International Journal of Irrigation and Agricultural Development
Agricultural Science and Development
IJIRAD 9(1) [2025] [470 – 479]
IJIRAD
ISSN: 2616-1508
https://www.ijirad.org

# Effects of Irrigation Methods and Soil Amendment Practices on Growth and Yield of Okra

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**ARTICLE INFO**

**Article History:**
Received: **Oct. 1, 2025**
Received in revised form: **Nov. 8, 2025**
Accepted: **Nov. 14, 2025**

**Keywords:**
Supplementary irrigation,
Soil amendment,
Okra,
Yield.

**DOI**:
https://doi.org/10.47762/2025.964x.179

## ABSTRACT

*Irregular rainfall pattern and distribution coupled with soil health challenges has led to water stress challenges, hindering crop and water productivity. The objective of this study was to evaluate the interactive effect of irrigation methods and soil amendment practices on soil chemical characteristics, moisture content, growth, yield and water productivity of okra during the production season. Generally, there was a sharp decrease in the soil pH, EC, nitrogen and phosphorus content after the experiment indicating the use of soil nutrients by plants under each treatment. The average soil moisture content as influenced by soil amendment practices, ranked as cow dung > 50% cow dung + 50 % NPK > NPK > zero soil amendment. Supplementary irrigated okra had 6.3%, 17.5%, 25.1%, 35.4% and 19.7% increase in chlorophyl content, plant height, stem girth, leaf area index and yield of okra than rainfed okra. Supplementary irrigated okra combined with cow dung treated soils (20.1 t/ha) as well as soil treated with 50 % cow dung and 50 % NPK (20 t/ha) recorded similar yield, being the best yield. These combinations are recommended for farmers for better economic value and soil water retention, towards soil health.*

## INTRODUCTION

The agricultural sector employs majority of Ghanaians, of which according to Darfour and Rosentrater (2016), most are smallholder farmers. However agricultural productivity is affected negatively affected by climate change. Erratic and irregular rainfall distribution coupled with drought spells, harsh temperatures and heat waves are fundamental to the food insecurity challenges. Khan and Akhtar (2015) indicated that crop productivity suffers from water unavailability. This is partly due to the insufficient rainfall and large dependence and rivalry for water among the agricultural sectors, industries and domestic users (Odo, 2017). Tan *et al.,* (2009) revealed that over 80% of available water resources is used for agricultural irrigation purposes. Efficient techniques are thereby required to maximize the efficient use of water and nutrients applied (Kumar, 2020). Supplementary irrigation is an irrigation technique which enables the farmer to be climate sensitive (Davis, 1951) while providing the required amount of water to essentially rainfed crops during periods of dry spell or inadequate rainfall, in an effort to boost or stabilize yield. This is done successfully through drip, sprinkler or other surface irrigation methods to keep the soil moist enough to enhance water and nutrients uptake by plant root. This then helps farmers to stabilize and increase yield, thereby increasing revenue. Notably, Chiang *et al.,* (1993) disclosed that the revenue of farmers is greatly increased by supplementary irrigation, which produces greater and more consistent harvests as well as noticeably higher agricultural water productivity.

The applications of fertilizers help to enhance plant growth by providing amendments to the soil via various macro-and micronutrients (Dhaliwal *et al.,* 2019). Different organic manure such as cow dung, pig manure, poultry manure and plant manure, are used in crop production. Unlike the inorganic fertilizers, organic manure boost soil health by providing nutrients, enhancing soil water holding capacity and enhancing soil pH levels for plant growth and productivity (Kasongo

