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EFFECTS OF VERMICOMPOST ON GROWTH, YIELD COMPONENTS AND NUTRIENT UPTAKE OF MAIZE UNDER DROUGHT CONDITION

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ABSTRACT

Maize is one of the world most recognized annual plants with huge utilizations. However, irregular rainfall leading to drought condition of soil from which plants find all the nutrients required for optimum productivity has been one of the greatest unseen threats maize farmers can ever have. As a results, this study was carried out purposefully to evaluate the effects of vermicompost on morphological, yield and physiological components of maize under drought condition. Treatments include first control, which represented normal watering regime without alleviation; second control, which represented water-stressed plants without alleviation; vermicompost level at 75 g (15 t/ha) per 10 kg of soil; and vermicompost level at 125 g (25 t/ha) per 10 kg of soil. To achieve this objective, SAMMAZ 52 maize variety were locally sourced and the experiment was laid out in Randomized Completely Block Design (RCBD) with four replications for each of the treatment. Also, laboratory analysis was done for both physical and chemical property of the vermicompost as well as soil used prior to the experiment and data were collected on growth parameters, yield components and nutrient content under drought condition. The results showed that vermicompost at 25 t ha^{-1} generally improved maize growth under water deficit. Plant height under the 25 t ha^{-1} treatment increased from 65.39 cm before drought to 118.62 cm at mild drought and 120.80 cm at severe drought, while stem girth increased from 4.84 to 5.50 and 5.88 cm, respectively. Under water deficit, the 25 t ha^{-1} treatment also recorded the highest cob weight (79.50 g) and stover weight (230.80 g) among the drought-stressed treatments. Grain number and grain weight were 80.00 and 8.48 g, respectively, under 25 t ha^{-1} compared with only 2.00 grains and 0.23 g in the water-stressed control without vermicompost. Nutrient concentrations were generally reduced under severe drought, particularly in plants without vermicompost, while vermicompost application moderated these reductions for several nutrients. The study demonstrates that vermicompost, particularly at 25 t ha^{-1}, can improve maize growth and selected yield components under water deficit conditions. Application of 25 t ha^{-1} vermicompost is therefore recommended as a soil amendment for improving the performance of maize subjected to drought stress, subject to economic and field-scale validation.

Keywords: Drought stress, Maize growth, Nutrient uptake, Vermicompost, Yield components

INTRODUCTION

Drought is the most critical environmental factor that limits crop production (Blouin *et al*., 2019). Yield reductions reported from different parts of the world caused by drought stress often exceed 50%, particularly in maize-based systems under semi-arid conditions (Younas *et al*., 2021; Khan *et al*., 2022). Although several crops can tolerate drought to some extent, substantial research has focused on strategies to mitigate water stress and improve plant growth and productivity under limited moisture conditions (Dawar *et al*., 2022; Ebrahimi *et al.*, 2021). Responses of plants to soil moisture deficiency vary depending on stress intensity and duration. Studies have shown that plants respond to increasing moisture stress by accumulating osmotically active substances, thereby lowering cellular osmotic potential and maintaining turgor under reduced water availability (Ebrahimi *et al*., 2021; Toor *et al*., 2024).

Vermicompost is an organic soil amendment produced through vermicomposting that contains essential plant nutrients and possesses favourable physical and chemical properties, including high porosity and water-holding capacity, which can improve soil fertility, nutrient availability and plant performance under water-deficit conditions. In comparison with other organic fertilizers, vermicompost contains high levels

of essential nutrients such as nitrogen, phosphorus, potassium, calcium, and magnesium, as well as micronutrients including iron, zinc, copper, and manganese (Mohite *et al*., 2024). Vermicompost is highly porous, improves aeration and drainage, and possesses a high water-holding capacity, making it effective under drought conditions (Blouin *et al*., 2019).

Drought stress has been shown to cause considerable impairment of growth-related traits, including leaf area, number of leaves per plant, plant height, shoot biomass, and cob development. Reproductive growth stages are particularly sensitive to drought stress. The susceptibility of maize during the reproductive stage under drought is largely attributed to the preferential translocation of photosynthates to reproductive organs rather than roots, thereby limiting adaptive root elongation (Younas *et al*., 2021). Drought stress also affects pollen development, leading to reduced pollen viability, altered pollen morphology, and impaired dispersal due to dehydration (Sarathambal *et al*., 2024).

