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Growth Characters and Yield of Taro [*Colocasia esculenta* (L.) Schott] as Influenced by Organic Nutrient Management

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An experiment was undertaken at the College of Agriculture, Vellayani, Kerala to study the effect of organic nutrition on growth attributes and yield of taro during 2019-20 and 2020-21. The treatments comprised six levels of 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 levels of *in-situ* green manuring (G_1 - *in-situ* green manuring with cowpea; G_2 - *in-situ* green manuring with *dhaincha*) with three controls (C_1 - Nutrient management through chemical fertilizers as per KAU PoP (80:25:100 kg NPK ha^{-1}); C_2 - Nutrient management as per KAU organic PoP (Adhoc); C_3 - Absolute control). During both years, the highest plant height was recorded with application of poultry manure along with wood ash, PGPR mix I and vermiwash (S_6) at all stages of crop growth. Cormel yield was also the highest for the organic source S_6 during both years. *In-situ* green manuring with *dhaincha* (G_2) was found superior to cowpea in producing taller plants, more leaves per plant and cormel yield during both years. The treatment S_6G_2 was found equally effective as chemical nutrient management and superior to existing Adhoc organic management of KAU and absolute control in case of both growth parameters and yield. Based on the results of the study it can be concluded that organic nutrition involving the application of poultry manure, wood ash along with PGPR mix I, vermiwash and *in-situ* green manuring with *dhiancha* can be adopted for organic cultivation of taro.

(***Key words:*** *Colocasia, Green manuring, Growth attributes, Organic nutrition, Vermiwash*)

Taro (*Colocasia esculenta*) is an underexploited crop, grown throughout the tropics, especially in the warmer regions for its edible cormels, leaves and petioles. It is a staple food in many countries like the Pacific, Caribbean and Asia and a supplement to potatoes in the southern United States. In India, taro is mostly cultivated in the northern and eastern states. Taro is adapted to a wide variety of soil and climatic conditions and is an integral component of different farming systems adopted in the state of Kerala. The crop is mainly used as a vegetable in the state and has good keeping quality compared to other vegetables. As compared to other vegetables, it is a highly remunerative crop and has potential industrial uses (e.g., taro starch). A significant proportion of the produce is exported mainly to the Gulf countries, USA and UK (Ravi *et al.,* 2021) Growing concerns regarding food safety, environmental degradation and human health have generated interest in alternative agricultural systems like organic farming. The demand for organic food is steadily increasing both in developed and developing countries. There is scope for increasing the export of organically produced cocoyams (taro and tannia) fetching higher prices in the market. Taro is highly responsive to organic manures and has fewer pest and disease problems as compared to other vegetables. One of the importatnt aspects in organic production of tuber crops is the scientific use of available organic plant nutrients sources and the adoption of organic nutrient management practices to enhance crop productivity while maintaining soil health. However, there is limited knowledge about the effect of organic nutrition on the performance of the taro crop. The present study was therefore planned to asses the impact of organic nutrient management on growth and yeld of taro.

MATERIALS AND METHODS

The experiment was conducted in a Farmer's field,

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Peringamala, Thiruvananthapuram, near the College of Agriculture, Kerala Agricultural University, Vellayani, Kerala from June 2019 to January 2020 and June 2020 to January 2021. The taro variety Muktakeshi used in this study was sourced from ICAR-Central Tuber Crops Research Institute, Sreekaryam, Thiruvananthapuram. The experiment was conducted in a two-factorial arrangement in a randomized block design and replicated three times. The treatments comprised six levels of organic sources [(S_1 - farm yard manure (FYM) + wood ash; S_2 - FYM + wood ash + plant growth promoting rhizobacteria 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 levels of *in-situ* green manuring (G_1 - *in-situ* green manuring with cowpea; G_2 - *in-situ* green manuring with *dhaincha*) with three controls [(C_1 - Nutrient management through chemical fertilizers as per Kerala Agricultural University (KAU) package of practices (PoP) (80:25:100 kg NPK ha^{-1}); C_2 - Nutrient management as per KAU organic PoP (Adhoc); C_3 - Absolute control)]. KAU organic PoP (Adhoc) for taro (C_2) consisted of cattle manure or compost @ 12 t ha^{-1} applied as basal dressing. In addition green manuring was also done with cowpea/ *dhaincha*. Rock phosphate @ 10 kg P_2O_5 was applied to the green manure crop at sowing time. The green manure crops were incorporated at flowering (40-45 DAS) along with 4 t FYM/ 2 t poultry manure (PM)/ 2 t vermicompost/ 2 t coir pith compost and 1500 kg wood ash. The absolute control (C_3) treatment was without application of any chemical fertilizers or organic manures.

