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Effect of poultry manure and NPK on yield and storability of orange-and white-fleshed sweet potato [*Ipomoea batatas* (L.) Lam]

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Sweet potato [*Ipomoea batatas* (L.) Lam] is amongst the most commonly grown root crops in Sub-Saharan Africa. Comparatively,orange-fleshed cultivars of sweet potato are richer in beta carotene, a precursor to dietary vitamin A than white-fleshed ones. In spite of their health benefits, yields have been low in Africa due to low soil fertility. Studies were therefore conducted to determine the effect of amending soils with poultry manure and NPKmineral fertiliser on the yield and storability of orange-fleshed (OFSP) and white-fleshed sweet potato (WFSP). The field experiment was 3x2 factorial laid out in a randomised complete block design. Factors were fertiliser at two levels (poultry manure at 8.6 t/ha and NPK at 200 kg/ha) and control (no soil amendment) and sweet potato cultivars at two levels (orange-flesh and white-flesh). The highest yield of 12.4 t/ha was obtained from white-fleshed sweet potato (WFSP) to which poultry manure was applied compared with 4 t/ha for OFSP. Poultry manure treated plots generally produced the highest average number of tubers per mound (9) and average unit storage tuber weight of 0.64 kg. In orange-fleshed sweet potato (OFSP) tubers from plants treated with poultry manure and NPK 30% showed signs of rot during storage whereas 80-100% of tubers in other treatments were recorded with rots within 18 weeks. Tubers from orange-fleshed sweet potato plants treated with NPK had significantly lower levels of weight loss (25%) compared to other treatments. From this study, it can be concluded that although WFSP recorded higher yield under the poultry manure, but storage losses of up to 80% could make WFSP less available during the lean season. The OFSP tubers on the other hand had better storage-life irrespective of whether treated with poultry manure or NPK. Therefore, the cultivation of OFSP with the application of poultry manure or NPK, but preferably the former could extend food availability well into the lean season.

Key words: Sweet potato, poultry manure, fertiliser, storability.

INTRODUCTION

Sweet potato [*Ipomoea batatas,*(L.) Lam] is among the world's important, versatile, and underexploited food crops and presently ranked the seventh most vital food crop world-wide (CIP, 1999). Sweet potato is considered to be the most widely grown root crop in Sub-Saharan Africa, covering an estimated 2.1 million hectares with an annual estimated production of 9.9 million tonnes of roots (FAO, 1999; Stathers et al., 2005). The Asian continent

(China) is estimated to account for 80% of world sweet potato production, Africa 15% and the rest of the world making about 5% (Collins, 1998).

Notwithstanding Africa's comparatively small share of production comparedwith China, some African countries where it is a staple food such as Burundi, Rwanda and Uganda are among those with the greatest sweet potato per-capita production (Anonymous, 2010). Due to the increasing awareness of the importance of sweet potato in managing vitamin A deficiency, it is becoming a crucial food security crop among the vulnerable in Ghana, though it has been neglected for many years (IFAD, 2004). Sweet potato varieties grown by farmers throughout Sub-Saharan Africa, especially Eastern and Southern Africa are white or cream-fleshed, and contain little or no beta carotene. This may account for the observation that many rural people in these same areas, particularly children, suffer from vitamin A deficiency (Stathers et al., 2005): beta carotene is a precursor of vitamin A.

On the other hand, 80 g of locally bred orange-fleshed sweet potato varieties or those introduced from other parts of the world contain sufficient beta-carotene that provides 66% of recommended dietary allowance (RDA) of vitamin A, which can play an important role in eliminating vitamin A deficiency (Stathers et al., 2005, Bengtsson et al., 2009). Evidence exists that the orange-fleshed varieties may also have a major impact on other diseases, such as limiting the transmission of the HIV/AIDS virus from pregnant mothers to their babies, anaemia (low amount of red blood cells) and malaria (Stathers et al., 2005). An Orange-fleshed variety, rich in beta-carotene has been identified as the least expensive, year round source of dietary vitamin A and plays a vital role in boosting household nutrition (Stathers et al., 2005). Sweet potato also has higher energy efficiency ratio than the cereals when produced in a non-mechanisation situation (Woolfe, 1992).

