

Effects of Compost Application on Growth, Gas Exchange, and Green Yield of Cowpea [vigna Unguiculata (L.) Walp.] Varieties

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Abstract

Cowpea is an important dual-purpose legume grown for leaves, fresh pods, and grain, but its productivity in Ethiopia is limited by low-yielding varieties and poor soil fertility. This study evaluated the effects of compost application on growth, physiological traits, and yield of two cowpea varieties (Bole and Kenkety) during the main rainy season at Hawassa University, southern Ethiopia. Four compost rates (0, 2.5, 5.0, and 7.5 t ha⁻¹) were tested using a randomized complete block design with four replications. Compost application significantly ($P < 0.05$ – 0.001) increased plant height, leaf number, leaf area, leaf dry weight, photosynthesis, transpiration, pod traits, and green pod yield. Varietal differences were significant ($P < 0.05$) for growth, physiological traits, and pod characteristics. Significant compost $\times$ variety interactions affected shoot biomass, branch number, leaf fresh weight, and pod length. The highest plant height, leaf area, and photosynthesis rate were recorded at 7.5 t ha⁻¹ compost. The Bole variety combined with 7.5 t ha⁻¹ compost produced the highest biomass and pod length. Overall, compost at 7.5 t ha⁻¹, particularly with Bole, improved cowpea growth, physiology, and yield, demonstrating its potential as a sustainable soil fertility management option.

1. INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp.) is one of the most important food legumes cultivated in the semi-arid tropics, including parts of Asia, Africa, Southern Europe, the southern United States, and Central and South America (Singh, 2005; Timko et al., 2007). It is also among the most valued African leafy vegetables due to its adaptability and multiple uses (Keller, 2004). According to FAOSTAT (2020), global cowpea production reached approximately 8.9 million tonnes in 2019, with Africa contributing more than 90% of total output. In Ethiopia, cowpea is well adapted to diverse agro-ecological zones, including Eastern Ethiopia (East and West Hararghe), Northern Ethiopia (South Wollo, Wag Himra, and Tigray), the Central Rift Valley, and southern areas such as Konso, Derashe, Jinka, and Goffa. Despite its wide adaptation, cowpea production in Ethiopia remains largely subsistence-oriented rather than commercial (Sisay, 2015; David et al., 2016).

Cowpea is a dual-purpose leguminous crop cultivated for both its leaves and grains and is recognised for its high nutritional value. Protein contents of up to 39.24% in the leaves (Chikwendu et al., 2014) and about 30% in the grains (Boukar et al., 2011) have been reported. All edible parts of the plant provide essential nutrients, including proteins and vitamins (Islam et al., 2006). Immature pods and seeds are commonly consumed as vegetables, while the grains are used in various snacks and staple foods (Agbogidi & Egho, 2012). Harvesting pods before physiological maturity allows cowpea to complement cereal-based diets, thereby enhancing household nutrition (Timko & Singh, 2008). In addition, early-maturing cowpea varieties provide food earlier than many other crops, making the crop an important component of food security strategies, particularly in Sub-Saharan Africa where seasonal food shortages are common (Sariah, 2010). In Ethiopia, cowpea leaves are traditionally consumed as vegetables in regions such as Gambella (Itang and Abobo) and the Southern Nations, Nationalities and Peoples' Region, including Konso and South Ari (Sissay, 2015).

Beyond its nutritional importance, cowpea plays a significant role in sustainable farming systems, especially in low-input agricultural environments. As a legume, cowpea can fix up to 240 kg ha⁻¹ of atmospheric nitrogen and contribute approximately 60–70 kg ha⁻¹ of nitrogen to subsequent crops grown in rotation (Aikins & Afuakwa, 2008). This characteristic makes cowpea particularly valuable in regions where access to inorganic fertilisers is limited or costly.

In this context, composting has emerged as an environmentally friendly and low-cost technology for improving soil fertility through the recycling of organic waste. Compost application has been shown to enhance soil physical properties, nutrient availability, and plant growth, while reducing environmental pollution associated with nutrient runoff and nitrogen leaching (Nyamangara et al., 2003). The use of composted organic materials therefore offers both agronomic and economic benefits for smallholder farmers.

In Ethiopia, the use of inorganic fertilizers is constrained by high prices, limited availability, and inadequate knowledge of appropriate fertilizer types and application rates for specific crops, soils, and agro-ecological conditions (Morris *et al.*, 2007; Murage et al., 2000). Consequently, soil fertility decline remains a major challenge. Despite its multiple uses, cowpea productivity in Ethiopia is generally low due to poor-yielding varieties and declining soil fertility, particularly deficiencies in nitrogen and phosphorus (Afutu *et al.*, 2017). These constraints are exacerbated by widespread soil degradation problems, including erosion, acidity, nutrient depletion, and salinity (Zelege et al., 2010).