The site was double-ploughed and marked out into three blocks, which represent the replicates. Each block was divided into fifteen experimental plots (Plot size: 4.8 m x 4.5 m), thus a total of forty-five plots were used. A uniform dose of farm yard manure @ 12 t ha^{-1} was applied at the time of land preparation. One cormel weighing about 25-35 g was planted at a spacing of 60 cm x 45 cm. The recommended dose of NPK for colocasia @ 80:25:100 kg ha^{-1} as per KAU was supplied through organic sources on N equivalent basis as per the treatments as basal dose except for wood ash (applied while incorporating green manure). Corm treatment with 5% suspension of PGPR mix I followed by soil application of PGPR enriched cow dung @ 10 g pit^{-1} (mixture of dry cow dung and PGPR mix I in 50:1 proportion) were done at planting and 2 months after planting (MAP) in treatments S_2, S_3, S_5 and S_6. Vermiwash (10% dilution) 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% flowering stage by uprooting. All plots were kept weed-free by manual weeding at monthly intervals. All other crop management practices were followed as per the KAU PoP. Four cocoyam plants were randomly selected from each of the net plots, tagged and then used for the determination of plant height (cm) and number of leaves at bi-monthly intervals. The height of the plant was measured from the ground (base of the plant) to the tip of the longest petiole at the blade joint (Mohankumar, 1986). The number of fully opened green leaves of the observational plants at the time of observations was counted and recorded. The yield of cormels obtained from the net plot area was noted and from this corm yield per hectare was calculated and expressed in t ha^{-1}.

RESULTS AND DISCUSSION

Growth parameters

In general, the height of plants increased up to 4 MAP during both years after which the height reduced up to harvest (Table 2a). This clearly indicated the three growth stages of taro as explained by Sivan (1982) - a period of establishment of up to 6-8 weeks (phase I), a grand growth period of up to 20 weeks (Phase II) and a growth declining period but corm growth continues (Phase III). This is in agreement with the findings of Rajasree (1993) who observed that the plant height of taro increased progressively up to 120 days after planting and then declined. During both years, the highest number of leaves (Table 3a) 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) and it might be due to abscission of existing leaves.

Plant height varied significantly with different organic sources at all stages of observation during both years (Table 1a). During the first year (2019-20), the organic source S_6 (application of poultry manure along

Table 1a. *Effect of organic sources and in-situ green manuring on plant height*

Treatments	Plant height (cm)							
	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)	4.89	3.03	3.71	3.56	4.20	5.46	7.31	5.69
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 - *Dhaincha*	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

MAP: Months after planting

Table 1b. *Effect of S x G interaction and treatment vs. control effect on plant height*

