EVALUATION OF THE PHYSICO-CHEMICAL PROPERTIES OF CATTLE AND KITCHEN MANURES DERIVED COMPOSTS AND THEIR EFFECTS ON FIELD GROWN *Phaseolus vulgaris* L.

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ABSTRACT

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Composting was conducted in the guinea-savannah zone of Cameroon from January to April 2007 and the field trial was carried out during the April-July cropping season of the same year. The aims of the study were to improve the soil fertility with cattle and kitchen manures derived composts and to assess their effects on common bean (*Phaseolus vulgaris)* productivity in the field. Determinations of temperature, pH, electrical conductivity (EC), organic matter, nitrogen phosphate and sulphate contents of composts, as well as growth of *P. vulgaris* seeds were assessed. There were decreased fluctuations in temperature during the composting process. The pH of cattle manure (CM), kitchen manure (KM) and the mixture of cattle-kitchen manures (CKM) derived compost ranged from 5.94-6.94, and was significantly ($p < 0.001$) higher than the constant pH (4.88) of the growing soil (GS) or control. Compost improved the overall soil fertility by significantly ($p < 0.024$) increasing the organic matter, nitrogen, phosphate and sulphate contents. The losses in organic matter were respectively 6.51, 12.86 and 7% (w/w) for CM, KM and CKM. Cattle and kitchen manures derived composts consistently ($p < 0.001$) induced enhanced nodulation and *P. vulgaris* L. biomass at 30 days after planting. Amending plots with CM and KM derived composts significantly increased the seed yield at maturity by respectively 1.53, 1.43 and 1.86 folds, compared to that of the control. These results suggest that not only the quality, but also the source of composting substrate were important for improving growth and yield of organically grown *P. vulgaris* L in Ngaoundéré.

Key words: Organic manures, compost properties, *Phaseolus vulgaris*, yield

INTRODUCTION

One of the main constraints to populations in towns and particularly, students living in hostels is the management of their organic wastes, because of the slowness of the urban community services in charge of this duty. Hence, mountains of wastes are built up daily in public environments, around houses, cities and universities restaurants. Within these wastes, biological decomposition and putrefaction are taken place resulting in proliferation of pathogens which are the causative agents of various human diseases. In certain cities in contrast, waste stores are created far away from living environments and are controlled either by incineration or composting. After heavy rains, leaching from these wastes can constitute a source of pollution to rivers and neighbouring wells (Follea and Brunet, 2001). Despite its efficacy, incineration of wastes release duts, ashes, and dangerous gases such as CO_2, CO, H_2SO_4, which are the main pollutants of the atmosphere (Favoino and Hogg, 2008). Composting is a controlled natural aerobic process in which beneficial micro-organisms (bacteria, fungi, protozoa, insects) reduce and transform organic wastes into a useful end product called compost (Michel *et al*., 2002; Ryckeboer *et al*., 2003, Charnay, 2005). This process naturally occurs, but at a much slower rate than can be achieved by controlled manipulation of organic residues. The main goal of agriculture is to obtain food for staple diet of human and animals, satisfy their energetic needs or use as basic substrates in agro-industries. The optimisation of agriculture is more often impeded by the low soil fertility (Barbier and Cattin, 1994). However, the major problem linked to agriculture is maintaining this soil fertility, while exploiting lands regularly. The continuous exploitation of lands leads to impoverishing of soils and lowering of crop yields. These constraints have stimulated farmers to abandon lands into fallow (Bosc *et al*., 1990). However, the demographic pressure has constrained them to reduce the fallow time, thus the efficacy of the process (Floret and Pontanier, 2001). On the other hands, chemical fertilizers that are either natural or synthetic are also used to increase crop yields, but their high cost is not always affordable to poor farmers (Gonlaïna, 2003). Moreover, their negative effects on the environment, plants and animals when they are mis-used have resulted to water pollution and acidification of soils (Barbier and Cattin, 1994). To overcome these difficulties, biological fertilizers have often been used (Landais *et al*., 1990; Ismaïli, 1994; Silguy, 1991; Ngakou *et al*., 2007). Nevertheless, the lack of appropriate structures of production of bio-inoculants restrains the vulgarisation of this innovative technology in developing countries. Other alternatives can be the use organic fertilizers that include: (i) fresh manure that cannot be higher than de 170 kg equivalent nitrogen.ha^{-1} $year^{-1}$ and may engender competition for oxygen between soil decomposers of organic matters, (ii) chicken manures that cannot be incorporated to soil in its fresh state due to numerous pathogens that it contains (Znaïdi, 2002); or (iii) compost. Compost has the advantage of improving the soil quality and crop yields through increased oligoelements

