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Effects of Deficit Irrigation and Chicken Manure Interactions on the Growth and Yield of Okra in a Pot Experiment

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ABSTRACT

The study was conducted at University of Cape Coast Research Farm, Cape Coast, Ghana from February, 2014 to December, 2014. The objective of the research was to investigate the effects of deficit irrigation and chicken manure interactions on the growth and yield of okra. Nine treatments (T1 = 100% CRW, T2 = 90% CWR, T3 = 80% CWR, T4 = 100% CWR+5 t ha^{-1} chicken manure, T5 = 100% CWR+10 t ha^{-1} chicken manure, T6 = 90% CWR+5 t ha^{-1} chicken manure, T7 = 90% CWR+10 t ha^{-1} chicken manure, T8 = 80% CWR+5 t ha^{-1} chicken manure and T9 = 80% CWR+10 t ha^{-1} chicken manure) replicated three (3) times were laid out in a Randomized Complete Block Design (RCBD). The T5 dominated in the growth and yield parameters of okra followed by T4. It was observed that T7 had a comparable yield with full Crop Water Requirements (CWR)+chicken manure (T4 and T5) and 20% deficit irrigation+chicken manure performed poorly (T8 and T9). For efficient water use without any significant yield reduction, 10% deficit irrigation+10 t ha^{-1} chicken is best for okra production.

Key words: Efficient water use, crop water requirements, yield reduction

INTRODUCTION

Irrigated agriculture is a key contributor to food security, producing 40% of food and agricultural commodities on 17% of agricultural land (FAO., 2012).

Forecasts of water withdrawals on a global scale predict sharp increases in future demand to meet the needs of the urban, industrial and environmental sectors. This is due to the fact that more than one billion people do not yet have access to running water or sanitary facilities and also to insufficient attention being paid, until now, to meet the water requirements of natural ecosystems (Fereres and Evans, 2006). The single biggest water problem worldwide is its scarcity (Jury and Vaux, 2005). There is significant uncertainty about what the level of water supply will be for future generations.

In Ghana, analysis of 40 year climatic data (1960-2000) from the Ghana Meteorological Agency reveals a progressive and visible rise in temperature with a 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.

As agriculture accounts for 70% of freshwater withdrawals worldwide and, furthermore, as most irrigation systems are very inefficient (only 30-50% of the water distributed is taken up by the plant), deficit irrigation is not only of high significance in water scarce areas or in dry seasonal periods; it also has the potential to optimize and reduce water use in irrigated systems (Sadras *et al*., 2007).

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). It is particularly relevant for crops in which flowering and fruit development take place in the dry season (Norman, 1992). 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). Furthermore, since water use is reduced, the irrigated area can be increased and additional crops can be irrigated and amplifying the diversity of the household production which decreases the farmers' risk aversion (Spreer *et al*., 2007).

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 1548-4507 metric t (SRID-MOFA., 2007).

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

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.

The research was carried out to investigate the effect of deficit irrigation and chicken manure interactions on the growth and yield of okra.

MATERIALS AND METHODS

Study location: The study was conducted at the School of Agriculture, Teaching and Research Farm, University of Cape Coast, Cape Coast, Ghana from February, 2014 to December, 2014. It is found on Latitude 05-06°N and Longitude 01-15°W at an altitude of 1.1 m above sea level.

The soil at the research 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%.

The research site is characterized by two rainy seasons: The major season which starts from May-July and the minor season 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).

Experimental design and field layout: The experiment was laid out in a Randomized Complete Block Design (RCBD) with nine treatments. Each treatment was replicated three times. The treatments were 100% Crop Water Requirement (T1), 90% Crop Water Requirement (T2) and 80% Crop Water Requirement (T3), while Crop Water Requirement (CWR) and chicken manure were combined in T4 (100% CWR+5 t ha^{-1} chicken manure), T5 (100% CWR+10 t ha^{-1} chicken manure), T6 (90% CWR+5 t ha^{-1} chicken manure), T7 (90% CWR+10 t ha^{-1} chicken manure), T8 (80% CWR+5 t ha^{-1} chicken manure) and T9 (80% CWR+10 t ha^{-1} chicken manure).

There were a total of twenty-seven plots with each plot containing five buckets. The plot size was 1×1 m. A total of one hundred and thirty-five buckets were used for the research. The buckets were filled with 8 kg soil each.

Planting of the crop: A local variety of okra was used for the experiment. The seeds were placed in water for a day before planting to increase sprouting. The seeds were sown directly on the 20th of February, 2014, three seeds per bucket following 60×60 cm spacing between each bucket and plants. The Chicken Manure was applied a week before planting. After a week of sowing, the three plants per bucket were thinned to one.

Cultural practices: Weeding was done using the native hoe and cutlass as the need arose. The use of the native hoe is a typical practice by many local farmers.

