Fermented biofertilizer from banana fruit waste: It's role in the Integrated Nutrient Management System for Abelmoschus esculentus (Ladies Finger) vegetative growth

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Research Article

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Abstract

Agronomic practices using organic manure to restore soil fertility and increase crop yield are the need of the hour. Recycling organic wastes into biofertilizers is a nutrient recovery strategy in waste management. Banana waste (peels and pulp) was converted into biofertilizer using cow's urine and cow dung. The inclusion of organic biofertilizer along with chemical fertilizer forms the Integrated Nutrient Management (INM) concept, which aids in the increment of crop yield and the quality of soil properties. Taking the aforementioned information into consideration, a pot research was carried out to evaluate the impact of the nutrient management system on the growth of *Abelmoschus esculentus* (Ladies finger), a vegetable of economic importance and the NPK status of the soil. Four treatments were included in the experimental design: Group 1- water control; Group 2 - Recommended dose of Chemical Fertilizer (RDCF) - NPK (120–60–80 kg ha^{-1}); Group 3 – 1:100 diluted Fermented Biofertilizer made from Banana Fruit Waste (FB-BW); and Group 4–50% (RDCF + FB-BW) integrated nutrient management (INM). Among the different treatments, the ladies finger plant height, leaf area, stem girth and lateral root growth have increased and well developed when FB-BW and chemical fertilizer are combined. Along with soil macronutrients, *Abelmoschus esculentus* leaf photosynthetic pigment levels and protein content improved in Group 4. Thus, the combined application of chemical fertilizer and fermented banana fruit waste could enhance the soil quality and productivity of *Abelmoschus esculentus* (ladies finger).

Introduction

Abelmoschus esculentus (okra / ladies's finger / bhindi) (*Malvaceae*) is a commonly grown vegetable cooked worldwide in nearly every kitchen due to its exquisite delicacy and high nutritional content. Okra pods are rich in carbohydrates, proteins, fibre, nutrients and vitamins [1]. According to Markose and Peter [2], a fresh pod has 18% moisture content and includes calcium (90 mg), potassium (103 mg), magnesium (43 mg), phosphorus (56 mg), and vitamin C (18 mg) per 100 g. *Abelmoschus esculentus* is produced at a lower rate (30%) in the summer than it is in the winter (70%) [3]. When heavy manuring was used, okra's nutrient status and yield could be improved [4]. As imbalanced application of chemical fertilizers has caused the soil barren it is the right time to include the application of organic manure as sustainable agricultural practice.

Injudicious application of chemical fertilizers to meet the growing demand for food has yielded unstable production with poor nutritional quality. This has urged the need for integrated nutrient management (INM) to provide balanced nutrition for adequate and sustainable crop yield. This practice of INM maintains the soil health, increases the yield and also prevents pest infection. Organic agriculture is applying science to bring back the indigenous agricultural knowledge to promote / introduce innovation which will benefit all the life forms and the ecosystem and lead to quality life. Recovery, recycling and reuse of organic waste in to a value added product is an essential strategy to be adopted in management of solid waste without loss of nutrients. The potential of microorganisms in conversion of organic waste by fermentation / composting is utilised in organic manure preparation like Farmyard manure, vermicompost etc., India led the world in banana production with 34.9 million metric tons in 2023, with Tamil Nadu as the top-producing state [5]. Banana is one of the delicious easy digestable fruits farmed in more than 130 countries. According to Qamar and Shaikh [6], bananas are a great source of carbohydrates, amino acids, vitamin C, vitamin B6, dietary fiber, pectin, and essential elements like calcium, magnesium, phosphorus, potassium, and salt. They also contain very little fat. There is an enormous amount of banana waste due to the rapidly perishable nature of banana fruits, improper transportation, and inadequate storage facilities. Unattended banana wastes when dumped / thrown out, draw in scavenger animals, emit an offensive odor, or endanger human health. Making biofertilizer from banana waste is one of the less expensive, more environmentally friendly and long-lasting method and a cleaner and sustainable strategy to reutilise organic matter and nutrients.

