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Kunapajala- An Organic and Innovative Way Towards Sustainable Crop Production

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ABSTRACT

Kunapajala is a traditional and fermented liquid organic manure. Two types of *Kunapajala*, viz., herbal and non-herbal *Kunapajala* getting pace among farmers. Herbal *Kunapajala* is prepared from plant leaves while non herbal *Kunapajala* is prepared from animal products. A field experiment was carried out to evaluate the soil and foliar efficacy of herbal and non-herbal *Kunapajala* on soil health and crop nutrition by using okra as a test crop at College of Agriculture, Vellayani, Thiruvananthapuram. The experiment was carried out in Randomized Block Design with 13 treatments replicated thrice. The treatments comprised of KAU POP recommendations (T_1), Organic Adhoc POP recommendations (T_2), Organic Adhoc POP recommendations + 3% Panchagavya (T_3), Organic Adhoc POP recommendations + 5% Fish Amino Acids (T_4), 50% N as FYM + Water (T_5), Soil and foliar application of 2% and 5% herbal and non-herbal *Kunapajala* along with 50% N as FYM (T_6-T_{13}). Foliar application of 5% non-herbal *Kunapajala* (T_{13}) recorded the highest growth and yield attributes such as plant height (124.4 cm), number of branches (3.73), leaf area index (1.42), dry matter production (3845.51 kg ha^{-1}), number of fruits per plant (25.5), length, girth of fruits (15.24 cm, 7.22 cm), average fruit weight (22.30 g) and yield (20.78 t ha^{-1}) of okra *Kunapajala* indirectly enhance the crop growth by soil fertility build up. The soil analysis revealed that application of non- herbal *Kunapajala* improved the soil health in terms of soil chemical and biological properties. The highest NPK contents were observed in T_{13}. Treatment T_{13} recorded the highest mean values for all macronutrients, micronutrients and enzymatic activity and soil microbial count. The foliar application of 2% or 5% non- herbal *Kunapajala* can reduce the dose of FYM to half without sacrificing the yield. Present study confirmed that *Kunapajala* is a promising, eco-friendly, innovative and low-cost plant stimulant for sustainable crop production and safe agroecosystem.

Keywords Liquid organic manures, Herbal and non- herbal *Kunapajala*, Yield and yield attributes of okra, Soil health.

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INTRODUCTION

India has made spectacular breakthrough in production and consumption of fertilizers during the last five decades. The cost of fertilizers has been enormously increasing to an extent that they are out of reach to the small and marginal farmers. It has become improbable to apply such costly inputs for a crop of marginal returns. Also, continuous consumption of chemical fertilizers has hardened the soil, reduced fertility, polluted air and water, thus bringing threat to soil, plant and ultimately human health. In order to pertain the ecological diversity for future generations and to maintain a balance, the human race should be more responsible to take up eco-friendly measures of agriculture. This increasing responsibility demands our nation to prefer, promote and preserve organic farming. Thus, organic farming will pave the way for sustainable production. In India, organic farming was a well developed and systematized agricultural practice during the past and this "ancient wisdom" obtained through Indian knowledge systems such as *Vedas* indicated the use of liquid organic manures in agriculture for improving soil and plant health and protective measure against plant diseases. *Vrikshayurvedha* by Surapala, an ancient literature, specify the use of *Kunapajala* and Panchagavya to enhance the biological efficiency of the crop plants.

