Producing White Yam for Export: The Influence of Seed Sett Size and Planting Density on Tuber Size

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Abstract
The study was conducted to evaluate the effect of seed sett sizes and planting density on the tuber size and yields of yam. The treatments were arranged in a split-split plot design with two premium Dioscorea rotundata varieties (Pona and Dente) as main plot. Seed sett sizes (farmers' sett size 350 g, half farmers' sett size 175g) as subplot and Planting density (6944 plt/ha; 8333 plt/ha; 10417plt/ha; 13889 plt/ha; 20833 plt/ha) as sub-sub plot in 2014. Mini-setts (50 g) a popular yam multiplication technique was added in 2015. The results showed no significant interactions in the 3 way and 2 way factors. However, seed set size and planting density had significant (P< 0.05) effect on tuber sizes and yields. Whiles mini-sett 50 g had a significantly lower average tuber size of 0.22 kg/tuber, farmers' sett size 350 g and half farmers' size 175 g had similar and bigger average tuber sizes of 2.04 kg/tuber and 2.02kg/tuber respectively. Similar trends were observed on tuber yields with farmers' sett size 350g and half farmers' size - 175 g recording similar and significantly higher yield of 24.23t/ha and 22.85t/ha compared to mini-sett 50 g which had lower yield of 3.94t/ha. Low planting densities (6944 - 8333 plt/ha) and high planting densities (10417 - 20833plt/ha) recorded tuber sizes ranging between 2.48 2.55 kg/tuber and 1.6 - 2.0 kg/tuber for 2014 and 2.51 - 1.95 kg/tuber and 1.47 - 1.11kg/tuber in 2015. The similar tuber size and yield of famers' sett size and half farmers' sett size suggest reducing farmers' current sett size to half and planting density of about 20000 plt/ha on ridges would maximize profit.

Key words: Export market; Farmers' sett size; Half farmers' sett size; Tuber Sizes

Production De l'Igname Blanche Pour L'exportation: L'influence De La Taille D'ensemble Semences Et De La Densité De Plantation Sur La Taille Du Tubercule

Résumé
L'étude a été menée pour évaluer l'effet de la taille des semences plantés et de la densité de plantation sur la taille des tubercules et les rendements de l'igname. Les traitements ont été organisés en parcelles divisées en deux parties avec deux variétés de Dioscorea rotundata de première qualité (Pona et Dente) comme parcelle principale. Taille des colonies de semences (taille des paysans - 350g, taille des paysans moitié - 175g) comme sous-parcelle et densité de plantation (6944plt / ha, 8333plt / ha, 10417plt / ha, 13889plt / ha, 20833plt / ha) comme sous-sous-parcelle en 2014. Mini-fragmentation (50g) une technique de multiplication d'igname populaire a été ajoutée en 2015. Les résultats n'ont révélé aucune interaction

significative dans les facteurs 3 fa□on et 2 fa□on. Cependant, la taille de la semence et la densité de plantation ont eu un effet significatif (P <0,05) sur la taille et le rendement des tubercules. Alors que la mini-fragmentation - 50g avaient une taille de tubercule moyenne significativement plus faible de 0,22 kg / tubercule, la taille des agriculteurs - 350g et la moitié des agriculteurs - 175g avaient des tailles de tubercules moyennes similaires et plus grandes de 2,04 kg / tuber et 2,02 kg / tuber. Des rendements similaires ont été observés sur les rendements des tubercules avec la taille des agriculteurs - 350g et la moitié des agriculteurs -175g enregistrant un rendement similaire et significativement plus élevé de 24,23t / ha et 22,85t / ha comparé au mini-sett - 50g qui avait un rendement inférieur de 3,94 t / ha. Des densités de plantation basses (6944 - 8333plt / ha) et des densités de plantation élevées (10417 - 20833plt / ha) ont enregistré des tailles de tubercules comprises entre 2,48 - 2,55kg / tubercule et 1,6 - 2,0kg / tubercule pour 2014 et 2,51 - 1.95kg / tubercule et 1,47 - 1,11 kg / tubercule en 2015. La taille et le rendement des tubercules et la taille des terres des agriculteurs suggèrent une réduction de la taille actuelle des agriculteurs de moitié et une densité de plantation de 20000plt / ha sur les billons maximiserait les profits.