(Wiart, 2000), rendering plants resistant to diseases (Tremier *et al*., 2002), and thus is appropriate for a sustainable agriculture for poor resource farmers (FAO, 2006). It also contributes to sanitation of the environment, or considerable reduction of intoxication and diseases risks (Mariet, 1996). Despite these attributes, composting is still practiced in many countries at a domestic scale. There is a need to optimise this process at industrial level, notably by foremost mastering the factors influencing it. The diet of the population in the guinea-savannah to which belongs Ngaoundéré is mainly based on cereals that are deficient in certain proteins found in grain legumes. Legumes account for 27% of the world's primary crop production, with grain legumes alone contributing 33% of the dietary protein needs of humans (Vance *et al*., 2000). Grain legume seeds generally are lysine-rich, and therefore, can complement the nutritional profiles of cereals and tubers in the diet (Duranti and Gius, 1997). All these attributes can account for the promotion of their growth. It is thus important to supplement the diet of the aforementioned population with grain legumes such as *P. vulgaris* (L.). This research was carried out to produce composts from cattle and kitchen manures, and evaluate their potentials on growth of *P. vulgaris* in Ngaoundéré.

MATERIALS AND METHODS

Description of the composting site

The composting experiment was conducted at the Ngaoundéré University campus in 825 m^2 area (latitude: 7°24.635'N; longitude: 13°32.827'E; altitude: 1091.49 m) in the Adamawa province of Cameroon. The climate is of the sudano-guinea type, characterized by a rainy season (April to October) and a dry season (November to March). The annual rainfall is 1479 mm, with a coefficient of variation of 9.8 % (Yonkeu, 1993). The temperature ranges from 5 °C to 7 °C for the minima, and 30 °C to 35 °C for the maxima, while the average hygrometry varies from 37.7 % to 81 % (Mope Simo, 1997).

Substrates of composting

Cattle manure originated from a sheep-pen located nearby the campus were sequentially collected from 6-7 am everyday according to its availability. Kitchen manures were collected from Sorbonne, Glad, Discipline and university hostels and restaurant waste bins from 17-18 pm daily. All the particles resistant to biodegradation were manually discarded, leaving potatoes, banana peelings, stems of legumes, residues of fruits, and other food wastes. Both kitchen and cattle manures were stored in 50 kg bags and then, transported in the composting site using a rickshaw.

Composting inoculum and Experimental design

The composting inoculum was prepared by mixing 40 kg biodegradable wastes to 10 kg of growing soil. The mixture was incubated for 14 days to enable proliferation of decomposers that were to be used in the process. Composting in pile (Rieux, 2006) was used in the process. It consists of successive layers of wastes organized in 1.5 m^2 piles of 1m height. A total of 100 kg of substrate was used for each of the waste types: cattle manure (CM), kitchen manures (KM) and the mixture of cattle-kitchen manures (CKM). From the bottom to the top, each pile was made up of layers of *Abelmochus esculentus* stems; substrate; inoculum; grasses; and growing soil. Each pile was covered with a transparent white plastic sheet bore with holes to ensure ventilation. The experimental design was factorial (4 x 3), with four treatments represented by the three types of substrates and the control consisting of growing soil (GS), each of which was replicated thrice.