Meaning of Sanskrit word *Kunapa* is "smelling like a dead body, stinking" and *Jala*- "water" (Sarkar *et al*. 2013). As the name indicates, non-herbal *Kunapajala* prepared by fermentation of animal or fish remains. The complex molecules like proteins, fats, carbohydrates get broken down into simpler molecules during fermentation, thus becoming readily available to plants (Deshmukh *et al*. 2012). Herbal *Kunapajala* is a modified form, prepared from plant leaves which is commonly available and widely used by the farmers in organic farming. *Kunapajala* can be applied to any crop at any growth stage. The threat of passing on dormant pathogens to fields with plant-based compost is averted by the way of *Kunapajala* due to the fact that, the ingredients are cooked and fermented. The ingredients such as honey, milk, cow dung, cow's urine and plant leaves enhance the quality of *Kunapajala* (Nene 2012). Honey contains proline, which induces systemic resistance in plants. It is antimicrobial and antibacterial. It contains increased quantities of plant growth promoting substances like cytokinin and auxin. Likewise, milk is an amino acid rich compound which induces general disease resistance in plants (Nene 2012). Neem is rich in anti-microbial compounds and it modifies the biological process of harmful insects in a detrimental way. It imposes antifeedant effect, larval repellent, oviposition deterrent, growth and metamorphosis inhibiting effects, effect on fecundity and egg sterility (Nene 2012). The medicinal herb *Clerodendron infortunatum* Linn have anti-microbial and anti-inflammatory activities (Mohandas and Narayanan 2017). Thus, it provides disease resistance in plants.

Usage of *Kunapajala* conserves natural count and enhanced the microbial population in the soil. *Kunapajala* also avoids the nitrogen loss through volatilization, since, during decomposition, it liberates organic acid, which mixes to form ammonium salts. The efficiency of *Kunapajala* in providing a synchronous supply of essential nutrients inclusive of micronutrients during the critical growth stages of vegetables has been well established (Deshmukh *et al*. 2012, Sarkar *et al*. 2013). In the past few decades, fish amino acid, a 1:1 mixture of fish and jaggery have been recognized by its plant growth promoting activities and its beneficial effects in soil health. In this paper, we present the results of an experiment conducted to evaluate the efficacy of soil and foliar application of herbal and non- herbal *Kunapajala* along with Panchagavya and Fish amino acid using okra (*Abelmoschus esculentus* (L.) Moench) as an experimental plant.

MATERIALS AND METHODS

Preparation of liquid organic manure- *Kunapajala*, Panchagavya, Fish amino acid *Kunapajala*

In *Vrikshayurvedha*, various preparation methods for *Kunapajala* have explained. According to the ingredients available, a minor modification in the preparation of *Kunapajala* was done by Nene (2012) and popularized among farmers.

For the preparation of non- herbal *Kunapajala*, boil 2 kg fish (*Sardinella longiceps*), 1 kg bone meal, 1 kg rice husk, 1 kg coconut oil cake and 500 g sprouted black gram in 10 lit of water till it become viscous and semi solid and transferred to a plastic barrel. 10 kg cow dung, 10 L cow's urine were added along with 250 g honey, 250 g ghee, 2 kg jaggery, 1L milk and 75 L water. The barrel was tightly closed with lid and kept in warm place for 15 days with clockwise and anticlockwise stirring at regular intervals. The content of the pot was filtered and the resultant filtrate was non- herbal *Kunapajala*. The prepared non- herbal *Kunapajala* recorded 1.28 % total nitrogen, 0.11% total phosphorus, 0.44% total potassium, 340 mg L^{-1} total calcium, 324 mg L^{-1} total magnesium and 1.80% total sulfur.

The herbal *Kunapajala* was prepared from the leaves of (non-milky and non-grazing) *Adathoda vasica*, *Vitex negundo*, *Azadirachta indica*, *Ocimum tenuiflorum*, *Chlerodendron infortunatum*, *Eupatorium odoratum*, *Cassia fistula*, *Glyricidia maculata*, *Mimusops elengi* and *Pongamia pinnata*. 2 kg of each plant leaves were cut into small pieces and mix with 10 kg cow dung, 2 kg sprouted black gram, 2 kg jaggery and 15 L cow's urine in 80 L water. The content was mixed well with a bamboo pole twice a day, three minutes each, in both directions, for 15 days. After 15 days, the content was filtered to get herbal *Kunapajala* with total nitrogen, 1.09%, total phosphorus 0.10%, total potassium 0.33%, total Ca 340 mg L^{-1}, total Mg 240 mg L^{-1} and total S 1.40%.