et al., 2013; Asomah *et al.,* 2021). However the irregularity of rainfall causes water stress during crop production, which negatively affects plant stomata conductance, photosynthesis, leaf area, flower and fruit formation (Moussa *et al.,* 2011; Nuhu and Mukhtar, 2013; Martine *et al.,* 2021). Also, Verma *et al.* (2020) established that, despite the enormous advantages of organic farming, there is close to 20 % loss in yield due to inadequate release of nutrients into soils for plants uptake. However, Selim, (2020), disclosed that it the combined amendment of soils with both organic and inorganic fertilizers is an effective strategy to boost crop yield, while enhancing the physical and chemical characteristics of soils and Improving crop nutrients absorption. In effect, as proposed by Moyin-Jesu and Adekayode (2010) and adopted by Ghanaian farmers, organic fertilizers are incorporated into the soil, about two weeks before planting, to enable further decomposition of the organic matter and to avoid plant disease infestation.
Okra (*Abelmoschus esculentus* L.) is an important annual vegetable crop, largely produced in the tropical and sub-tropical nations across the world (Benchasri, 2012; Food and Agriculture Organization of the United Nations, 2020). Okra production by mono cropping or inter-cropping, covers about 2.5 million hectares and yields 10.5 million tonnes in each year. Okra is a nutrient rich vegetable (fats, proteins, carbohydrates, minerals and vitamins (Omotoso and Shittu, 2007)), with health benefits such as digestion enhancement, cholesterol regulation and a potential anti-diabetic effect. In Ghana, okra may be used in its fresh or dehydrated state, often in the rainy or dry seasons respectively (Oppong-Sekyere *et al.,* 2012). In Northern Ghana, it's of a strong commercial value for women farmers and used in most dishes among the inhabitants of the cities and villages. Despite this importance, the yield is reportedly falling and thus, require the identification of appropriate combination of technologies to improve yield and sustain livelihood of farmers (Sugri *et al.,* 2015).

## MATERIALS AND METHODS

### Study Area

The study was carried out at the experimental field of the West African Centre for Water, Irrigation and Sustainable Agriculture, University for Development Studies (WACWISA-UDS) at Nyankpala Campus (Figure 1). Nyankpala is situated in the Northern Region of Ghana, 16 km west of Tamale. It is 200 meters above sea level and sits at latitude N 09º 25' and longitude W 0º 58'. The location is characterised by a unimodal rainy season ranging between 1000 - 1200 mm of annual precipitation. Typically, the rainy season spans between 140 to 190 days per year, with the highest precipitation occurring in August and September. The domestic and agricultural sectors find it challenging to secure water during the extremely dry months from November and May.

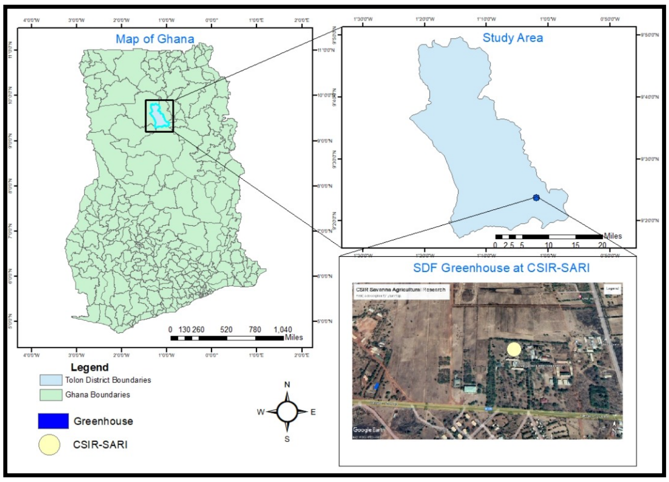


**Figure 1.** Map of the study area

### Experimental Design

A 2 x 4 factorial experiment laid in a split-plot design and of three replications. The whole plot was irrigation methods, constituting two treatments, thus supplementary irrigation and rainfed methods. The sub-plot was soil amendment methods, comprising of four treatments, of which were the incorporation of; Cow Dung, N P K (15:15:15), combination of 50% Cow Dung + 50% N P K (15:15:15) and Zero Amendment (Table 1). The experiment last from May to July 2024 on a field area, 8 m × 10.2 m.

**Table 1.** Experimental Treatment Structure

| Treatment No. | Variety | Whole-Plots | Sub-Plots |
|---|---|---|---|
| | | Water Applications | Soil Amendments |
| T1 | Okra Indiana | Rainfed | Zero amendment |
| T2 | Okra Indiana | Rainfed | NPK |
| T3 | Okra Indiana | Rainfed | Cow Dung |

| | | | |
|---|---|---|---|
| T4 | Okra Indiana | Rainfed | 50% Cow Dung + 50% NPK |
| T5 | Okra Indiana | Supplementary Irrigation | Zero amendment |
| T6 | Okra Indiana | Supplementary Irrigation | NPK |
| T7 | Okra Indiana | Supplementary Irrigation | Cow Dung |
| T8 | Okra Indiana | Supplementary Irrigation | 50% Cow Dung + 50% NPK |