Unfortunately in Africa the annual average rate of improvement in yields has beendecreasing, and in some cases yields have actually decreasedby (for example, Uganda) 1.9% (CIP, 1999). Average yields of 5 tonnes/ha in Africa is low compared to those of 14 tonnes/ha in other developing regions of Asia (that is, China) (CIP, 1999; Stathers et al., 2005). The long-term challenge for sweet potato development in sub-Saharan Africa is to increase production per unit area; yield has not only remained static but is below the continental average (Stathers et al., 2005).

It has been reported that the application of fertiliser is one of the most important inputs for increasing the productivity of crops (Ali et al., 2009). Fertiliser application may increase yield of sweet potato by at least 32% under poor soil conditions and nearly double (83.93%) the yield under better soil conditions (Stathers et al., 2005). However, there is also a challenge to improve storage potential of the roots. It has also been reported that fertiliser application affects the storage behaviour and quality of sweet potato (Data et al., 1989). For example, there have been claims by Eze and Orkwor (2010) that some root and tuber crops grown with chemical fertiliser are more susceptible to pathological deterioration and that tubers produced with organic manure store better and have a longer shelf life. Organic fertilisers also provide all the important nutrients needed by the crop (Stathers et al., 2005). Again, increasing production and utilisation of sweet potato is often considered as a means to improve incomes and food security among the poorer segments of the rural population since production of the crop is concentrated in these areas (CIP, 1999).

For the purpose of establishing optimum yield through the application of manure or mineral fertilizer, this study therefore sought to determine the performance of organic and inorganic fertiliser usage on yield and storability of orange- and white-fleshed sweet potato.

MATERIALS AND METHODS

Experimental site

The experiment was carried out at the Faculty of Agriculture of the University for Development Studies, Nyankpala, about 16 km west of Tamale in Ghana. The site lies within latitude 09°25' 41" N and longitude 0°58' 42" W at an altitude of 185 m above sea level (SARI, 2010).

Ecologically, the experimental area is within the Northern Guinea Savannah Agricultural zone of Ghana. The rainfall is unimodal of about 1000-1100 mm unevenly distributed from April to October. The mean monthly rainfall recorded in 2010 cropping season from February to September was 149 mm with August recording the highest value (330.8 mm). The site used for this experiment had been cropped to maize in the previous season. The soil at the site is slightly acidic and very low in N, P and K (Abubakari et al., 2011)

Experimental design

The field experiment was a 2 x 3 factorial laid out in a randomized complete block design (RCBD) with three replications per treatment. Each replication was made up of six experimental plots measuring 4 × 4 m. A total land size of 434 m^2 was marked out (14 x 31 m) for the study. Alleys of 1 and 2 m were left between the plots and replicates respectively to prevent treatment drift to adjacent plots. The factor levels comprised two varieties of sweet potato namely; orange-fleshed sweet potato (OFSP) and white-fleshed sweet potato (WFSP) and two fertilizer types namely poultry manure and NPK) with a control (no fertiliser). There were six treatments each replicated three times. The sweet potato tubers harvested from this treatment were stored in a barn for 18 weeks and data on shelf-life recorded.

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Treatments

Two varieties combined with two levels of fertiliser and a control (no fertiliser) produced six treatments: OFSP without fertiliser (T1), OFSP with poultry manure (T2), OFSP with NPK fertiliser (T3), WFSP without fertiliser (T4), WFSP + poultry manure (T5) and WFSP + NPK fertiliser (T6).

