Original Research Article

Nutrient availability from an organic fertilizer produced by chemical decomposition of solid wastes in relation to dry matter production in banana

ABSTRACT

Aims: To evaluate the suitability of an organic fertilizer produced by rapid chemical decomposition of organic waste as a substitute for farmyard manure for banana cultivation with reference to its effects on soil properties, nutrient availability and dry matter production.
Study design: A field experiment was laid out in Randomized Block Design involving eight treatment combinations with three replications.
Place and Duration of Study: A field experiment involving banana (*Musa* spp. variety Nendran) was conducted from October 2014 to August 2015 at the College of Agriculture, Trivandrum, Kerala, India.
Methodology: Healthy, uniform sized suckers of banana were planted at a spacing of 2×2 m on 4 October, 2014 in individual plots of size 6×6 m. The treatments were selected to compare conventional farmyard manure based and soil test based fertilizer recommendations with those of the newly produced rapid organic fertilizer. Treatments to study the combined effect were also included. Fertilizers were applied basally and in six split doses in accordance with the recommended package of practices. The fresh weight of the pseudostem, leaves, fruits and rhizome were recorded at harvest and dry matter production computed after oven drying the samples.
Results: The study revealed that the substitution of farmyard manure with rapid organic fertilizer imparted a better buffering action to soil with only 51.43% decline in pH, without significant changes in electrical conductivity and ensured a steady supply of major nutrients during the active growth stages of the crop. Total and fruit dry matter production also differed significantly
Conclusion: The rapid organic fertilizer based fertilizer application can substitute the conventional farmyard manure based fertilizer application for banana cultivation.

Keywords: Organic fertilizer; chemical decomposition; rapid processing; degradable solid waste; dry matter production; nutrient availability

1. INTRODUCTION

In India, the most commonly used organic manure is farmyard manure [1], but there is a wide gap between demand and availability that is currently filled by the application of composts. The most attractive method for recycling organic wastes is composting because the waste materials are converted into environmentally benign products [2]. Although composting is a popular practice, the scarcity of land and the long time required pose serious limitations to large-scale production. However, extensive dumping of solid waste for long periods creates environmental and human health hazards. As an alternative to conventional composting practices, Sudharmaidevi et al. [3] reported on the thermochemical treatment of degradable solid wastes to rapidly produce organic fertilizer (Fig. 1). The method is scientific, efficient and capable of providing a rapid and sustainable solution for hygienic waste disposal and the production of organic fertilizer. Processing waste at the point of its generation avoids the need for transportation to centralized processing yards, and since the waste can be processed on the day of generation, dumping is avoided, which prevents other environmental problems. Banana is a popular fruit crop that is cultivated all over the world, but because it is an annual crop with a duration of 10 months, large quantities of organic fertilizers are required. However, in the context of scarce availability of farmyard manure, organic fertilizer that is rapidly produced by chemical decomposition of degradable solid wastes can be a good substitute. Hence, this study was conducted to evaluate the suitability of such organic fertilizer as a substitute for farmyard manure and its effects on soil properties, nutrient availability and dry matter production in banana.

Fig.1. Waste processing machine (modified model) used for the rapid processing of degradable solid waste to organic fertilizer (A), rapid organic fertilizer produced by thermochemical conversion (B)

2. MATERIALS AND METHODS

2.1. Experimental Site

A field experiment involving banana (*Musa* spp. variety Nendran) was conducted from October 2014 to August 2015 at the College of Agriculture, Trivandrum, Kerala, India, located at 8° 25'46.94"N latitude and 76° 59'1.12"E longitude at an altitude of 23.8 m above MSL. The mean annual temperature ranged from 21.56°C to 32.74°C, and the relative humidity ranged from 78.25 to 87% during the crop growth period. The total rainfall during the study was 1634 mm, which ranged from 0 to 406 mm in different months. The soil in the experimental site was clayey, kaolinitic, isohyperthermic, Typic Kandiustult. The physico- chemical properties of the experimental site is presented in Table1.