Cow dung manure was applied at the rate of 15 t/ha two weeks before sowing okra on respective experimental treatment plots. This enhanced a uniform mixture and decomposition of the manure as required. The NPK (15:15:15) fertilizer was applied through side placement on respective treatment plots at a rate of 20 g per plant at two weeks after germination of okra. Supplementary irrigation was administered using the drip irrigation system on corresponding treatment plots, while rainfall was generally across all fields. Supplementary irrigation water requirement (Table 2.2) was estimated with the aid of the CROPWAT 8.0 software, considering real time climate data (minimum and maximum temperature, relative humidity, rainfall, wind speed, sunshine hours and radiation) (Agbemabiese *et al*., 2018). Figure 2, however shows that most of the production period, the amount of rainfall recorded was 0 mm, showing that there was no rain most of the time, and the highest rainfall was 18.3 mm. Average temperature recorded throughout the experiment ranged from 24.5 °C to 30.5 °C, which is suitable for production according to E-Kader *et al*. (2010) who reported that optimum temperatures of 18 – 35 °C was suitable for okra production.

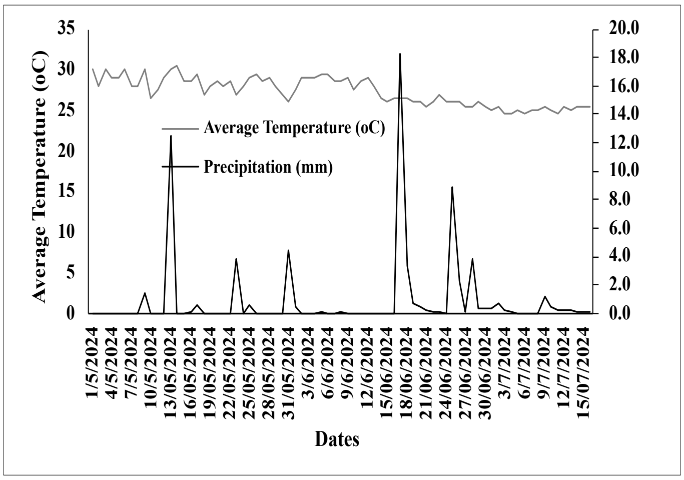


**Figure 2.** Average Temperature and Precipitation Over the Production Period (Source: WACWISA -UDS Field, ATMOS 41 Weather Station)

**Table 2.** Estimated Amount of Water used by Okra Using CROPWAT 8.0

| Month | Decade | Stage | Kc Coefficient | ETc mm/day | ETc mm/dec | Eff rain mm/dec | Irr. Req. mm/dec. |
|---|---|---|---|---|---|---|---|
| May | 2 | Initial | 0.46 | 2.78 | 13.9 | 0.6 | 13.3 |
| May | 3 | Initial | 0.46 | 2.81 | 30.9 | 1.4 | 29.5 |
| June | 1 | Development | 0.51 | 3.21 | 32.1 | 1.5 | 30.5 |
| June | 2 | Development | 0.79 | 5.07 | 50.7 | 1.7 | 49 |
| June | 3 | Development | 1.11 | 6.37 | 63.7 | 1.9 | 61.9 |
| July | 1 | Mid | 1.25 | 6.21 | 62.1 | 2 | 60.1 |
| July | 2 | Late | 0.97 | 4.22 | 37.9 | 1.9 | 35.8 |
| **Total** | | | | | **291.3** | **11** | **280.1** |

## Soil Physicochemical Characteristics

Prior to the experiment, a composite soil sample was taken from the field and analysed for soil textural class, bulk density, field capacity, soil available water content, pH (IITA, 1982), electrical conductivity (EC), phosphorus content (Bray and Kurtz, 1945) and nitrogen content (Novozamsky *et al.,* 1983) (Table 3). This helped establish a baseline data on the general soil physical and chemical characteristics, and was used un the estimation of supplementary irrigation water requirement. A soil moisture meter (Campbell H2S Hydro Sense II (CS658) moisture meter) was used to read the soil moisture content of soil daily across all treatment plots before supplementary irrigation. Composite samples of soil were collected with the soil core-sampler from each treatment plot at the end of the experiment for chemical analysis (pH, EC, phosphorus and nitrogen) to assess the impact of the treatments.