Fertilizer application

Before planting, poultry manure (containing 3.7 ± 0.03 %, 0.94 ± 0.06 %, 2.7 ± 0.09 % of N, P,and K, respectively)was incorporated at a recommended rate of 8.6 t/ha two weeks before planting (County, 1996). The NPK (15-15-15) was also applied at a rate of 600 kg/ha (Woolfe, 1992) in the following order; one-third of the rate before planting, one-third at four weeks after planting and the remaining one-third was applied at eight weeks after planting.

Harvesting

Senescence of leaves and also cracking of mounds indicated maturity of the sweet potato. The OFSP were harvested when these signs manifested clearly at 16 weeks after planting (WAP) (that is, 112 days). The WFSP roots were harvested at 18 WAP (that is, 126 days after). During harvesting the vines of the sweet potato were removed with a cutlass to make it easier and also to avoid damage to the storage roots. Part of the stem (about 5cm) was still attached to the roots to prevent them from being damaged.

Data collection

Five plants of each treatment combination were randomly selected and tagged. Vine survival, vine length, leaf area index, number of branches, root weight and storage root length were recorded. The leaf area index wascalculated using this formula; Leaf Area= 0.56 x P x 6.20 where P= length x breadth of sweet potato leaves, 0.56 and 6.20 are constants which account for the irregularity of sweet potato leaves (Owudike, 2010).

Curing

One hundred and twenty healthy roots were selected for curing prior to storage in a well-ventilated room. Treatments were arranged in three replicates according to the treatment plan in the field. Sacks were laid down, covered with plywoodand old newspapers before placing the sweet potatoes on them. Dry and wet bulb thermometers were used in monitoring the temperature and relative humidity. The average temperature and relative humidity during curing were 25°C and 85%, respectively. After curing for seven days roots were taken to the barn for storage.

Storage barn conditions

The cured sweet potato tubers were stored in an improved, ventilated barn with rat-proof netting on the Nyankpala campus. The stored tubers were placed on wooden shelves. Dry and wet bulb thermometers were used in monitoring temperature and relative humidity twice daily at 10:00 am and 4:00 pm. The average temperature for the morning and evening were 27 and 34°C respectively, while the relative humidities were 49 and 42%.

Root storage and quality data

Tubers were weighed at two weekly intervals up to eighteen weeks during storage. Weight loss was determined as the difference between the initial weight and successive weights divided by the initial weight, and multiplied by 100 to get the percentage weight loss.

Weekly percentage weight loss = (Wp - Wc)/(Wp)*100.

Where, Wp= previous weight of the tuber and Wc= current or present weight of the tuber.

Sprouting and rotting of the tubers was also recorded at two weekly intervals. Percentage sprouting was obtained by dividing the number of roots with sprouts with the total number of tubers stored multiplied by 100. Also percentage rot was obtained by dividing the numbers of the tubers rotted with the total number of tubers stored multiplied by 100 (Figure 6). Thus,

$$\% \text{ Sprout/rot} = \frac{\text{Number of tubers sprouted/rotted}}{\text{Total number of tubers}} \times 100$$

Data analysis

Data collected were subjected to the Analysis of Variance with GenStat (Discovery Edition, 2011). Where significant differences were observed among treatments, SED (5%) was used to generate error bars for the graphs.

RESULTS AND DISCUSSION

Plant survival and vine length

The white-fleshed sweet potato vines planted survived (90.3%) significantly better (P<0.008) than the orange-fleshed sweet potato (57.3%) (Figure 1). This indicates that WFSP may have inherently better resistance to planting shock than OFSP. This is consistent with the report that survival of sweet potato vines is more related to the conditions in the agro-ecological zones and that the most common cause of planting material failing to take off is drought (Ebregt et al., 2004; Ndolo et al., 2007).

Vines of orange-fleshed sweet potato plants treated with poultry manure were significantly longer than OFSP plants treated with NPK at week 10 (P<0.005), 12 (P<0.029) and 14 (P<0.005) (Figure 2). This may have been due to the high nitrogen content in poultry manure (3.37%) with a potential to supply about 240 kg of N over a longer period compared to NPK which could supply about 30 kg of N within a short period of time (Owudike, 2010).