Although cowpea fixes atmospheric nitrogen, effective nitrogen fixation typically begins about three weeks after planting and does not supply other essential macro- and micronutrients such as phosphorus, sulfur, and boron, which are critical for nodulation, enzyme activity, and reproductive development (Basak et al., 2013). Inadequate supplies of these nutrients can result in poor nodulation, reduced pod set, and lower yields in leguminous crops (Meena et al., 2015). Moreover, cowpea varieties differ in their response to nutrient inputs due to variations in growth habit and nutrient uptake efficiency (Tripathi & Saini, 2018). Therefore, evaluating the interaction between compost application rates and cowpea varietal differences is essential for identifying optimal combinations that enhance growth, yield, and resource-use efficiency under specific Ethiopian agro-ecological conditions.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The study was conducted at the Hawassa University experimental site in Southern Ethiopia during the main rainy season. The site is located approximately 273 km south of Addis Ababa, at 7°04' N latitude and 38°31' E longitude, with an altitude of 1,708 meters above sea level. The mean annual rainfall of the area ranges from 900 to 1,110 mm, while the average daily minimum and maximum temperatures are 12°C and 27°C, respectively. The main rainy season extends from April to September and is intermittently

interrupted by short dry periods with sunshine from May to July (NMA, 2015). The Overall, climatic conditions of the study area during the experiment are summarized in Fig. 1.

2.2. Soil Sampling and Analysis

Soil samples were collected randomly from the experimental fields at a depth of 0–30 cm before planting to determine the initial fertility status. Sampling was conducted using an auger in an X-shaped pattern. The collected samples were thoroughly mixed to prepare a composite representative sample for analysis of physical and chemical properties, including pH, total nitrogen (N), available phosphorus (P), available potassium (K), exchangeable sodium (Na^+), exchangeable calcium (Ca^{2+}), exchangeable magnesium (Mg^{2+}), organic carbon (OC), C:N ratio, and cation exchange capacity (CEC), as presented in Table 1. Soil texture, acidity, and electrical conductivity were measured using the hydrometer method, potentiometric method, and conductivity cell potentiometric method, respectively. Nitrogen content was determined using the Kjeldahl procedure (Jackson, 1958), while available potassium, exchangeable sodium, calcium, magnesium, and the sum of cations were measured using the ammonium acetate method. Organic carbon and available phosphorus were analyzed using the Walkley–Black and Olsen methods, respectively.

Table 1
Physicochemical characteristics of the
experimental soil.

Parameters	Values
pH-H ₂ O (1:2.5)	5
EC(Ms/cm) (1:2.5)	2.97
Sand (%)	44.12
Clay (%)	26.90
Silt (%)	28.97
Textural class	Loam
Exch.Na(meq/100gm of soil)	3.16
Exch(meq/100gm of soil)	1.02
Exch.Ca(meq/100gm of soil)	14.55
Exch.Mg(meq/100gm of soil)	7.28
CEC(meq/100gm of soil)	34.60
Sum of Cations (meq/100gm of soil)	26.01
Organic carbon (OC) (%)	1.06
Total Nitrogen (TN) (%)	0.14
Available P (AV.P)(mgP ₂ O ₅ /kgsoil)	714.33
Available(AV.K)(mgK ₂ O/kgsoil)	157.35
C:N	7.5

2.3. Physico-chemical Analysis of the Compost

The compost was prepared at the Hawassa University College of Agriculture experimental site. Samples of the compost were dried for chemical analysis, and quality parameters including nitrogen (N), phosphorus (P), potassium (K), compost pH, organic carbon (OC), carbon nitrogen ratio (C:N), and heavy metals—were determined, as presented in Table 2. Nitrogen content was measured using the Kjeldahl procedure (Jackson, 1958), while calcium (Ca), potassium (K), magnesium (Mg), phosphorus (P), sulfur (S), silicon (Si), molybdenum (Mo), boron (B), copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn) were analyzed using the Mehlich-3 method. Cation exchange capacity (CEC) was determined by the ammonium acetate method (Black, 1965), and the percentage moisture content of the compost was calculated according to the equation described by MAFF (1986).

$$\text{Moisture content (\%)} = \frac{\text{wet mass} - \text{dry mass}}{\text{wet mass}} * 100$$

The carbon- nitrogen ratio of compost was determined following the formula (Martin, 1991).

$$C : N = \frac{TOC (\%)}{TN(\%)}$$

Table 2
Physicochemical characteristics of the
experimental compost.

Parameters	Values
Moisture (%)	32
pH-H ₂ O	7.00
Total Nitrogen (%)	0.25
Phosphorus (mg/kg	251.03
Potassium(Cmol+)/Kg compost)	7.92
Sodium(Cmol+)/Kg compost)	1.72
Organic Carbon (%)	2.15
Calcium(Cmol+)/Kg compost)	23.53
Magnesium(Cmol+)/Kg compost)	5.69
Sulphate (mg/kg	132.81
Iron(mg/kg)	206.54
Manganese (mg/kg)	137.71
Zinc(mg/kg)	12.93
Boron (mg/kg)	2.37
Copper (mg/kg)	1.71
Molybdenum (mg/kg)	0.20
Silicon (mg/kg)	794.20
C:N	8.70

2.4. Experimental Materials

Two cowpea varieties and in-site prepared compost were used for the study. The compost was prepared from organic materials such as green plants, leaves, food-processing residues, and waste material from

the marketplace. The two cowpea varieties were obtained from Melkasa Agricultural research center, EIAR, Ethiopia.