Table 1. Soil fertility parameters of experimental site

Fertility parameters	Content	Status
pH	5.45 ± 0.05	Moderately acidic
OC %	1.69 ± 0.3	High
N (kg ha^{-1})	539 ± 13	Medium
P (kg ha^{-1})	180 ± 23	High
K (kg ha^{-1})	358 ± 26	High
Ca (mg kg^{-1})	448 ± 40.1	Sufficient

Mg (mg kg $^{-1}$)	78.6 ± 4.4	Deficient
S (mg kg $^{-1}$)	13.5 ± 5.4	Sufficient
Fe (mg kg $^{-1}$)	193.9 ± 55.6	Sufficient
Mn (mg kg $^{-1}$)	3.0 ± 1.1	Sufficient
Zn (mg kg $^{-1}$)	12.60 ± 0.85	Sufficient
Cu (mg kg $^{-1}$)	1.07 ± 0.21	Sufficient
B (mg kg $^{-1}$)	0.08 ± 0.01	Deficient

2.2. Experimental Design and Treatments

The experiment had a randomized block design with 8 treatments and 3 replications and with Nendran variety of banana with 10 months duration. The treatments were selected to compare conventional farmyard manure (FYM) based and soil test based fertilizer recommendations with those for newly produced rapid organic fertilizer (ROF). The treatments were (1) CR: conventional recommendation followed in the state ($FYM_{10kg}+N_{190g}+P_{115g}+K_{300g}$), (2) ST:CR modified on the basis of soil test data ($FYM_{10kg}+lime_{100g}+N_{135g}+P_{30g}+K_{75g}$), (3) STSM:ST with secondary nutrients and micronutrients ($ST+MgSO_{4(50g)}+B_{4g}$), (4) STSM(F): STSM with foliar-applied micronutrients, (5) FSTSM:STSM with ROF_{1kg} as topdressing, (6) FSTSM(F):FSTSM with foliar-applied micronutrients, (7) FSTSMP:FSTSM with $PGPR_{2\%}$, and (8) OFSTSM:FSTSM, in which basal farmyard manure was replaced with ROF_{1kg}. The FYM was basally applied. Inorganic fertilizers, except P, were applied in 6 equal top dressing applications at 1-month intervals, and P was applied in two split doses at one and two months after planting. The FYM used for the study was obtained from the College Farm and contained organic carbon (20.5%), N (0.78%), P (0.44%) and K (0.73%). ROF was produced from degradable solid wastes by rapid thermochemical processing, as reported by Sudharmaidevi *et al.* [3]. PGPR was obtained from the Department of Microbiology. The ROF was neutral in reaction and contained organic carbon (23.6%), N (2.31%), P (1.01%) and K (1.37%).

2.3. Dry Matter Production

The fresh weight of the pseudostem, leaves, fruits and rhizome were recorded at harvest. Samples of these parts were separately oven dried at 65℃ to a constant weight to determine the dry weight, and the total dry weight was computed and expressed in kg ha^{-1}. Weight of the bunch including the portion of the peduncle up to the first scar (exposed outside the plant) was recorded in kg.

2.4. Soil and Plant Analysis

For soil analysis, samples from 0-15 cm in depth were collected prior to the start of the experiment, at monthly intervals up to the last top dressing and at harvest. The pH and electrical conductivity were determined in a 1:2.5 (w/v) soil/water extract using a pH meter (Cyber Scan PC 510, Eu Tech Instruments, Singapore) and an EC-TDS Analyser (CM183, Elico, India), respectively. Other parameters were determined as follows: soil organic C by $K_2Cr_2O_7$ oxidation; available N by distillation (Kelplus KEL VAC, Pelican Equipments, India); Bray No.1-extractable P by spectrophotometry (Double Beam UV-VIS Spectrophotometer 2201, Systronics) and available (neutral 1*N* ammonium acetate-extractable) K (by flame photometry).

2.5. Statistical Analysis

The data from the field experiment were statistically analyzed by analysis of variance. The F values for the treatments were compared with the table values, and if the effects were significant, critical differences were determined at the 5% level of significance by a means comparison. The software Web Agri Stat Package (WASP) ver. 2.0 was used for data analysis.