**Table 3.** Physical Properties of the Soil in the Experimental Field

| Soil Properties | Value |
|---|---|
| Sand (%) | 65.15 |
| Silt (%) | 28.02 |
| Clay (%) | 6.83 |
| Soil texture | Sandy loam |
| Bulk density (g/cm$^3$) | 1.42 |
| Field capacity (%) | 21.9 |
| Permanent wilting point (%) | 8.9 |
| Available water (%) | 13 |

Source: WACWISA Laboratory Results (2024)

### Agronomic Data Collection and Analysis

A sample of three plants were chosen form the middle plants within each treatment plot in each replicate. Data was then taken from these plants at six weeks after planting on, plant height, stem girth, leaf area index (Musa and Hassan 2016; Tunca *et al.,*2018) and SPAD (Chlorophyl content). At harvesting stage, fruit number, average fruit weight, yield and crop water productivity (Agbemabiese *et al,* 2017) were estimated from the sampled plants. The GenStat Edition 12th was used the carry out an analysis of valiance for all data recorded from the field. Means were separated at a 5% probability level using the Tukey confidence test.

## RESULTS AND DISCUSSION

### Influence of Soil Amendment Practices and Irrigation Methods on Soil Moisture Content and Chemical Properties

The soil used for the experiment was classified as sandy loam with a bulk density of 1.42 g/cm$^3$ which is conducive for agricultural purposes (Amhakhian *et al.,* 2021). The estimated available moisture content recorded was 13 %, as field capacity was 21.9 % and wilting point was 8.9 %. The highest daily moisture content recorded was under cow dung amended soil with supplementary irrigation (28.20 %) whereas the soil no amendment under rainfed recorded the least soil moisture content of 1.50 % (Figure 3). Throughout most of the experimental duration, it's evident that soil moisture content under rainfed irrigation was beneath permanent wilting point compared to the supplementary irrigated soil moisture content. This could be due to the event of little to no rainfall over the experimental period, thereby influencing the evapotranspiration rates in the field. Variation in the soil moisture content may as well be due to the soil amendment practices and irrigation practices in the field as stated by Sedara *et al.,* (2021).

The total amount of precipitation during the experiment was 67.2 mm representing the depth of water applied under rainfed treatment. On the other hand, a total irrigation water depth of 291.3 mm was used under supplementary irrigation. This was 333.22 % more than the rainfed water depth and as such, implied its irrigation water deficit. The deficit recorded in rainfall could be ascribed to climate change, resulting in less rainfall within the year.