Control of the composting process

For the process to be conducted favourably, certain parameters such as temperature, humidity, ventilation and aeration were to be controlled. Temperature was measured using an industrial thermometer graduated from -1°C to 240°C, by fixing this apparatus in the pile for 5 min between 10-12 am and 15-17 pm a day. The ambient temperature was also measured by leaving the thermometer in the air for 5 min. Each pile was watered with 15L tape water once a week to soften the substrate and thus, facilitate their degradation by decomposers. The holes born in the piles were aimed to provide ventilation, hence oxygen needed by micro-organisms for their growth during the process. In addition, turning the piles after every two weeks with a shovel was to ensure the homogenous mixture of the components of pile with added oxygen. At maturity, the compost obtained was stored in 50 kg bags until needed for in field experiments.

Assessment of the chemical quality of composts

After each turning, 100 g of compost from each pile was sampled for chemical analysis that was performed in the Food Chemistry laboratory of the National High School of Agro-nutritional industry. 0.5 g of each sample was diluted in 500 ml distilled water, homogenized for 30 min and then, let to settle for 3 days to recover the supernatant that was submitted to the chemical analysis. The soil pH was measured from 20g of air dried sample suspended in 50 ml distilled water as described by Okalebo, (1993). The assessment of conductivity was performed through the measurement of the resistivity on a resistimeter CD-60 (Djakou *et al*., 1986).

The resistivity of samples is given by the relation: $R = \rho = R \times S/L$.

Where
R is the resistance of the compost solution expressed in ohm (Ω)
ρ is the resistivity of the compost solution expressed in (Ω/cm)
L is the length of the liquid column (cm)
S is the surface of the section (cm^2)

The orthophosphates, sulphates and irons in the samples were assessed based on the methods described by Rodier (1978). The official method of analysis was used to assess the total nitrogen content of samples (AOAC, 1980). Compost organic carbon content was determined by calcination method (Djakou *et al*., 1986): A compost sample (10 g) = P_0 was weighed in a chinaware vat and incinerated at 105°C for 24h to colour change (black). The discolorated sample was weighed again (P_1), and the percentage of carbon in the sample assessed as follow: $\%C = (P_0 - P_1.)/ P_1 \times 100$.

Evaluation of different composts on Phaseolus vulgaris growth and yield
The 21.78 m² experimental plot established on one year old sweet potato fallow was cleaned with cutlasses, plough with hoes, and organized in (600 x 60) cm² elementary plots or replicates. The three composts produced from January to April 2007 (CM, KM and their mixture CKM) were used as amendment for growth of *P. vulgaris* var meringue seeds purchased in the local market of Ngaoundéré town. Each compost was amended at 10 kg/1.2 m² elementary plot, thus 55,10t/ha. The experiment was carried out in a randomised block design comprising four treatments represented by the three types of compost and the growing soil as control (GS), each of which was replicated thrice. Three *P. vulgaris* seeds were sown in rows on the 12th July 2007 (2 rows per experimental unit, 20 cm apart) during the July to November cropping season. Two weeks after planting, plantlets were thinned into two per hole to reduce competition between individual plants. During the vegetative growth, nodulation, and plant biomass were assessed on 30 randomly selected plants per treatment (Ngakou *et al*., 2007). At maturity (78 days after planting), grain yield was evaluated on 30 randomly selected plants per treatment.

Statistical analysis
Data were statistically analyzed by ANOVA using a Statgraphic Plus, version 5.0 (SIGMA PLUS) computer program. Means were compared between treatments using the least honestly significant difference (LSD) procedure at 5 % level. Correlations between parameters within cropping seasons were assessed using the SPSS computer program.

RESULT AND DISCUSSIONS

Physico-chemical properties of cattle and kitchen manures derived composts
The measurement of temperature during composting is an indirect method of assessing the degradation of organic matter. The fluctuations of temperature were similar for all the treatments apart from the control, decreasing gradually toward maturation, and dropping down when the piles were turned (indicated by arrows) to provide aeration and oxygen (Figure 1A). At the beginning of the process, temperatures in the piles were 34.67, 42.33 and 37°C, respectively for treatments CM, KM and CKM, favoured by the activity of mesophilic micro-organisms. Temperatures then rise to averagely 57°C after few weeks due to replacement of mesophilic by thermophilic micro-organisms. As soon as the piles are depleted from oxygen, anaerobic micro-organisms take over, resulting in the progressive decrease of temperature. Temperature was found to decrease faster in CM and CKM than in KM wastes indicating that the degradation of organic matter was slower in this treatment. Composting is the aerobic process through which biodegradable organic materials undergo a partial mineralisation and profound transformations due to the metabolism of a complex microbial population. It has been thought that the micro-organisms contributing to organic matter decomposition will change as composting progresses, since temperature, pH, moisture content, and the quality and quantity of organic wastes also change during composting (De Bertoldi *et al*., 1983; Nakasaki *et al*., 2005). This high temperature was reported to ensure sanitation in the process with destruction of pathogens (Mustin, 1987). Similar typical time courses of temperature showing fluctuations were obtained during composting of *Pitia stratiotes* from a waste treatment station (Agendia *et al*., 1997), or microbial biomass remaining after fermentation of antibiotic production

