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The Effect of Deficit Irrigation, Manure and NPK on Quality and Proximate Content of Orange Fleshed Sweet Potato (OFSP)

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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 proximate content of Orange Fleshed Sweet Potato roots. Sixteen treatments (four levels of irrigation and four soil amendments) with three replicates were laid out in a Randomized Complete Block Design (RCBD). Deficit irrigation and soil amendments interaction significantly influenced fibre content of roots. For Poultry manure and Cow dung treatment, deficit irrigation increased root fibre content. PM and 100 % CWR interaction resulted in the lowest root fibre content of 5.96 %. Cow dung and 70 % CWR produced the highest root fibre content of 15.62 %. Deficit irrigation decreased sugar content of roots. Deficit irrigation did not influence starch and phenol content of roots. Deficit irrigation increased carotenoid and ash content. For cow dung treatment deficit irrigation increased phenol content of roots. Irrigation and soil amendments interaction had no influence on Phosphorous, Calcium and Magnesium content of roots.

***Keywords**: Deficit irrigation, manure, NPK, orange fleshed sweet potato, proximate content*

1. Introduction

Sweet potato is high in nutritive value and it outranks most carbohydrate based food (Onuh et al., 2004). Sweet potato serves as a staple food vegetable, snack food, weaning food and animal feed. It also serves as raw material for the production of starch and alcohol. Sweet potatoes are a good source of minerals (Luis et al., 2013), carbohydrates, fibre, antioxidants, starch and vitamins (Anderson & Gugerty, 2013). According to Shih et al. (2007), among the other root and tuber crops, sweet potato possesses higher contents of carbohydrates, various vitamins, minerals, and protein than other vegetables. Sweet potato roots and leaves are also good sources of antioxidants (Toew et al., 2007). Sweet potato roots are good sources of fibre, vitamin C and minerals such as zinc, potassium, sodium, manganese, calcium, magnesium and iron (Antia et al., 2006). Orange Fleshed Sweet Potato (OFSP) especially is high in carotenoids, particularly βeta carotene which is a precursor to vitamin A and it contributes in alleviating vitamin A deficiency (Strobe et al., 2007). The importance of carotenoid in nutrition and health in the developing countries where deficiency of vitamin A remains a serious health problem cannot be over-emphasized. Vitamin A deficiency is a major public health problem in developing countries such as Ghana. According to Hinneh (2013), statistics by the Ghana Health Service (GHS) (2012) indicate that 12,000 children in Ghana die every year due to malnutrition. It was further indicated that malnutrition contributes to about half of all child deaths beyond early infancy and one out of every thirteen children in Ghana die before their fifth birthday due to under-nutrition. Increased production and utilization of OFSP could be cost effective solution to vitamin A deficiency in children in Ghana and other developing countries.

However, the production of sweet potato is going down despite its nutritional and economic value. Average yield of 5 tonnes ha^{-1} is low as compared to 14 tonnes ha^{-1} in China and other developing regions of Asia. The reduction in production can be attributed to poor soil nutrient status and rapid growth in population leading to excessive cultivation of land (IITA, 1995). Excessive cultivation of land leads to excessive nutrient removal and thereby soil nutrient depletion which results in low yields. 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 (Ali et al., 2009). Manure is an age-old source of fertilizer which modifies soil physical and chemical properties and releases nutrients for a longer period of time. Plant nutrients are essential for the production of high quality crops to provide nutrient requirement for the world's expanding population. Therefore increased crop production largely relies on the type of fertilizer used to supplement essential nutrients for plants. An earlier study showed that increase in the levels of poultry manure applied resulted in an increase in dry matter, starch, fiber and protein contents and a decrease in fat content of *Dioscorea. bulbifera*. Dry matter, β-carotene and starch content in roots were lower in traditional system of production where no manure and fertilizer was applied (Nedunchezhiyan et al., 2010). However, they found that traditional system of production of sweet potato recorded higher sugar content in roots.

Prolonged drought condition reduces the formation and growth of roots and dry matter accumulation (Pardales et al., 2000). On the contrary Indira and Wanda (2004) stated that higher irrigation levels resulted in lower dry matter content of roots. They however indicated that the total nitrogen content of sweet potato roots was significantly responsive to irrigation and that lower water stress (higher irrigation levels) resulted in higher total nitrogen content of roots.

