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Experimental Study and Comparative Effects of Bean (*Phaseolus vulgaris* L.) crop residues and effective Microorganisms (EM) on the Fertilizer value of Coffee Pulp Compost

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ABSTRACT

In order to evaluate the fertilizer potentials of coffee pulp as compost, three field experiments were set up with bean (Phaseolus vulgaris L.) and potato (Solanum tuberosum L.). For that end, fresh coffee pulp was composted with accelators addition. Evaluated treatments in a Completely Randomized Block Design (CRBD) with 4 replicates were as follows : T_1 *= Coffee pulp (CP) alone ;* T_2 *= CP + 1 L molasse + 1 L Effective Microorganisms (*EM_1*) + 37 kg of dolomitic lime ;* T_3 *= CP + 16.75 kg of bean residues (*BR_1*) + 16.75 kg of soil (forest soil) ;* T_4 *= CP + 2 L molasse + 2 L* EM_2 *+ 74 kg of dolomitic lime ;* T_5 *= CP + 33.5 kg of bean residues (*BR_2*) + 33.5 kg of soil (forest soil) ;* T_6 *= Farm manure + 1.5 T/ha dolomitic lime + 200 kg/ha DAP+ 100 kg/ha KCl + 50 kg/ha Urea and* T_7 *= Control (non amended/fertilised). In both the bean and the first potato (Victoria variety) experiments, recommended organo-mineral fertilization (*T_6*) was not significantly differerent from either* T_4 *(CP+*EM_2*) or* T_5 *(CP +* BR_2*). In the second potato (Mabondo) study, T6 (Farm Manure + 60-90-60) producted significantly higher yields than the other treatments (*T_7*,* T_6*,* T_5*, and* T_4*), which did not show any significant differences among them. Accross the three field studies, treatments* T_4 *(CP+*EM_2*) and* T_5 *(CP +* BR_2*) are equivalent and substituable. Nevertheless, being imported, EM is surely problematic with regard to cost, conservation and manipulation. In that context, we contend that* T_5 *(CP +* BR_2*) is more accessible to farmers and could be widely adopted as a source of organic fertilizer. We then advance that this compost treatment (*T_5*) is the one to be disseminated as a potential coffee pulp based source of organic fertilizer in coffee growing Burundi areas. We further propose to test the minerally-complemented* T_5 *(CP+*BR_2*+mineral fertilizers) against the currently recommended Farm Manure+mineral fertilizer applications for bean (18-46-0) and potato (60-90-60) crops. Such experimental study would evaluate the substituability of farm manure by CP compost boosted by bean residues addition.*

Keywords: Coffee pulp, Compost, Accelerators, EM, Residues, Bean Residues, Potato, Yield.

1. INTRODUCTION

Coffee is cultivated in 80 world countries for different products, including natural oxidants, vitamins, cellulose, starch, lipids, pigments, pharmaceutical, cosmetic and food industries [1]. Over ten millions of solid residues per year are generated by coffee industries all over the world, causing environmental concen in Burundi (see picture below) and elsewhere [2].

Figure 1. Soil disposed coffee pulp with environmental effects

Coffee is the most important agro-industrial export commoditie in Burundi. In most coffee factories, coffee pulp is left on the ground for natural decay and stabilisation with liberation of noxious odors, leaching of nutrients to the environment, emitting heat and gases with potential harm to plants, humans and soil microorganisms [3-5].

Coffee pulp is a fibrous mucilagenous subproduct from processing of coffeee cherries, containing caffeine and tannins [6]. It constitutes 29 % of dry weight of the whole coffee bean, 50 % of processed coffee, 44-50 % carbohydrates, 10-12 % proteins, 18-21 % fibers, 1.48 % polyphenols and 1.3 % caffeine [6]. Potential utilisations of coffee pulp are numerous and diversified: fuel, animal feed, fermentation, biodiesel production, briquetting, pelletizing, tannin extraction, biogas production, direct applications to crop fields and composting (soil fertility and soil erosion control), support for fungus aromatic products, edible mushroom production, anthocyanins for natural food colorant and bioactive ingredients, coffee flour for breads, cookies, muffins, brownies, pastas, sauces and even beverages, pharmaceutical applications, emulsifiers and stabilizers, biogas, tea and flour for baking [6-15].

In Burundi, as coffee berry production, coffee pulp nationwide production follows a cyclic trend, a good year yield followed by a low one. This tendancy is verified in the data illustred in Figure 1, except for the years 2014 to 2018 where coffee pulp production oscillated around 30,000 T/year, which is the mean coffee pulp production from 2006-2007 to 2019-2020. This quantity of 30,000 T/year represents the potentially compostable coffee pulp in Burundi.

