*Journal of Scientific Research & Reports*
*8(6): 1-7, 2015; Article no.JSRR.5522*
*ISSN: 2320-0227*

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# Yield and Storage Characteristics of White Yam (*Dioscorea rotundata* Poir) as Influenced by Fertilizer Application and Time of Harvesting in Forest Zone of Ghana

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***Authors' contributions***

*This study was a collaborative work among the three authors. All authors were involved in concept development, experimental design, analysis of data, interpretation of results, literature searches and making inferences and final write up. Author YA had an additional task of collecting field data. All authors agree with the content and substance of the final manuscript.*

***Article Information***

DOI: 10.9734/JSRR/2015/5522
Editor(s):
(1) Ana Ribeiro-Barros, Biotrop Center - Environment, Agriculture and Development, Tropical Research Institute (IICT), Oeiras, Portugal.
(2) Lesław Juszczak, University of Agriculture in Krakow, Poland.
Reviewers:
(1) Anonymous, Babcock University, Nigeria.
(2) Anonymous, Universidad de Córdoba, Colombia.
Complete Peer review History: http://sciencedomain.org/review-history/10645

***Original Research Article***

***Received 25th May 2013***
***Accepted 30th May 2015***
***Published 23rd August 2015***

## ABSTRACT

A field trial was conducted at the CSIR-Crops Research Institute (CRI) experimental fields to evaluate the effects of organic and inorganic fertilizers, and time of harvesting on the yield and quality of white yam (*Dioscorea rotundata*). The experiment was a 4x3 factorial arranged in a Randomised Complete Block Design (RCBD) with three replications. The treatments consisted of four fertilizer rates [(i) No fertilizer (ii) 4t poultry manure (PM) per hectare (iii) 300 kg NPK 15:15:15/ha (iv) 2 t poultry manure + 150 kg NPK 15:15:15/ha and three harvesting times [(i) milking at 20 weeks after planting (WAP) (ii) milking at 24 WAP and (iii) harvesting at 32 WAP]. The combined application of organic and inorganic fertilizer gave significantly higher (P=.05) total yield

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of yam than their sole applications. All treated plots had higher (P=.05) yields than the control. The combination of PM+NPK gave higher number of tubers of 2.12 per stand. Tuber length of 37.9 cm was significantly higher (P=.05) in PM treatment than 29.23 cm for the PM+NPK amended treatment. The study also revealed significant tuber weight loss of 23.8%, 19.0% and 16.7% for PM, PM+NPK and the control respectively, over a three month storage period. Tuber weight was 36% and 41% higher at 32 WAP than at 24 and 20 WAP, respectively. Higher rotting rates were recorded under PM+NPK amended treatments compared to the other amended treatments and the control.

*Keywords: Yams; poultry manure; quality; fertilizer; harvesting.*

## 1. INTRODUCTION

Yam belong to the genus *Dioscorea* which consists of about 600 species of which only six are important as staples in the tropics [1,2]. Yam is a multispecies crop important for food, income and socio-cultural activities [3]. The Guinea yams (*Dioscorea rotundata* Poir and *D. cayenensis* Lam.) of African origin, account for most of the yam production in Africa. . About 80% of the principal commercial yam produced in Ghana is *D. rotundata* [4].

*D. rotundata* is able to produce two separate products in one season. For early maturing varieties of *D. rotundata*, harvesting of tubers about two-thirds into the growing season without destroying the root system (known as "milking") provides early yams for home consumption and market, and allows the regeneration of fresh and small tubers from base of vine [5] used as planting materials the following season.

Yield increases of 10.7 and 15.6 percent were obtained in 1980 and 1981 respectively with the application of 35 kg N/ha to white yam (D. *rotundata*). Phosphorus and potassium had no effects on yield and none of the three had effect on starch content [6]. In 2008, Ghana exported nearly 21,000 metric tons of yam valued at 14.89 million USD [7].

