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The Effect of Deficit Irrigation and Manure on Soil Properties, Growth and Yield of Orange Fleshed Sweet Potato [Ipomea Batatas Lam]

Dukuh Isaac Gibberson[1], Owusu-Sekyere Joshua, Bart-Plange Ato[3], Okyere Justice[4], Asagadunga Akidiwe Paul[5]
[1]Department of Agricultural Engineering, Bolgatanga Polytechnic, Post Office Box 767, Bolgatanga, Ghana
[2]Department of Agricultural Engineering, University of Cape Coast, University Post Office, Cape Coast, Ghana
[3]Department of Agricultural Engineering, Kwame Nkrumah University of Science and Technology, University Post Office, Kumasi, Ghana
[4]Department of Agricultural Engineering, Wa Polytechnic, Post Office Box 767, Bolgatanga
[5]Department of Agricultural Engineering, Bolgatanga Polytechnic, Post Office Box 767, Bolgatanga, Ghana

***Corresponding Author**
Name: Isaac Gibberson Dukuh
Email: isaacgdukuh@yahoo.co.uk

Abstract: The study was conducted at University of Cape Coast Research Farm, Cape Coast, Ghana from September, 2014 to April, 2015. The objective of the research was to investigate the effects of irrigation levels, chicken manure, cow dung, NPK and interactions on the: growth and yield of OFSP. Sixteen treatments (four levels of irrigation and four soil amendments) with three replicates were laid out in a Randomized Complete Block Design (RCBD). Irrigation did not influence significantly soil physical properties studied; Bulk density, Pore volume and Particle density. Water stress (DI, 70% CWR) increased tuber yield and water use efficiency (WUE) as compared to 100% CWR while growth of leaves and branches were reduced. PM + 70 % CWR produced the highest tuber yield (10.56 kg m^{-3}) as compared to PM + 100 % CWR (4.87 kg m^{-3}), PM + 90 % CWR (6.21 kg m^{-3}) and PM + 80 % CWR (6.51 kg m^{-3}). Deficit irrigation reduced vine yield. Soil amendment improved significantly tuber yield better under reduced irrigation (70% CWR) conditions than under full irrigation.
Keywords: Crop Water Requirement, Cow dung, Deficit Irrigation, Growth and Yield, NPK, Orange Fleshed Sweet Potato, Poultry Manure, Water Use Efficiency

INTRODUCTION

Orange-fleshed sweet potatoes can be a very suitable crop for combating vitamin A deficiency in humans and it is becoming an important crop among the vulnerable in Ghana though its utilization have been neglected for a long time [1]. In Ghana sweet potato is becoming an important export crop in the Bawku East District of the Upper East Region where farmers export the crop to neighbouring Burkina Faso, where they obtain good prices for the crop [2]. However the production of sweet potato is going down despite its nutritional and economic value. Average yield of 5 tons ha^{-1} is low as compared to 14 tons ha^{-1} in China and other developing regions of Asia. The reduction in production can be attributed to poor soil nutrient status, crop removal, rapid mineralization of soil organic matter and rapid growth in population leading to excessive cultivation of land [3]. The causes of low yields can also be attributed to poor agronomic practices. There is therefore the need to reinvigorate over cultivated soils and improve the physical and chemical conditions of the soil. It has been stated that the application of fertilizers is one of the most important ways of increasing the productivity of crops [4]. Depending on the fertility status of the soil, fertilizer may increase the yield of sweet potato by 32-83 %. Manure is an age-old source of fertilizer which modifies soil physical and chemical properties and releases nutrients for a longer period of time. In recent years the use of organic manures as fertilizers has increased tremendously as a result of serious environmental pollution [5] caused by the use of agro-chemicals. To achieve efficient use of animal manure there is the need to thoroughly understand crop responses and availability of nutrients supplied by manure and also compares different types of animal manures under similar field conditions.

Though sweet potato is generally considered as a drought tolerant crop, Nedunchezhiyan *et al.;* [6] showed leaf area reduction in sweet potato plants as water stress increased and some cultivar exhibited yield reduction under deficit irrigation [7]. Globally drought is problem that inhibits the growth of plants and leads to yield reduction. However there is greater demand for more food, more raw materials, more water, higher energy consumption, etc. as world population is estimated to exceed 8.2 billion people. As food requirements increase and water resources decrease, it becomes more and more important to make the best of both rain fed and irrigated crop production. A worldwide shortage of freshwater resources and more frequent and severe drought due to climate change has stimulated research into water-saving irrigation strategies aimed at producing more crops. It has become essential to enhance crop water use efficiency to increase crop productivity while sustaining the environment. Therefore research into the combined effect of manure and water stress on growth and yield is considered essential toward meeting food security.