2.5. Experimental Design

The experiment employed two cowpea varieties and four compost application levels, arranged in a randomized complete block design (RCBD) with four replications. The plot size was 9 m² (3 m x 3 m). The spacing between plots and blocks was 0.5 and 1 m, respectively and spacing between rows and plants was 50x20cm, respectively. The treatments were randomly assigned to each plot. There were six rows per plot, and data were collected from the middle four rows, excluding plants in the two border rows as well as those at both ends of each row to avoid border effects. The two inner rows from both sides were used for destructive sampling while the three central rows were used for yield data collection.

2.6. Collected data

To evaluate the effects of compost on cowpea, data were collected on growth, physiological, and yield related parameters.

Growth Parameters

Vegetative development was assessed by measuring plant height, number of primary branches per plant, number of leaves per plant, leaf fresh weight, leaf dry weight, shoot fresh weight, shoot dry weight, and leaf area index. These parameters were chosen to quantify the effect of compost on plant architecture and biomass accumulation, which are directly linked to yield potential.

Physiological Parameters: Gas-exchange characteristics, including photosynthetic rate, stomatal conductance, and transpiration rate, were measured on ten young, fully expanded leaves per plot using a portable infrared gas analyzer (ADC Bio Scientific LCI-SD System). Measurements were taken twice daily (08:00–11:00 and 14:00–16:00 hours) to account for diurnal variation. These physiological parameters were monitored to understand how compost application influences carbon assimilation, water relations, and plant performance.

Yield and Yield-Related Parameters

Reproductive performance was evaluated through the number of green pods per plant, total fresh pod weight per plant, pod length; pod diameter, green pod yield, and aboveground dry biomass. These parameters were measured to determine the contribution of vegetative and physiological responses to overall productivity.

2.7. Statistical Analysis

All parameters were subjected to analysis of variance (ANOVA) through the GLM procedure using the SAS software program version 9.2 (SAS Institute, 2002). Treatment means were compared using the Least Significant Difference (LSD) test at 5% level of significance.

3. RESULTS AND DISCUSSIONS

3.1 Effects of variety and compost on Plant growth parameters

Plant height

Plant height of cowpea was significantly affected by the main effects of variety ($P \leq 0.05$) and compost ($P < 0.001$). Variety Bole had significantly higher plant height than the Kenkety variety. (Table 3). The difference in plant height between the varieties may have been due to the genetic makeup of the varieties. The finding agreed with Fantaye et al. (2017), who found higher plant height (51.54cm) from the Bole variety compared with the Kenkety variety (37.46cm) at another agro ecology of Ethiopia.

Concerning compost, the tallest plant height of cowpea was recorded under the application of 7.5 t.ha^{-1} of compost, and the shortest plant height of cowpea was recorded when no compost was applied (Table 3). Plant height was increased by 8.1%, 16.4%, and 24.3% when plants were treated with 2.5, 5, and 7.5 t.ha^{-1} of compost, respectively, compared to the control treatment. The increase in height due to the increased rate of compost might be attributed to the fact that compost contains a good range of additional essential macro- and micronutrients in addition to the NPK required for healthy plant growth. Similarly, the increment in plant height is due to the increased rate of the compost because compost improves the soil structure and aggregation. This change can improve the availability of nutrients as well as encourage the plant to have good root development by improving the aeration in the soil, which leads to higher plant growth. This result is in agreement with the findings of Raja and Bharani (2012), who evaluated the plant growth-promoting effect of compost, derived from decomposed fruit wastes by commercial formulation of effective microorganisms, on plant growth parameters of black gram and found that plant height was increased in compost-treated plots. Mahmoud et al., (2013), also found that the vegetative growth characters of the pea plant were significantly increased by raising the rates of organic manure usage in sandy soil. Additionally, Balbhim et al. (2015), reported that compost and chemical fertilizers increased the plant height of leguminaceae and found that compost gave the highest values for plant height, followed by chemical fertilizers, compared with the control.

Leaf number per plant

Leaf number of cowpea plants was significantly affected by the main effects of variety ($P \leq 0.05$) and compost ($P < 0.001$). Maximum leaf number per plant was recorded from the Bole variety compared with the Kenkety variety (Table 3). The maximum leaf number of cowpea was recorded under the application of 7.5 t.ha^{-1} of compost, which was not significantly different from 5 t.ha^{-1} compost treated plots, and the minimum leaf number of cowpea was recorded from the control treatment (Table 3). 15.9%, 40.7% and 48.7% at the application of 2.5, 5, and 7.5 t.ha^{-1} of compost, respectively, compared to the control, increased leaf number of cowpea plants. The increment in leaf number with increasing compost rate might be compost consists essential macro and micro elements that are important for growth and

developments of plants, for example nitrogen is a macro element essentially required for plant growth and contribute to increase the meristematic activity of the plant tissues and make the formation of leaves on nodes by delaying of their maturity. This could encourage the growth of plants through prompting the plants to generate leaves and cause an increasing number of leaves per plant, thereby increasing photosynthetic area. This result is supported by the findings of Fatma *et al.* (2014), who observed that the application of compost at two rates significantly increased vegetative growth characters like plant height, average number of leaves, and fresh and dry weight of the whole plant and its different organs of the onion plant.