Amudham is one of the indigenous biofertilizer prepared used fruit wastes, cow dung and cow's urine [7]. Cow's urine and dung has important minerals N, P, K and other micronutrients and they both aid in providing the temperature sufficient for the decomposition especially cow's urine plays the role of a catalyst [8]. Banana waste contains carbohydrates, minerals and vitamins which are broken by microbes present in cow dung to form a valuable liquid biofertilizer. The liquid biofertilizers are preferred over solid organic manure as it could be easily applied and absorbed by the roots, evenly spread in the soil preventing accumulation, and also used as foliar spray. According to Muniappan et al. [9], fermented banana waste liquid fertilizer is abundant in macro and micronutrients as well as beneficial bacteria. As such, it is the most suitable option to be used with chemical fertilizer in the long-term sustainable management of okra. The purpose of this study was to evaluate the effects of liquid fertilizer made from banana waste combined with chemical fertilizer on the morphological and biochemical components of *Abelmoschus esculentus* (okra).

Materials and Methods

Preparation of Fermented Biofertilizer from Banana wastes (FB-BW)

Biofertilizer was prepared by mixing 1 kg of cow dung and 1 lit of cow's urine in a plastic container and left in the shade for 24 hours. The mouth of the container was covered with a muslin cloth to keep flies out. Then 1 kg of well-ripened, mashed banana fruit wastes along with the skin was added and allowed to ferment for 5 days [7]. After that, it was filtered and 1:100 diluted FB-BW was used as biofertilizer.

Experimental design

The pot study was carried out at Ethiraj College for Women, Chennai, Tamil Nadu. The seeds of *Abelmoschus esculentus* were procured form Tamil Agricultural University's Extension Unit in Anna Nagar, Chennai. The experimental treatments groups were: Group 1- water control; Group 2 - Recommended dose of Chemical Fertilizer (RDCF) -NPK (120–60–80 kg ha^{-1}); Group 3 – 1:100 diluted fermented biofertilizer made from banana fruit waste (FB-BW); and Group 4–50% (RDCF + FB-BW) integrated nutrient management (INM). Recommended dose of chemical fertilizer was added as basal dose to Group 2 and Group 4. 2 seeds were sown in an earthen clay pot and ten replications were maintained for each treatment. After germination, the pots received water based on the requirement. Diluted FB-BW was added once in 10 days.

Vegetative growth traits and Biochemical analysis

After 30 days, measurements and analyses were conducted on all treated *Abelmoschus esculentus* plants with respect to leaf area, plant height, stem girth, number of branches, number of leaves, and root architecture. The levels of photosynthetic pigment [10] and protein content [11] in okra leaves were determined. Soil pH and NPK level were analysed [12].

Statistical Analysis:

Statistical analysis was done using SPSS 12.0 and results were reported as mean ± standard error of mean (n = 6). Significance of differences between groups was assessed by one-way analysis of variance (ANOVA) followed by Tukey's multiple comparison test and probability value of $P < 0.05$ was considered as statistically significant.

Results

The pH of the soil under various treatments was given in Table 1. The pH of the soil in Group 3 was lower when compared to other groups. An increase in soil organic carbon was observed on application of 50% (RDCF + FB-BW) over 100% chemical fertilizer, 100% FB-BW and water control. The N, P, and K content were found to be increased in INM by 50% (RDCF + FB-BW) (Table 1). The vegetative growth traits like plant height, number of leaves, leaf area (Fig. 3), number of branches, root length, number of lateral roots, stem girth (Fig. 2), and root architecture (Fig. 1) were found to be significantly improved in *Abelmoschus* esculentus treated with INM (50%) (RDCF + FB-BW) after 30 days (Tables 2 and 3). The height of *Abelmoschus esculentus* plants was found to be significantly higher (41.64 ± 2.20 cm) when compared to chemical fertilizer (31.55 ± 1.59 cm), FB-BW (25.6 ± 0.14 cm), and water (19.5 ± 0.99 cm) treatments (Table 2).