3. RESULTS AND DISCUSSION

3.1. Soil pH and Electrical Conductivity

A decrease in soil pH was observed in all the treatments up to 2 months (Fig. 2) after which the treatments which received ROF recorded an increase of up to 5 months and again decreased. But in treatments which received FYM only, the decrease was continuous up to harvest stage. A drastic decline was observed in CR in contrast to ST. The inorganic fertilizers contained in the treatments might have caused a reduction in pH initially. A decrease in soil pH has been reported due to the acidifying effect of urea fertilizer which generate H^+ ions along with loss of NO_3 by crop uptake or leaching [4] and pH decreased with increasing doses of nitrogen fertilizer. In our experiment, the highest quantity of inorganic fertilizers especially N fertilizer was applied in CR. Moreover, application of fertilizers was not done based on soil test data and hence lime was not added, which can also be a reason for the continuous decline of soil pH in this treatment. The increase in pH at 5 months may be attributed to mineralization of C and production of OH^- ions by ligand exchange and the introduction of a large amount of basic cations [5]. The trend obtained in EC in the present study supports this. However, at the harvest stage, soil reaction was rendered more acidic than the initial level in all the treatments. A decrease of 0.53 to 1.57 units in different treatments was observed. Acidification of tropical soils due to the release of organic acids from applied organic manures especially FYM has been reported by Wakene et al. [6]. The treatments FSTSMP and OFSTSM maintained a similar trend which was statistically on par at all stages. However, the lowest decrease of 0.57 units was recorded in OFSTSM where ROF was applied basally. This is because ROF, besides having a neutral pH, was enriched with lime which would have provided a buffering effect. Composts release alkaline substances and cations such as Ca^{2+}, Mg^{2+}, K^+ [7] which increase pH and counteract soil acidification. In contrast to pH, soil EC (Fig. 3) showed an increasing trend up to 4 months and then decreased. The decrease was gentle in CR and OFSTSM. Soil EC is a measure of soluble nutrients in soil. The increase in EC observed is due to the release of nutrients from inorganic and organic fertilizers. EC gives an indication of the rate of mineralization of organic matter. Mineralization of organic manures produce cationic and anionic nutrients [8] contributing to soil electrical conductivity. Significant increase in EC with application of different types of organic manures had been reported [9]. The trend observed in the present study corresponded well with the release pattern of N, K, Mg and S, in different treatments.

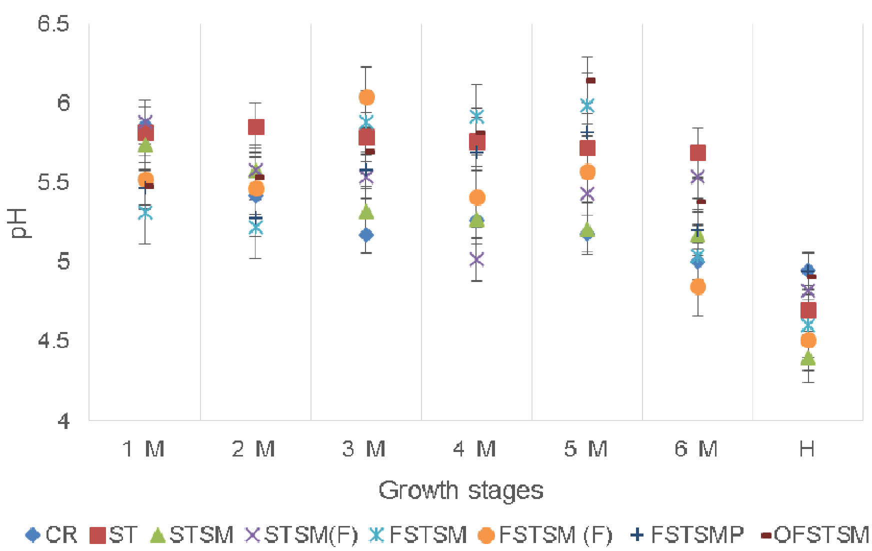

Fig. 2. Soil pH as affected by farmyard manure and rapid organic fertilizer based treatments

CR: Conventional recommendation, ST: CR modified on the basis of soil test data, STSM: ST with secondary and micronutrients, STSM(F): STSM with micronutrients as foliar, FSTSM: STSM with rapid organic fertilizer for top dressing, FSTSM(F): FSTSM with micronutrients as foliar, FSTSMP: FSTSM with PGPR and OFSTSM: In FSTSM basal farmyard manure replaced with rapid organic fertilizer .Growth stages are in months (M) and harvest stage (H). The vertical bars represent standard error of means.