Crop yield is the outcome of interactions among several developmental components. Drought stress results in significant reductions in yield quality by disrupting leaf gas exchange, limiting source–sink relationships, and impairing phloem loading, assimilate translocation, and dry matter partitioning (Dawar *et al*., 2022). Reduced leaf development under drought further limits light interception, thereby suppressing dry matter production (Toor *et al*., 2024). Drought-induced stomatal closure reduces CO_2 uptake, leading to decreased photosynthetic efficiency and overall plant productivity (Ebrahimi *et al*., 2021). Prolonged drought conditions therefore restrict plant growth and reproductive success, resulting in poor flower formation and reduced grain filling (Younas *et al*., 2021; Dawar *et al*., 2022).

The availability, assimilation, distribution, and redistribution of nutrients within plants can be severely disrupted by climatic stressors such as drought and heat waves (Xue *et al*., 2022). Climatic stresses and nutrient deficiencies influence leaf longevity and harvest composition, including grain and stover yield. However, plants contribute to improved soil nutrient availability through interactions with rhizospheric microorganisms, enhancing nutrient uptake efficiency (Dominguez *et al*., 2019). Seed micronutrient enrichment depends on nutrient storage, uptake, mobilization, and translocation within plant tissues. Drought reduces nutrient diffusion in the soil and limits root uptake and translocation due to reduced transpiration flux and membrane transport activity (Khan et al., 2022). Therefore, this study aimed to evaluate the effects of vermicompost on growth, yield components, and nutrient uptake of maize under drought conditions

MATERIALS AND METHODS

Experimental Site

The study was conducted at the greenhouse of the Department of Agronomy, Faculty of Agriculture, University of Ilorin, Kwara State, located in the Southern Guinea Savanna Ecological Zone of Nigeria. The site is situated at latitude $8^0$29'N, and longitude $4^0$35'E. The area is characterized by a bimodal rainfall with peaks in June and September and a dry spell between mid-July and August. (Kwara State Government, 2023)

Experimental Design and Treatment Application

The potted experiment was laid out using a Randomized Complete Block Design (RCBD). Each treatment was replicated four times. Maize seeds (*Zea mays* L.) of SAMMAZ 52 variety were sown using the drilling method at 1.5 cm depth and spacing of 50 cm × 50 cm before covering with soil. The seeds were purchased locally from Ipata Market, Ilorin, Kwara State, Nigeria.

There were two treatments and two controls. The first control represented normal watering regime without alleviation, while the second control represented water-stressed plants without alleviation. Treatment 1 represented vermicompost level at 75 g (15 t/ha) per 10 kg of soil, while Treatment 2 represented vermicompost level at 125 g (25 t/ha) per 10 kg of soil. Vermicompost was incorporated into the soil one week before sowing.

Soil Analysis

Soil and vermicompost samples were analyzed for physical and chemical properties at the Department of Agronomy Laboratory, University of Ilorin, using standard laboratory procedures before sowing

Data Collection

Plant height

This was measured using a meter rule graduated in cm, from the soil level to the point of terminal growth. The average height of the plant per treatment was obtained by adding up the heights of plants and dividing this sum by the number of plants measured.

Number of Leaves

This data was obtained by counting the number of leaves per plant. The average number of leaves per plant was obtained by adding up the total number of leaves per treatment and dividing this total by the number of plants per the treatment.

Stem diameter/girth

This was done with the use of ruler and tiny rope. The rope was wrapped around the stem and then placed on a ruler to obtain the circumference measurement in centimeters.

Number of fruits per plant

This was done by counting number of fruits produced by each plant.

Numbers of fruits per plot

This was determine by counting the number of fruits produced by each plants in a plot and summing them up.

Fruit weight per plant (g)

This was carried out by weighing the matured harvested fruit from each sampled plant.

Yield Components

The weight of seeds of the plants per plot was assessed using a sensitive weighing balance. The seeds of the plants per plot were weighed and extrapolated to get the yield per hectare ($kgha^{-1}$).

