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Productivity and Quality of Orange Fleshed Sweet Potato (*Ipomoea batatas* (L) Lam) as Affected by Irrigation and Fertilizer Application

Dukuh Isaac Gibberson[1], Owusu-Sekyere Danso Joshua[2], Bart-Plange Ato[3], Seweh Amomba Emmanuel[4], Okyere Justice[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, Bolgatanga Polytechnic, Post Office Box 767, Bolgatanga, Ghana
[5]Department of Agricultural Engineering, Wa Polytechnic, Post Office Box 553, Wa, Ghana

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

Abstract: The study was conducted at University of Cape Coast Research Farm, Cape Coast, Ghana from September, 2014 to January, 2015. The objective of the research was to investigate the effects of irrigation levels, chicken manure, cow dung, NPK and interactions on the: quality and yield of OFSP roots. Sixteen treatments (four levels of irrigation and four soil amendments) with three replicates were laid out in a Randomized Complete Block Design (RCBD). DI (70 % CWR) increased marketable root yield, jumbo root yield and number of roots per plant as compared to full irrigation. On the contrary DI reduced dry matter content. DI did not significantly reduce root decay, root sprouting and root cracking, root damage, weevil infestation and moisture content in the field. Soil amendments did not significantly influence root decay, root sprouting and root cracking, root damage and weevil infestation in the field. PM, CD and NPK significantly increased marketable yields by 40.96 %, 30.34 % and 21.36 % respectively as compared to control.
Keywords: Cow dung, Deficit Irrigation, Quality and Yield, NPK, Marketable yield, Orange Fleshed Sweet Potato, Poultry Manure, Weevil infestation

INTRODUCTION

Globally, 102 million tonnes of sweet potato is produced with 12.1 t ha^{-1} as an average yield. Food and Agriculture Organisation Statistics [1]. It is one of the most widely grown root crops in Sub-Saharan Africa [2]. According to FAO [3] statistics, West African Sweet potato production stood at 2.516 million tonnes. In Ghana, farmers plant 73,400 ha of sweet potato yearly that comes after cassava and yam in order of importance [1, 3]. In 2010 Center of International Potato (CIP) began operating in Ghana with a goal of reaching an estimated 500,000 households with nutritious sweet potato by 2020. However constraints to improved productivity and incomes for smallholder sweet potato farmers in Sub-Saharan Africa including Ghana includes: the lack of timely access to virus and pest-free planting material, lack of improved varieties adapted to local conditions, damage to roots caused by the sweet potato weevils, particularly in drier production areas, little knowledge and use of better agronomic practices and inappropriate storage systems [2].

There are also critical challenges to increasing sweet potato availability which includes; poor crop management strategies such as crop-water management regimes, soil nutrient regimes and inefficient technologies to reduce perishability. It has been stated that sweet potato is sensitive to water stress. Hirich *et al*. [4] observed that dry matter yield was significantly affected by deficit irrigation, while harvested yield was affected significantly ($P < 0.05$) by both deficit irrigation and organic manure. The main problems in postharvest handling of sweet potato roots include the loss of the skin from the surface of the roots, which is referred to as ‘skinning’. The skin can also be lost through cuts. Skinning and cuts (skin damage) leads to an increased rate of moisture loss, resulting in weight loss and shrinkage of the root. Skin damage also increases susceptibility to pathogen attack, lowers the value of the crop and economic profits for the farmers.

In recent times organic farming has received tremendous attention worldwide [5]. There is widespread belief that organic farming improves the environment, increases the quality of food products and the health of consumers [6]. The use and misuse of chemical fertilizers has resulted in pollution of farmlands, surface and ground water, the entire ecosystem and can adversely affect the health of animals and humans. In response to environmental concerns several countries throughout the world are considering the use of organic manure in the production of crops.

In spite of the lack of strong evidence in literature that organic foods are significantly more nutritious than non-organic foods most producers and consumers worldwide are currently moving towards organic production of crops due to discovered and envisaged advantages. Also, there have been several research efforts to improve sweet potato root and vine yield but there is little information, if at all there is any, on comparative study of organic, inorganic fertilizers and deficit irrigation in improving quality determinants of orange fleshed sweet potato. There is not much information on the effect of irrigation, manure and NPK on quality traits such as storage root dry matter yield, sprouting, decay, weevil infestation, and marketable yield of Orange Fleshed sweet potato.