Table 1

Changes in soil parameters after the application of chemical fertilizer, FB-BW and 50% (RDCF + FB-BW)

Parameters	**Group 1- Water control**	**Group 2 – Recommended Dose of Chemical Fertilizer (RDCF) NPK (120-60-80 kg ha-1)**	**Group 3 – 1:100 diluted Fermented Biofertilizer from Banana fruit Waste (FB-BW)**	**Group 4 - Integrated Nutrient Management (INM) – 50% (RDCF + FB-BW)**
pH	8.20	8.30	8.11	8.27
Electrical conductivity mS/cm	0.157	0.205	0.177	0.225
Organic Carbon %	1.21	1.45	1.38	1.33
Nitrate Nitrogen (ppm)	182	292	239	307
Phosphorous (ppm)	31.44	58.06	75.24	107.36
Potassium (ppm)	102	152	137	219

Table 2

Effect of 50% (RDCF + FB-BW) on morphological traits of *Abelmoschus esculentus* (Ladies Finger) after 30 days

Group / Treatment	**Plant Height (cm)**	**Root Length (cm)**	**No. of lateral roots**
Group 1- Water control	19.5 ± 0.99	8.5 ± 0.9	4 ± 0.42
Group 2 - Recommended Dose of Chemical Fertilizer (RDCF) NPK (120-60-80 kg ha-1)	31.55 ± 1.51 ***	14.27 ± 2.17*	20.33 ± 2.14 ***
Group 3 – 1:100 diluted Fermented Biofertilizer from Banana fruit Waste (FB-BW)	25.6 ± 0.14 **	12.9 ± 0.36 NS	12.2 ± 1.32 ***
Group 4 - Integrated Nutrient Management (INM) – 50% (RDCF + FB-BW)	41.64 ± 2.20***	20.8 ± 1.01***	25.14 ± 2.68***
Values are expressed as mean ± S.E.M (n = 6). ANOVA followed by Tukey’s multiple comparison tests was used to analyse the data. Statistically significant variations are expressed as *p < 0.05, **p < 0.01, *** p < 0.001, NS - non-significant. Group 1 vs Group 2 / Group 3 / Group 4			

Table 3
Influence of chemical fertilizer, FB-BW and 50% (RDCF + FB-BW) on vegetative traits of *Abelmoschus esculentus* (Ladies Finger)

Group / Treatment	No. of Branches	Stem girth (cm)	No. of leaves	Leaf Area (cm^2)
Group 1- Water control	2 ± 0.35	0.29.5 ± 0.9	5.07 ± 0.28	15.27 ± 1.2
Group 2 - Recommended Dose of Chemical Fertilizer (RDCF) NPK (120-60-80 kg ha-1)	4.33 ± 0.60 *	1.10 ± 0.10 ***	11 ± 0.58***	43.51 ± 0.31***
Group 3 – 1:100 diluted Fermented Biofertilizer from Banana fruit Waste (FB-BW)	3 ± 0.67 NS	0.61 ± 0.07*	7 ± 0.58 NS	27.07 ± 0.32 ***
Group 4 -Integrated Nutrient Management (INM) – 50% (RDCF + FB-BW)	7.92 ± 0.65***	1.90 ± 0.06***	13.67 ± 0.33***	52.65 ± 0.66***
Values are expressed as mean ± S.E.M (n = 6). ANOVA followed by Tukey's multiple comparison tests was used to analyse the data. Statistically significant variations are expressed as *p < 0.05, **p < 0.01, *** p < 0.001, NS - non-significant. Group 1 vs Group 2 / Group 3 / Group 4				