Tuber yield (kg/ha)

White-fleshed sweet potato plants treated with poultry manure significantly out yielded (12,381 kg/ha) all other treatments. In earlier research work, the yield of potato was also found to be influenced by poultry manure (Agbede and Adekiya, 2011).

Varietal effect was highly significant (p<0.001) with the white-fleshed sweet potato producing heavier storage

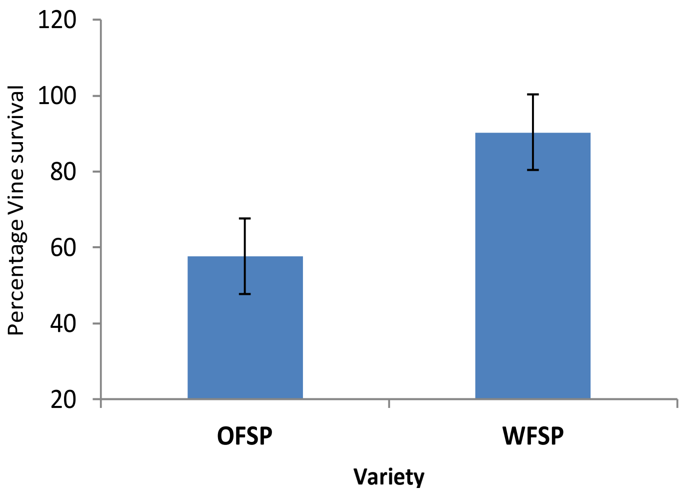

Figure 1. Vine survival of orange-fleshed (OFSP) and white-fleshed sweet potato (WFSP) at 2 weeks after planting (WAP).

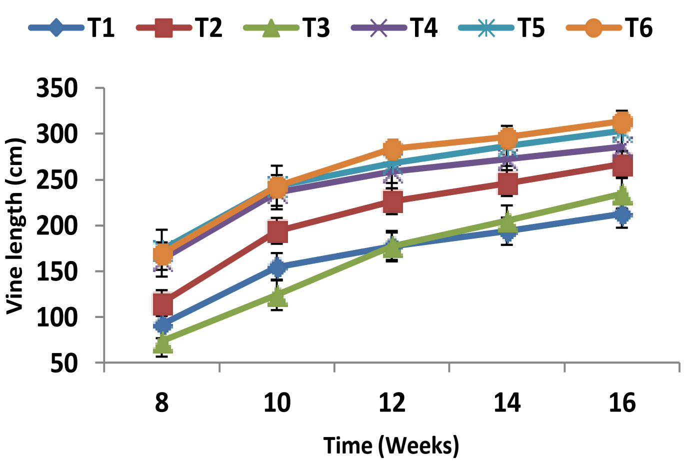

Figure 2. Effect of poultry manure and NPK on vine length. T_1= Control + OFSP, T_2= PM + OFSP, T_3= NPK + OFSP, T_4= Control + WFSP, T_5= PM + WFSP, T_6= NPK + WFSP.

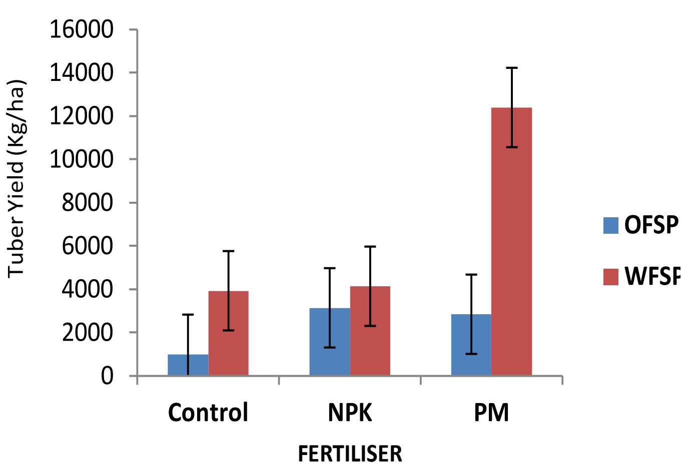

Figure 3. Fertiliser effects on tuber yield.

