Morpho-Physiological Responses of Cowpea to Different Time and Rates of Compost Application under Water Stress

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Abstract

Drought and poor soil fertility constitute serious threats to crop production. Water stress reduces crop yield by about 80%. In this study, the effect of Mexican sunflower compost on the morpho-physiological and biochemical responses of cowpea under water stress (100, 50 and 25% field capacity) was investigated. Compost was applied at different rates (10:C1 and 15 t/ha: C2) and at different times (two weeks before (B) and after (A) planting of cowpea seeds as well as repeated application (BA) during one cropping season. Data were collected on growth and yield parameters, chlorophyll and carotenoid content and stomata density. The results showed that although water stress adversely affected cowpea growth and development, soil amendment with compost increased the growth and yield parameters of cowpea. Variations were however observed in the performance of plants treated with compost based on different rates and time of application under different water stress regimes. Application before seed sowing and repeated application after seed sowing resulted in better plant performance compared to the application after seed sowing alone. Cowpea plants grown on soil amended with the higher rate (15t/ha) of compost both before and after seed sowing (C2B+C2A) also showed superiority in all the parameters considered. Cowpea dry matter yields were increased by 98, 110, 153 and 223 % in C1B+C1A, C1B+C2A, C2B+C1A and C2B+C2A compared with control (P<0.05). Chlorophyll content, carotenoid content, and stomata density of cowpea under water stress were also enhanced with compost application. Application of compost both before and after seed sowing enhanced cowpea growth and yield under water stress.

Keywords: Abiotic stress, Drought, Crop production, Organic manure, Nutrition.

Introduction

Cowpea (*Vigna unguiculata* L.Walp), is an annual leguminous crop that is grown extensively mostly in sixteen African countries including Nigeria (Ng and Marechal 1985; Porbeni and Fawole, 2004). It is widely utilized for human consumption, as a constituent of animal feed or silage for animals. In Nigeria, cowpea seeds are the most important and cheapest source of high-quality plant protein in human diet. The grain contains an average of 23-25% protein and 50-67% starch (Agro Nigeria, 2015). Cowpea is cultivated on at least 12.5 million hectares with an annual production of over 3 million tonnes worldwide (AATF, 2012). Cowpea is a warm season crop that is well adapted to many areas of humid tropics and temperate zones. It tolerates heat and dry conditions but is intolerant of frost and drought. Cowpea performs well on a wide variety of soils and soil conditions but performs best on well-drained sandy loam or sandy soil where pH is in the range of 5.5 to 6.5 (Fox and Young, 1982).

The challenges of different abiotic stresses on crop production constitute serious threats to food security. Plants are challenged with different abiotic stresses particularly with the increasing effect of climate change. These abiotic constraints include drought, salt stress, heavy metal stress, light and heat stress all of which cause significant yield reduction during the seedling and/or reproductive stage(s) of cowpea. The most prominent of these is drought. It is estimated that 10 billion people in the world will be hungry and malnourished by the end of this century because of drought (FAOSTAT, 2012). Drought generally affects crop growth and development (Wein *et al*., 1979; Morgan and Condon, 1986). The research focus must, therefore, be channeled towards enhancing the survival of plants during the period of short or long drought.

The physiological responses of plants to water stress is said to depend on soil nutrient supply/availability and interaction occurring at the root-soil interface (Gutierrez-Boem and Thomas, 1999). Drought stress reduces the ability of plants to absorb nutrients due to low solubility, however, in a well-nourished soil like organically amended soil, the adverse effect of stress on the plant is reduced (Singh and Singh, 2004). This was attributed partly to increase in water retention capacity of the amended soil and reduction in the oxidative stress in the stressed crop. For instance, in heavy metal-stressed plants, application of organic amendment to heavy metal contaminated soil was reported to enhance crop growth and reduce the effect of heavy metal stress (Rennevan *et al*., 2007; Adejumo *et al*., 2011).

Tolerance of plants to water stress has also been reportedly enhanced in response to organic amendment through increase in soil water holding capacity, humic acid and organic matter contents (Heckman *et al.,* 1989; Elsharawy *et al.,* 2003; Konomi *et al.,* 2005; Newman *et al.,* 2005).