Though many works have been conducted on the effect of organic manure, chemical fertilizer and deficit irrigation (DI) on different crops, little information is available on the combined effect of DI, CD, PM and NPK (15:15:15) fertilizer on soil properties, nutrient removal, growth and yield of sweet potato. Farmers in the study area do not know the combined effect of manure, inorganic fertilizers, (NPK) and water stress for production of the crop. Therefore, a systematic investigation into the combined effect of using locally available, accessible and affordable farmyard manure (cow dung & poultry manure), NPK and irrigation is of paramount importance for increasing yield of sweet potato.

To address those problems, the study was initiated with the objective of evaluating the effect of poultry manure, cow dung, NPK and Irrigation at different levels on soil chemical and physical properties, water use efficiency, growth and yield of sweet potato in the coastal savanna zone of Ghana.

MATERIALS AND METHODS

A field experiment was conducted between October, 2014 and January, 2015 planting season at the Teaching and Research Farm of University of Cape Coast in the Central Region of Ghana. Cape Coast is located on latitude 5.06° N and longitude 5° W with altitude of 31 m above sea level. The research site is characterized by two rainy seasons, relatively high temperatures humidity throughout the year. The major rainy season starts from March to July and the minor rainy commences from September to October. Maximum temperature is between 30 ^{o}C to 36 ^{o}C while minimum temperatures range between 22 ^{o}C to 26 ^{o}C [8]. February and March are the hottest months, while June and August are the coolest months. Natural vegetation is coastal savanna [9] consisting of shrubs, grasses and a few scattered trees. The soil at the research site is sandy loam in texture, slightly acid in reaction (pH 5.8), low in nitrogen and potassium contents but marginal in available phosphorus.

Irrigation water quality was analysed. Major cations such as, Ca, P, NO_3 Fe, Cu and Zn. Ca and NO_3 were determined by titration and P by Flame photometer. Fe, Zn and Cu were analysed by Atomic Absorption Spectrometer. Electrical conductivity (EC) was determined by using electrical conductivity meter and pH meter was used to determine pH.

Soil samples of one augar per plot from each of the experimental plots were collected after application of the treatments and at the end of the study. The samples were air-dried, ground and passed through 2 mm-mesh sieve and used for laboratory analysis.

The web based International Plant Nutrition Institute (2015) [10] Crop Nutrient Removal Calculator was used to estimate removal of nitrogen, phosphorus and potassium. The calculator estimates crop nutrient removal of nitrogen (N), phosphorus (expressed as P_2O_5), potassium (expressed as K_2O), and sulfur (S) for a broad, and continually expanding, list of field crops.

Experimental Design:

There were 16 treatments which consisted of four levels of irrigation; 100%, 90%, 80%, 70% Crop Water Requirement (CWR), four types of fertilizer, Poultry manure (PM), Cow dung (CD), NPK 15:15:15 and No Fertilizer (Control). The OFSP variety was used for the study. The sixteen treatments were 100% CWR + PM, 90% CWR + PM, 80% CWR + PM, 70% CWR + PM, 100% CWR + CD, 90% CWR + CD, 80% CWR + CD, 70% CWR + CD, 100% CWR + NPK, 90% CWR + NPK, 80% CWR + NPK, 70% CWR + NPK, 100% CWR + Control, 90% CWR + Control, 80% CWR + Control and 70% CWR + Control. The experiment was laid out as a Randomized Complete Block Design in a factorial arrangement with three replications. Rain shelter was erected over the plots to prevent any form of precipitation on the plots. The rain shelter consisted of galvanized steel metal frame roofed with transparent water proof plastic sheet which transmitted solar radiation but kept precipitation off the plot.

Each plot measured 3m by 1m and planting distance was 30cm between plants and 70cm between rows. There were 20 plants per plot and a total of 960 plants was the research population. A sampled of 10 plants per plot was selected for growth and yield related data.

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 ET_o and estimated K_c. Estimated K_c of sweet potato was obtained from FAO 56 [11] at the four growth stages and ET_c (crop water requirement) was calculated using the equation:

$$\mathbf{ET_c = ET_o \times K_c}$$

Where, ET_c is the crop evapotranspiration (mm per day), K_c is the crop coefficient (dimensionless) and ET_o is reference crop evapotranspiration (mm per day).