The present work, therefore, evaluated the effectiveness of organic, inorganic fertilizer and irrigation on quality traits of OFSP. This study examined the effect of irrigation treatments, manure and NPK application on the response patterns of marketable root yield, decay, weevil infestation, skin damaged, sprouting and root dry matter content of OFSP 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. The location of Cape Coast is latitude 5.06° N and longitude 5° W with altitude of 31 m above sea level. The are two rainy seasons and the major rainy season starts from March to July and the minor rainy commences from September to October. Temperatures and humidity are high throughout the year. Maximum temperature is between 30 ^{o}C to 36 ^{o}C while minimum temperatures range between 22 ^{o}C to 26 ^{o}C [7]. Natural vegetation is coastal savanna [8] 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 were determined. 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 after harvest. The samples were air-dried, ground and passed through 2 mm-mesh sieve and used for laboratory analysis.

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 sample of 10 plants per plot was selected for data collection.

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 [10] 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 (15 tons ha^{-1}) and Cow dung (30 tons ha^{-1}) were applied 2 weeks before planting the vines and NPK 15:15:15 (1300 kg ha^{-1}) was applied a week after planting.

Crop data

In each experimental plot, 10 plants were tagged, harvested and roots were examined for quality analysis. Harvested roots were examined for cracks, sprouting, decay and weevil infestation. Root yield, marketable and unmarketable yield were also determined.

Harvesting and curing

Vines were cut and rolled to the side of the plot. 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 roots. Roots weighing 100g and above from 10 sampled plants per plot were considered and weighed.

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 was analyzed by Flame photometer, Atomic Absorption Spectrometer, Electric Conductivity meter and by titration. 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.

The following data were collected:

All plots were harvested at 97 days after planting. Storage roots were graded into two size classes and weighed. Tubers weighing 100 g and above from 10 sampled plants were considered. Total yield per plot was determined by multiplying the total number of plants by the yield per plant. Root yield was determined as total root yield per plot projected to per hectare basis

Economic Yield: marketable yield excluded small roots (<100 g), misshapen and damaged roots. Mean marketable root weight per plot were determined and projected to per hectare basis as in Equation 1:

$$Marketable\ yld = \frac{wt\ of\ marketable\ roots}{Total\ root\ wt\ per\ plot} x\ ha \quad (1)$$

Jumbo Tuber Yield: Large size roots or jumbo sized roots (>350 g) were graded and weighed. Mean jumbo sized root weight per plot were determined and projected to per hectare basis as in Equation 2:

$$Jumbo\ root\ yld = \frac{Wt\ of\ roots > 350\ g}{Total\ root\ yld\ per\ plot} x\ ha \quad (2)$$

Small root yield: roots less than 100 g were considered small and not marketable. Mean small tuber yield per plot were determined and projected to per hectare basis as in Equation 3:

$$Tuber\ per\ plant = \frac{Number\ of\ roots}{Number\ of\ plants} x\ ha \quad (3)$$

Weight per tuber was determined by Equation 4:

$$Weight\ per\ tuber = \frac{Total\ weight\ of\ roots}{Number\ of\ roots} x\ ha \quad (4)$$

Dry matter yield was determined by drying a composite 250 g sample to a constant weight in an oven for 48 h at > 65 ^oC and re-weighing. Dry matter content was determined as in Equation 5:

$$Dry\ matter\ yield = \frac{Weight\ of\ samples\ after\ drying}{Weight\ of\ samples\ before\ drying} x\ 100 \quad (5)$$

Tubers from sampled plants were examined for cracks. Roots with 5 % of surface having cracks were considered cracked. Percentage cracked roots was determined as in Equation 6:

$$Percentage\ cracked\ roots = \frac{No.of\ cracked\ roots}{Total\ No.of\ roots} x\ 100 \quad (6)$$