Mots clés: Marché d'exportation; La taille des agriculteurs; La taille de la moitié des agriculteurs; Tailles des Tubercules

Introduction and rationale of the study

Yam is an important staple food tuber crop produced and consumed in Ghana and West Africa. Average daily consumption of yam is about 300 kcal per capita and it is the third most important source of energy in the Ghanaian diet, accounting for 20 percent of total caloric intake (FAOSTAT, 2012). With Ghana being the leading exporter of yams in the world, yam is not only extremely important to the local market but also the international market. Yam growing has been mainly by smallholder farmers who plant on mounds resulting in just about 5000 - 7000 mounds per hectare resulting in significantly lower tuber yield as compared to the use of ridging (Ennin *et al,* 2014; Ennin *at al.,* 2009). The ridging technology makes efficient use of the land by allowing easier manipulation of the plant stands to achieve optimum population and tuber yields. The use of ridging planting method results in plant stand between 10000 and 10500 plants per hectare resulting in more number of tubers than the use of mounds. The tuber sizes on ridges are generally smaller and cylindrical as compared to generally bigger size tubers produced on mounds (Ennin *et al.,* 2009). Therefore, the sizes of the tubers on the ridges would be more preferred and fit the export size (2.0 - 2.5 kg/ tuber required by the export market), than the tuber size on the mound. Tuber size and variety are key criteria for premium price on the export market. Pona, a white yam variety, is mostly preferred both in the export and local market because of its sweet taste (GSB, 2011; MoTI, 2013). For example, premium price for Pona is obtained from a 20 kg box of yam with 10-12 tubers and in extreme cases 14 tubers, Corresponding with average tuber sizes of 2 kg -1.7 kg - 1.4 kg/tuber respectively. A 25 kg box of other white yam varieties should contain 14 - 16 tubers (1.8 and 1.6 kg/tuber), mostly within the medium class (GSA, 2011). Limited supply of affordable good quality planting material has been observed to be a major constraint to yam production. Seed sett as planting materials account for about 50% of the cost of production in yam (RTIMP Gh. 2012; Aighewi *et al.,* 2014). Currently, farmers are using sett size of about between 300 1000 g which are too big in the face of these constraints (Ogbona *et al.,* 2011; Aighewi *et al.,* 2014, Osei-Sarpong, 2009). This paper presents an evaluation of sett size and planting density of yam with an aim of achieving suitable tubers for the export market and increase farmers' income and livelihoods.

Materials and Method

The study was conducted at Fumesua in the forest and Ejura in the forest-savanna transition agro-ecologies of Ghana (Table 1). The experimental design was split-split plot with two premium *Dioscorea rotundata* varieties (Pona and Dente) as main plot. Seed sett size (farmers' sett size 350 g, half farmers' sett size - 175 g) as subplot and Planting density (6944 plt/ha; 8333 plt/ha; 10417plt/ha; 13889 plt/ha; 20833 plt/ha corresponding to 1.2m, 1.0m, 0.8m, 0.6m and 0.4m on ridges respectively) as sub-sub plot in 2014. The study was repeated for validation during the 2015 cropping season. However, seed set size of 50 g mini-sett was added to the seed sett factors in 2015 cropping season. This was to evaluate mini-setts (50 g) a popular yam multiplication technique. Based on recommendations by Ennin *et al.,* 2014 and Ennin *et al,* 2013, in each planting season poultry manure was applied at 6t/ha before land preparation. 23-23-30 kg/ha N-P_2O_5-K_2O fertilizer were applied 11 - 12 weeks (bulking stage of the yam) after planting of the yam. All plots were ploughed and harrowed after which mechanized ridges of 40 - 45 cm high were constructed in rows. Each plot had an area of 144 m^2 with ten rows of ridges and 1.2 m between them with yam planted depending on the planting density. The data collected on growth, tuber size and yield performance of the yam were subjected to analysis of variance at 5% significant level using SAS, 2007 version.

Results and Discussions

There were no significant differences in the 3-way and 2-way factor interaction for both 2014 and 2015. The stand establishment was similar for farmers sett size 350 g and half

Table 1: Agro-ecological characteristics of the site

Characteristics	Location	
	Fumesua (6o 41' N, 1o 28' W)	Ejura (7o 23' N, 1o21' W)
Agro-ecological zone	Humid Forest	Forest-Savannah Transition
Soil type	Ferric Acrisol; Asuasi series upper top soil consisted of 5 cm greyish brown sandy loam topsoil of dark brown gritty clay loam	Ferric Lixisol; Ejura series with 20-30cm thick top layer of loam soils. Soils are dark brown to brown fine sandy loam
Temperature (Min-Max) 2010-2015	21-32^{0}C	21-34^{0}C
Wet season	Bimodal rainfall pattern	Bimodal rainfall pattern
Major	March mid August	March mid August
Minor	Sept-Nov; peak in Oct	Sept-Nov; peak in Oct
Total annual rainfall (mm) 2010 -2015	1127-1300; averaging 1184 mm/yr	1317-1456; averaging 1213 mm/yr