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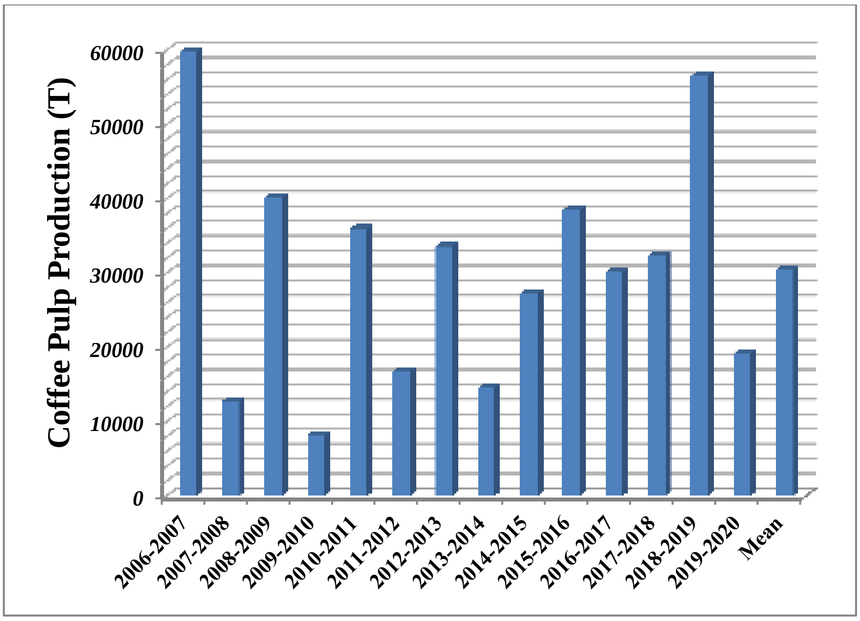

Figure 1. Evolution of the Burundi nationwide coffee pulp production (2006-2020) (Source: ARFIC, 2020. Personal Communication)

Although most valuable when composted, coffee pulp could be an alternative as mulching material to protect the soil against erosion, regulate water evaporation and temperature control pathogens, increase plant nutrients (N, P, K, Ca, Mg, Fe, Cu, B, Zn), improve soil organic matter quality and reduce soil acidity [4, 6, 16].

In agriculture, coffee pulp is treated by composting and subsequently recycled and used as soil organic fertilizers, reducing the cost of coffee production compared to chemical fertilizers aiming to partial subsitution of inorganic fertilizers [3]. Composting contributes to the promotion of growth of beneficial microorganisms, improvement of soil quality and health, biogeochmical cycles such as C, N, P and S and quality of crops [17]. Composting decreases volume, weight, moisture and odor of the composted organic materials, and as such is a viable and durable residue management leading to an environnementally safe agriculture [7, 15, 18]. Aerobic composting (reduced risks of phytotoxiciy) with results of production of stable organic matter (humus), CO_2, N, water, heat and nutrients, hormones and enzymes. Coffee pulp composting is generally made by earthworms and effective micro-organisms [3, 6-7, 19-24].

Co-composting with accelerators either mineral (urea) or organic (sappy green manure) is used to hasten, shorten stabilisation and improve the compost quality, while reducing lengthy composting time requirement [25-27]. Most studies have used microrganisms and inorganic fertilizers as compost activators to improve compost quality [25, 26-27]. Microorganisms used in the composting process belong mostly to lactic acid bacteria, yeasts, photosynthetic/photoautotrophic bacteria, actinomycetes, fermenting fungi [30].

Additives to compost affect many composting parameters: temperature, pH, moisture content, aeration, reduction of gas emissions and mobility of mineral ions, increase in plant available nutrients, decrease N leaching, heavy metal mobility and composting time, as well as stimulation of microbial activity [31]. According to these investigators, as many as 20 factors control the composting process : lignin and polyphenol contents, biotoxic substances, phytotoxic substances, organic acids, density of composted organic materials and their porosity, aeration (O_2 pressure), dimension of organic particules with regard to their specific surface and their contact with microorganisms, N, P, K, Ca, Mg and micro-nutrients contents, C/N ratio, pH of the soil and the composted and composting materials, Cation Exchange Capacity (CEC), temperature of the thermophilic phase (50-60° C), humidity (50-60 %), heavy metals (Cd, Pb, Cr, Zn, Ni, Hg, Co), salinity, plant and animal pathogens, soil mesaufona and effective microorganisms [6, 17, 19, 22, 24].

The concept of Effective Microorganisms has been introduced by Professor Teruo Higa through EM Research Organization, Inc (EMRO), Uruma, Okinawa, Japan [17]. The EM package is made of selected species of lactic bacteria (*Lactobacillus casei*), photosynthetic bacteria (*Rhodopseudomonas palutris*) and yeasts (*Saccharomyces cerevisiae*) and other types of organisms, mutually compatible [15,17]. Defined as « mixed cultures of beneficial and naturally-occurring microorganisms that can be

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applied as inoculants to increase the microbial diversity of soil and plant » used in acceleration of beakdown of crop residues, agro-industrial and organic wastes in general [19-21].