Crop planting and cultural practices:

Vines were planted on 10th October, 2014, at 30cm between plants and 70 cm between rows. Poultry manure (10 tons ha^{-1}) and Cow dung (20 tons ha^{-1}) were applied 2 weeks before planting the vines and NPK 15:15:15 (900 kg ha^{-1}) was applied a week after planting.

Crop data:

In each experimental plot, five plants were tagged for measurement of number of leaves, number of branches and leaf area from 3 weeks after planting to mid-season stage. Three weeks after planting, the number of leaves on tagged plants was counted and the average calculated weekly. Similarly the number of branches per plant was counted three weeks after planting. Leaf area was determined by tracing sampled leaves from five plants on graphs and area determined.

Harvesting and curing:

Harvesting was done by first cutting vines. Cut vines were rolled to the side of the plot and weighed. Tubers were pulled up with the hand and what was left in the soil was dug up with a hoe carefully to reduce damage to tubers. Tubers weighing 100g and above from 10 sampled plants per plot were considered and weighed. Harvested root tubers were cured bulked and stored in three types of evaporative storage structures. Tubers were cured at a temperature of 29-32 °C and relative humidity of 85-90 % for 4 days. Curing is a standard procedure which helps wound healing [12]. It prevents entry of pathogens through the wounds and thereby protects the roots against deterioration in storage.

Data collected

The following data were collected:

Climatic data for calculation of ET_o was obtained from Meteorological Agency of Ghana.

Chemical and physical properties of irrigation water quality were analyzed by Flame photometer, Atomic Absorption Spectrometer, Electric Conductivity meter and by titration. Estimation of soil nutrient removal by crop was by the web based International Plant Nutrition Institute (2015) Crop Nutrient Removal Calculator was used to estimate removal of nitrogen, phosphorus and potassium. Soil samples were air-dried, ground and passed through 2 mm-mesh sieve and used for laboratory analysis; Flame photometer, Atomic Absorption Spectrometer and titration were employed to determine soil chemical properties. Crop water use efficiency was computed using equation 1:

$$Crop\ water\ use\ efficiency\ (WUE) = \frac{\text{tuber yield (kg } ha^{-1})}{\text{water applied } (m^3\ ha^{-1})} \qquad 1$$

Five non-border plants from each treatment plot were randomly sampled and the number of branches per plant was counted at the third, fourth and fifth weeks.

Five non-border plants from each treatment plot were randomly sampled and the number of leaves per plant was counted at the third, fourth and fifth weeks.

Leaves from sampled five plants were traced on graphs and area determined to determine leaf area. Leaf Area Index was determined by equation 2:

$$Leaf\ Area\ Index\ (LAI) = \frac{Leaf\ area\ (Sampled\ plants)}{Area\ occupied\ by\ sampled\ plants} \qquad 2$$

Tuber yield was determined by weighing tubers 100g and above from 10 sampled plants. Total yield per plot was determined by multiplying the total number of plants per plot (20) by the yield per plant. The yield per plot was projected to per hectare basis. Vine yield was determined by weighing vines from 10 sampled plants and vine yield per plot was projected to per hectare basis. Total yield was determined as total tuber yield plus total vine yield per plot projected to per hectare basis.

DATA ANALYSIS

All data were subjected to analysis of variance using Gen-stat Discovery software version 4.0. For treatments that were significant, mean separation was done using the Least Significant Difference (LSD) test at 5 % probability level.

RESULTS AND DISCUSSION

The result of the quality of the irrigation water is shown Table 1. The pH was 6.5 which is suitable for the growth of sweet potato.

Table 1: Chemical and physical properties of irrigation water

Properties of water	Values
pH	6.5
Ca	2.4 mg l^{-1}
NO_3^-	1.5 mg l^{-1}
P	0.36 mg l^{-1}
Fe	3.95 mg l^{-1}
Zn	1.1 mg l^{-1}
Cu	0.03 mg l^{-1}
EC	0.01 ms

Source: Data (2015)

The effect of Cow dung, Poultry manure, NPK and level of irrigation water on soil chemical and physical properties before planting