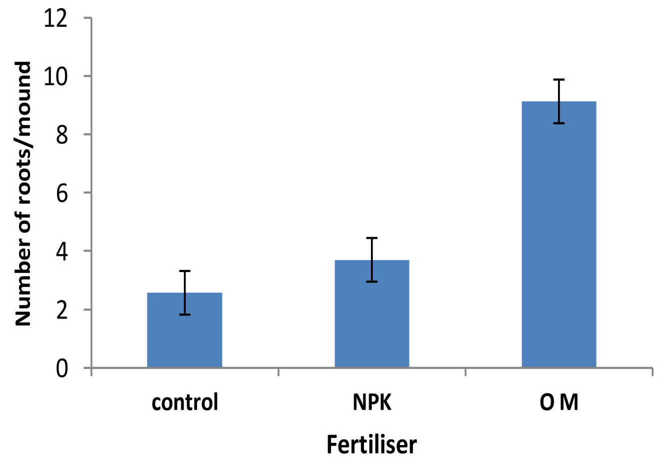

Figure 4. Effect of treatments on the number of tubers per mound.

roots than the orange-fleshed sweet potato (Figure 3). Storage roots vary in size according to the cultivar, the type of soil where the plant is grown, and other factors (Huaman, 1992). Although production of orange-fleshed sweet potato (OFSP) varieties is being promoted, they are reported to be unpopular with farmers in some parts of Africa such as Kenya because of their poor adaptability, less yield, smaller roots and low root dry matter content (Ndolo et al., 2007). The yield obtained here for WFSP was only 4 ton lower than the national average of 16 ton obtained in Ghana for 2010 (FAOSTATS, 2010). The higher response of WFSP could have been due to its better N use efficiency. The poultry manure yielded better because the 6 ton of manure supplied about 222 kg of N compared to 90 kg of N supplied by the 600 kg of NPK

Number of tubers per mound

Plots treated with poultry manure produced more tubers than those to which NPK had been applied (Figure 4). This confirms results of other field trials that showed that sweet potato yields were higher and more consistent where organic manure rather than inorganic inputs were applied (Hartemink, 2003).

Although NPK application decreased the number of tubers, average size of tubers was larger and more uniform compared with the poultry manure and control treatments. This is in line with the findings that inorganic fertilizer gives large roots while the number of tubers harvested decreases (FAO, 2005).

Weight loss, sprouting and rotting

Weight loss of stored tubers was affected by fertiliser application and the type of cultivar. Orange-fleshed sweet potato tubers treated with mineral fertiliser had the signifi-

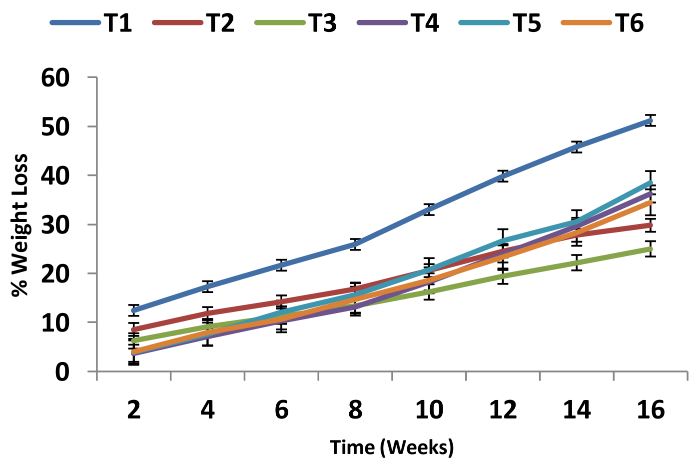

Figure 5. Effect of treatment on weight loss of storage roots.T_1= Control + OFSP, T_2= PM + OFSP, T_3= NPK + OFSP, T_4= Control + WFSP, T_5= PM + WFSP, T_6= NPK + WFSP.