Nutrient Uptake Determination

Healthy leaves were randomly selected and collected from each pot at mild drought stress, while both root and leaf samples were collected again at severe drought stress. The roots and leaves were thoroughly washed with distilled water and dried at 75 °C for 72 hours, after which the samples were taken to the Department of Agronomy Laboratory, University of Ilorin, for further laboratory analysis using standard procedures (Padhi *et al*., 2022) which utilized AOAC method for determination of nitrogen, phosphorus, potassium, calcium and magnesium.

Statistical Analysis

Data collected was subjected to Analysis of Variance (ANOVA) using Genstat (11th Edition) to determine treatment effects. Means were separated using Duncan's Multiple Range Test (DMRT) at 5% probability level.

RESULTS

Physical and chemical Properties of both Soil and Vermicompost before Sowing

In determining the physical and chemical properties of the soil as well as the vermicompost used for the experiments, Table 1 shows that vermicompost characterized with a sandy loam texture have highest mean value in C.E.C (5.49 **cmol kg^{-1}**), Organic matter (6.45%), total nitrogen (2.10%), Total phosphorus (3.82%), total potassium (2.28%) with a neutral pH of 7.00 compared to the ordinary soil which was characterized with loamy sand and was slightly alkaline (8.1).

Table 1: Selected Physical and Chemical Properties of the Soil and the Vermicompost Used

COMPOSITION	SOIL	VERMICOMPOST
TEXTURE	Loamy sand	Sandy loam
A. (Cmol kg-1)	3.9	5.49
ORGANIC MATTER (%)	5	6.45
TOTAL N (%)	1.34	2.1
TOTAL P (%)	2.7	3.82
TOTAL K (%)	2.1	2.28
pH	8.1	7

Effect of Vermicompost on Mean Germination Time, Day to Tassel and Silking

Table 2 shows that the plot amended with 25 t/ha of vermicompost had the shortest day to germination with a mean value of 3.25, followed by plot amended with 15 t/ha with a mean value of 4.2, then the control (normal watering) with a mean value of 4.50) while the longest day to germination (4.67) was found in the plot without incorporation of vermicompost before planting of the maize seeds. However, analysis of variance shows that there was no significant different ($p>0.05$) in average number of days to germination and day to tassel while the effects of drought was felt at silking stage as there was a significant difference ($p<0.05$) in day to silking. The shortest day to silking was found in the control (normal watering) with a mean day of 57.82, followed by the 25 t/ha with a mean day of 60.25 then 63.33 which was found in plot amended with 15 t/ha of vermicompost and the longest day to silk (65.40) was found in the stressed plot without alleviation.

Table 2: Effect of Vermicompost on Mean Germination Time, Day to Tassel and Silking.

TREATMENTS	Mean germination time (days)	Day to tassel	Day to silk
Control (normal watering)	4.50	52.26	57.82
VC @ 0.00 t/ha (stressed, no alleviation)	4.67	52.27	65.40
VC @ 15 t/ha (75 g)	4.20	52.17	63.33
VC @ 25 t/ha (125 g)	3.25	52.18	60.25
LSD (0.05)	NS	NS	2.69

Means having the same letter in the same column are not significantly different at p= 0.05 level of probability. LSD=Least Significant Difference, VC= Vermicompost.
NS: Not Significant

Effects of Drought on Growth Parameters in Maize

Table 3 shows there was a significant difference ($p<0.05$) in plant height after incorporation of vermicompost before the plant were exposed to water deficit condition, at mild and severe drought respectively. However, plots amended with 25 t/ha of vermicompost had the best performance before and at mild drought with the

highest mean value of 65.39 and 118.62, followed by the plots amended with 15 t/ha with a mean value of 53.06 and 95.62. The least performance before drought was found in the control plots with a mean value of 46.75 while the plots with 0.0 t/ha of vermicompost had the least performance at mild and severe drought (84.12 and 92.60) compared to the control plots with normal watering.