The results of the initial soil physical and chemical properties studied are shown in Table 2. Reduced level of water application (DI) resulted in numerical increases in some parameters while it resulted in decreases in other parameters. Bulk density and particle density were highest, 1.52 g cm^{-3} and 2.47 respectively at 70 % crop water requirement (70 % CWR) as compared to 1.47 g cm^{-1} and 2.45 respectively at 100 % CWR (Table 2). CD increased potassium by 141.5 % (From 0.41 cmol kg^{-1} to 0.99 cmol kg^{-1}) while NPK and PM increased potassium by 31.7 % and 29.3 % respectively as compared to the control. However PM, NPK and CD increased P by 170.2 %, 168.0 % and 57.7 % respectively (From 24.19 µg g^{-1} to 65.37 µg g^{-1}, 64.84 µg g^{-1} and 38.15 µg g^{-1} respectively) as shown in Table 2. Application of PM resulted in the highest increase in available P. Nitrogen content of the soil was increased by 27.3 %, 18.2 % and 9.1 % by CD, PM and NPK respectively. NPK increased N from 0.11 % to 0.12 % which was lowest.

Table 2: Initial Soil chemical and physical properties as influenced by the application of CD, PM, NPK and level of irrigation

Treatments	Soil Properties							
Irr. % ETc	% N	P µg g^{-1}	K cmol kg^{-1}	Ca cmol kg^{-1}	Mg cmol kg^{-1}	B D g cm^{-3}	Pore vol. %	Part Den
70	0.12	53.37	0.55	3.02	2.30	1.52	38.50	2.47
80	0.12	44.41	0.62	2.84	1.65	1.50	38.0	2.41
90	0.13	50.36	0.62	3.10	1.69	1.47	40.0	2.46
100	0.13	44.42	0.67	3.43	1.47	1.47	40.50	2.45
Manure/Fertilizer								
Control	0.11	24.19	0.41	2.36	1.46	1.47	39.50	2.43
NPK	0.12	64.84	0.54	2.94	1.40	1.52	38.50	2.46
CD	0.14	38.15	0.99	2.57	1.53	1.48	39.50	2.44
PM	0.13	65.37	0.53	4.51	2.73	1.49	39.50	2.46

Source: Data (2015)

This could be attributed to rapid release of nutrients from NPK which could lead to leaching of nutrients. Rapid release and leaching of nutrients from soil treated with NPK could also be responsible for reduction of nitrogen from 0.12 % to 0.0925 % after harvest (Table 3) representing 22.9 % reduction. This could be attributed to higher nitrogen removal (199.9 Kg ha^{-1}) from plots treated with PM.

Table 3 shows the effect of CD, PM, NPK and irrigation level on soil chemical and physical properties after harvest**.** The results indicate that soil chemical properties and some physical properties studied were significantly responsive to CD, PM and NPK application. This is consistent with findings by Agbede *et al.;* [13], Mbah and Mbagwu [14], Adeniyan and Ojeniyi [15], and Ewulo *et al.;* [16] who found that PM and CD increased soil OM, N, P, K, Ca and Mg significantly. Bulk density was however not responsive to all of the soil amendments contrary to findings by Agyenim Boateng *et al.;* [17] and Obi and Ebo [18] poultry manure increased soil moisture content and reduced bulk density of the soil. This contrary finding could be due to insufficient accumulation of organic matter after only one year of application of PM and CD.

Table 3: The effect of CD, PM, NPK and Irrigation on soil chemical and physical properties after harvest

Treatments	Soil Properties							
Irr. % ETc	% N	P µg g^{-1}	K cmol kg^{-1}	Ca cmol kg^{-1}	Mg cmol kg^{-1}	B D g cm^{-1}	Pore vol. %	Part Den
70	0.110	17.63	0.464	2.205	1.45	1.477	40.25	2.4725
80	0.108	23.96	0.456	1.794	1.73	1.507	38.25	2.436a
90	0.103	19.19	0.482	2.124	1.61	1.490	39.00	2.4438
100	0.104	19.04	0.527	2.039	1.58	1.510	38.25	2.4487
F-test	NS	*	NS	NS	NS	NS	*	NS
Lsd	0.0095	5.837	0.0808	0.445	0.67	0.0259	1.399	0.0548
CV	8.4	27.4	15.7	20.5	39.5	1.6	3.4	2.1
Manure/Fertilizer								
Control	0.1013	5.33	0.314	1.900	1.77	1.4863	37.75	2.3887
NPK	0.0925	28.00	0.467	1.555	1.07	1.5138	39.00	2.4838
CD	0.1288	15.77	0.721	1.974	2.10	1.4900	39.00	2.4450
PM	0.1025	30.72	0.427	2.732	1.44	1.4950	40.00	2.4837
T-test	**	**	**	**	*	NS	*	**
Lsd	0.00953	5.837	0.0808	0.445	0.67	0.0259	1.399	0.0548
CV	8.4	27.4	15.7	20.5	39.5	1.6	3.4	2.1

Source: Data (2015). Where NS = non-significant at $p<0.05$ and ** = highly significant at $p<0.01$ probability level; CV = coefficient of variation; LSD = Least Significant Difference between means.

