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Original Research Article

Growth and Yield Response of Tomato to Different Soil Amendment Techniques under Different Water Stress

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Abstract: The research was aimed at evaluating the growth and yield performance of tomato under different water regimes and different ricehusk biochar application rates. A trial was conducted during the 2022 dry season at Wudil in Kano State. The experiment was laid out in a Split Plot design. The experiment consisted of two factors; biochar at six different application rates (15, 13.75, 12.5, 11.25, 8.75 and 5tons/ha) and irrigation regimes (100, 50 and 25% irrigation). Which were combined to produce 18 treatments? Prior to planting, fifteen soil samples (0-15 cm) were collected randomly and bulked to obtained three composite soil samples for physical and chemical analysis using standard laboratory procedures. Growth and yield parameters were taken from 2WAT at 2 weeks intervals in each plot and. The result showed that aplication of biochar has a significant effect on crop growth and yield especially at 50% irrigation. Therefore it is recommended that 15tons/ha of rice husk biochar at 50% irrigation is very suitable for use by farmers in the study area.

Keywords: Solanum lycopersicum L, nutrients, soil loss, Biochar.

INTRODUCTION

Originating from the Andes, tomatoes (Solanum lycopersicum L.) were imported to Europe in the 16th century. At present, this plant is common around the world, and has become an economically important crop. Furthermore, this plant is a model species for introducing agronomically important genes into dicotyledonous crop plants (Paduchuri *et al.*, 2010). The tomato is considered a protective food because of its particular nutritive value, as it provides important nutrients such as lycopene, beta-carotene, flavonoids, vitamin C and hydroxycinnamic acid derivatives. Furthermore, this crop has achieved tremendous popularity especially in recent years with the discovery of lycopene's anti-oxidative activities and anti-cancer functions (Wu *et al.,* 2011; Raiola *et al.,* 2014). Thus, tomato production and consumption are constantly increasing. It is noteworthy that tomatoes are not only sold fresh, but also processed as soups, sauces, juices or powder concentrates. The tomato ranks 7th in worldwide production after maize, rice, wheat, potatoes, soybeans and cassava, reaching a worldwide production of around 160 million tons on a cultivated area of almost 4.8 million hectares in 2011 (FAOSTAT 2011).

Biochar is a solid and carbon-rich material produced by pyrolysis of biomass in a low oxygen (O) environment (Joseph *et al.,* 2010; Lehmann & Joseph, 2015; Solaiman & Anawar, 2015; Wang *et al.,* 2016). The term "biochar" was introduced in 2006 by Lehmann *et al.*, specifying charcoal used for environmental purposes and in particular to maintain or improve soil fertility.

Since the mid-1990s, Anthropogenic Dark Earths or terra preta de Índio soils located in the Central Amazon received growing attention in soil research (Lehmann *et al.,* 2003; Neves *et al.,* 2004). These relict Anthrosols have been heavily modified by pre-Columbian settlers by the addition of several inorganic and organic materials, e.g. charcoal, ash, bones, biomass waste, manure, faeces, and urine (Glaser & Birk, 2012). Radiocarbon data revealed ages of the analysed soil samples ranging from 350 to 2310 years BP (Neves *et al.,* 2004). Other than the relatively poor soils in their direct vicinity, terra preta soils exhibit large stocks of stable organic matter and high nutrient levels that facilitate agricultural use (Glaser *et al.,* 2001; Glaser & Birk, 2012). These favourable soil properties still persist despite challenging conditions of the humid tropics (Lehmann *et al.,* 2003). Inspired by these findings, the interest in charcoal application to improve soils is growing worldwide. Since 2008, the number of scientific articles about biochar application started to increase (Lehmann *et al.,* 2015), reaching a total of 6934 scientific publications in late 2018 (Wu *et al.,* 2019)

