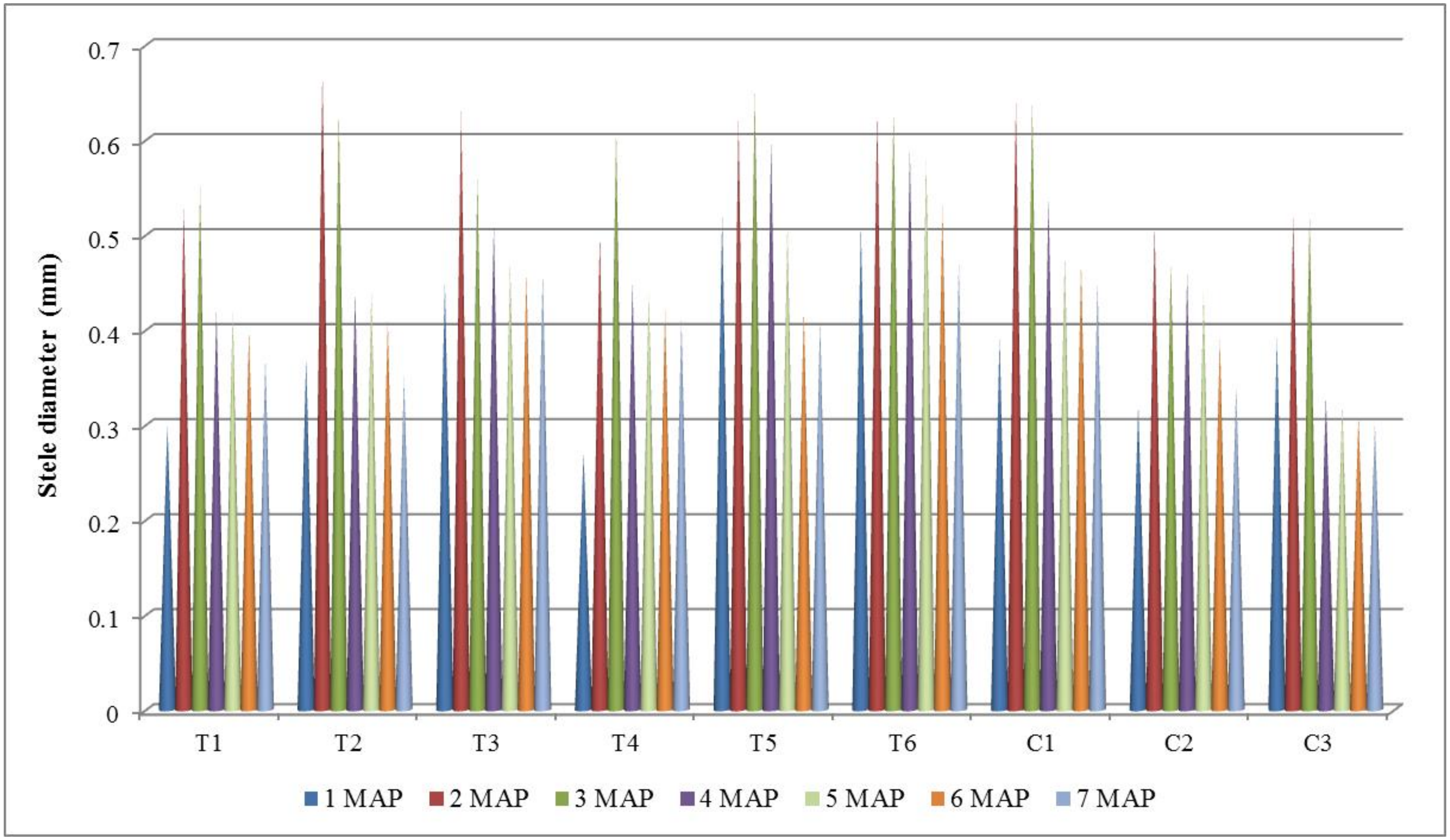


Fig. 50. Effect of organic sources on stele diameter of taro root, mm

pattern and its anatomy compared to without PGPR application. Similar result of improvement in anatomical characters with the application of biofertilizers including N fixers and phosphate dissolving bacteria was reported by Selim *et al.* (2015).

5.2.4 Tuberisation Pattern of Taro

Corm initiation has occurred between 1 MAP and 2 MAP in the treatments C_1 and T_6 and between 2 MAP and 3 MAP in all other treatments (T_1, T_2, T_3, T_4, T_5, C_2 and C_3). The rapid availability of nutrients to the plants through chemical fertilizers as compared to organic manures might have resulted in rapid crop growth, production of more assimilates and early tuber initiation in C_1. The quick release of N from poultry manure combined with crop growth augmenting effect of PGPR and vermiwash resulted in the on par performance of T_6 with chemical fertilizers during initial stages and rapid availability of nutrients might have led to higher crop growth and early tuber initiation.

Nutrient management through chemical fertilizers as per KAU POP (C_1) recorded the highest corm weight per plant at 3 MAP and 4 MAP and cormel weight per plant at 3 MAP, 4 MAP and 5 MAP (Fig. 51 and 52). During the later stages of plant growth, the organic nutrition treatment T_6 (Poultry manure + wood ash + PGPR mix I + vermiwash) recorded the highest corm weight per plant from 5 MAP onwards and the highest cormel weight at 6 MAP and 7 MAP. As explained earlier, the rapid availability of nutrients from chemical fertilizers resulted in the higher corm and cormel weight during early crop growth. As tuber initiation was noticed earlier in these treatments (T_6 and C_1), the cormel and corm weight during later stages were also higher in these treatments. The quick release of N from poultry manure combined with crop growth augmenting effect of PGPR and vermiwash as discussed earlier might have resulted in higher cormel and corm weight in T_6.

The highest values of cormel bulking rate were observed between 3 MAP and 4 MAP and after that a decreasing trend of bulking rate was noticed towards harvest in all the treatments (Fig. 53). Kumar (1986) also recorded the highest cormel bulking