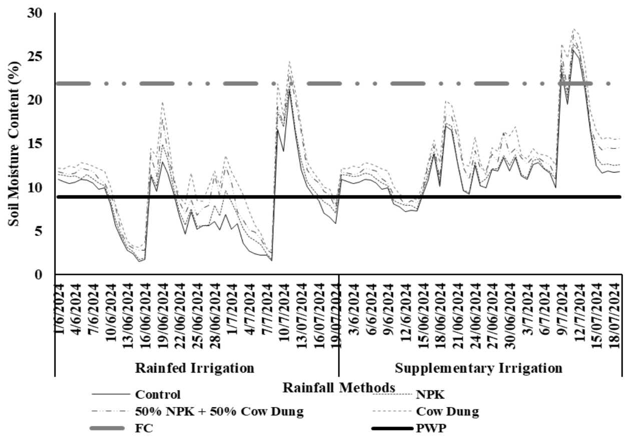


**Figure 3.** Soil Moisture Content as Influenced by the Interaction of Soil Amendments Practices and Irrigation Methods

Table 4 presents the status of soil pH, EC, phosphorus and nitrogen before and after the application of treatments. The level of soil pH was within the neutral level and optimal for plant growth. After the application of treatments, the soil pH increased (7.05) when soil was amended with 50% Cow Dung combined with 50% NPK under supplementary irrigated fields**.** Soil pH under the remaining treatments reduced to pH ranging between 6 to 5.56. While okra may grow in a variety of soil types, it thrives in soils with pH between 6.0 and 6.8. According to Brandenberger *et al.,* (2018) soils with pH at or below 5.8 can result in okra with poorly developed pods. The recorded electrical conductivity of the soil was 5.42 µS/cm prior to the experiment. After the experiment, average soil electrical conductivity across treatment plots further reduced, ranging between 0.2 to 0.7 µS/cm. This is however not conducive for okra production, as report by Abid et al. (2002) indicated that, vegetables like okra grow well in soil electrical conductivity ranging between 2.0 to 3.5 µs/cm. Similarly, the initial average phosphorus and nitrogen content of soil were 7.44 mg/l and 1100 mg/l respectively. After the application of treatments, there was a general reduction in soil phosphorus and nitrogen levels ranging from 1.43 – 0.1 mg/l and 1.89 – 0.3 mg/l respectively (Table 4).

**Table 4.** Influence of Soil Amendment Practices and Irrigation Methods on the Chemical Properties of Soil

| **Treatments** | **pH** | **EC (µS/cm)** | **Phosphate (mg/l)** | **Nitrogen (mg/l)** |
|---|---|---|---|---|
| Initial | 6.8 | 5.42 | 7.44 | 1100 |
| Rainfed + Zero Amendment | 5.82 | 0.4 | 0.12 | 0.44 |
| Rainfed + NPK | 5.57 | 0.6 | 1.43 | 0.3 |
| Rainfed + Cow Dung | 5.56 | 0.4 | 0.1 | 0.3 |
| Rainfed + 50% Cow Dung + 50% NPK | 6.1 | 0.7 | 0.1 | 1.89 |
| Supplementary Irrigation + Zero Amendment | 5.77 | 0.6 | 0.1 | 0.3 |
| Supplementary Irrigation + NPK | 6 | 0.4 | 0.1 | 0.3 |
| Supplementary Irrigation + Cow Dung | 5.65 | 0.3 | 0.1 | 0.3 |
| Supplementary Irrigation + 50% Cow Dung + 50% NPK | 7.05 | 0.2 | 0.1 | 0.43 |

## Combined Effect of Soil Amendment and Irrigation Methods on Growth Characteristics of Okra

Table 5 presents the combined effect of soil amendment practices and irrigation methods on growth characteristics of okra plant. The height of okra plant varied significantly ($p < 0.003$) with the interaction of soil amendment practices and irrigation methods. The interaction of supplementary irrigation and cow dung amended soil (74.13 cm) recorded the tallest okra plant and the shortest plant was recorded in plants treated with the combination of zero amended soil under rainfed (54.77 cm). Supplementary irrigated okra, treated with a combination of 50 % cow dung and 50 % NPK produced the highest stem girth (2.55 cm), leaf area index (2.81) and chlorophyl content (53.57). However, rainfed okra under zero soil amendment produced the least stem girth (1.57 cm), leaf area index (1.63) and chlorophyl content (48.9). The combination of irrigation methods and soil amendment practices significantly influenced stem girth, leaf area index and chlorophyl content at $P < 0.001$ and $P < 0.045$ respectively. The single factor, irrigation methods significantly influenced plant height, stem girth, chlorophyl content and leaf area index with supplementary irrigation recording the highest plant height (70.33 cm), stem girth (2.19 cm), chlorophyl content (52.64) and leaf area index (2.69). Similarly, there was a highly significant variation ($P < 0.001$) in plant height, stem girth, chlorophyl content and leaf area index as influenced by soil amendment practices. Soils treated with a combination of 50 % cow dung and 50 % NPK produced the highest plant height (67.42 cm), stem girth (2.29 cm), chlorophyl content (51.77) and leaf area index (2.44). There was however no significant variation in the leaf area index, plant height and chlorophyl content of okra plants treated with cow dung as well as the combination of 50 % cow dung and 50 % NPK.