Tubers from sampled plants from each plot were counted and examined for sprouting and percentage sprouting was determined as in Equation 7:

$$Percentage\ sprouted\ roots = \frac{No.of\ sprouted\ roots}{Total\ No.of\ roots} x\ 100 \quad (7)$$

Tubers with 5 percent or more surface cut, bruised or skinned were considered damaged**.** The level of damage was determined by using Equation 8:

$$Percentage\ damaged\ roots = \frac{Damaged\ roots\ (kg)}{Total\ yield\ (kg)} x\ 100 \quad (8)$$

Tubers from each plot were examined for weevil infestation. Roots with 5 % or more of surface area infestation were considered insect (weevil) infested. The level of insect infestation was determined by using Equation 9:

$$Percentage\ insect\ infestation = \frac{No.of\ infested\ roots}{Total\ No.of\ roots} x\ 100 \quad (9)$$

Tubers from sampled plants from each plot were counted and examined for decay. Roots with decay regardless of the spread were considered rotten and level of decay was determined as in Equation 10:

$$Percentage\ decayed\ tubers = \frac{No.of\ decayed\ roots}{Total\ No.of\ roots} x\ 100 \quad (10)$$

Statistical Analysis

The data collected were subjected to statistical analysis using Analysis of Variance (ANOVA). The data obtained were analyzed using the GenStat Discovery Edition 4.0 statistical package. Least

Significant Difference (LSD) was used to separate the means at 5 % level of probability.

RESULTS AND DISCUSSION

The effect of CD, PM, NPK and Irrigation on productivity of OFSP

Table 1 shows that marketable yields or economic yields are significantly responsive to deficit irrigation. Marketable yield decreased from 10.21 t ha^{-1} to 8.57 t ha^{-1} when irrigation reduced from 100 % CWR to 80 % CWR. However, marketable yield increased to 13.01 t ha^{-1} when irrigation was further reduced to 70 % CWR as shown in Table 1. The finding is supported by Thompson *et al*. [9] who showed that marketable yields of sweet potato were slightly reduced when water application was less than 76 % but substantially reduced when irrigation was greater than 76 % of pan evaporation. Fertilization significantly improved marketable yield. PM, CD and NPK yielded 11.94 t ha^{-1}, 11.04 t ha^{-1} and 10.28 t ha^{-1}, marketable yield respectively. Thus marketable yields were increased by 40.96 %, 30.34 % and 21.36 % by PM, CD and NPK, respectively as compared to the control (Table 1). This could be attributable to higher concentration of nitrogen in PM, CD and NPK fertilized plots.

Table 1: Main effects of irrigation and fertilization on Economic yield of sweet potato at Cape Coast during the 2014 minor cropping season

Treatment				
Irr. % ET_c	Marketable yld t ha^{-1}	Small root yld t ha^{-1}	Root yld t ha^{-1}	Marketable yld %
70	13.01	18.07	15.95	41.85
80	8.57	24.68	11.23	25.78
90	9.93	18.05	13.50	35.49
100	10.21	23.93	12.84	29.91
F-test	**	**	**	**
LSD	1.617	4.671	1.672	
CV (%)	7.2		15.0	
Fertilization				
PM	11.94	23.33	15.85	33.85
CD	11.04	22.06	13.35	33.35
NPK	10.28	23.91	12.82	30.06
Control	8.47	15.43	11.50	35.43
F-test	**	**	**	**
LSD	1.617	9.341	1.672	
CV (%)	7.2		15.0	

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

Irrigation and soil amendments interaction significantly (P<0.05) affected marketable yield of roots (Table 2). PM + 70 % CWR resulted in the highest marketable yield (16.34 tons ha^{-1}) while the interaction of 80 % CWR and the Control yielded 5.09 t ha^{-1}, which was the lowest marketable yield (Table 2). PM + 100 % CWR resulted in the lowest yield (9.82 t ha^{-1}) while PM and 70 CWR + resulted in the highest marketable yield (16.34 t ha^{-1}) as shown in Table 2. Thus DI increased marketable yield for PM while DI reduced marketable yield for CD.