Less number of leaves were observed in Group 1 (water treatment) (5.67 ± 0.33), whereas significantly more leaves were observed in Group 4 (INM) (13.67 ± 0.35), followed by Group 2 (RDCF) (11.00 ± 0.58) and Group 3 (FB-BW) (7.00 ± 0.62) (Table 3). The leaf area of *Abelmoschus esculentus* plants (Fig. 3) in Group 4 was significantly wider than in other groups. Comparing INM- 50% (RDCF + FB-BW) to other groups, it was observed that the amount of photosynthetic pigments (total chlorophyll and carotenoid-xanthophylls) in okra leaves was considerably higher (0.69 ± 0.03 mg/g leaf and 5.38 ± 0.42 mg/g leaf, respectively) (Table 4). Maximum protein content of *Abelmoschus esculentus* leaves was recorded in INM- 50% (RDCF + FB-BW) (1.37 ± 0.02 mg/gm leaf), followed by Group 2 - RDCF (0.87 ± 0.05 mg/gm leaf), Group 3 - (FB-BW (0.59 ± 0.03 mg/gm leaf), and Group 1 (water treatment) (0.49 ± 0.01 mg/gm leaf) (Table 4).

Table 4
Influence of INM (RDCF + FB-BW) on photosynthetic pigments and protein content of *Abelmoschus esculentus* (Ladies Finger) after 30 days

Group / Treatment	**Total Chlorophyll (mg/gm leaf tissue)**	**Carotenoids & Xanthophyll (mg/gm leaf tissue)**	**Protein (mg/gm leaf tissue)**
Group 1- Water control	0.47 ± 0.02	3.69 ± 0.15	0.49 ± 0.01
Group 2 - Recommended Dose of Chemical Fertilizer (RDCF) NPK (120-60-80 kg ha-1)	0.62 ± 0.01***	5.10 ± 0.35 *	0.87 ± 0.05***
Group 3 – 1:100 diluted Fermented Biofertilizer from Banana fruit Waste (FB-BW)	0.55 ± 0.01*	4.18 ± 0.02 NS	0.59 ± 0.03 NS
Group 4 -Integrated Nutrient Management (INM) – 50% (RDCF + FB-BW)	0.69 ± 0.03***	5.38 ± 0.42**	1.37 ± 0.02 ***
Values are expressed as mean ± S.E.M (n = 6). ANOVA followed by Tukey’s multiple comparison tests was used to analyse the data. Statistically significant variations are expressed as *p < 0.05, **p < 0.01, *** p < 0.001, NS - non-significant. Group 1 vs Group 2 / Group 3 / Group 4			

Discussion

When the soil contains the necessary quantity of macro- and micronutrients, high-quality okra pods can be produced. By mixing chemical fertilizers with organic biofertilizer, the integrated nutrition management (INM) system addresses the latent demand for micronutrients in addition to N, P, and K. This method promotes sustained agricultural production in addition to restoring soil fertility. The current study's results confirmed that the INM-50% (RDCF + FB-BW) treatment enhanced the nutritional status of the soil and, as a result, the vegetative characteristics of *Abelmoschus esculentus* (okra).

Well-ripened banana fruits were combined with cow dung and cow urine to prepare fermented banana waste biofertilizer. The nutrients contained in fruit, cow dung and cow’s urine were thus recovered. According to Muniappan et al. [9], the biofertilizer made from fermented banana waste has a pH of 6.72 ± 0.05. There were nutrients such as N, P, K, Ca, Mg, S, Fe, Zn, Cu, Pb, and Mn, and phosphate solubilizers dominated the bacterial population. In the current study, comparatively little difference was observed in soil pH between the various treatments. The slightly lower pH of the soil in Group 3 was due to the addition of fermented banana waste fertilizer, which was slightly acidic in nature. The microbial population in FB-BW produces organic acids, which chelate and mobilize minerals, especially phosphorus, and make them available to plants.

When FB-BW is combined with N-P-K, Group 4's soil organic carbon content increases. This was due to the interactive effects between chemical fertilizer and organic biofertilizer. In the current study, FB-BW when mixed with 50% chemical fertilizer, has improved the soil's nutrient content. The urease, phosphatase, and dehydrogenase activities of soil microbes, which mobilize nutrients, increase their solubility, and enable their uptake by roots and plants, may also be responsible for the improvement in nutritional status of soil. Following the addition of organic manure with chemical fertilizer, Saha et al. [13] and Chaudhry et al. [14] have noted improvements in soil properties such as moisture retention capacity, organic carbon, particle density, porosity, pH, organic matter, soil microbial biomass, total nitrogen, and available P and K status.