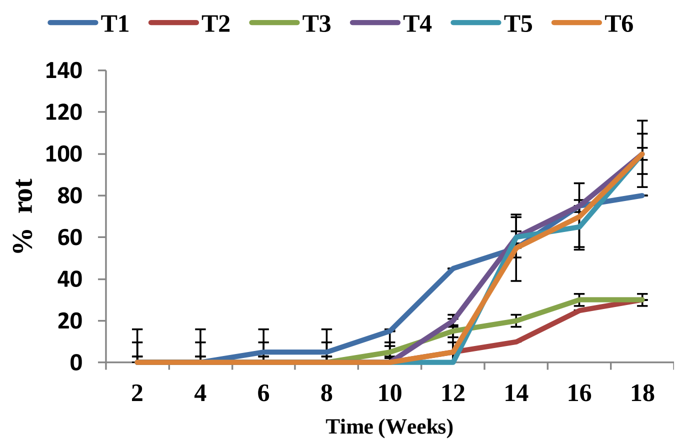

Figure 6. Influence of treatments on sweet potato rot.T_1= Control + OFSP, T_2= PM + OFSP, T_3= NPK + OFSP, T_4= Control + WFSP, T_5= PM + WFSP, T_6= NPK + WFSP.

cantly lowest (P<0.001) percentage weight loss compared with other treatments. OFSP tubers amended with NPK lost the least weight of25% from 10^{th} to 16^{th} week. Unfertilised OFSP tubers had the highest percentage weight loss (51.2%) (Figure 5). Earlier reports indicated that sweet potato tubers from unfertilized plants exhibited the highest percentage weight loss, severity of decay, and degree of shrivelling (Data et al., 1989). This observation suggests addition of an N source to soil reduces weight losses in potatoes. A similarbut more pronounced observation was made with tuber rot in OFSP which was much lower with poultry manure or NPK fertilization (Figure 6). Fertilizer treatment could have increased the water content of roots and thus slowing down weight loss and tuber rot under well ventilated conditions.

The highest percentage sprout (95%) was found in white-fleshed sweet potato roots from plants treated with organic manure. However, the difference between NPK and control plants roots was not significant. By the 18^{th} week all tubers belonging to T4 (WFSP without fertilisation), T5 (WFSP + PM) and T6 (NPK + WFSP) had rotted completely. About 80% of tubers belonging to T1 (OFSP without fertilisation) were rotten by the 18^{th} week (Figure 6). Tubers of T2 (OFSP + PM) and T3 (OFSP + NPK) recorded the lowest rot of about 25%.

Previous studies have already examined availability and cost of organic amendments and concluded that poultry manure is widely available in Ghana and relatively cheaper than NPK (Agyarko et al., 2014).

Conclusion

WFSP gave a better response to poultry manure than OFSP and the control treatments in terms of vine survival, vine length number of tubers and tuber yield. Poultry manure improved yield better than NPK. OFSP in poultry manure and NPK amended soils recorded the lowest tuber rots and weight losses. The OFSP tubers hand had better storage-life irrespective of whether treated with poultry manure or NPK. Therefore, the cultivation of OFSP with the application of poultry manure or NPK, but preferably the former could extend food availability well into the lean season.

Recommendations

It is recommended that poultry manure should be adopted for the cultivation of sweet potato since it is widely available, cheaper and has a huge potential to improve yield. WFSP may be adopted by farmers, but they should be processed immediately to avoid the large tuber rots and weight losses associated with it. For extended availability of fresh tubers into the lean season, orange-fleshed sweet potato cultivated with the application of poultry manure should be encouraged since it has longer storage life and better storage qualities than white fleshed sweet potato.

Conflict of interests

The authors have not declared any conflict of interest.

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