The quality of the composted organic materials can be improved by adding compost accelarators or boosters. Such composting adjuvants could be mineral N such as urea or sources of easily decomposable C (like molasses, bagases) with a low C/N [32]. Sources of N, generally inorganic fertilizers (urea) have been experimented in Burundi in the late 1990's without much success, because inorganic N is not accessible to poor farmers [25]. Recently, replacement of mineral additive by green manure or leguminous crop residues has been proposed as alternatives to mineral additives [26-27].

Bean (*Phaseolus vulgaris* L.) is the most important grain legume in Burundi with annual production of 300,856 MT per year [33]. Bean represents 16.5 % of the total cereal equivalent (EC) of the food consumption per year in the country, more than maize (10.4 %) but largely surpassed by cassava (41 %). An estimate of bean crop residues produced per year based on the yearly production above and a havest index (HI) of 0.46 would be estimated at 138,394 MT. This quantity could be used as coffee pulp compost accelarators among other uses.

One of the ways to increase crop production in Burundi is through valorization through composting of organic sources available on farm. These include livestock manures, green manures, composted materials, crop residues and agro-industrial subproducts [34]. On the other side, manure demand and requirements on farm are far higher than their availability [26]. Therefore, in that context, we contend that coffee pulp constitutes a potential source of compostable organic materials.

Composting accelerators, such as filter cake from sugar industry and poultry litter enhance composting of coffee pulp, promoting a shorter stabilization and yielding a higher quality of compost in comparison of coffee pulp alone [3, 35]. This valorisation of coffee pulp is a response to a current trend of growing coffee on organically fertilized soils [3].

The general objective of the present study was to explore the agricultural potential of coffee pulp and, at the same time, reduce environmental pollution, while initiating an eco-sustainable agriculture with farmer's participation. The specific objective of the investigation was to evaluate the potential fertilizer value of coffee pulp compost using EM and bean residues (BR) on potato (*Solanum tuberosum* L.) and bean (*Phaseolus vulgaris* L.) yields. Our research hypotheses were as follows: i) Additives of effective micro-organisms (EM) or bean residues improve the fertilizer value of coffee pulp compost; 2) Coffee pulp compost could be used as a sound total or partial alternative to organo-mineral fertilizers in Burundi.

2. MATERIALS AND METHODS

2.1 Experimental site and soils

The study was conducted on plots provided by collaborative farmers in Mbuye and Bukeye Communes, Muramvya Province (Burundi). The experimental sites are characterized by a bimodal rainfall distribution with a long rainy season from february to may and a short rainy season from september to december. The two rainy seasons are separated by a short dry season from mid-december to mid-january, and a long dry season from june to august. Mean annual rainfall is 1078.4 mm. Average annual temperature is 20.8°C. Mbuye geographic information is as follows: Latitude = 3°3'54'' South, Longitude = 29°45'35'' East. Soils of Mbuye commune are considered of poor quality, acidic, deficient in P, B, Ca, Mg and Al-saturated [36].

Prior to trials installation, composite soil samples were randomly collected at 0-20 cm depth, air-dried, bulked, crashed and sieved through a 2-mm sieve. Performed soil chemical analyses included pH, % C, % N, cation exchange capacity (CEC), exchangeable Ca^{2+}, Mg^{2+}, K^{+}, Al^{3+} and H^{+}. Soil pH was measured using a 1:1 soil-water mixture [37]. Organic C was determined using the Walkely-Black wet oxidation method [38]. Organic N was measured as described by Bremner and Mulvaney [39]. Cation exchange capacity (CEC) was determined by the 1 M ammonium acetate saturation method (pH=7.0) [40]. Exchangeable cations were determined by ICP spectrophotometry after extraction by the Mehlich III method [41]. Selected chemical characteristics are shown in Table 1.

2.2 Planting materials and fertilization

Two weeks before planting, an equivalent 1.500 kg/ha of dolomitic lime ($CaCO_3.MgCO_3$) was broadcasted over the entire experimental field. Manure and compost were applied at 10 T/ha at the seeding. In treatments receiving mineral fertilizers, all the required quantities of DAP and KCl were applied at planting, while urea application was split: half applied at the first weeding, the remainder at hilling. The precedent crop was maize (*Zea mays* L.) for both Victoria and Mabondo trials. Potato fertilizers formula was 60-90-60, obtained by bulking 200 kg of DAP, 100 kg of KCl and 50 kg of Urea. Bean fertilizer formulation was 18-46-0 equivalent to 100 kg DAP.

