EFFECT OF ORGANIC MATTER FROM COFFEE PULP COMPOST ON YIELD RESPONSE OF CHICKPEAS (*CICER ARIETINUM* L.) IN ETHIOPIA

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Abstract. The influence of coffee pulp organic matter as a substrate for the growth of chickpeas (*Cicer arietinum* L.) was compared with substrates of diverse origins to increase soil organic carbon and provide the basis for the use of the organic coffee by-product for the production of legumes in the tropical arable cultivation condition of Ethiopia. Four kinds of substrates, namely topsoil (Treatment I), topsoil + animal manure compost (Treatment II), topsoil + pine sawdust compost (Treatment III), and topsoil + coffee pulp compost (Treatment IV) were used as the matrixes in the experiment to observe the dynamic growth and development of *C. arietinum* L. The emergence and growing speed of the plant in Treatment I was delayed (12.89 ± 1.17 days, $p < 0.006$) compared with other treatments; and in Treatment IV, *C. arietinum* L. emerged fastest (10.89 ± 1.27 days, $p < 0.006$) and produced larger biomass. The final product: the plant height, fresh, and dry biomass weight in the Treatment II and IV were better than those of the other treatments. The largest plant fresh weight (46.08 ± 0.92 grams, $p < 0.001$) and dry weight (14.69 ± 0.9 grams, $p < 0.001$) appeared in Treatment II and the smallest fresh weight (31.18 ± 1.47 grams, $p < 0.001$), a 67.7 % reduction and dry weight (8.62 ± 1.33 grams, $p < 0.001$), a 58.7 % reduction was observed in Treatment I. The mixture of the existing topsoil + animal manure, topsoil + coffee pulp compost, topsoil + sawdust compost could be used in the *C. arietinum* L. production. The most appropriate choice of *C. arietinum L.* cultivation and organic carbon sequestration under the tropical condition is the existing topsoil + manure compost followed by arable soil + coffee pulp compost.

Keywords: tropical, chickpea, *Cicer arietinum*, coffee pulp, compost, manure.

Introduction

From the time immemorial, the coffee sector is one of the backbones of the economic and social development in Ethiopia [1]. It generated 29.2 percent of Ethiopia's foreign exchange earnings in 2014 [2] and provides livelihoods for more than 4.7 million households [3]. About half a million hectares of land are covered by coffee plantations in 2015 that gave a yield of about 0.42 million metric tons of green coffee beans [3]. This yield is associated with an estimated amount of 45 percentage of by-product as coffee husk and pulp [4]. The South, South Western and South Eastern highlands of the country are the main coffee growing districts [5]. There are more than 565 coffee processing industries in the Southern Region alone. The Gidabo watershed that is located in the region takes the lion-share of the distribution of the processing plants [6]. About 33 750 metric tons of coffee residues were produced in the area in one season [7]. The current practices of green coffee bean production are not promoting the health of the community or well-being of the land on which coffee cherries are being produced. Despite its contribution to the national as well as the regional economy, the coffee sector is among the most unsustainable as far as environmental sound solid waste management is concerned. The residue from dry coffee processing is burnt while those from wet processing are dumped into rivers, both being disposed into landfills and surface water. The residue from the wet coffee processing factories particularly coffee processing effluents is causing considerable pollution to the wetlands [8]. The waste is rich in organic matter that can be used for different purposes [9; 10]. The proposed use can be either for energy or nutrient/material recovery [11]. The nutrient recovery options include the production of compost [12-14] and uses as a substrate for mushroom production [15; 16].

Solid waste composting is a low costing, low technology demanding, less polluting, and more environmentally acceptable method in contrast to the existing system of waste management in the Gidabo watershed. Soil organic matter depletion is a critical issue for the health of Ethiopian soils. In addition to soil organic matter improvement, many studies on solid waste revealed numerous benefits of composting to the economy and the environment. The objective of this study was to investigate the influence of compost made from coffee pulp as a substrate on the yield variables of chickpeas (*Cicer arietinum* L. *subsp. Akaki*) as compared to the different substrates of diverse origins to provide the basis for the use of the by-product for the production of field crops in the tropical arable cultivation condition of Ethiopia.