There is less information about the sensitivity of root carbohydrates, total nitrogen, fibre content, ash content, beta carotene, total phenols, dry matter, etc. of OFSP to irrigation and manure in the coastal savanna zone of Ghana. This study therefore examined the effect of irrigation and manure treatments on the root carbohydrates, total nitrogen, fibre content, ash content, beta carotene, total phenols, dry matter, etc. on OFSP. The specific objectives of the study were: (1) to determine the effect of the level of irrigation and manure on nutritional content of OFSP, (2) to determine the interaction effect of irrigation and fertlization on the nutritional content of OFSP and (3) to determine the effect of evaporative storage structure on the nutritional content of OFSP.

2. 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 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 (Ayittah, 1996). Natural vegetation is coastal savanna (Teye, 2010) 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 to determine major cations and anions 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 from each experimental plot were air-dried, ground and passed through 2 mm-mesh sieve and used for laboratory analysis.

2.1. Experimental Design

There were 16 treatments consisting 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 treatment combinations 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 experimental lay out was Randomized Complete Block Design in a factorial arrangement with three replications. Rain shelter consisting of galvanized steel metal frame roofed with transparent water proof plastic sheet was erected over the plots to prevent any form of precipitation on the plots.

2.2. 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 (1998) 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).

2.3. 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.

2.4. Sample Collection

A sampled of 5 plants per plot were harvested and sample of OFSP roots were selected for analysis.

2.4.1. Preparation of Sample for Analysis

Three sweet potato roots were randomly selected from each treatment at harvest. The freshly harvested sweet potato samples were washed with clean water and sliced into thin slices for drying. The sliced samples of OFSP roots were dried in an oven at 60 ^{o}C. The dried samples (10 g) were then homogenized into powdery form ready for the analysis. Preparation of sample solution for the determination of N, K, Na, Ca, Mg, P, Zn, Cu and Fe was done following standard protocols.

The preparation of sample solutions suitable for elemental analysis involved an oxidation process which is necessary for the destruction of the organic matter, through acid oxidation before a complete elemental analysis could be carried out. Sulphuric acid-hydrogen peroxide digestion procedure as outlined in Jones et al. (1991) was employed.

2.5. Data Collected

2.5.1. Determination of total Nitrogen was by the MICRO-KJEDAHL Method.

Percentage nitrogen content was determined as in Equation 1.

$$N\,(\%) = \frac{(\mathrm{S.B})\ \mathrm{x\ solution\ volume}}{102\ \mathrm{x\ aliquot\ x\ sample\ weight}} \qquad 1$$

Where, S = Sample titre value and B = Blank titre value.

2.5.2. Colorimetric determination of phosphorous (P) using the ascorbic acid method

Phosphorous was determined by Molybdate yellow method (Onwuka, 2005) using spectrophotometer. A calibration curve was plotted using their concentrations and absorbances. The concentrations of the sample solutions were extrapolated from the standard curve. Phosphorous in the digested samples were calculated using Equation 2.

$$P(\mu\, g/g) = \frac{\mathrm{C\ x\ Dilution\ Factor}}{\mathrm{weight\ of\ sample}} \qquad 2$$

Where C = P g ml^{-1} obtained from the graph.

2.5.3. Total Phenols

The total phenolics in sweet potato extracts were estimated by Folin-Ciocalteu colorimetric method according to Ju (1989) with slight modification. Results were expressed as mg of gallic acid equivalents (GAE) per gramme dry weight (mg kg^{-1} dw).

2.5.4. Sample Preparation for Proximate Analysis

For each treatment or sweet potato sample, three roots were randomly taken, washed with tap water, peeled and cut into thin slices, packed into plastic bags and frozen for analysis. Samples were taken from the stem end, the mid-section, the root end and pooled for analysis.

2.6. Determination of Nutrient Composition

2.6.1. Starch Determination

The determination of starch in sweet potato was measured by a rapid method with acid hydrolysis. Starch was first extracted with perchloric acid and determined colorimetrically after it had formed a blue complex with potassium iodide (Allen et al., 1974). The percentage starch content of samples were determined with Equation 3.

$$Starch\,(\%) = \frac{C\ (mg) x\ solution\ volume\ (ml)}{10\ x\ aliquot\ (ml)\ x\ sample\ weight\ (g)} \qquad 3$$

Where: C = miligrammes of starch from graph

2.6.2. Sugar Determination

Sugar was determined by extraction with ethanol and determined by calorimetric means.

