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Interactions of Deficit Irrigation, Chicken Manure and NPK 15:15:15 on Okra Growth and Yield and Soil Properties

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ABSTRACT

The field experiment was carried out at the University of Cape Coast Research Farm, Cape Coast, Ghana, from August, 2014 to February, 2015. The objectives of the study were to determine the effects of deficit irrigation-chicken manure interactions, deficit irrigation-NPK interactions and compare the results of deficit irrigation-chicken manure and deficit irrigation-NPK. Fifteen (15) treatments replicated three (3) times were laid out in a Randomized Complete Block Design (RCBD). The 15 treatments were 100% Crop Water Requirement (CWR); (T1) 90% CWR, (T2) 80% CWR, (T3) 100% CWR+5 t ha^{-1} chicken manure, (T4) 100% CWR+10 t ha^{-1} chicken manure, (T5) 90% CWR+5 t ha^{-1} chicken manure, (T6) 90% CWR+10 t ha^{-1} chicken manure, (T7) 80% CWR+5 t ha^{-1} chicken manure, (T8) 80% CWR+10 t ha^{-1} chicken manure, (T9) 100% CWR+200 kg ha^{-1} NPK 15:15:15, (T10) 100% CWR+250 kg ha^{-1} NPK, (T11) 90% CWR+200 kg ha^{-1} NPK, (T12) 90% CWR+250 kg ha^{-1} NPK, (T13) 80% CWR+200 kg ha^{-1} NPK, (T14) and 80% CWR+250 kg ha^{-1} NPK (T15). Deficit irrigation-chicken manure performed better than deficit irrigation-NPK at 100% CWR and 90% CWR. The 20% deficit irrigation plus high doses of chicken manure and NPK performed poorly. The 10% deficit irrigation with 10 t ha^{-1} chicken manure and 250 kg ha^{-1} NPK are best for okra production.

Key words: Deficit irrigation, chicken manure, NPK, crop water requirement, okra

INTRODUCTION

Drought is considered one of the most important factors that limit plant production in arid and semi-arid zones (Ehdaie, 1995; Hussein *et al*., 2011), where such areas are subjected to a wide range of climate variation as well as climate changes. Under such conditions, lower yield and lower water use efficiency take place especially under the instability of water amounts from year to year (Oweis *et al*., 2000).

According to Ghana Meteorological Agency, a 40-year (1960-2000) climatic data analysis shows a progressive and visible rise in temperature with simultaneous decline in rainfall across all agro-ecological zones (EPA., 2007). Climate change scenarios developed based on the forty-year data, predicted a continuous rise in temperature with an average increase of about 0.6, 2.0 and 3.9°C by the year 2020, 2050 and 2080, respectively. Rainfall is also predicted to decline on average by 2.8, 10.9 and 18.6% by 2020, 2050 and 2080, respectively in all agro-ecological zones in Ghana (EPA., 2007). These predicted changes can have impact on the pattern of agricultural production in Ghana, especially in the regions where the agro-ecological systems are in transition. Small holder farmers in Ghana who produce the bulk of the food and cash crops are the most vulnerable to the various manifestations of climate change.

Deficit irrigation techniques are very interesting when it comes to an efficient allocation of scarce water resources. These techniques maximize water productivity, generally with good or unchanged harvest quality (Spreer *et al*., 2007). Due to the application of relatively small amounts of water the harvest can be stabilized over time and it improves economic planning for farmers, which is increasingly interesting under climate change conditions where water resources are becoming scarce and rains unpredictable (Sadras *et al*., 2007).

The application of less water reduces the leaching effects of nutrients from the root-zone and agrochemicals and the groundwater quality is preserved (Pandey *et al*., 2000). Furthermore, it reduces the risk of the development of certain diseases linked with high humidity (e.g., fungi) that are common in full irrigation systems (Spreer *et al*., 2007).

Poultry manure's relative resistance to microbial degradation is essential for establishing and maintaining optimum soil physical condition and is important for plant growth. It is also very cheap and effective as a good source of nitrogen for sustainable crop production (Dauda *et al*., 2008). Surekha and Rao (2001) and Prakash *et al*. (2002) had earlier explored the use of organic manures for managing the pests of okra.

Akanbi *et al*. (2010) asserted that inorganic fertilizers can improve crop yields and soil pH, total nutrient content and nutrient availability, but their use is limited due to scarcity, high cost, nutrient imbalance and soil acidity. Therefore, there is a need to look for alternative ways of improving this crop.

Okra, *Abelmoschus esculentus* L. (Moench), is an economically important vegetable crop grown in tropical and sub-tropical parts of the world. This crop is suitable for cultivation as a garden crop as well as on large commercial farms.

In Ghana, okra is among the non-traditional export crops of importance, contributing 0.02% of Gross Domestic Product (GEPC., 2002). Annual production of okra in Ghana is estimated between 1.548-4.507 metric t (SRID-MOFA., 2007).

Okra is cultivated for its fibrous fruits or pods which contain round, white seeds. The fruits are harvested when immature and eaten as a vegetable.

Thus, the objectives of the study were to determine the effects of deficit irrigation-chicken manure interactions, deficit irrigation-NPK interactions and compare the results of deficit irrigation-chicken manure and deficit irrigation-NPK.