(Glavica *et al*., 2002). Regular watering was necessary to hasten the composting process (Zhu *et al*., 2004). Hence, each pile of 100 kg was provided once a week with 15 L of water.

During the composting process, the pH ranged from 6.5-6.53, 6.08-6.94 and 5.94-6.91, respectively from CM, KM and CKM composted wastes, and were significantly ($p < 0.001$) higher than the constant pH of the control (4.88) (Figure 1B). The pH values obtained were within the range of 6-8 revealed to favour microbial activity of composting (Agendia *et al*., 1997). Glavica *et al*. (2002) reported pH values of between 5.6 to 7.5 from microbial biomass wastes, while Rodriguez *et al*. (2003) observed a high pH range of 8.6 to 9.3 at the end of composting process involving liquid poultry and barley wastes, suggesting that the pH of mature compost may depend on the nature and origin of the composting substrate, and how this pH is adjusted during the process. In the present experiment no chemical was used to adjust the pH. The increase in pH values was reported to be attributed to both the production of ammonia associated with protein degradation in wastes and to the decomposition of organic acids (Ohtaki *et al*., 1998; Kumar *et al*., 2007).

The electrical conductivity (ELC) in KM derived compost was always significantly greater ($p = 0.001$) than that of CM or CKM composts, above that of the control (GS) (Figure 1C). Losses of organic matter, also due to microbial degradation, may account for increased ELC in CM, KM and CKM derived compost over that of the control. The observed ELC values were lower than those reported by (Abdelhamid *et al*., 2004) during composting of rice straw.

The chemical properties of different composts are represented in (Table 1). Organic carbon was consistently ($p < 0.0001$) greater in KM (386.3 g/kg) than in CKM (57.9 g/kg), CM (93.3 g/kg) derived compost and the control (38.8 g/kg). The C/N ratios obtained from this study varied from one waste derived compost to another and were significantly ($p = 0.019$) greater in KM (46.9), CM (40.6) and CKM (31.56) derived compost than the control (16. 19). Similarly, KM, CM and CKM treatments significantly recorded more sulphate ($p < 0.0001$) and phosphate ($p = 0.024$) concentrations than the control compost. The increase of phosphate content in different composts resulted from degradation of substrate rich in phosphorus through release of orthophosphate. The C/N rotios obtained from this research were far higher than the range of 13.9-30.9 previously reported in garbage derived compost (Nakasaki *et al*., 1992), or from dead birds compost with values between 15.94 and 23.09 (Kumar *et al*. (2007). C/N ratio range between 20 and 40 was reported to be ideal for mature compost (Maze *et al*, 1996). Organic carbon decreased with composting time due to transformation of wastes accompanied by loss of CO_2 and energy in the form of CH_4 (Roux, 2006). Our findings are in agreement with those of Commins *et al*. (1993), Rouan *et al*. (2003), who reported organic carbon and matter ranges of respectively 348-498 g/kg and 600-850 g/kg from poultry wastes. The losses in organic matter were respectively 6.51, 12.86 and 7% (w/w) for CM, KM and CKM, and were close to 6.27% (w/w) reported by Nakasaki *et al*. (1992). Our results on phosphate concentration were lower than reported values by Rouan *et al*. (2003) with phosphate content between 12-39 g/kg from poultry wastes. The low content of sulphate in our composts was probably due to consumption of sulphur in the substrates by sulfo-reducer bacteria with the resulting release of hydrogen sulphur responsible for odours compromising respiratory health in the absence of oxygen. The reported N values for mature compost ranged from 25.7 to 40.9 g/kg (Commins *et al*., 1993), 15-18 g/kg (Rouan *et al*., 2003), 13.80 to 17.92 g/kg (Kumar *et al*., 2007), which are higher than the observed values (4.70 to 8.24 g/kg). The mixture of cattle and kitchen manure derived composts recorded the highest N, organic carbon and matter contents, hence, were more indicated for field experiments. Similar results were obtained from dead birds manures (Kumar *et al*., 2007), with however, more N released by dead birds than kitchen manures. In a comprehensive study, Griffin and Honeycutt (2000) indicated that the amount of N varied in cattle, dairy, poultry, and swine manures. Composts maturation was reported to occur after 103 days (Rodriguez *et al*., 2001), compared in our case to 90 and 118 days respectively for CM-CKM and KM composts.