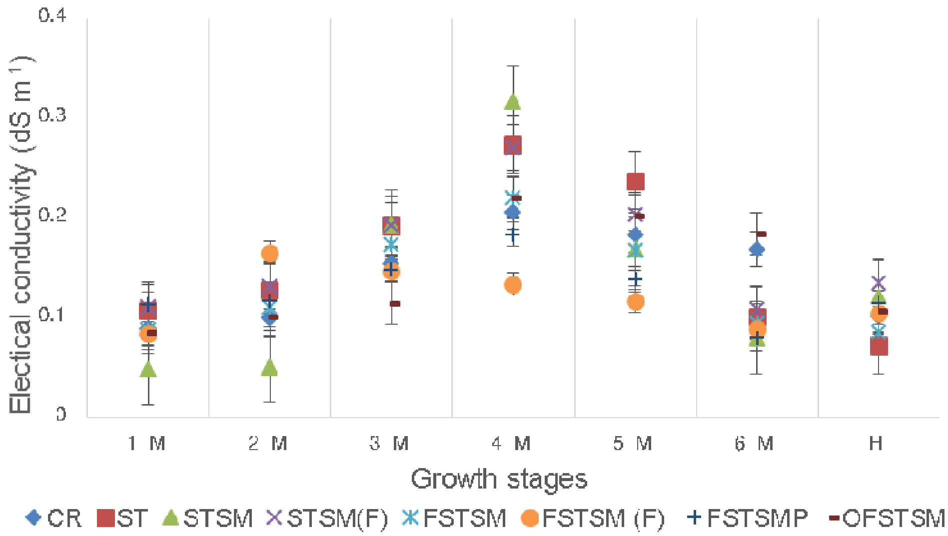

Fig. 3. Effect of farmyard manure and rapid organic fertilizer on electrical conductivity

CR: Conventional recommendation, ST: CR modified on the basis of soil test data, STSM: ST with secondary and micronutrients, STSM(F): STSM with micronutrients as foliar, FSTSM: STSM with rapid organic fertilizer for top dressing, FSTSM(F): FSTSM with micronutrients as foliar, FSTSMP: FSTSM with PGPR and OFSTSM: In FSTSM basal farmyard manure replaced with rapid organic fertilizer .Growth stages are in months (M) and harvest stage (H). The vertical bars represent standard error of means.

3.2. Soil Availability of Plant Nutrients

A general decrease in soil availability of N was observed up to 4 months stage in all the treatments compared to initial status (Fig. 4). The lowest availability at 4M was recorded in treatments ST and FSTSMP and the highest by OFSTSM. But all the treatments except OFSTSM registered an increase in available N content at the end of the experiment compared to 4 month stage. Decline in available N might be due to plant uptake, since high quantity of N is required for vegetative growth of banana. Agele et al. [10] reported that in Ultisols under combined application of organic and inorganic fertilizers, the NO_3 –N availability was at its lowest at 120 days after planting. The foliar concentration of ST showed that the released N was absorbed by the plants. Low availability in FSTSMP might be due to the utilization of N by the PGPR in this treatment in addition to plant uptake. High content of organic matter in OFSTSM at this stage led to highest availability. Soil N is highly correlated with the amount of soil organic matter [11]. Organic manures with high N content and low C:N ratio mineralize N in sufficient quantities for plant use [12]. Moreover, the release of N from organic manures is decided mainly by its chemical composition and the nature of soil microorganisms. Organic manures with high N content and low C:N ratio mineralize N in sufficient quantities for plant use. Nutrient content could vary in composts made from the same source depending upon the technology used for production of compost [13]. A high N availability after a period of one year in plots applied with organic amendments as reported by Kowaljow et al. [14] supports the increased N availability at the end of the experiment. Mineral N release from organic waste composts from 12 weeks to 49 weeks is significantly correlated with the properties of functional groups [12]. However the status in all the treatments were well below that of initial level. The treatments CR, FSTSM and FSTSMP exhibited same pattern throughout the crop growth period. Although the pattern was similar,