2.6.3. Protein Determination

Protein was determined by finding total nitrogen by the Kjeldahl method. Protein content of sweet potato sample was calculated with conversion ratio N (%) x 6.25.

2.6.4. Crude Fibre

Crude fibre in sweet potato was measured using modification of Moir (1971) method (Allen et al., 1974). Fibre was first extracted with diethyl ether and then the sample hydrolyzed by boiling with 1.25 % w/v sulphuric acid. This was followed by alkali extraction with 1.25 % w/v NaOH. The percentage fibre content of samples were determined using Equation 4.

$$Crude\ fibre\,(\%) = \frac{Uncorrected\ fibre(g) x\ loss\ in\ wt(g) x\ total\ extracted\ material\ x 10^2}{wt\ of\ ash\ (g) x\ wt\ of\ hydrolysis\ (G) x\ sample\ wt\ (g)} \qquad 4$$

2.6.5. Dry Matter and Ash Content Determination

Dry matter content was determined based on the oven-drying method at 105 ˚C for 48 hours or dried till constant weight. Dry matter content of the samples was calculated from the initial and final weight of each sample (Equation 5). Ash content in sweet potato was measured by the standard GB/T5009.4-2010 method.

$$Dry\ matter\ content\ (\%) = \frac{Weight\ of\ sample\ after\ dring}{Weight\ of\ sample\ before\ drying}\ x\ 100 \quad 5$$

2.6.6. Carotenoid Analysis (Harvestplus Method)

Determination of ß-carotene in frozen and milled sweet potato roots was done by HarvestPlus method (Rodriguez-Amaya and Kimura, 2004). The procedure consisted of sample preparation, extraction, partitioning and Spectrophotometric analysis. The carotenoid ethereal extract was read at 450 nm using Cecil CE 1021 spectrophotometer. The total carotenoid concentration was then calculated using the coefficient of absorption for β-carotene (2592). The total carotenoid content of samples were determined with Equation 6.

$$Total\ Carotenoid\ content = \frac{A_{total}\ \ x\ Vol(ml) x\ 10^4\ x\ (DF)}{A^{1\%}{}_{1cm}\ x\ sample\ weight} \quad 6$$

Where:

A_{total} = Absorbance at 450 nm, Volume (ml) = Total volume of extract (25 mls),

$A^{1\%}{}_{1cm}$ = 2592 (absorption coefficient of beta-carotene in petroleum ether (PE) and DF = Dilution factor

2.7. 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.

3. Results and Discussion

3.1. Fibre Content (%)

Fibre content of OFSP roots was significantly ($p<0.05$) responsive to level of irrigation as shown in Table 1. Fibre content of tubers increased with decreasing level of irrigation. The ranking order of fibre content of tuber was 70 % ET_c (12.70 %) > 80 % ET_c (12.42 %) > 90 % ET_c (11.82 %) > 100 % ET_c (10.97 %) as shown in Table 1. Thus water stress resulted in higher fibre content of roots. This could be beneficial in the sense that lower application of water saves water for other uses while it produces more dietary fibre. Moreover, dietary fibre has the potential to reduce the incidence of a variety of diseases in man including colon cancer, diabetes, heart diseases and digestive disturbances (Palmer, 1982).

Soil amendment significantly influenced the level of fibre content of root (Table 1). However, CD and NPK were not significantly better than the control in influencing fiber yield. PM resulted in the lowest root fibre content (10.01 %) and it was significantly lower than CD, NPK and the control.

Irrigation and soil amendments interactions significantly influenced root fibre content (Figure 1). For PM and CD treatment fiber content of roots increased as water stress (DI) increased. PM and 100 % CWR interaction resulted in the lowest root fibre content of 5.96 %. CD and 70 % CWR produced the highest root fibre content of 15.62 %. However, fibre content increased to 11.21 %, 11.64 % and 11.09 % as water stress (DI) increased to 90 %, 80 % and 70 % CWR, respectively. Root fibre content decreased with water stress for NPK and Control. On the contrary, fibre content of roots decreased from 14.27 % to 11.89 % for plots treated with NPK, as level of irrigation decreased from 100 % CWR to 70 % CWR, respectively as shown in Figure 1. Similarly, for the control experiment, fibre content of roots decreased from 13.23 % to 11.84 % as irrigation level decreased from 100 % CWR to70 % CWR. Fibre content increased with water stress for PM and CD but not for NPK and Control. Thus it can be concluded that fibre content increased with water stress for manure.