The maturation of CM and CKM composts was obtained after 12 weeks of the process. The compost obtained was odourless, with fine-textured, and low moisture, uniformly dried, thus have potentials for agricultural purposes.

Table 1. Chemical properties in mature composts

Treatments	Chemical parameters and properties					
	SO_4 (g/kg)	OM (g/kg)	N(g/kg)	PO_4 (g/kg)	C/N ratio	OC (g/kg)
GS	2.9a	6.68a	2.7a	69a	16.21a	38.8a
CM	6.3b	333.2b	4.7b	159b	40.9c	93.3c
KM	11.7d	666.0d	8.3c	165.4c	46.9c	386.3d
CKM	9.6c	444.6c	8.2c	193.5d	31.56b	57.9c
p-values	< 0.0001	0.039	0.006	0.024	0.019	0.001

GS: growing soil or control compost; CM: compost from cattle dung: KM: compost from kitchen manures; CKM: compost from CM and KM maures; OM: organic matter; OC: organic carbon; N: Nitrogen Values in the same column followed by the same letter are not significantly different at 5% level.

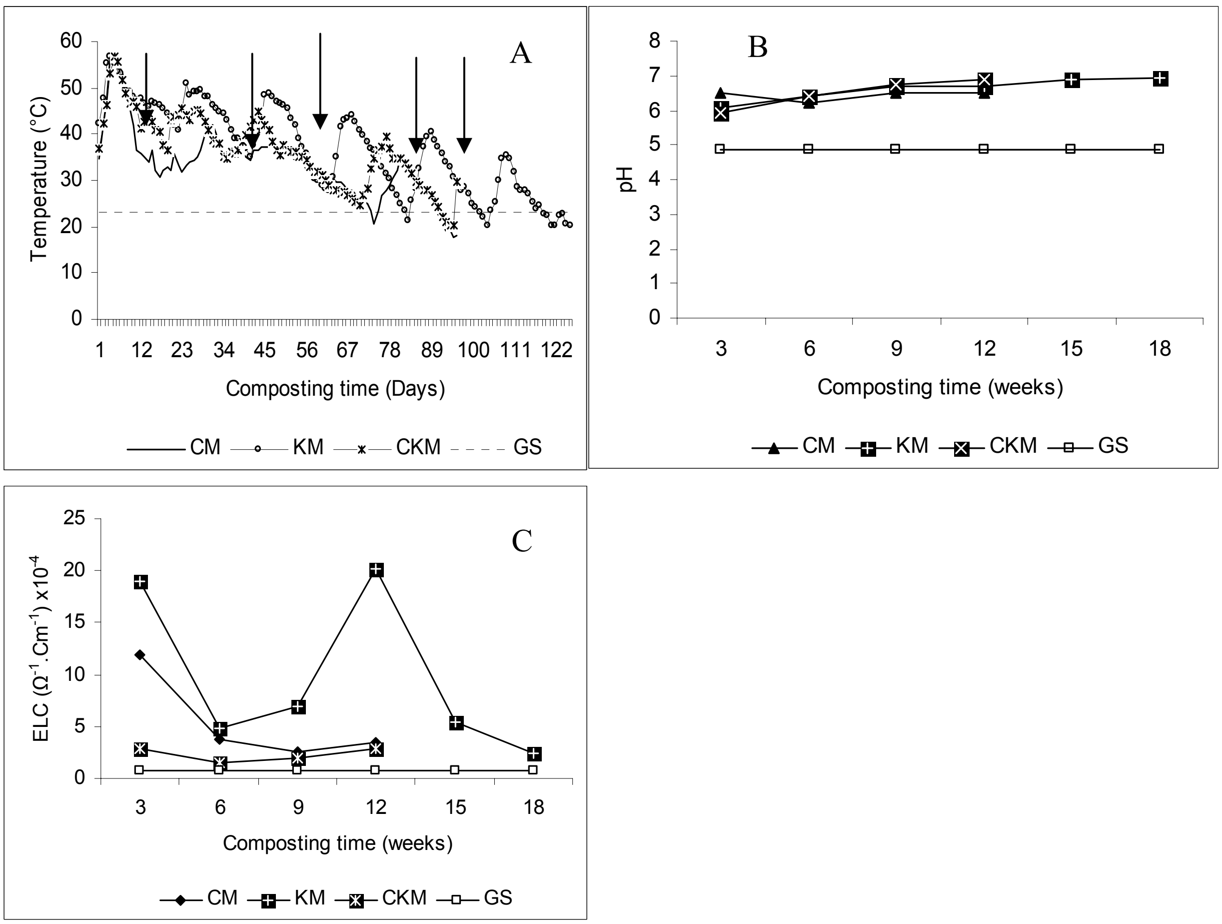

Figure 1. Time-course variations in compost temperature (A), pH (B) and Electrical conductivity (C) patterns during composting of cattle dung and kitchen manures derived wastes.

GS: growing soil or control compost; CM: compost from cattle manure: KM: compost from kitchen manures; CKM: compost from CM and KM manures; ELC: Electriccal conductivity; Arrows indicate the different periods where the wastes were turned (after every three weeks).

Phaseolus vulgaris growth response to cattle and kitchen manures derived composts

Nodulation of *P. vulgaris* L. expressed in number and dry weight of nodules per plant is represented in Table 2. The number of root nodules was significantly lower ($p < 0.0001$) in control than in compost amended plants. These results are similar to those obtained by combining legumes and compost in field experiment (Astier *et al*., 1994). However, no significant difference was observed between amended plants as far as the number of nodules per plant is concerned. Cattle and kitchen manures derived composts consistently enhanced ($p < 0.001$) the plant biomass at 30 DAP, but the difference was not significant between compost amended plants. A positive and significant correlation was observed between the number of root nodules and their dry weight on one hand (r = 0.087; p = 0.001), the number of nodules and the plant biomass (r = 0.79; p = 0.001), at 30 days after planting on the other.