Table 2: Interaction effect of fertilizer and irrigation on marketable yield of sweet potato at Cape Coast during the 2014 minor cropping season

Marketable yield t ha^{-1}				
Treatments	Fertilization			
Irr. % ET_c	Control	CD	NPK	PM
70	13.56	10.45	11.67	16.34
80	5.09	10.61	7.47	11.13
90	7.07	10.42	11.77	10.47
100	8.14	12.67	10.22	9.82
F-test		*		
LSD		3.324		
CV (%)		20.4		

Source: Author's Data (2015) Where * = significant at p<0.05 probability level; CV = coefficient of variation; LSD = Least Significant Difference between means

On the contrary, CD and 100 % CWR gave the highest marketable yield (12.67 tons ha^{-1}) while CD and 70 % CWR yielded 10.45 t ha^{-1} (Table 2). For the control treatment, reduced water application resulted in reduced marketable yield till 70 % CWR when marketable yield significantly increased to 13.56 t ha^{-1} (Table 2).

Small root yield (unmarketable yield) was highly significantly (p<0.01) affected by irrigation and fertilization (Table 1). DI (70 % CWR) produced highly significantly (P<0.01) lower unmarketable yield (18.07 t ha^{-1}) as compared to irrigation at 100 % CWR which yielded (23.93 t ha^{-1}) as shown Table 1. Thus DI (70 % CWR) reduced unmarketable yield and increased marketable yield. This assertion is shown in Table 1 where 100 % CWR yielded 29.91 % marketable roots while 70 % CWR yielded 41.85 % marketable roots. The Control experiment significantly (P<0.01) produced lower amount of unmarketable roots (15.43 t ha^{-1}) as compared to PM, CD and NPK fertilization (Table 1). The Control also gave the lowest total yield (11.50 t ha^{-1}). NPK fertilization produced the highest unmarketable root yield, 23.91 t ha^{-1} (Table 1) which was 69.9 % of the total yield.

Table 3 shows the effect of interaction of fertilizer and irrigation on unmarketable yield. The effect was highly significant (p<0.01). PM + 100 CWR produced the highest unmarketable root (38.35 tons ha^{-1}) while PM + 70 % CWR reduced unmarketable yield by 48.7 % to 19.66 t ha^{-1}. Thus it can be suggested that, to reduce the production of unmarketable ORFSP roots, PM fertilization should be irrigated with less than 100 % CWR.

DI increased unmarketable root yield for NPK. NPK and 100 % CWR interaction yielded 14.3 t ha^{-1} while NPK + 80 % CWR produced 36.07 t ha^{-}1 unmarketable roots. The Control and 70 % CWR produced 16.05 t h^{-1} unmarketable roots which was significantly lower than yield from Control and 100 % CWR (27.17 t h^{-1}). Thus for soils without amendment, reducing water application to 70 % ET_c results in reduced production of small unmarketable roots and increased marketable yield (Tables 2 and 3). This could be attributed to reduced number of roots development as a result of deficit water application [11, 12].

From Table 4, number of roots per plant was responsive to irrigation and fertilizer application. Significant differences (P<0.05) in number of roots per plant were observed between different levels of water application. DI (70 % CWR) produced the highest number of roots per plant (3.91). However, it was not significantly higher than the number of roots per plant at 100 % CWR and 90 % CWR but significantly higher than 80 CWR (3.10). The increased number of roots at the lower level of water application (70 % CWR) is supported by Hirich *et al.* [4] who stated that deficit irrigation when applied during vegetative growth stage could stimulate root development, increase water and nutrient uptake and subsequently increase the yield. It is therefore suggestive that many more roots of OFSP roots can be produced by reducing water application to 70 % ET_c.