MATERIALS AND METHODS

Research setting: The research was conducted at the School of Agriculture Teaching and Research Farm, University of Cape Coast, Cape Coast, Ghana from August, 2014 to February, 2015. It is found on latitude 05-06°N and longitude 01-15°W at an altitude of 1.1 m above sea level.

Before the start of the research, composite surface soil samples were randomly collected from the experimental site and were carefully mixed together. The samples were divided into four and two opposite quadrants were taken out. This was repeated and each time, another opposite quadrant was taken off until a considerable amount was obtained. The sample was then air-dried for a week after which it was ground and then analyzed for percent organic matter, the amount of nitrogen, potassium and phosphorus as well as the pH and textural class. The soil at the study site is sandy loam and is slightly acidic. The site lies within the Coastal Savannah vegetation zone of Ghana. The annual temperature ranges between 23.2-33.2°C with an annual mean of 27.6°C and a relative humidity of 81.3-84.4%.

There were two rainy seasons observed at the research site: the major season which starts from May-July and the minor which commences from September and runs through to the middle of November. The mean annual rainfall for the site is between 900 and 1000 mm (Asamoah, 1973; Owusu-Sekyere and Annan, 2010).

Research design and field layout: The field experiment was setup under a rain shelter from August, 2014 to December, 2014. Fifteen treatments replicated 3 times were laid out in a Randomized Complete Block Design (RCBD). The 15 treatments were 100% Crop Water Requirement (CWR), (T1); 90% CWR (T2); 80% CWR (T3); 100% CWR+5 t ha^{-1} chicken manure (T4); 100% CWR+10 t ha^{-1} chicken manure (T5); 90% CWR+5 t ha^{-1} chicken manure (T6); 90% CWR+10 t ha^{-1} chicken manure (T7); 80% CWR+5 t ha^{-1} chicken manure (T8); 80% CWR+10 t ha^{-1} chicken manure (T9); 100% CWR+200 kg ha^{-1} NPK 15:15:15 (T10); 100% CWR+250 kg ha^{-1} NPK (T11); 90% CWR+200 kg ha^{-1} NPK (T12); 90% CWR+250 kg ha^{-1} NPK (T13); 80% CWR+200 kg ha^{-1} NPK (T14) and 80% CWR+250 kg ha^{-1} NPK (T15).

Each plot measured 1.50×1.50 m making a plot size of 2.25 m^2. There were a total of 45 plots under the rain shelter.

Crop planting and cultural practices: The seeds were sown on 23rd August, 2014, three seeds per hole following 50×50 cm spacing between rows and plants. After a week, the 3 three plants per hole were thinned to one (1). Chicken Manure was applied 2 weeks before sowing the seeds and NPK 15:15:15 was applied a week after sowing. After planting, regular weeding and spraying of insecticide were done.

Research population: Of the 45 plots, each had 16 plants. A total of 720 plants constituted the research population. A sample of 8 plants was selected for growth, yield and yield related data analyses. The total research sample was 360 plants.

Statistical analysis: Data collected were subjected to analysis of variance (ANOVA) using GenStat 10.3. Mean comparisons were performed using Duncan Multiple Range Test (DMRT) at 5% probability level.

Data collection: Eight plants per plot were selected during the four growth stages (Initial, Developmental, Mid-Season and Late Season) for data collection and the following parameters were measured: (1) Plant height (cm)-a meter rule was used, (2) Leaf area (cm^2)-length from the petiole line was multiplied by the breadth of the leaf, (3) Stem circumference (cm), (4) Number of pods per treatment-pods were counted per treatment during each harvest till the final harvest, (5) Pod weight per treatment (g) was measured using an electronic balance and converted to ton per hectare, (6) Pod length (cm), (7) Pod circumference (cm) and (8) Root length (cm) were measured using a 30 cm ruler. The plant was carefully uprooted and the roots washed before measuring with ruler.

Calculation of crop water requirement and irrigation water application: An irrigation interval of two days was adopted for the experiment and the water application for each watering day was generated from the computed reference crop evapotranspiration and adopted Kc of okra at the four growth stages by using the equation:

$$Et_c = ET_o \times K_c$$

where, ET_c is the crop evapotranspiration (mm day^{-1}), K_c is the crop coefficient (dimensionless) and ET_o is reference crop evapotranspiration (mm day^{-1}).

Crop coefficient (K_c) for Okra was adopted from the work done by Owusu-Sekyere and Annan (2010), for the four growth stages (Initial = 0.20, 10 days; Developmental = 0.40, 31 days; Mid-season = 1.0, 25 days and Late Season = 0.90, 20 days).

ETo was calculated using the formula:

$$ET_o = E_{pan} \times K_{pan}$$

where, E_{pan} is the depth of water lost from the evaporation pan during each irrigation water application day and K_{pan} is the pan coefficient which was 0.8.

A US Class A Evaporation Pan was used to obtain the evapotranspiration rate.

At the end of each growth stage, crop evapotranspiration was calculated (Table 1).