Treatments	Plant height (cm)							
	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	71.55a	104.98a	90.32ab	69.93a	61.67a	93.54a	81.00a	-
S_1G_2	72.67	114.10ac	93.67a	73.74ac	64.00	102.81ac	83.67a	68.08a
S_2G_1	74.33	128.17abc	109.00abc	89.33abc	65.33	117.17abc	101.33c	85.48c
S_2G_2	76.67	141.28abc	98.33ac	78.82ac	67.00c	128.11bc	87.33a	71.45a
S_3G_1	78.33c	133.33abc	112.13abc	91.85abc	65.33	120.70abc	104.76bc	86.51bc
S_3G_2	82.33c	137.25abc	117.19bc	95.84bc	72.33c	124.06abc	104.72bc	87.75bc
S_4G_1	73.11	118.89abc	90.86ab	70.11a	63.00a	104.64ac	85.86a	69.14a
S_4G_2	75.11	124.62abc	103.76ac	83.12ac	65.67	114.12abc	92.76a	76.18ac
S_5G_1	77.66c	143.22abc	123.67bc	104.15bc	67.66c	130.82bc	118.67bc	95.58bc
S_5G_2	79.77c	148.43bc	126.00bc	102.79bc	71.00c	131.70bc	113.58bc	95.04bc
S_6G_1	81.33c	154.34bc	128.67bc	108.67abc	73.33c	137.27bc	116.33bc	101.67bc
S_6G_2	84.00c	158.18abc	130.58bc	106.39bc	70.67c	141.13bc	115.67bc	93.45bc
SEm (±)	2.36	1.46	1.79	1.72	2.02	2.63	3.52	2.75
CD (0.05)	NS	4.28	5.25	5.04	NS	NS	NS	8.05
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

a - significantly different from C_1; b - significantly different from C_2; c - significantly different from C_3

S - Significant at 5% level, NS- Non significant

Table 2a. *Effect of organic sources and in-situ green manuring on number of leaves per plant*

Treatments	Number of 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 (±)	0.124	0.089	0.091	0.11	0.149	0.123	0.112	0.074
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 - *Dhaincha*	4.67	3.52	2.69	2.46	4.52	3.59	2.78	2.56
SEm (±)	0.072	0.052	0.053	0.064	0.086	0.071	0.065	0.043
CD (0.05)	NS	0.151	0.155	NS	NS	NS	NS	NS

NS - Non significant; MAP - Months after planting

with wood ash, PGPR mix I and vermiwash) recorded the highest plant height which was significantly superior to all other organic sources at all stages of observation (156.26, 129.62 and 107.53 cm at 4 MAP, 6 MAP and at harvest respectively) except at 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 recorded the values 78.72 and 80.33 cm respectively. During 2020-21 also, the highest plant height was recorded with S_6 (application of poultry manure along with wood ash, PGPR mix I and vermiwash) at all stages of observation (72.00, 139.20, and 97.56 cm at 2 MAP, 4 MAP and harvest respectively) except at 6 MAP and was comparable with 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 (116.00 cm).

During 2019-20, organic sources significantly influenced leaf number (Table 2a) at all stages of crop growth except at harvest with the highest number being recorded by S_6 (4.94, 3.67 and 2.95) 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 (2020-21), the number of leaves per plant was significantly influenced by organic sources only at 4 MAP and harvest. As in the case of the first year, the organic source S_6 recorded the highest number of leaves per plant (3.84 at 4 MAP and 2.73 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 a significant effect

Table 2b. *Effect of S x G interaction and treatment vs. control effect on number of leaves per plant*

Treatments	Number of 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	2.112	2.11	4.22	3.22	2.44	2.22
S_1G_2	4.89	3.20	2.332	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	2.222	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	3.00c	2.78
SEm (±)	0.176	0.126	0.129	0.156	0.211	0.174	0.159	0.105
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

a - significantly different from C_1; b - significantly different from C_2; c - significantly different from C_3
S - Significant at 5% level, NS- Non significant

on plant height only at 4 MAP and 6 MAP during the first year (Table 1a). In both the stages, *in-situ* green manuring with *dhaincha* produced significantly taller plants (137.31 cm at 4 MAP and 111.59 cm at 6 MAP) than cowpea. 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 *dhaincha* recorded a significantly higher value of plant height (123.65 cm) than cowpea. *In-situ* green manuring showed a significant effect on the number of leaves per plant only at 4 MAP and 6 MAP during first year and *in-situ* green manuring with *dhaincha* was found superior to cowpea at both stages for producing higher leaf number per plant (3.52 at 4 MAP and 2.69 at 6 MAP). *In-situ* green manuring could not exert any significant influence on the number of leaves per plant at any growth stage of the crop during the second year.