With the exception of phosphorus (P) and percentage pore volume none of the soil chemical and physical properties were responsive to different levels of irrigation. Available phosphorus was lowest at 70 % CWR and this can be attributed to high estimated crop removal of phosphorus (35.1 Kg ha^{-1}) as shown in Table 4. Soil irrigated with 70 % CWR was the most porous with 40 % pore space which facilitate infiltration of moisture and air.

Table 4: Nutrient removal by crop (Estimated)

Treatments	Soil nutrients (Kg ha^{-1})		
DI	N	P	K
70	182.0	35.1	290.5
80	158.0	30.5	252.2
90	174.0	33.6	277.7
100	172.1	33.2	274.6
Manure/NPK			
PM	199.9	38.5	319.9
CD	172.8	33.3	275.9
NPK	163.8	31.5	261.0
Control	143.8	27.7	229.6

Source: Data 2015

The Effect of Irrigation, CD, PM and NPK on growth parameters of sweet potato

Sweet potato number of leaves per plant and number of branches per plant at crop development stage were not responsive to all treatments as shown in Table 5. The interaction of manure, NPK and irrigation also had no significant effect on the number of branches and leafs per plant. Abdissa *et al.;* [19] and Lynch, & Rowberry [20] reported similarly in other studies that stem number is determined very early in the growth and development of plant.

Table 5: Main effects of irrigation and manure on the number of branch per plant and number of leaves per plant of sweet potato at Cape Coast during the 2014 minor cropping season

Treatments			
Irr. % ETc	No. of leaves/plant Crop dev'pt stage	No. of leaves/plant Mid-season stage	No. branches/plant Crop dev'pt stage
70	15.88	23.01	2.18
80	17.03	27.22	2.58
90	14.17	22.03	2.57
100	15.03	23.84	2.22
F-test	NS	NS	NS
LSD	4.313	4.381	0.99
Manure			
PM	15.18	23.30	2.53
CD	16.63	27.15	2.28
NPK	12.84	19.49	2.50
Control	17.45	26.17	2.23
F-test	NS	**	NS
LSD	4.313	4.381	0.99

Source: Data 2015. Where NS = non-significant at p<0.05 and ** = highly significant at p<0.01 LSD = Least Significant Difference between means.

Peter & Huska [21] also explained that potato average number of stem per plant is more dependent on the inherent potential of the cultivar rather than on application of inputs such as fertilizers. However, at the mid-season stage sweet potato leaves per plant was significantly (p<0.01) responsive to CD, PM and NPK (Table 5) but not responsive to levels of irrigation or deficit irrigation (DI). Hilaru *et al.;* [22] and El-Glamry [23] reported similar findings that vegetative growth parameters of sweet potato tend to increase with increasing application of mineral fertilizer and different forms of organic manure. Cow dung (CD) treatment produced the highest number of leaves per plant, 27 while NPK produced the lowest number of leaves (19) as shown in Table 5. The rank order of number of leaves per plant was CD (27) > Control (26.17) > PM (23.30) > NPK (19.49).

Manure and DI interaction significantly affected number of leaves per plant as shown in Figure 1. Cow dung and 80 % ET_c (80 % CWR) interaction produced the highest number of leaves per plant 39, while NPK and full irrigation (100 % CWR) produced the least number of leaves per plant (17) at mid-season stage as shown in Figure1. For PM and DI treatments, reduced irrigation decreased leaf numbers (Table 5).

