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Vegetable Yield responses to Coffee pulp Co-composted with Effective Microorganisms (EM) and bean (*Phaseolus vulgaris* L.) Crop Residues

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ABSTRACT

In a follow-up study to experiments conducted in order to evaluate the fertilizer potentials of coffee pulp composts enhanced with (micro) biological accelerators on potato (Solanum tuberosum L.) and bean (Phaseolus vulgaris L.) crops, a triple experiment was conducted on two cabbage (Brassica oleracea L.) varieties (Mukasi and Kidodo) and on egg plant (Solanum melongena L.). Tested treatments were: T_1=Coffee pulp (CP) alone, T_4=CP + 2 L molasse + 2 L EM + 74 kg of dolomitic lime (CP+EM_2), T_5= CP + 33.5 kg of bean residues (BR) + 33.5 kg of soil (forest soil) (CP+BR_2), T_6=Recommended organo-mineral fertilizer application for cabbage and T_7=Control (non amended/fertilised). The first experiment with the Mukasi cabbage (Brassica oleracea L.) variety showed that CP+EM_2 (T_4) and CP+BR_2 (T_5) gave statistically equivalent yields. In the second experiment with the cabbage (Kidodo variety), fresh head yields followed the order: T_5 (CP + BR_2) ≥ T_6 (organo-mineral fertilizer) ≥ T_1 (CP alone) ≥ T_4 (CP+ EM_2) ≥ T_7 (Control), indicating the superiority of the coffe pulp co-composted with bean (Phaseolus vulgaris L.) residues. Overall, CP+EM_2 treatment (T_4) did not perform well, particularly with Kidodo variety. The low performance of CP+EM_2 (T_4) was confirmed by the egg plant experiment, in which the highest yield was registered with the CP compost alone (T_1), followed by CP + BR_2 (T_5), the control treatment (T_7) and lastly by CP + EM_2 (T_4). In accordance with the previous potato (Solanum tuberosum L.) and bean (Phaseolus vulgaris L.) experiments, we confirm the consistent agronomic superiority of the CP+BR_2 treatment (T_5) over other tested treatments, including the costy inorganic treatment (T_6). This conclusive statement is enhanced by the fact that the CP+BR_2 treatment (T_5) is more accessible and more reproducible by farmers (because locally available), in comparison with the CP+EM_2 treatment (T_4). The latter compost treatment is more problematic with regard to cost of acquisition (importation), conservation, manipulation and availability to poor rural Burundi farmers.

Keywords: Coffee Pulp, Co-Compost, Bean Residues, Cabbage, Egg Plant, Yield.

1. INTRODUCTION

Information on potential co-composting coffee pulp with ou without decomposition accelerators is lacking in the Burundi agriculture sector. Coffee factory waste composting is a means of transforming coffee factory waste into organic fertilizers. Hence, coffee pulp is usable as manure but fresh it can be very acid, slow to decompose and may spread diseases and pathogens [1]. Moreover, coffee pulp compost can be used as « inoculum » for following composting operations [2]. In Vietnam, considered the second coffee country producer in the world, 1 million cubic meter of coffee pulp constitute a potential source of environnemental pollution, although they contain subsantial amounts of essential micronutrients [3].

It has been proven that composting coffee pulp decreases environmental pollution on land and surface water and leads to the promoton of eco-sustainable agriculture [4]. Beyond the agriculture sector as a source of organic fertilizer (compost), coffee pulp contains caffein and tannin and is a substrate for mushroom cultivation and production of biogas, enzymes and mushroom and compost [5-6]. Coffee pulp compost can be used as bulking agent with improving effect on soil porosity, soil water retention and aeration, together with increasing nutrient availability [1].