In addition, cowpea is a leguminous crop which is capable of fixing atmospheric nitrogen, however, nutrient imbalance and stress affect its growth and yield. Low soil fertility as a result of low phosphorous availability particularly in the soil of the savannah areas is a major production constraint (Boukar *et al*., 2011). Compost made from materials of plant and animal origins has been reported to increase soil organic matter which supplies plant nutrients (Malama, 2001; Akanbi and Togun, 2002; Abou El- Magd *et al*., 2006; Olabode *et al*., 2007). Compost also increases soil phosphorus content and plant-available phosphorus which is considered as a limiting nutrient in cowpea production (Eghball *et al*., 2004). Unlike inorganic fertilizer, compost is environment-friendly and has high water retention capacity which could be an added advantage in the period of drought (Sahs and Lesoing, 1985; Atiyeh *et al*., 2002). Sahs and Lesoing (1985) reported that under drought stress conditions, application of organic soil amendments as fertilizer improved crop growth over crops on which inorganic fertilizers were applied.

However, the effectiveness of organic amendment is dose-dependent (Akanbi and Togun, 2002; Adejumo *et al*., 2010). The time of application is equally important in achieving the desired goals. This study was therefore carried out to assess the effect of different rates and time of application as well as repeated application of compost on the physiology, growth and yield of cowpea under water stress conditions. The study tested the null hypothesis that time of application of compost does not have any effect on its ameliorative role on drought-stressed cowpea plants.

Materials and Methods

Experimental procedure

The experiment was conducted at the University of Ibadan, Ibadan in South-western Nigeria, located 7º 24' N, 3º 54' E, and is 234 m above sea level. The experiment was divided into two (First and Residual trials). The first trial was carried out to determine the effect of organic amendment on cowpea growth under water stress while the second trial was to determine the residual effect of repeated and single compost application as well as short-term water stress on the subsequent crop. The top soil used for the experiment was collected randomly from five equidistant points at the crop garden of the Department of Crop Protection and Environmental Biology, University of Ibadan. The soil was then mixed thoroughly to achieve homogeneity, air-dried, sieved and analyzed for physical and chemical parameters. Thereafter, soil was filled into 5 kg capacity experimental pots. A total of 108 pots were used. Compost was prepared from Mexican sunflower and poultry manure in ratio 3:1 using Partially Aerated Composting Technology method (Adediran *et al*., 2001). The Mexican sunflower plants were collected along Ajibode road adjacent to the University campus, while poultry manure was collected from Teaching and Research farm, University of Ibadan. The chemical properties of the matured compost were then determined following standard procedure. Compost was mixed with the soil at the rates of 0, (compost rate 0 = control), 10 t/ha (compost rate 1 = 12.5 g / 5 kg soil) and 15 t/ha (compost rate 2 = 18.75 g / 5 kg soil).Treatments also included the application of compost before seed sowing (B), after seed sowing (A) and application of compost both before and after seed sowing (BA). These were designated as: C1B = Compost rate 1 (10 t/ha) before seed sowing, C1A= Compost rate 1 (i.e. 10 t/ha) after seed sowing, C2B= Compost rate 2 (i.e. 15 t/ha) before seed sowing, C2A = Compost rate 2 (15 t/ha) after seed sowing, C1B+C1A = Compost rate 1 before seed sowing and after seed sowing, C1B + C2A = compost rate 1 before seed sowing + Compost rate 2 after seed sowing, C2B +C1A = Compost rate 2 before seed sowing + compost rate 1 after seed sowing, C2B +C2A = Compost rate 2 before seed sowing + compost rate 2 after seed sowing and C0 =Control. The pots were laid out in a Completely Randomised Design with three replicates.

The variety of cowpea used was IT 04K-343-1. Seeds were sown a week after compost application. Field capacity (FC) was obtained by subtracting the dry weight of the soil from the fresh (field) weight to give the quantity of water which the known soil quantity (5 kg) could hold. Fresh weight was obtained by weighing the soil as collected from the field, while dry weight was taken after oven drying in a hot air circulating oven at 70^o C for 72 hours. At the initial stage, the soil was irrigated with 500 ml of water and this was followed by the addition of 100 ml once every other day from the planting date to four weeks after sowing (WAS). At 4WAS the plants were subjected to the following watering regimes for two weeks; W_1: Watering to field capacity every other day; W_2: Watering to 50% field capacity every other day; W_3: Watering to 25% field capacity every other day. A second study was conducted using the same organic amended soil used in the first experiment to grow cowpea under water stress in order to determine the residual effect of repeated and single compost application as well as short-term water stress on the subsequent crop.