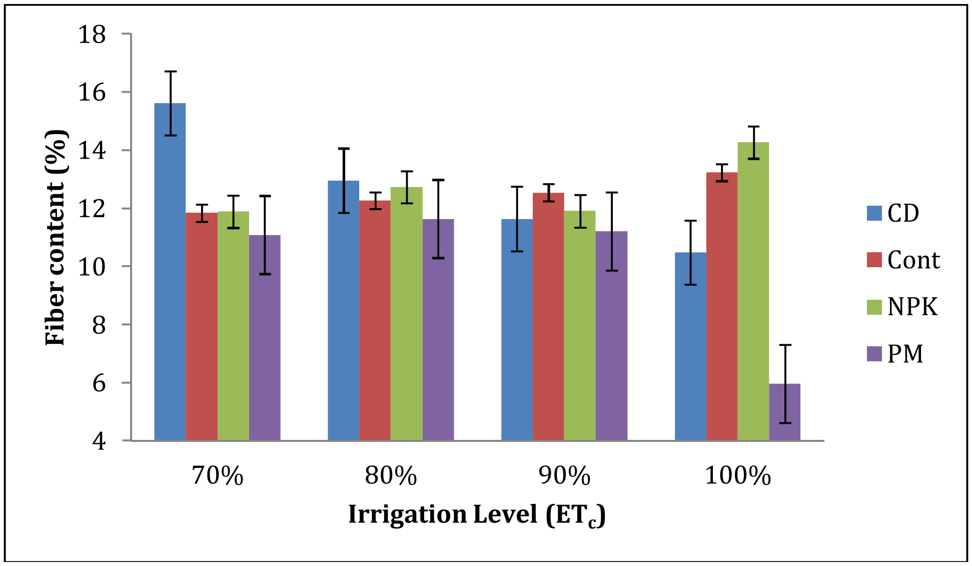

Figure 1: Interaction effect of Manure, NPK and irrigation on percentage fibre content of OFSP (Lsd = 2.082, p<0.01)

3.2. Sugar Content (%)

Sugar content of roots was significantly ($p<0.01$) responsive to irrigation (water stress). Table 1 shows that sugar content of roots decreased as water stress increased. Application of 100 % CWR and 90 % CWR resulted in 8.034 % and 8.141 % sugar content respectively which were not significantly different. However, further reduction of irrigation to 80 % CWR and 70 % CWR significantly decreased sugar content to 7.791 % and 7.641 %, respectively. It can thus be stated that the sugar content of OFSP roots can be increased or decreased by regulating irrigation depending on the purpose of production.

Treatments				
Irr. % ETc	**% Sugar**	**% Fibre**	**% Starch**	**Dry matter Cont. (%)**
70	7.641	12.70	49.48	20.37
80	7.791	12.42	52.68	21.24
90	8.141	11.82	51.47	20.84
100	8.034	10.97	50.48	21.02
F-test	**	*	NS	NS
LSD	0.2641	1.042	2.775	1.188
CV (%)	3.13	8.09	5.10	6.8
Fertilization				
PM	8.267	10.01	51.60	21.59
CD	6.959	12.77	47.59	19.68
NPK	4.484	12.68	39.52	20.61
Control	11.981	12.45	65.84	21.58
F-test	**	**	**	**
LSD	0.2641	1.042	2.775	1.188
CV (%)	3.13	8.09	5.10	6.8

Table 1: Main effects of irrigation, Manure and NPK on percentage fiber, sugar, starch and dry matter content of OFSP
*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*

Soil amendment significantly ($p<0.01$) influenced sugar content of roots (Table 1). The ranking order of sugar content of roots was Control (11.981 %) > PM (8.267 %) > CD (6.959 %) > NPK (4.484 %). The Control resulted in higher sugar content than PM, CD and NPK which is supported by similar finding by Essilfie (2012). She observed that in the minor season *apomuden* (OFSP) from control (unfertilized plots) contained 12.1 % sugar while roots from 10 tons ha^{-1} PM and 30-30-30 kg ha^{-1} NPK treated plots contained 11.7 % and 10.5 % respectively.