Panchagavya

Panchagavya was prepared in a plastic drum of capacity 100 L. Cow dung (7 kg) and cow ghee (1kg) were mixed in a clean plastic drum thoroughly both in morning and evening hours and kept aside for 3 days. After 3 days cow urine (10 L) and water (10 L) were added. The mixture was kept for 15 days with regular mixing both in morning and evening hours. After 15 days, cow milk (3 L), cow curd (2 L), tender coconut water (3 L), jaggery (3 kg) and well ripened poovan banana (12 Numbers) were added. The contents were stirred twice a day both in morning and evening. Panchagavya was ready in 30^{th} day after proper sieving through a fine cloth (KAU 2017). The estimated nutrient content of prepared Panchagavya- 2.30% total nitrogen, 0.43% total phosphorus, 0.14 % total potassium, 215 mg L^{-1} Ca, 76.8 mg L^{-1} Mg, and 0.21% S.

Fish amino acid

Fish was cut into small pieces and the fish pieces were added to sliced jaggery in the ratio 1:1 in a plastic bucket layer by layer and stored in a cool place under anaerobic condition. It was kept away from direct sun light for 30 days. The end product was filtered and diluted for application (Sundararaman 2009). The fish amino acid with 3.90 % N, 0.31% P, 0.24% K, 330 mg L^{-1} Ca, 90 mg L^{-1} M and 0.49% S was prepared and used for the study.

Field study

A pot culture experiment was conducted from November 2018 to February 2019, at the College of Agriculture, Trivandrum to study the yield response of okra (var Varsha Uphar) to organic liquid manures. Geographically the area is situated at $8^{0}50'$ North latitude and $76^{0}90'$ East longitude and at an altitude of 29 m above MSL. The soil of the experimental site was sandy clay loam belonging to family Loamy Kaolinitic Isohyperthermic Typic Kandiustult. The sandy clay loam soil exhibited moderately acidic pH (5.25) and EC 0.179 dSm^{-1}. Soil had medium organic carbon % (1.35%), low N content (169.5 kg ha^{-1}), high P (63.74 kg ha^{-1}) and medium K content (125.50 kg ha^{-1}). Regarding secondary nutrients Ca (327.50 mg kg^{-1}) and S (8.71 mg kg^{-1}) were in the sufficient range, while Mg was deficient (71.38 mg kg^{-1}). Soil contained sufficient quantities of micro nutrient such as Fe (18.87 mg kg^{-1}), Mn (18.88 mg kg^{-1}), Zn (5.44 mg kg^{-1}) and Cu (2.04 mg kg^{-1}), but B was deficient (0.051 mg kg^{-1}). The dehydrogenase enzyme activity and microbial load were very low.

The design used was Randomized Block Design with 13 treatments and three replications. The treatments comprised of KAU Package of Practices (T_1), Organic Adhoc POP (T_2), Organic Adhoc POP + 3% Panchagavya (T_3), Organic Adhoc POP + 5% Fish Amino Acids (T_4), 50% N as FYM + Water (T_5), 50% N as FYM + 2% Herbal *Kunapajala* soil application (T_6), 50% N as FYM + 5 % Herbal *Kunapajala* soil application (T_7), 50% N as FYM + 2 % Non- Herbal *Kunapajala* soil application (T_8), 50% N as FYM + 5% Non-Herbal *Kunapajala* soil application (T_9), 50% N as FYM + 2% Herbal *Kunapajala* foliar application (T_{10}), 50% N as FYM + 5% Herbal Kunapajala foliar application (T_{11}), 50% N as FYM + 2% Non-Herbal *Kunapajala* foliar application (T_{12}), 50%

N as FYM + 5% Non- Herbal *Kunapajala* foliar application (T_{13}). Vermicompost at 1 t ha^{-1} was applied for the treatments T_2, T_3 and T_4 at 10 days interval. Herbal and non- herbal *Kunapajala* was applied as per the treatments at 10 days interval (KAU POP- FYM 20 t ha^{-1}, NPK 110:35:70 kg ha^{-1}).

Biometric observations

The biometric observations were recorded from the representative plants in each plot. Height of plants was measured from base of the plant to the terminal leaf bud at first and final harvest and then expressed in centimeters. Number of branches per plant was recorded at first harvest. The dry matter production was calculated from fresh and dry weight of plant samples. Leaf area index was estimated by measuring leaf area at 50 % flowering stage. Number of fruits per plant, average fruit weight, length and girth of fruits were recorded.