Leaf dry weight per plant

Leaf dry weight of cowpea was significantly affected by the main effect of variety ($P \leq 0.05$) and compost ($P \leq 0.01$). Although the relatively higher leaves dry weight of the cowpea plant was recorded from the Bole variety than the Kenkety variety (Table 3). The highest leaf dry weight was achieved with the application of 7.5 t.ha^{-1} compost, and the lowest was attained from the control (Table 3). In general, leaf dry weight was increased with the increase in compost rate. The increase in leaf dry weights due to compost application could be related to the increase in leaf number. The finding is in line with the response observed by Abou *et al.* (2012), on snap bean; they reported that leaf dry weight per plant was increased with increased rates of compost application. Similarly, Aly and El-Naggar (2010), detected a gradual increment in leaf dry weight because of increasing the rate of organic compost on narcissus tazetta plant.

Leaf area

Leaf area was significantly ($P \leq 0.001$) affected by the main effect of compost. Meanwhile, varieties did not have any effect on leaf area. The maximum leaf area was recorded from the application of 7.5 t.ha^{-1} compost, and the minimum leaf area of cowpea was recorded from nil application of compost (control) (Table 3). The leaf area of cowpea increased as the amount of compost increased. This might be due to the higher nutrient composition of the compost, as this soil physical property improved, and increased activity of microbes with higher levels of organics might have helped in increasing leaf area. The finding is in accordance with the result observed by Abou *et al.* (2012) on snap bean, who reported that leaf area per plant was increased with the increment of compost rate. Similarly, Raja and Bharani (2012) reported that leaf area was increased in compost derived from decomposed fruit wastes treated black gram plants. Mostafa *et al.* (2016) also stated that leaf area per plant was increased when rates of organic mineral fertilizer compost increased in common bean.

Leaf area index

Leaf area index was significantly ($P \leq 0.001$) affected by the main effect of compost. Meanwhile, varieties did not affect leaf area index. The maximum leaf area index recorded from application of 7.5 t.ha^{-1} compost and the minimum leaf area index of cowpea were recorded from nil application of compost (control) (Table 3). The increase in leaf area index in response to increasing rates of compost might be

attributed to the availability of optimum nutrients in compost that led to high leaf area index through facilitated vegetative growth and more expansion of leaves. The finding is in accordance with Mehdi et al. (2012), who reported that significantly increased leaf area index in response to applied municipal solid waste-sourced compost and vermicompost.

Table 3
Main effects of variety and compost on plant height, leaf number per plant, leaf dry weight, Leaf area and Leaf area index of cowpea at Hawassa.

Treatments	PH(cm)	LNPP	LDW(g)	LA (cm ²)	LAI
Varieties					
Bole	50.21 ^a	166.81 ^a	15.35 ^a	4558.2 ^a	6.0781 ^a
Kenkety	48.17 ^b	154.26 ^b	14.19 ^b	4270.0 ^b	5.6934 ^b
LSD (0.05)	1.65	9.97	1.08	283.92	0.38
Compost (t.ha ⁻¹)					
0 (Control)	43.85 ^d	127.08 ^c	12.81 ^c	3844.20 ^c	5.13 ^c
2.5	47.38 ^c	147.34 ^b	14.67 ^b	4233.50 ^{bc}	5.64 ^{bc}
5.0	51.02 ^b	178.78 ^a	15.29 ^{ab}	4573.20 ^b	6.10 ^b
7.5	54.51 ^a	188.96 ^a	16.30 ^a	5005.60 ^a	6.67 ^a
LSD (0.05)	2.33	14.1	1.53	418.66	0.56
CV (%)	6.65	12.33	14.50	12.83	12.83

Leaf fresh weight

Leaf fresh weight was significantly influenced by main effects of variety ($P < 0.01$), compost ($P < 0.001$), and the interaction between varieties and compost ($P \leq 0.05$). The maximum leaf fresh weight was recorded from the Bole variety with the application of 7.5 t.ha⁻¹ compost, and the minimum leaf fresh weight of cowpea was recorded from the Kenkety variety with nil application of compost (control) (Table 4). Generally, leaf fresh weight was increased when the rates of compost increased in both varieties. The results are in agreement with Abou et al. (2012) on snap bean; they reported that leaf dry weight per plant was increased with increased rates of compost application. Similarly, Aly and El-Naggar (2010), reported higher leaf fresh weight because of the increased rate of organic compost on narcissus tazetta plant.

Number of branches per plant

The number of branches per plant was significantly affected by varieties ($P < 0.01$), compost ($P < 0.001$), and the interaction between varieties and compost ($P \leq 0.05$). The highest number of branches was obtained from the Bole variety with the application of 7.5 t.ha^{-1} compost, whereas the lowest was obtained from the Kenkety variety with nil application of compost (control) (Table 4). The number of branches was increased with increasing compost rate in both varieties. The result is in line with Girma et al. (2005), who reported that a higher number of branches per plant of cowpea was obtained from manure-treated soils (6.84) over the control (4.2), which was about 62.9% higher for manure-treated pots over the control.