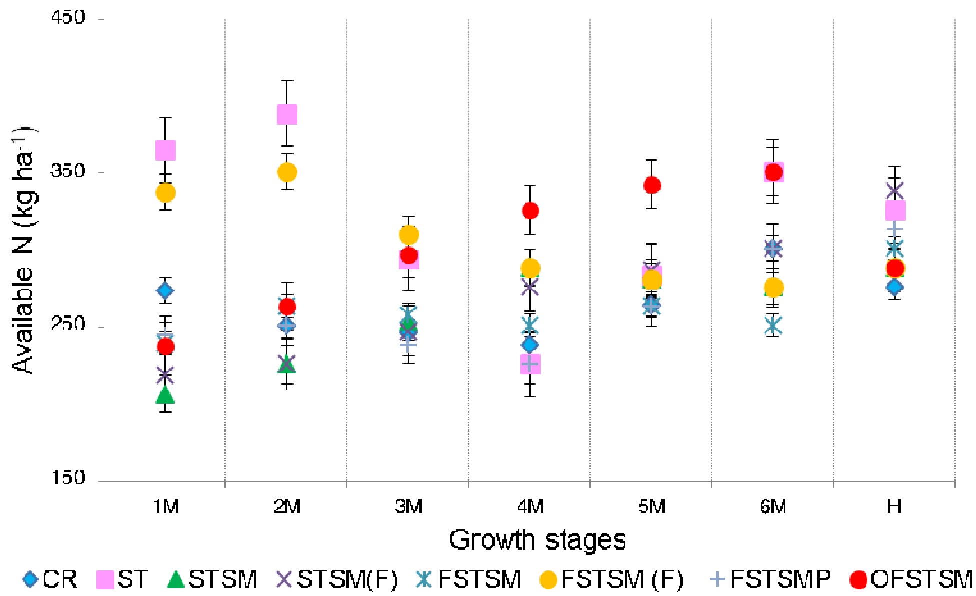

Fig. 4. Temporal variation in soil available Nitrogen as affected by farmyard manure and rapid organic fertilizer based treatments

CR: Conventional recommendation, ST: CR modified on the basis of soil test data, STSM: ST with secondary and micronutrients, STSM(F): STSM with micronutrients as foliar, FSTSM: STSM with rapid organic fertilizer for top dressing, FSTSM(F): FSTSM with micronutrients as foliar, FSTSMP: FSTSM with PGPR and OFSTSM: In FSTSM basal farmyard manure replaced with rapid organic fertilizer .Growth stages are in months (M) and harvest stage (H). The vertical bars represent standard error of means.

actual N availability was low initially and high in later growth stages in FSTSMP. This treatment was enriched with PGPR in addition to the essential nutrients. Initial low availability might be due to the utilization of N by the PGPR in this treatment for its growth and once they flourished, released nutrients to the rhizosphere. N fixing microorganisms which are components in PGPR, also might have contributed to increase in later stages. The two treatments receiving micronutrients through foliar spray exhibited contrasting patterns of N availability. The treatment STSM(F) which did not receive ROF as top dressing showed an increasing trend whereas FSTSM(F) which received ROF in addition to FYM, exhibited a decreasing trend from the beginning. This could be attributed to the increased absorption of N in FSTSM(F) which was used for dry matter production, as evidenced by a higher dry matter content. The lowest availability was in CR. This is because in all others N was applied on soil test basis.

A steady increase in P availability (Fig. 5) was observed in all the treatments up to 4 M after which a steep increase was recorded up to the harvest stage. The farmyard manure applied plots recorded a higher content of available P compared to organic fertilizer treated plots. Soil pH has a direct bearing on P availability. P availability is inversely proportional to soil pH [11]. The availability of P from added MSW compost is low initially but increases within 3 months to make it sufficiently available for plants. The increased availability may be attributed to the P release from Fe and Al compounds by the chelating action of organic anions. In banana P is applied at the initial growth period. The soil of the experimental site was having a high status of P but at the same time a high P fixation capacity (>90%). Maximum P sorption by the plants take place at the early growth period since P is required for root formation. Since there was no addition of external P after 2 months, the balance after plant uptake might have been fixed by the Fe and Al compounds present in the soil as