Materials and methods

Material preparation

To study the effect of composted coffee pulp as an amendment of topsoil, an experiment was conducted using chickpeas (*Cicer arietinum L. subsp. Akaki*) as a model plant. Chickpeas are commonly used in Ethiopia for the preparation of a roasted snack (locally kollo/ nifro) and an input for a stew (shiro, or shiro wot) preparation, one of the dishes individuals consume with Ethiopia's traditional flatbread, injera. The experiment was designed to evaluate the impact of topsoil improvement with different types of composts as compared with coffee pulp compost on the plant growth and yield performance in a greenhouse. The greenhouse experiments were done between June and September 2015 in the compound of the Hawassa University, College of Agriculture (HUCA), Ethiopia.

The fresh coffee pulp [14] composted (refer Table 2 for the mix composition) was purchased from *Teremessa* coffee processing cooperative of *Shebedino Woreda* and composted on site for 70 days following the common method practiced by farmers as recommended by Kassa and Workayehu [14]. Farmers are practicing the aerobic windrow composting method using a unit windrow of 10 m length, 1m width, and 80cm height [11] (Figure 1).

Fig. 1. **On field aerobic windrow composting of coffee pulp:** a – before; b – after composting

Similarly, fresh animal dung and sawdust of pine wood [14] were obtained (refer Table 2 for the mix composition) from the dairy farm and the Wood Workshop of Hawassa University and composted in a cubic pit of one meter length, width, and height for 70 days following the ordinary practices of the farmers. The material used for composting was heaped up sequentially at 20 cm thickness and set up either underground (animal dung and sawdust composting) or on the earth surface (coffee pulp composting). The compost piles were turned once every fortnight to enhance the composting process [14]. Topsoil for the experiment was collected and transferred to HUCA from the neighboring farms (from 0-30 cm depth) to replicate the real farm situation.

Experimental procedure

The experiment was conducted in the compound of HUCA, a fully illuminated plastic greenhouse, on an altitude of 1700 masl, 38ºE, and 7ºN. The mean daily temperature is 210C. The topsoil is moderate sandy-loam texture with a pH of 5.5. The topsoil and the compost were sifted using a 2 mm wire mesh to eliminate unwanted materials (stone, clumps and roots) before use. The compost was amended to the topsoil at three variations – 20 % coffee pulp compost, 20 % animal manure compost, and 20 % pine sawdust compost by volume (Table 1). The non-amended soil was used as a control.

Initially, five seeds were planted in a pot and afterwards thinned to three seedlings. Uniform size seeds of local chickpeas (*Cicer arietinum L. subsp. Akaki*) were purchased from the local suppliers. At local conditions chickpeas mature for fresh harvest between 70 to 75 days from sowing. Overall four treatments were employed in a completely randomized block design (CRBD) with each of nine replications. Every week the pots were reshuffled twice to avoid unexpected variations in the greenhouse. Nine pots in every treatment having three seedlings each were employed to evaluate the impact of different types of composts on the plant yield performances. For the first two weeks, each pot was homogeneously and independently watered using a fine nozzle watering can with an equal amount of water (one litter of water per day per pot) during the sunrise and sunset and only sunset then after. Continuous observations of plant growth and leaf number were conducted on a weekly interval. Dry and wet above and below ground biomass assessments were conducted during flowering. Each time, score values of the nine replications were recorded for statistical analysis and the mean values are presented in the result part. The pot preparation on the greenhouse tables are shown in Figure 2.

Table 1

Substrate compositions of the different treatments

Treatments	No of replications	Substrate (Volume ratio)
T1	9	100 % topsoil
T2	9	80 % topsoil + 20 % animal manure
T3	9	80 % topsoil + 20 % pine sawdust compost
T4	9	80 % topsoil + 20 % coffee pulp compost

Note: T1 – arable topsoil (Treatment I), T2 arable topsoil + animal manure compost (Treatment II), T3 arable topsoil + pine sawdust compost (Treatment III), and T4 arable topsoil + coffee pulp compost (Treatment IV)

Fig. 2. **Set-up of the experiment rearranged for a shot**

Chemical and physical analysis of substrates

The physicochemical properties of the substrate were analyzed using the Soil Laboratory facility of HUCA, Ethiopia. The pH was measured at a 1:5 (compost: water) v/v water suspension measured using pH meter model ELE international (Rice, 1996). The total N of the raw material and compost was determined by the Kjeldahl method as described by Chapman [17]. Available phosphorus was measured using the Olsen method with the spectrophotometer model 6400 [18]. Exchangeable potassium was determined by using the flame photometer [19]. The total organic matter content of the samples was measured using the standard formula from a loss in the ignition. The compost sample used to determine the moisture content was ground, thoroughly mixed and five grams sub-sample was placed in a crucible and thermally ignited at 375 ºC for four hours using a muffle furnace [20]. The mean physicochemical properties of the substrates used are presented in Table 2.