The interaction effect of irrigation and soil amendment on sugar content was highly significant as shown in Table 2. Sugar content of roots from control was not affected by irrigation level as there was only an insignificant reduction of sugar content as irrigation was reduced from 100 % to 70 % CWR. For NPK treatment sugar content decreased significantly from 4.96 % to 4.045 % as irrigation decreased from 100 % to 70 % CWR. For CD and PM treatment, water stress (DI) resulted in non-significant reduction in sugar content of roots. Thus sugar content decreased with water stress for NPK but not PM, CD and control.

Percentage Sugar				
Treatments	**Fertilization**			
Irri. % ETc	CD	Control	NPK	PM
70	6.820	11.891	4.045	7.909
80	6.969	11.815	4.111	8.372
90	7.049	12.209	4.877	8.565
100	7.016	12.020	4.960	8.265
F-test	**			
LSD	0.5274			
CV (%)	3.13			

Table 2: Interaction effect of CD, PM NPK and irrigation level on percentage sugar content of OFSP
*Source: Author's Data (2015) Where ** = highly significant at $p<0.01$ probability level; CV = coefficient of variation; LSD = Least Significant Difference between means.*

3.3. Starch Content (%)

Starch content of roots was not significantly responsive to DI (water stress) as shown in Table 1. However, starch content of roots increased from 50.48 % to 52.68 % as irrigation decreased from 100 % to 80 % CWR. Soil amendments had significant ($p<0.01$) effect on starch content of OFSP roots at harvest. The rank order of sugar content of roots was Control (65.84 %) > PM (51.60 %) > CD (47.59 %) > NPK (39.52 %). The control had the highest starch content than the application of PM and NPK which is supported by similar finding by Essilfie (2012). She noted that in the minor season *Apomuden* (OFSP) from unfertilized plots contained 16.8 % starch while roots from 10 t ha^{-1} PM and 30-30-30 kg ha^{-1} NPK treated plots contained 13.3 % and 11.9 % starch respectively.

Irrigation and soil amendments interaction also significantly ($p<0.01$) influenced starch contents of roots after harvest (Figure 2). From Figure 2 sugar content of roots produced from CD, PM and control plots decreased as irrigation decreased (water stress increased). For NPK produced roots sugar content increased (from 34.05 % to 41.47 %) as irrigation decreased from 100 % CWR to 70 % CWR.

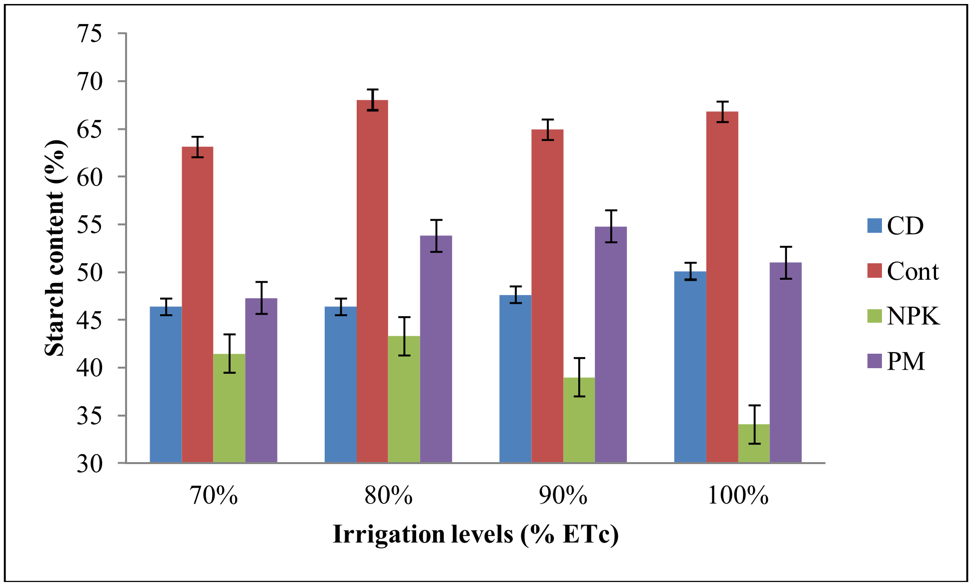

Figure 2: Interaction effect of CD, PM NPK and irrigation level on percentage starch content of OFSP (Lsd 5.542; p<0.01)

3.4. Dry Matter Content (%)

Dry matter accumulation was not significantly influenced by level of irrigation (Table 1). However, reduced water application to 70 % CWR resulted in the lowest dry matter content (20.37 %). Manure and NPK application, however, significantly affected dry matter content of tubers (Table 1). CD produced the lowest dry matter content of roots (19.68 %) while PM gave the highest dry matter yield (21.59 %) which was not significantly different from NPK and control.