**Table 5.** Combined Effect of Soil Amendment and Irrigation Methods on Growth Characteristics of Okra

| Treatments | Plant Height (cm) | Stem Girth (cm) | Chlorophyl Content | Leaf Area Index |
|---|---|---|---|---|
| Rainfed + Zero Amendment | 54.77bc | 1.57e | 48.9d | 1.63f |
| Rainfed + NPK | 60.77b | 1.73d | 49.23cd | 1.96e |
| Rainfed + Cow Dung | 60.33b | 1.67de | 50.04c | 2.29c |
| Rainfed + 50% Cow Dung + 50% NPK | 63.63b | 2.03c | 49.97c | 2.07d |
| Supplementary Irrigation + Zero Amendment | 64.67b | 1.94c | 51.08b | 2.55b |
| Supplementary Irrigation + NPK | 71.3a | 2.27b | 52.77a | 2.8a |
| Supplementary Irrigation + Cow Dung | 74.13a | 2c | 53.13a | 2.59b |
| Supplementary Irrigation + 50% Cow Dung + 50% NPK | 71.2a | 2.55a | 53.57a | 2.81a |
| Grand Mean | 65.1 | 1.97 | 51.09 | 2.34 |
| LSD | 5.646 | 0.149 | 0.933 | 0.04801 |
| C.V | 1.7 | 3.5 | 1.1 | 1.3 |
| Irrigation Method | 0.023 | 0.009 | 0.002 | <.001 |
| Soil Amendment | <.001 | <.001 | 0.001 | <.001 |
| Irrigation Method+ Soil Amendments | 0.003 | <.001 | 0.045 | <.001 |

Plants respond to water stress as in the rainfed method by closing their stomata, which then inhibits photosynthesis, thereby affecting its development (Boland *et al.,* 2000). Viets (1965), noted that deficit in irrigation water application implies deficiency in crop carbohydrate utilization, thereby decreasing fruit size. Under optimal soil moisture conditions as seen in the supplementary irrigation, a conducive nutrient environment is created, aiding the absorption of moisture and nutrients for plant physiological growth. Thus, supplementary irrigation resulted in 6.3%, 17.5%, 25.1%, 35.4% and 19.7% increase in chlorophyl content, plant height, stem girth, leaf area index and yield of okra respectively, relative to rainfed. Similarly, West *et al*. (2004), Owusu-Sekyere and Annan (2010), Babu *et al.,* (2015) and Willie *et al.*, (2016) affirmed that fruit weight, length, circumference and yield reduced with deficit irrigation, as it retards nutrient availability to plant. Inversely, water productivity of okra under rainfed irrigation method, was about 132 % more than supplementary irrigation.

**Crop Water Productivity and Yield Characteristics of Okra**

The yield characteristics and crop water productivity of okra as influenced by the interaction of soil amendment practices and irrigation methods was significant at $p < 0.001$ and $p < 0.012$ respectively (Table 6). There was no significant variation in yield of okra as affected by the interaction of soil amendment practices and irrigation methods. The combined application of 50 % cow dung with 50 % NPK to okra under supplementary irrigation recorded 14 and 41.4g as the highest number of fruits per plant and average fruit weight respectively. The least number of fruits per plant (9) and average fruit weight (12.5 g) was recorded under rainfed okra with zero soil amendment. The least yield was 15 t/Ha resulting from rainfed okra under zero amendment. The highest yield was recorded from okra treated with the combination of supplementary irrigation and cow dung (20.1 t/Ha) but didn't significantly vary from okra yield gotten from the combination of supplementary irrigation and 50 % cow dung with

50 % NPK (20 t/Ha). The highest crop water productivity was obtained from okra grown under rainfed and treated with 50 % cow dung and 50 % NPK (42.48 Kg/m$^3$). The least crop water productivity was obtained from okra grown under supplementary irrigation and treated with zero soil amendment (9.86 Kg/m$^3$). The number of fruits per plant, average fruit weight, yield and crop water productivity of okra production under rainfed conditions significantly varied from okra production under supplementary irrigation. Supplementary irrigated okra recorded the highest number of fruits per plant (13.01), average fruit weight (32.7 g) and yield (19.36 t/Ha), but recorded the least crop water productivity (15.24 Kg/m$^3$). Okra grown in zero amended soils recorded the least number of fruits per plant (10.41), average fruit weight (16.84 g), yield (16.75 t/Ha) and crop water productivity (18.01 Kg/m$^3$). Okra grown in 50 % cow dung and 50 % NPK amended soils recorded the highest number of fruits per plant (13.35), average fruit weight (30.85 g), yield (18.84 t/Ha) and crop water productivity (30.89 Kg/m$^3$). Thus, there was a significantly high ($P < 0.001$) variation in the number of fruits per plant, average fruit weight, yield and crop water productivity as affected by soil amendment practices.