Soil analysis

Chemical parameters such as pH, EC, organic carbon, Available N, P, K, Ca, Mg, S, Na, Fe, Mn, B, Cu and Zn were determined as per the standard analytical procedures.

Statistical analysis

The data on the field experiment was analyzed statistically by applying the techniques of ANOVA. The F values for treatments were compared with the table values. Critical differences at the 5% significance level were calculated for the treatments were found significant. Data analytical package Web Agri Stat Package (WASP) ver. 2.0 was used for data analysis.

RESULTS AND DISCUSSION

Biometric observations

The results of biometric observation of okra plants in herbal and non-herbal *Kunapajala*, Panchagavya and FAA along with control and recommended dose of inorganic fertilizers and organic manures (vermicompost) are presented in Table 1. In control condition, average plant height was found to be 87.07 cm at final harvest, whereas significant increase in height of okra plant was noticed in plots treated with *Kunapajala*. The foliar application of 5% non- herbal *Kunapajala* along with 50% N as FYM resulted into height of 74.93 cm and 124.43 cm at first and final harvest stages. The total number of branches also exhibited significant enhancement when provided with herbal and non- herbal *Kunapajala* at 10 days interval. Highly significant increase in number of branches per plant (3.73) was recorded in plants having foliar application of 5% non-herbal *Kunapajala*.

Table 1. Plant height, number of branches, leaf area index and dry matter production as influenced by different treatments on bhindi.

Treatments	Plant height First harvest (cm)	Plant height Final harvest (cm)	Number of branches per plant	Leaf area index	Dry matter production (kg ha^{-1})
T_1	56.65	104.60	2.60	0.99	3066.44
T_2	56.79	104.67	2.80	0.39	2971.48
T_3	62.10	111.20	1.87	0.56	3092.09
T_4	59.20	106.43	2.43	0.59	2875.34
T_5	45.27	87.07	1.70	0.33	2525.21
T_6	52.03	97.17	2.80	0.54	2733.19
T_7	61.08	109.30	2.40	0.78	2771.02
T_8	66.40	114.83	2.47	0.87	3240.86
T_9	56.47	100.73	2.50	0.81	3326.97
T_{10}	65.87	113.73	2.60	0.84	3563.04
T_{11}	69.64	121.40	2.77	0.80	3565.31
T_{12}	72.40	123.60	3.17	1.03	3682.24
T_{13}	74.93	124.43	3.73	1.42	3845.51
SE	3.170	4.766	0.119	0.099	10.253
CD (0.05)	9.255	13.993	0.345	0.290	30.091

Total dry matter production in control conditions was found to be 2525.21 kg ha^{-1}, but the value was significantly high in the treatment receiving foliar application of 5% non- herbal *Kunapajala* along with 50% N as FYM (3845.51 kg ha^{-1}). Leaf area index at first harvest was significantly influenced by the treatments and the best index (1.42) was reported with foliar application of 5% non- herbal *Kunapajala* along with 50% N as FYM.

Yield characters

Impact of soil and foliar application of herbal and non-herbal *Kunapajala* on yield attributes in fruits of okra is depicted in Table 2. The fruit characters like number of fruits per plant, average fruit weight, length

Plate 1. Effect of treatments on fruit length of bhindi.

and girth of fruits were significantly influenced by the treatments. Results of the statistical analysis of the data on number of fruits revealed that the treatment with 5% non- herbal *Kunapajala* as foliar application had recorded the highest (25.50) number of fruits per plant and was found to be on par with T_{12} (2% non -herbal *Kunapajala* as foliar application-24.80). Average fruit weight in control plots was 10.20 g, but the treatment T_{13} registered the highest fruit weight (22.30 g) which was statistically superior to all other treatments. Results of length (Plate 1) and girth of fruits indicated that, the significantly highest fruit length and girth was recorded in treatment T_{13} (15.24 cm and 7.22 cm respectively).

Foliar administration of 5% non-herbal *Kunapajala* resulted in higher yield (20.78 t ha^{-1}) and was statistically on par with the treatment 50% N as FYM + 2% non- herbal *Kunapajala* -20.06 t ha^{-1} (Plate 2).