Data collection

Data collection started at 4 WAS (before application of water regimes) and was done fortnightly. Data were collected on growth parameters, stomata density, carotenoid and chlorophyll content, yield parameters, proximate analysis of cowpea seeds and nutrient uptake following standard procedures. The stomata density was obtained by coating the cowpea leaf with a colourless varnish. Cellotape was then placed on the coated leaf, and then removed and placed on a slide for viewing under the microscope. Chlorophyll and carotenoid contents were obtained following the procedure described by Sarropoulou *et al.* (2012). The calculation was determined using the formula:

Total Chlorophyll (a+b) =
$(6.10\times A_{665}+20.04\times A_{649})\times 15\div 1000/FW$ (mg/g FW)

Carotenoid was estimated using:
$(4.69\times A_{440}-1.96\times A_{665}-4.47\times A_{649})\times 15\times 0.1$

At harvest, dry matter yield of root and shoot were determined. Statistical analysis of the data collected was carried out using analysis of variance (ANOVA) and Least Significant Difference $(LSD)_{0.05}$ was used to separate the significant means.

Results

The soil pH of 6.4 was within the recommended range for agricultural production. Organic carbon was 3.77% but the soil was low in Nitrogen (0.36%). The exchangeable bases; Mg, K, Ca and Na were 0.68, 0.27, 0.50 and 0.17 cmol/kg, respectively, while P was 0.18 cmol/kg in soil. The micronutrients were Mn: 2.30, Fe: 88.00, Cu: 44.50 and Zn: 88.50 mg/kg (Table 1).

Table 1: Pre-cropping physico-chemical properties of soil and compost used for the experiments

Parameters	Values in soil	Values in Compost
$pH(H_2O)$	6.37	7.4
Organic carbon (%)	3.77	38.00
Total Nitrogen (%)	0.36	2.74
Exchangeable base (cmol/kg)		
Potassium	0.27	1.08
Calcium	0.50	1.73
Magnesium	0.68	1.04
Sodium	0.17	
Phosphorus	0.18	1.17
Extractable Micronutrients (mg/kg)		
Mn	2.30	276.50
Iron	88.00	1285.00
Copper	44.50	19.45
Zinc	88.5	6.00
Particle size distribution (g/kg)		
Sand	84.6	
Silt	7.4	
Clay	8.0	

Effect of compost rate, application time and water stress on growth parameters of cowpea

Compost application both before and after seed sowing increased leaf area and performed better than control. Repeated applications (before and after seed sowing) also enhanced cowpea leaf area more than other compost treatments. Cowpea plants treated with C2B+C2A under 100% FC had the highest mean leaf area of 79.1cm^2 at 12 WAS while treatments with 25% FC had the lowest mean.

Leaf area was highest in 100% FC compared to 50 and 25 % FC where a reduction in the leaf area was recorded. Compost application also increased the number of leaves both in water-stressed and unstressed cowpea. The cowpea plants treated with higher rates of compost before and after seed sowing had the highest number of leaves. There was a reduction in number of leaves with increase in stress. C2B+C2A treatment under 100% FC had the highest mean number of leaves (5.3) while 25% FC had the lowest mean number of leaves. As observed for other parameters water stress also had a significant effect on plant height. Plant height was reduced at 25% FC compared to 100% FC. Application of compost either before or after seed sowing however increased plant height in the stressed and unstressed plants compared to control. Those treated with higher rates of compost both before and after seed sowing had the highest mean plant height (Table 2).

Effect of rate, application time of compost and water stress on fresh weight and dry matter accumulation of cowpea

The dry matter accumulation in the stressed plants was reduced compared to those grown under 100% field capacity. Application of compost increased dry matter accumulation in compost treated cowpea compared to control. Treatment with 100% FC and with the two rates of compost recorded highest value while treatments with 25% FC recorded the lowest value. However, there were significant differences in the dry weight of the various plant parts of the cowpea under the different water regimes and in response to compost application compared with control ($P<0.05$). There was no significant difference between treatments C1B+C2A and C2B+C1A when compared with each other but they out-performed other compost treatments. A significant difference was observed in the dry matter accumulation of cowpea that received

Table 2: Effect of rates and time of compost application on vegetative growth parameters of cowpea in 100, 50 and 25% field capacity water regimes

	Leaf Area (cm^2)			Number of leaves			Plant Height (cm)		
Treatments*	100	50	25	100	50	25	100	50	25
C0	43.4	42.2	35.0	3.0	3.0	2.7	75.0	66.8	38.4
C1B	48.9	47.2	41.9	3.7	3.5	2.8	84.9	74.3	41.9
C2B	66.9	64.6	61.1	4.7	4.7	4.2	107.7	98.7	59.3
C1A	48.4	45.3	41.7	3.3	3.2	2.7	81.4	75.4	41.8
C2A	49.5	45.4	42.0	3.3	4.2	3.0	90.4	80.4	45.7
C1B+C1A	60.5	57.5	54.1	3.5	3.2	3.0	95.9	87.1	47.3
C1B+C2A	66.5	65.4	62.5	4.2	4.0	3.3	99.4	95.3	52.2
C2B+C1A	76.8	74.3	66.1	4.7	4.3	4.0	109.4	103.5	52.4
C2B+C2A	79.1	76.4	71.7	5.3	5.2	4.8	120.0	109.4	61.0
LSD	0.65	1.15	1.37	0.21	0.27	0.24	1.36	1.59	1.91