The use of inorganic fertilizer is strongly believed by farmers to be a major factor causing rot of yam tubers in storage [8]. As a consequence, some yam farmers refuse to use inorganic fertilizer in the production of seed yams meant to be stored beyond six months after harvest [8]. Studies carried out in Côte d'Ivoire showed that fertilization, while increasing the unit weight of the tubers also led to losses during storage, depending on the species. Large tubers, which respond well to fertilization, are preserved better in the case of *D. alata*, while for *D. cayenensis-rotundata* it is the opposite [9].

## 2. MATERIALS AND METHODS

### 2.1 Experimental Site

The experiment was conducted on the research field of the CSIR-Crops Research Institute (CRI) at Fumesua, Kumasi from April to December 2010, located within the humid forest agro-ecological zone of Ghana. The station has a total annual rainfall of 1345 mm/year and mean annual temperature ranges from 22 - 31ºC.

### 2.2 Treatments and Experimental Design

The trial was conducted using a 4x3 factorial experiment arranged in a Randomized Complete Block Design (RCBD) with 3 replications. The two factors studied were, (i) Rate of fertilizer application (poultry manure and NPK, 15:15:15) and (ii) Time of milking.

The fertilizer treatment (Factor A) consisted of four levels namely:

> F1= Control (No fertilization), F2 = Organic fertilizer only (poultry manure) at 4 t/ha, F3 = Inorganic fertilizer only (i.e. NPK 15:15:15 at 300 kg/ha i.e. 45 kgN, 19.80 kgP, 37.35 kgK), F4 = Inorganic fertilizer ($^1/_2$ rate – 150 kg/ha i.e. 22.5 kgN 9.9 kgP, 18.7 kgK) + organic fertilizer ($^1/_2$ rate – 2 t/ha). The time of milking treatment (Factor B) consisted of three levels namely; M1 = First Milking at 20 weeks after planting (WAP), M2 = Second Milking at 24 weeks after planting (WAP), M3 = Zero milking or harvesting at senescence/physiological maturity.

### 2.3 Land Preparation and Soil Analysis

The experimental field was tractor ploughed and mounds made 1 meter apart. Soil samples were randomly taken before planting from five (5) different spots across each block from a depth of 0-15 cm and 15-30 cm. Representative samples were bulked, air-dried and sieved to pass through a 2-mm mesh. Each composite sample was analyzed separately for soil pH, total nitrogen (N), organic carbon, available P, and exchangeable K. Poultry manure was ashed before chemical analysis to determine the concentration of the major nutrient elements of nitrogen (N), phosphorus (P) and potassium (K).

## 2.4 Data Collection

Three harvesting regimes were imposed. Two milking treatments were conducted at 20 and 24 WAP when the tubers were still at economic maturity stage (when tubers were well developed for consumption) and at physiological maturity (32 WAP) when almost all the yam plants had completely senescence. Two middle rows were harvested from each plot for yield determination. The treatments that were milked were harvested twice and these amounted to the total yield for those plots. The tuber fresh weight per plot was measured.

The yield per plot was determined for all treatments at each harvest. This was extrapolated to kilogram per hectare. The total yield per plot for the treatments that were harvested twice was determined by summing the yield at milking and that at final harvest. The yield of the “unmilked” plots was determined at senescing of the yam vines. The mean number of tubers per stand and average tuber weight per treatment were determined at each harvest. Five average tubers per treatment were used to determine mean diameters of tubers using venier calipers while their lengths and circumference were measured with a tape measure.

Weight loss (%) = Difference between initial and final weights at end of 3 months of storage x 100 divided by Initial weight of tubers at the start of storage

## 2.5 Data Analysis

The data was subjected to the analysis of variance (ANOVA) technique using Genstat statistical package (Discovery Edition 3) and mean values compared using the Least Significant Difference (LSD) at P=.05.

## 3. RESULTS

The physical and chemical properties of the top soils (0-30 cm) of the experimental site are presented in Table1. Available phosphorus of 4.84 mg/kg and soil total nitrogen of 0.12% were low [10]. Exchangeable potassium was 0.19cmol/kg and was classified as moderate [11]. Soil pH was strongly acidic (4.72) and organic carbon percentage was low (1.03%) across the field.