Table 4 shows that there was no significant differences ($p>0.05$) in leaf number at 5% level of significant across the treatments before, at mild and severe although the control plots (normal watering) had the best performance with a mean value of 13.10, followed by 25 t/ha with a mean value of 12.70 then plot amended with 15t/ha with an average value of 12.42 while the least performance was found in the stressed plots without incorporation of vermicompost with an average value of 12.25. In the same vein, Table 5 shows that stem girth of maize plants was statistically influenced (at 5% level of probability) by vermicompost as maize amended with 25 t/ha had the best performance while the control had least performance.

Table 3: Effects of Vermicompost on Plant Height Under Water Deficit Condition

TREATMENT	BEFORE (cm)	MILD DROUGHT (cm)	SEVERE DROUGHT (cm)
CONTROL	46.75	89.10	127.21
VC @ 0.00 t/ha	47.02	84.12	92.60
VC @ 15 t/ha (75 g)	53.06	95.62	108.60
VC @ 25 t/ha (125 g)	65.39	118.62	120.80
LSD (0.05)	11.49	12.99	10.52

Means having the same letter in the same column are not significantly different at p= 0.05 level of probability. LSD=Least Significant Difference, VC= Vermicompost

Table 4: Effects of Drought on Number of Leaves of Maize

TREATMENT	BEFORE	MILD DROUGHT	SEVERE DROUGHT
CONTROL	11.10	12.36	13.10
VC @ 0.00 t/ha	10.62	12.25	12.25
VC @ 15 t/ha (75 g)	11.25	12.38	12.42
VC @ 25 t/ha (125 g)	11.50	12.50	12.70
LSD (0.05)	NS	NS	NS

Means having the same letter in the same column are not significantly different at p= 0.05 level of probability. LSD=Least Significant Difference, VC= Vermicompost.

Table 5: Effects of Vermicompost on Stem Girth of Maize Under Water Deficit Condition.

TREATMENT	BEFORE (cm)	MILD DROUGHT (cm)	SEVERE DROUGHT (cm)
CONTROL	3.50	4.82	5.31
VC @ 0.00 t/ha	3.90	4.79	4.91
VC @ 15 t/ha (75 g)	4.36	4.84	5.10
VC @ 25 t/ha (125 g)	4.84	5.50	5.88
LSD (0.05)	0.59	0.44	0.40

Means having the same letter in the same column are not significantly different at p= 0.05 level of probability. LSD=Least Significant Difference, VC= Vermicompost.

Effects of Vermicompost on Yield Components under Water Deficit Condition

Table 7 shows that there were no significant differences on number of cobs across the treatments compared with the control. There was a statistically differences in the mean value across the treatments on a weight basis, where the highest value (79.50 g) was found in VC at 25 t/ha. The result also reveals that there was no statistical difference between the stover weight of the control and that of VC at 15 t/ha. However, the result between control and VC at 25 t/ha as well as between VC at 15 t/ha and VC at 25 t/ha were statistically significance ($p<0.05$).

Also, table 8 reveals that there was a significant difference ($p>0.05$) between plot amended with vermicompost and normal soil on number of grain and weight of the grains whereas there was no significant difference soil treated with vermicompost at 15t/ha (75 g) and 25t/ha (125 g). However, the soil treated with 25t/ha (125 g) of vermicompost shows the best performance both in growth parameters and yield compare to the other treatment and control. The result obtained reveals that plot amended with 25/ha of vermicompost have the highest number of cobs, grains, cob weight as well as the weight of the grain. Since maize seeds are usually sold in weight, this result has therefore revealed to us that vermicompost does not only enhance the germination, growth and development of maize plants but they also play a great impact in improving maize seeds quality. Only two grain was recorded in the control plots, this implied that 100% yield loses is possible in maize under the adverse effect of severe drought.

Table 7: Effect of Vermicompost on Number of Cobs, Cob Weight and Stover Weight of Maize Under Water Deficit Condition

TREATMENT	No of cobs/plant	Cob weight (g)	Stover weight (g)
CONTROL	4.0	92.4	213.1
VC at 0.00 t/ha	1.5	15.00	73.50
VC at 15 t/ha (75g)	1.5	48.75	74.50
VC at 25 t/ha (125g)	2.0	79.50	230.80
LSD (0.05)	2.49	26.37	54.86

Means having the same letter in the same column are not significantly different at p= 0.05 level of probability. LSD=Least Significant Difference, VC= Vermicompost.