RESULTS AND DISCUSSION

Effects of deficit irrigation, deficit irrigation-chicken manure combination and deficit irrigation-NPK 15:15:15 Interactions on the growth parameters (Plant height, leaf area and stem circumference): Data collected during the four growth stages on plant height are presented in Table 2. The results show that there were significant ($p<0.05$) differences in the mean of some the treatments applied.

Plant height for the four growth stages: Ten Days After Planting (DAP) which is the duration for the initial stage, plant height data were recorded. The T11 (100% CWR+250 kg ha^{-1} NPK) recorded the tallest plant (53.7 cm) followed by T13 (90% CWR+250 kg ha^{-1} NPK), (46.9 cm) and

Table 1: Water requirements for the four growth stages

CWR (%) applied	Water requirements (mm day^{-1})			
	Initial (mm/10)	Dev'tal (mm/31 days)	Mid (mm/25 days)	Late (mm/20 days)
100	16.04	131.52	236.80	164.16
90	14.44	118.37	213.12	147.74
80	12.83	105.22	189.44	131.33

Table 2: Mean plant height for the four growth stages

Treatment coding	Initial stage	Developmental stage	Mid stage	Late stage
T1	34.0^{de}	73.9^{ef}	123.7^{b}	167.3^{b}
T2	36.6^{cde}	61.0^{fg}	115.1^{b}	159.0^{b}
T3	20.0^{f}	60.0^{fg}	107.2^{b}	151.7^{bc}
T4	41.1^{bcd}	88.7^{bcde}	192.3^{a}	208.0^{a}
T5	43.7^{bc}	90.3^{abcd}	194.5^{a}	225.0^{a}
T6	44.3^{bc}	95.4^{abc}	176.2^{a}	202.0^{a}
T7	38.6^{bcd}	80.1^{cde}	188.3^{a}	216.7^{a}
T8	38.6^{bcd}	45.6^{g}	120.8^{b}	154.7^{bc}
T9	41.9^{bcd}	60.0^{fg}	109.4^{b}	129.7^{cd}
T10	46.6^{ab}	94.6^{abcd}	182.7^{a}	204.3^{a}
T11	53.7^{a}	105.6^{a}	195.9^{a}	215.3^{a}
T12	43.8^{bc}	79.1^{de}	169.8^{a}	197.0^{a}
T13	46.9^{ab}	103.0^{ab}	180.5^{a}	214.0^{a}
T14	28.2^{ef}	46.1^{g}	102.1^{b}	140.0^{bcd}
T15	21.1^{f}	50.2^{g}	91.9^{b}	114.0^{d}

Mean within the same column with similar letters are not significantly different at 5% probability level

T10>T6,<T12>T5>T9>T4>T7>T8>T2>T1>T14>T15>T3 in that order (Table 2). No significant difference existed between T11, T13 and T10. Also, T13, T10, T6, T12, T5, T9, T4, T7 and T8 had no significant differences. Also, there was no significant difference among T6, T12, T5, T9, T4, T7, T8 and T2. The T1 (100% CWR), 34.0 cm and T2 (90% CWR), 36.6 cm had no significant difference. The least plant height in the Initial Stage was produced by T3 (80% CWR) but was not different from T14 and T15 statistically. Deficit irrigation-NPK 15:15:15 treated plots at 100% CWR and 90% CWR had taller plant height than Deficit irrigation-chicken manure treated plots at 100% CWR and 90% CWR in the initial growth stage. On the other hand, T14 (80% CWR+200 kg ha^{-1} NPK) and T15 (80% CWR+250 kg ha^{-1}) performed poorly as compared to T8 (80% CWR+5 t ha^{-1} CM) and T9 (80% CWR+10 t ha^{-1} CM) (Table 2).

At the end of the developmental stage (31 days), the mean tallest plant (105.6 cm) was obtained in plots treated with 100% CWR+250 kg ha^{-1} NPK (T11) while T8 (80% CWR+5 t ha^{-1} CM) gave the least plant height (45.6 cm). Statistically, no significant difference was seen among T11, T13, T6, T10 and T5. Though T10 (100% CWR+200 kg ha^{-1} NPK), T5 (100% CWR+10 t ha^{-1} CM) and T4 (100% CWR+5 t ha^{-1} CM) had their full CWR, there were no significant differences in the plots treated with a 10% CWR reduction (T6, 90% CWR+5 t ha^{-1} CM). The application of CWR alone, T1 (100% CWR), T2 (90% CWR) and T3 (80% CWR) had no significant effects. No significant difference was seen among T2, T3, T9, T15, T14 and T8.

Recorded data on mean plant height during the mid-season stage had significant effects at $p<0.05$ (Table 2). It was observed that the tallest plant (195.9 cm) was recorded in the plots treated with 100% CWR+250 kg ha^{-1} NPK (T11) and the least plant height was seen in the plots treated with 80% CWR+250 kg ha^{-1} NPK (T15). From the results in Table 2, no significant differences existed among T11, T5, T4, T7, T10, T13, T6 and T12 with decreasing plant height in that order. T1, T8, T2, T9, T3, T14 and T15 had no significant difference. Plots treated with chicken manure at 100% ET_c and 90% ET_c combinations had taller plants than those treated with NPK at 100% ET_c and 90% ET_c in the mid-season stage.