The first potato (*Solanum tuberosum* L.) crop, variety Victoria (90-100 days' maturity and 20-25 T/ha yield potential) released in 1998 was installed in season 2016B on 18 March and harvested on June 26. Mabondo potato variety (120-130 days and 25-30

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T/ha yield potential) was installed during season 2017A on 22th October 2016 and harvested on 3rd February 2017. Both Victoria and Mabondo trials were set up in a completly randomized block design with 4 replicates. Experimental units were 6 m x 2.4 m for the Victoria trial and 6 x 2.8 m for the Mabondo experiment. Both experimental potato trials adopted an 80 cm x 40 cm spacing equivalent to 31.250 plants/ha plant density. Phytosanitary treatments (Dithane and Ridomil) were applied as recommended by research.

The bean (*Phaseolus vulgaris* L.) variety used in the study was the climbing Kinure released in 2013. This biofortified variety has a high commercial value [42]. It has an extended adaptative agro-ecological zone ranging from 1550 to 2650 m asl with a wide tolerance to pests and diseases. Kinure variety yields as much as 2 500 kg/ha on station decreasing to 1 500 kg/ha under farmers' conditions [42]. The bean crop was installed in season 2016B in a completely randomized block design with 4 replicates and 16 experimental units. Each experimental unit was 4.5 m long and 3.4 m wide with 0.4 m x 0.2 m spacing. Planting occurred on 25th February 2016 and harvested on 23th May 2016.

2.3 Composting procedures and chemical analyses

Processed coffee pulp was collected from a private coffee processing factory own by SCERT. The factory capacity is 300 T coffee berries at 40 % pulp [15-16, 35, 43], leading to 120 T of compostable coffee pulp annually. The samples of organic materials were dried at 70°C to a constant weight, kept in labeled polythene bags before chemical analyses were performed using standard procedures. Samples were analyzed for pH, % C, % N, % P, % Mg and % Ca. Total N was determined by digestion with sulphuric acid (H_2SO_4) and hydrogen peroxyde (H_2O_2) followed by steam distillation [39]. Total C was determined by wet combustion [38]. Total P, K, Ca and Mg were analyzed by ICP spectrometry after digestion with HNO_3 and H_2O_2 at 120°C for 3 hours [41].

Selected chemical properties of the organic materials used in the two studies are shown in Tables 2 and 3.

2.4 Measured Parameters

Potato (*Solanum tuberosum* L.) yields and yield components were evaluated on plot basis and extrapolated to a hectare basis. Potato yields were categorized into small size (SST < 35 mm) medium size (MST: 35-65 mm) and big size tubers (> 65 mm). Grain yield was the only parameter recorded for the bean (*Phaseolus vulgaris* L.) crop.

2.4. Experimental Design and Statistical Analyses

The first Victoria potato variety trial and the bean trial used a coffee pulp compost aged 8 months. On the contrary, the Mabondo experiment, in which treatments T_2 and T_3 were omitted, used a 3-month coffee pulp compost. Treatments under evaluation were:

T_1: Coffee pulp (CP) alone

T_2: CP + 1 L molasse + 1 L Effective Microorganisms (EM) + 37 kg of dolomitic lime

T_3: CP + 16.75 kg of bean residues (BR) + 16.75 kg of soil (forest soil)

T_4: CP + 2 L molasse + 2 L EM + 74 kg of dolomitic lime

T_5: CP + 33.5 kg of bean residues (BR) + 33.5 kg of soil (forest soil)

T_6: Farm Manure (FM) + 1.5 T/ha dolomitic lime + 200 kg/ha DAP+ 100 kg/ha KCl + 50 kg/ha Urea

T_7: Control (non amended/fertilised)

EM is a fabric of confidential composition commercially available [19]. The EM used in the present study was obtained from Rwanda. T_6 treatment is equivalent to the recommended organo-mineral potato fertilization rates. In the present experiments, it is considered a reference.

Data were subjected to an analysis of variance (ANOVA I) using Genstat Discovery package VSN International [43]. When statistical significance was observed, mean separation was performed with the Newman-Keuls method based on the Least Significant Difference (LSD). [44].

3. RESULTS AND DISCUSSION

3.1 Characteristics of the soil used in the study

Chemical characteristics of teh soils used in the two experiments are depicted in Table 1. No chemical analyses were performed for Ca^{2+}, Mg^{2+} and K^+ contents in the second potato (Mabondo) experiment.