Shoot fresh weight

The shoot fresh weight was significantly influenced by the variety ($P < 0.01$), the type of compost used ($P < 0.001$), and the interaction between the varieties and the compost ($P < 0.01$). The highest shoot fresh weight was observed in the Bole variety with the application of 7.5 t.ha^{-1} of compost, while the lowest was recorded in the Kenkety variety with no compost application (control) (Table 4). Overall, shoot fresh weight increased with higher compost application rates for both varieties. This finding aligns with the results of Abdel-Mawgoud (2006), which indicated that shoot fresh weight in green bean plants also increased with higher compost rates.

Shoot dry weigh

The main effect of varieties ($P < 0.001$), compost ($P < 0.001$), and the interaction between varieties and compost ($P < 0.001$) showed a statistically significant effect on shoot dry weight. The maximum leaf fresh weight was recorded from the Bole variety with the application of 7.5 t.ha^{-1} compost, and the minimum leaf fresh weight of cowpea was recorded from the Kenkety variety with nil application of compost (control) (Table 4). Shoot dry weight was increased with the increasing rates of compost in both varieties. This might be the fact that compost has both macro and micronutrients that enhance the vegetative growth of crops. The result is in line with the findings of Abdel-Mawgoud (2006), who reported that shoot dry weight was increased when the rate of compost increase in green bean plants.

Table 4

Interaction effects of variety and compost on the number of branches per plant, shoot fresh weight, leaf fresh weight, and shoot dry weight of cowpea, at Hawassa

Treatments		LFW(g)	NBPP	SFW(g)	SDW(g)
Variety	Compost(t.ha ⁻¹)				
Bole	0 (Control)	122.81 ^c	5.03 ^{de}	334.68 ^c	41.32 ^d
	2.5	127.04 ^{bc}	5.28 ^{cd}	352.07 ^{bc}	43.45 ^d
	5.0	137.00 ^{ab}	5.43 ^{cd}	371.57 ^{ab}	47.37 ^{cb}
	7.5	147.94 ^a	6.85 ^a	392.41 ^a	57.59 ^a
Kenkety	0 (Control)	94.97 ^d	4.75 ^e	221.88 ^d	27.14 ^e
	2.5	125.47 ^{bc}	5.15 ^{cde}	344.78 ^{bc}	42.07 ^d
	5.0	130.25 ^{bc}	5.53 ^{bc}	369.18 ^{abc}	44.59 ^{cd}
	7.5	145.14 ^a	5.93 ^b	379.29 ^{ab}	49.47 ^b
LSD (0.05)		3.63	0.45	39.63	12.68
CV (%)		8.21	8.13	11.43	9.81

3.2. Effects of variety and compost on Physiological parameters

Photosynthesis rate (PS)

Main effects of variety ($P \leq 0.05$) and compost ($P \leq 0.001$) significantly affected photosynthesis rate. Variety Bole had a significantly higher photosynthesis rate than the Kenkety variety (Table 5). This might be the genotypic difference of the variety, which affects the plant's photosynthesis rate.

With regard to compost maximum photosynthesis rate was obtained from the application of 7.5 t.ha⁻¹ compost, whereas the minimum photosynthesis rate was obtained from the control plot (Table 5). Compost has adequate macro and micronutrients, which might have helped plants increase in uptake of nutrients, promoting greater meristematic and photosynthetic activities. Nitrogen supplied by the organic compost favors the higher chlorophyll content. Plants with a high concentration of chlorophyll are potentially capable of achieving higher photosynthetic rates due to their light energy capture value per unit time (Taiz and Zeiger 2013). Similarly, previous studies (Furtini et al., 2006) showed that application of organic and inorganic fertilizers enhanced the shoot biomass of plants. Hence, the improved biomass accumulation is attributed to increased availability of plant nutrients, which might have enhanced the photosynthetic capacity of the plants.

Transpiration rate (E)

Main effects of variety ($P \leq 0.05$) and compost ($P \leq 0.001$) significantly affected transpiration rate. Variety Bole had a significantly higher photosynthesis rate than the Kenkety variety (Table 5). This might be attributed to genetic differences, which influence the plant's transpiration rate.

Maximum transpiration rate was gained from the application of 7.5 t.ha^{-1} compost, whereas the minimum transpiration rate was recorded from the control treatment (Table 5). Transpiration rate was increased by 10.0%, 18.1% and 46.8% with the rates of compost increased by 2.5, 5.0, and 7.5 t.ha^{-1} , respectively, compared with the control treatment. The reason behind the increment of transpiration rate might be the increment of stomatal conductance with increased rates of compost.

Stomatal conductance (gs)

Analysis of variance showed that stomatal conductance was significantly ($P \leq 0.001$) affected by the main effects of compost. Maximum stomatal conductance was obtained from the application of 7.5 t.ha^{-1} compost, whereas the minimum stomatal conductance was obtained from the control (Table 5). In general, stomatal conductance was increased by 23.5%, 36.7% and 58.2% when the rate of compost increased by 2.5, 5.0, and 7.5 t.ha^{-1} , respectively, over the control treatment.