At the end of the research, i.e. the late season stage, final data was collected on plant height. The mean was tabulated as shown in Table 2 and was significant at 5% level. The tallest plant was recorded in T5 (100% CWR+10 t ha^{-1} CM), 225 cm, followed by T7 (90% CWR+10 t ha^{-1} CM). The third and fourth tallest plants were produced by T11 (100% CWR+250 kg ha^{-1} NPK), 215.3 cm and T13 (90% CWR+250 kg ha^{-1} NPK), 214.0 cm, respectively. There were no significant differences among T5, T7, T11, T13, T4, T10, T6 and T12. Similarly, no significant effects were seen among T1, T2, T8, T3 and T14 (Table 2). Moreover, T8, T3, T14 and T9 had no statistical difference. The T14, T9 and T15 produced statistically the same results even though T15 produced the least plant height among all the treatments. It was also observed that as the level of fertilizers increases be it chicken manure or NPK, plant height also increases at 100% CWR and 90%CWR compared to 80% CWR.

Leaf area for the four growth stages: Leaf area for the four growth stages was analyzed and presented in Table 3. Deficit irrigation, deficit irrigation-chicken and deficit irrigation-NPK combinations affected leaf area. It was observed from the initial stage that the leaf area from plants subjected to T11 (100% CWR+250 kg ha^{-1} NPK), 168.4 cm^2, T10 (100% CWR+200 kg ha^{-1}), 165.9 cm^2 and T5 (100% CWR+10 t ha^{-1} CM), 162.0 cm^2 had no significant difference. There was no significant difference between T5 and T12 (90% CWR+200 kg ha^{-1} NPK, 148.73 cm^2). The T4 (100% CWR+5 t ha^{-1} CM) was significantly different from the rest of the treatments but produced

Table 3: Mean leaf area for the four growth stages

Treatment coding	Initial stage	Developmental stage	Mid stage	Late stage
T1	79.5^{d}	161.6^{de}	186.3^{de}	259.1^{e}
T2	78.4^{d}	160.3^{de}	183.3^{de}	256.0^{ef}
T3	30.0^{f}	99.7^{f}	104.4^{f}	217.3^{efg}
T4	119.8^{c}	251.6^{b}	315.4^{b}	428.4^{b}
T5	162.0^{ab}	207.0^{c}	377.0^{a}	478.5^{a}
T6	78.5^{d}	277.8^{ab}	312.8^{b}	437.5^{ab}
T7	89.2^{d}	288.4^{a}	339.9^{ab}	467.0^{ab}
T8	43.5^{ef}	141.9^{e}	180.2^{de}	211.4^{efg}
T9	84.4^{d}	185.4^{cd}	204.2^{cd}	208.3^{fg}
T10	165.9^{a}	209.8^{c}	329.3^{ab}	360.1^{cd}
T11	168.4^{a}	288.7^{a}	345.7^{ab}	373.1^{c}
T12	148.7^{b}	204.8^{c}	332.4^{ab}	321.9^{d}
T13	93.9^{d}	284.6^{b}	250.7^{c}	353.1^{cd}
T14	43.3^{ef}	81.7^{fg}	161.0^{de}	200.9^{gh}
T15	49.8^{e}	59.9^{g}	140.7^{ef}	156.1^{h}

Mean within the same column with similar letters are not significantly different at 5% probability level

the fifth largest leaf area. Besides, T13, T7, T9, T1, T6 and T2 had statistically the same results. Comparably, identical statistical results were seen among T15, T8 and T14. T8, T14 and T3 had no significant difference among them (Table 3).

The T11 produced the largest leaf area (288.7 cm^2) compared to the rest of the treatments while T15 (80% CWR+250 kg ha^{-1} NPK) produced the least leaf area (59.9 cm^2) in the developmental stage. Statistically, similar results were seen among T11, T7, T13 and T6 on one hand, while T6 and T4 were the same on the hand. The T10 (100% CWR+200 kg ha^{-1} NPK), 209.8 cm^2, T5 (100% CWR+10 t ha^{-1} CM), 207.0 cm^2, T12 (90% CWR+200 kg ha^{-1} NPK), 204.8 cm^2 and T9 (80% CWR+10 t ha^{-1} CM), 185.4 cm^2 had no significant differences among them. Also, identical statistical results were recorded among T9, T1 and T2. Though T1 had the largest leaf area compared to T2 and T8, no statistical differences were seen among them. The T3 (80% CWR), 99.7 cm^2 and T14 (80% CWR+200 kg ha^{-1} NPK), 81.8 cm^2, had no significant difference between them. The increment of NPK fertilizer from 200-250 kg ha^{-1} had no significant effect when combined with 80% CWR (T14 and T15) in the developmental stage.

Treatments imposed had significant effect on leaf area during the mid-season stage and were significant at 5% probability (Table 3). The data collected during the mid-season stage showed that 80% CWR had the least leaf area, 104.4 cm^2, while T5 (100% CWR+10 t ha^{-1} CM), 377.0 cm^2 had the largest leaf area among all the treatments. There were no significant difference among T5, T11, T7, T12 and T10 on one hand and no statistical difference among T11, T7, T12, T10, T4 and T6 on the other hand (Table 3). Mean leaf area showed that no significant difference existed among T1, T2, T8, T14 and T15. T15 (80% CWR+250 kg ha^{-1} NPK) and T3 (80% CWR) had no significant difference.