3.5. Ash Content of Roots

Irrigation significantly ($p<0.01$) influenced ash content of roots as shown in Table 3. Full irrigation (100 % CWR) resulted in the lowest ash content of tubers (2.078 %) while 90 % CWR (4.195 %) and 70 % CWR (4.180 %) recorded the highest ash content. It can be stated that reduced irrigation resulted in increased ash content of tubers. Soil amendment had no significant influence on ash content of roots (Table 3). Soil amendment and irrigation interaction also had no significant effect on ash content of roots.

3.6. Protein Content

Irrigation did not significantly influence protein content of tubers. Protein content of tubers increased as water stress increased (Table 3) though differences were not significant. This observation is contrary to Indira and Wanda (2004) who indicated drought reduced total nitrogen content of roots and root yield. Though fertilization did not significantly influence protein content of roots manure and NPK application resulted in higher protein content of roots than the control. Manure and irrigation interaction significantly ($p<0.05$) influenced protein content of roots (Figure 3). Protein content increased with water stress for NPK. NPK and 100 % CWR yielded 6.27 % protein but increased to 9.17 % and 7.76 % protein as DI increased to 80 % CWR and 70 % CWR respectively. For CD and PM, protein content decreased as DI increased from 100 % CWR to 80 % CWR. However, further increase in DI to 70 % CWR increased protein content of roots.

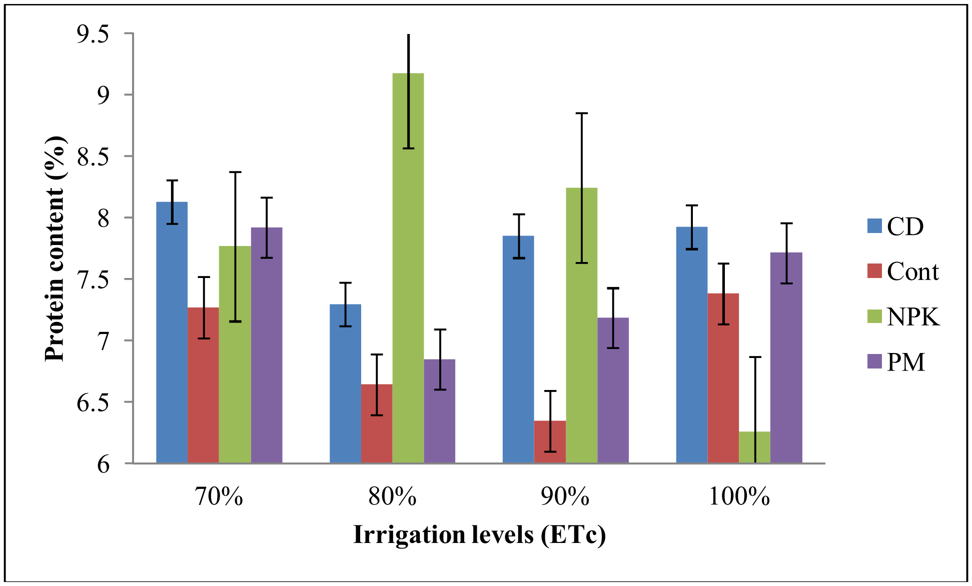

Figure 3: Interaction effect of CD, PM NPK and irrigation level on percentage protein content of OFSP roots (Lsd = 1.606; p<0.05)

3.7. Phenol Content (%)

From Table 3 irrigation had no significant influence on phenol content of OFSP roots at harvest. Hence reducing water application does not affect the phenol content of OFSP roots. However, soil amendment significantly influenced phenol content of roots at harvest. The ranking order of phenol content of roots was Control (1.628 mg kg^{-1}) > NPK (1.131 mg kg^{-1}) > CD (1.271 mg kg^{-1}) > PM (0.975 mg kg^{-1}). The Control produced significantly more phenol than NPK, CD and PM. Soil amendment and irrigation interaction significantly ($p<0.05$) influenced phenol content of roots as shown in Figure 4. For CD treatment, reduced irrigation (DI) increased phenol content. For NPK and Control, DI reduced phenol content of roots as shown in Figure 4. PM and irrigation interaction caused no significant change in phenol content as irrigation reduced from 100 % CWR to 70 % CWR.