In recent times, several studies have evaluated the use of biochar for environmental and agricultural applications. The Physico-chemical properties of the alfisol soil in Owo, Ondo state was found to be improved by the application of biochar (Adekiya *et al.,* 2020). Furthermore, the yield of cocoyam was improved and soil loss was reduced. The yield of maize grains in Abeokuta, Ogun state was improved by the application of corn cob biochar in the soil (Olusegun *et al.,* 2019). The optimum yield was observed at a 20 t/ha biochar application. Faloye *et al.,* established that biochar was a statistically significant factor in maize production albeit to a lesser extent than irrigation. Positive results of biochar application in Nigeria have also been observed for cashew (Nduka *et al.,* 2019), maize (Ogunyemi *et al.,* 2018) and upland rice (Oladele *et al.,* 2019). Nworie *et al.,* studied the adsorption of methylene blue from aqueous media using biochar prepared from the pyrolysis of rice husk. The biochar was suitable for the intended application and the pollutant sorption was according to the Hill isotherm and intra-particle diffusion kinetic models. Oziegbe *et al.,* utilised biochar from acacia wood for the remediation of heavy metal pollution in landfill soil. The soils and sorghum (planted on the soil) were found to have less heavy metal content. Furthermore, the yield of the sorghum was improved. Application of 10-15 t/ha was observed to be optimal. Adeniyi *et al.,* discussed some of the peculiar challenges of biochar production in Nigeria. A thermal process without any power requirement will inadvertently gain more acceptances due to the epileptic power supply in the country and its non-availability in remote/rural locations. Agriculture in Nigeria is usually practised in the rural areas hence such technologies would be relevant. Modern agricultural practice like mechanisation and the use of agrochemicals is still not quite popular in remote locations as a farming practice is still done by hand in the interior villages. This suggests that biochar technologies suitable for such locations would need to be developed to help improve productivity. The onus falls on agricultural extension workers to help give proper orientation to the local farmers on the use of biochar to farming. Only the effort of these agricultural extension workers can help bridge the gap between research findings and actual implementation/utilisation of these results by farmers. This paper therefore investigates the response of tomato in terms of growth and yield to rice husk biochar at different application rates.

MATERIALS AND METHODS

Study Area

The research was conducted at Kano University of Science and Technology, Wudil research farm. The experimental site is located at wudil local government area, having a land co-ordination of (N11°48'38.5" E 008°51'14.0") and elevation of 419m

Experimental Design

The research was conducted using split plot design in a 3 plots of 17m×12m by size each.

Eigteen treatment combinations were used on each plot (15tons/ha, 13.75tons/ha, 12.5tons/ha, 11.25tons/ha, 8.75tons/ha and 5tons/ha of biochar) and three levels of irrigation schedules (100%, 50% and 25%)

SOIL SAMPLING AND PREPARATION

Soil auger was used to collect the soil sample from a 15cm soil depth using random sampling method.

Soil Analysis

Before the application of the biochar, the chemical and hydrophysical conditions of the soil was determined. Properties such as the bulk density, particle density, hydraulic conductivity, soil texture were deteemined. Others included pH, organic carbon, total nitrigen and available phosphorus was equally evaluated.

Growth and Yeild Response Analysis

Growth parameters were monitored included; number of leaves, stem height, stem diameter, leaf length. Yield parameters evalluated include; fruit weight, number of fruits, fruit diameter.

RESULTS AND DISCUSSION

Table 1: Physico – chemical properties of soil (0-15cm in depth) of experimental farm during 2022 irrigation season at Wudil farm areas in Kano state

Soil properties	
Physical composition (%)	
Sand	59.1
Clay	18.8
Silt	21.35
Textural class sandy loam	
Bulk density	1.1gcm^{-3}
Porosity	1.173
Hydraulic conductivity	3.4x10^{-5}ms^{-1}
Chemical composition	
pH (H_2O)	6.42
Organic Carbon (g kg)	0.61
Total Nitrogen (g kg)	0.09
Available Phosphorous (mg/kg)	11.14
Exchangeable Base (cmol kg^{-1})	
CA	1.39
Mg	0.34
K	0.08
Na	0.02
CEC	1.82