Water use efficiency (WUE)

Water use efficiency was highly significantly ($P \leq 0.01$) affected by the main effects of compost. Not the main effects of variety affected it. Maximum Water use efficiency was obtained from the application of 7.5 t.ha^{-1} compost, whereas the minimum water use efficiency was obtained from the control one (Table 5). In general, water use efficiency was increased by 11.3%, 17.5% and 25% when rates of compost increased by 2.5, 5.0, and 7.5 t.ha^{-1} , respectively, as compared to the control.

Table 5

Main effects of variety and compost on photosynthesis rate, transpiration rate, stomatal conductance and water use efficiency of cowpea at Hawassa

Treatments	Ps($\mu\text{mol m}^{-2}\text{s}^{-1}$)	E($\text{mmol m}^{-2}\text{s}^{-1}$)	gs($\text{mmol m}^{-2}\text{s}^{-1}$)	WUE($\text{mmol Co}_2/\text{mol H}_2\text{O}$)
Varieties				
Bole	21.80 ^a	6.18 ^a	1.31	3.69
Kenkety	20.49 ^b	5.79 ^b	1.23	3.57
LSD(0.05)	1.28	0.37	Ns	ns
Compost (t.ha⁻¹)				
Control(0)	18.10 ^c	5.04 ^c	0.98 ^c	3.20 ^c
2.5	20.98 ^b	5.55 ^{bc}	1.21 ^c	3.56 ^{bc}
5.0	21.72 ^b	5.95 ^b	1.34 ^{ab}	3.76 ^{ab}
7.5	23.78 ^a	7.40 ^a	1.55 ^a	4.00 ^a
LSD(0.05)	1.80	0.53	0.21	0.41
CV%	11.98	12.42	23.13	15.94

3.3. Effects of variety and compost on Green Yield and Yield related parameters

Pod number per plant

Pod number per plant of cowpea plants was significantly affected by the main effect of variety ($P \leq 0.05$) and compost ($P \leq 0.001$). Maximum pod number per plant was obtained from the application of 7.5 t.ha⁻¹ compost, whereas the minimum pod number per plant was obtained from zero application of compost (control) (Table 6). This might be due to the release of nutrients from compost, which is an essential component of protoplasm, chlorophyll molecules, and photosynthesis that make enhancement of pod filling by ensuring more survival of flowers. The result is in line with Smith et al. (2001), who reported increasing proportion of compost generally led to higher numbers of pods and seeds in common bean. Similarly, Abdel-Maywood (2006) reported that pod number per plant was increased with increasing compost rates, 10, 15, and 20 m³ per feddan in green bean, and the maximum pod number per plant (15.44) was recorded from 20 m³/feddan compost applications. Additionally, Khan et al. (2017) investigated that the pod number per plant of cowpea was increased with increased application rate of vermicompost.

Fresh pod diameter

Analysis of variance showed that the main effects of variety ($P \leq 0.01$) significantly affected pod diameter, and compost ($P \leq 0.001$). With regard to variety maximum pod diameter was recorded from the Kenkety variety, whereas the minimum pod diameter was recorded from the Bole variety (Table 6).

Generally, pod diameter was increased by 19.9%, 36.8% and 54.8% from the compost application rates of 2.5, 5.0, and 7.5 t.ha⁻¹, respectively, over the control. This is because compost-enhanced soil aeration increases nutrient holding capacity and offers good environmental conditions for the root system. These favorable conditions might create better nutrient absorption and enhance the crop growth, thereby improving the vegetative growth, photosynthetic activity, and dry matter accumulation. Lixandru et al. (2010) also reported improved weight, length, and diameter of pods due to the application of compost in bean and pea crops.

Total pod fresh weight per plant

Total fresh pod weight was significantly ($P \leq 0.001$) affected by rates of compost. While main effects of varieties did not have any significant effect on total fresh pod weight per plant. The maximum total fresh pod weight was recorded from the application of 7.5 t.ha⁻¹ compost, and the minimum pod weight of cowpea was recorded from the control treatment (Table 6). The increase in pod weight due to the increase in the rate of applied compost might be related to the increase in pod number per plant. The result is in line with Eletr *et al.* (2004), who reported that pod weight was significantly increased by increasing the applied compost rates from 100, 120, up to 140 kg N/feddan on pea plants. Additionally, Lixandru et al. (2010) found that application of different rates of compost to bean and pea plants improved weight, length and diameter of pods.

Green pod yield

Green pod yield was significantly ($P \leq 0.001$) affected by the main effect of compost. While main effects of varieties did not have any significant effect on green pod yield. The maximum green pod yield was recorded from application of 7.5 t.ha⁻¹ compost, while the minimum pod yield of cowpea was recorded from nil application of compost (control) (Table 6). Generally, green pod yield increased when the rate of compost increased. The current results are in agreement with Mahmoud et al. (2013), who reported a significant increase in green pod yield with increasing level of compost application up to 180 kg N/feddan on pea plants. Similarly, Babaji *et al.* (2010) found that green pod yield of cowpea increased with increasing rates of applied FYM from 5 to 15 t.ha⁻¹, with a (3.5 t.ha⁻¹) green pod yield from the application of 15 t.ha⁻¹ farmyard manure.