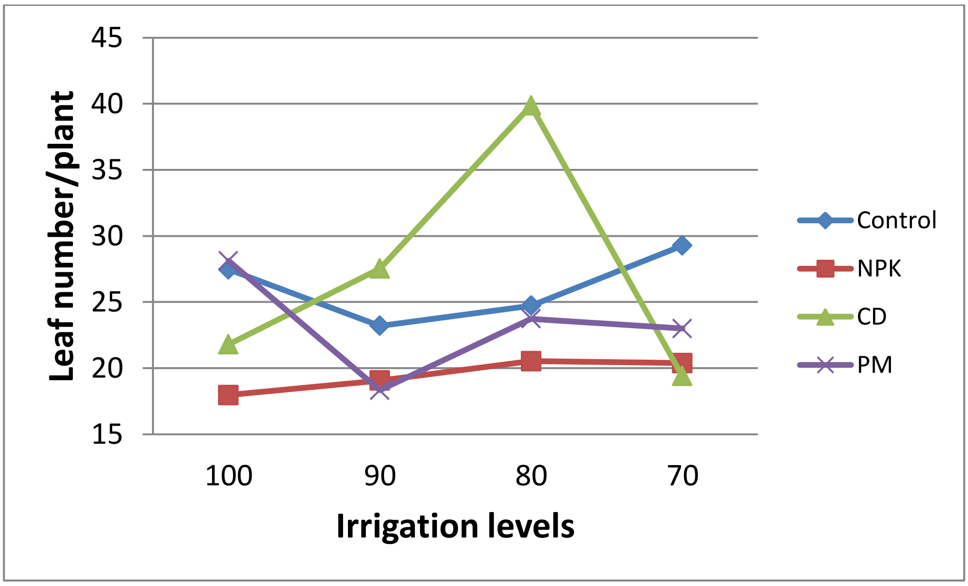

Fig 1: Number of leaves per plant at mid-season stage of sweet potato as influenced by CD, PM, NPK and DI at Cape Coast during the 2014 minor cropping season [F-test ** Lsd 8.763]

Table 6 shows that leaf area at 3, 4 and 5 weeks after planting were not significantly affected by deficit irrigation (DI), CD, PM and NPK. However application of 100 % CWR resulted in highest leaf area 74.0cm^2, 115.9cm^2 and 125.5cm^2 at 3, 4 and 5 weeks respectively after planting (Table 6). DI 70 % CWR produced leaf area 70.9cm^2, 113.4cm^2 and 120.2cm^2 at 3, 4 and 5 weeks respectively after planting. Thus DI reduces leaf area of sweat potato which is corroborated by findings by Sarawasti *et al.;* [24] who observed that stem length, diameter and length, leaf area and number decreased in response to drought stress. This observation is further corroborated by Nedunchezhiyan *et al.;* who showed that leaf area in sweet potato plants decreases as water stress increases. The reduction in leaf area and number could be attributed to changes in chlorophyll, reducing net CO_2 uptake by leaves resulting in reduction in photosynthetic ability of plant [25].

Table 6: Leaf Area of sweet potato plant as influenced by CD, PM, NPK and Irrigation

Treatments	Leaf Area (cm^2) Weeks after Planting		
DI(% CWR)	3	4	5
70	70.9	113.4	120.2
80	79.9	110.9	110.9
90	67.5	111.7	116.2
100	74.0	115.9	125.5
F-test	NS	NS	NS
Lsd	13.84	7.35	15.72
CV	22.7	7.8	16.0
Manure/Fertilizer			
Control	72.4	109.4	112.8
NPK	74.8	119.4	123.9
CD	75.4	112.1	121.8
PM	69.6	111.0	114.2
T-test	NS	NS	NS
Lsd	13.84	7.35	15.72
CV	22.7	7.8	16.0

Source: Data 2015. Where ** = highly significant at p<0.01 probability level; CV = coefficient of variation; LSD = Least Significant Difference between means.

At the mid-season stage however, the interaction of irrigation and soil amendments significantly affected leaf area as shown in Table 7. Interaction of NPK and 70 % CWR (DI 70) produced the highest leaf area, 134.6 cm^2 per plot while PM and 70 CWR interaction produced the lowest leaf area, 90.3 cm^2 per lot at the mid-season stage. For PM and CD treatments, increased DI reduced leaf area (Table 7).

Similar to leaf area, leaf area index at 3, 4 and 5 weeks after planting were not significantly affected by level of irrigation, CD, PM and NPK (Table 8).

Table 7: Interaction effect of CD, PM, NPK and irrigation on Leaf Area at mid-season stage at Cape Coast during the 2014 minor cropping season

Leaf Area at mid-season stage (cm^2)				
Treatments	Manure/Fertilizer			
Irr. % CWR	Control	NPK	CD	PM
70	118.6	134.6	110.2	90.3
80	109.0	114.6	108.9	111.1
90	113.7	107.4	113.3	112.2
100	96.3	121.0	115.9	130.3
F-test	**			
LSD	14.69			
CV (%)	7.8			

Source: Data 2015. Where ** = highly significant at p<0.01 probability level; CV = coefficient of variation; LSD = Least Significant Difference between means.