Plate 13. Corm development in T_6 and C_1 at 2 MAP

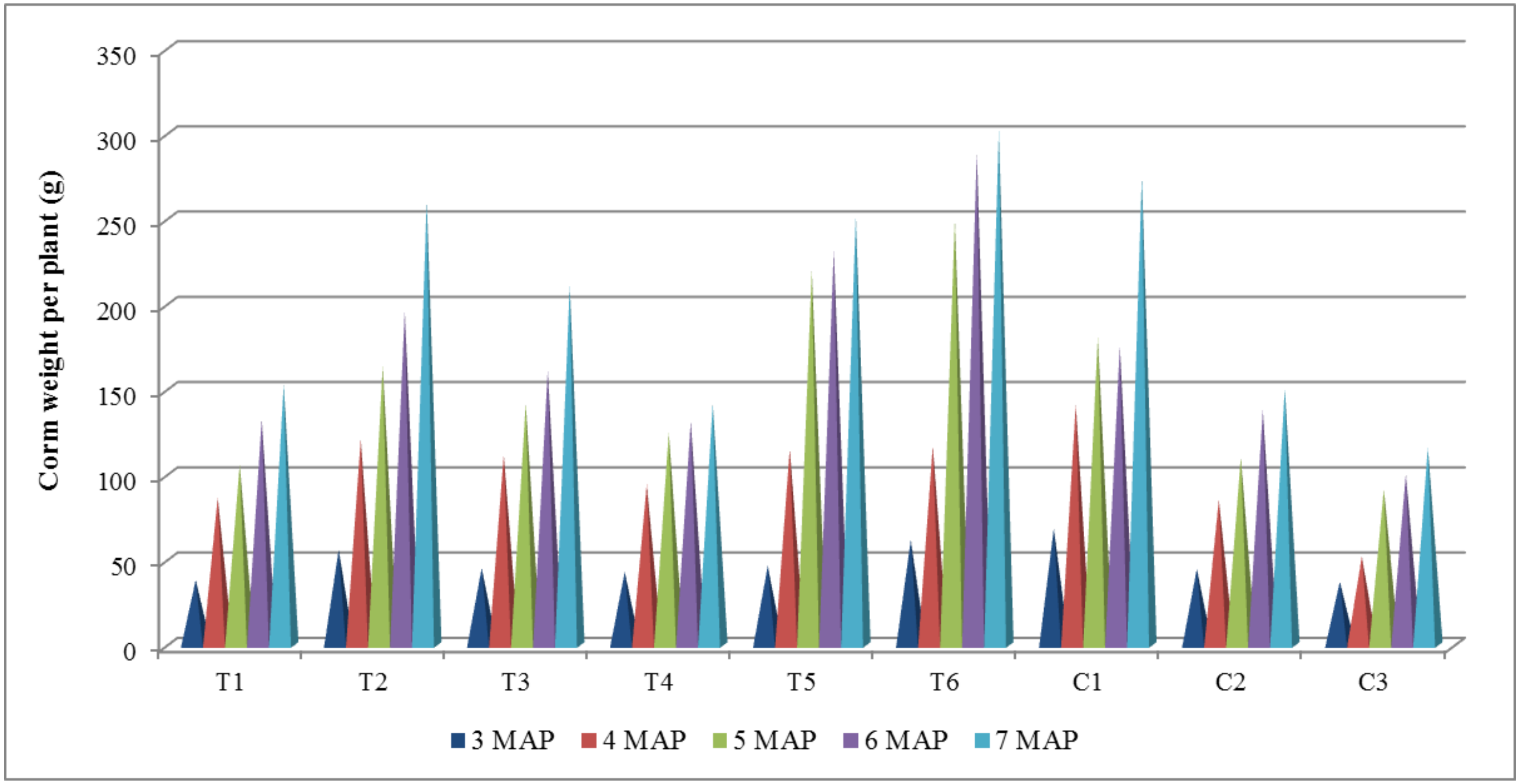


Fig. 51. Effect of organic sources on corm weight per plant, g

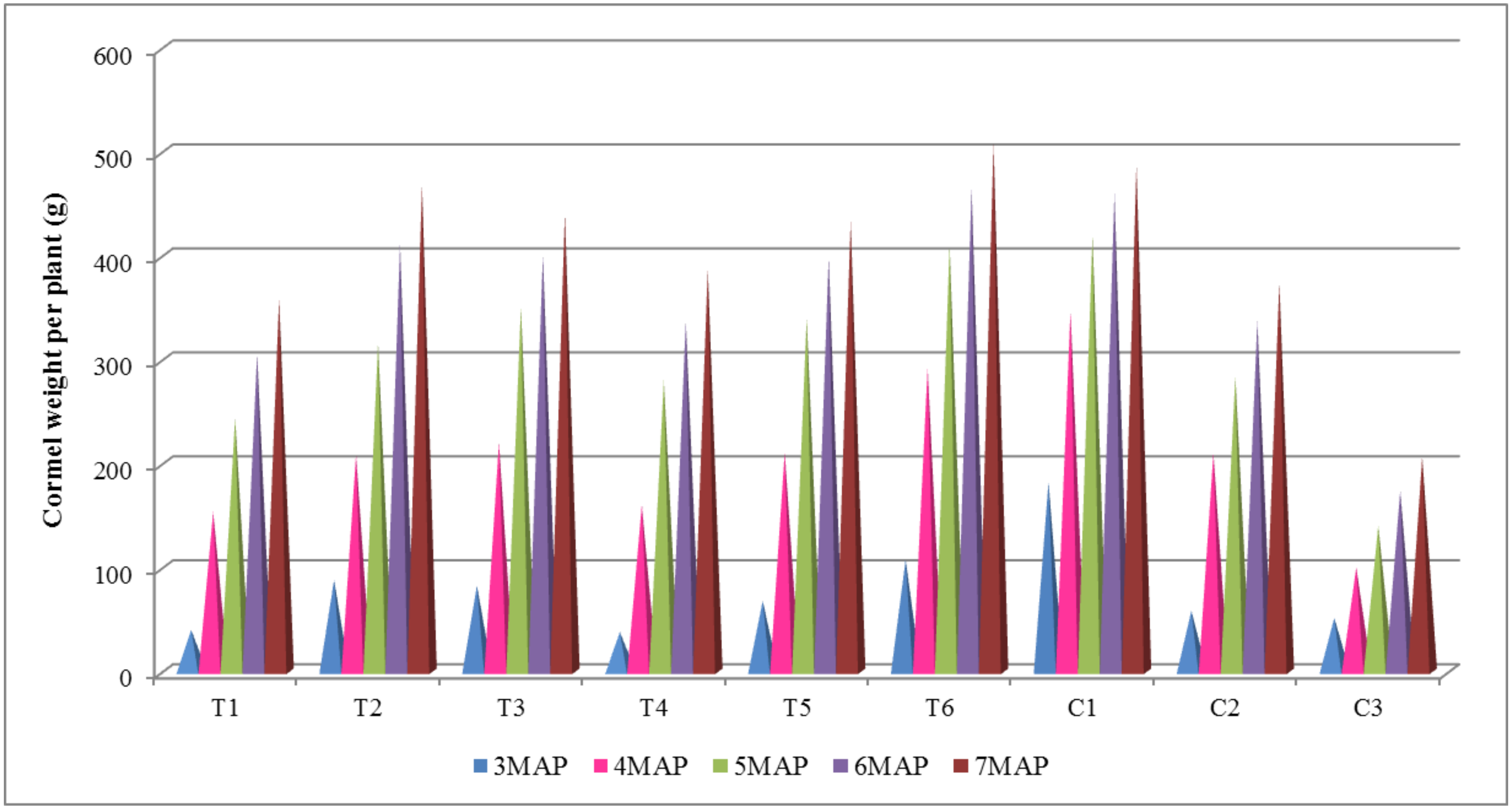


Fig. 52. Effect of organic sources on cormel weight per plant, g

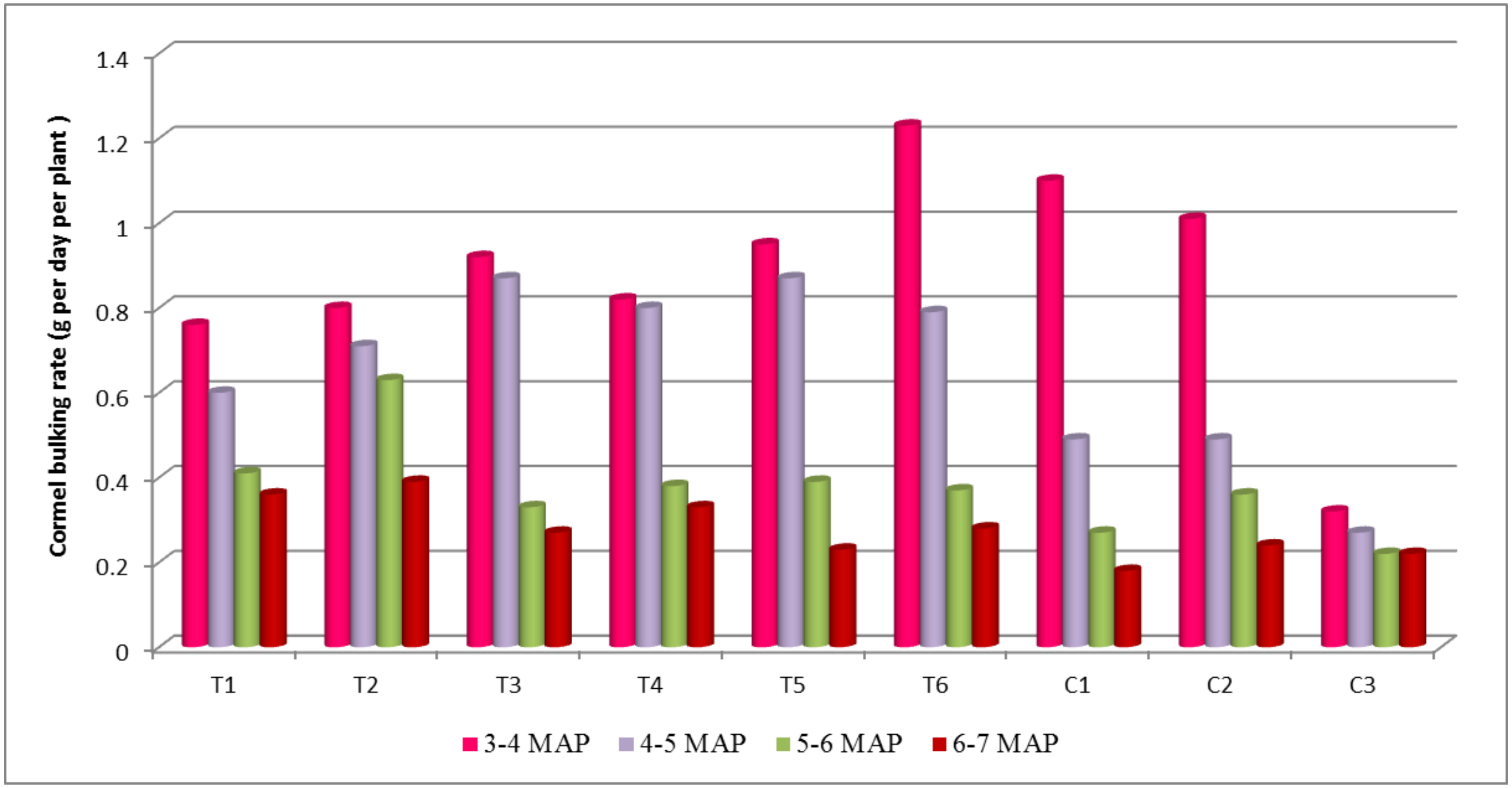


Fig. 53. Effect of organic sources on cormel bulking rate, g per day per plant

rate of taro at 3-4 MAP. In taro 3-4 MAP, denotes the period of active tuber development and hence the peak value was obtained during this period. The growth parameters of taro such as plant height, leaf area and leaf area index as noted from experiment I were also recorded higher values at 4 MAP. In general, the higher pH, available P, K, population of *Azotobacter, Azospirillum* and dehydrogenase activity were also higher during 4 MAP. The root parameters like root apex diameter, root number and root weight per plant were also recorded higher values in this period. The higher nutrient availability and higher growth parameters (both root and vegetative portion) recorded in this period might have led to higher production of assimilates and efficient synthesis of storage starch. The available K was also higher under this period, beneficial effect of K in the synthesis and translocation of starch is well known.

The treatment T_6 (Poultry manure + wood ash + PGPR mix I + vermiwash) recorded the highest bulking rate during 3-4 MAP. During 4-5 MAP, the treatments T_3 and T_5 recorded the highest bulking rate and T_2 (FYM + wood ash +PGPR mix I) had the highest bulking rate during 5-6 MAP. The quick availability of nutrients from poultry manure might be the reason for higher bulking rate during early period of 3-4 MAP. The FYM applied treatments had higher bulking rate during later stages and this might be due to initial immobilization and gradual availability of nutrients from FYM compared to poultry manure. Application of PGPR mix I and vermiwash under these treatments also might have contributed to higher availability of nutrients such as K, mostly used for cormel growth and development. The higher growth parameters recorded in these treatments with application of PGPR mix I and vermiwash also might have contributed to higher production of assimilates and synthesis of starch.

5.3 CORRELATION STUDY ON ROOT ANATOMY AND NUTRIENT UPTAKE

The correlation study of nutrient uptake and root anatomical characters such as root apex diameter, late metaxylem number, early metaxylem number and stele diameter shows a significant and positive relationship. Plant anatomical structures are important for the resource absorption and transportation. The early and late metaxylem indicates the relative time of maturation of vascular vessels and these two types of primary xylem are involved in the transport of water and solutes from roots to shoots (McCully, 1995). In absorptive roots, the cortex is used for resource absorption, while the stele is responsible for resource transportation and proportion of stele in root cross section could be considered as a potential index for assessing nutrient and water transport potential in plants (Guo *et al*., 2008). This indicates the importance of root anatomical characters on nutrient uptake by crop. Improving the root anatomical characters through balanced nutrition will results in increased nutrient uptake by the crop thereby resulting in increased growth and yield of the crop. Addition of nutrient N increasing the stele diameter in roots and consequently resulting in increased water and nutrient uptake has been previously reported by Wang *et al*. (2017).

SUMMARY

6. SUMMARY

The study entitled "Organic nutrition in taro (*Colocasia esculenta* (L.) Schott)" was conducted in the farmer field at Peringamala, Thiruvananthapuram during June to January 2019-20 and 2020-21 to investigate the effect of organic nutrition on growth, yield, quality, soil organic carbon build up and economics of cultivation of taro and to study rooting and tuberisation pattern of taro under organic nutrition. The investigation comprised two separate experiments: (1) Organic nutrition in taro (field experiment) and (2) Rooting and tuberisation pattern study in taro (pot culture). The field experiment was laid out in randomized block design with three replications during June to January 2019-20 and repeated during 2020-21. The treatments consisted of six organic sources (s_1- FYM + wood ash; s_2- FYM + wood ash +PGPR mix I; s_3- FYM + wood ash + PGPR mix I + vermiwash; s_4- Poultry manure + wood ash; s_5- Poultry manure + wood ash + PGPR mix I; s_6- Poultry manure + wood ash + PGPR mix I + vermiwash) and two *in situ* green manuring (g_1- *in situ* green manuring with cowpea; g_2- *in situ* green manuring with daincha) with three control treatments (C_1- Nutrient management through chemical fertilizers as per KAU POP (80 : 25: 100 kg ha^{-1}); C_2 - Nutrient management as per KAU organic POP (*Ad hoc*); C_3 - Absolute control). The tuberization study (pot culture) was laid out as completely randomized design during June to January 2019-20 with the six organic sources (T_1- FYM + wood ash; T_2- FYM + wood ash +PGPR mix I; T_3- FYM + wood ash + PGPR mix I + vermiwash; T_4- Poultry manure + wood ash; T_5- Poultry manure + wood ash +PGPR mix I; T_6- Poultry manure + wood ash + PGPR mix I + vermiwash) and three control treatments, replicated thrice.