Table 8: Effects of Vermicompost on Yields Components of Maize Under Water Deficit Condition

TREATMENT	Number of grains	Weight of grains (g)
CONTROL	204.00	20.2
VC at 0.00 t/ha	2.00	0.23
VC at 15 t/ha (75g)	53.75	6.08
VC at 25 t/ha (125g)	80.00 9	8.48
LSD (0.05)	101.40	2.31

Means having the same letter in the same column are not significantly different at p= 0.05 level of probability. LSD=Least Significant Difference, VC= Vermicompost.

Results on the Effect of Drought on Nutrient Uptake on Maize Plants

Table 9 shows that there was no significant differences (p>0.05) in nitrogen and phosphorus uptake at mild drought although the best uptake was found in the control (normal watering) with a mean value of 1.42 and 0.11, followed by VC at 25 t/ha with a mean value of 1.22 and 0.07, then 15t/ha with a mean value of 1.17 and 0.05 while the least uptake (1.02 and 0.05) was found in the stressed plant without incorporation of vermicompost. The table shows that there were no significant differences (p>0.05) between the mean between the stressed plants without alleviation and those with VC at 15 t/ha. There was a significant difference (p< 0.05) in the uptake of potassium, calcium and magnesium across the treatment. However, the table shows that the control plots (normal watering) had the best uptake compared to others with a value of 3.00, 0.50 and 0.57 respectively. The uptake of potassium, calcium and magnesium was found to be least in VC at 15t/ha as the mean value was found to be the lowest (1.00, 0.20 and 0.25) compared to the control (0.0 t/ha) at mild drought.

At severe drought (Table 10), there were no significant differences (p>0.05) in the uptake of nitrogen and potassium although the control (normal watering) plot had the best uptake (1.21 and 3.00) while the least uptake 0.84 and 1.00 was found in stressed plants without incorporation of vermicompost. However, table (8) shows that there was a significant difference (p<0.05) in the uptake of phosphorus, calcium and magnesium although the table shows that there was no significant difference (p>0.05) in the uptake of phosphorus between VCat 0.0 t/ha, VC at15 t/ha and VC at 25 t/ha compared to the control plots with normal watering.

Table 9: Effects of Vermicompost on Nutrients Uptake at Mild Drought

TREATMENT	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
CONTROL	1.42	0.11	3.00	0.50	0.57
VC at 0.00 t/ha (0 g)	1.02	0.05	1.00	0.30	0.28
VC at 15 t/ha (75 g)	1.17	0.05	1.00	0.20	0.25
VC at 25 t/ha (125 g)	1.22	0.07	2.00	0.40	0.42
LSD (0.05)	NS	NS	1.89	0.19	1.89

Means having the same letter in the same column are not significantly different at p= 0.05 level of probability. LSD=Least Significant Difference, VC= Vermicompost

Table 10: Effects of Vermicompost on Nutrients Uptake at Severe Drought

TREATMENT	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
CONTROL	1.21	0.09	3.00	0.40	0.42
VC at 0.00 t/ha (0 g)	0.84	0.04	1.00	0.30	0.21
VC at 15 t/ha (75 g)	1.12	0.05	1.00	0.10	0.21
VC at 25 t/ha (125 g)	1.06	0.04	1.00	0.20	0.32
LSD (0.05)	NS	0.03	NS	0.19	0.19

Means having the same letter in the same column are not significantly different at p= 0.05 level of probability. LSD=Least Significant Difference, VC= Vermicompost.

DICUSSION

Plots amended with vermicompost showed better germination index, although higher weed competition was observed at the early growth stage compared to the control. Therefore, the application of pre-emergence herbicide is recommended to suppress weed emergence, reduce competition, and enhance plant growth and development. Seed germination, which is regulated by both internal and external factors, is strongly influenced by organic acids and phytohormones present in organic amendments, resulting in complex modifications of germination patterns (Blouin *et al*., 2019; Mohite *et al*., 2024).