Table 2

Physicochemical properties of the substrate

Treatments	Bulk density, $g\cdot cm^{-3}$	Total porosity, %	OM, $g\cdot kg^{-1}$	Total N $g\cdot kg^{-1}$	Available P, $mg\cdot kg^{-1}$	Available K, $mg\cdot kg^{-1}$	pH
T1	1.87	31.25	291.62	1.72	135.9	969.68	5.5
T2	1.305	51.23	507.25	5.2	293.95	14215.34	6.79
T3	1.075	60.2	581.7	3.11	169.8	877.34	6.34

T4	1.082	59.2	589.22	4.3	242.95	3804.84	6.74

Note: T1 – arable topsoil, T2 – arable topsoil + animal manure compost, T3 – arable topsoil + pine sawdust compost, and T4- arable topsoil + coffee pulp compost.

Data collection

Days of emergence, mean number of leaves, mean plant height (cm), fresh weight (g), and mean dry weight (g) of the plant stock were determined. The emergence days were counted and recorded after 50 % of the seedling emerged as the first date, and the last seed that emerged is recorded the last. The number of leaves from each replication was counted and recorded separately. The plant height was measured using a ruler from the ground to the tipping point and recorded in cm. After eight weeks of phenotype observation, the whole plants in each replication were harvested for material analysis. The harvested plants were carefully washed with tap water and rinsed with de-ionized water, separated from living roots and shoots for fresh weight recording [21]. Finally, oven dried to constant weight in a forced draft oven at 80^0c and then bulked for each replication for above ground and below ground dry biomass analysis [21].

Data analysis

The response data were analyzed on IBM SPSS Statistics 20. For each response variable, two phases of statistical analysis were employed. The first step involved one way ANOVA to determine whether the observed response among the main factors of interest (compost types) was significant. The second phase involved further analysis in comparing means to detect the differences among the tested treatments. The means of significant response parameters were separated using the Tukey-Kramer Honestly Significant Difference (HSD) test at $\alpha < 0.05$ level of significance.

Results and discussion

Literature confirms that increase of the grain yield of chickpeas with the application of various nutrients is due to the improvement of plant growth and yield attributes [22]. In spite of its virtues, compost from coffee pulp and husk was not extensively used in field crop production of the Ethiopian farming system. The impacts of different types of substrates on the plant growth and yield are presented in Figures 3-6, and 7.

For plant height at flowering, the interaction between the growth media and the plant height was highly significant ($p < 0.001$) (Figure 3). Similar to the observation made by Mula et al. [23] the topsoil that received compost and manure had significantly produced taller plants at flowering with 39.31cm (topsoil amended with animal manure) and 36.65cm (topsoil amended with coffee pulp compost). The minimum height of 31.78 is recorded for compost unamended topsoil.