Table 6
Main effects of varieties and compost on pod number per plant, pod diameter, pod fresh weight and green pod yield of cowpea, at Hawassa

Treatments	PNPP	PD(mm)	PFW(g)	GPY(t.ha ⁻¹)
Varieties				
Bole	28.63 ^a	5.71 ^b	113.29	13.38
Kenkety	26.41 ^b	6.11 ^a	109.49	13.03
LSD(0.05)	1.73	0.25	ns	ns
Compost(t.ha⁻¹)				
0 (Control)	22.80 ^c	4.62 ^d	97.87 ^b	11.91 ^c
2.5	28.61 ^b	5.54 ^c	106.18 ^b	12.85 ^{cb}
5.0	26.31 ^b	6.32 ^b	119.72 ^a	13.64 ^{ab}
7.5	32.35 ^a	7.15 ^a	121.79 ^a	14.43 ^a
LSD (0.05)	2.45	0.36	9.05	0.97
CV (%)	12.49	8.54	11.40	10.32
Pod length				

Analysis of variance showed that pod length was significantly ($P \leq 0.01$), ($P \leq 0.001$) affected by the main effects of variety and compost. The interaction between variety and compost was also significantly ($P \leq 0.05$) affected pod length. Maximum pod length was obtained from the Bole variety with the application of 7.5 t.ha⁻¹ compost, whereas the minimum pod length was obtained from the Kenkety variety with zero application of compost (Table 7). In general, pod length was increased with increasing compost rate. The increment of pod length associated with the increment of compost rate is related to the important role of macro and micronutrients that are released from compost to soil solution to plant tissues, which then affect the pod length by stabilizing photosynthesis, carbohydrate transportation and protein formation. These findings are in line with EL-Desuki et al. (2010) who reported that the pod length of pea plant was significantly increased by increasing the applied compost rates of 100, 120 up to 140 kg nitrogen ha⁻¹. Similarly, Mahmoud et al. (2013) reported that pod length was gradually and significantly increased by increasing the level of compost application up to 180 kg N/feddan on pea plants.

Above ground dry biomass yield

Above ground, dry biomass yield was significantly affected by variety ($P \leq 0.001$), compost ($P \leq 0.001$), and the interaction between variety and compost ($P \leq 0.001$). The maximum above-ground dry biomass was obtained from the Bole variety with the application of 7.5 t.ha^{-1} compost, whereas the minimum above-ground dry biomass was obtained from the Kenkety variety with zero application of compost (Table 7). Overall, above-ground dry biomass was increased with increasing compost rates. The reason behind this might be that compost releases both macro and micronutrients to the soil for plant uptake, which play a major role in vegetative growth of plants by increasing physiological activities, nutrient transportation, and protein formation. The findings are in line with Singh and Chauhan (2009), who reported that the above-ground dry biomass of French bean increased with the application of different rates of organic manure.

Table 7
Interaction effects of variety and compost on pod length and above ground dry biomass of cowpea, at Hawassa

Treatments		Pod length(cm)	Above ground dry biomass (kg/ha)
Variety	Compost (t.ha^{-1})		
Bole	0 (Control)	12.30 ^d	8.22 ^d
	2.5	12.67 ^{cd}	8.53 ^{cd}
	5.0	13.03 ^{abc}	8.95 ^{bc}
	7.5	13.31 ^a	10.36 ^a
Kenkety	0 (Control)	11.19 ^e	6.22 ^e
	2.5	12.55 ^{cd}	8.34 ^d
	5.0	12.78 ^{bcd}	8.74 ^{bcd}
	7.5	13.22 ^{ab}	9.20 ^b
LSD (0.05)		0.53	0.53
CV (%)		4.33	6.33

Conclusion

Cowpea is a dual-purpose legume cultivated for its leaves, fresh pods, and grain; however, its productivity in Ethiopia remains low due to poor-yielding varieties and declining soil fertility. Although cowpea fixes atmospheric nitrogen, effective fixation begins several weeks after planting and does not supply other essential nutrients required for optimal growth. This study evaluated the effects of compost application on growth, physiological gas-exchange parameters, and green and grain yield of cowpea

varieties at Hawassa, Southern Ethiopia. Treatments consisted of four compost rates (0, 2.5, 5.0, and 7.5 t ha⁻¹) and two cowpea varieties (Bole and Kenkety), arranged in a factorial randomized complete block design with four replications.

Compost application significantly affected leaf area, leaf area index, plant height, leaf number, leaf dry weight, stomatal conductance, photosynthetic rate, transpiration rate, pod weight, green pod yield, pod number per plant, and pod diameter. Varietal effects were significant for plant height, leaf number, leaf dry weight, photosynthetic rate, transpiration rate, pod number per plant, and pod diameter. Significant compost × variety interactions were observed for shoot fresh weight, shoot dry weight, aboveground biomass, number of primary branches, leaf fresh weight, and pod length. Overall, the highest growth, physiological performance, and yield were obtained with 7.5 t ha⁻¹ compost, particularly when combined with the Bole variety. These findings suggest that compost application at 7.5 t ha⁻¹ can enhance cowpea productivity under the study conditions. However, multi-location and multi-season trials are required to validate these results.