Treatments				
Irr. % ETc	**% Ash**	**% Protein**	**Phenols (mg/kg)**	**% Fat**
70	4.180	7.784	1.227	1.618
80	2.956	7.487	1.286	1.511
90	4.195	7.422	1.221	1.348
100	2.078	7.340	1.277	1.988
F-test	**	NS	NS	NS
LSD	1.488	0.804	0.07095	0.6570
CV (%)	41.19	10.02	5.31	38.24
Fertilization				
PM	2.276	7.434	0.975	1.925
CD	3.511	7.812	1.271	1.490
NPK	3.446	7.860	1.131	1.196
Control	4.259	6.923	1.628	1.871
F-test	NS	NS	**	NS
LSD	1.488	0.804	0.07095	0.6570
CV (%)	41.19	10.02	5.31	38.24

Table 3: Main effects of irrigation, CD, PM and NPK on percentage ash, protein, phenols and fat content of OFSP
*Source: Author's Data (2015) Where NS = Not significant and ** = highly significant at p<0.01 probability level; CV = coefficient of variation; LSD = Least Significant Difference between means.*

3.8. Fat Content (%)

Irrigation and soil amendments and their interactions had no significant influence on fat content of OFSP roots after harvest (Table 3). However, application of 100 % CWR resulted in the highest fat content of 1.988 %. Similarly, PM application resulted in 1.925 % fat content which was the highest among the different soil amendments.

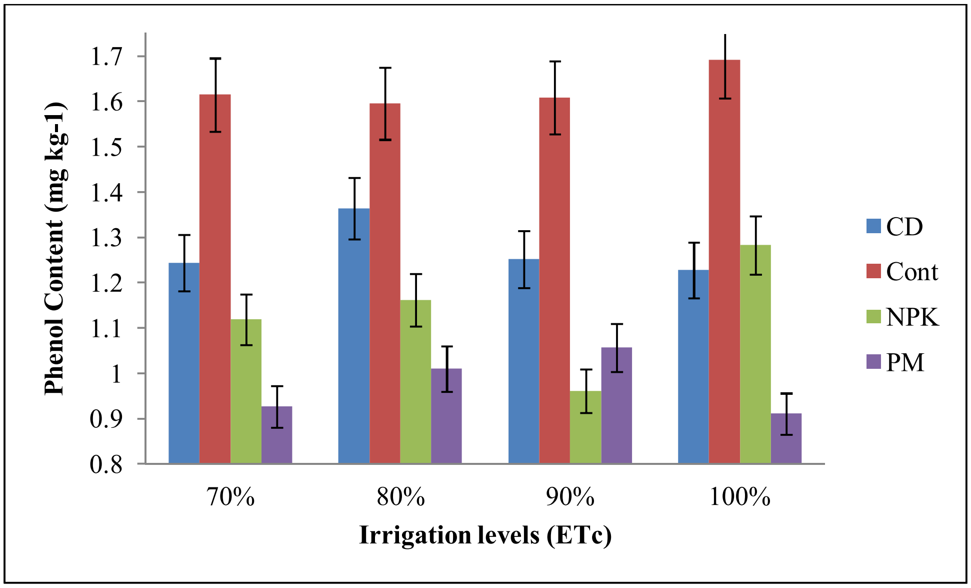

Figure 4: Interaction effect of CD, PM NPK and irrigation level on total phenol content (mg kg^{-1}) of OFSP roots (Lsd = 0.1417; p<0.05)

Treatments				
Irr. % ET$_c$	**% Ca**	**% Mg**	**Carotenoid (μg g^{-1})**	**P(μg/g)**
70	0.9452	7.784	9.94	66.63
80	0.9433	7.487	51.78	67.73
90	0.9535	7.422	37.37	68.88
100	1.0342	7.340	33.95	69.66
F-test	NS	NS	**	NS
LSD	0.09308	0.804	0.937	24.12
CV (%)	9.02	10.02	3.4	16.65
Fertilization				
PM	1.1070	7.434	19.83	67.56
CD	0.8675	7.812	40.77	75.46
NPK	0.9275	7.860	45.57	62.80
Control	0.9839	6.923	26.87	65.98
F-test	**	NS	**	NS
LSD	0.09308	0.804	0.937	24.12
CV (%)	9.02	10.02	3.4	16.65

Table 4: Main effects of irrigation, CD, PM and NPK on percentage Ca, Mg, P and total carotenoid content of OFSP
*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

3.9. Mineral Content

3.9.1. Phosphorus content (µg/g)

Phosphorus content was not responsive to irrigation, manure and their interactions as shown in Table 4. Though differences were not significant, DI decreased phosphorus content.