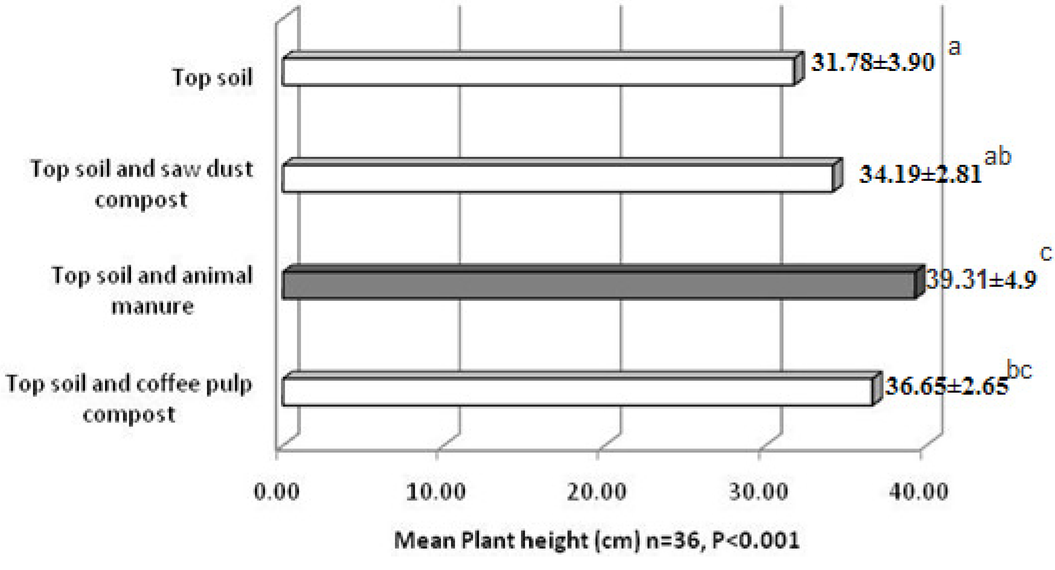

Fig. 3. **Effect of growth media on the *Cicer arietinum* L. height at flowering (mean ± stdev):** values with different subscripts are non-homogeneous at $\alpha < 0.05$ Tukey-Kramer's HSD test

For the average leaflet number per plant per pot, the relations between the growth media and the number of leaflets was not significant ($p < 0.63$) (Figure 4). However, in terms of the leaf health and vitality, the topsoil that received animal manure and coffee pulp compost is better than the other two.

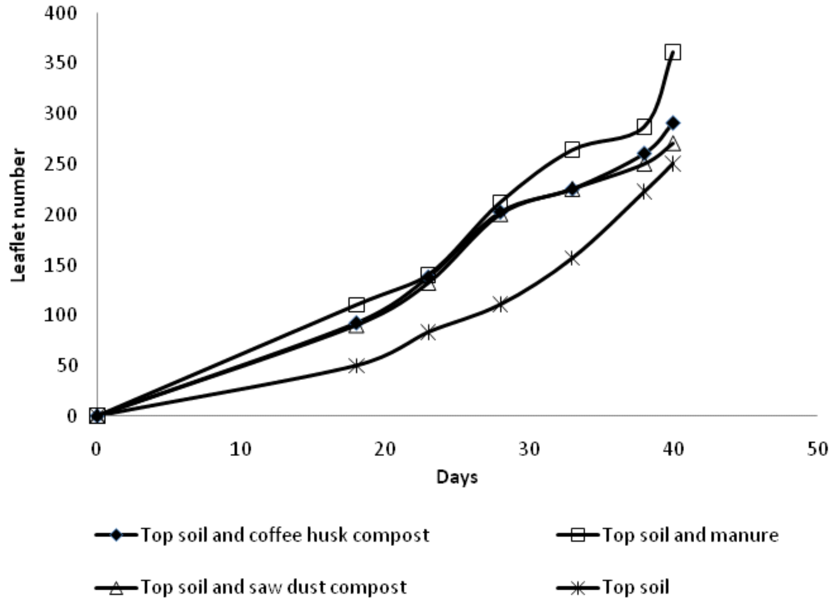

Fig. 4. **Effect of the growth media on the number of *Cicer arietinum* L. leaflets on different days of growth**

For mean days of the emergency, the interaction between the growth media and the average day of emergency was highly significant ($p < 0.003$) (Figure 5). The topsoil that received coffee pulp compost gave rise to all the seedlings two days before the non amended topsoil.