Some of the drawbacks of natural composting is the increased duration of time to complete the composting process with emissions of unpleasant odors (H_2S) and heavy metals detrimental to human and animal health [7]. Commercially available effective microorganisms (EM) accelerate the composting process, with an improving effect of nutrient content in compost, a controlling effect on temperature and reduced pathogens in the produced compost [7]. Different microrganisms are selected for use in the composting process. Lactic acid bacteria inhibit growth of pathogens and increase soil health, yeast participate in the production of amino acids and polysaccharides which constitute basic food for other microbes, whereas photosynthetic bacteria control C and N cycles. It appears that all three microorganisms are mutually supportive microorganisms [7].

With or without biological boosts (effective microorganisms, vermi-compost) or organic and inorganic additives, an increasing interest has been shown on composting or co-composting by soil agronomists, chemists and biological scientists [8]. A number of studies have evaluated composting or co-composting of animal manure and crop residues [9-20], food and mucicipal wastes [7, 21-22], pine bark composting [23], rice straw compost quality [24], crop yields and quality [3, 25-28], soil properties and nutrients availability [1, 29-31], water quality restoration [32]. At the same time, other investigators have rightly pointed out some limitations associated with compost and composting with regard to the relationship between compost maturity and the risks of phytotoxicity [33-34].

In a twin study to the present investigation [35], it was shown that coffee pulp composts improved with he highest application rates of effective microorganisms (EM) and bean residues gave equivalent results on potato (*Solanum esculentum* L.) and bean (*Phaseolus vulgaris* L.) crop yields. The study also highlighted the fact that, due to the fact that EM is imported and not locally available and surely problematic with regard to cost, conservation and manipulation, coffee pulp compost enriched with bean residues (BR_2) is more accessible and reproducible by Burundi farmers.

The objective of this follow up experiment on cabbage [*Brassica oleracea* L.) and egg plant (*Solanum melongena* L.) was to verify, confirm or else infirm research results produced on potato (*Solanum esculentum* L.) and bean (*Phaseolus vulgaris* L.) crops. As a remainder, the specific objective of the investigation was to evaluate the potential fertilizer value of coffee pulp compost using EM and bean residues (BR). The research hypotheses tested were as follows: i) Additives of effective micro-organisms (EM) or bean residues improve the fertilizer value of coffee pulp compost on on cabbage and egg plant; ii) Coffee pulp compost could be used as an alternative to organo-mineral fertilizers used on cabbage and egg plant in Burundi.

2. MATERIALS AND METHODS

2.1 Sites and soil description and compost chemical analysis

Characteristics of the experimental site and soils have been described elsewhere [35]. Soils parameters were as follow: pHeau=5.65, % C=0.86, % N=0.08, C/N=10.75, available P (Olsen) = 46, CEC ($cmol_c$/kg of soil) = 8,9, Ca^{2+} ($cmol_c$/kg of soil) = 3.68, Mg^{2+} ($cmol_c$/kg of soil)) = 0.44 and K^+ ($cmol_c$/kg of soil) = 0.29. Table 1 shows selected chemical characteristics of the 3-month old coffee pulp compost used in the cabbage and egg plant experiments. Analytical procedures for soil and coffee pulp compost are also reported elsewhere [35]. Coffe pulp composting process is illustrated by Figure 1. It was performed in open house structure with cemented floor with a tile shade.

2.2 Planting materials

Two cabbage varieties (Mukasi and Kidodo) and one egg plant variety were used. Both cabbage and egg plant trials were installed at Musumba location during season 2017A growing season (september 2016-february 2017). The cabbage crop was planted on 16 november and harvested on 21 february 2017, 98 days after planting. The egg plant was planted at the same date as for cabbage. Cabbage was planted at 0.6 m x 0.5 m spacing on a 2 m x 0.6 m experimental unity for Kidodo variety and 2 m x 1.2 m experimental parcel for Mukasi variety. Egg plant was planted at 0.8 m x 0.6 m spacing. Respective plant densities were equivalent to 33.333 cabbage plants/ha and 20.833 egg plants/ha. Compost was applied at 10 T/ha at planting. The cabbage crop was fertilized with 175 kg/ha N, 80 kg/ha P_2O_5 and 215 kg/ha K_2O. No mineral fertilization treatment was included in the egg

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plant experiment. Phytosanitary treatments were applied when needed using ridomil and dithane, in accordance to research and extension services recommandations.