Table 2. Effect of treatments on fruit characters of bhindi.

Treatments	Number of fruits	Length of fruits (cm)	Girth of fruit (cm)	Average fruit weight (g)
T_1	16.70	15.07	6.55	18.10
T_2	13.70	13.98	6.48	14.50
T_3	17.50	14.57	6.60	15.90
T_4	17.30	13.55	6.42	16.80
T_5	14.20	11.48	5.38	10.20
T_6	18.60	13.42	6.43	18.10
T_7	18.90	14.41	6.58	19.20
T_8	18.70	14.56	6.54	19.20
T_9	19.10	14.92	6.71	19.60
T_{10}	19.30	15.01	6.74	19.50
T_{11}	19.60	14.81	6.72	20.80
T_{12}	24.80	14.30	6.77	20.70
T_{13}	25.50	15.24	7.22	22.30
SE	0.269	0.395	0.110	0.357
CD (0.05)	0.782	1.151	0.328	1.044

The effect of soil and foliar application of herbal and non-herbal *Kunapajala* on soil health and plant growth were analyzed by using okra as test crop. The overall results suggested that the foliar application of 5% non- herbal *Kunapajala* along with 50% N as FYM registered significantly higher values for biometric characters, yield attributes of okra and enhances soil health.

The plant growth parameters such as plant height, number of branches, and leaf are index exhibited the

Plate 2. Effect of treatments on yield of bhindi.

highest values for the treatment T_{13}. The better growth resulted by the foliar application of non- herbal *Kunapajala* may be due to the rapid availability of essential nutrients to the plants. The plant can absorb nutrients about 20 times faster through the leaves than if they are applied through the soil (Agro Chadza 2011). These observations are in confirmity with the report of Deshmukh *et al*. (2012), Ali *et al*. (2012), Sarkar *et al*. (2013) and Ankad *et al*. (2017). This may be ascribed to the higher relative proportion of nutrients in the readily available form. Deshmukh *et al*. (2012) observed the maximum number of leaves, leaf area index and total biomass in tomato plants by the application of *Kunapajala* for five times at an interval of 10 days as compared to conventional and organic farming. Nene (2018) highlighted the fact that the complex molecules in ingredients of *Kunapajala* become readily available to the plants through boiling and subsequent fermentation process. *Kunapajala* possesses the plant growth regulatory activity, which increases the foliage, enhance profuse flowering, fruiting, and overall growth in plants (Rajasekharan and Nair 2017). Higher level of nitrogen availability through foliage favored with highest plant growth attributes. The increased nitrogen supply enhanced the protein content and also allowed the plant leaves to grow larger and increased the photosynthesis (Bassi *et al*. 2018). The mineralization of organic nitrogen to ammoniacal and nitrate nitrogen through bacterial action and its long-term availability expedited the vegetative growth of plants (Wang *et al*. 2022). The hasty availability of nitrogen accelerated the protein synthesis and ultimately resulted in more dry matter production (Jia *et al*. 2022). According to Geng *et al*. (2019), the dry weight of plants increased after the organic manure addition due to the production of humus substances and which improved the physical, chemical properties of the soil and enhanced the growth of plants.

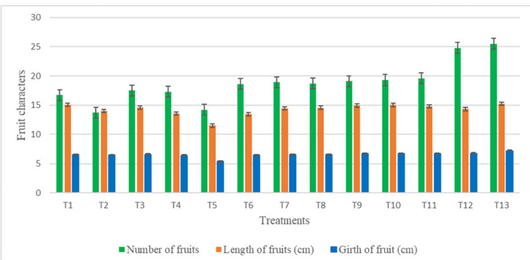

Fig. 1. Effect of treatments on fruit characters of bhindi.

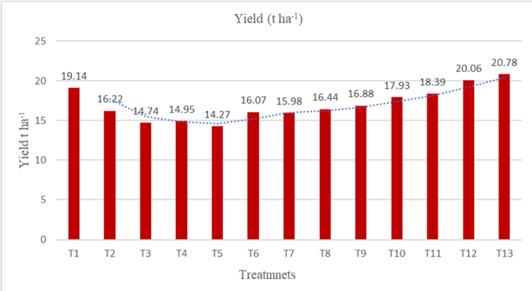

Fig. 2. Effect of treatments on yield (t ha^{-1}) of bhindi.