Soil amended with 25 t ha^{-1} of vermicompost recorded a shorter period to tasseling, while the control soil showed fewer days to tasseling than soil treated with 15 t ha^{-1} of vermicompost. At the silking stage, when maize plants were exposed to severe drought stress, plots treated with vermicompost exhibited shorter days to silking. This indicates that drought slightly influenced tasseling but significantly affected pollen

shedding during silking, resulting in yield loss and poor seed quality. Thus, environmental stresses such as drought alter the synchronization between tasseling and silking in maize (Younas *et al*., 2021; Dawar *et al*., 2022).

Drought stress affects pollen development through dehydration-induced damage, leading to reduced pollen viability, altered morphology, and impaired dispersal. These changes are associated with physiological disruptions under water stress conditions (Sarathambal *et al*., 2024; Toor *et al*., 2024).

The highest stover weight recorded in plants treated with 25 t ha^{-1} of vermicompost may be attributed to growth-promoting substances released from vermicompost, which enhance photosynthetic efficiency during vegetative growth and grain-filling stages. Enhanced microbial activity in vermicompost-amended soils improves nutrient mineralization, root elongation, and water absorption, ultimately increasing biomass accumulation and yield (Dominguez *et al*., 2019; Dawar *et al*., 2022; Mohite *et al*., 2024). These results indicate that increased vermicompost application improves maize productivity, although optimal vermicompost quality depends on earthworm activity and substrate composition.

Vermicompost application contributes to carbon replenishment in soils, leading to gradual humus formation and improved nutrient availability over time. Stable humic substances and fulvic acids enhance soil fertility, water retention, and drought resilience in maize-based systems (Blouin *et al*., 2019; Benaffari *et al*., 2022). Drought stress reduces photosynthesis, assimilate translocation, and grain filling, thereby decreasing kernel size and yield due to impaired carbohydrate metabolism and enzyme activity (Younas *et al*., 2021; Khan *et al*., 2022).

Consequently, weight reduction and poor seed quality observed under drought conditions are associated with limited moisture availability during the reproductive and grain-filling stages. In contrast, vermicompost-amended soils mitigate these adverse effects by improving soil moisture status and nutrient availability (Abera *et al*., 2019; Ebrahimi *et al*., 2021).

Rapid growth and development observed in vermicompost-treated plants can be attributed to improved soil moisture conditions, balanced nutrient supply, and enhanced microbial activity. Vermicompost improves soil physico-chemical properties, nutrient availability, and biological activity, leading to superior growth performance under drought stress (Xue *et al*., 2022; Bolou-Bi *et al*., 2023; Mohite *et al*., 2024). The improved water-holding capacity, porosity, and aeration provided by vermicompost enable maize plants to better withstand prolonged drought stress.

Vermicompost also supplies readily available essential nutrients such as potassium, phosphorus, calcium, and magnesium, along with biologically active compounds that function as phytohormones, thereby enhancing drought tolerance in maize plants (Atakli *et al*., 2022; Sarathambal *et al*., 2024).

Drought stress symptoms appeared earlier in control plants following water withdrawal, as indicated by leaf wilting and accelerated senescence starting from leaf margins and tips. In contrast, plants grown in soil amended with 25 t ha^{-1} and 15 t ha^{-1} of vermicompost exhibited delayed leaf senescence, indicating improved drought tolerance (Ebrahimi *et al*., 2021; Toor *et al*., 2024).

Reduced leaf area under drought conditions lowers plant water demand and enhances survival, although chlorophyll content and photosynthetic activity decline, resulting in reduced grain yield. Maize susceptibility to drought during the reproductive stage is largely due to preferential translocation of assimilates to reproductive organs rather than roots, limiting adaptive root growth under stress (Younas *et al*., 2021; Dawar *et al*., 2022).

Conclusion

This study has revealed that vermicompost its not only renewable, sustainable substitute, free of odor and eco-friendly alone but its role in mitigating drought stress is magical because despite the water deficit, it offers a favorable condition for maize growth, development and total yields. Also, the higher the vermicompost incorporated to the soil the better. Therefore, if vermicompost should be incorporated at higher ratio to the soil before sowing or planting, according to this study, it is recommended to applied pre-emergence herbicide so as to suppress weed competition at seedling or establishment stage. Again, incorporation of vermicompost at 25 t/ha is recommended in cultivation of maize as this level will not only boost the morphological parameters of maize but also sustain optimum productivity and total yield of maize.

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