According to Davenport, (1994), stress (nutrient, water, temperature, light, etc.) in vegetable production, affect yield quality and quantity. Similar to results in Figure 3, soil amendment practices or nutrient source have variable impact on soil moisture retention, thereby affecting growth characteristics and yield of okra (Shaaban, 2006). The average soil moisture content as influenced by soil amendment practices, ranked as cow dung (12.9 %) > 50 % cow dung + 50 % NPK (11.9 %) > NPK (10.8 %) > zero soil amendment (10.1 %). This contributed to the 12.5 % and 71.5 % variation in yield and crop water productivity of okra respectively resulting from the soil amendment practice combining of 50 % cow dung and 50 % NPK and zero amendment practice. This variation could as well be due to the dual advantage of water retention properties and readily available nutrients in the 50 % cow dung and 50 % NPK amended soil, compared to the other treatments. In similar reports by El-Kader *et al.,* (2010) and Embiowei and Emiri (2017) results showed that the interaction of irrigation levels and organic manure statistically affected plant height, stem diameter, leaf area index and yield of okra.

**Table 6.** Combined Effect of Soil Amendment and Irrigation Methods on Yield Characteristics and Water Productivity of Okra

| Treatments | No. of Fruits per Plant | Avg. Fruit Weight (g) | Yield (t/Ha) | Crop Water Productivity (Kg/m$^3$) |
|---|---|---|---|---|
| Rainfed + Zero Amendment | 9g | 12.5e | 15 | 26.16 c |
| Rainfed + NPK | 10.2f | 15.2d | 15.67 | 31.8 b |
| Rainfed + Cow Dung | 11e | 19.6c | 16.33 | 41.04 a |
| Rainfed + 50% Cow Dung + 50% NPK | 12.7c | 20.3c | 17.67 | 42.48 a |
| Supplementary Irrigation + Zero Amendment | 11.83d | 21.17c | 18.5 | 9.86 f |
| Supplementary Irrigation + NPK | 13c | 28.3b | 18.83 | 13.19 e |
| Supplementary Irrigation + Cow Dung | 13.53b | 39.93a | 20.1 | 18.62 d |
| Supplementary Irrigation + 50% Cow Dung + 50% NPK | 14a | 41.4a | 20 | 19.3 d |
| Grand Mean | 11.908 | 24.8 | 17.76 | 25.31 |
| LSD | 0.4292 | 1.75 | 1.311 | 3.089 |
| C.V | 2 | 3.5 | 2.8 | 6.6 |
| Irrigation Method | 0.002 | <.001 | 0.015 | 0.001 |
| Soil Amendment | <.001 | <.001 | <.001 | <.001 |
| Irrigation Method + Soil Amendment | <.001 | <.001 | 0.123 | 0.012 |

## CONCLUSION

The irregular rainfall coupled with soil health challenges leading to water stress challenges, hinder crop and water productivity. The objective of this study was to evaluate the effect of irrigation methods and soil amendment practices on soil chemical characteristics, moisture content, growth, yield and water productivity of okra during the production season. Generally, there was a sharp decrease in the soil pH, EC, nitrogen and phosphorus content after the experiment indicating the use of soil nutrients by plants under each treatment. The average soil moisture content as influenced by soil amendment practices, ranked as cow dung (12.9 %) > 50 % cow dung + 50 % NPK (11.9 %) > NPK (10.8 %) > zero soil amendment (10.1 %). Supplementary irrigated okra had 6.3%, 17.5%, 25.1%, 35.4% and 19.7% increase in chlorophyl content, plant height, stem girth, leaf area index and yield of okra than rainfed okra. Supplementary irrigated okra combined with cow dung treated soils (20.1 t/ha) as well as soil treated with 50 % cow dung and 50 % NPK (20 t/ha) recorded the best yield and is recommended for farmers for better economic value and soil water retention, towards soil health.

**ACKNOWLEDGEMENT**

This publication was made possible through support provided by the West African Centre for Water, Irrigation and Sustainable Agriculture (WACWISA), University for Development Studies, Ghana, with funding support from the Government of Ghana and the World Bank through the African Centres of Excellence for Development Impact (ACE Impact) initiative with Grant No. IDA Credit 6389.

**CONFLICT OF INTEREST**

The authors have declared no conflict of interest regarding the publication of the paper.

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