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Table 1. Chemical characteritics of used soils

Parameter	Soil 1 (2016B)	Soil 2 (2017A)
pH_{eau}	5.65	4.69
% C	0.86	0.79
% N	0.08	0.06
C/N	10.75	13.17
P Olsen (ppm)	46	21
CEC ($cmol_c$/kg of soil)	8.9	7.4
Ca^{2+} ($cmol_c$/kg of soil)	3.68	-
Mg^{2+} ($cmol_c$/kg of soil)	0.44	-
K^+ ($cmol_c$/kg of soil)	0.29	-
Al^{3+} exchangeable ($cmol_c$/kg of soil)	0	2.01
H^+ exchangeable ($cmol_c$/kg of soil)	0.25	0.26
% Al exchangeable	0	27.2
Ca^{2+}/ Mg^{2+}	8.37	-
Mg^{2+}/ K^+	1.52	-
$(Ca^{2+}+ Mg^{2+})/K^+$	14.21	-

Chemical analyses of soil 1 indicate a slightly acidic soil with very low in % C and % N, lox in P, deficient in Mg and K, with an optimal C/N and average content in Ca. Soil 2 was acidic, very low in % C and N, deficient in P with high risk of Al toxicity [36].

3.2 Characteristics of composts used in the study

Table 2 below shows the chemical characteristics of the 8-month coffee pulp compost used in the Victoria potato variety and bean experiments. Symbols $EM_{1,2}$ or $BR_{1,2}$ denote simple and double application rates of effective microorganisms and bean residues as described under paragraph 2.4.

Table 2. Chemical composition of used organic materials in Experiment 1 (8-month old compost)

Organic material	pH_{H2O}	% C	% N	C/N	% P	C/P	N/P	% K
CP + EM_2	7.73	4.53	1.24	3.65	0.27	16.78	4.59	0.21
CP + EM_1	7.16	5.82	1.41	4.13	0.30	19.40	4.70	0.59
CP + BR_2	7.59	4.69	3.87	1.21	0.27	17.37	14.33	0.75
CP + BR_1	7.55	4.92	1.21	4.07	0.32	15.38	3.78	0.97
CP alone	6.74	4.78	1.50	3.19	0.36	13.28	4.17	0.75
Farm manure	8.68	7.24	0.73	9.92	0.32	22.63	2.28	0.57

Obtained compost materials had an earthy musty smell like a forest soil, dark brown in color and crumby. Chemical analyses performed on organic materials listed in Table 2 show near neutral to alkaline pH in all organic materials. Farm manure was characteized by a pH as high as 8.68, illustrating its liming potential. Typical compost pH values range between 6 (plant based compost) and 9.5 (manure based compost) [44-45]. The values of pH registered in our experiment are in the standard range [46].

Percent organic C were very low (< 7 %) for all organic materials, concomittantly leading to low C/N ratios, ranging from 1.2 (CP + BR_2) to 9.9 (farm manure). These very low C/N values were observed for the coffee pulp compost boosted with BR and EM additives are uncharacteristic. Percent N accross coffe pulp composts was in a narrow range (1.21-1.50), with the exception of coffee pulp composted with the highest BR application rate with % N equals 3.87, twice or thrice as much as other coffe pulp composts. Percent total P was comparable for all treaments ranging from 0.27 % (CP + BR_2 and CP + EM_2) to 0.36 % (CP alone). Percent % K was lowest (0.21) for the coffee pulp compost amended with EM_2, and, in the decreasing order, highest (0.97) for coffee pulp composted with BR_2, (0.75), CP alone (0.75) and finally coffee pulp composted with EM_1 (0.59). Apart from the % N content, % K content constitutes the discriminating factor of tested CP treatments.

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Table 3. Chemical composition of used organic materials in Experiment 2 (3-month old compost)

Organic material	pH_{H2O}	% C	% N	C/N	% P	C/P	N/P	% K
CP + BR_2	8.47	9.84	1.19	8.27	-	-	-	-
CP + EM_2	8.00	6.52	0.73	8.93	-	-	-	-
CP alone	8.09	9.37	1.02	9.19	-	-	-	-
Farm manure	8.37	19	1.56	12.18	0.30	63.3	5.2	1.22

The second composting operation lasted 3-months and included limited treatments as illustrated in Table 3 above. Comparatively to the 8-month duration compost, pH values were more alkaline (> 8.0) with relatively higher % organic C and globally comparable % N for CP + BR_2 (1.19) and CP alone (1.02) but lower for CP + EM_2 (0.73). Consequently, deducted C/N values were higher (8-12) in comparison to chemical analysis data associated with the first compost set. For the second experiment, only farm manure could be characterized for % N, % P and % K contents. In this specific farm experiment (Tables 2 and 3), manure had equivalent % P but twice as much % N and K as compared to the farm manure used in the first coffee pulp compost of 8-month duration.

Our composting experimentations compare quite well with other similar initiatives. For example, using effective microorganisms has materialized into increased N, P, C, K contents, but were characterized by reduction of heavy metals concentration [19]. Similarly, in an experiment combining pile needles, goat manure and effective microorganisms, it was found that CEC, Ca, Mg and K increased with a neutral pH and a low C/N [16, 46].