The nutrient content of the poultry manure on dry matter basis was relatively low; in the range of 4.06%, 1.65% and 3.01% for N, P, and K respectively. Poultry manure according to [12] has about 11% N, 11% P and 5% K.

Table 2 shows the effect of fertilizer on tuber weight and weight loss of white yam during storage. Application of poultry manure led to significant weight loss during storage compared to the no fertilization and combined application of PM and NPK. However, other treatment means were not significantly different from one another. Time of harvesting significantly influenced mean tuber weight loss during storage. Weight loss under storage was significantly higher when yam was harvested at 20 WAP compared to 24 and 32 WAP which were not significantly different from each other.

Tuber rot score at storage was greatest in the combined organic and inorganic fertilizer treatment, which was significantly higher than all other treatment effects. All other treatment differences were statistically similar. Harvesting at 24 WAP gave the greatest tuber rot score, which was significantly higher than the other treatment effects.

Tuber weight at harvest among all fertilizer treatments was not significantly different (*P*=.05) from one another. Harvesting at 32 WAP, however, produced the greatest tuber weight, which was significantly higher than the other treatment effects.

Table 3 shows fertilizer application and time of harvesting did not significantly (*P*=.05) affect tuber length and tuber girth. The effect of half rates organic and inorganic fertilizer treatment on number of tubers per stand was, however, significantly higher (*P*=.05) compared to the control treatment. There was significant interaction effect of treatments on tuber length.
Total tuber yield was statistically different (*P*=0.01) among the fertilizer treatments (Table 4). Application of half rates (i.e. 2 t/ha + 150 hg/ha) of PM+ NPK recorded the highest yield of 38.97 t/ha, which was significantly higher than the control treatment effect value. All other treatment means were statistically similar. Time of milking did not affect milked tuber yield.

Seed yam yield was significantly (*P*=.05) affected by fertilizer application (Table 4). The effects of the half organic and inorganic fertilizer treatments and NPK treatment only were not significantly different from one another, but either effect was significantly higher than the control treatment effect. Seed yam yield from the poultry manure only treatment was significantly lower than that of the half rates of the organic and inorganic fertilizer treatment. Seed yam yield was significantly (*P*=.05) affected by time of milking. Milking at 20 WAP produced seed yam that was significantly higher than milking at 24 WAP (Table 4).

## 4. DISCUSSION

From Table 2, the application of fertilizer had significant ($p<0.05$) effect on the percentage weight loss of white yam during the 3-month storage period. Application of PM led to 23.8% tuber weight loss, which was significant (*P*=.05) compared to 16.7% of the control treatment and 19.0% of PM+NPK. It was however, not significantly different from sole NPK treatment (*P*=.05). Optimum fertilizer combination would reduce weight loss of yam under storage [13]. Weight losses of up to 25% of initial weight of tuber during the first 5 months of storage have been reported by [14]. Tuber weight losses are basically due to rotting and physiological activities of the tubers [15]. There was significant difference (*P*=.01) in weight loss of yam when it was harvested at 20 WAP (23.5%) compared to 24 (19.5%) and 32 WAP (16.45). There was highly significant (*P*<.001) interaction effect of fertilization and time of harvest on tuber weight loss observed.

The influence of harvest time on tuber weight (kg) of yam was, however, significant (*P*=.01). Tuber weight of harvest at 32 WAP was 36% and 41% higher than harvesting at 24 and 20 WAP respectively. This means that yam tuber undergoes dry matter accumulation during the