The difference between the control and the other treatments was more perceived in the field as from the 21 days after planting (Figure 2). On this figures the plants growing on plots that were not amended with compost (GS) did not look healthy as those raised from composted plots (CM and CKM). Thus, significant differences were found in plant height or leaves number between compost and control plots (Figure 3). The height and the number of leaves per plant increased with time to a maximum estimated at 51 days after planting (DAP). The number of leaves per plants varied from 1 at 14 DAP, to 13 for all the treatments at 51 DAP (Figure 3A), and was always lower in control plants than in plants raised from cattle or kitchen manures amended treatments or their mixture. The control plants that were not amended with compost had an optimum number of leaves of 7 per plant. As from 44 DAP, the number leaves per plant in other treatments was almost twice that of the control. Similarly, the maximum height of control plants was 22 cm, significantly less than 44 cm for plants raised from compost amended plots (Figure 3B). Amending plots with cattle or kitchen manures derived compost consistently increased the *P. vulgaris* L. seed yield at maturity by 1.53, 1.43 and 1.86 folds, respectively for treatments CM, KM and CKM compared to that of the control as indicated in Figure 3C. The improved *P. vulgaris* seed yield by CM, KM, CKM derived composts corroborate with yield from grass and legume–grass forage production (Lyinch *et al*., 2004), and are slightly higher than those reported from amended common bean yield in America (FAO, 2006). A pH close to neutrality was revealed to facilitate the absorption of nutrients by plants (N'Dayegamine *et al*., 1997; Znaïdi, 2002). The improved growth of *P. vulgaris* in CM, KM and CKM plots can account for increased pH as the result of amendment of plots with compost. Similar results were obtained in potato amended with mushroom compost and straw mulch (Gent *et al*., 1998). The improved plant growth have been attributed to enhanced humic acid in compost, that may act by making oligoelements more available to plants (Chen *et al*., 1994; Zinati and Bryan, 2001). The differences in seed yield between the treatments may be due to differences in qualitative properties of compost types.