Treatments

Treament1 = 15.0 tons/ha at 100% irrigation
Treatment2 = 13.75 tons/ha at 100% irrigation
Treatment 3 = 12.5 tons/ha at 100% irrigation
Treatment 4 = 11.25 tons/ha at 100% irrigation
Treatment 5 = 8.75 tons/ha at 100% irrigation
Treatment 6 = 5.0 tons/ha at 100% irrigation
Treatment 7 = 15.0 tons/ha at 50% irrigation
Treatment 8 =13.75 tons/ha at 50% irrigation
Treatment 9 = 12.5 tons/ha at 50% irrigation
Treatment 10 = 11.25 tons/ha at 50% irrigation
Treatment 11 = 8.75 tons/ha at 50% irrigation
Treatment 12 = 5.0 tons/ha at 50% irrigation
Treatment 13 = 15.0 tons/ha at 25% irrigation
Treatment 14 = 13.75 tons/ha at 25% irrigation
Treatment 15 = 12.5 tons/ha at 25% irrigation
Treatment 16 =11.25 tons/ha at 25% irrigation
Treatment 17 =8.75 tons/ha at 25% irrigation
Treatment 18 =5.0 tons/ha at 25% irrigation

Table 2: Stem Height of Tomatoas affected by Biochar and Stress in the Sudan Savanna during the 2022 dry season

Treatments	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
1	6.72b	14.46	22.30	28.62	38.32	38.32
2	12.05a	17.12	28.96a	31.12	39.66	39.66
3	11.39	16.46	23.80	33.08	41.32	41.32
4	9.39	14.12	23.63	34.38	43.32	43.32
5	11.06	15.22	25.13	33.25	42.66	42.66
6	9.39	14.12	23.00	33.58	39.66	39.66
7	8.28	11.75	18.31	33.81	43.68	43.68
8	8.94	13.75	23.45	28.61	37.71	37.71
9	10.61	14.75	25.71	30.14	41.91	41.91
10	10.94	15.75	26.98	38.47a	46.24a	46.24a
11	10.61	19.08a	27.38	35.47	41.24	41.24

Treatments	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
12	10.61	16.42	24.98	27.84	34.24	34.24
13	9.33	15.19	24.05	33.68	42.10	42.10
14	12.00a	16.79	28.45a	38.28a	44.43	44.43
15	8.33	16.79	23.49	32.28	40.77	40.77
16	9.00	13.46	21.39	26.61	39.77	39.77
17	11.00	16.13	24.05	33.25	42.10	42.10
18	10.33	13.13	25.39	27.84	35.77	35.77
SE±	2.995	4.219	6.203	6.228	6.875	6.875

Means followed by unlike letter(s) are statistically significant at 5% level of probability; WAT= Weeks after Transplanting.

Table 3: Stem Diameter of Tomatoas affected by Biochar and Stress in the Sudan Savanna during the 2022 dry season

Treatments	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
1	1.2210	1.446	2.019	2.822	3.663	3.950
2	1.4872a	1.480	2.352	2.989	3.763	3.917
3	1.139	1.413	1.919	20722	3.396	6.517
4	1.125	1.380	1.085	2.789	3.630	3.950
5	1.106	1.280	2.052	2.589	3.596	3.617
6	1.201	1.413	1.785	2.322	2.830	2.983
7	1.021	1.235	2.069	2.878	3.941a	4.128a
8	1.147	1.435	1.835	2.444	3.241	3.161
9	1.261	1.635a	1.835	2.611	3.474	3.661
10	1.094	1.269	2.035	2.478	3.374	3.661
11	1.261	1.535	2.634a	3.311a	3.874	3.994
12	1.061	1.302	1.802	2.511	2.974	3.261
13	1.001	1.285	2.146	2.633	3.396	3.522
14	1.468a	1.385	2.113	2.767	3.630	3.956
15	1.021	1.385	1.813	2.533	3.496	3.756
16	1.225	1.619	1.880	2.500	2.930	3.156
17	1.100	1.382	1.846	2.633	3.530	3.522
18	1.033	1.385	2.413	3.167	3.896a	4.022
SE±	0.1157	0.2157	0.4710	0.5862	0.5082	0.5558