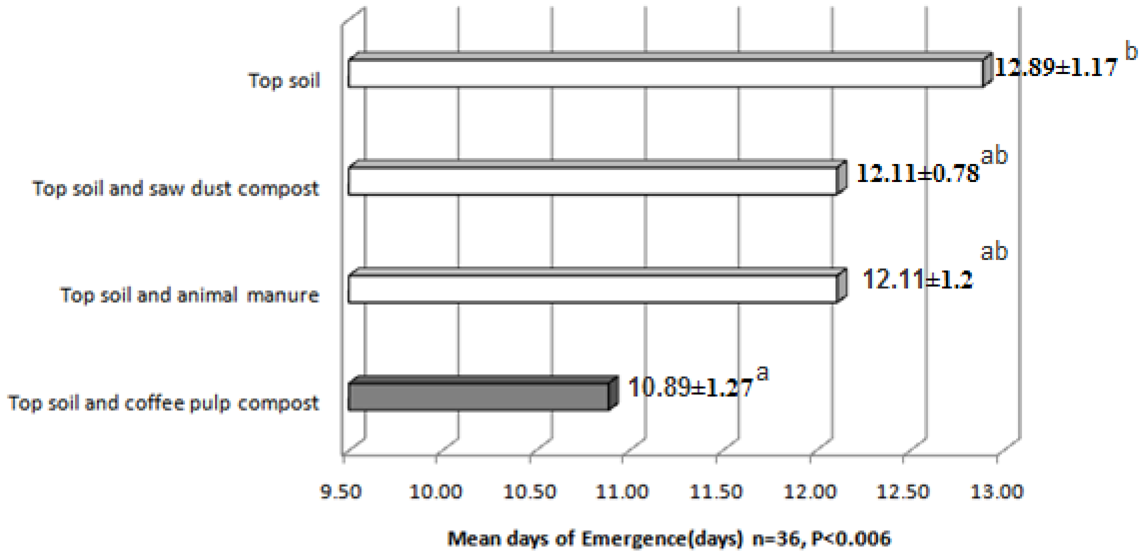

Fig. 5. **Effect of growth media on the days of *Cicer arietinum L.* emergence (mean ± stdev):** values with different subscripts are non-homogeneous at $\alpha < 0.05$ Tukey-Kramer's HSD test.

For the total above and below ground biomass, the interaction between the growth media with *Cicer arietinum* L. harvested clean weight was highly significant ($p < 0.001$) (Figure 6). The topsoil that received compost from different sources gave a similar fresh weight. The maximum value of 46.08 grams of fresh weight was recorded for the topsoil that received animal manure.

For the total above and below ground dry weight per pot, the interaction between the growth media with *Cicer arietinum* L. dry weight was highly significant ($p < 0.001$) (Figure 7). The fresh weight, as well as the dry weight measured for the topsoil that received compost made from coffee pulp and sawdust, were quite similar. The maximum dry weight of 14.69 grams per pot was recorded for the topsoil that received animal manure.

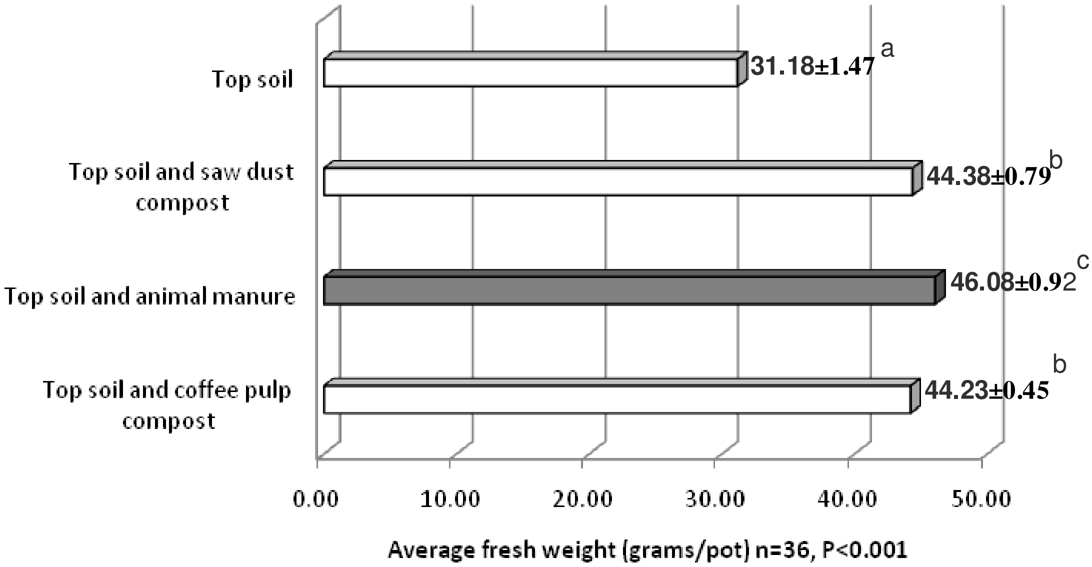

Fig. 6. **Total fresh weight of *Cicer arietinum* L. in different growth media (mean ± stdev):** values with different subscripts are non-homogeneous at $\alpha < 0.05$ Tukey-Kramer's HSD test.