The soil organic carbon gained after integrated nutrient management practices is retained for a longer time, thereby withstanding the temperature-induced organic matter breakdown that happens in tropical countries like India [15]. Therefore, the combination of inorganic fertilizer and FB-BW creates an environment that is conducive to increased soil microbial biomass and enzymatic activity. The root architecture and root aeration are also improved in organic manure/INM practice [16]. Thus, the observed improvement in soil quality parameters will improve the growth of lady finger and also retain nutrients in the soil for a longer time.

The physiological traits of plants, like root length and root morphology, play a vital role in determining their health and yield potential of okra. In the current study, okra plants treated with INM- 50% (RDCF + FB-BW) had a longer primary tap root with more lateral roots and root surface area than the other treatments. The maximum absorption of nutrients and water from the soil and their transfer to the shoot system by the lateral roots will increase photosynthesis and plant growth as observed in INM-50% (RDCF + FB-BW) treatment [17, 18]. The current study's observation of better root architecture can be attributed to the interaction between plant growth-promoting rhizobacteria and FB-BW biofertilizer, which provides nutrients and phytohormones to shape the roots. When organic manure loaded with rhizobacteria that promote plant growth was applied to okra, a similar alteration in root architecture was seen [19].The Group 4 okra plants' larger stem girth was caused by an adequate supply of potassium, which makes the stem of the plant robust and larger and prevents the plant from withering too quickly. Because there was less potassium present in Group 1 (water-control) okra plants' the meristematic growth, leaf area expansion, chlorophyll-promoting activity, and protein synthesis were reduced [20].

The major macronutrient that supports the vegetative growth of plants is nitrogen. The increase in okra plant height in the INM-50% (RDCF + FB-BW) treatment was due to the sufficient amount of nitrogen in the soil that promotes cell division, enlargement of new cells, increases the level of cytokinin, and also aids in the absorption of phosphorus and potassium. As nitrogen moves throughout the plant tissue and gets attracted to the younger tissue, the continuous cell division has led to an increase in plant height and a greater number of leaves [21]. The enlarged stem girth observed in Group 4 okra plants was contributed by a sufficient amount of potassium that makes the plant stem sturdy and bigger, so the plant will not wither easily.

The adequate translocation of iron and magnesium as well as the increased activity of the enzymes involved in chlorophyll biosynthesis may also be contributing factors to the increase in chlorophyll concentration in Group 4 [22, 23]. Mishra et al. [24] found that the chlorophyll content of okra exhibited the favorable effects of chemical fertilizer when mixed with organic manures (neem oil cake, poultry manure, vermicompost, FYM, biofertilizer, and sea weed extract). The integrated nutrient management approach of combining chemical fertilizer with vermicompost and farmyard manure has improved the vegetative, reproductive, and yield aspects of okra, according to identical findings published by Ruby et al. [25].

The observed higher content of protein in okra leaves treated with INM (50%) (RDCF + FB-BW) was due to the optimal availability of nitrogen, phosphorus, and potassium provided by inorganic fertilizer. Mirudkar et al. [26] have also reported similar findings in okra when chemical fertilizer was combined with farmyard manure. Many studies have reported that the combination of organic manure and chemical fertilizer outnumbers the effects of chemical fertilizers or organic manure when added individually. The results of the present study confirmed that the efficacy of 50% chemical fertilizer was pronounced when combined with 50% FB-BW. Improvements in soil nutritional status and consequently vegetative features have been brought about by the micronutrients and microbial population in FB-BW, which have conditioned the soil to support PGPR.