**Table 1. Physical and chemical properties (0-30cm) of the experimental site and poultry manure applied on trial**

| Soil properties | 0-15 cm | 15-30 cm | Poultry manure | Manure |
|---|---|---|---|---|
| Organic carbon (%) | 1.19 | 0.87 | 9.67 | |
| Organic matter (%) | 2.06 | 1.49 | 16.67 | |
| Total Nitrogen (%) | 0.13 | 0.11 | 4.06 | |
| Potassium (K) (cmol kg-1) | 0.23 | 0.15 | 3.01 | |
| Available P(mg/kg) | 8.44 | 1.24 | 1.65 | |
| pH ($H_2O$) | 4.84 | 4.6 | | |
| Sand (%) | 84.3 | 80.97 | | |
| Silt (%) | 3.9 | 4 | | |
| Clay (%) | 11.77 | 15.1 | | |
| Textural class: | Sandy loam | | | |

**Table 2. Tuber weight loss and rot score during 3 months storage**

| Treatment | Weight loss of tuber (%) (3 mths) | Mean tuber wt at harvest (kg) | Rot score of tubers in storage (%)* |
|---|---|---|---|
| **Fertilization (A)** | | | |
| No fertilizer | 16.7b | 1.35ab | 8.0c |
| Poultry manure | 23.8a | 1.37a | 16.0b |
| NPK 15:15:15 (300kg/ha) | 19.8b | 1.22c | 16.8b |
| PM + NPK (half rates) | 19.0b | 1.24b | 35.3a |
| Lsd (0.05) | 4.5 | 0.12 | 12.0 |
| **Milking (B)** | | | |
| 20 WAP | 23.5a | 1.03c | 14.9b |
| 24 WAP | 19.5ab | 1.11b | 30.1a |
| 32 WAP | 16.4b | 1.75a | 12.1b |
| Lsd (0.05) | 4.0 | 0.26 | 10.4 |
| CV (%) | 23.2 | 23.9 | 64.4 |

** Data was Arc transformed before analysis;*
*NB: Figures followed by similar letters are not statistically significant at P=.05*

**Table 3. Effect of fertilizer and time of harvest on yield components of yam**

| Treatment | Number of tubers | Tuber length (cm) | Tuber girth (cm) |
|---|---|---|---|
| **Fertilization (A)** | | | |
| No fertilizer | 1.68 | 33.3 | 22.4 |
| Poultry manure (4 t/ha) | 1.89 | 35.2 | 23.4 |
| NPK15:15:15 (300 kg/ha) | 1.92 | 33.1 | 23.2 |
| PM + NPK (half rates) | 2.12 | 32.9 | 22.1 |
| Lsd (0.05) | 0.43 | Ns | Ns |
| **Milking (B)** | | | |
| 20 WAP | 2.05 | 32.2 | 22.7 |
| 24 WAP | 1.81 | 34.9 | 23.3 |
| 32 WAP | 1.85 | 33.8 | 22.3 |
| Lsd (0.05) | Ns | Ns | Ns |
| CV (%) | 23 | 10.4 | 10.6 |

*NB: No significant interaction effects of treatment values at P=.05*

**Table 4. Effect of fertilizer and milking time on milked tuber yield, seed yam and total tuber yield of *D. rotundata* (t/ha)**

| Treatment | Yield of milked yam) (t/ha) * | Yield of seed yam (t/ha) | Total tuber yield (t/ha) |
|---|---|---|---|
| **Fertilization (A)** | | | |
| No fertilizer | 18.57b | 9.91b | 28.48c |
| Poultry manure (PM)(4 t/ha) | 23.86ab | 10.65ab | 34.50ab |
| NPK 15:15:15 (300 kg/ha) | 23.26ab | 11.87ab | 39.73ab |
| NPK + PM (half rates) | 27.86a | 14.44a | 42.30a |
| Lsd (0.05) | 7.29 | 3.23 | 5.23 |
| **Milking (B)** | | | |
| 20 WAP | 21.60 | 16.66a | 38.28a |
| 24 WAP | 25.22 | 6.77b | 31.93b |
| 32 WAP (no milking) | - | - | 29.77b |
| Lsd (0.05) | Ns | 2.28 | 4.36 |
| CV (%) | 30 | 26.5 | 18.2 |

**significant interaction effects of treatment values at P=.05*

later stages of development resulting in reduced moisture content. This observation is similar to earlier report by [16,17].