Table 3: Interaction effect of manure and irrigation on small root yield of sweet potato at Cape Coast during the 2014 minor cropping season

Small root yield t $ha-^{1}$				
Treatments	Fertilization			
DI % ETc	Control	CD	NPK	PM
70	16.05	15.94	20.65	19.66
80	27.22	17.73	36.07	17.71
90	25.22	12.16	17.20	17.61
100	27.17	15.92	14.30	38.35
F-test		**		
LSD				
CV (%)				

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

From Table 4, PM treated plots produced the highest number of roots per plant (4.22) which was significantly (p<0.05) higher than yields per plant from CD (3.39) and NPK (3.35) treated plots. This is consistent with findings by Hartemink [13] and Sowley *et al.* [14] which showed that sweet potato yields were higher when organic manure (PM) was applied as compared to NPK application. However, root count per plant from the Control were not significantly different from PM fertilization. This is contrary to the findings by Sowley *et al.* [14] which showed that PM fertilization produced more roots per plant than NPK and control. However, this result is in conformity with the finding of Parwada *et al.* [15] who found insignificant root counts per plant of sweet potato in response to PM manure applied at planting. They suggested that tuberous root number development from a plant is highly dependent on the genetic make-up of a given plant rather than fertilizer application. The interaction of irrigation and fertilization had no significant ($p<0.05$) effect on root count per plant.

The effect of irrigation level on jumbo root yield was highly significant. DI (70 % CWR) resulted in the highest jumbo tuber yield (7.57 tons ha^{-1}) which is 61.4 % higher than yields from 100 % CWR (4.69 tons ha^{-1}). It is therefore suggested that larger size tubers could be produced by reducing water application to 70 % CWR. DI (80 % CWR) produced the lowest jumbo yield (4.19 tons ha^{-1}) and were not significantly different from results from 100% CWR treatment. Jumbo yield was highly responsive to soil amendment with PM, CD and NPK (Table 4). PM treated plots yielded 7.35 tons ha^{-1} which was the highest jumbo root yield and was 81.5 % higher than yield from control plots (4.05 t ha^{-1}). CD and NPK treated plots yielded 5.59 tons ha^{-1} and 5.57 t ha^{-1}, respectively which were higher but not significantly different from yield from control plots.

Table 4: Main effects of irrigation and fertilization on root per plant, Jumbo tuber yield, weight per tuber and dry matter content of sweet potato at Cape Coast during the 2014 minor cropping season

Treatment				
Irr % ET_c	Root per plant	Jumbo yld t ha^{-1}	Weight per root (kg)	Dry matter cont. (%)
70	3.91	7.57	0.1983	20.37
80	3.10	4.19	0.2983	21.24
90	3.83	6.11	0.1988	20.84
100	3.74	4.69	0.211	21.02
F-test	*	**	NS	NS
Lsd	0.628	1.834	0.03858	1.188
CV (%)	20.7	39	22.4	6.8
Fertilization				
PM	4.22	7.35	0.2026	21.59
CD	3.39	5.59	0.2123	19.68
NPK	3.35	5.57	0.2157	20.61
Control	3.61	4.05	0.1969	21.58
F-test	*	**	NS	**
Lsd	0.628	1.834	0.03858	1.188
CV (%)	20.7	7.2	22.4	6.8

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

OFSP weight per root was not responsive to irrigation level and fertilizer application (Table 4). No significant differences were observed in weight per root among the levels of water application. However 70 % CWR yielded the lowest weight per root (0.1983 kg) which is consistent with findings by Bourke [12] and Pardales *et al.* [11]. Similarly no significant differences were observed in weight per root among the different types of soil amendment. However, NPK produced roots had the highest average weight (0.2157 kg). The interaction of irrigation and fertilization also had no significant ($p<0.05$) effect on weight per tuber.

Dry matter accumulation was not significantly influenced by level of irrigation (Table 4). However, DI (70% CWR) produced the lowest dry matter content (20.37 %) which is consistent with work done by Pardales *et al.* [11] who stated that drought condition reduces the formation and growth of roots and dry matter accumulation. Fertilizer application, however, significantly affected dry matter content of roots (Table 4). CD fertilization produced the lowest dry matter content (19.68 %) while PM gave the highest dry matter yield (21.59 %) which was not significantly different from NPK and the Control.