Generally, pH values situated between 6 and 8 are indicative of mature compost [3, 22, 47-48], although some other investigators reported that a high pH is generally indicative of immature compost with a tendancy to loose ammonia through volatilization [34]. On the other side, compost with low pH values contain higher concentrations of organic acids. Immature compost may also contain high levels of organic acids with the risks of damaging plant growth [34].

In a rice (Oryza sativa L.) hull and olive (Olea europaea L.) dough compost improved by EM, rice crop yield and quality were higher, and soil fertility and plant availability and nutrition (N, P, Ca, Mg, K, Fe, Cu, Mn, Zn, B) was improved compared to conventional farming [1, 5, 16, 17, 22-23, 48-49]. Moreover, a reduction of soil acidity and salinity was noticed, concommittantly with a reduction of irrigation and an increase in WHC and water application efficiency [1, 17]. Similar effects of compost improved by EM on crop yields, soil physico-chemical properties, above and below ground biomass, plant height and soil organic C content were reported elsewhere [1, 13].

Table 4 below compares selected nutrient contents of treatments under evaluation in our studies and some animal manures and improved maize residue composts.

Table 2. Comparative chemical composition of coffee pulp compost and farm manure

Organic Material	% N	% P	N/P	% K
CP + EM_2 (1)	1.24	0.27	4.59	0.21
CP + EM_1 (1)	1.41	0.30	4.70	0.59
CP + BR_2 (1)	**3.87**	0.27	14.33	0.75
CP + BR_1 (1)	1.21	0.32	3.78	**0.97**
CP compost alone (1)	1.50	0.36	4.17	0.75
Farm manure (1)	0.73	0.32	2.28	0.57
Farm manure (1)	1.59	0.40	3.98	1.78
Maize compost +Calliandra (2)	0.73	0.13	5.62	0.22
Maize compost + Tithonia (2)	1.24	0.14	8.86	0.26
Poultry manure (3)	1.78	**2.00**	0.89	**1.80**
Swine manure (3)	0.14	0.51	0.27	**3.31**

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(1) This study (2) Kaboneka et al., 2021[27] (3) Unpublished data (S. Kaboneka)

Data on nutrient contents generated through our coffee pulp compost globally compare well with N, P, K chemical values observed in improved crop residue composts and animal manures. Besides $CP+BR_2$ which shows higher % N content, other organic materials indicated in Table 4 are characterized by close values, with the exception of swine manure (0.14 % N), CP compost alone and maize compost + calliandra (0.73 % N). Typical crop residues composts show low % P in comparison with coffe pulp compost and animal manures (farm and swine manures). However, poulty manure contains 4 to 15 times % P as much as in other organic materials listed in Table 4. Percent K content registered in CP composts used in our experiments are higher than % K contents in crop residue compost but lower than those associated with animal manures.

3.3 Bean yields

Table 5 illustrates the comparative effects of coffee pulp composts on bean (*Phaseolus vulgaris* L.) yields as showed by an analysis of variance (ANOVA 1).

Table 5. Effect of coffee pulp compost improved with EM and Bean Residues (BR) on bean yields

Treatment	Yield --- kg/ha---
Farm manure + 18-46-0 (T_6)	1314±483a
CP + BR_2 (T_5)	1270±459a
CP + EM_2 (T_4)	1262±253a
CP + BR_1 (T_3)	1138±349ab
CP + EM_1 (T_2)	1061±344ab
CP compost alone (T_1)	840±302bc
Control (T_7)	605±216c
LSD	337
General Mean	1070
Probability	0.003**

Mean values with identical letters within the column are not statistically different at $p < 0.05$.

Statitistical analysis performed on bean crop yield (variety Kinure) highlights a significant ($p < 0.05$) difference between tested treatements. Highest bean yields were recorded with T_6 (FM+18-46-0) followed by T_5 (CP+ BR_2) and T_4 (CP+EM_2), while lowest yields were observed with T_7 (CP alone) and T_1 (Control). The latter treatments (T_7 and T_1) were significantly inferior to T_6, T_5 and T_4. A fine observation of yield data shown in Table 5 shows an additive application rate effect, as treatments amended with higher rates of bean residues (T_5) and EM_2 (T_4) yielded 16 to 20 % more than treatments which received the lower additive rates (T_3 and T_2). Recommended bean organo-mineral fertilization (T_6) was not significantly differerent from the coffeee pulp compost improved with EM and BR. Comparatively to the coffee pulp alone, additions of compost accelerators increased bean yields by 51.1 % for T_5 (CP + BR_2), 50.2 % for T_4 (CP + EM_2), 35.5 % T_3 (CP + BR_1) and 26.3 % respectively for T_2 (CP + EM_1). Interestingly, when the recommended organo-mineral fertilizer treatment (T_6) is compared to the two highest yielding coffe pulp compost (T_5 and T_4), it appears that gains in bean yields were only of 3.5 and 4.1 %, respectively. From this finding, we conclude that the three top treatments, namely T_6, T_5 and T_4, are equivalent and substituable. Moreover, treatments T_5 and T_4 being equivalent in bean yields, added to the fact that EM is imported and not locally available and surely problematic with regard to conservation and manipulation, we conclude that T_5 made of coffee pulp compost enriched with the double application rate of bean residues is more accessible to farmers and could be disseminated as a potential coffee pulp based source of organic fertilizer.