A uniform dose of FYM at the rate of 12 t ha^{-1} was applied (except for absolute control) at the time of land preparation. The recommended dose of NPK for Colocasia was supplied at the rate of 80: 25: 100 kg ha^{-1} through organic sources on N equivalent basis, as per the treatments as basal dose except wood ash (applied while incorporating green manure in field experiment and one half months after

planting in pot culture study). Corm treatment with 5 per cent suspension of PGPR mix I followed by soil application of PGPR enriched cow dung at the rate of 10 g pit^{-1} (mixture of dry cow dung and PGPR mix I in 50:1 proportion) was done at planting and 2 MAP as per treatments. Vermiwash (10 times dilution) was sprayed at 2nd, 3rd and 4th month after planting in respective treatments. Green manure crops were raised (seed rate – 30 kg ha^{-1}) as per the treatments in the interspaces and incorporated in basins at 50 per cent flowering stage by uprooting. Plastic sacks of uniform size (50 kg capacity) were used for raising plants for rooting and tuberisation study. Soil at the experimental site was used as potting medium for filling the sacks. The salient findings of the study are summarized below.

Major findings of the field experiment are as follows:

The result of field experiment indicated that the organic sources had significant influence on number of days taken for 50 per cent sprouting of seed corm during the first year. Application of FYM + wood ash +PGPR mix I (s_2) took less number of days (24.33 days) for 50 per cent sprouting and was on par with s_3. Growth characters were recorded from 2 MAP onwards at bimonthly interval. In general, plant height, leaf area per plant and LAI increased upto 4 MAP after which it showed a declining trend upto harvest during both the years. Application of poultry manure along with wood ash, PGPR mix I and vermiwash (s_6) produced taller plants during both the years (82.67 cm, 156.26 cm, 129.62 cm and 107.53 cm at 2 MAP, 4 MAP, 6 MAP and at harvest respectively during the first year and 72.00 cm, 139.20 cm, and 97.56 cm at 2 MAP, 4 MAP and at harvest during the second year respectively) except at 6 MAP during the second year, wherein s_5 produced the tallest plants (116.12 cm). The highest number of leaves per plant was recorded by s_6 at all stages except harvest during the first year and at 4 MAP and harvest during the second year. The highest leaf area per plant and LAI were recorded by s_6 at 4 MAP, 6 MAP and harvest during the first year and at 2 MAP, 4 MAP and 6 MAP during the second year. However at 2 MAP during the first year, application of FYM along with wood ash, PGPR mix I and vermiwash (s_3) recorded the highest leaf area per plant and LAI. *In situ* green manuring with daincha (g_2) produced significantly taller plants, higher number of leaves per plant at 4 MAP and 6 MAP during the first year and significantly taller plants at 4 MAP during the second year. Higher leaf area and LAI were also recorded by g_2 at all stages of observation except 2 MAP during the first year and at 4 MAP and 6 MAP during the second year.

With respect to SxG interaction, application of poultry manure along with wood ash, PGPR mix I and vermiwash combined with *in situ* green manuring with daincha (s_6g_2) produced the tallest plants at 4 MAP (158.18 cm) and 6 MAP (130.58 cm) during the first year, while at harvest, the highest plant height was recorded with treatment combination s_6g_1. During the second year, SxG interaction was significant only at harvest and the plants were the tallest with treatment combination s_6g_1. The number of leaves per plant was significantly influenced by SxG interaction only at 2 MAP during the first year and the treatment combinations s_1g_2 and s_6g_1 produced more number of leaves (4.89 leaves per plant). The treatment combination s_6g_2 recorded significantly the highest leaf area per plant and LAI at 4 MAP and 6 MAP during the first year and at 4 MAP during the second year.

While comparing the organic nutrition treatments with nutrient management through chemical fertilizers as per KAU POP, it was found that, in general the treatments s_6g_2, s_6g_1, s_5g_2, s_5g_1 and s_3g_2 were equally effective as chemical nutrient management in all growth parameters *viz*. plant height, number of leaves per plant, leaf area and LAI during both years. In case of plant height, s_6g_2 at 4 MAP and s_6g_1 at harvest were significantly superior to C_1 during fist year. While comparing C_2 (nutrient management as per KAU organic *Ad hoc* POP) with treatments, in general, s_5g_1, s_5g_2, s_6g_1, s_6g_2, s_3g_1 and s_3g_2 were recorded significantly higher plant height than C_2 at all stages from 4 MAP onwards. The treatments s_6g_1 and s_6g_2 at 4 MAP and s_2g_2, s_3g_1, s_3g_2, s_5g_2, s_6g_1 and s_6g_2 at 6 MAP during the first year and s_5g_1, s_5g_2, s_6g_1, s_6g_2, s_2g_2, s_3g_1 and s_3g_2 at 4 MAP during the second year recorded significantly higher leaf area and LAI compared to $C_{2.}$ Regarding number of leaves per plant, all treatments during both years except $s_1g_{1,}$ s_1g_2 and s_4g_1 at 6 MAP during the first year were produced statistically equal number of leaves as that of $C_{2.}$ While comparing organic treatments with absolute control (C_3), in general organic treatments performed better than absolute control in all growth parameters.

Application of FYM + wood ash and PM + wood ash recorded the highest number of cormels per plant during first (23.50 cormels per plant) and second year (23.50 cormels per plant) respectively. Application of poultry manure along with wood ash, PGPR mix I and vermiwash (s_6) recorded the highest mean weight of cormel (34.86 g) during the first year, the highest cormel yield during both the years (20.89 t ha^{-1} during the first year and 16.47 t ha^{-1} during the second year) and also in the case of pooled mean (18.68 t ha^{-1}). The treatment also recorded the highest corm yield during the first year (13.48 t ha^{-1}) and under pooled analysis (12.21 t ha^{-1}). During the second year, s_3 registered the highest mean weight of cormel (26.01 g) and corm yield (12.07 t ha^{-1}). Cormel to corm ratio was not affected by organic sources during the first year, while the organic treatment s_5 recorded the highest cormel to corm ratio during the second year (1.80). *In situ* green manuring with daincha (g_2) recorded the highest mean cormel weight (29.51 g during the first year and 24.48 g during the second year), cormel (19.57 t ha^{-1}, 14.99 t ha^{-1} and 17.28 t ha^{-1} during the first year, second year and for pooled mean respectively) and corm yield (12.27 t ha^{-1}, 10.01 t ha^{-1} and 11.14 t ha^{-1} during the first year, second year and for pooled mean respectively) during both the years and under pooled analysis. Number of cormels per plant and cormel to corm ratio were not significantly affected by *in situ* green manuring during both the years. The treatment combination s_3g_2 recorded the highest mean weight of cormel (41.26g and 31.47g during first and second year respectively). The treatment combination s_6g_2 recorded the highest cormel yield of 21.27 t ha^{-1}, 16.77 t ha^{-1} and 19.02 t ha^{-1} during the first year, second year and in the pooled analysis respectively. The SxG interaction was significant only during the first year in case of corm yield and s_6g_2 combination recorded higher corm yield (13.94 t ha^{-1}). Cormel to corm ratio was significantly influenced by SxG interaction only during the second year and s_5g_1 registered the highest value (2.12). The SxG interaction did not show any significant influence on number of cormels per plant during both the years.

The treatments s_3g_2, s_6g_1 and s_6g_2 recorded significantly higher mean weight of cormel than C_1 during the first year. In general, the organic treatments s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 were found to be equally effective as C_1 in corm and cormel yield of taro. The treatment s_6g_2 recorded a 0.90 percentage increase of cormel yield over chemical nutrient management during the first year and a 2.67 percentage increase of corm yield over chemical nutrient management for pooled mean. The treatment combinations s_3g_1, s_3g_2, s_4g_2, s_6g_1 and s_6g_2 during the first year and s_3g_2, s_5g_2 and s_6g_2 during the second year registered significantly higher mean weight of cormels than C_2. Significance difference was observed between treatments and control C_2 during both the years in case of cormel yield and the treatments s_2g_2, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 recorded significantly higher cormel yield than C_2. The corm yield showed significant difference only during the first year and the treatments s_2g_2, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 recorded significantly higher corm yield than C_2. The treatment s_6g_2 recorded a 37.83 percentage and 27.82 percentage increase of cormel yield and corm yield respectively over KAU organic POP for pooled mean. The organic treatment combinations s_3g_2, s_4g_2, s_6g_1 and s_6g_2 during the first year and s_3g_2, s_5g_2 and s_6g_2 during the second year recorded significantly higher mean weight of cormel than absolute control. Both cormel yield and corm yield showed significant variation between treatments and C_3 during both the years. All treatments except s_1g_1 in case of cormel yield and all treatments in case of corm yield for pooled mean recorded significantly higher value than C_3 (absolute control).

The leaf chlorophyll content was not affected organic sources, *in situ* green manuring, SxG interaction and treatment vs. control effect during both the years. Harvest index was also not affected by organic sources and *in situ* green manuring during both the years, while SxG interaction had significant effect on harvest index during the second year and the treatment combinations s_5g_1 and s_2g_2 recorded the highest harvest index (0.60). The organic source poultry manure application along with wood ash, PGPR mix I and vermiwash (s_6) and *in situ* green manuring with daincha (g_2) recorded the highest dry matter production at harvest during both the years. Treatment combination s_6g_2 during the first year (8.37 t ha^{-1}) and s_3g_2 during the second year (6.55 t ha^{-1}) recorded the highest dry matter production at harvest.

In general, the organic treatment combinations s_2g_2, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 were on par with nutrient management through chemical fertilizers (C_1) in dry matter production at harvest. Significant difference was observed during the first year between organic treatments and nutrient management as per KAU organic POP-*Ad hoc* (C_2). Except s_1g_1, s_1g_2 and s_4g_2, all other treatment combinations resulted in significantly higher value of dry matter production compared to C_2. Harvest index also showed significant variation between treatments and control C_2 during the second year, wherein s_2g_2 and s_5g_1 were significantly superior to C_2. All organic treatments were significantly superior to absolute control with respect to dry matter production during both the years.