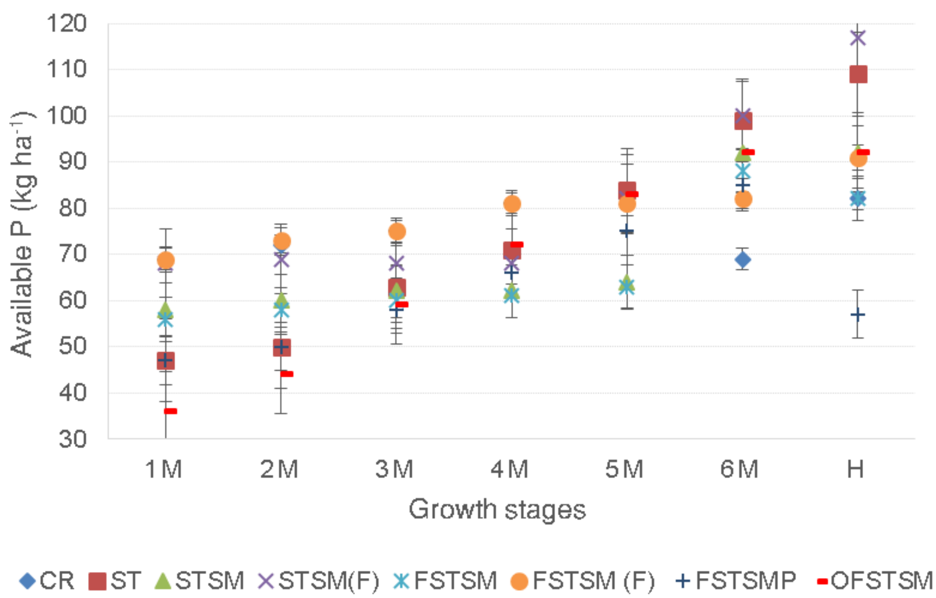

Fig. 5. Effect of farmyard manure and rapid organic fertilizer on Phosphorus availability in soil

CR: Conventional recommendation, ST: CR modified on the basis of soil test data, STSM: ST with secondary and micronutrients, STSM(F): STSM with micronutrients as foliar, FSTSM: STSM with rapid organic fertilizer for top dressing, FSTSM(F): FSTSM with micronutrients as foliar, FSTSMP: FSTSM with PGPR and OFSTSM: In FSTSM basal farmyard manure replaced with rapid organic fertilizer .Growth stages are in months (M) and harvest stage (H). The vertical bars represent standard error of means.

reported by Bolan et al. [15] for weathered soils. High content of available P in the farmyard manure applied plots as compared to organic fertilizer treated plots is attributable to differences in P sorption by these sources. Release of available P from bio solids composts where P is bound to Fe and Al was lower than farmyard manure where P is bound by Ca phosphates [16]. Increased P availability from farmyard manure is related to the decrease in orthophosphate sorption. In banana the fertilizers are applied up to 6 months which coincide with stages of active uptake and as a result after 6 months even if the P availability in soil is high, it will not be properly utilized by the plant.

K availability in all the treatments increased up to 2M and continued to increase up to 4M except in FSTSM(F) and FSTSMP (Fig. 6). In ST and OFSTSM the status remained high up to 6 M. However the values at harvest stage were lower than the initial in all treatments except in CR and STSM. The release of K from the organic and inorganic fertilizers together with the high initial availability in the soil gave an enhanced K availability. Application of organic manures as well as combined application of organic and inorganic fertilizers increased K availability in soil [17]. Even at low rates of application MSW compost is able to increase soil K concentrations [18]. However the values at harvest stage were lower than the initial in all treatments. The uptake pattern of K showed that the nutrient was absorbed by plants resulting in a shortage in soil.

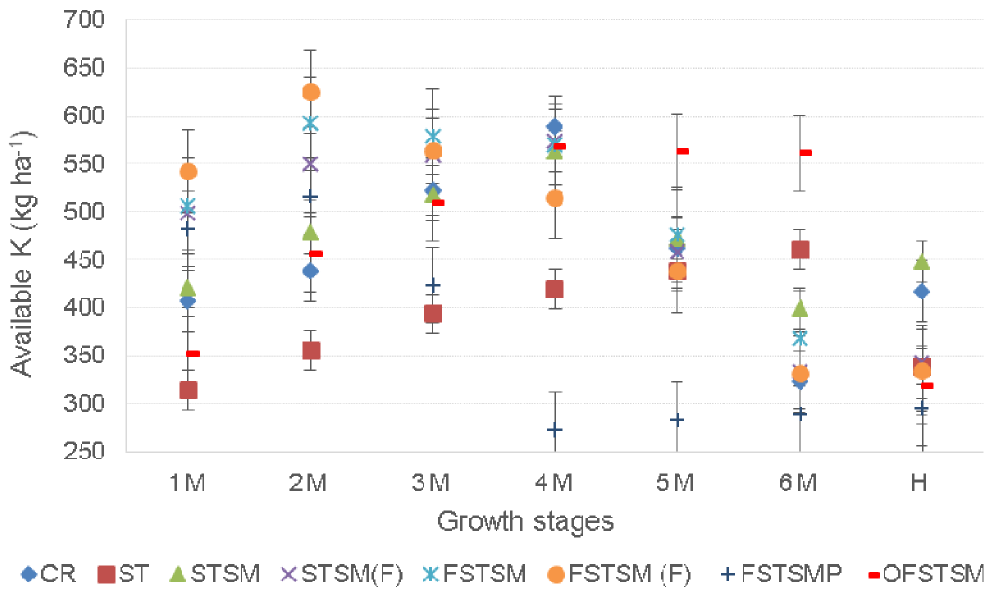

Fig. 6. Effect of farmyard manure and rapid organic fertilizer based treatments on soil available Potassium