Regarding the yield characters (Fig. 1-2) foliar application of 5% non- herbal *Kunapajala* recorded the highest mean value for number of fruits, length and girth of fruits, average fruit weight and yield. The addition of liquid manures through foliage provides growth promoters and nutrients. These hormones present in these liquid manures might have improved the physiological activities and leading to better fruit production in bhindi. the marketable yield per plant was correlated with the plant height, number of branches and fruit characters (Prabhu *et al*. 2008). Ramesh and Vasanthi (2008) recorded a greater number of branches, higher yield and fruits with lesser seeds in brinjal fruits by the application of *Kunapajala* when compared with plants grown with synthetic fertilizers. The fermentation of liquid manure breaks down the complex forms into simpler forms, making it rapidly available to plants than the traditionally applied organic matter (Prabha *et al*. 2008). The nutrients are readily available to the plants from the liquid organic manure. This might be the reason for better yield attributes of bhindi. Similar results were obtained also by the application of Panchagavya and fish amino acid (Krishnan 2014, Parvathy 2017 and Dhanalakshmi 2017).

The application of liquid manures enhanced the soil biological activity and foliar application provided nutrients readily to the plants. *Kunapajala* is a rich source of beneficial micro organims and these might be the reason for better yield and yield attributes of bhindi. The beneficial micro-organisms presented in the *Kunapajala* may produce growth hormones like IAA and GA and resulted in improvement in plant

Table 3. Effect of treatments on physico-chemical properties of soil (post-harvest analysis).

Treatments	pH	EC (dS m^{-1})	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	Calcium (mg ha^{-1})	Magnesium (mg kg^{-1})	Sulfur (mg kg^{-1})
T_1	6.08	1.13	255.1	83.8	201.6	280.0	102.0	13.0
T_2	6.29	1.25	225.8	93.1	156.8	263.3	96.0	16.0
T_3	5.97	1.33	238.3	90.0	149.3	250.0	90.0	17.3
T_4	6.28	1.24	238.3	94.8	130.7	280.0	108.0	13.3
T_5	5.99	0.98	225.8	73.7	100.8	220.0	88.0	12.2
T_6	5.97	1.25	238.3	84.6	168.0	280.0	84.0	16.7
T_7	5.78	1.18	250.9	94.4	156.8	270.0	106.0	21.3
T_8	5.95	1.23	263.4	96.8	168.0	290.0	110.0	23.0
T_9	5.76	1.40	276.0	98.9	156.8	270.0	106.0	23.5
T_{10}	6.14	1.41	351.2	97.1	175.5	280.0	116.0	22.0
T_{11}	5.87	1.44	288.5	96.1	179.2	310.0	108.0	22.7
T_{12}	6.02	1.41	351.2	100.7	182.9	300.0	114.0	26.5
T_{13}	6.03	1.51	363.8	100.7	209.1	340.0	124.0	28.5
SE	0.053	0.011	9.76	1.05	9.25	5.37	3.81	0.55
CD (0.05)	0.150	0.031	28.48	3.06	27.00	15.67	11.12	1.62

growth. Rhizosphere activity was enhanced by the foliar application of organic liquid manures (Subha *et al*. 2014). Nene (2018) opined that being a liquid *Kunapajala* can quickly reach the rhizosphere. The production, translocation and assimilation of photosynthates from source to sink might have increased by the better nutrient availability and uptake during the vegetative and fruiting phase and resulted in better yield attributes.