The organic source s_6 recorded the highest starch during both the years (63.72 % during the first year and 60.44 % during the second year) and the highest total sugar content (3.97 %) crude protein (13.91 %) and the lowest crude fibre content (1.24 %) during the second year. While the highest total sugar content (4.02 %) during the first year was recorded by s_3. The organic sources s_3 and s_6 recorded the lowest oxalic acid (0.25 %) during the first year. Significantly higher starch (63.26 % during the first year and 59.18 % during the second year) and total sugar (3.78 % during the first year and 3.79 % during the second year) during both the years and significantly lower oxalic acid (0.24 %) during the second year were recorded with g_2. The treatment s_3g_2 recorded the highest total sugar content (4.50 %) during the first year and s_6g_1 recorded the highest crude protein content (14. 53 %) during the second year. In general, the organic treatments s_2g_2, s_3g_1, s_3g_2, s_5g_2 and s_6g_2 recorded significantly higher dry matter content of cormel than C_1. During the first year, all organic treatments except s_1g_1 and s_4g_1 were found to be significantly superior to C_1 in case of starch content. During the second year, s_3g_2 and s_6g_2 recorded significantly superior values of starch content than $C_{1.}$ The treatments s_5g_2 and s_6g_2 were significantly superior to C_1 during the second year with respect to total sugar content of cormel. The organic treatments $s_1g_{1,}$ $s_1g_{2,}$ $s_2g_{1,}$ $s_2g_{2,}$ $s_3g_{1,}$ $s_3g_{2,,}$ $s_5g_{2,}$ s_6g_1 and s_6g_2 during the first year and $s_2g_{1,}$ $s_2g_{2,}$ $s_3g_{2,}$ $s_5g_{1,}$ $s_5g_{2,}$ s_6g_1 and s_6g_2 during the second year recorded significantly lower values of crude fibre content of cormel compared to $C_{1.}$ During the first year, the treatments $s_2g_{2,}$ s_3g_1 and s_6g_2 recorded significantly lower oxalate content than $C_{1.}$ During the second year, s_3g_2, s_5g_2 and s_6g_2 recorded significantly lower oxalate content than $C_{1.}$ The treatment combination s_3g_2 and s_6g_2 recorded significantly higher starch content of cormel than control nutrient management as per KAU organic POP (C_2) during the first year. The treatment combination s_3g_2 and s_6g_2 during the first year and $s_2g_{2,}$ s_3g_2, $s_5g_{1,}$ s_6g_1 and s_6g_2 during the second year recorded significantly lower values of crude fibre content of cormel than C_2. In general, improvement in quality parameters was observed due to organic nutrition treatments compared to absolute control.

The organic source s_6 recorded the highest plant N content during the second year, tuber K content and uptake of N and K during both the years. During the first year, uptake of P was the highest in $s_{3.}$ *In situ* green manuring with daincha recorded significantly higher N and P content of plant and P content of tuber, uptake of P during the first year and significantly higher uptake of N and K during both the years. The highest N (149.03 kg ha^{-1}) and K (232.80 kg ha^{-1}) uptake was recorded with treatment combination s_6g_2 during the second year. During the first year, the treatment s_3g_2 recorded the highest tuber P (0.46 %) and P uptake (35.12 kg ha^{-1}). During the second year, there was significant difference between treatments and control C_1 in case of N and P uptake. The treatment combinations s_2g_2, s_3g_1, s_3g_2,

s_5g_1, s_5g_2, s_6g_1 and s_6g_2 were found to be at par with C_1 in case of N uptake. All the treatments except s_4g_1 were found to be on par with C_1 in case of P uptake. The organic treatment combination s_6g_2 was found to be significantly superior to chemical nutrient management (C_1) in case of K uptake during the first year and treatment combinations s_2g_1, s_2g_2, s_3g_1 s_3g_2, s_5g_1, s_5g_2 and s_6g_1 during the first year and s_2g_2, s_3g_1, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 during the second year were found to be on par with C_1. While comparing treatments with nutrient management as per KAU organic *Ad hoc* POP (C_2), the treatment combination s_6g_1 and s_6g_2 during the first year and s_5g_1 and s_6g_2 during the second year recorded higher K content of tuber than C_2. The treatment combinations s_2g_1, s_3g_2 and s_6g_2 during the first year were found to be significantly superior to C_2 in case of P uptake. The treatment combinations s_2g_1, s_2g_2, s_3g_1, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 during the first year and s_3g_2 and s_6g_2 during the second year were superior to C_2 in case of K uptake. The C_3 (absolute control) showed significant difference from treatments during the first year and the treatment combinations s_5g_2 and s_6g_2 recorded significantly higher plant N content and the treatment combination s_3g_2 recorded higher content of tuber phosphorus than absolute control. While comparing treatments with C_3 in case of K content of tuber, it was found that the treatment combinations s_2g_1, s_4g_2, s_5g_2, s_6g_1 and s_6g_2 during the first year and s_3g_2 , s_4g_1, s_4g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 during the second year recorded significantly higher K content of tuber than C_3. All treatments except s_1g_1, s_1g_2, s_2g_1 and s_4g_1 during the first year and all treatments except s_1g_1 during the second year were significantly superior to C_3 with respect to N uptake by the crop. The organic treatment combinations s_1g_2, s_2g_1, s_3g_1, s_3g_2, s_4g_2, s_5g_2 and s_6g_2 during the first year and s_3g_2, s_4g_2, s_6g_1 and s_6g_2 during the second year recorded significantly higher values of P uptake than absolute control. All treatments during the first year and all treatments except s_1g_1 during the second year were significantly superior to C_3 in case of K uptake.

A decrease in pH of soil was observed after the experiment than the initial values. The pH of the soil was not affected by the organic nutrition treatments after the experiment. However, significant difference was observed for treatments *vs.* C_1 and C_3 during the second year. The organic treatments s_3g_1 and s_5g_2 recorded significantly higher values of pH than C_1 and C_3. The EC values of the soil increased after the experiment compared to initial values. After the experiment the EC of soil was significantly influenced by organic sources only during the second year. The organic source s_5 (application of PM along with wood ash and PGPR mix I) recorded the lowest value (0.40 dS m^{-1}). However the EC was not affected by any of treatments during the first year and not affected by *in situ* green manuring and SxG interaction during the second year. The treatments *vs.* control effects were also not significant to influence the EC of soil after experiment during both the years.

The organic carbon content of soil increased after the experiment compared to the initial values. The highest organic carbon content of soil after the experiment was recorded by organic source s_6 (1.57 %) during the first year and s_5 (1.55 %) during the second year. *In situ* green manuring with daincha registered significantly higher organic carbon content (1.39 %) of soil after the experiment during the first year and it is not affected by *in situ* green manuring during the second year. The treatment s_6g_2 during the first year and s_5g_2 during the second year recorded significantly higher values of organic carbon content of soil after the experiment than absolute control.

The highest available nitrogen content in soil was recorded by s_5 (PM+ wood ash + PGPR mix I) during the first year (303.15 kg ha^{-1}) and s_6 (PM+ wood ash + PGPR mix I + vermiwash) during the second year (233.11 kg ha^{-1}). *In situ* green manuring with daincha (g_2) recorded significantly the highest available nitrogen content in soil during both the years (284.33 kg ha^{-1} - first year and 224.40 kg ha^{-1} - second year). Regarding interaction effect, available N content in soil was significantly influenced by S x G interaction only during the first year and the treatment combination s_6g_2 recorded the highest value (326.14 kg ha^{-1}). Treatment *vs.* C_1 and C_2 effects were not significant during both the years. All organic treatments recorded significantly higher values of available N content of soil after the experiment during both the years than C_3. FYM application along with wood ash, PGPR mix I and vermiwash (s_3) recorded the highest available P content of soil during both the years (78.87 kg ha^{-1} during the first year and 72.46 kg ha^{-1} during the second year). *In situ* green manuring had significant effect on available P content of soil only during the second year and g_2 registered higher available P (68.88 kg ha^{-1}). The organic treatments s_2g_2 and s_3g_2 were found to be significantly superior to C_1 (nutrient management through chemical fertilizers as per KAU POP) and C_2 (nutrient management as per KAU organic POP) during the second year. All organic nutrition treatments except s_1g_1, s_1g_2, s_4g_1, s_4g_2 and s_6g_1 during the first year and all treatments except s_1g_1, s_4g_1 and s_4g_2 during the second year recorded significantly superior values of available phosphorus content of soil than absolute control (C_3). There was a decrease in the available K status of the soil after the experiment compared to initial value. Neither the main effects nor the interaction effects of organic sources and *in situ* green manuring exerted significant influence on the available K. The treatments did not show any significant difference from control $C_1$and C_2 during both the years, while significant difference was observed between treatments and absolute control during both the years. The organic nutrition treatments s_3g_1 and s_6g_1 during the first year and all treatments except s_1g_1, s_1g_2, s_4g_1 and s_4g_2 during the second year recorded significantly higher values of available potassium content of soil after the experiment than absolute control.

The organic source s_5 recorded the highest total organic carbon (4.79 %) and recalcitrant carbon (1.08 %) during the first year. The organic source s_3 recorded the highest recalcitrant carbon (1.25 %) during the second year and water soluble carbon (47.48 mg kg^{-1}) content during the first year. The s_6 resulted in higher labile carbon (694.00 mg kg^{-1}) and water soluble carbon content (45.60 mg kg^{-1}) during the second year. *In situ* green manuring with daincha recorded significantly higher total organic carbon during the first year (4.73 %) and higher labile carbon (662.15 mg kg^{-1} and 648.50 mg kg^{-1} during the first year and second year respectively) and water soluble carbon (41.98 mg kg^{-1} during the first year and 41.15 mg kg^{-1} during the second year) during both the years. The treatment combination s_3g_2 and s_6g_2 during the first year (47.85 mg kg^{-1}) and s_6g_2 during the second year (47.40 mg kg^{-1}) resulted in the highest water soluble carbon of soil. All organic nutrition treatments were found superior to control treatments in soil organic carbon buildup.

The N balance of soil was negative for all treatments after first year of experiment. After second year, the N balance was positive for absolute control (24.08 kg ha^{-1}). For all other treatments the balance sheet was negative. The balance sheet of P was negative for all treatments during both the years. The balance sheet of K was positive for s_3g_1 (16.93 kg ha^{-1}), s_5g_1 (1.86 kg ha^{-1}), s_6g_1 (60.74 kg ha^{-1}), s_6g_2 (7.75 kg ha^{-1}) and C_1 (58.71 kg ha^{-1}) after first year of experiment. For all other treatments the balance sheet was negative. After second year of experiment the balance sheet was negative for all the treatments.

Among organic sources, application of poultry manure along with wood ash, PGPR mix I and vermiwash (s_6) registered the highest net income (₹ 846714 ha^{-1} during the first year, ₹ 584157 ha^{-1} during the second year and ₹ 715435 ha^{-1} for mean) and BCR (3.08 during the first year, 2.45 during the second year and 2.76 for mean) during both the years and for mean also. *In situ* green manuring with daincha resulted in higher net income (₹ 778699 ha^{-1} during the first year, ₹ 507417 ha^{-1} during the second year and ₹ 643058 ha^{-1} for mean) and BCR (2.97, 2.29 and 2.63 during the first year, second year and for mean respectively.) during both the years and for mean also over *in situ* green manuring with cow pea. Regarding SxG interaction, the treatment combination s_6g_2 registered the highest net income (₹ 870813 ha^{-1} during the first year, ₹ 603670 ha^{-1} during the second year and ₹ 737241

ha^{-1} for mean) and BCR (3.15 during the first year, 2.50 during the second year and 2.82 for mean) during both the years and for mean also.