CR: Conventional recommendation, ST: CR modified on the basis of soil test data, STSM: ST with secondary and micronutrients, STSM(F): STSM with micronutrients as foliar, FSTSM: STSM with rapid organic fertilizer for top dressing, FSTSM(F): FSTSM with micronutrients as foliar, FSTSMP: FSTSM with PGPR and OFSTSM: In FSTSM basal farmyard manure replaced with rapid organic fertilizer .Growth stages are in months (M) and harvest stage (H). The vertical bars represent standard error of means.

2.4. Dry Matter Production in Banana

The dry matter content at harvest stage (Table 2) differed significantly. Total, leaf, rhizome and fruit dry matter production were significantly superior in OFSTSM and STSM. The values were significantly lower in FSTSM, FSTSMP and FSTSM (F). The lowest value was recorded by STSM(F) which received farmyard manure as basal and micronutrients through foliar application. All the parameters were significantly lower in STSM(F) and FSTSM (F) indicating that soil application is better in the case of micronutrients. The treatments with farmyard manure produced more pseudostem dry matter when compared to treatments which received rapid organic fertilizer. The highest pseudostem weight was recorded in CR followed by ST, STSM and FSTSM. The lowest rhizome dry matter was also recorded in CR. In ROF based treatments allocation to fruit dry matter was more compared to farmyard manure based treatments. Use of agricultural wastes either alone or in combination with N, P, K fertilizers is reported to enhance the growth and yield characters of maize [10].

Table 2. Effect of farmyard manure and rapid organic fertilizer based treatments on dry matter production in banana

Treatments	Leaf (kg ha^{-1})	Pseudostem (kg ha^{-1})	Rhizome (kg ha^{-1})	Fruit (kg ha^{-1})	Total (kg ha^{-1})
CR	1574.93 ^{bc}	4301.54 ^{a}	1217.12 ^{d}	2535.11 ^{cd}	9628.77 ^{c}
ST	1924.22 ^{b}	3350.00 ^{a}	2376.48 ^{ab}	2535.71 ^{cd}	10186 .41 ^{bc}
STSM	2082.06 ^{b}	3975.41 ^{a}	2838.67 ^{a}	2966.43 ^{b}	11862.55 ^{ab}
STSM(F)	1620.00 ^{bc}	1682.00 ^{b}	1533.63 ^{cd}	2372.56 ^{d}	7208.20^{d}
FSTSM	844.72 ^{c}	1953.33 ^{b}	1896.83 ^{bcd}	2546.50 ^{cd}	7241.39 ^{d}
FSTSM(F)	1835.04 ^{b}	1443.74 ^{b}	2034.75 ^{bc}	2555.35 ^{cd}	7868.88 ^{d}
FSTSMP	1604.35 ^{bc}	1610.49 ^{b}	1451.18 ^{cd}	2875.06 ^{bc}	7541.07 ^{d}
OFSTSM	2995.83 ^{a}	3511.61 ^{a}	2840.98 ^{a}	3519.80 ^{a}	12868.21 ^{a}
SEm (±)	391.14	632.28	327.18	163.49	1263.64
CD (0.05)	839.006	1356.242	701.81	350.685	2710.50

Means in a column followed by the same letter do not differ significantly at 5% level.
CR: Conventional recommendation, ST: CR modified on the basis of soil test data, STSM: ST with secondary and micronutrients, STSM(F): STSM with micronutrients as foliar, FSTSM: STSM with rapid organic fertilizer for top dressing, FSTSM(F): FSTSM with micronutrients as foliar, FSTSMP: FSTSM with PGPR and OFSTSM: In FSTSM basal farmyard manure replaced with rapid organic fertilizer .

4. CONCLUSION

The buffering action of the organic fertilizer produced through thermochemical decomposition qualifies it for application particularly in acidic soils. Ensuring of a steady availability of major nutrients throughout the crop growth period by the organic fertilizer resulted in realising significantly higher dry matter production in banana. The rapid organic fertilizer in combination with inorganic fertilizers on soil test basis is an ideal substitute to conventional farmyard manure application combined with soil test based fertilizers.