2.3 Experimental Design and data collection

A 3-month old coffee pulp compost was used in both the cabbage (*Brassica oleracea* L.) and egg plant (*Solanum melongena* L.) experiments. The experimental design used in both experiments was a completely randomized block design (RCBD) with three replicates.
Treatments under evaluation were:

T_1: Coffee pulp (CP) alone
T_4: CP + 2 L molasse + 2 L EM + 74 kg of dolomitic lime ($CP+EM_2$)
T_5: CP + 33.5 kg of bean residues (BR) + 33.5 kg of soil (forest soil) ($CP+BR_2$)
T_6: Recommended fertilizer application for cabbage
T_7: Control (non amended/fertilised)

At harvest, measured parameters were fresh cabbage heads and egg plant yields expressed in kg/ha after extrapolation from expermental units.

Figure 1 Mature coffee pulp compost ready for field application.

2.4 Statistical Analyses

Data were subjected to an analysis of variance (ANOVA I) using Genstat Discovery package VSN International [36]. When statistical significance was observed, mean separation was performed with the Newman-Keuls method based on the Least Significant Difference (LSD). [37].

3. RESULTS AND DISCUSSION

3.1. Compost chemical characteristics

The chemical characteristics of the 3-month coffe pulp used in the cabbage and agg plant studies are given in Table 1. It appears that all coffe pulp composts were characterized by alkaline pH values, with CP + BR_2 having the highest pH value. On the other side, $CP+EM_2$ showed lowest % C and N contents, which are expected to translate into lowest crop yields (see Tables 2 and 3) generated by the former treatment ($CP+EM_2$).

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Table 1. Chemical composition of 3-month coffee pulp compost used in the experiments

Organic material	pH_{H2O}	% C	% N	C/N
CP + BR_2 (T_5)	8.47	9.84	1.19	8.27
CP + EM_2 (T_4)	8.00	6.52	0.73	8.93
CP alone (T_1)	8.09	9.37	1.02	9.19

3.1. Cabbage yields

Table 2 below shows cabbage yields obtained on Mukasi and Kidodo varieties following application inorganic and coffee pulp based composts.

Table 6. Effect of mineral fertilizer and coffee pulp compost on cabbage yields

Treatment	Yield (Mukasi Variety)	Yield (Kidodo Variety)
	kg/ha	
Mineral Fertilizer (T_6)	48379±7104 a (+27.3 %)	67450±22822 a (+150 %)
CP alone (T_1)	47776±3393 a (+25.7 %)	52644±19475 a (+95 %)
CP+ EM_2 (T_4)	46511±8904 a (+22.4 %)	48161±7270 ab (+78.4 %)
CP + BR_2 (T_5)	44615±4311 a (+ 17.4 %)	67579±21918 a (+150 %)
Control (T_7)	38003±15186 a -	27000±22777 b -
LSD	11669	25373
General Mean	45057	52567
Probability	0.324NS	0.031*

Mean values (+ standard deviations) with identical letters within the column are not statistically different at $p < 0.05$. NS = Non Significant ($p > 0.05$).

Statistical analysis performed on variety Mukasi did not show any difference between tested treatments ($p > 0.05$). Fresh cabbage head yields for Mukasi variety ranked from lowest 38 T/ha (T_5=control) to highest 48 T/ha (T_6=Mineral fertilizer) and followed the order hereafter: T_6 (Mineral Fertilizer) ≥ T_1 (CP alone) ≥ T_4 (CP+ EM_2) ≥ T_5 (CP + BR_2) ≥ T_7 (Control). Coffee pulp compost amended with EM_2 (T_4) and BR_2 (T_5) gave pratically equivalent yields, 4 to 8 % lower than the mineral fertilizer treatment (T_6) and 3 % lower than the coffee pulp compost alone (T_1). Compared to the control treatment (T_7), cabbage head gains in yields were + 17.4 % for T_5 (CP+BR_2), 22.4 % for T_4 (CP+EM_2), + 25.7 % for T_1 (CP alone) and + 27.3 % for T_6 (organo-mineral fertilizer).