From science-based evidence, the time-course of composting parameters and the physico-chemical properties of the end product varied with the source and quality of wastes. By producing and adding composts as soil amendment for *P. vulgaris* growth in Ngaoundéré, we have contributed in our way, not only to improving the crop yield, but also, to sanitation of the neighbouring environment, implying reduction of uses of hazardous chemical fertilizers and pesticides. Integrating compost in agricultural system in the region may reduce the risk of soil nutrient deficits and moderate the losses in crop yield and quality. Further research will be emphasized on the potentials of this organic fertilizer on reduction of *P. vulgaris* diseases, the long-term benefits of compost to the soil-plant system, as well as the diversity and enzymatic activities of micro-organisms within the compost.

Table 2. Nodulation and biomass responses of *Phaseolus vulgaris* to different compost types in the field at 30 DAP

Growth/Yield parameters	Treatments					
	GS	CM	KM	CKM	p-values	LSD 5%
Nodules (plant^{-1})	9.40a	254.9b	245.3b	160.4b	p< 0.001	151
NodDw (g.plant^{-1})	0.02a	0.45b	0.36b	0.33b	p< 0.001	0.318
PltDw (g.plant^{-1})	1.31a	8.54b	9.05b	6.51b	p< 0.001	5.197

NodDw: Dry weight of nodules; PltDw: Dry weight of plant; GS: growing soil or control compost; CM: compost from cattle manure: KM: compost from kitchen manures; CKM: compost from CM and KM manures.
Values in the same row followed by the same letter are not significantly different for a parameter at 5% level.

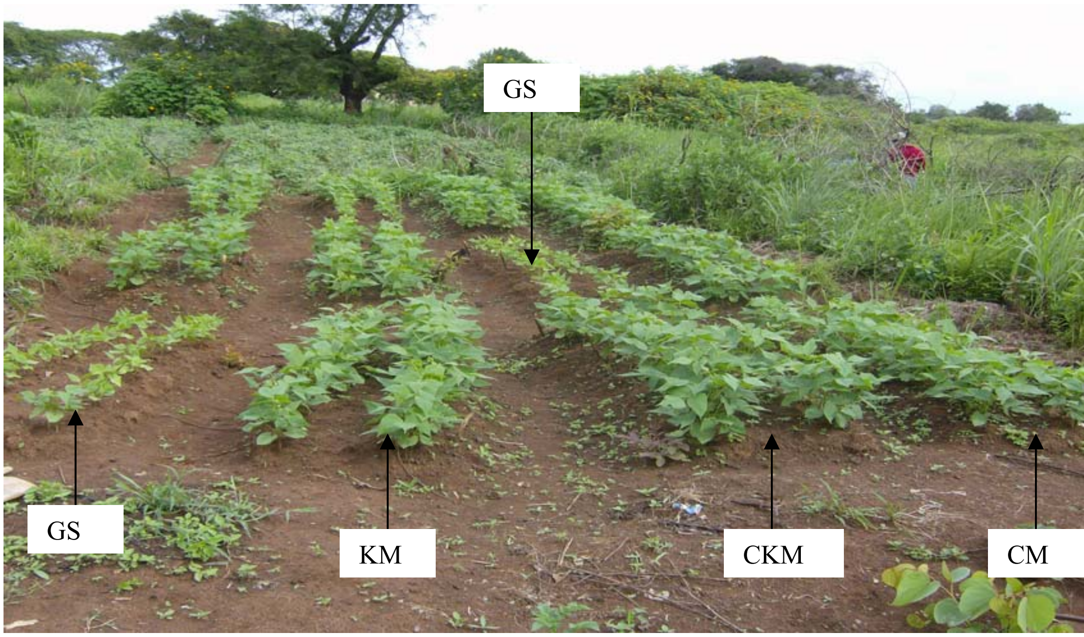

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Figure 2. Experimental layout showing different treatments

GS: growing soil or control compost; CM: compost from cattle manure: KM: compost from kitchen manures; CKM: compost from CM and KM manures.