Summary and Conclusion

For sustainable agricultural practices, organic biofertilizers should be used with inorganic fertilizers based on their nutrient status. By concentrating on an integrated nutrient management system, soil fertility can be increased with no compromise on the quantity and quality of food supply. This is achieved by leveraging the benefits of both organic and inorganic fertilizers. The current study's findings showed that the soil's macronutrient status had improved when 50% of the chemical fertilizer's prescribed dosage was combined with 50% Fermented Biofertilizer from Banana Fruit Waste (FB-BW). This improved soil health is demonstrated by the morphological and vegetative traits, which include enhanced root architecture and a rise in root length, plant height, leaf area, number of leaves, and branches. Furthermore, there has been a rise in biomass and photosynthetic pigment with the 50% integrated nutrition management (RDCF + FB-BW). FB-BW based INM might be recommended to improve soil fertility and agricultural productivity. As a result, there will be less chemical fertilizer requirement and application and less detrimental effects on the environment. Further evaluation of the field-level implementation of INM-50% (RDCF + FB-BW) is required.

Declarations

Funding

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Availability of Data and Materials

All the data generated for this study are included in this article.

Ethical Approval

Not applicable

Consent to participate

Not applicable

Authors Contributions

B. Thendral Hepsibha - conceptualization, investigation and writing (original draft preparation)

B. Lavanya and P. Jayanthi – performed the study and analysis

Competing Interest

The authors declare no competing interests.

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Figures

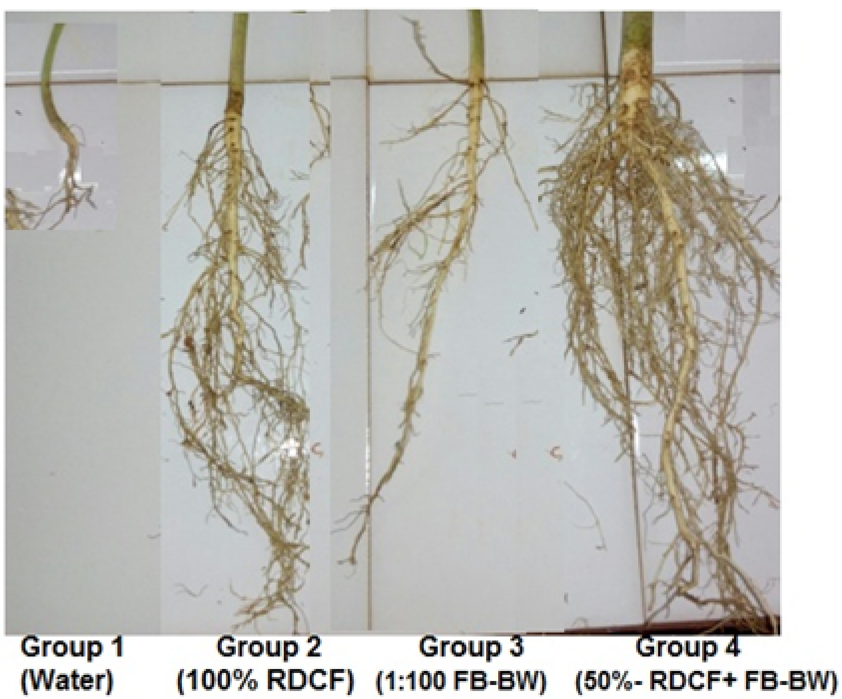

Figure 1

Impact of Integrated Nutrient Management (INM) – 50% (RDCF + FB-BW) on stem girth of *Abelmoschus esculentus* (Ladies Finger) leaf area after various treatments