* C1= 10 kg/ha compost rate; C2 = 15 kg/ha compost rate, B = application **B**efore sowing A = application **A**fter sowing (e.g. C1A = 10 kg/ha rate applied after sowing), C0 = Control (no compost application).

compost before seed sowing compared to those that received compost after seed sowing with the higher rate being superior. A significant difference was also observed in all the treatments when compared with the control (Table 3).

Effect of different rates of compost, application time and water stress on the yield components of cowpea

Compared to the control, compost application also had a significant effect on the number of pods especially in the unstressed treatment (100% FC). A significant difference was observed in all the treatments compared with control except in those that received single dose of compost after seed sowing. Plants that received repeated doses of compost application also performed better than with single application irrespective of time of application. However, there was no significant difference in the number of pods recorded from the treatments that received single dose of compost either before seed sowing or after seed sowing. A similar result was obtained regarding the pod fresh weight per plant compared to control except in those that received a single dose of compost either before or after seed sowing. Application of compost also had a significant effect on the seed weight compared to control (P< 0.05). Cowpea that was grown on the soil that received repeated application of higher rate of compost (C2B+C2A) also gave the highest seed weight while control recorded the lowest value. This was similar in all the water stress treatments (Table 4).

Table 3: Effect of rates and time of compost application on dry matter accumulation (g) of cowpea in three water regimes

Treatments	Root	Shoot	Root	Shoot	Root	Shoot
	100% FC		**50% FC**		**25%FC**	
CO	1.0	5.4	0.9	4.3	0.3	2.4
C1B	0.6	7.0	0.7	7.5	0.2	2.8
C2B	1.6	14.0	1.3	7.8	0.6	7.5
C1A	1.1	6.4	0.4	4.9	0.2	2.6
C2A	0.9	10.9	0.9	6.7	0.5	3.8
C1B+C1A	1.9	10.6	0.5	6.3	0.8	4.7
C1B+C2A	1.3	12.2	1.4	8.6	0.3	5.4
C2B+C1A	1.4	14.1	1.1	10.2	0.7	6.6
C2B+C2A	1.5	17.1	1.5	11.5	0.9	7.9
LSD	0.4	1.9	0.3	1.9	0.3	1.4

C1= 10 kg/ha compost rate; C2 = 15 kg/ha compost rate; B = application **B**efore sowing A = application **A**fter sowing (e.g. C1A = 10 kg/ha rate applied after sowing); C0 = Control (no compost application); FC = Field capacity.

Table 4: Effect of different rates and time of compost application on the yield components of cowpea under water stress

Treatments*	100%FC			50%FC			25%FC		
	NP	PFW (g)	SFW (g/pod)	NP	PFW (g)	SFW (g/pod)	NP	PFW (g)	SFW (g/pod)
CO	1.33	2.93	2.36	2.33	2.51	2.02	2.00	3.20	2.56
C1B	3.67	6.90	5.26	2.67	3.61	2.69	2.67	4.80	3.73
C2B	4.00	4.78	3.35	3.00	6.73	5.15	4.00	5.69	4.41
C1A	1.67	2.64	2.19	2.67	5.00	3.63	2.33	5.47	4.41
C2A	2.67	4.75	3.50	2.33	3.46	2.14	2.67	4.52	3.57
C1B+C1A	3.67	7.42	5.74	2.67	5.63	4.25	3.00	6.51	5.11
C1B+C2A	4.00	7.32	5.39	3.00	5.26	4.19	4.33	9.55	7.51
C2B+C1A	6.00	13.12	10.42	3.67	7.33	4.74	5.00	7.21	5.89
C2B+C2A	6.33	10.43	8.20	4.33	7.00	5.11	5.67	9.46	6.94
LSD	1.22	3.24	2.54	1.23	2.58	2.24	1.46	3.24	2.61

* C1= 10 kg/ha compost rate; C2 = 15 kg/ha compost rate, B = application **B**efore sowing A = application **A**fter sowing (e.g. C1A = 10 kg/ha rate applied after sowing); C0 = Control (no compost application); NP= Number of Pods; PFW = Pod Fresh Weight; SFW = Seeds Fresh weight; FC = Field capacity.