The interaction of fertilization and irrigation had a significant ($p<0.05$) effect on jumbo root yield (Figure 1). PM + 90 % ET_c produced the highest jumbo yield of 10.06 t ha^{-1} while Control + 80% CWR resulted in the lowest jumbo yield (0.82 t ha^{-1}). For CD, NPK and Control the interaction with 70 % CWR resulted in 6.47, 7.37 and 8.3 t ha^{-1} jumbo roots respectively which were the highest within each fertilizer treatment.

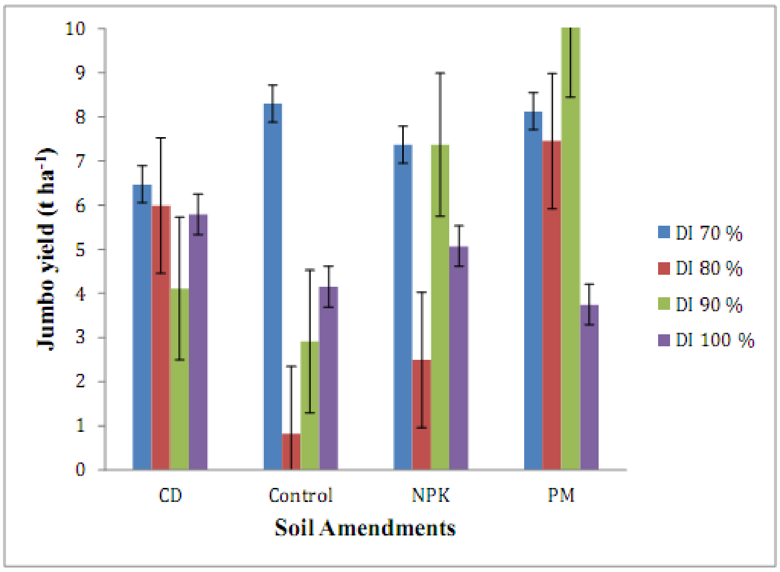

Fig-1: Interaction effect of CD, PM, NPK and irrigation level on jumbo root yield per hectare of sweet potato at Cape Coast during the 2014 minor cropping season (Lsd = 1.834)

The interaction of fertilization and irrigation significantly ($p<0.01$) affected dry matter yield as shown in Table 5. CD + 100 % CWR produced the lowest dry matter (18.59 %) while CD + 70 % CWR produced 21.62 % dry matter which was the highest for CD fertilization. Conversely PM and 70 % CWR interaction produced 20.14 % dry matter the lowest while PM + 100 % CWR produced the highest dry matter (23.48 %) for PM fertilization. NPK and irrigation interaction effect on dry matter production was similar to PM and irrigation interaction.

Table 5: Interaction effect of CD, PM NPK and irrigation level on dry matter content of roots of sweet potato at Cape Coast during the 2014 minor cropping season

Dry Matter Content				
Treatments	Fertilization			
DI % ETc	CD	Control	NPK	PM
70	21.62	20.38	19.35	20.14
80	18.95	24.15	20.28	21.58
90	19.57	20.88	21.74	21.16
100	18.59	20.9	21.09	23.48
F-test		**		
LSD		2.376		
CV (%)		6.8		

Source: Author's Data (2015)

The effect of CD, PM, NPK and Irrigation on quality of OFSP in the field

Root cracking in the field was not responsive to irrigation levels and soil amendments. Seventy percent CWR (70 % ET_c) resulted in the lowest (1.86 %) cracked roots (Table 6). It was however not significantly different from root cracking at 80 % CWR, 90 % CWR and 100 % CWR which recorded 2.54 %, 2.94 % and 1.88 % root cracking, respectively. Similarly soil amendments did not significantly affect tuber cracking (Table 6). Soil amendment, however, resulted in higher root cracking as compared to the control. CD, PM and NPK treatments resulted in 3.57 %, 2.79 % and 1.79 % root cracking, respectively while the control resulted in 0.77 % root cracking.