Plots treated with chicken manure plus 100% CWR and 90% CWR combinations gave larger leaf area in the late growth stage than those treated with NPK plus 100% CWR and 90% CWR combinations. The T5 (100% CWR+10 t ha^{-1} CM) recorded the largest leaf area while T15 (80% CWR+250 kg ha^{-1} NPK) recorded the least. No significant difference existed among T5, T7 and T6. Also, T7, T6 and T4 had no significant difference though there was 10% water reduction in T6 and T7. T11 (100% CWR+250 kg ha^{-1} NPK), 373.1 cm^2, T10 (100% CWR+200 kg ha^{-1} NPK), 360.1 cm^2 and T13 (90% CWR+250 kg ha^{-1} NPK), 353.1 cm^2 had no significant effects. In addition, plants treated with 100% CWR+200 kg ha^{-1} NPK (T10), 90% CWR+250 kg ha^{-1} NPK (T13) and 90% CWR+200 kg ha^{-1} NPK (T12) had no significant effects. The T1, T2, T3 and T8 had statistically

Table 4: Mean stem circumference for the four growth stages

Treatment coding	Initial stage	Developmental stage	Mid stage	Late stage
T1	2.2^{abcd}	4.1^{def}	6.9^{bc}	9.5^{e}
T2	2.1^{bcd}	4.2^{def}	6.7^{bcd}	9.5^{e}
T3	1.1^{e}	4.1^{def}	5.8^{cde}	7.4^{fgh}
T4	2.3^{abcd}	5.0^{bcd}	7.5^{ab}	11.2^{bc}
T5	2.7^{abc}	6.2^{a}	8.4^{a}	13.0^{a}
T6	2.6^{abc}	5.8^{ab}	7.7^{ab}	11.0^{bcd}
T7	2.2^{abcd}	5.9^{ab}	7.8^{ab}	11.9^{b}
T8	1.9^{cde}	4.0^{ef}	6.4^{bcde}	8.3^{f}
T9	2.1^{bcd}	3.9^{ef}	6.6^{bcde}	7.8^{fg}
T10	2.6^{abc}	4.7^{cde}	7.3^{ab}	11.0^{bcd}
T11	3.0^{a}	5.8^{ab}	7.0^{abc}	11.6^{b}
T12	2.0^{cde}	5.2^{abc}	6.7^{bcd}	10.0^{de}
T13	2.9^{ab}	5.3^{abc}	7.5^{ab}	10.2^{cde}
T14	2.2^{abcd}	3.5^{f}	5.5^{de}	6.9^{gh}
T15	1.6^{de}	3.4^{f}	5.3^{e}	6.5^{h}

Mean within the same column with similar letters are not significantly different at 5% probability level

similar results. T2, T3, T8 and T9 had no significant effects despite the fact that T8 and T9 had some levels of chicken manure as compared to T2 and T3. No significant effects were recorded among T3, T8, T9 and T14. About 80% CWR+200 kg ha^{-1} (T14) and 80% CWR+250 kg ha^{-1} NPK (T15) had no significant difference despite the increase of NPK from 200-250 kg ha^{-1}.

Stem circumference for the four growth stages: There were significant differences ($p<0.05$) in stem circumference at various growth stages (Table 4). In the initial stage, T11 (100% CWR+250 kg ha^{-1} NPK) produced the biggest stem circumference (2.993 cm) but was not significantly different from T13, T5, T10, T6, T4, T1, T14 and T7 while T5 (100% CWR+10 t ha^{-1} CM) gave the biggest stem circumference (6.2 cm) in the developmental stage, the Mid-season stage (8.4 cm) and the late season stage (13.0 cm). The T3 produced the least stem circumference in the initial stage while T15 gave the least in the developmental stage (3.4 cm), mid-season stage (5.3 cm) and the late season stage (6.5 cm). The second, third and fourth biggest stem circumference were produced by plants treated with T13 (90% CWR+250 kg ha^{-1} NPK), 2.9 cm, T5 (100% CWR+10 t ha^{-1} CM), 2.7 cm and T10 (100% CWR+200 kg ha^{-1} NPK), 2.6 cm but were not statistically different from T6, T4, T1, T14, T7, T2 and T9 in the initial growth stage while the second, third and fourth biggest stem circumference were produced by T7, T11 and T6 but were not significantly different from T5, T13 and T12 in the developmental growth stage.