Effect of rates, application of compost time and water stress on amount of chlorophyll and carotenoid and stomatal density of cowpea

Significant differences in the effect of compost application on the chlorophyll and carotenoid contents of cowpea, were observed among treatments when compared with control (P <0.05). Cowpea plants grown on soil amended with higher rates of compost both before and after seed sowing (C2B+C2A) had the highest chlorophyll content while control, C1A, and C2A recorded the lowest chlorophyll content and were not significantly different from control (Figure 1A). Compost amendments also increased carotenoid content of cowpea leaves at 4WAS. Repeated application of the higher rate of compost before and after seed sowing also performed better with regards to carotenoid content than other compost treatments while the lowest value was recorded in the control. Treatment with C2B+C2A however had the highest carotenoid content compared to its counterparts. Those that received compost after seed sowing (C1A, and C2A) recorded the lowest value compared to those that received compost before seed sowing (Figure 1B). The stomatal density was also affected by compost application. Compost treatments almost had equal amount of stomata but C2B+C2A, C2B+C1A, C1B+C2A recorded the highest level of stomata density and they were all better than the control which had the lowest (Figure 2).

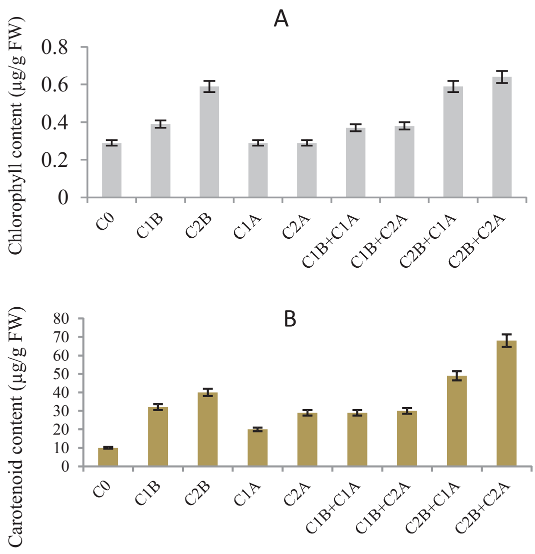

Figure 1: Effect of different rates and time of compost application on chlorophyll and carotenoid concentrations of cowpea under water stress.

C1= 10 kg/ha compost rate; C2 = 15 kg/ha compost rate, B = application **B**efore sowing A = application **A**fter sowing (e.g. C1A = 10 kg/ha rate applied after sowing), C0 = Control (no compost application).

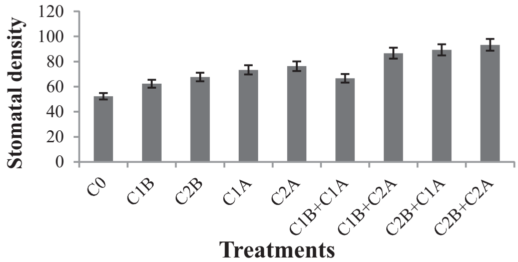

Figure 2: Effect of different rates and time of compost application on Stomata density of Cowpea under water stress.
C1= 10 kg/ha compost rate; C2 = 15 kg/ha compost rate, B = application **B**efore sowing A = application **A**fter sowing (e.g. C1A = 10 kg/ha rate applied after sowing), C0 = Control (no compost application).

Effect of rates, application time of compost and water stress on nutrient uptake of cowpea and grain food components

The potassium, sodium and manganese concentrations were higher in the compost treated cowpea grains compared to control (Table 5). C2B+C2A recorded the highest values for K, Na and Mn while control recorded the lowest values. However, there was no significant difference in the calcium and magnesium contents of seeds from the compost treatments when compared with control especially in those that received single compost application. Treatments with double applications recorded the highest value while control recorded the lowest. For zinc and copper, the same trend was observed with C2B+C2A treatment giving the highest value while control recorded the lowest value (Table 5).

There was an increase in the ash and crude protein contents of seeds from compost treatments compared to control (Table 6). As was observed in all other parameters, repeated dose treatments also recorded the highest while control had the lowest. Except in those that received single dose of compost after sowing in the first planting, crude fibre content was significantly higher in all other compost treatments compared with control. Similarly, the crude lipid and dry matter yield of cowpea seeds were also enhanced significantly in cowpea grown in soil initially treated with composts compared to control (Table 6).