Declarations

Ethics Approval:

Not applicable.

Clinical trial

Not applicable.

Consent to publish:

The authors declare that they have read and approved the manuscript and consent to its publication.

Consent to participate:

The authors declare that both authors contributed to the study conception, research design, and manuscript editing, and approved the final version of the manuscript.

Conflict of interest:

The authors declare no conflicts of interest

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Author Contribution

Both authors contributed to the study's conception and design. Material preparation, data collection, and analysis were carried out by Mekete Fentaw. The first draft of the manuscript was written by Mekete Fentaw and revised by Tewodros Ayalew. Both authors read and approved the final manuscript.

Data Availability:

The data are available from the corresponding author upon reasonable request

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Figures

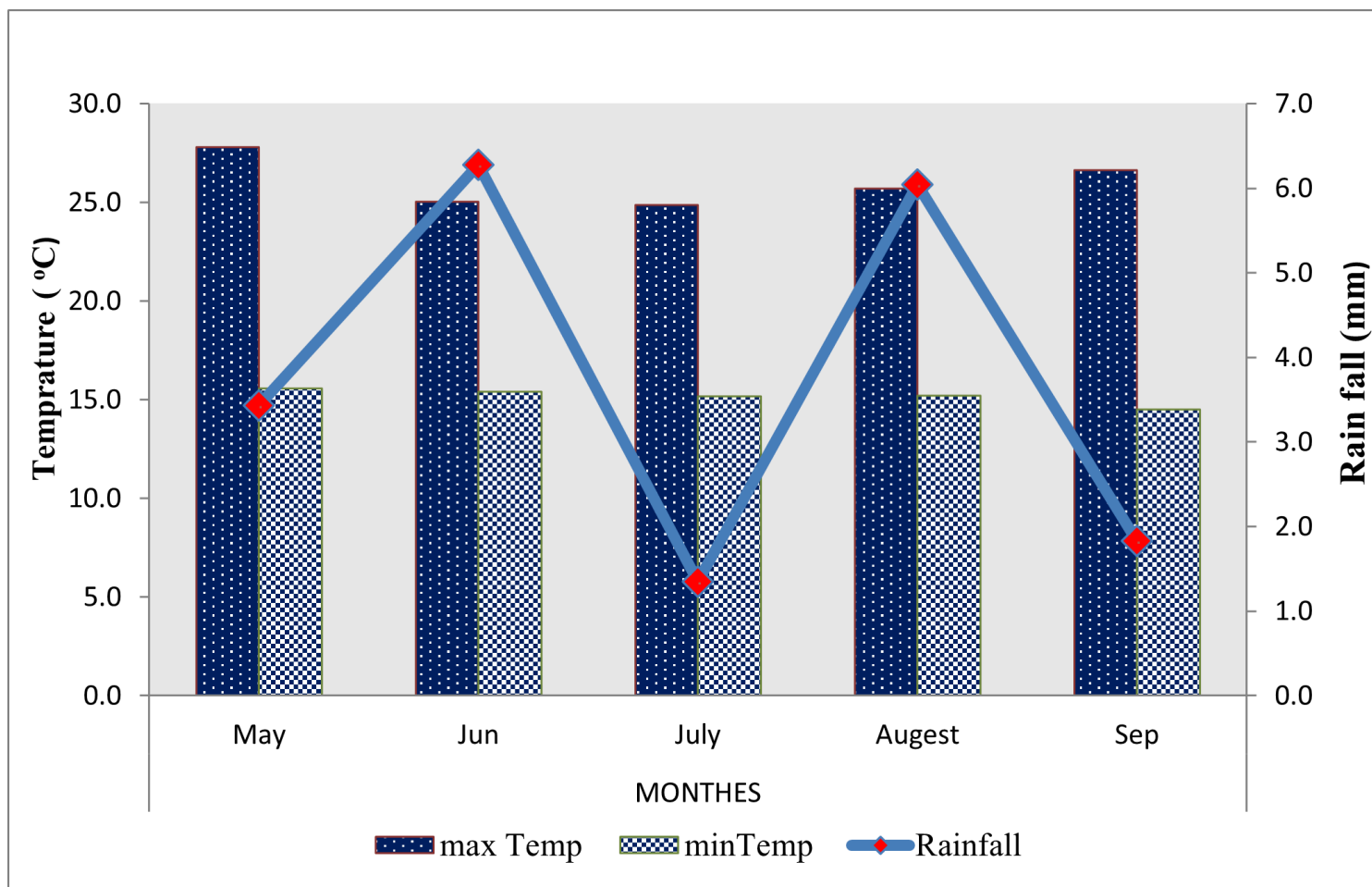


Figure 1

Monthly means for rain fall, minimum and maximum temperature of the area during the experimental period