Similarly, the second, third and fourth biggest stem circumference were recorded by T7, T6 and T4 plants but were not significantly different from T5, T13, T10 and T11 in the Mid-season stage, while T7, T11 and T4 recorded the second, third and fourth biggest stem circumference in the late season stage but were statistically similar to T6 and T10. In the initial growth stage, T5, T10, T6, T4, T1, T14, T7, T2, T9, T8 and T12 were statistically the same and also, there were no significant differences among T4, T1, T14, T7, T2, T9, T8, T12 and T15. The T8, T12, T15 and T3 had no significant difference in the initial stage. At the end of the developmental stage, data collected on stem circumference showed that no significant difference existed among T13, T12, T4 and T10 on one hand and T4, T10, T2, T1 and T3 on the other hand. Furthermore, T10, T2, T1, T3, T8 and T9 had no statistical difference and T2, T1, T3, T8, T9, T14 and T15 obtained similar statistical results in the developmental stage. No significant difference existed among T11, T1, T12, T2, T9, T8 and T3 while T12, T2, T9, T8, T3 and T14 had no statistical difference among them in the mid-season stage. Plants treated under T9, T8, T3, T14 and T15 showed no significant difference in the mid-season stage. The late season stage stem circumference showed no significant difference among

T4, T6, T10 and T13 on one side and T6, T10, T13 and T12 on the other side. Treated plants with T13, T12, T1 and T2 showed no statistical difference and T8, T9 and T3 had similar results statistically. T9, T3 and T14 had stem circumference of 7.8, 7.4 and 6.8 cm, respectively, but no significant difference existed among them while T3, T14 and T15 produced similar results in the late stage.

The combinations of deficit irrigation-chicken manure and deficit irrigation-NPK had great effects on growth parameters of okra. It was observed in the first two growth stages, i.e., initial and developmental stage, that deficit irrigation-NPK combination dominated in plant height, leaf area and stem circumference as compared to deficit irrigation-chicken manure. This was a clear indication that NPK was readily available to the plants for utilization. It was also seen that at 100% CWR and 90% CWR, as the NPK level increased from 200-250 kg ha^{-1}, the growth parameters also increased except for 80% CWR where NPK performed poorly. The improvement of growth parameters with increase in NPK rate could be due to increased uptake of NPK, their roles in chlorophyll synthesis and hence the process of photosynthesis and carbon dioxide assimilation (Jasso-chaverria *et al*., 2005; Ng'etich *et al*., 2013) leading to enhanced growth. This was evident in the work.

In the mid and late season stages, deficit irrigation-chicken manure combinations dominated in the growth parameters. This shows the long term effects of organic fertilizer as they decompose slowly. The beneficial effects of chicken manure on growth and yield of different vegetables were also reported by earlier investigators (Estefanous and Sawan, 2003; Rajpaul *et al*., 2004; El-Nemer *et al*., 2005; Faten and Ismaeil, 2005; Siddiqui *et al*., 2009). Also, plant height, leaf area and stem circumference were improved as chicken manure rate was increased from 5-10 t ha^{-1} when they were in combinations with 100% CWR and 90% CWR. Again, 20% CWR reduction with 5 and 10 t ha^{-1} chicken manure combination had no comparable results with full CWR and 10% CWR reduction. Moreover, there was no statistically significant difference in 100% CWR, 90% CWR and 80% CWR treatments alone even though there was growth reduction.

Effects of deficit irrigation, deficit irrigation-chicken manure and deficit irrigation-NPK interactions on the yield, yield related components and root length of okra: The effects of the treatments on the yield, yield related parameters and root length are presented in Table 5. Results obtained showed significant differences at 5% probability level among some treatments.

Table 5: Yield related parameters and root length

Treatment coding	Mean number of pod/trmt	Mean pod weight (t ha^{-1})	Mean pod length (cm)	Mean pod circum (cm)	Mean root length (cm)
T1	31^{f}	6.0^{b}	8.2^{de}	8.2^{ef}	23.9^{gh}
T2	30^{f}	6.0^{b}	8.1^{de}	7.5^{ef}	24.0^{gh}
T3	28^{f}	5.7^{b}	8.0^{de}	7.4^{ef}	30.3^{def}
T4	66^{c}	8.4^{a}	10.4^{c}	11.4^{bc}	21.1^{h}
T5	76^{a}	8.9^{a}	13.6^{a}	12.3^{ab}	24.4^{gh}
T6	65^{c}	8.2^{a}	10.9^{bc}	9.8^{d}	26.8^{efg}
T7	73^{b}	8.6^{a}	12.8^{a}	12.8^{a}	30.1^{def}
T8	23^{g}	4.1^{c}	6.8^{f}	8.4^{e}	30.9^{cde}
T9	23^{gh}	3.7^{cd}	7.2^{ef}	7.1^{f}	33.4^{cd}
T10	42^{e}	8.0^{a}	9.9^{c}	10.2^{d}	25.2^{fgh}
T11	71^{b}	8.8^{a}	11.7^{b}	11.3^{bc}	26.6^{efgh}
T12	61^{d}	7.9^{a}	8.4^{d}	10.6^{cd}	31.9^{cde}
T13	70^{b}	8.2^{a}	10.4^{c}	9.6^{d}	36.2^{bc}
T14	21^{gh}	3.9^{cd}	6.4^{fg}	6.3^{gh}	40.8^{b}
T15	19^{h}	2.3^{d}	5.8^{g}	6.0^{h}	47.4^{a}

Mean within same column with similar letters are not significantly different at 5% probability level