Insect pests were controlled by using the Pawa Insecticide at three weeks interval. A 50 mL dose of insecticide was mixed in 16 L knapsack can.

Research population: Each plot contained 5 buckets with each bucket containing a plant. There were a total of 27 plots. The total plant population was one hundred and thirty-five plants.

Irrigation regime employed: A two-day irrigation interval was employed. Each experimental bucket was weighed using a weighing scale during each irrigation day to determine the loss of water and amount to replace. The amount of water loss in volume was calculated and was applied for each water treatment (100% CWR, 90% CWR and 80% CWR).

Also, Evaporation Pan was used during the experiment to record the reference crop evapotranspiration (ET_o) during the entire growing period and for K_c calculation purpose (Table 1).

The equation used is:

$$ET_c = ET_o \times K_c$$

where, ET_c is the crop evapotranspiration (mm day^{-1}), K_c is the Crop Coefficient (dimensionless) ET_o is reference crop evapotranspiration (mm day^{-1}), thus, K_c is calculated as $K_c = ET_c/ET_o$.

Table 1: Accumulated ET_c, ET_o and calculated K_c

CWR applied (%)	Initial (mm/10 days)	Developmental (mm/31 days)	Mid (mm/25 days)	Late (mm/20 days)
100	14.62	139.76	227.10	163.08
90	13.16	125.78	204.39	146.77
80	11.70	111.81	181.68	130.46
Accumulated ET_o from E-Pan (mm)	63.70	322.40	209.60	170.90
Calculated K_c ($K_c = ET_c/ET_o$)	0.23	0.43	1.08	0.95

Calculated K_c values were similar to those used by Owusu-Sekyere and Annan (2010).

A Rain shelter was constructed to house the 135 experimental buckets to avoid any external moisture.

Soil and chicken manure analysis: Before the start of the research, surface soil samples at 0.25 cm depth were randomly collected from the experimental site and carefully mixed together. The samples were divided into four and two opposite quadrants were taken out. This was repeated and each time the process was done, 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 grounded and then analyzed for percent organic matter, amounts of nitrogen, phosphorous and potassium as well as soil pH and textural class.

Chicken manure samples were also taken and air dried and analysed for: percent nitrogen, phosphorus, potassium and pH.

Data collection: Five plants per plot were selected for assessment 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, (6) Pod weight (in both grams and ton per hectare) per treatment was determined, (7) Pod length (cm), (8) Pod circumference (cm) and (9) Root length (cm) were measured using a 30 cm ruler.

Statistical analysis: Treatment effects on okra growth and yield components were analyzed using Analysis of Variance (ANOVA) procedure of GenStat Version 16. Mean comparisons were performed using Duncan Multiple Range Test (DMRT) at $p = 0.05$ to statistically find any significant difference between treatment means.

RESULTS AND DISCUSSION

The effects of different levels of ET_c and their combination with chicken manure on the growth parameters of okra such as plant height, leaf area, stem circumference and root length and yield parameters such as number of pods per treatment, pod weight, pod length and pod circumference were analyzed using Analysis of Variance and treatment means were compared using the Duncan Multiple Range Test (DMRT) at $p<0.05$ level. The results of these growth parameters are presented in Table 3 and the results of the yield parameters are presented in Table 4. The results showed variations among all the treatments and were found to be statistically significant at 5% level.

Okra growth

Plant height: Crop Water Requirements (CWR) applied at 100, 90 and 80% or in combination with Chicken Manure (CM) had some effects on okra plant height (Table 2). Plots treated with 100% CWR+10 t ha^{-1} CM (T5) had the tallest plant (134.5 cm) but were not statistically different from T4 (100% CWR+5 t ha^{-1} CM, 116.1 cm) and T7 (90% ET_c+10 t ha^{-1} CM, 126.9 cm). The T7 produced

Table 2: Chemical compositions of soil and chicken manure samples

Samples	Organic matter (%)	Nitrogen (%)	Phosphorus (µg P g^{-1})	Potassium (cmol K kg^{-1})	pH
Soil	0.44	0.04	21.89	0.41	5.97
Chicken manure	-	2.92	6296.41	28.57	7.33

Table 3: Growth parameters of okra as affected by sole deficit irrigation and deficit irrigation-chicken manure combinations in a pot experiment

Treatment coding	Mean plant height (cm)	Mean leaf area (cm^2)	Mean stem circumference (cm)	Mean root length (cm)
T1	100.2^{cd}	127.6^{cd}	4.3^{bcde}	18.9^{bc}
T2	74.0^{ef}	116.3^{cd}	3.7^{cde}	18.9^{bc}
T3	53.0^{f}	88.5^{d}	2.4^{e}	25.7^{ab}
T4	116.1^{a}	205.8^{b}	7.9^{a}	16.5^{c}
T5	134.5^{abc}	278.6^{b}	8.9^{a}	18.9^{bc}
T6	110.6^{bc}	155.7^{a}	6.4^{abcd}	21.7^{abc}
T7	126.9^{ab}	220.8^{c}	7.4^{abc}	25.1^{ab}
T8	84.0^{de}	107.6^{cd}	3.4^{de}	27.4^{a}
T9	63.0^{ef}	91.9^{d}	3.8^{cde}	28.3^{a}