Table 5: Effect of compost application on nutrient composition of harvested cowpea seeds

Treatments*	Ca (g/kg)	Mg (g/kg)	K (mg/kg)	Na (mg/kg)	Mn (mg/kg)	Fe (g/kg)	Cu (mg/kg)	Zn (mg/kg)
CO	1.05	0.53	2830.00	190.00	0.06	2.00	0.35	0.22
C1B	1.13	0.46	3990.50	210.00	0.21	1.68	0.12	0.21
C2B	1.46	0.52	5400.00	330.00	0.31	2.42	0.34	0.38
C1A	1.16	0.62	4800.50	140.00	0.24	1.48	0.31	0.24
C2A	1.10	0.59	5400.00	100.00	0.18	1.66	0.59	0.32
C1B+C1A	1.50	0.49	5070.50	350.00	0.19	2.15	0.32	0.29
C1B+C2A	1.72	0.63	4480.00	320.00	0.28	2.23	0.14	0.21
C2B+C1A	1.73	0.61	4830.50	360.00	0.19	2.35	1.06	0.46
C2B+C2A	1.81	0.72	5550.00	280.00	0.22	2.77	0.33	0.40
LSD	0.40	0.11	1140.64	120.82	0.09	0.56	0.38	0.12

* C1= 10 kg/ha compost rate; C2 = 15 kg/ha compost rate, B = application **B**efore sowing
A = application **A**fter sowing (e.g. C1A = 10 kg/ha rate applied after sowing),
C0 = Control (no compost application).

Table 6: Effect of compost application on food components of cowpea seeds

Treatments*	Ash (g)	Crude protein (%)	Crude fibre (%)	Crude lipid (%)	100 seed dry matter (g)
CO	10.68	22.55	4.40	13.23	32.47
C1B	27.78	30.80	7.80	14.70	31.07
C2B	29.92	32.20	7.70	15.10	44.83
C1A	24.90	31.85	3.40	14.80	39.47
C2A	26.97	35.50	3.70	14.60	54.99
C1B+C1A	28.61	34.30	6.40	14.70	61.62
C1B+C2A	42.31	31.80	7.80	14.70	48.51
C2B+C1A	54.67	35.70	7.80	15.00	45.80
C2B+C2A	57.97	32.90	9.70	14.80	62.48
LSD	20.17	5.23	2.93	0.82	15.25

* C1= 10 kg/ha compost rate; C2 = 15 kg/ha compost rate, B = application **B**efore sowing
A = application **A**fter sowing (e.g. C1A = 10 kg/ha rate applied after sowing),
C0 = Control (no compost application).

Residual effect of compost application on yield components and dry matter accumulation in cowpea

Significant differences were observed among the treatments compared with control except in those that previously received single dose of compost after planting (Table 7). Plants that previously received repeated doses of compost application also performed better than those with single doses irrespective of time of application and the initial stress treatments. However, there was no significant difference in the number of pods recorded from the treatments that received single dose of compost either before planting or after planting. Similar result was obtained for the pod fresh weight per plant compared to control except in those that received single dose of compost either before or after planting. Application of compost also had significant ($P< 0.05$) effect on seed weight compared to control. Cowpea grown on plots that previously received double application of higher rate of compost (C2B+C2A) also gave the highest seed weight while control recorded the lowest value. This was similar in all the water stressed treatments (Table 7).

Table 7: Residual effect of different rates and repeated compost application on yield components of cowpea

Treatments	NP	PFW (g)	SFW (g/pod)	NP	PFW(g)	SFW (g/pod)	NP	PFW (g)	SFW (g/pod)
	100% FC			50% FC			25% FC		
CO	1.33	2.93	2.36	2.33	2.51	2.02	2.00	3.20	2.56
C1B	3.67	6.90	5.26	2.67	3.61	2.69	2.67	4.80	3.73
C2B	4.00	4.78	3.35	3.00	6.73	5.15	4.00	5.69	4.41
C1A	1.67	2.64	2.19	2.67	5.00	3.63	2.33	5.47	4.41
C2A	2.67	4.75	3.50	2.33	3.46	2.14	2.67	4.52	3.57
C1B+C1A	3.67	7.42	5.74	2.67	5.63	4.25	3.00	6.51	5.11
C1B+C2A	4.00	7.32	5.39	3.00	5.26	4.19	4.33	9.55	7.51
C2B+C1A	6.00	13.12	10.42	3.67	7.33	4.74	5.00	7.21	5.89
C2B+C2A	6.33	10.43	8.20	4.33	7.00	5.11	5.67	9.46	6.94
LSD	1.22	3.24	2.54	1.23	2.58	2.24	1.46	3.24	2.61

C1= 10 kg/ha compost rate; C2 = 15 kg/ha compost rate, B = application **B**efore sowing A = application **A**fter sowing (e.g. C1A = 10 kg/ha rate applied after sowing), C0 = Control (no compost application). NP= Number of Pods; PFW = Pod Fresh Weight; SFW = Seeds Fresh weight.