With regard to the Kidodo cabbage variety, Table 3 illustrates a significant effect of treatment on cabbage head yields ($p < 0.05$). Treatments T_6 (organo-mineral fertilizer) and T_5 (CP + BR_2) rank on top and are significantly superior to the control (T_5). However, they are not significantly superior to treatments T_1 (CP compost alone) and T_4 (CP + EM_2). Fresh cabbage head yields followed the order hereafter: T_5 (CP + BR_2) ≥ T_6 (organo-mineral fertilizer) ≥ T_1 (CP alone) ≥ T_4 (CP+ EM_2) ≥ T_7 (Control). This trend indicates the superiority of the coffe pulp co-composted with bean (*Phaseolus vulgaris* L.) residues on Kidodo cabbage head yields, which was not observed in the Mukasi variety experiment.

Although comparison between cabbage varities were not part of the present experiments, yield registered with the control (unamended soil) is higher with Mukasi than Kidodo. An opposite yield treand was observed with mineral and organic fertiliers applications. Kidodo variety responds much better to mineral fertilizer (T_6) and coffee pulp composts, particularly when amended with BR_2 (T_5), and to a lesser extent with EM_2 (T_4). This last treatment gave even lower cabbage yields than the coffee pulp compost alone (T_1).

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When yield gains relative to the control treatments are calculated, it appears that the highest % gain (+ 150 %) was equally registered with T_6 (organo-mineral fertilizer) and T_5 (CP + BR_2). Yield gains associated with T_1 (coffee pulp alone) and CP+EM_2 were respectively 95 % and 78.4 %. This is an indication of an absence of agronomic EM effect on the yield of Kidodo. CP+EM_2 treatment did not perform well, particularly with Kidodo variety. This low performance of CP+EM_2 treatment could found in its low N content as indicated in Table 1, comparatively to the other coffee pulp compost (CP + BR_2 and CP alone).

3.2. Egg plant yield

Egg plant yield responses as affected by tested coffee pulp composts are indicated in Table 3 below. The organo-mineral treatment (T_6) was discarded from the series of treatments tested on egg plant.

Table 3. Effect of coffee pulp compost on egg plant yields

Treatment	**Yield**
	----- kg/ha-----
CP alone (T_1)	14913±974a **(+110 %)**
CP + EM_2 (T_4)	5911±1840c **(-16 %)**
CP + BR_2 (T_5)	10342±3310b **(+46.4 %**)
Control (T_7)	7065±1209c -
LSD	3213
General Mean	9558
Probability	0.002**

Mean values (+ standard deviations) with identical letters within the column are not statistically different at $p < 0.05$.

Statistical analysis performed on egg plant yields (Table 3) indicates significant differences between the 4 tested treatments: Coffee pulp composted alone (T_1), coffee pulp amended with EM_2 (T_4), coffee pulp amended with BR_2 (T_5) and the unamended control treatment (T_7). Interestingly, the highest egg plant yield was registered with the CP compost alone (T_1), followed by CP + BR_2 (T_5), the control treatment (T_7) and finally by CP + EM_2 (T_4). Egg plant yields followed the order: $T_1 > T_5 > T_7 \geq T_4$. Compared to the control treatment without compost application, the gains in egg plant yields expressed in % were: + 110 % for T_1 (CP alone), + 46,4 % for T_5 (CP+BR_2). The control treatment was statistically equivalent to CP + EM_2 but produced 16 % more egg plant yield than the latter treatment. Egg plant yields associated with CP+EM_2 were the lowest of all tested treatments, highlighting once more the absence of agronomic effect of effective microorganisms (EM) in the context of our experiments.