Means followed by unlike letter(s) are statistically significant at 5% level of probability; WAT= Weeks after Transplanting,

Table 4: Number of leaves of Tomatoas affected by Biochar and Stress in the Sudan Savanna during the 2022 dry season

Treatments	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
1	3.852	14.72	54.16	90.67	115.0	117.8
2	4.852	12.06	55.15	100.00	124.0	146.4
3	5.182	14.06	46.81	96.33	112.7	95.4
4	4.519	16.72	83.15a	138.00a	157.7	147.7
5	4.852	11.06	35.15	71.33	109.2	124.4
6	5.852	12.06	50.81	70.33	84.40	83.10
7	4.074	10.06	66.98	135.94	171.6a	173.6a
8	5.407	12.72	44.65	83.61	103.00	112.2
9	4.407	12.39	67.31	105.61	106.6	101.2
10	3.741	15.72	51.31	79.28	102.6	103.9
11	5.407	12.72	53.65	91.61	130.6	128.6
12	6.074	17.06	41.31	71.61	88.30	95.20
13	3.741	14.22	58.87	117.06	129.7	129.3
14	5.074	18.22a	73.87	117.39	155.4	150.0
15	5.407	10.56	35.54	6439	117.7	122.0
16	5.074	16.89	50.20	91.72	98.7	113.3
17	5.074	9.20	37.54	9239	99.70	102.70
18	4.741	11.56	69.20	103.72	101.7	97.3
SE±	0.915	3.386	27.00	34.47	35.21	35.42

Means followed by unlike letter(s) are statistically significant at 5% level of probability; WAT= Weeks after Transplanting.

Table 5: Leaf Length of Tomato as affected by Biochar and Stress in the Sudan Savanna during the 2022 dry season

Treatments	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
1	1.511	2.502	4.181	5.248	5.746	5.761
2	1.544	3.569	3.715	4.981	5.746	5.761
3	1.411	3.369	4.581	5.381	6.013	6.028
4	1.378	3.802a	5.648a	6.281	6.880a	6.894a
5	1.444	2.902	3.181	4.215	4.780	4.794
6	1311	3.425	3.281	4.215	4.780	4.794
7	1.439	3.363	4.759	5.620	6.346	6.361
8	1.539	2.996	3.859	4.520	5.413	5.428
9	1.439	3.163	4.426	5.587	6.313	6.328
10	1.339	3.463	3.259	4.454	5.113	5.128
11	1.339	3.130	5.259	5.920	6.413	6.428
12	1.509	3.463	3.026	4.354	4.480	4.494
13	1.283	3.502	4.459	5.631	6.341	6.311
14	1.450	2.935	4.426	5.231	5.941	5.911
15	1.583	3.069	4.126	5.293	5.941	5.911
16	1.383	2.902	3.859	4.765	5.607	5.844
17	1.450	3.635	3.093	4.298	4.707	4.678
18	1.450	3.535	4.593	5.231	5.541	5.511
SE±	0.1869	0.7058	1.380	1.368	1.325	1.365

Means followed by unlike letter(s) are statistically significant at 5% level of probability; WAT= Weeks after Transplanting.