The highest number of pod per treatment was recorded in plot treated with 100% CWR+10 t ha^{-1} CM (T5), 76 and was statistically different from the rest of the treatments. The second (73), third (71) and fourth (70) highest number of pods were produced by 90% CWR+10 t ha^{-1} CM (T7), 100% CWR+250 kg ha^{-1} CM (T11) and 90% CWR+250 kg ha^{-1} NPK (T13), respectively. The T4 (100% CWR+5 t ha^{-1} CM), 66 and T6 (90% CWR+5 t ha^{-1} CM), 65, had no statistical difference. The T12 (90% CWR+200 kg ha^{-1} NPK), 61 and T10 (100% CWR+200 kg ha^{-1} NPK), 42 were statistically different from each other and different from the rest of the treatments. Though there was reduction in number of pods in 100% CWR, 90% CWR and 80% CWR treatments alone, no significant difference was seen among them. Similarly, no statistically significant difference existed among T8 (80% CWR+5 t ha^{-1} CM), 23, T9 (80% CWR+10 t ha^{-1} CM), 23 and T14 (80% CWR+200 kg ha^{-1} NPK), 21 on one hand and T9, T14 and T15 (80% CWR+250 kg ha^{-1} NPK), 19 on the other hand.

At the end of the research, pod weight in grams per treatment was converted and expressed in ton per hectare (t ha^{-1}). The first four highest pod weight in ton per hectare were recorded by plots treated with 100% CWR+10 t ha^{-1} CM (T5); 8.9 t ha^{-1}; 100% CWR+250 kg ha^{-1} NPK, (T11); 8.8 t ha^{-1}; 90% CWR+10 t ha^{-1} (T7); 8.6 t ha^{-1} and 100% CWR+5 t ha^{-1} (T4); 8.4 t ha^{-1}, but were not statistically significant from T6; (90% CWR+5 t ha^{-1} CM), 8.2 t ha^{-1}, T13; (90% CWR+250 kg ha^{-1} NPK),8.2 t ha^{-1}, T10; (100% CWR+200 kg ha^{-1} NPK), 8.0 t ha^{-1} and T12; (90% CWR+200 kg ha^{-1} NPK), 7.9 t ha^{-1}. Yield decreased as full CWR was reduced by 10 and 20% in T2 and T3 but no significant difference existed among T1; (100% CWR), 6.0 t ha^{-1}, T2; (90% CWR), 6.0 t ha^{-1} and T3; (80% CWR), 5.7 t ha^{-1}. No significant differences were seen among T8; (80% CWR+5 t ha^{-1} CM), 4.1 t ha^{-1}, T14 (80% CWR+200 kg ha^{-1} NPK), 3.9 t ha^{-1} and T9; (80% CWR+10 t ha^{-1} CM), 3.7 t ha^{-1}. Moreover, T14, T9 and T15 (80% CWR+250 kg ha^{-1} NPK), 2.3 t ha^{-1} expressed no significant differences.

Pod length and pod circumference were measured during every harvest till the last harvest. From the results obtained, T5 gave the longest pod length and the second longest pod length was produced by T7 but no significant difference existed between the two while the biggest pod circumference was given by T7 and the second biggest pod circumference by T5 again with no significant difference between the two. There was no statistical difference between T11 and T6 and there was no significant difference among T6, T13, T4 and T10 in term of pod length. Though T12 had 90% CWR+200 kg ha^{-1} NPK, it had no significant difference with T1, T2 and T3 in pod length. T1, T2, T3 and T9 showed statistically the same pod length. T9, T8 and T14 recorded no significant difference in pod length. The T14 and T15 had statistically the same pod length.

The biggest pod circumference was produced by T7 (12.767 cm) but was not statistically different from T5 (12.3 cm). The least pod circumference was given by T15 (6.0 cm). No significant difference existed among T5, T4 and T11. Similar results were seen among T4, T11 and T12 on one hand and T12, T10, T6 and T13 on the other hand. Plots treated with 100% CWR, 90% CWR and 80% CWR alone were not significantly different from each other and from T8. Moreover, T1, T2, T3 and T9 had no significant difference. The T9 and T14 had the same results while T14 and T15 had statistically the same results.

Plots treated with crop water requirement treatments alone had decreasing yield and yield related components as water was decreased from 100% CWR to 90% CWR and 80% CWR. This result is in line with the work done by Owusu-Sekyere and Annan (2010) and Calvache and Reichardt (1999) where water stress during vegetative growth led to decline in yield.

There were higher increases in yield in plots treated with chicken manure in combination with 100% CWR and 90% CWR than NPK-deficit irrigation plots. This could be due to available nutrients such as N and organic matter that are essential for the growth of the crop. This is in agreement with work done by Ojeniyi and Adejobi (2002) and Ojeniyi (2000). Also, there were increase in yield and yield related components as both chicken manure and NPK 15:15:15 increase from 5-10 t ha^{-1} chicken manure and 200-250 kg ha^{-1} NPK in combination with 100% CWR and 80% CWR. The 80% CWR in combination with chicken manure and NPK performed poorly especially with high fertilizer doses.