Soil analysis

Changes in soil physical, chemical and biological properties as a result of treatment application, as measured at the end of the field experiment, are presented in Tables 3 - 5. The soil pH and electrical conductivity were increased after the experiment and pH value ranged from strongly acidic to slightly acidic and enhancement in electrical conductivity was within the safe limit. Organic carbon content analysis in soil samples revealed that the foliar application of 5% non- herbal *Kunapajala* registered significantly highest value (1.50%) which was found to be on par with, T_{11} (1.44%), T_{10} (1.41%) and T_{12} (1.40%). Lowest value was noticed by treatment received 50% N as FYM + Water. The amount of available nitrogen, phosphorus and potassium were significantly affected by soil and foliar application of herbal and non- herbal *Kunapajala*. Even though the treatment T_{13} recorded the highest mean value for available N, P and K, it shows statistically on par values with other treatments. Secondary nutrients, Ca and S was significantly the highest in soil samples collected from the plots having foliar application of 5% non-herbal *Kunapajala* along with 50% N as FYM. The value of exchangeable Mg in the plots with treatment T_{13} registered a 71.71% increase over the initial content. Considering micronutrients, the percentage increase for available Zn, Fe, Mn and Cu in T_{13} over control (T_5) were 119.91%, 26.67%, 54.64% and 150.73% respectively.

The effect of herbal and non- herbal *Kunapajala* in the biological activity of the soil can be evaluated by examine dehydrogenase enzyme activity and

Table 4. Effect of treatments effect of treatments on micronutrients.

Treatments	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})	B (mg kg^{-1})
T_1	11.90	34.40	6.54	2.60	0.15
T_2	13.67	32.32	7.37	2.11	0.21
T_3	12.73	27.06	7.60	1.41	0.20
T_4	12.70	26.21	7.14	1.61	0.22
T_5	10.87	22.71	4.72	1.36	0.06
T_6	11.43	24.46	6.37	1.43	0.25
T_7	11.70	26.58	6.79	1.46	0.27
T_8	11.70	28.39	7.23	1.57	0.34
T_9	12.47	30.08	7.30	1.79	0.37
T_{10}	12.40	31.00	7.41	2.17	0.42
T_{11}	12.97	31.09	7.83	2.17	0.45
T_{12}	12.83	31.57	8.17	2.43	0.50
T_{13}	13.77	35.12	10.38	3.41	0.52
SE	0.256	0.085	0.439	0.175	0.009
CD (0.05)	0.771	2.489	1.288	0.515	0.022

Table 5. Influence of treatments on biological and biochemical properties of post-harvest soil.

Treatments	Bacteria (log cfu g soil^{-1})	Fungi (log cfu g soil^{-1})	Actinomycetes (log cfu g soil^{-1})	Dehydrogenase (µg of TPF g^{-1} soil 24 h^{-1})
T_1	8.95	4.43	5.17	42.61
T_2	8.98	4.24	5.19	39.22
T_3	8.93	4.36	5.20	44.91
T_4	8.93	4.29	5.22	45.43
T_5	8.43	4.07	4.94	37.49
T_6	8.81	4.17	5.17	44.27
T_7	8.85	4.25	5.19	46.13
T_8	8.92	4.35	5.23	48.05
T_9	8.98	4.37	5.31	48.62
T_{10}	8.97	4.38	5.36	50.54
T_{11}	8.98	4.43	5.43	51.25
T_{12}	9.03	4.46	5.49	56.24
T_{13}	9.04	4.52	5.53	62.00
SE	0.035	0.015	0.007	3.549
CD (0.05)	0.102	0.043	0.027	10.36

counting the microbial population in the soil. Data furnished in the Table 5 revealed that a pronounced increase of enzyme activity occurred after the experiment and the treatment T_{13} had the highest mean value of 62.00 µg of TPF g $^{-1}$ soil 24 h^{-1} and was on par with T_{12} (56.24 µg of TPF g $^{-1}$ soil 24 h^{-1}). Statistically superior values for fungal (4.46 log cfu g^{-1} soil) and actinomycetes (5.53 log cfu g^{-1} soil) was registered by the treatment T_{13}. Regarding bacterial count, the highest bacterial population was noticed in T_{13} (9.04 log cfu g^{-1} soil) which was on par with T_{12}, T_{11}, T_{10} and T_9.