The SxG interaction (Table 1b) showed a significant response with respect to plant height 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 (126.00 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, SxG interaction was significant only at harvest and 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). SxG interaction significantly influenced the number of leaves (Table 2b) per plant only at 2 MAP during the first year and S_1G_2 and S_6G_1 produced more leaves (4.89) and was on par with, S_5G_2, S_2G_1, S_2G_2, S_3G_1, S_5G_2, S_4G_1

Table 3. *Nutrient content and quantity of green manure crops (on dry weight basis) added*

Green manure crop	Nutrient content (%)			Quantity added (t ha^{-1})
	N	P	K	
Cowpea	1.18	0.12	0.83	1.57
Dhaincha	1.34	0.26	0.53	4.55

and S_5G_1. The SxG interaction failed to produce any significant effect on the number of leaves per plant at any stage of observation during the second year.

The superiority of the organic source S_6 (application of poultry manure along with wood ash, PGPR mix I and vermiwash) in plant height and the number of leaves per plant may be due to the combined effect of poultry manure, PGPR mix I and vermiwash. The mineralization pattern of poultry manure has indicated that nearly 60% of nitrogen in this manure is present as uric acid which quickly changes to the ammoniacal form that can be easily utilized by crops (Smith, 1950). The PGPR mix I is a microbial consortium for supplementing all the major nutrients which contain components cultures, *viz.*, *Azospirillum lipoferum, Azotobacter chroococcum, Bacillus megaterium* and *Bacillus sporothermoduransas* 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 and Mahmoud (2019) also reported the enhanced plant height in taro with the application of biofertilizers. Vermiwash is a very good liquid manure which favourably affects the growth and productivity of the crop when applied as a foliar spray (Subasashri, 2003). Ansari *et al.* (2015) reported excellent shoot growth and an increase in the number of leaves of colocasia plants with vermiwash hydroponic solution. The initial immobilization of nutrients on applying large quantities of FYM compared to the continuous availability of nutrients from poultry manure may be the reason for higher growth parameters recorded with treatments having poultry manure. Poultry manure is a bulky organic manure having a higher content of mineralizable nitrogen due to its narrow C:N ratio. Singh *et al.* (1973) also attributed the higher efficiency of poultry manure to its narrow C:N ratio and comparatively higher content of mineralizable nitrogen.

The superiority of *dhiancha* over cowpea in producing higher plant height and the number of leaves may be due to the higher biomass production and higher content of nitrogen and phosphorus in *dhaincha* compared to cowpea (Table 3). This may have resulted in higher available soil nutrients and uptake of nutrients by crops in turn higher growth parameters. 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 phosphorus, potassium, 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 readily available to the succeeding crop (Palaniappan and Annadurai, 1999). Irin *et al.* (2019) also reported a higher biomass production of *dhaincha* than cowpea. Singh and Shivay (2014) stated that the increase in biomass accumulation of *Sesbania* might be due to its fast and determinate growth habit leading to enhanced biomass incorporation/addition and nutrient availability in soil. Khind *et al.* (1987) opined that *Sesbania aculeata* could produce 21.1 t ha^{-1} of green biomass and accumulate about 133 kg N ha^{-1}. Sanjay *et al.* (2015) reported that among the summer green manuring crops, *dhaincha* recorded significantly higher total fresh and dry matter accumulation compared with cowpea.

Regarding the treatments vs. control (Table 1b), the effect of organic treatments on plant height showed a 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, all organic treatments except S_1G_1 were on par with C_1 (82.78 cm) at 2 MAP. At 4 MAP, the treatment S_6G_2 (158.18 cm) was significantly superior to C_1 (151.48) and S_5G_2 and S_6G_1 were on par with C_1. 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. 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, 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 a significantly lower value than C_1. 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 years for the number of leaves per plant (Table 2b). The on-par effect of treatments especially S_3G_2, S_5G_1, S_5G_2, S_6G_1 and S_6G_2 with the C_1 indicates the efficiency of organic treatments as that of chemical nutrient management in the growth of taro.