.

Table 8: Leaf Area Index of sweet potato plant as influenced by CD, PM, NPK and DI

Treatments	Weeks after Planting		
Irr. % CWR	3	4	5
70	0.426	0.674	0.996
80	0.465	0.667	0.942
90	0.331	0.568	0.841
100	0.418	0.682	1.028
F-test	NS	NS	NS
Lsd	0.1975	0.2971	0.3728
CV	57.8	45.9	39.2
Manure/Fertilizer			
Control	0.440	0.671	0.941
NPK	0.412	0.678	0.958
CD	0.428	0.638	1.012
PM	0.359	0.604	0.895
T-test	NS	NS	NS
Lsd	0.1975	0.2971	0.3728
CV	57.8	45.9	39.2

Source: Data 2015. Where NS = Non-significant at p<0.05; LSD = Least Significant Difference between means

The Effect of DI, CD, PM and NPK on yield parameters of sweet potato

Water stress (DI) did not significantly influence vine yield and total yield (Table 9). However, 100 % ET_c (CWR) resulted in the highest vine yield, 20.25 tons ha^{-1}. The rank order of vine yield was 100 % CWR (20.25) > 90 % CWR (19.96) > 80 % CWR (19.16) > 70 % CWR (17.88). Thus irrigation reduced growth of leaves and branches. This could be as a result of osmotic stress created by water deficit which causes water to be removed from the cytoplasm of cells thus inhibiting the growth of leaves and stems of plants Placide *et al.;* [26] Conversely irrigation at 70 % CWR resulted in the highest total yield (33.83 tons ha^{-1}) while 100 % ET_c produced the lowest total yield (33.09 tons ha^{-1}).

Table 9: Main effects of DI, CD, PM and NPK on vine yield, tuber yield and total yield of OFSP at Cape Coast during the 2014 minor cropping season.

Treatments			
Irr. % CWR	Tuber Yield tons ha^{-1}	Vine Yield tons ha^{-1}	Total Yield tons ha^{-1}
70	15.95	17.88	33.83
80	11.23	19.16	30.39
90	13.50	19.96	33.46
100	12.84	20.25	33.09
F-test	**	NS	NS
LSD	1.672	3.887	5.492
CV (%)	15.0	24.1	19.5
Manure/Fertilizer			
PM	15.85	22.59	38.44
CD	13.35	19.89	33.24
NPK	12.82	18.62	31.44
Control	11.50	16.16	27.66
F-test	**	*	**
LSD	1.672	3.887	5.492
CV (%)	15.0	24.1	19.5

Source: Data 2015. Where NS = non-significant, ** = highly significant at p<0.01 and * = significant at p<0.05 probability; LSD = Least Significant Difference between means

Tuber yield of OFSP was significantly influenced by DI (Table 9). Irrigation at 70 % CWR produced the highest yield (15.95 tons ha^{-1}) as compared to 12.84 tons ha^{-1} at 100 % CWR. This could be beneficial in the sense that lower application of water saves water for other uses. Lewthwaite and Triggs [27] made similar observation that sweet potato produced higher yield of good quality roots under water stress. This unique characteristic of drought tolerance of OFSP that enabled positive response to water stress can be attributed to the big root surface that allows easy access to available soil water [28]. Additionally sweet potato is very rich in antioxidants which scavenge reactive oxygen species (ROS) which are the major cause of reduction of photosynthesis ability and growth under drought stress [29]. Accumulation of organic metabolites in sweet potato [29] help cells to retain water without disturbing normal cell function during water stress.

The interaction of irrigation and manure significantly influenced tuber yield (Table 10). NPK + 70 % CWR, PM + 70 % CWR and control + 70 % CWR treatments produced the highest tuber yield in NPK, PM and Control treatments. PM and 70 % CWR interaction produced the highest tuber yield of 20.3 tons ha^{-1}. For plots treated with CD reduced irrigation (DI) decreased tuber yield. It could be attributed to too much sodium (from CD) for the healthy growth of crop under water stress conditions. The rank order of tuber yield was CD + 100 % CWR (15.05) > CD + 90 % CWR (13.01) > CD + 80 % CWR (12.95) > CD + 70 % CWR (12.38). PM + 100 % CWR produced 13.38 tons ha^{-1} which was 18.4 % higher, compared to Control + 100 % CWR (11.30) as shown in Table 10. The result is in agreement with findings by Hirich *et al.;* [30] who indicated that organic amendment increased pea seed yield by 41 % under water stress and by 25 % under full irrigation. Thus it can be concluded that soil organic amendment improved significantly yield better under deficit irrigation conditions than under full irrigation.