Table 8: Residual effect of compost application on dry weight of cowpea

TRTS	SDW	RDW	LDW	SDW	RDW	LDW	SDW	RDW	LDW
		100% FC			50% FC			25% FC	
CO	8.5	0.9	1.8	7.0	0.9	2.2	6.3	0.7	1.5
C1B	11.4	0.8	2.2	11.7	1.3	2.9	7.7	1.2	1.8
C2B	14.9	5.3	3.7	14.4	2.2	4.4	17.2	1.2	3.1
C1A	8.5	0.6	1.2	7.6	0.9	2.8	11.1	1.1	3.1
C2A	12.2	1.5	3.4	11.4	1.3	3.1	11.1	1.1	3.7
C1B+C1A	12.8	1.4	2.3	14.9	1.6	6.2	14.6	1.7	4.1
C1B+C2A	12.4	1.5	4.2	12.7	1.4	2.6	10.9	1.6	6.5
C2B+C1A	19.0	1.9	6.3	14.9	2.2	4.5	12.5	1.6	2.4
C2B+C2A	18.9	1.90	4.9	17.5	1.9	6.5	18.8	2.3	5.2
LSD	4.19	2.00	1.06	3.13	0.49	1.45	4.12	0.64	1.19

* C1= 10 kg/ha compost rate; C2 = 15 kg/ha compost rate, B = application **B**efore sowing A = application **A**fter sowing (e.g. C1A = 10 kg/ha rate applied after sowing), C0 = Control (no compost application). SDW = Stem Dry Weight: RDW = Root Dry Weight; LDW = Leaf Dry Weight. Different watering regimes; 100, 50 and 25 Field capacity.

There were significant differences in the dry weight of the various plant parts, dry matter accumulation, and partitioning in cowpea in response to the residual effect of compost application. Cowpea plants grown on soil that previously received compost before and after planting gave the highest dry weight while control had the lowest value (Table 8).

Discussion

Water stress generally decreased biomass accumulation as a result of the reduction in nutrient and water uptake by plants (Moustafa *et al*., 1996; Singh and Singh, 2004). This, in turn, affects different physiological processes in plants especially photosynthesis, where water serves as one of the reactants. Singh and Singh, (2004) reported that total nutrients of the crop decreased with increasing water stress. This was confirmed by the reduction in leaf area and number of leaves which was observed in all the water-stressed treatments. The results agreed with the finding of Manikavelu *et al.* (2006) that stress during vegetative stage irreversibly reduced leaf area and number of leaves thereby causing significant yield loss. However, the ability of compost to supply the required nutrients for plant growth at any rate made the compost treated cowpea to perform better than the untreated plants (Akanbi *et al*., 2000; Premsekhar and Rajashree, 2009; Adejumo *et al.,* 2011). This is because plants grown on fertile soil will have enough nutrients in its tissue to adjust its osmotic status in the time of drought. Highly concentrated solute in plant tissue will increase the osmotic potential and the ability of such plant to draw water from its surrounding environment. It is well documented that essential plant nutrients regulate plant metabolism even in plants exposed to stress by acting as cofactors or enzyme activators (Nicholas, 1975). Higher concentrations of nutrients in plants also give the plant a temporary succour by maintaining the turgidity of the plant under stress or at low water potential (Morgan and Condon, 1986). Availability of nutrients in the growing medium has also been reported to enhance nitrogen fixing capability of cowpea (Israel, 1987; Hafner *et al*., 1992) which in turn would have contributed to increased yield under stress. The application of humic substances has been shown to ameliorate the effect of water stress in crops by increasing antioxidant and phyto-hormonal activities of the organically fertilized crops (Xu, 2000). The increase in leaf area and number of leaves with increase in application of compost confirmed the earlier reports that higher compost rate enhanced crop yield more than lower rates (Adediran *et al.,* 2001; Akanbi and Togun, 2003).