While comparing C_2 (Nutrient management as per KAU organic Adhoc PoP) with other organic treatments, it was found that organic treatments were not significantly different from C_2 at 2 MAP during both years (Table 1b). During 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.

In the case of number of leaves per plant, there was a significant difference between treatments and C_2 at 6 MAP during the first year (Table 2b). All treatments except S_1G_1, S_1G_2 and S_4G_1 were on par with C_2. During II year all treatments were on par with C_2 at all stages of observation. The superiority of organic treatments in plant height compared to KAU organic PoP indicates 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 may be due to the effect of additional organic sources like PGPR mix I and vermiwash. 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.

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 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 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 (Table 1b). While comparing absolute control (C_3) with treatments, no significant difference was observed during the first year in the number of leaves per plant. While during the second year, S_6G_2 recorded a significantly higher number of leaves (3.00) than C_3 at 6 MAP (2.33), however at all other stages the C_3 was found to be on par with organic treatments (Table 2b). The effect of organic sources and *in-situ* green manuring is reflected in the superiority of organic treatments in growth parameters compared to absolute control.

Cormel yield

Cormel yield (Table 4a) was highest for the organic source in which application of poultry manure along with wood ash, PGPR mix I and vermiwash were done (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 and which in turn was on par with S_3 (19.45 t ha^{-1}). During the second year, S_6 (poultry manure along with wood ash, PGPR mix I and vermiwash were applied) was found on par with S_5 (15.72 t ha^{-1}) and S_3 (14.55 t ha^{-1}). The lowest value was recorded with the organic source S_1 (12.63 t ha^{-1}) which 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 4a. *Effect of organic sources and in-situ green manuring on cormel yield, t ha^{-1}*

Treatments	Cormel yield		
	I year	II year	Pooled mean
Organic sources (S)			
S_1 - FYM + wood ash	17.20	12.63	14.91
S_2 - FYM + wood ash + PGPR mix I	19.14	14.14	16.64
S_3 - FYM + wood ash + PGPR mix I + vermiwash	19.45	14.55	17.00
S_4 - PM+ wood ash	17.91	12.74	15.33
S_5 - PM+ wood ash + PGPR mix I	20.28	15.72	18.00
S_6 - PM+ wood ash + PGPR mix I + vermiwash	20.89	16.47	18.68
SEm (±)	0.36	0.71	0.53
CD (0.05)	1.07	2.09	1.57
In-situ green manuring (G)			
G_1 - Cowpea	18.72	13.76	16.24
G_2 - *Dhaincha*	19.57	14.99	17.28
SEm (±)	0.21	0.41	0.31
CD (0.05)	0.62	1.21	0.90

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 by *in-situ* green manuring with *dhaincha* over cowpea. Cormel yield recorded with *in-situ* green manuring with *dhaincha* 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.

A significant effect of treatment combinations on cormel yield (Table 4b) was observed during both the years and in the 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 dhaincha) recorded the highest cormel yield of 21.27 t ha^{-1}, 16.77 t ha^{-1}, 19.02 t ha^{-1} during the first year, second year and in the pooled analysis, respectively. The S_1G_1 (application of FYM and wood ash + *in-situ* green manuring with cowpea) recorded the lowest cormel yield during the first year, second year and in the pooled analysis also. Improvement in growth characters of taro by S_6G_2 (application of poultry manure along with wood ash, PGPR mix I and vermiwash + *in-situ* green manuring with *dhaincha*) culminated in the improvement in yield. The quick release of nitrogen from the poultry manure coupled with direct availability of nutrients through vermiwash application and increased nutrient availability consequent to the PGPR application would have resulted in higher tuber yield in S_6G_2. As explained earlier, the higher biomass production of *dhaincha* compared to cowpea resulted in higher soil nutrient availability and it might have resulted in higher yield.