3.3 Potato yields

Effects of coffe pulp composts were evaluated on two potato varieties, Victoria (Table 4a) and Mabondo (Table 4b). A straitfoward observation to be stressed out from the Victoria experiment is that obtained yields were low, whe compared to the variety potential (20-25 T/ha). This was due to the rainfall shortage during the experimental period (march-june 2016).

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Table 4a. Effect of coffee pulp compost improved with EM and Bean Residues on Victoria yields.

Treatment	SST	MST	BST	Total
	------kg/ha			------
Farm manure + 60-90-60 (T_6)	781±285a	4570±1505a	430±357a	5781±1813a
CP + BR_2 (T_5)	195±78b	3984±1474a	391±342a	4570±267ab
CP + EM_2 (T_4)	234±90b	3633±1575a	273±300a	4141±2344ab
CP + BR_1 (T_3)	391±372b	4492±1422a	352±316a	5234±1279ab
CP + EM_1 (T_2)	313±128b	3984±1439a	313±367a	4609±1738ab
CP compost alone (T_1)	391±90b	4023±590a	313±285a	4727±547ab
Control (T_7)	313±221b	3164±1475a	78±341a	3555±941b
LSD	299	1591	461	1823
General Mean	374	3979	307	4660
Probability	0.014*	0.573NS	0.77NS	0.05*

Mean values with identical letters within the column are not statistically different at $p < 0.05$.
NS = non significant ($p > 0.05$).

Statistical analyses were performed on Victoria potato variety total yields and its yield components: small size tubers (SST), medium size tubers (MST) and big size tubers (BST). Across all treatments, MST category was the major yield compost and represented more than 80 % of the total potato yields.

No satistical differences ($p > 0.05$) between all tested treatments were observed for the MST and BST potato yields. For SST yields, T_6 treatment (Farm manure + 60-90-60) stood alone and was statistically superior ($p < 0.05$) to the rest of treatments, themselves not statistically different from each other. On the basis of the total yields, only T_6 treatment was statistically superior ($p < 0.05$) to the control (T_7) and did not significantly demark itself from other coffee pulp compost treatments.

Nevertheless, beyond statistics, total potato yields as well as medium sized tubers (MST) yields followed the increasing order: $T_6 \geq T_3 \geq T_1 \geq T_2 \geq T_5 \geq T_4 \geq T_7$. The highest total potato yield was recorded with T_6 (FM+60-90-60) treatment (5781±1813) followed by T_3 (CP+BR_1) treatment (5234±1279). When a similar comparison between coffee pulp compost receiving double EM and BR residues application rates to those with the single applications rates, we observe a decrease in yields with increasing additive applications rates, ranging from – 14.5 % (between T_5 and T_3) to – 11.3 % (between T_4 and T_2). Thus, contrarily to the bean experiment reported above, increasing coffee pulp compost accelerators rates did not materialize into yield gains. Among coffee pulp composts, the only treatment close to the organo-fertilizer recommended treatment is T_3 (CP+BR_1) treatment.

The second potato experiment was performed on Mabondo variety from october 2016 to february 2017 (2017A).

Table 4b. Effect of coffee pulp compost improved with EM and Bean Residues Mabondo yields.

Treatment	SST	MST	BST	Total
	------ kg/ha			------
Farm manure + mineral fertilizer (T_6)	1690±2163a	24934±9112a	2750±948a	29374±10691a
CP + EM_2 (T_4)	223±258a	9671±2738b	2080±394a	11974±2894b
CP + BR_2 (T_5)	0	8235±3303bc	1762±706a	9997±4029b
CP compost alone (T_1)	0	7398±2879b	1880±911a	9278±2958b
Control (T_7)	0	4445±3761bc	2728±944a	7173±3689b
LSD	1484	4294	1031	4875
General Mean	383	10937	2240	13559
Probability	0.114NS	< 0.001***	0.16NS	< 0.01**

Mean values with identical letters within the column are not statistically different at $p < 0.05$.
NS = non significant ($p > 0.05$).