3.9.2. Calcium content (%)

Calcium content of roots was not responsive to levels of water application. Though differences were not significant water stress decreased calcium content. Fertilization, however, influenced calcium content significantly (p<0.05) as shown in Table 4. PM improved Ca content of roots by 12.5 % as compared to the control. However, CD and NPK application were not significantly better than the control.

3.9.3. Magnesium content (%)

Irrigation and manure had no significant influence on magnesium content of OFSP roots after harvest (Table 4). Though differences were not significant, water stress increased magnesium content of roots by 6.04 % from 7.34 % to 7.784 as irrigation decreased from 100 CWR to 70 % CWR.

3.10. Total carotenoid content (µg/g)

Irrigation significantly ($p<0.01$) influenced carotenoid content of OFSP roots after harvest (Table 4). Carotenoid content increased as irrigation decreased from 100 % CWR (33.95 $\mu g\ g^{-1}$) to 80 % CWR (51.78 $\mu g\ g^{-1}$). However, further reduction of irrigation to 70 % CWR resulted in lower carotenoid content of 9.94 $\mu g\ g^{-1}$. Thus, it can be suggested that DI at 80 % CWR produced the highest carotenoid content. Soil amendment also influenced carotenoid content significantly ($p<0.01$). The ranking order of carotenoid content of roots was NPK (45.57 $\mu g\ g^{-1}$) > CD (40.77 $\mu g\ g^{-1}$) > Control (26.87 $\mu g\ g^{-1}$) > PM (19.83 $\mu g\ g^{-1}$). Table 5 shows carotenoid content of tubers was significantly ($p<0.01$) influenced by the interaction of soil amendment and irrigation. Carotenoid content decreased with increasing water stress (DI) for NPK and Control. For NPK treatment, carotenoid content decreased from 49.63 $\mu g\ g^{-1}$ to 11.41 $\mu g\ g^{-1}$ as DI increased from 100 % CWR to 70 % CWR. For CD and PM treatments maximum carotenoid content of 73.91 $\mu g\ g^{-1}$ and 55.23 $\mu g\ g^{-1}$, respectively, was produced at 80 % CWR. Further increase in irrigation to 90 % ET_c or decrease to 70 % ET_c resulted in decrease in carotenoid content of roots.

Carotenoid content µg g⁻¹				
Treatments Fertilization				
Irr. % CWR	CD	Control	NPK	PM
70	13.64	8.01	11.41	6.7
80	73.91	18.72	59.24	55.23
90	64.24	13.76	62.01	9.49
100	11.28	66.98	49.63	7.92
F-test	**			
Lsd	1.875			

Table 5: Total carotenoid content of tubers as influenced by interaction between irrigation and soil amendments

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

4. Conclusions

Fibre content increased with water stress for PM and CD but not for NPK and Control. The interaction of irrigation and soil amendments also significantly influenced fibre content of roots. Reduced water application (DI) decreased sugar content of roots. Control produced more sugar and starch than NPK, CD and PM. Irrigation and soil amendment interaction significantly influenced sugar content of roots. Sugar content of tubers from NPK amended plots decreased as irrigation decreased from 100 % to 70 % ET_c. Deficit irrigation did not influence starch and phenol content of tubers. Soil amendments significantly influenced starch and phenol content of OFSP root. Irrigation and soil amendments interaction also significantly influenced starch contents of tubers after harvest. Starch content of roots decreased as irrigation decreased for CD, PM and Control. On the contrary sugar content of roots increased as water stress increased from 100 % CWR to 70 % CWR for NPK. Soil amendment and irrigation interaction significantly ($p<0.05$) influenced phenol content of tubers. Phenol content of roots increased as water stress increased for CD. Irrigation and soil amendments had no significant influence on fat content of OFSP roots after harvest. Irrigation and soil amendment significant ($p<0.01$) influenced carotenoid content of OFSP roots. Carotenoid content increased as deficit irrigation increased from 100 % to 80 % CWR. NPK treatments gave the highest carotenoid yield. Carotenoid content decreased with decreasing irrigation for NPK and Control. For CD and PM treatments maximum carotenoid yield was produced at 80 % CWR.

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