Regarding the treatments vs. C_1 (nutrient management through chemical fertilizers) effect, there was a significant difference between organic treatments and C_1 during both the years and for pooled mean with respect to cormel yield (Table 4b). 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 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 case of the 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 on par with C_1 (19.55 t ha^{-1}) for pooled mean also. As in the case of growth characters some of the treatments were found as effective as nutrient management through chemical fertilizers in

***Table 4b.** Effect of S x G interaction and treatments vs. control effect on cormel yield*

Treatments	Cormel yield (t ha^{-1})		
	I year	II year	Pooled mean
S x G interaction			
S_1G_1	16.43ac	11.34a	13.88a
S_1G_2	17.96ac	13.91c	15.94ac
S_2G_1	18.03ac	11.63a	14.83ac
S_2G_2	20.26bc	16.64bc	18.45bc
S_3G_1	18.59abc	12.90a	15.74ac
S_3G_2	20.31bc	16.20bc	18.26bc
S_4G_1	18.34ac	13.77c	16.05ac
S_4G_2	17.49ac	11.72a	14.60ac
S_5G_1	20.40bc	16.74bc	18.57bc
S_5G_2	20.15bc	14.71c	17.43bc
S_6G_1	20.51bc	16.17bc	18.35bc
S_6G_2	21.27bc	16.77bc	19.02bc
SEm (±)	0.51	1.01	0.75
CD (0.05)	1.51	2.96	2.21
C_1 - KAU PoP	21.08	18.03	19.55
Treatments vs. C_1	S	S	S
C_2 - KAU organic PoP	16.25	11.35	13.80
Treatments vs. C_2	S	S	S
C_3 - Absolute control	13.15	9.60	11.37
Treatments vs. C_3	S	S	S

a - significantly different from C_1; b - significantly different from C_2; c - significantly different from C_3
S - Significant at 5% level, NS- Non significant

the case of cormel yield. This result is in agreement with the findings of Suja *et al.* (2017) who reported a similar performance of the organic system to that of the conventional with a slight yield reduction (-5%) at on station trial and a 29% higher yield at farm level over the chemical based farming.

A significant difference was observed between treatments and control C_2 (nutrient management as per KAU organic Adhoc PoP) during both the years and for pooled mean. The treatments 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 first year; 11.35 t ha^{-1} during second year and 13.80 t ha^{-1} for pooled mean) and all other treatments were at par with C_2. The enhancement of growth parameters by the treatments S_2G_2, S_3G_2, S_5G_1, S_5G_2, S_6G_1 and S_6G_2 over Adhoc organic KAU PoP reflected in the cormel yield also. 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 than C_3 (absolute control). As observed in the case of growth attributes, the higher yield of organic treatments over absolute control is undoubtedly the effect of applied organic sources and *in-situ* green manuring which enhanced soil nutrient status and direct feeding of nutrients through vermiwash spraying.

The results of the study revealed that the best organic source for taro cultivation is the application of poultry manure along with wood ash, PGPR mix I and vermiwash as it resulted in higher vegetative growth and yield. *In-situ* green manuring with *dhiancha* resulted in higher vegetative growth and higher cormel yield. The study also indicated that the application of poultry manure, wood ash, PGPR mix I and vermiwash along with *in-situ* green manuring with *dhiancha* was equally effective as chemical fertilizer application and superior to existing adhoc organic KAU PoP and absolute control. This nutrient management strategy can therefore be adopted for organic cultivation of taro for producing a safe and quality food having a premium price in the market without deteriorating the environment.

CONFLICTS OF INTEREST

There are no conflicts of interest.

REFERENCES

Ansari, A.A., Pereira, M. and Jaikishun, S. (2015). Effect of vermiwash obtained from different sources (neem, rice straw and bagasse) and standardised hydroponics solution on the growth of *Colocasia esculenta* (Australian Poi) in Guyana. *American Journal of Experimental Agriculture* **7**(5): 275-283.