All the treatments during the first year and all treatments except s_1g_1, s_2g_1, s_3g_1 and s_4g_2 during the second year and except s_1g_1 and s_2g_1 for mean recorded higher net income than C_1. All the treatments except s_1g_1, s_2g_1, s_3g_1 and s_3g_2 during the first year and treatments s_5g_1 and s_6g_2 during the second year s_4g_1, s_5g_1, s_6g_1 and s_6g_2 for mean recorded higher BCR than C_1. The treatment s_6g_2 recorded a 43.96 percentage increase of net income and an added profit of ₹ 225124 ha^{-1} over chemical nutrient management for mean. All treatments except s_1g_1 during the first year, except s_1g_1 and s_2g_1 during the second year and for mean recorded higher net income compared to C_2. All treatments except s_1g_1, s_2g_1 and s_3g_1 during both the years and for mean also recorded higher BCR compared to C_2. The treatment s_6g_2 recorded a 54.71 percentage increase of net income and an added profit of ₹ 260703 ha^{-1} over KAU organic POP for mean. All organic nutrition treatments recorded higher net income compared to absolute control during both the years and for mean also. The added profit of s_6g_2 over absolute control for mean was ₹ 476110 ha^{-1}. All organic nutrition treatments except s_2g_1 during the first year, except s_1g_1, s_2g_1 and s_3g_1 during the second year and except s_2g_1 and s_3g_1 for mean recorded higher BCR compared to absolute control.

Major findings of the pot culture study are as follows:

In pot culture experiment, the analysis of potting media was done at initial, 1 MAP, 4 MAP and at harvest. The highest pH was recorded by the treatment T_6 (poultry manure + wood ash + PGPR mix I + vermiwash) at 1 MAP, T_6 and T_5 (poultry manure + wood ash + PGPR mix I) at 4 MAP and T_5 at harvest. The absolute control recorded the lowest value of EC at 1 MAP and harvest. The highest organic carbon content was recorded by T_2 (FYM + wood ash + PGPR mix I) at 1 MAP and 4 MAP and T_2 and T_3 (FYM + wood ash + PGPR mix I + vermiwash) at harvest. The organic source T_6 recorded the highest available nitrogen status at 1 MAP and harvest while at 4 MAP, C_1 (nutrient management through chemical fertilizers) recorded the highest available nitrogen status. The organic source T_3 recorded the highest available P at 1 MAP and harvest. At 4 MAP, T_2 recorded the highest available P. The organic source T_6 recorded the highest available K content at 1 MAP and harvest. At 4 MAP, C_1 recorded the highest available K content. Organic source T_5 recorded the highest bacterial population at all stages. The highest fungal population was recorded by organic source T_6 at 1 MAP, T_3 at 4 MAP and T_2 at harvest. The highest actinomycetes population recorded by T_2 at 1 MAP, T_5 at 4 MAP and T_2 and T_3 at harvest. At 4 MAP and harvest, the organic source T_6 recorded the highest population of *Azospirillum*. The organic source T_2 recorded the highest population of *Azotobacter* at 1 MAP. At 4 MAP and harvest, T_6 recorded the highest population of *Azotobacter*. The organic source T_3 recorded the highest population of P solubilisers at 1 MAP and 4 MAP. The organic source T_5 recorded the highest dehydrogenase activity at 1 MAP and harvest. At 4 MAP, T_3 recorded the highest dehydrogenase activity.

The treatment T_6 (poultry manure + wood ash + PGPR mix I + vermiwash) recorded the highest root apex diameter at 1, 4, 5, 6 and 7 MAP and C_1 at 2 MAP, T_5 at 3 MAP. The control C_1 recorded the highest root number per plant at 2 and 3 MAP, T_6 at 4 and 5MAP, T_3 at 6 and 7 MAP. The treatment T_6 recorded the highest root weight per plant at all stages of observation except 7 MAP, wherein T_3 recorded the highest root weight per plant. The highest number of late metaxylem was recorded by T_1, T_3 and T_5 at 1 MAP, T_6 at 2 MAP and T_3 and T_6 at 6 MAP. At 1 MAP, T_6 recorded the highest early metaxylem number. The treatment T_3 recorded the highest early metaxylem number at 3MAP. The highest stele diameter was recorded by T_5 at 1 MAP, 3 MAP and 4 MAP, T_2 at 2 MAP and T_6 at 5, 6 and 7 MAP. The highest stele diameter to root diameter ratio was recorded by T_5 and C_2 at 1 MAP, T_2 at 3 MAP and T_1, T_3 and T_4 at 7 MAP.

Significant and positive correlation was observed between nutrient uptake *Vs.* root apex diameter, late metaxylem number, early metaxylem number and stele diameter.

Corm initiation has occurred between 1 MAP and 2 MAP in the treatments C_1 and T_6 and between 2 MAP and 3 MAP in all other trearments (T_1, T_2, T_3, T_4, T_5, C_2 and C_3). Nutrient management through chemical fertilizers recorded the highest corm weight per plant at 3 MAP (68.41 g) and 4 MAP (140.96 g) and cormel weight per plant at 3 MAP (182.36 g plant^{-1}), 4 MAP (346.80 g plant^{-1}) and 5 MAP (420.34 g plant^{-1}). The T_6 recorded the highest corm weight per plant from 5 MAP onwards (249.71 g plant^{-1} at 5 MAP, 289.30 g plant^{-1} at 6 MAP and 301.88 g plant^{-1} at 7 MAP and the highest cormel weight at 6 MAP (465.23 g plant^{-1}) and 7 MAP (507.04 g plant^{-1}). The highest values of cormel bulking rate were observed between 3 MAP and 4 MAP. The treatment T_6 recorded the highest bulking rate during 3-4 MAP (1.23 g per day per plant). The highest bulking rate was recorded by T_3 and T_5 during 4-5 MAP (0.87 g per day per plant) and T_2 during 5-6 MAP (0.63 g per day per plant). During 6-7 MAP, bulking rate of cormel was not significantly influenced by treatments.

The results of the study revealed that the best organic nutrient management for organic production of taro is the application of poultry manure, wood ash, PGPR mix I and vermiwash and i*n situ* green manuring with diancha, which resulted in higher growth , yield, quality, net income and BCR. The study also indicated that the application of poultry manure, wood ash, PGPR mix I and vermiwash along with *in situ* green manuring with diancha was equally effective as chemical fertilizer application and superior to existing *Ad hoc* organic KAU POP and absolute control. All the organic nutrient management practices were found to improve soil organic carbon build up. The organic source application of poultry manure, wood ash, PGPR mix I and vermiwash was found as superior in rooting and tuberisation pattern of taro. Thus it can be concluded that the organic nutrition involving application of

FYM 12 t ha^{-1} at the time of land preparation, application of poultry manure (6.25 - 7.14 t ha^{-1}) as basal dose, treatment of cormels with 5 per cent PGPR mix I suspension, soil application of PGPR mix 1 enriched cow dung at the rate of 10 g per plant (mixture of dry cow dung and PGPR mix 1 in 50:1 proportion) at planting and 2 MAP, *in situ* green manuring with daincha (30 kg ha^{-1}), wood ash (0.80 - 0.98 t ha^{-1}) application at time of gren manure incorporation and vermiwash (10 times dilution) spraying at 2^{nd} , 3^{rd} and 4^{th} MAP can be adopted for organic cultivation of taro for producing safe and quality food without deteriorating the environment and for fetching a premium price in the market.

FUTURE LINE OF WORK

- Organic nutrient management for other tuber crops may be experimented
- The feasibility of reducing the cost of organic nutrition through low cost management practices has to be explored
- Exploring the organic ways of plant protection and weed management in tuber crops
- Response of different high yielding varieties of taro to organic nutrition has to be studied
- Possibility of liquid organic fertilizers for organic nutrient management of tuber crops

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APPENDICES

APPENDIX I

Weather parameters during the period of experiment

Standard week	First year					Second year				
	Mean temperature (°C)		Mean RH (%)		Rain Fall (cm)	Mean temperature (°C)		Mean RH (%)		Rain Fall (cm)
	Max	Min	Max	Min		Max	Min	Max	Min	
24 (11 Jun – 17 Jun)	31.1	24.8	93.3	80.0	114.4	32.6	25.7	90.4	74.1	15.0
25 (18 Jun - 24 Jun)	31.9	24.9	90.0	78.7	28.6	32.3	24.5	88.7	73.7	12.8
26 (25 Jun - 01 Jul)	32.1	26.1	87.1	75.3	0.0	31.3	24.7	91.4	76.9	48.4
27 (02 Jul - 08 Jul)	32.2	25.9	90.3	77.1	32.1	32.1	24.6	90.9	75.7	15.1
28 (09 Jul -15 Jul)	30.8	25.4	90.3	79.0	42.1	32.4	25.2	87.9	72.3	1.4
29 (16 Jul - 22 Jul)	30.1	23.7	94.1	81.6	100.8	31.6	25.0	91.3	74.7	11.4
30 (23 Jul - 29 Jul)	30.4	24.3	92.3	82.4	7.7	31.3	24.2	91.9	76.9	53.0
31 (30 Jul - 05 Aug)	31.5	25.6	89.3	77.6	17.5	30.3	24.3	92.4	81.3	34.2
32 (06 Aug -12Aug)	30.0	23.6	94.6	81.7	198.1	30.3	23.8	95.7	80.9	144.7
33 (13 Aug -19Aug)	30.4	24.1	91.6	76.6	18.2	32.6	31.3	89.9	68.4	2.0
34 (20 Aug -26Aug)	31.1	24.2	92.1	77.4	34.9	32.6	25.6	90.1	72.9	0.0
35 (27 Aug -02 Sep)	30.7	23.9	93.1	77.9	91.9	32.7	25.9	90.1	72.9	0.0
36 (03 Sep -09 Sep)	30.9	24.4	90.6	80.1	84.0	31.4	24.7	97.1	76.7	229.9
37 (10 Sep -16 Sep)	31.3	24.4	88.9	76.4	12.9	30.5	23.9	94.6	89.3	46.9
38 (17 Sep - 23 Sep)	30.9	24.9	91.1	77.9	19.4	30.8	24.3	96.3	90.6	128.6
39 (24 Sep - 30 Sep)	31.0	24.2	93.3	75.6	123.8	31.2	25.1	93.3	87.1	3.4
40 (01 Oct-07 Oct)	31.5	24.6	91.3	72.1	7.0	31.8	25.1	91.9	78.3	3.6

Standard week	First year					Second year				
	Mean temperature (°C)		Mean RH (%)		Rain Fall (cm)	Mean temperature (°C)		Mean RH (%)		Rain Fall (cm)
	Max	Min	Max	Min		Max	Min	Max	Min	
41 (08 Oct -14 Oct)	31.1	24.4	91.7	77.0	133.1	30.7	24.0	95.7	85.9	118.2
42 (15 Oct -21 Oct)	30.9	24.2	94.9	80.3	125.7	30.7	24.8	93.7	80.9	26.7
43 (22 Oct -28 Oct)	30.3	23.6	91.3	77.7	42.8	31.9	25.3	90.3	82.7	0.8
44 (29 Oct -04 Nov)	28.8	24.0	95.0	78.7	105.6	32.4	25.2	88.4	74.7	0.0
45 (05 Nov -11Nov)	32.5	24.8	89.3	68.1	0.0	33.2	25.8	92.1	76.3	2.4
46 (12 Nov -18Nov)	32.5	24.6	90.7	67.4	9.0	30.6	24.5	94.7	86.1	71.0
47 (19 Nov -25Nov)	32.1	24.3	92.4	74.4	49.9	32.6	24.9	91.7	75.3	0.0
48 (26 Nov -02Dec)	32.6	24.5	94.0	69.1	31.0	33.0	25.1	88.6	78.1	11.7
49 (03 Dec -09 Dec)	32.0	24.1	91.3	69.6	38.1	31.3	24.3	93.3	81.7	60.9
50 (10 Dec -16 Dec)	32.2	23.6	91.0	70.9	53.0	32.8	24.4	93.4	74.7	0.4
51 (17 Dec -23 Dec)	31.4	23.9	92.9	72.4	41.4	32.2	23.9	94.4	83.4	9.5
52 (24 Dec -31 Dec)	31.9	23.8	92.7	69.0	60.5	33.2	23.5	89.7	74.0	0.0
1 (01 Jan-07 Jan)	32.2	24.1	92.3	66.1	0.0	32.0	23.6	94.7	84.0	32.2
2 (08 Jan -14 Jan)	32.0	22.7	93.4	66.3	45.0	30.4	24.0	94.4	87.9	42.3
3 (15 Jan -21 Jan)	32.2	22.5	92.3	63.7	10.0	32.0	24.2	92.7	77.3	1.4
4 (22 Jan -28 Jan)	32.7	23.0	91.4	64.1	0.0	32.6	22.2	92.1	71.6	0.0
5 (29 Jan -04 Feb)	32.7	22.3	92.7	57.9	0.0	33.0	23.7	91.4	69.1	0.0