Application of compost before and after seed sowing particularly with 15 kg/ha rate, increased the dry matter accumulation in cowpea more than other compost treatments. This is because crop growth and development is a function of soil nutrient status. Soil that received higher rate of compost as expected was able to supply enough nutrients to the crop and this was responsible for the higher yield recorded in this treatment. Though previous reports demonstrated that compost or organic amendments generally last longer in the soil than inorganic fertilizers that are prone to leaching (Akanbi, 2002; Adediran *et al*., 2004), repeated application of compost (both before and after seed sowing) ensured continuous supply of nutrients to crop thereby making room for the replacement of nutrients that might have leached out and this was reflected in the performance of these treatments..

Different rates and time of compost application also had a significant effect on chlorophyll and carotenoid contents of cowpea compared to control. This could also be attributed to the availability of major nutrients especially Mg and Fe which are the major constituents of photosynthetic pigments. Increase in chlorophyll and carotenoid contents in plants leads to enhanced light trapping and increase in photosynthesis (Moore *et al*., 2003). Availability of nutrients also enhances the activity of most metabolic enzymes particularly, those enzymes that use different metals as cofactors. This in turn will increase the physiological processes like photosynthetic activities in plants which consequently results in dry matter production. Xu (2000) also reported higher photosynthetic rates in maize grown on organically treated soil.

The density of stomata was also affected by compost application before and after sowing where 15 kg/ha produced the highest number of stomata. The effect of all these culminated in increased dry matter production recorded in these treatments. The more the number of stomata, in water-stressed plant, the more effective the plant is in trapping atmospheric CO_2 and water vapour which are the major requirements for photosynthesis. This agreed with the report of Mladenova *et al*. (1998) where stomata conductance was enhanced following foliar application of humic substances to drought-stressed wheat.

Water stress had adverse effects on growth and yield parameters when comparing stressed and unstressed cowpea, however, those treated with compost were able to compare favourably with unstressed ones in terms of growth and yield parameters. This was so, probably because, stress treatment commenced at 6 weeks after sowing, during which compost might have absorbed enough water. Also the ability of compost to retain water ensured that the plants did not suffer much during the period of short drought. The better performance observed in cowpea treated with a higher rate of compost and repeated application could be due to increase in water retention in this soil. Organic amendment has been reported to increase water holding capacity at a higher rate (Sheng-Gao and Lei, 2004). Although not determined in this study, increase in water holding capacity between 0.03 and 1.5 MPa is said to be beneficial to crop growth and has been attributed to increase in crop yield observed in organically amended soil (Hangarge *et al*., 2002; Curtis and Claasen, 2005). Application of fertilizer like phosphorus has also been reported to enhance recovery in drought-stressed cowpea better than untreated cowpea (Chiulele and Agenbag, 2005).

Furthermore, increase in the root fresh and dry weight in compost treated cowpea under water stress indicates that root growth was also enhanced. This has been identified as one of the important factors that adapt plants to drought conditions. This is because well-developed root system will enable the plant to take up more water as well as nutrients from deeper soil layers during insufficient water supply which must have enhanced osmotic potential thereby ensuring plant survival under drought (Tanguilig *et al*., 1987). At 8WAS the number of leaves was generally reduced in plants subjected to 0% field capacity, but the reduction in plants with compost treatments was not as pronounced as in control treatment. The shedding of leaves under extreme drought also has its own advantage in that it is a physiological strategy to reduce the rate of water evaporation or transpiration in plants as a result of increase in production and enhanced mobilization and up-regulation of abscisic acid.

The increase observed in dry matter of cowpea from the residual trial showed the ability of compost to release plant nutrients for a long period of time. Meanwhile, cowpea plants grown on soil that previously received compost before and after planting also gave the highest dry weight in the residual trial while the untreated plants had the lowest value. This could be due to the fact that high rate of compost application before and after seed sowing provided enough nutrient to the plant as at when needed and this could have enabled the plant to develop more leaves for higher photosynthetic efficiency than the other treatments. The dry matter yield in the second experiment was more than that of the first experiment probably due to the unrestricted access of the plants to water compared with plants in the first experiment in which they received limited amount of water (data nor shown). The seed yield among the treatments at maturity was high in the second planting as the first was unable to produce seeds due to water stress. The results obtained for the yield components also confirmed the fact that plant response to compost is rate and time dependent. The result of this study showed that the treatments with the highest compost rate at 15 t/ha and applied before and after seed sowing had the highest number of pods, total seed yield and seed dry weight compared with other treatments.

Conclusion

It could be concluded that the higher compost rate of 15 t/ha applied two weeks before seed sowing followed by another application at two weeks after seed sowing enhanced cowpea growth and dry matter yield under water stress. Using compost for soil amendment can therefore help in reducing the drought stress in plants and adapting to climate change. It also gave many agronomic benefits and ensures long-term agricultural production under unpredictable weather conditions.

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