Prior to these studies on coffee pulp compost, a number of investigators have worked on the coffee pulp compost and its improvement through the use of effective microorganisms (EM). Most of them observed an improving effect of EM on compost quality. For Gemechu and Beyene (2020) [4], coffee factory subproducts are extensively used in crop yield and yield components on soybean (*Glycine max* L.), lettuce (*Lactuca sativa* L.), cabbage (*Brassica oleracea* L.), rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L.) and even coffee itself. In a study conducted on egg plant (*Solanum melongena* L.) using vermicompost, Mar et al. (2018) [27] reported a significant effect of biofertilizer on egg plant. Similarly, Nurhidayati et al. (2016) [28] observed an increase in cabbage yield and quality (sugar, vitamin C) following organic fertilizes, as compared to inorganic fertilizers.

However, some other investigations comply with the results obtained in our studies with regard to the lack of effectiveness of effective microorganisms (EM) on cabbage and egg plant in the conditions of our investigations. As an illustrative example, Mupondi et al. (2006) [23] did not observe any effect of EM on pine bulk compost combined with goat manure and sewadge sludge.

4. CONCLUSION

In order to evaluate the potential fertilizer value of coffee pulp compost using effective microorganism (EM) and bean residues (BR), two cabbage (*Brassica oleracea* L.) and one egg plant (*Solanum melongena* L.) experiments were conducted in a RCBD with three replicates. Tested treatments were as follow: T_1=Coffee pulp (CP) alone, T_4=CP + 2 L molasse + 2 L EM + 74 kg of dolomitic lime (CP+EM_2), T_5=CP + 33.5 kg of bean residues (BR) + 33.5 kg of soil (forest soil) (CP+BR_2), T_6=Recommended fertilizer application for cabbage and T_7=Control (non amended/fertilised). T_6 was not included in the egg plant experiment. Coffe

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pulp composts were characterized by alkaline pH values (8-8.5), with CP+EM_2 showing lowest pH, % organic C and % N. The first experiment with the cabbage (*Brassica oleracea* L.) crop showed that CP+EM_2 (T_4) and CP+BR_2 (T_5) gave statistically equivalent yields. Compared to the control treatment (T_7), cabbage head gains in yields were + 17.4 % for T_5 (CP+BR_2), 22.4 % for T_4 (CP+EM_2), + 25.7 % for T_1 (CP alone) and + 27.3 % for T_6 (organo-mineral fertilizer). In the second experiment with the cabbage (Kidodo variety), fresh cabbage head yields followed the order: T_5 (CP + BR_2) ≥ T_6 (organo-mineral fertilizer) ≥ T_1 (CP alone) ≥ T_4 (CP+ EM_2) ≥ T_7 (Control), indicating the the superiority of the coffe pulp co-composted with bean (*Phaseolus vulgaris* L.) residues, which was not clearly expressed in the Mukasi variety experiment. Overall, CP+EM_2 treatment (T_4) did not perform well, particularly with Kidodo variety. This low performance of CP+EM_2 treatment (T_4) could be explained by its low N content. The low performance of CP+EM_2 (T_4) was confirmed by the egg plant (third) experiment, in which the highest yield was registered with the CP compost alone (T_1), followed by CP + BR_2 (T_5), the control treatment (T_7) and lastly by CP + EM_2 (T_4). Consequently, from to this study findings, added to previously obtained research results on potato (*Solanum tuberosum* L.) and bean (*Phaseolus vulgaris* L.) crops [35], we confirm the superiority of the CP+BR_2 treatment, over other compost tested treatments. Moreover, the CP+BR_2 treatment is more accessible when compared to the costy inorganic fertilizers (T_6), and more reproducible by farmers (because locally available), in comparison with the use of effective microorganisms (T_4). The latter treatment is challenging with regard to cost of acquisition (importation), conservation, manipulation and availability to poor rural Burundi farmers.

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