There was high significant difference (p<.001) in percentage rot of yam as a result of fertilizer application (Table 2). Chukwu et al. [8] reported that some yam farmers would not use inorganic fertilizer in the production of seed yams meant to be stored beyond six months after harvest. Percentage rot difference was not significant amongst sole PM, NPK and the control (*P*=.05). However, Asadu [18] reported that tubers grown with organic manure stored longer than those treated with chemical fertilizer in the field. High rotting rate could also be due to the type of cultivar. Gray [19] observed “pona” to be more perishable and susceptible to rotting under storage compared to other varieties of *D. rotundata* species.

There was highly significant difference (P=.01) in rot (%) of tubers when yam was harvested at 24 WAP compared to harvesting at 20 and 32 WAP. This could be attributed to high humidity and temperatures at that time which could be predisposing factors.

The results (Table 3) indicate that the application of fertilizer PM+NPK on yam did give significantly higher number of tubers (2.12) per stand compared to the control (1.68) (P=.05).

Time of harvesting did not make significant difference in the mean number of tubers per stand. This is expected as tuber initiation and development precede harvesting. No significant interaction effect was observed with respect to the number of tubers per stand.

The interaction effect of harvesting at 20 WAP and organic fertilizer (PM) application on tuber length (37.93 cm) was significantly higher than that of PM + NPK (29.23 cm). Interaction effects of harvesting time at 24 WAP with PM+NPK treatment was also found to influence tuber length (38.33 cm) significantly compared to 32.20 cm of the control at the same harvest time. Contrary, [20] reported longer tubers under yam without fertilizer than fertilizer treatments. The period between the first and final harvest (20-32 WAP) recorded insignificant changes in tuber girth between the various harvest times. This is probably because tuber growth had reached the gradual phase but it continues to accept dry matter accumulation [16].

The fertilizer treatments had significantly higher tuber yields than the control (no fertilizer) treatment. Yield from PM +NPK treatment was significantly higher (p=<.001) than the PM, NPK and no fertilizer treatment effects. This could be due to the early nutrients supply by the NPK and the gradual release of nutrients by the poultry manure [21]. The highest yield (38.97 t/ha) was obtained from the PM+NPK treatment while the lowest (27.42 t/ha) was from the control treatment. Similar results were obtained when 300 kg of NPK (15:15:15) was applied in fertilizer studies in white yam [22,23]. The results also indicated that the time of harvest treatment made significant difference in yield of white yam ("pona"). Harvesting at 20 WAP (Table 4) gave the highest yield of 38.28 t/ha. This was found to be significantly higher (p<.001) than harvesting at 32 WAP (29.77 t/ha) and a better option seed yam production. The yams harvested at 32 WAP were basically ware tubers, which are not very good for seed yam. The higher total yield for the 20 WAP harvest treatment could be attributed to the milking.

There were no significant interaction effects on tuber yield. During both harvestings PM+NPK fertilizer treatment gave significant yield difference compared to the no fertilizer treatment (Table 4). It was realised that harvesting at 20 WAP gave seed yam yield of 16.66 t/ha which was 60% higher than seed yam yield at 24 WAP milking (6.77 t/ha). This observation was similar to findings made by [24] that milking was good at 5-6 months after planting to regenerate seed yam.

## 5. CONCLUSION

The application of PM+NPK (2 t/ha +150 kg/ha) proved to be the best as it recorded the highest yield of 42.3 t/ha while milking yam at 20 WAP also gave the highest yield of 38.28 t/ha. Application of sole PM resulted in tuber weight loss of 23.8% while PM+NPK fertilizer application recorded high tuber rot of 35.3% under storage. Even though application of fertilizer NPK is recommended for ware yam production at physiological maturity (32 WAP), harvesting *D. rotundata* at 20 weeks after planting gave the highest quantity of seed yam.

## ACKNOWLEDGEMENT

The authors wish to thank the West Africa Agricultural Productivity Programme (WAAPP) for providing financial support for this research work.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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