APPENDIX II

Quantity of nutrients added

Treatments	Quantity of nitrogen added (kg ha^{-1})													
	First year							Second year						
	Through FYM (basal dose)	Through fertilizer	Through organic sources			Through *in situ* green manuring	Total	Through FYM (basal dose)	Through fertilizer	Through organic sources			Through *in situ* green manuring	Total
			FYM/ PM	Wood ash	Vermiwash					FYM/ PM	Wood ash	Vermiwash		
s_1g_1	114.00	-	80.00	5.45	-	18.53	217.98	127.20	-	80.00	4.90	-	25.31	237.41
s_1g_2	114.00	-	80.00	5.45	-	60.97	260.42	127.20	-	80.00	4.90	-	41.02	253.12
s_2g_1	114.00	-	80.00	5.45	-	18.53	217.98	127.20	-	80.00	4.90	-	25.31	237.41
s_2g_2	114.00	-	80.00	5.45	-	60.97	260.42	127.20	-	80.00	4.90	-	41.02	253.12
s_3g_1	114.00	-	80.00	5.45	1.20	18.53	219.18	127.20	-	80.00	4.90	1.20	25.31	238.61
s_3g_2	114.00	-	80.00	5.45	1.20	60.97	261.62	127.20	-	80.00	4.90	1.20	41.02	254.32
s_4g_1	114.00	-	80.00	4.64	-	18.53	217.17	127.20	-	80.00	4.70	-	25.31	237.21
s_4g_2	114.00	-	80.00	4.64	-	60.97	259.61	127.20	-	80.00	4.70	-	41.02	252.92
s_5g_1	114.00	-	80.00	4.64	-	18.53	217.17	127.20	-	80.00	4.70	-	25.31	237.21
s_5g_2	114.00	-	80.00	4.64	-	60.97	259.61	127.20	-	80.00	4.70	-	41.02	252.92
s_6g_1	114.00	-	80.00	4.64	1.20	18.53	218.37	127.20	-	80.00	4.70	1.20	25.31	238.41
s_6g_2	114.00	-	80.00	4.64	1.20	60.97	260.81	127.20	-	80.00	4.70	1.20	41.02	254.12
C_1	114.00	80.00	-	-	-	-	194.00	127.20	80.00	-	-	-	-	207.20
C_2	114.00	-	38.00	8.70	-	18.53	179.23	127.20	-	42.40	7.20	-	25.31	202.11
C_3	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Treatments	Quantity of phosphorus added (kg ha^{-1})													
	First year							Second year						
	Through FYM (basal dose)	Through fertilizer	Through organic sources			Through *in situ* green manuring	Total	Through FYM (basal dose)	Through fertilizer	Through organic sources			Through *in situ* green manuring	Total
			FYM/ PM	Wood ash	Vermiwash					FYM/ PM	Wood ash	Vermiwash		
s_1g_1	86.40	-	60.62	3.48	-	1.88	152.38	81.60	-	51.27	11.22	-	3.39	147.48
s_1g_2	86.40	-	60.62	3.48	-	11.83	162.33	81.60	-	51.27	11.22	-	7.63	151.72
s_2g_1	86.40	-	60.62	3.48	-	1.88	152.38	81.60	-	51.27	11.22	-	3.39	147.48
s_2g_2	86.40	-	60.62	3.48	-	11.83	162.33	81.60	-	51.27	11.22	-	7.63	151.72
s_3g_1	86.40	-	60.62	3.48	0.90	1.88	153.28	81.60	-	51.27	11.22	0.90	3.39	148.38
s_3g_2	86.40	-	60.62	3.48	0.90	11.83	163.23	81.60	-	51.27	11.22	0.90	7.63	152.62
s_4g_1	86.40	-	99.96	2.96	-	1.88	191.20	81.60	-	88.75	10.78	-	3.39	184.52
s_4g_2	86.40	-	99.96	2.96	-	11.83	201.15	81.60	-	88.75	10.78	-	7.63	188.76
s_5g_1	86.40	-	99.96	2.96	-	1.88	191.20	81.60	-	88.75	10.78	-	3.39	184.52
s_5g_2	86.40	-	99.96	2.96	-	11.83	201.15	81.60	-	88.75	10.78	-	7.63	188.76
s_6g_1	86.40	-	99.96	2.96	0.90	1.88	192.10	81.60	-	88.75	10.78	0.90	3.39	185.42
s_6g_2	86.40	-	99.96	2.96	0.90	11.83	202.05	81.60	-	88.75	10.78	0.90	7.63	189.66
C_1	86.40	25.00	-	-	-	-	111.40	81.60	25.00	-	-	-	-	106.60
C_2	86.40	10.00	28.80	5.55	-	1.88	132.63	81.60	10.00	27.20	16.5	-	3.39	138.69
C_3	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Treatments	Quantity of potassium added (kg ha^{-1})													
	First year							Second year						
	Through FYM (basal dose)	Through fertilizer	Through organic sources			Through *in situ* green manuring	Total	Through FYM (basal dose)	Through fertilizer	Through organic sources			Through *in situ* green manuring	Total
			FYM/ PM	Wood ash	Vermiwash					FYM/ PM	Wood ash	Vermiwash		
s_1g_1	73.20	-	51.36	48.50	-	41.61	214.67	74.40	-	46.75	53.35	-	47.01	221.51
s_1g_2	73.20	-	51.36	48.50	-	89.18	262.24	74.40	-	46.75	53.35	-	59.15	233.65
s_2g_1	73.20	-	51.36	48.50	-	41.61	214.67	74.40	-	46.75	53.35	-	47.01	221.51
s_2g_2	73.20	-	51.36	48.50	-	89.18	262.24	74.40	-	46.75	53.35	-	59.15	233.65
s_3g_1	73.20	-	51.36	48.50	1.05	41.61	215.72	74.40	-	46.75	53.35	0.90	47.01	222.41
s_3g_2	73.20	-	51.36	48.50	1.05	89.18	263.29	74.40	-	46.75	53.35	0.90	59.15	234.55
s_4g_1	73.20	-	58.55	41.28	-	41.61	214.64	74.40	-	48.75	51.25	-	47.01	221.41
s_4g_2	73.20	-	58.55	41.28	-	89.18	262.21	74.40	-	48.75	51.25	-	59.15	233.55
s_5g_1	73.20	-	58.55	41.28	-	41.61	214.64	74.40	-	48.75	51.25	-	47.01	221.41
s_5g_2	73.20	-	58.55	41.28	-	89.18	262.21	74.40	-	48.75	51.25	-	59.15	233.55
s_6g_1	73.20	-	58.55	41.28	1.05	41.61	215.69	74.40	-	48.75	51.25	0.90	47.01	222.31
s_6g_2	73.20	-	58.55	41.28	1.05	89.18	263.26	74.40	-	48.75	51.25	0.90	59.15	234.45
C_1	73.20	100.00	-	-	-	-	173.20	74.40	100.00	-	-	-	-	174.40
C_2	73.20	-	24.40	77.40	-	41.61	216.61	74.40	-	24.80	78.45	-	47.01	224.66
C_3	-	-	-	-	-	-	-	-	-	-	-	-	-	-

APPENDIX III

Media for microbial culture

Nutrient Agar (1 Litre)

Particulars	Quantity
Peptone	5 g
Beef extract	3 g
Agar	20 g
Distilled water	1000 ml

Martin's Rose Bengal Agar (1 Litre)

Particulars	Quantity
Glucose	10 g
Peptone	5 g
KH_2PO_4	1 g
$MgSO_4.\ 7H_2O$	0.5 g
Streptomycin	30 mg
Agar	15 g
Rose Bengal	35 mg
Distilled water	1000 ml

Kenknight's Agar (1 Litre)

Particulars	**Quantity**
Dextrose	1 g
KH_2PO_4	0.1 g
$NaNO_3$	0.1 g
KCl	0.1 g
$MgSO_4 . 7H_2O$	0.1 g
Agar	15 g
Distilled water	1000 ml

N free semisolid malate medium (1 Litre)

Particulars	**Quantity**
Malic acid	5 g
KH_2PO_4	0.5 g
$MgSO_4 . 7H_2O$	0.2 g
NaCl	0.1 g
$CaCl_2$	0.02 g
Trace element solution	2 ml
BTB (0.5% alcoholic solution)	2 ml
$FeSO_4$	0.5 g
Vitamin solution	4 ml
KOH	4 g
Agar	20 g
Distilled water	1000ml

Pikovskaya's medium (1 Litre)

Particulars	Quantity
Glucose	10 g
$Ca_3(PO_4)_2$	5 g
$(NH_4)_2SO_4$	0.5 g
KCl	0.2 g
$MgSO_4 . 7H_2O$	0.1 g
$MnSO_4$	Trace
Yeast extract	0.5 g
Agar	15 g
Distilled water	1000 ml
$FeSO_4$	Trace

Jensen's medium

Particulars	Quantity
Sucrose	20 g
K_2HPO_4	1 g
$MgSO_4$	0.5 g
NaCl	0.5 g
$FeSO_4$	0.1 g
Na_2MoO_4	0.005 g
CaCO3	2 g
Agar	15 g
Distilled water	1000 ml

APPENDIX IV

Average input cost and market price of produce

Items	**Cost (₹)**
Inputs	
Labour wage	850 per day
Planting material (taro cormels)	60 kg^{-1}
Cowpea seeds	160 kg^{-1}
Daincha seeds	60 kg^{-1}
FYM	5 kg^{-1}
Poultry manure	3 kg^{-1}
Wood ash	2 kg^{-1}
PGPR mix I	70 kg^{-1}
Earthworm	700 kg^{-1}
Urea	8 kg^{-1}
Rajphos	15 kg^{-1}
Muriate of Potash (MOP)	23 kg^{-1}
Market price of produce	
Inorganic cormels	42 kg^{-1}
Organic cormels	60 kg^{-1}

APPENDIX V

Cost of cultivation (₹ ha^{-1})

Treatments	First year	Second year
s_1g_1	372080	367680
s_1g_2	369030	364630
s_2g_1	427710	423310
s_2g_2	422760	418360
s_3g_1	429310	424910
s_3g_2	426260	421860
s_4g_1	351120	348450
s_4g_2	348070	345400
s_5g_1	405850	403180
s_5g_2	402800	400130
s_6g_1	408350	405680
s_6g_2	405300	402630
C_1- KAU PoP	309099	309099
C_2- KAU organic PoP	351500	351500
C_3- Absolute control	216500	216500

ORGANIC NUTRITION IN TARO
(*Colocasia esculenta* (L.) Schott)

by

LIMISHA N. P.