Table 6: Main effects of irrigation and fertilization on percent damaged roots, percent root cracked and percent weevil infestation of sweet potato at Cape Coast during the 2014 minor cropping season

Treatments				
Irr. % ETc	Percent root cracked	Root damaged %	Weevil infestation %	Moisture content %
70	1.86	13.2	9.1	79.63
80	2.25	13.6	10.2	78.76
90	2.94	10.7	7.4	79.16
100	1.88	15.0	12.2	78.98
F-test	NS	NS	NS	NS
LSD	3.086	6.47	4.81	1.188
CV (%)	7.2	59.1		1.8
Fertilization				
PM	2.79	11.1	10.5	78.41
CD	3.57	13.2	6.2	80.32
NPK	1.79	15.5	13.2	79.32
Control	0.77	12.8	9.0	78.42
F-test	NS	NS	NS	**
LSD	3.086	6.47	4.81	1.188
CV (%)	7.2	59.1		1.8

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

Deficit irrigation had no significant effect on root damage during harvesting (Table 6). Though not significant, 100 % CWR resulted in 15.0 % tuber damage while 70 % ET_c resulted in 13.2 % damage roots. Similarly root damage during handling was not influenced by soil amendment. However, NPK treatment resulted in the highest root damaged (15.5 %) while PM resulted in the lowest root damage (11.1 %). Irrigation and soil amendment interaction had no significant effect on root damage during harvesting as shown in Figure 2. Though not significant, NPK interaction with 70 % CWR and 80 % CWR resulted in the highest root damage during harvesting (16.69 % and 19 %, respectively).

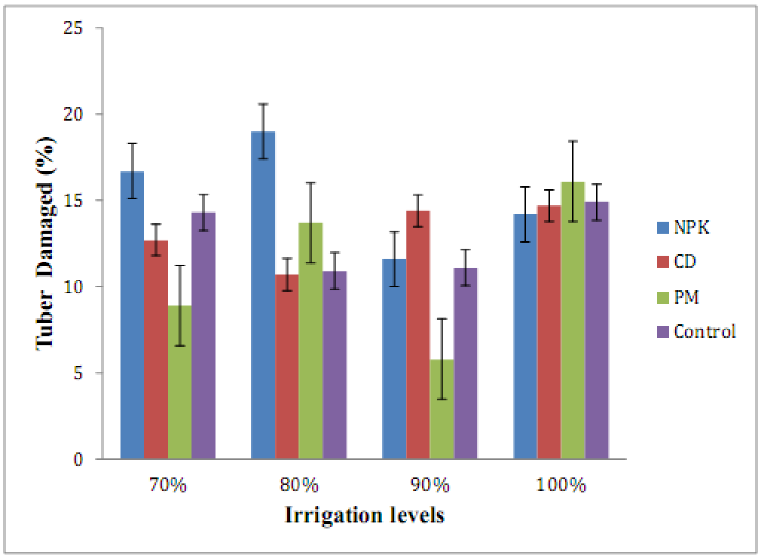

Fig-2: Interaction effect of CD, PM, NPK and Irrigation on percent OFSP root damaged at Cape Coast during the 2014 minor cropping season (Lsd = 13.94)

Root moisture content was not responsive to levels of irrigation (Table 6). Though not significant, DI (70 % CWR) recorded the highest moisture content (79.63 %) as compared to 100 % CWR which recorded 78.98 %. Fertilization, however affected root moisture content significantly (p<0.01). The application of CD recorded the highest moisture content 80.32 % which is significantly (p<0.01) higher than PM and control (78.41% and 78.42 %, respectively). NPK recorded 79.32% moisture content and was not significantly different from CD. The interaction of irrigation, CD, PM and NPK had no significant effect on root moisture content.

The effect of irrigation on weevil infestation of tuber in the field was non-significant (Table 6). Though not significant, reduced water application resulted in lower weevil infestation in the field. As shown in Table 6, 100 % CWR caused 12.2% weevil infestation while 90% CWR and 70% CWR resulted in 7.4% and 9.1 % weevil infestation, respectively. Manure and NPK application did not cause significant difference in weevil infestation of roots in the field. The interaction of irrigation, CD, PM and NPK did not cause significant difference in weevil infestation of roots in the field.