Means followed by common letters in a column are not significantly different at 5% Probability level using DMRT

Table 4: Yield parameters of okra as affected by deficit irrigation and deficit irrigation-chicken manure interactions in a pot experiment

Treatment	Mean No. of Pod/Trmt	Mean pod weight (t ha^{-1})	Mean pod length (cm)	Mean pod circumference (cm)
T1	21^{cd}	2.0^{cd}	6.4^{c}	6.6^{de}
T2	16de	1.8^{cde}	4.1^{de}	5.3^{ef}
T3	9 d	0.7^{f}	3.5^{e}	4.0^{f}
T4	61^{a}	4.0^{b}	8.8^{b}	9.1^{b}
T5	53^{ab}	5.2^{a}	11.6^{a}	11.2^{a}
T6	31^{c}	2.5^{c}	9.4^{b}	7.3^{cd}
T7	49^{b}	4.2^{b}	10.1^{ab}	8.6^{bc}
T8	12de	1.2^{def}	6.1^{cd}	6.0^{de}
T9	15de	1.0^{ef}	5.5^{cde}	6.5^{de}

Means followed by same letters in a column are not significantly different at 5% Probability level using DMRT

the second tallest plants followed by T4, T6 (90% CWR+5 t ha^{-1} CM, 110.6 cm), T1 (100% CWR, 100.2 cm), T8 (80% CWR+10 t ha^{-1} CM, 84.0 cm), T2 (90% CWR, 74.0 cm), T9 (80% CWR+10 t ha^{-1} CM, 63.0 cm) and T3 (80% CWR, 53.0 cm) in that order. With the application of CWR alone at 100% (T1), 90% (T2) and 80% (T3), T1 produced the tallest plants compared to T2 and T3. There was significant difference between T1 and T2; T1 and T3 but no significant difference existed between T2 and T3.

Leaf area: The T5 produced the largest leaf area (278.6 cm^2) (Table 3). The second largest leaf area (220.8 cm^2) was obtained by T7. No significant difference existed between T4 (205.8 cm^2) and T7. Furthermore, no significant difference existed between T8 (107.6 cm^2) and T9 (91.9 cm^2). The T1, T2 and T3 had statistically comparable results with those plants/plots treated with both ET_c and Chicken Manure (T8 and T9). The T3 had the least leaf area (Table 3).

Stem circumference: Statistically, similar stem circumferences were obtained from T4 (7.9 cm), T5 (8.9 cm), T6 (6.4 cm) and T7 (7.4 cm) with T5 producing the biggest stem circumference followed by T4, T7 and T6 in that order. The T1, T6 and T7 showed no significant difference even though T6 and T7 had manure. There were no significant difference among the sole ET_c treatments but T1 gave the biggest stem circumference followed by T2 and T3 with T3 producing the least stem circumference of all the treatments.

Root length: According to the results presented in Table 3, deficit irrigation and chicken manure combinations had effects on root length. The T9 had the longest root length (28.3 cm) while T4 had the least root length (16.5 cm). T9, T8 (27.4 cm), T3 (25.7 cm), T7 (25.1 cm) and T6 (21.7 cm) had no significant differences. Furthermore, T1 (18.9 cm), T2 (18.9 cm), T3, T5 (18.9 cm), T6 and T7 had no significant effects. The T1, T2, T4, T5 and T6 had similar results statistically with T6 producing the longest root length and T4 producing the least. It was observed that deficit irrigation had a great influence on root length. The lower the water application and the higher the chicken manure concentration, the longer the root length.

It was observed that the addition of chicken manure to crop water requirement treatments (T1-100%, T2-90% and T3-80%) resulted in increase in growth parameters as compared to the crop water requirement treatments alone. This means that chicken manure was in a readily accessible form for easy absorption by the plant roots. Hence, there was an increase in the morphological growth of okra plant. The results obtained agreed with the finding of Onwu *et al*. (2014) and Ajari *et al*. (2003), in okra production in which they reported that organic manure, especially poultry manure, could increase plant height and crop branches. Data analyzed showed that increase in the level of chicken manure from 5-10 t ha^{-1} with 100% CWR and 90% CWR had significant effects on the growth parameters of okra. This result is in line with the findings of Onwu *et al*. (2014, 2008) and Aliyu (2000) that there is increase in growth with increased organic manure.