Gopi, G.K., Meenakumari, K.S., Anith, K.N., Nysanth, N.S. and Subha, P. (2020). Application of liquid formulation of a mixture of plant growth promoting rhizobacteria helps reduce the use of chemical fertilizer in Amaranthus (*Amaranthus tricolor* L.). *Rhizosphere* **15**: 212-217.

Irin, J., Biswas, P.K., Ullah, M.J., Roy T.S. and Khan M.A. (2019). Influence of green manuring crops on dry matter production and soil health improvement. *Bangladesh Agronomy Journal* **22** (1): 39-45.

Khind, C.S., Maskina, M.S. and Meelu, O.P. (1987). Effect of green manuring on rice. *Journal of the Indian Society of Soil Science* **35**: 135-145.

Mohankumar, C.R. (1986). Agronomic investigations on colocasia (*Colocasia esculenta* L.) variety Thamarakannan. *Unpublished Ph.D. Thesis,* Kerala Agricultural University, Thrissur, Kerala. 240 p.

Palaniappan, S.P. and Annadurai, K. (1999). *Organic Farming: Theory and Practice*, Scientific Publishers, Jodhpur, India. 258 p.

Rajasree, J. (1993). Nutrient management for intercropped *Colocasia esculenta* var. Thamarakannan. *Unpublished M. Sc. (Ag.) Thesis*, Kerala Agricultural University, Thrissur, Kerala. 148 p.

Ravi, V., Pandey, V., Devi, A. and Giri, N.A. (2021). Prospects of underutilized taro (*Colocasia esculenta*) for sustainable biodiversity and nutritional security in India. In: *Promotion of Underutilized Taro for Sustainable Biodiversity and Nutrition Security in SAARC Countries*, N. Sultana, F.N. Jahan, S. Attaluri and M.B. Hossain (eds.), SAARC Agriculture Centre (SAC), Dhaka, Bangladesh. pp 61-112.

Sanjay, K., Chand, S. and Gautam, B.P.S. (2015). Enhance the soil health, nutrient uptake and yield of crops under rice-wheat cropping systems through green manuring. *International Journal of Tropical Agriculture* **33**(3): 2025-2028.

Singh, A. and Shivay, Y.S. (2014). Enhancement of growth parameters and productivity of basmati rice through summer green manuring and zinc fertilization. *International Journal of Bio-resource and Stress Management* **5**(4): 486-494.

Singh, K., Minhas, M.S. and Srivastava, O.P. (1973). Studies on poultry manure in relation to vegetable production in potato. *Indian Journal of Horticulture* **30**: 537-541.

Sivan, P. (1982). Growth and development of taro under dryland conditions in Fiji. In: Proceedings Fifth International Symposium on *Tropical root and tuber crops*, Philippines Council for Agriculture and Resources Research, September 17-21, 1979, Los Banos, Philippines. pp 637-646.

Smith, R. (1950). Poultry manure - A fertilizer. *Poultry Digest.* **9**: 550-551.

Soubeih, Kh. A.A. and Mahmoud, H.F. (2019). Response of taro (*Colocasia esculenta* L.) to natural and bio-fertilizers under Siwa Oasis conditions. *Middle East Journal of Applied Science & Technology* **09**(02): 297-309.

Subasashri, M. (2003) Vermiwash collection and its pesticidal properties. *The Hindu* **17**: 1-2.

Suja, G., Byju, G., Jyothi, A.N., Veena, S.S. and Sreekumar, J. (2017). Yield, quality and soil health under organic vs conventional farming in taro. *Scientia Horticulturae* **218**: 334-343.

Vacheron, J., Desbrosses, G., Bouffaud, M., Touraine, B., Moenne-Loccoz, Y., Muller, D., Legendre, L., Wisniewski-Dye, F. and Prigent-Combaret, C. (2013). Plant growth promoting rhizobacteria and root system functioning. *Frontiers in Plant Science* **4**: 356-375.