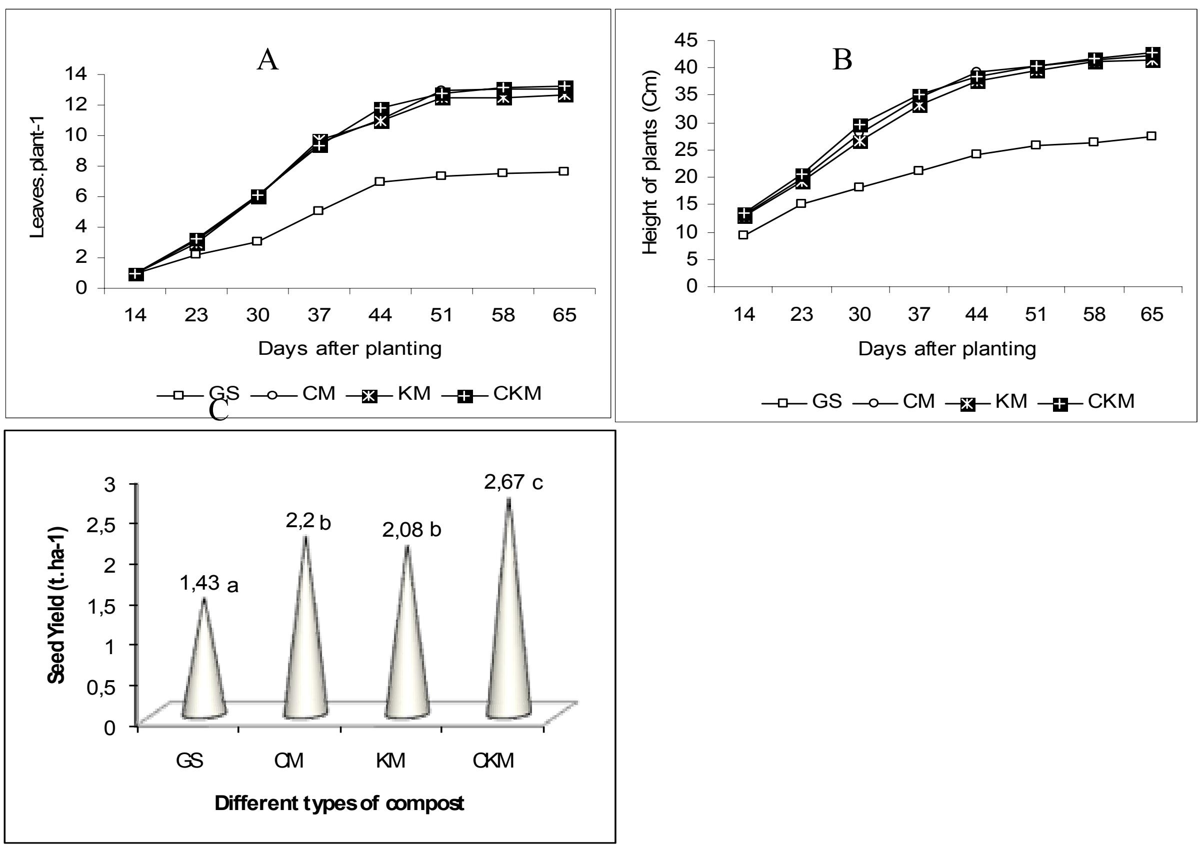

Figure 3. Influence of compost types on *Phaseolus vulgaris* L. production in the field

GS: growing soil or control compost; CD: compost from cattle manure: KM: compost from kitchen manures; CKM: compost from CM and KM manures. Bars followed by the same letter are not significantly different at 5% level.

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