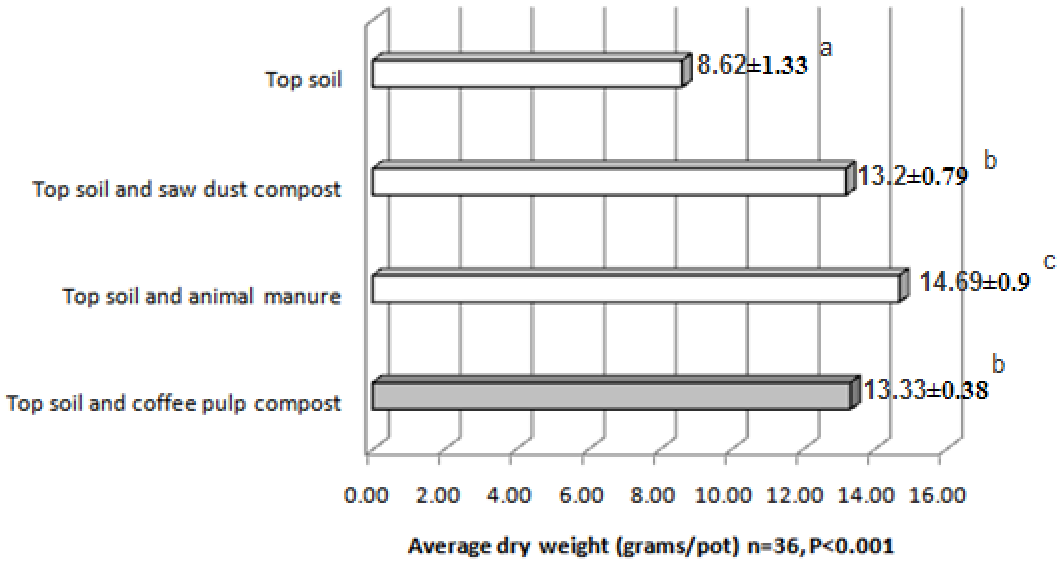

Fig. 7. **Total dry weight of *Cicer arietinum* L. in different growth media (mean ± stdev):** values with different subscripts are non-homogeneous at $\alpha < 0.05$ Tukey-Kramer's HSD test.

In most yield attributes, the pots that received animal manure performed better than the other organic substrates followed by coffee pulp compost. Amending the topsoil with different types of organic substrates resulted in a lower date of emergency, higher plant height, and higher above and below ground biomass indicating the possibility of transferring the present non beneficial use of coffee pulp into coffee pulp compost for better management.

The observed results might be due to the improvement of the physicochemical and biological properties of the topsoil such as the fertility, structure and texture, water holding capacity, water infiltration, permeability, and aeration following the application of soil organic matter (compost) [24]. Soil organic matter is a host for microorganisms in the soil, maintains aggregate stability, decreases bulk density and is used as an exchange site for different chemical elements in the soil. These functions are all essential for soil health. Similar studies indicated that amending agricultural soils with organic matter such as compost supplies plant nutrients and improves the physicochemical and biological characteristics and enhances the natural exchange of gasses with the atmosphere [25; 26].

Catalin [27] confirmed that applying compost on mining sterile soil at different periods increased an average chickpeas yield attributes in harmony with the results of the current study. The significant lower growth rate of seedling in unamended topsoil and low rate of seed germination and emergence might be due to lower pH (5.5) of the soil as compared to the recommended crop requisite span of 6-7 [28]. The higher organic matter content of coffee pulp compost (Table 2) as compared to sawdust and its free availability as compared with animal manure could make it a better option to be used as a field soil amendment to improve the soil organic matter content for field crop production.

Supplementing the topsoil with compost significantly increased the foliar growth and improved the plant biomass. Enhancement of the microbial nitrogen fixation activities in the soil from the improved soil physicochemical properties following composting was the main cause of the change. In a comparable observation [22], the use of compost from various organic sources improved the chickpeas growth and yield attributes over none application trials. It is also reported that the use of compost has a beneficial effect on the chickpeas yield and nutrient content [29-32].

Conclusions

The current study statistically and numerically showed that the use of compost made from coffee pulp as an amendment to the topsoil improved the physicochemical properties of the soil thereby enhanced the yield components of chickpeas under a greenhouse condition. Coffee pulp compost amended topsoil gave a significantly higher above ground and below ground fresh and dry weight compared with the non-amended topsoil and topsoil amended with sawdust compost. There was a significant difference between the topsoil amended with coffee pulp compost on the seedling emergence and plant height confirming the coffee pulp compost use being the best in enhancing Chickpeas (*Cicer arietinum L.*) performances in the current study. A superior enhancement effect of farm animal manure compost on the yield attributes was also observed. Generally, amending topsoil with 20 % of coffee pulp compost by volume improved the soil physicochemical and biological properties that enhanced the plant growth and yield attributes, indicating the potential use of composted coffee pulp on the field as an alternative source of bio-fertilizer to improve the organic carbon content of poor soils in Ethiopia.

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