The root is the first organ of the crop to be exposed to water deficit. The change in moisture status in the soil also affects the spatial distribution of the roots and the efficiency of available nutrient and water absorption. The roots and shoots of the crop would function normally and benefit from each other when the conditions of the water and nutrient are favorable. Otherwise, their functions would be weak (Price *et al*., 2002; Woodall and Ward, 2002; Benjamin and Nielson, 2006). High or moderate water stress may induce the spread of roots in deeper layers of soil, so that plants would obtain a larger spatial distribution from which to uptake more nutrients and water (Zhang and Wang, 1997; Yan *et al*., 2008).

Data was collected to determine root length variations among the fifteen treatments. Data collected show significant differences among the treatments (Table 5). The longest root length was produced by T15 (47.38cm) and was statistically different from the rest of the treatments and the least root length was given by T4. Root lengths collected from T14 and T13 showed no significant difference. Also, T13, T9, T12 and T8 had no significant difference in root length. Comparable results were seen among T9, T12, T8, T3 and T7 where no significant difference existed. The T12, T8, T3, T7, T6 and T11 had no significant difference among them. In addition to treatment comparison, T3, T7, T6, T11 and T10 had no significant differences. Statistically, similar results existed among T6, T11, T10, T5, T2 and T1 while similar statistical results also existed among T11, T10, T5, T2, T1 and T4.

Soil analysis: Table 6 indicates some soil parameters analyzed before and after the experiment (0-25 cm depth). The initial results indicate that the soil was acidic with low organic matter. Also, the soil was low in nitrogen, phosphorus, potassium and available moisture content. The addition of crop water to the soil through irrigation and the application of chicken manure and NPK had effects on the soil properties. From Table 6, initial soil pH (4.82) increased in plots treated with deficit irrigation-chicken manure and deficit irrigation-NPK but decreased at 80% CWR+NPK. This result is in line with work done by Fubara-Manuel (2005) and Dikinya and Mufwanzala (2010) who found similar increase in pH in soil treated with chicken manure. Ano and Agwu (2006) also

Table 6: Results of soil analysis before (initial) and after the experiment

Parameters	Soil pH	Organic matter (%)	Nitrogen (%)	Phosphorus (μg P/g)	Potassium (cmol kg^{-1})	Moisture content (% by volume)
Initial	4.82	0.61	0.06	20.98	0.46	13.71
100% CWR	5.34	0.44	0.04	9.11	0.28	21.34
90% CWR	5.55	0.41	0.05	8.42	0.21	19.32
80% CWR	5.49	0.35	0.03	7.30	0.30	9.11
100% CWR+CM	5.95	2.62	0.08	47.92	7.00	23.21
90% CWR+CM	6.07	2.44	0.06	45.72	6.00	26.45
80% CWR+CM	5.58	0.77	0.03	35.06	4.00	19.25
100% CWR+NPK	5.75	0.68	0.07	11.32	6.00	21.22
90% CWR+NPK	5.03	0.62	0.08	10.60	6.00	13.44
80% CWR+NPK	4.03	0.47	0.07	12.84	7.00	11.36

CWR: Crop water requirement, NPK: Nitrogen-phosphorus potassium observed increase in pH after the addition of organic manure to the soil. Besides, Ouda and Mahadeen (2008) found that soil pH was not significantly affected by different doses of organic and inorganic fertilizers. There was enhancement in soil organic matter in plots given chicken manure and NPK than crop water requirement treatments alone. Moreover, there were decreases in NPK in plots with crop water requirement treatments alone maybe due to the uptake of those available minerals by the crop while increase in NPK was seen in plots treated with 100% CWR, 90% CWR and 80% CWR plus chicken manure.

Comparing chicken manure and NPK treated plots at the three levels of crop water requirements, chicken manure improved the soil properties more than NPK though there were some increases in NPK after the experiment. Similar observations were made by Fubara-Manuel (2005) and Adesodun *et al*. (2005).

The soil moisture content increased from the initial (13.71%) as a result of water applied (Table 6). There were increases at 100% CWR and 90% CWR treatments alone but a drop in 80%CWR. Moisture content was higher in chicken manure plots than NPK plots. Aluko and Oyedele (2005) attributed the improvement of soil moisture with poultry manure to the mulching effect of the organic matter, improved moisture retention and water acceptance as a result of improved soil structure and macro porosity.

CONCLUSION

It was observed that combination of deficit irrigation and fertilizer sources increased growth and yield of okra at 100% CWR and 90% CWR compared to the water treatments alone. Growth and yield also increased as chicken manure dose was increased from 5-10 t ha^{-1} and NPK 15:15:15 dose from 200-250 kg ha^{-1} when they were combined with 100% CWR and 90% CWR. Comparing chicken manure and NPK fertilizer performances on okra growth and yield, chicken manure had better results than NPK. Moreover, at either 80% CWR combination with chicken manure or NPK, 80% CWR+chicken manure performed better than 80% CWR+NPK.

On the other hand, there were no significant differences among the crop water requirement treatments alone (100% CWR, 90% CWR and 80% CWR) though there were growth and yield reduction as crop water requirement decreases. In a water scare environment, 80% CWR can be used to produce okra without significant yield reduction. For better yield, 10% deficit irrigation with high dose of chicken manure and NPK 15:15:15 is recommended.

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