The results revealed that pH of the soil varied significantly with the treatments. pH increased after the experiment and values ranged from strongly acidic to slightly acidic. This might be due to the application of organic manures to the soil. The highest pH value was recorded by the treatment received Organic Adhoc POP. Application of lime also decreased the soil acidity and activity of Fe and Al. The active degradation of organic matter increased the bases and suppressed the activity of H^+ ions and Fe and Al oxides. An increase in EC was the indication of increased content of total soluble salts. Addition of organic manure with beneficial microorganisms facilitated the mineralization of nutrients and faster release of bases. The increase in the availability of nitrogen may be due to the presence of microbes and enzymes in the non- herbal *Kunapajala* which might have enhanced the mineralization of organic matter resulting in the release of more available nitrogen. The *Kunapajala* is rich in N- fixers (Nene 2018) which might have responsible for increased N availability. According to Kara *et al*. (2007) application of organic manure facilitated the biological and enzymatic activities and resulted in mineralization of nitrogen into available forms viz., NH_4^+ N and NO_3^- N. The presence of Phosphorus Solubilizing Bacteria and its improved activity resulted in the rapid release of phosphate ions from the soil (Ninan *et al*. 2013 and Nene 2018). The highest uptake of nutrients through foliage may have enhanced the rhizosphere activities and its exudates resulted in faster decomposition of organic matter in the soil. Sushma *et al*. (2007) reported that the significant increase in available P content might be due to the complexation of cations like Cu, Mg and Al by organic colloids and which reduced the fixation of P. The organic acids produced from the decomposition of added organic matter accelerated the release of non- exchangeable K to the water-soluble forms (Sadri *et al*. 2016). The availability of secondary and micronutrients enhanced due to its less susceptibility to absorption, fixation or precipitation reaction in soil. The addition of organic matter facilitated the microbial action, pH of the soil and also the formation of stable complexes with the organic colloids (Boyd and Mortland 2017). The availability of native nutrients to the crops through the addition of organic manure.

The dehydrogenase enzyme activity of soil was found affected by different treatments. Dehydrogenase activity serves as an indicator of the microbiological redox systems. Parvathy (2017) reported that increased microbial activity increased the content of enzyme activities. The enzyme activity depends on numerous external factors such as climate, amendments, soil properties and crop cultivation. The treatment comprising of 5% non- herbal *Kunapajala* as foliar application along with 50% N as FYM recorded the highest enzyme activity and was on par with T_{12}. The highest microbial count in soil was due to the addition of microbial rich organic manures. The foliar application of non- herbal *Kunapajala* recorded the highest microbial load. This is in accordance with the findings of Subha *et al*. (2014) who reported that the foliar application of Panchagavya improved the rhizosphere microbial activity. The increased microbial activity might be due to the increased availability of nutrients through foliage and this stimulated proliferous root system and enhanced the production of root exudates and thereby the rhizosphere activity. This leads to better absorption of water and nutrients from lower layers resulting in higher uptake and yield (Larsen *et al*. 2015). Gaind and Nain (2010) studied the synergism among soil organic material and microorganisms and reported that organic matter addition stimulated the biological activity of soil. Lower availability of organic matter and unfavourable conditions due to various kinds of losses of applied nutrients in the soil also may be responsible for the lowest microbial count in soil applied treatments. The increased microbial activity on addition of microbial rich organic liquid manures could improve the nutrient availability of crops (Gore and Sreenivasa 2011). The increased microbial load might be responsible for the enhanced dehydrogenase enzyme activity, as this assay is an estimate of viable microbial activity. Nutrition through foliage facilitated better nutrient absorption than soil application and rapid translocation of nutrients from source to sink and high nutrient content might be responsible for the superiority of the treatment T_{13} than other treatments with respect to nutrient availability, growth and yield of bhindi.

Application of 50% N as FYM + 5% non-herbal *Kunapajala* as foliar application (T_{13}) was the best treatment in the field experiment which resulted in the highest growth, yield and yield attributes of bhindi and yield was on par with the treatment T_{12} (50% N as FYM+ 2% non-herbal *Kunapajala* as foliar application). From the study, it was clear that FYM as nutrient source can be reduced to half, if 2% or 5% non-herbal *Kunapajala* as foliar spray (at 10 days interval) was applied along with 50% N as FYM. *Kunapajala* is a good source of nutrients and therefore the deleterious chemical fertilizers can be substituted with it. Thus, *Kunapajala* is a promising and eco-friendly plant stimulant for sustainable crop production and safe agro ecosystem.

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