(2018 - 21 - 006)

ABSTRACT

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ABSTRACT

The study entitled "Organic nutrition in taro (*Colocasia esculenta* (L.) Schott)" was conducted at College of Agriculture, Vellayani, Thiruvananthapuram, Kerala to investigate the effect of organic nutrition on growth, yield, quality, soil organic carbon build up and economics of cultivation of taro and to study rooting and tuberisation pattern of taro under organic nutrition. The experiment was conducted in the farmer's field at Peringamala, Thiruvananthapuram from June 2019 to January 2020 and June 2020 to January 2021.

The investigation comprised two separate experiments: (1) Organic nutrition in taro (field experiment) and (2) Rooting and tuberisation pattern study in taro (pot culture). The first experiment was laid out in randomized block design with three replications. The treatments comprised six organic sources (s_1- FYM + wood ash; s_2- FYM + wood ash +PGPR mix I; s_3- FYM + wood ash + PGPR mix I + vermiwash; s_4- poultry manure + wood ash ; s_5- poultry manure + wood ash + PGPR mix I; s_6- poultry manure + wood ash + PGPR mix I + vermiwash) and two *in situ* green manuring (g_1- *in situ* green manuring with cowpea; g_2- *in situ* green manuring with daincha) with three controls (C_1- nutrient management through chemical fertilizers as per KAU POP (80 : 25: 100 kg ha^{-1}); C_2 - nutrient management as per KAU organic POP (*Ad hoc*); C_3 - absolute control). The tuberization study was laid out as completely randomized design as pot culture with the six organic sources (s_1 to s_6 used in field experiment) as treatments (T_1 to T_6) together with three controls, and were replicated thrice. The recommended dose of NPK for colocasia @ 80: 25: 100 kg ha^{-1} was applied through organic sources on N equivalent basis as per the treatments.

Application of FYM + wood ash +PGPR mix I (s_2) took less number of days (24.33 days) for 50 per cent sprouting of seed corm during first year. Application of poultry manure along with wood ash, PGPR mix I and vermiwash (s_6) and *in situ* green manuring with daincha (g_2) found superior with respect to growth characters such as plant height, number of leaves per plant, leaf area and leaf area index (LAI). The interaction s_6g_2 recorded taller plants, higher leaf area and LAI during both the years.

Taller plants were produced by s_6g_2 at 4 MAP and s_6g_1 at harvest compared to C_1 (151.48 cm) during first year. Organic treatments performed better than C_2 and C_3 with respect to all growth parameters.

FYM + wood ash and poultry manure + wood ash recorded the highest number of cormels per plant during first and second year respectively. Mean weight of cormel was higher in s_6 (34.86 g) during first year and in s_3 (26.01 g) during second year. The application of poultry manure along with wood ash, PGPR mix I and vermiwash (s_6) recorded the highest cormel yield (18.68 t ha^{-1}) and corm yield (12.21 t ha^{-1}) under pooled analysis. Organic treatment s_5 recorded the highest cormel to corm ratio (1.80) during second year. *In situ* green manuring with daincha (g_2) recorded the highest mean cormel weight during both the years while cormel and corm yield in pooled analysis were also the highest with this treatment. The treatment s_3g_2 recorded the highest mean weight of cormel and the treatment s_6g_2 recorded the highest cormel yield under pooled analysis (19.02 t ha^{-1}). The treatment s_5g_1 registered the highest cormel to corm ratio during second year. The organic treatments s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 were found to be equally effective as C_1 in case of corm and cormel yield of taro. The treatment s_6g_2 recorded a 0.90 percentage increase of cormel yield over chemical nutrient management during first year and a 2.67 percentage increase of corm yield over chemical nutrient management for pooled mean. The treatment combinations s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 were found superior to C_2 in case of corm yield, cormel yield and mean cormel weight. The treatment s_6g_2 recorded a 37.83 percentage and 27.82 percentage increase of cormel yield and corm yield respectively over KAU organic POP for pooled mean. The treatments s_3g_2, s_4g_2, s_6g_1 and s_6g_2 during first year and s_3g_2, s_5g_2 and s_6g_2 during second year recorded significantly higher mean weight of cormel than C_3. All the treatment combinations in case of corm yield and all the treatment combinations except s_1g_1 in case of cormel yield recorded significantly higher value than C_3. During second year, the treatments s_5g_1 and s_2g_2 recorded the highest harvest index (0.60) and were significantly superior to C_2 (0.47).

The organic source s_6 and *in situ* green manuring g_2 recorded the highest dry matter production (DMP). Treatment combination s_6g_2 (8.37 t ha^{-1}) during first year and

s_3g_2 (6.55 t ha^{-1}) during second year recorded the highest DMP. Except s_1g_1, s_1g_2 and s_4g_2, all other treatment combinations resulted in significantly higher DMP compared to C_2. All organic treatments were significantly superior to C_3 with respect to DMP during both the years. The organic source s_6 and *in situ* green manuring g_2 were found superior in improving quality characters of cormel.

The higher N and K content and uptake were noticed in organic source s_6, while P uptake was higher in s_3. *In situ* green manuring g_2 resulted in higher NPK contents and uptake. The highest N (149.03 kg ha^{-1}) and K (232.80 kg ha^{-1}) uptakes were recorded with treatment combination s_6g_2 during second year. During first year, the treatment s_3g_2 recorded the highest tuber P content and P uptake (35.12 kg ha^{-1}). The treatment combination s_6g_2 was significantly superior to C_1 in case of K uptake during first year. The treatment combinations s_2g_1, s_2g_2, s_3g_1, s_3g_2, s_5g_1, s_5g_2, s_6g_1 and s_6g_2 were found superior to C_2 in nutrient content and uptake. The organic treatments were superior to absolute control in nutrient contents and uptake.

The organic source s_5 recorded the lowest EC during second year. The organic sources s_5 and s_6 resulted in higher organic carbon and available N content in soil while available P content of soil was the highest with s_3. *In situ* green manuring with daincha found superior in organic carbon, available N and available P content of soil. Available N content in soil was the highest in s_6g_2 during first year. The treatments s_2g_2 and s_3g_2 were found to be significantly superior to C_1 and C_2 during second year with respect to available P status. The organic treatments were found superior to C_3 in case of pH, organic carbon and available NPK. The organic sources s_5, s_3, s_6 and *in situ* green manuring g_2 resulted in higher total organic carbon and recalcitrant carbon, labile carbon and water soluble carbon content of soil. All organic nutrition treatments were found superior to control treatments in soil organic carbon buildup. Balance sheet of K was positive for s_3g_1, s_5g_1, s_6g_1, s_6g_2 and C_1 after first year of experiment and the N balance was positive for absolute control after second year.

The organic source s_6 and *in situ* green manuring g_2 registered the highest net income and BCR. Treatment combination s_6g_2 resulted in the highest net income (₹737241 ha^{-1}) and BCR (2.82). All the treatments except s_1g_1 and s_2g_1 recorded higher net income and the treatments s_4g_1, s_5g_1, s_6g_1 and s_6g_2 resulted in higher BCR than C_1. The treatment s_6g_2 recorded a 43.96 percentage and 6.02 percentage increase of net income and BCR respectively over chemical nutrient management for mean. All treatment combinations except s_1g_1 and s_2g_1 recorded higher net income and all except s_1g_1, s_2g_1 and s_3g_1 recorded higher BCR compared to C_2. The treatment s_6g_2 recorded a 54.71 percentage and 19.49 percentage increase of net income and BCR respectively over KAU organic POP for mean. All organic nutrition treatments recorded higher net income and all treatments except s_2g_1 and s_3g_1 recorded higher BCR compared to absolute control.

In pot culture study, the treatments T_6 and T_5 in case of pH, absolute control in case of EC, T_2 and T_3 in case of organic carbon and available P and T_6 and C_1 in case of available N and K were found superior throughout the growing period. The higher microbial population was observed with organic sources T_6, T_5, T_3 and T_2. The organic sources T_5 and T_3 recorded the highest dehydrogenase activity. The treatments T_6, T_3 and T_5 excelled in rooting pattern and root anatomical characters. Significant and positive correlation was observed between nutrient uptake and root apex diameter, late metaxylem number, early metaxylem number and stele diameter. Corm initiation was early (between 1 MAP and 2 MAP) in treatments C_1 and T_6 while it was between 2 MAP and 3 MAP in all other treatments. Control C_1 and T_6 recorded the highest corm and cormel weight per plant during initial stages and later stages respectively. The highest values of cormel bulking rate were observed between 3 MAP and 4 MAP. The treatment T_6 recorded the highest bulking rate during 3-4 MAP, T_3 and T_5 during 4-5 MAP and T_2 during 5-6 MAP.

The study revealed that application of poultry manure, wood ash, PGPR mix I and vermiwash, along with *in situ* green manuring of daincha in taro resulted in higher growth, yield, quality, net returns and BCR under organic nutrition and hence can be recommended for its organic nutrient management. All the organic nutrient management practices were found to improve soil organic carbon build up. Application of poultry manure, wood ash, PGPR mix I and vermiwash as organic sources was also found to promote the rooting and tuberisation in taro.

സംഗ്രഹം

"ചേമ്പിലെ ജൈവിക പോഷകം" എന്ന ശീർഷകത്തിൽ ഒരു പഠനം വെള്ളായണി കാർഷിക കോളേജിൽ നടത്തുകയുണ്ടായി. ചെമ്പിന്റെ വളർച്ചയ്ക്കും വിളവിനും ഗുണമേന്മയ്ക്കും അനുയോജ്യമായ ജൈവിക പോഷക രീതി കണ്ടെത്തുക, ജൈവിക ചേമ്പ് കൃഷിയുടെ സാമ്പത്തിക വശം കണക്കാക്കുക, ജൈവിക പോഷണം മണ്ണിലെ ജൈവകാർബണിൽ ഉണ്ടാക്കുന്ന പ്രഭാവം കണ്ടെത്തുക, ജൈവിക പോഷണം അവലംബിക്കുമ്പോൾ ചേമ്പിലെ വേര് രൂപീകരണ രീതിയും കിഴങ്ങ് രൂപീകരണ രീതിയും പഠിക്കുക എന്നിവയായിരുന്നു ഈ പഠനത്തിന്റെ ഉദ്ദേശ്യങ്ങൾ. ഇതിനുവേണ്ടി തിരുവനന്തപുരം ജില്ലയിലെ പെരിങ്ങമലയിലെ കൃഷി സ്ഥലത്ത് 2019 ജൂൺ മുതൽ 2020 ജനുവരി വരെയും, 2020 ജൂൺ മുതൽ 2021 ജനുവരി വരെയും ചേമ്പ് കൃഷി നടത്തുകയുണ്ടായി.