The second experiment evaluating coffee pulp composts on potato, variety Mabondo tested 5 treatments: T_7, T_6, T_5, T_4 and T_1. Treatments corresponding to the lowest EM and BR rates were dropped out. Similarily to the first potato study on Victoria variety,

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no significant differences ($p > 0.05$) were observed between tested treatments for SST and BST yields for Mabondo variety. However, significant differences ($p < 0.05$) were noticed for MST and total yields. In both the MST and total potato yields, the coffee pulp compost complemented with mineral fertilizer (N-P_2O_5-K_2O 60-90-60) produced significantly higher yields than the other 4 treatments (T_7, T_6, T_5, and T_4), which were not significantly different among them, for either MST and total yields.

On a strictly yield basis, beyond statistics, the 5 tested treatments ranked as follows: T_6 (FM+60-90-60) >> T_4 (CP+EM_2) > T_5 (CP+BR_2) > T_1 (CP compost alone) > T_7 (Control). For all but the control treatment (62 %), most of the potato yields (80 %) were in the MST category which is commercial seed oriented. From this finding, we derive that application of coffee pulp composts and farm manure + 60-90-60 not only increased potato yields, but at the same time improved the quality of the yields, in terms of the seed oriented MST potato yield component.

The coffee pulp compost boosted by microbial accelerators (T_4) produced 2 T of potato yield more than the bean residues improved coffee pulp compost (T_5). Compared to the control treatment, gains in yields were 22201 kg for T_6 (FM+60-90-60), 4081 kg for T_4 (CP+EM_2), 2824 kg for T_5 (CP+BR_2) and 2105 for T_1 (CP compost alone). Hence, contrarily to the bean and Victoria potato variety, coffee pulp improved by EM (CP + EM_2) gave better yields as compared to the treatment with BR (CP + BR_2). A difference of about 2 T of potato yield was observed between the two treaments (T_4 and T_5).

When compared to bean yields registered under the CP compost alone treatment, a yield gain varying between 200 (T_2) to 400 (T_5) kg were observed with BR and EM additions. Such gain was only about 500 kg with the complete recommended organo-mineral fertilizer application rate (T_6). Similar analyses performed on Victoria potato experiment indicate either losses (T_2, T_4 and T_5) or insignificant gain of not more than 500 kg observed with treatment T_3 (CP + BR_1). On the other side, with reference to the CP compost alone, the Mabondo experiment showed potato gain yields of about 700 kg for T_5 (CP + BR_2) and 4 times as much for T_4 (CP+EM_2). Some research results reported by other investigators are in accordance with our findings. As an illustrative example, Berecha and his collaborators (2011) [51] have reported an increasing effect of coffee pulp compost on tomato seedling growth and yield.

4. CONCLUSION AND PERSPECTIVES

Currently associated with environnmetal pollution potential, coffee pulp could be of agriculture interest if it is transformed into organic fertilizers through composting. Hence, coffee pulp composting and agriculture use in crop production could be a sound agronomic solution to a pressing environmetal concern. Bearing these facts in mind, SCERT Kiyago, in collaboration with ADISCO/UPH and the Faculty of Agronomy and Bio-Engineering (FABI) of the University of Burundi established 3 field trials testing coffee pulp composts fertilizer values on Victoria potato variety, Mabondo potato variety and Kinure bean variety. Used coffee pulp (CP) compost accelarators were effective microorganisms (EM) and bean residues (BR) applied at two rates: simple (EM_1 and BR_1) or double (EM_2 and BR_2). In all three experiments, various CP composts were compared to recommended organo-mineral fertilizers and the controls. Obtained results on bean experiment and the first experiment (Victoria) indicate that the recommended organo-mineral fertilizers applications were not significantly differerent from coffeee pulp composts improved with EM and BR. However, in the second potato (Mabondo) experiment, the recommended fertilizer application produced significantly higher yields than all other treatments, which were not significantly different among them. The second and third potato producing treatments were T_5 (CP+ BR_2) and T_4 (CP+EM_2). For both the Victoria and Mabondo experiments, 80 % of the yields were in the medium size tubers (MST) category, which is the yield component oriented towards seed production. From this finding, we derive that application of coffee pulp composts improves the quality of the potato yields. Overall, with regards to their effects on tested crops, bean (*Phaseolus vulgaris* L.) and potato (*Solanum tuberosum* L.), coffee pulp composts improved with he highest application rates of EM and BR were statistically equivalent and therefore substituable. Nevertheless, due to the fact that EM is imported and not locally available and surely problematic with regard to cost, conservation and manipulation, we conclude that coffee pulp compost enriched with the double application rate of bean residues (BR_2) is more accessible and reproducible by farmers. We then advance that this compost treatment is the one to be disseminated as a potential coffee pulp based source of organic fertilizer. We further suggest to further test the comparative efficacy of CP+BR_2+mineral fertilizers against the recommended farm manure+mineral fertilizer applications for bean (18-46-0) and potato (60-90-60) crops. Such an additional experimental study would evaluate the substituability of farm manure by CP compost boosted by bean residues addition.

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