Okra yield: Table 4 shows yield parameters of okra which included number of pod per treatment, pod weight in ton per hectare, pod length and pod circumference.

Number of pod per treatment: The number of pod per treatment was affected by both irrigation water levels and levels of chicken manure. The highest number of pods (61) was seen in T4 followed by T5 (53), T7 (49) and T6 (31) in that order of decreasing number of pods. The differences among T1 (21 pods), T2 (16 pods) and T3 (9 pods), were not statistically significant. The T1 produced the highest number of pods followed by T2. The T3 gave the least number of pods among all the treatments. Statistically, no significant difference existed between T4 and T5. Similar results were seen between T5 and T7 (49 pods) where no significant difference existed. T1 and T6 (31 pods) had no significant difference even though T6 had the higher number of pods. Additionally, T1, T2, T8 and T9 had no significant differences and T2, T8 and T9 had no significant differences as well. The T2 in each case gave the highest number of pods (Table 4).

Pod weight (t ha^{-1}): The data in Table 4 indicate that of all the treatments, T5 gave the highest okra weight (5.2 t ha^{-1}) and was significantly different from all the other treatments. T7 was second in terms of pod weight (4.2 t ha^{-1}) followed by T4 (4.0 t ha^{-1}). The 80% CWR produced the least pod weight (0.7 t ha^{-1}). Comparing T4 and T7, there was no significant difference. Yields from T1, T2 and T6 were similar statistically. Also, T1, T2 and T8 were not significantly different. Moreover, T2, T8 and T9 had statistically similar results. Comparing T3, T8 and T9, though T3 produced the least, no significant differences existed among them.

Pod length: From Table 4, pod length was longest with T5 (11.6 cm) followed by T7 (10.1 cm) and then T6 (9.4 cm). Statistically, no significant difference existed between T5 and T7. In addition to treatments comparison, T4 (8.8 cm), T6 and T7 showed no significant difference, likewise T1 (6.4 cm), T8 (6.1 cm) and T9 (5.5 cm). T2 (4.1 cm), T8 and T9 had no significant difference even though the longest pod length was produced by T8. On the other hand, T2, T3 and T9 had no significant difference but T9 produced the longest pod.

Pod circumference: From Table 4, the biggest pod circumference (11.2 cm) was recorded in T5 and was significantly different from the rest of the treatments while T3 produced the least pod circumference (4.0 cm). The T4 (9.1 cm) and T7 (8.6 cm) showed no statistical difference. No significant difference existed between T6 (7.3 cm) and T7 (8.6 cm). Similar results were observed among T1 (6.6 cm), T6 (7.3 cm), T8 (6.0 cm) and T9 (6.5 cm) where no significant differences were seen. Besides, T1, T2, T8 and T9 had no significant differences.

According to Owusu-Sekyere and Annan (2010) and Calvache and Reichardt (1999), water deficit during vegetative growth leads to decline in yield. This was evident from the results in Table 4 where, T1, T2 and T3 gave 21, 16 and 9 pods, respectively. The effect of stress on vegetables affects yield quality of which the weight is not an exception (Davenport, 1994). This was evident in T2 and T3.

The effects of water stress also led to reduction in pod length and pod circumference. The decline in pod length and circumference as a result of decrease in crop water requirements is in line with work done by West *et al*. (2004) who reported that irrigation increases size and weight of fruit and that of Viets (1998) who found that low utilization of water deficient crops has poor carbohydrate utilization and therefore fruit decrease in size (pod length and circumference).

It is seen from Table 4 that yield parameters were greater in deficit irrigation-chicken manure combination (T4, T5, T6, T7, T8 and T9) than T1, T2 and T3. Also, it can be observed that as the level of chicken manure increased from 5-10 t ha^{-1}, there were increases in pod weight, pod length and stem circumference at the same level of irrigation water applied. This shows that chicken manure has beneficial effects on okra yield. The result is in conformity with earlier investigators, Abd El-Kader *et al*. (2010), Rajpaul *et al*. (2004), Estefanous and Sawan (2003), Rajpaul *et al*. (2004) El-Nemer *et al*. (2005), Faten and Ismaeil (2005) and Siddiqui *et al*. (2009) who reported the beneficial effect of chicken manure on growth and yield of different vegetables.

CONCLUSION

The combination of deficit irrigation and chicken manure improved growth of okra leading to increase in yield. On average, T5 produced the highest growth and yield parameters followed by T4. The T7 had similar result with T4 and T5. Also, as chicken manure doses increased from 5-10 t ha^{-1} with the same crop water requirements, (T4 and T5 on one hand and T6 and T7 on the other hand), there were increases in growth and yield parameters. T8 and T9 had poor results compared to all other results. It can therefore be concluded that a 10% reduction in CWR plus 10 t ha^{-1} of chicken manure is best for okra production under water stress condition.

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