Table 10: Interaction effect of CD, PM, NPK and Irrigation on tuber yield per hectare of sweet potato at Cape Coast during the 2014 minor cropping season.

Tuber Yield per hectare (Tons ha^{-1})				
Treatments	Manure/Fertilizer			
DI % ETc	Control	NPK	CD	PM
70	16.29	14.84	12.38	20.30
80	7.89	10.43	12.95	13.66
90	10.53	14.37	13.01	16.07
100	11.30	11.64	15.05	13.38
F-test	**			
LSD	3.344			
CV (%)	15.0			

Source: Data 2015. Where ** = highly significant at p<0.01 probability level; CV = coefficient of variation; LSD = Least Significant Difference between means

Conversely, for PM treated plots differences in yield were significant and highest at 70 % ET_c, and lowest at 100 % ET_c (Table 11). Thus amending the soil with PM improved significantly yield better under reduced irrigation conditions than under full irrigation.

The water use efficiency (WUE) or crop water productivity (WP) took the same trend of root tuber yield. DI increased water use efficiency (WUE) as shown in Table 11. PM + 70 % CWR produced the highest tuber yield (10.56 kg m^{-3}) as compared to PM + 100 % CWR (4.87 kg m^{-3}), PM + 90 % CWR (6.21 kg m^{-3}) and PM + 80 % CWR (6.51 kg m^{-3}). Water use efficiency (WUE) by crops on the amended plots was highest at DI 70 % CWR as shown in Table 11. The WUE values were 12.1 kg m^{-3} for PM + 70 % CWR, 7.4 kg m^{-3} for CD + 70 % CWR, 8.8 kg m^{-3} for NPK + 70 % CWR and 9.7 kg m^{-3} for Contorl + 70 % CWR. The lowest WUE values were by application of full irrigation (100 % CWR) and all the soil amendments. Thus water stress (DI) resulted in the highest WUE whilst full irrigation resulted in the lowest WUE. WUE differences were highly significant (Table 11). Zwart and Bastiaansen [31] and Fan *et al.;* [32] reported similar observations indicating that WP or WUE increases under DI, relative to its value under full irrigation for many crops. Under DI the level of water application is relatively low and water losses are lower thus, under DI WP or WUE is higher than that under full irrigation [33].

Table 11: The effect of CD, PM, NPK and Irrigation on yield and water use efficiency of OFSP.

Manure/ Fertilizer	Irr (% ET_c)	Water applied m^{-3}	Yield (tons ha^{-1})	WUE (kg m^{-3})
PM	70	1922.2	20.30	10.56
	80	2196.8	13.66	6.21
	90	2471.4	16.07	6.50
	100	2746	13.38	4.87
CD	70	1922.2	12.38	6.44
	80	2196.8	12.95	5.89
	90	2471.4	13.01	5.26
	100	2746	15.05	5.48
NPK	70	1922.2	14.84	7.72
	80	2196.8	10.43	4.74
	90	2471.4	14.37	5.81
	100	2746	11.64	4.23
Control	70	1922.2	16.29	8.47
	80	2196.8	7.89	3.59
	90	2471.4	10.53	4.26
	100	2746	11.30	4.11
F test				**
Lsd				1.672
CV				15.0

Source: Data 2015. Where ** = highly significant at p<0.01 probability level; CV = coefficient of variation; LSD = Least Significant Difference between means.

CONCLUSIONS

At the initial stage of study soil chemical properties studied were all increased by PM, CD and NPK even though differences were not significant. However analysis of the soil after harvest indicated that PM, CD and NPK application increased N, P, K, soil particle density and pore volume. Deficit irrigation (water stress) decreased nitrogen, calcium and potassium content of the soil while it increased phosphorous and magnesium content of the soil. Deficit irrigation (DI) did not influence significantly soil Bulk density, Pore volume and Particle density. Water stress (DI) reduced growth of leaves and branches. Reduced irrigation (DI) 70% CWR increased tuber yield and water use efficiency (WUE). Poultry manure, cow dung and NPK improved tuber yield, and PM gave the highest yield. Amending soil with PM and NPK improved significantly tuber yield better under reduced irrigation (70% CWR) conditions than under full irrigation.

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