From Table 7 there was no significant difference in root sprouting in the field among the levels of irrigation. Though not significant, DI (reduced water application) resulted in lower root sprouting. As shown in Table 7, 100% CWR resulted in 1.55% sprouting of roots in the field while 70% ET_c resulted in 0.35% sprouting. Root sprouting in the field was also not responsive to manure or NPK application as shown in Table 7. The application of NPK resulted in 1.59 % sprouting while the control resulted in the lowest sprouting of tubers (0.36%).

Table 7: Main effects of irrigation, CD, PM and NPK on percentage sprouted root, percentage root decay of OFSP at Cape Coast during the 2014 minor cropping season

Treatments		
Irr % ET_c	Percent root sprouted	Percent root decay
70	0.35	0
80	0.74	0
90	0.38	0.18
100	1.55	0.01
F-test	NS	NS
LSD	1.605	0.2035
CV (%)	28.4	27.6
Fertilization		
PM	0.38	0
CD	0.69	0
NPK	1.59	0.01
Control	0.36	0.17
F-test	NS	NS
LSD	1.605	0.2035
CV (%)	28.4	27.6

Source: Author's Data (2015) Where CV = coefficient of variation; LSD = Least Significant Difference between means.

Interaction of irrigation, CD, PM and NPK caused no significant difference in root sprouting in the field among the levels of irrigation and fertilizer application (Figure 4). Though not significant, NPK and 70 % CWR interaction recorded the highest root sprouting (3.44 %) as shown in Figure 4.

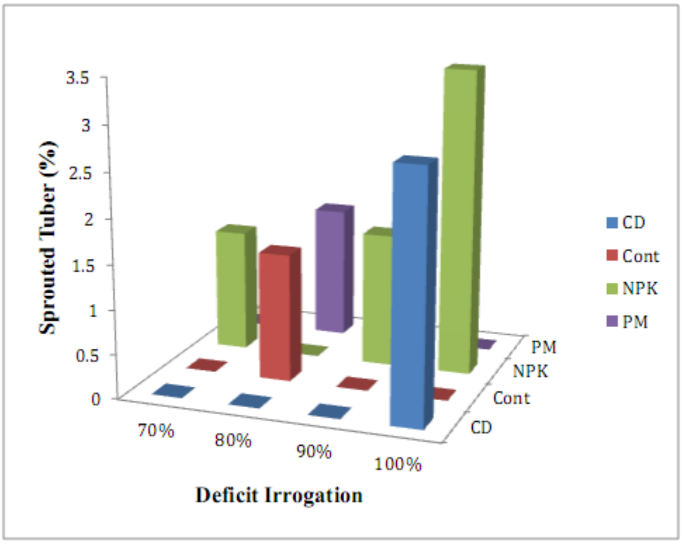

Fig-4: Interaction effect of CD, PM, NPK and irrigation on root sprouting OFSP in the field at Cape Coast during the 2014 minor cropping season (Lsd = 3.81)

The effect of irrigation on root decay in the field was not significant (Table 7). Though not significant, DI 70 % CWR and DI 80 % CWR resulted in the lowest tuber decay (0%) while 100 % CWR and 90 % CWR resulted in 0.01 % and 0.18 % root decay, respectively. The effect of application of fertilizer on root decay in the field was also not significant ($P<0.05$). The application PM of and CD resulted in zero percentage root decay in the field. The interaction of irrigation and fertilizer had no significant effect on tuber decay in the field.

CONCLUSIONS

Reduced water application (water stress) at 70 % CWR increased marketable root yield, jumbo root yield and number of roots per plant as compared to full irrigation. On the contrary water stressed plants produced lower dry matter content. DI (reduced water application) did not significantly reduce percentage root decay, root sprouting, root cracking, root damage, percent weevil infestation and moisture content in the field. Soil amendments did not significantly influence root decay, root sprouting, root cracking, root damage and weevil infestation in the field. Soil amendments significantly increased marketable yield. PM, CD and NPK significantly increased marketable yields by 40.96 %, 30.34 % and 21.36 % respectively as compared to control. Irrigation and manure interaction effect significantly influenced jumbo root yield. The application of 70 % CWR to plots treated with CD, NPK and control gave the highest jumbo yield within each manure treatment.

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