Table 6: Number of Branches of Tomato as affected by Biochar and Stress in the Sudan Savanna during the 2022 dry season

Treatments	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
1	2.426	5.063	14.59	23.35	30.72	34.15
2	3.426	4.462	13.20	24.35	35.39	36.81
3	3.093	3.426	17.20	26.02	36.06	40.81
4	3.093	5.426	21.87	31.69a	43.72	41.81
5	3.426	5759	9.87	16.02	29.39	29.15
6	3.426	5.729	12.54	19.69	27.72	29.48
7	2.704	3.926	16.87	29.30	46.06a	45.48a
8	3.037	4.926	10.54	17.30	28.72	32.81
9	3.037	4.926	15.87	25.30	34.06	37.15
10	2.704	4.926	16.87	23.96	32.72	32.81
11	3.370	6.259	16.34	24.96	33.06	34.15
12	4.037a	4.926	13.20	20.30	27.39	29.81
13	2.870	5.315	14.59	27.69	34.56	36.37
14	3.204	4.315	21.59	31.69a	40.89	43.37
15	3.204	5.315	11.59	17.35	29.89	31.37
16	3.204	6.315a	13.26	20.35	31.22	35.04
17	3.204	3.648	10.93	16.35	28.56	30.70
18	3.204	4.981	17.93	27.69	36.89	35.37
SE±	0.852	1.302	6.281	7.134	8.870	7.770

Means followed by unlike letter(s) are statistically significant at 5% level of probability; WAT= Weeks after Transplanting.

Table 7: Number of Fruits of Tomato as affected by Biochar and Stress in the Sudan Savanna during the 2022 dry season

Treatments	6 WAT	8WAT	10WAT	12WAT
1	2.815	15.04a	35.46	29.96
2	2.148	9.70	36.80	40.63
3	2481	16.04a	37.46	42.63
4	4.481	15.70a	35.13	39.96
5	2.481	11.37	35.46	39.96

Treatments	6 WAT	8WAT	10WAT	12WAT
6	3.481	8.04	26.46	30.30
7	3.981	13.26	30.02	33.02
8	2.648	15.26	37.35	41.02
9	6.315	14.93	38.35	41.02
10	2.647	11..59	37.69	42.35
11	4.981	10.93	34.69	39.69
12	3.112	9.93	28.69	33.35
13	1.204	15.37a	34.85	38.69
14	2.537	13.37	41.85a	44.02a
15	2.204	12.37	34.85	37.69
16	3.537	13.04	33.85	43.69
17	5.870	13.37	34.52	37.02
18	2.537	8.37	26.85	29.35
SE±	4.225	4.994	5.492	5.673

Means followed by unlike letter(s) are statistically significant at 5% level of probability; WAT= Weeks after Transplanting.

Table 8: Number of Flowers of Tomato as affected by Biochar and Stress in the Sudan Savanna during the 2022 dry season

Treatments	6 WAT	8WAT	10WAT	12WAT
1	4.722	28.13	66.93	40.30
2	5.722	26.13	57.63	31.30
3	6.056	26.13	69.30	41.96
4	10.722	29.13a	69.30	41.96
5	4.056	24.46	50.63	36.30
6	5.389	12.13	46.30	24.96
7	4.889	26.80	55.96	39.19
8	3.889	25.46	61.30	42.85
9	11.889a	28.46	70.96a	44.85a
10	5.889	20.80	54.96	33.52
11	8.889	24.46	59.30	27.19
12	1.222	20.13	42.96	27.85
13	1.389	27.07	59.41	38.85
14	5.772	24.74	67.07	33.52
15	7.389	26.07	64.07	42.52
16	7.722	23.74	53.41	49.15a
17	8.772	26.07	56.41	29.52
18	5.722	18.41	45.07	28.85
SE±	5.757	8.788	11.16	10.77

Means followed by unlike letter(s) are statistically significant at 5% level of probability; WAT= Weeks after Transplanting.

Table 9: Fruit Weight of Tomato as affected by Biochar and Stress in the Sudan Savanna during the 2022 dry season

Treatments	12 WAT
1	2.717
2	2.817
3	2.950a
4	2.183
5	2.883
6	1.583
7	2.006
8	2.806
9	2.739
10	2.872
11	2.806
12	1.906

Treatments	12 WAT
13	2.744
14	2.544
15	2.378
16	3.078a
17	2.544
18	1.844
SE±	0.4281

Means followed by unlike letter(s) are statistically significant at 5% level of probability; WAT= Weeks after Transplanting.