രണ്ട് പരീക്ഷണങ്ങളായിട്ടാണ് ഈ പഠനം നടത്തിയത്. (1) "ചേമ്പിലെ ജൈവിക പോഷകം"(വിളഭൂമി പരീക്ഷണം); (2) വേര്, കിഴങ്ങ് രൂപീകരണ പഠനം (പോട്ട് കൾച്ചർ പരീക്ഷണം). ആറ് ജൈവ പോഷക സ്രോതസ്സുകളും (കാലിവളം + ചാരം ; കാലിവളം + ചാരം + പി. ജി. പി. ആർ മിക്സ് 1 ; കാലിവളം + ചാരം + പി. ജി. പി. ആർ മിക്സ് 1 + മണ്ണിര ലായനി; കോഴിവളം + ചാരം ; കോഴിവളം + ചാരം + പി. ജി. പി. ആർ മിക്സ് 1 ; കോഴിവളം + ചാരം + പി. ജി. പി. ആർ മിക്സ് 1 + മണ്ണിര ലായനി) രണ്ടു പച്ചില വള പ്രോയോഗങ്ങളും ചേർത്ത് 12 ട്രീറ്റ്മെന്റ്കളും 3 കോൺട്രോളുകളും കൂടെ 15 പ്ലോട്ടുകളിലായി 3 തവണ ആവർത്തിച്ച് മൊത്തം 45 പ്ലോട്ടുകളിലായി റാംഡമൈസ്ഡ് ബ്ലോക്ക് ഡിസൈൻ എന്ന പരീക്ഷണ രീതി അവലംബിച്ചു ആദ്യ പരീക്ഷണം നടത്തി. ആദ്യ പരീക്ഷണത്തിലെ അതേ ജൈവ പോഷക സ്രോതസ്സുകളും കോൺട്രോളുകളും ഉപയോഗിച്ച് കംപ്ലീറ്റലി റാംഡമൈസ്ഡ് ഡിസൈൻ എന്ന പരീക്ഷണ രീതി അവലംബിച്ചു രണ്ടാമത്തെ പരീക്ഷണമായ വേര്, കിഴങ്ങ് രൂപീകരണ പഠനവും നടത്തുകയുണ്ടായി. ഹെക്ടർ ഒന്നിന് ചേമ്പിനു ശുപാർശ ചെയ്തിട്ടുള്ള പാക്യജനകം : ഭാവഹം : പൊട്ടാഷ് 80: 25:100 കിലോഗ്രാം എന്നിവ ജൈവ സ്രോതസ്സുകളിലൂടെ ട്രീറ്റ്മെന്റ് അനുസരിച്ച് നൽകി.

കോഴിവളം + ചാരം + പി. ജി. പി. ആർ മിക്സ് 1 + മണ്ണിര ലായനി എന്ന ജൈവ സ്രോതസ്സിന്റെ കൂടെ ഡെയ്ൻച പച്ചില വളമായി ഉപയോഗിച്ച രീതി ചേമ്പിനു മെച്ചപ്പെട്ട വളർച്ചയും വിളവും ഗുണമേന്മയും ലഭിക്കുന്നതിനായി സഹായിച്ചു. കൂടാതെ ഈ വളപ്രയോഗ രീതിയിൽ രാസവള പ്രയോഗത്തെക്കാൾ 0.90% അധിക വിളവ് ആദ്യ വർഷം

ലഭിക്കുകയുണ്ടായി. അതുപോലെതന്നെ കെ. എ. യു. ജൈവ വിളപരിപാലന രീതി അനുസരിച്ചുള്ള വളപ്രയോഗത്തെക്കാളും, തീരെ വളപ്രയോഗം നടത്താത്ത രീതിയെക്കാളും മികച്ച വിളവും ഗുണമേന്മയും ഈ ജൈവ വളപ്രയോഗ രീതി മൂലം ലഭിക്കുന്നതിനായി കണ്ടെത്തി. കൂടാതെ കോഴിവളം + ചാരം + പി. ജി. പി. ആർ മിക്സ് 1 + മണ്ണിര ലായനി എന്ന രീതി പാക്യജനകവും പൊട്ടാഷും, കാലിവളം + ചാരം + പി. ജി. പി. ആർ മിക്സ് 1 + മണ്ണിര ലായനി എന്ന രീതി ഭാവഹവും താരതമ്യേന അധിക അളവിൽ ആഗിരണം ചെയ്യുന്നതായി കണ്ടെത്തി. പയറിനേക്കാൾ ഡെയ്ൻചയുടെ പച്ചിലവളപ്രോയോഗം കൂടുതൽ അളവിൽ പോഷകങ്ങൾ ആഗിരണം ചെയ്യുന്നതായും പഠനം തെളിയിച്ചു. കോഴിവളം + ചാരം + പി. ജി. പി. ആർ മിക്സ് 1 + മണ്ണിര ലായനി എന്ന ജൈവ സ്രോതസ്സിന്റെ കൂടെ ഡെയ്ൻച പച്ചിലവളപ്രോയോഗമായി ഉപയോഗിച്ച രീതി കൺട്രോളുകളേക്കാൾ കൂടുതൽ പോഷകങ്ങൾ ആഗിരണം ചെയ്യുന്നതായും കണ്ടെത്തി. ജൈവ വള പ്രോയോഗ രീതി മണ്ണിൻറെ രാസഭൗതിക ഗുണങ്ങൾ മെച്ചെപ്പെടുത്തുന്നതായും മണ്ണിൽ ജൈവ കാർബണിന്റെ അളവ് വർദ്ധിപ്പിക്കുന്നതായും കണ്ടെത്തി.

കോഴിവളം + ചാരം + പി. ജി. പി. ആർ മിക്സ് 1 + മണ്ണിര ലായനി എന്ന ജൈവ സ്രോതസ്സിന്റെ കൂടെ ഡെയ്ൻച പച്ചിലവളപ്രോയോഗമായി ഉപയോഗിച്ച രീതി അറ്റാദായത്തിലും വരവ് ചെലവ് അനുപാതത്തിലും വർദ്ധനവ് രേഖപ്പെടുത്തി. മേൽ പറഞ്ഞ കൃഷി രീതി രാസവള പ്രോയോഗത്തെക്കാൾ 43.96 % അറ്റാദായവും 6.02 % വരവ് ചെലവ് അനുപാതവും, കെ . എ . യു ജൈവ വിള പരിപാലന രീതിയെക്കാൾ 54.71 % അറ്റാദായവും 19.49 % വരവ് ചെലവ് അനുപാതവും കൂടുതലായി നൽകുന്നതായി കണ്ടെത്തി.

രണ്ടാമത്തെ പരീക്ഷണമായ പോട്ട് കൾച്ചർ പരീക്ഷണത്തിൽ, കോഴിവളം + ചാരം + പി. ജി. പി. ആർ മിക്സ് 1 + മണ്ണിര ലായനി, കോഴിവളം + ചാരം + പി. ജി. പി. ആർ മിക്സ് 1, കാലിവളം + ചാരം + പി. ജി. പി. ആർ മിക്സ് 1 + മണ്ണിര ലായനി, കാലിവളം + ചാരം + പി. ജി. പി. ആർ മിക്സ് 1 എന്നീ ജൈവ വള സ്രോതസ്സുകൾ പോട്ടിങ് മിക്സ്ചറിന്റെ രാസഭൗതിക ഗുണത്തിനും സൂക്ഷ്മ ജീവാണുക്കളുടെ വർദ്ധനവിനും നല്ലതായി കണ്ടെത്തി. കൂടാതെ കോഴിവളം + ചാരം + പി. ജി. പി. ആർ മിക്സ് 1 + മണ്ണിര ലായനി, കോഴിവളം + ചാരം + പി. ജി. പി. ആർ മിക്സ് 1, കാലിവളം + ചാരം + പി. ജി. പി. ആർ മിക്സ് 1 + മണ്ണിര ലായനി എന്നിവ വേരു രൂപീകരണത്തിലും വേരിന്റെ ഘടനാ

സവിശേഷതകൾ മെച്ചപ്പെടുത്തുന്നതിനും മികച്ചതാണെന്ന് പഠനം തെളിയിച്ചു. വേരിന്റെ ആഗ്ര വ്യാസം, സൈലം നമ്പർ, സ്റ്റീൽ വ്യാസം എന്നിവ കൂടുന്നതനുസരിച്ച് പോഷകങ്ങളുടെ ആഗിരണത്തിലും കാര്യമായ വർദ്ധനവ് രേഖപ്പെടുത്തി.

ചേമ്പ് നട്ട് ഒന്നാം മാസത്തിനും രണ്ടാം മാസത്തിനും ഇടയിൽ കോഴിവളം + ചാരം + പി. ജി. പി. ആർ മിക്സ് 1 + മണ്ണിര ലായനി ജൈവ സ്രോതസ്സ് ആയി നൽകിയ ചെടികളിലും രാസവളം നൽകിയ ചെടികളിലും കിഴങ്ങ് ഉണ്ടാകാൻ തുടങ്ങി . എന്നാൽ മറ്റു ട്രീറ്റ്മെന്റ്കളിൽ രണ്ടാം മാസത്തിനും മൂന്നാം മാസത്തിനും ഇടയിലാണ് കിഴങ്ങ് ഉണ്ടാവാൻ തുടങ്ങിയത്. ഓരോ മാസ ഇടവേളയിൽ കിഴങ്ങിന്റെ വിളവ് പരിശോധിച്ചപ്പോൾ, ആദ്യ മാസങ്ങളിൽ രാസവളം നൽകിയ ചെടികളിൽ നിന്നും അവസാന മാസങ്ങളിൽ കോഴിവളം + ചാരം + പി. ജി. പി. ആർ മിക്സ് 1 + മണ്ണിര ലായനി നൽകിയ ചെടികളിൽ നിന്നുമാണ് കൂടുതൽ വിളവ് ലഭിച്ചത്. ചേമ്പ് നട്ട് മൂന്നാം മാസത്തിനും നാലാം മാസത്തിനും ഇടയിൽ ഏറ്റവും കൂടിയ നിരക്കിൽ കിഴങ്ങ് വലിപ്പം വയ്ക്കുന്നതായി കണ്ടെത്തി.

കോഴിവളം + ചാരം + പി. ജി. പി. ആർ മിക്സ് 1 + മണ്ണിര ലായനി എന്ന ജൈവ സ്രോതസ്സിന്റെ കൂടെ ഡെയ്ൻച പച്ചിലവളപ്രോയോഗമായി ഉപയോഗിക്കുന്ന രീതി ചെമ്പിന്റെ ജൈവ കൃഷിക്ക് ഏറ്റവും അനുയോജ്യമാണെന്ന് ഈ പഠനം തെളിയിച്ചു. ജൈവ കൃഷി സ്വീകരിക്കുന്നത് മൂലം മണ്ണിന്റെ ജൈവ കാർബണിന്റെ അളവ് കൂടുന്നതായും കണ്ടെത്തി.