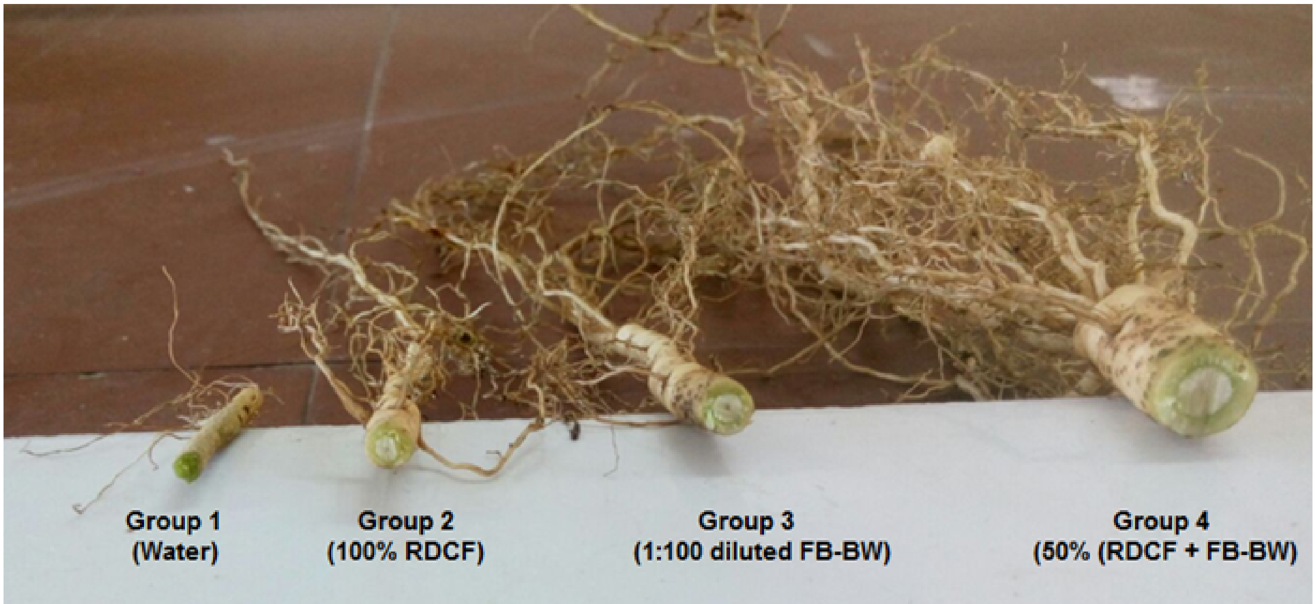

Figure 2

Influence of 50% (RDCF + FB-BW) on stem girth of *Abelmoschus esculentus* (Ladies Finger) leaf area after various treatments

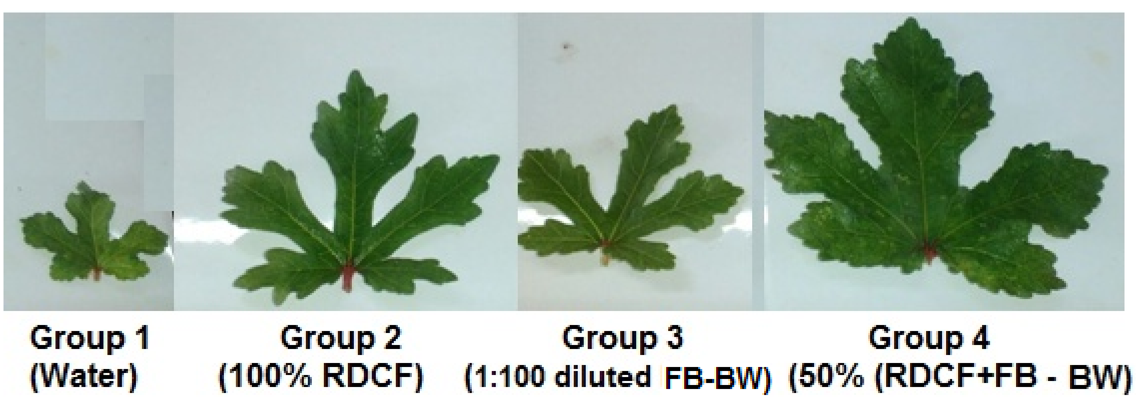

Figure 3

Comparison of *Abelmoschus esculentus* (Ladies Finger) leaf area after various treatments