Table 10: Fruit Diameter of Tomato as affected by Biochar and Stress in the Sudan Savanna during the 2022 dry season

Treatments	6 WAT	8WAT	10WAT	12WAT
1	0.4389	3.557	7.013	12.79
2	0.5050	3.124	7.883	14.39
3	0.9722	2.891	7.580	13.06
4	1.0389	2.557	8.880a	14.46
5	0.8722	2.891	8.513	13.86
6	0.9389	1.724	5.380	11.33
7	1.3167	3.052	7.696	7.860
8	0.5056	2.552	7.863	40.20a
9	1.3167	3.185	8.396	8.830
10	0.4500	2.885	6.963	7.900
11	0.8500	2.985	8.663a	8.700
12	0.3833	2.085	5.663	6.400
13	0.4111	2.891	8.524	13.24
14	1.011	3.891a	7.591	13.88
15	0.9778	2.291	8.324	13.18
16	0.944	2.624	6.091	11.84
17	1.011	3.057	8.191	15.11
18	0.4111	1.991	6.524	12.64
SE±	0.902	0.925	1.482	1347

Means followed by unlike letter(s) are statistically significant at 5% level of probability; WAT= Weeks after Transplanting.

DISCUSSION

The present study revealed the significant differences examined from growth and yield parameters in respect of stem height, stem diameter, number of leaves, leaf length, number of branches, number of fruits, number of flowers, fruit weight and fruit diameter throughout the sampling period of 2,4,6,8,10 and 12WAT. Plants applied with different levels of biochar were found to show varying results of growth and yield of tomato. The results indicated that the heighest value of stem height was obtained with the application of 11.25tons/ha biochar at 50% irrigation. This result is in agreement with Gamareldawla *et al.,* (2017) where theynoted that an increase in the quantity of biochar leads to an increase in the height of plant (stem).

The stem diameter showed relatively no significant difference amont the treatment means except for treatment 7 (15tons/ha at 50% irrigation) which was statistically different at 10 and 12WAT.

The number of leaves showed a statistical difference at treatments 7 and 14 (15tons/ha at 50% and 13.75tons/ha at 25% irrigation respectively). Also there was an increase in the number of leaves for all treatments across the weeks after transplant. These findings are in line with Gamareldawla *et al.,* (2017).

Tretaments 4(11.25tons/ha at 100% irrigation) also showed significant dfference from other treatment means at 4 and 8WAT.

Tomato leaf length showed significant difference only at treatment 4(11.24tons/ha at 100% irrigation) over 4,6,10 and 12 WAT. Overall, the experiment showed that leaf length had a positive growth over the period of 2 – 12 WAT. This is in line with the findings of Graber *et al.,* (2017).

Application of biochar showed a general increase in the numebr of leaves over the period of the observation but treatment 7 (15tons/ha at 50% irrigation) showed significant difference at the 10 and 12WAT.

There was an increase in the number of fruits with the apoplication of biochar over the period of the observation. Treatments with 15, 12.5and 11.25tons/ha all at 100% irrigation and 15tons/ha at 25% irrigation were statistically different at 8WAT. Also treatment 14(13.75tons/ha at 25% irrigation) was statistically different from the other treatment means. This is in line with the findings from Gamareldawla *et al.*, (2017) who observed that application of biochar increased fruit yield of tomato.

CONCLUSION

Results of this study have revealed evidence of significant differences in both growth and yield parameters. The research has indicated that addition of rice husk biochar can aid in the growth and yield of tomato.

RECOMMENDATION

Based on the results obtained and in comparison with other researchers' scientific findings, it should be suggested to farmers in the northern savannah ecological zone to adopt growing tomato under stressed conditions at both household and community levels to enhance the nutritional and healthy living status of the populace toward foods security in Nigeria.

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