REFERENCES

1. Reddy KS, Mohanty M, Rao DLN, Singh M, Rao AS, Pandey M, Blamey FPC, Dalal RC, Dixit SK, Menzies NW. Nutrient mass balances and leaching losses from a farmyard manure pit in Madhya Pradesh. J Indian Soc Soil Sci. 2015;63(1):64–68.

2. Rivero C, Chirenje T, Ma LQ, Martinez G. influence of compost on soil organic matter quality under tropical conditions. Geoderma. 2004;123:355–361.
3. Sudharmaidevi CR, Thampatti KCM, Saifudeen N. Rapid production of organic fertilizer from degradable waste by thermo chemical processing. Int J Recycl Org Waste Agricult. 2017;6:1–11.
4. Abreha KH. Soil acidity characterization and effects of liming and chemical fertilization on dry matter yield and nutrient uptake of wheat (*Triticum aestivum* L.) on soils of Tsegede district, northern Ethiopia. Doctoral Dissertation, Haramaya University, Ethiopia. 2013;142.
5. Brar BS, Singh J, Singh G, Kaur G. Effects of long term application of inorganic and organic fertilizers on soil organic carbon and physical properties in maize–wheat rotation. Agron. 2015;5(2), 220-238.
6. Wakene N, Heluf G, Friesen DK. Integrated use of farmyard manure and NP fertilizers for maize on farmers' fields. J Agric Rural Dev Trop Subtrop. 2005;106(2):131-141.
7. Sarwar G, Schmeisky H, Tahir MA, Iftikhar Y, Sabah NU. Application of green compost for improving soil chemical properties and fertility status. J Anim Plant Sci 2010;20:258-260.
8. Glaser B, Wiedner K, Seelig S, Schmidt HP, Gerber H. Biochar organic fertilizers from natural resources as substitute for mineral fertilizers. Agron Sustain Dev. 2015;35:667-678.
9. Moran-Salazar RG, Marino-Marmolejo EN, Rodriguez-Campos J, Davila-Vazquez G, Contreras-Ramos SM. Use of agave bagasse for production of an organic fertilizer by pretreatment with *Bjerkandera adusta* and vermicomposting with *Eisenia fetida*. Environ Technol. 2016;37(10):1220-1231.
10. Agele SO, Ojeniyi SO, Ogundare SK. The fluxes of organic C and N and microbial biomass and maize yield in an organically manured Ultisol of the guinea savanna agroecological zone of Nigeria. J Agric Chem Environ. 2015;4:83-95.
11. De Bauw P, Van Asten P, Jassogne L, Merckx R. Soil fertility gradients and production constraints for coffee and banana on volcanic mountain slopes in the east African rift: a case study of Mt. Elgon. Agric Ecosyst Environ. 2016;231:166-175.
12. Eldridge SM, Chen C, Xu Z, Chan KY, Boyd SE, Collins D, Meszaros I. Plant available N supply and recalcitrant C from organic soil amendments applied to a clay loam soil have correlations with amendment chemical composition. Geoderma. 2017;294:50-62.
13. Haynes RJ, Zhou YF. Comparison of the chemical, physical and microbial properties of composts produced by conventional composting or vermicomposting using the same feedstocks. Environ Sci Pollut Res. 2016;23(11):10763-10772.
14. Kowaljow E, Gonzalez-Polo M, Mazzarino MJ. Understanding compost effects on water availability in a degraded sandy soil of Patagonia. Environ Earth Sci. 2017;76(6):255-265.
15. Bolan NS, Adriano DC, Curtin D. Soil acidification and liming interactions with nutrient and heavy metal transformation and bioavailability. Adv Agron. 2003;78: 215–272.
16. Nest TV, Ruysschaert G, Vandecasteele B, Houot S, Baken S, Smolders E, Cougnon M, Reheul D, Merckx R. The long term use of farmyard manure and compost: effects on P availability, orthophosphate sorption strength and P leaching. Agric Ecosyst Environ. 2016;216:23-33.
17. Mahmood F, Khan I, Ashraf U, Shahzad T, Hussain S, Shahid M, Abid M, Ullah S. Effects of organic and inorganic manures on maize and their residual impact on soil physico-chemical properties. J Soil Sci Plant Nutr. 2017;17:22-32.
18. Giusquiani PL, Marucchini C, Businelli M. Chemical properties of soils amended with compost of urban waste. Plant Soil. 1988;109(1):73-78.