farmers sett size 175 g with mini-sett 50 g recording very poor establishment in both locations and years (Fig. 1). Planting density had significant ($P \leq 0.05$) influence on fresh biomass, tuber sizes (weight per tuber) and yields for 2014 and 2015 cropping seasons in both Fumesua and Ejura (Figs. 2, 3, 4 & 5). Planted seed sett size significantly ($P \leq 0.05$) influenced tuber size and yield upon introduction of mini-sett 50 g in 2015 (Fig. 6).

The generally relatively high tuber size and yield of yam tubers in 2014 as compared to 2015 could be attributed to the rainfall which was high in 2014 than 2015. Mostly, similar and significantly ($P < 0.05$) higher tuber sizes range of 2.19 - 2.55 kg/tuber were recorded for the low planting densities (6944 -

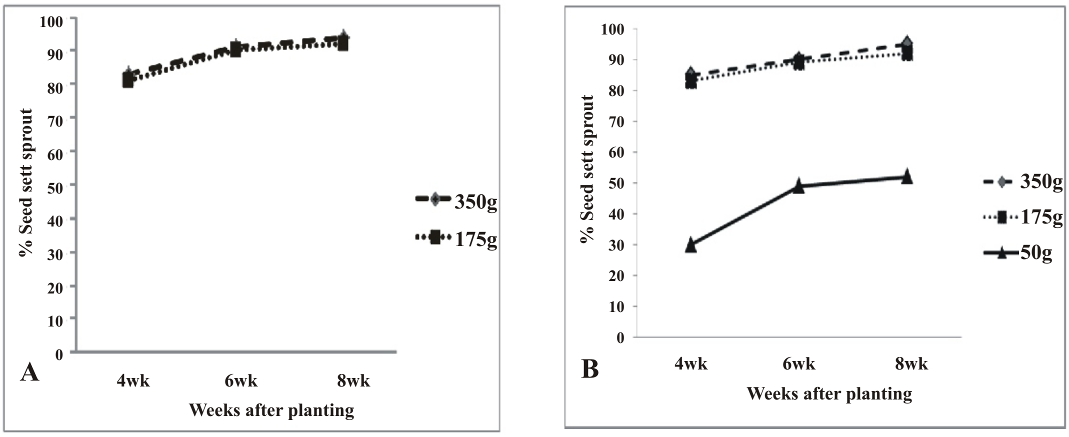

Figure 1: Effect of planted seed sett size on percentage sprout at Fumesua and Ejura, 2014 (A) and 2015 (B) cropping season

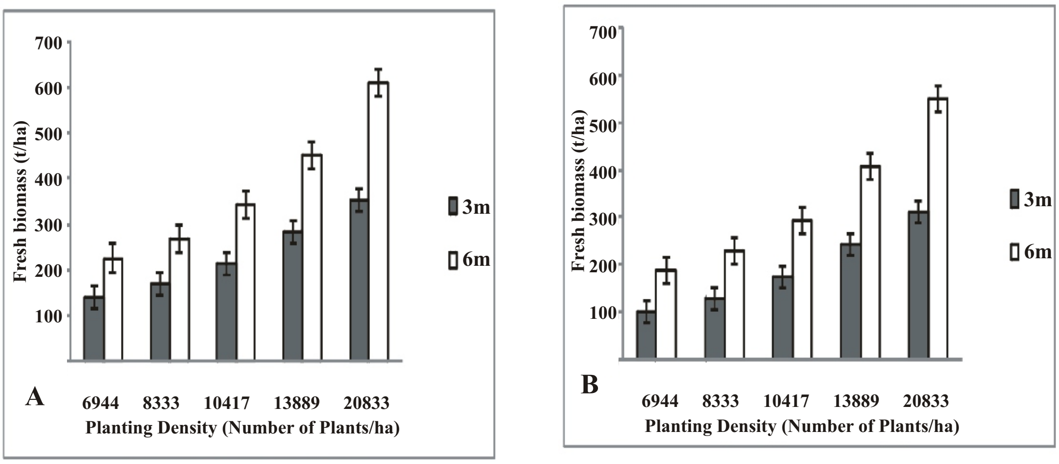

Figure 2. Effect of planting density on fresh biomass of yam 3 and 6 months after planting at Fumesua and Ejura, 2014 (A) and 2015 (B) cropping season.

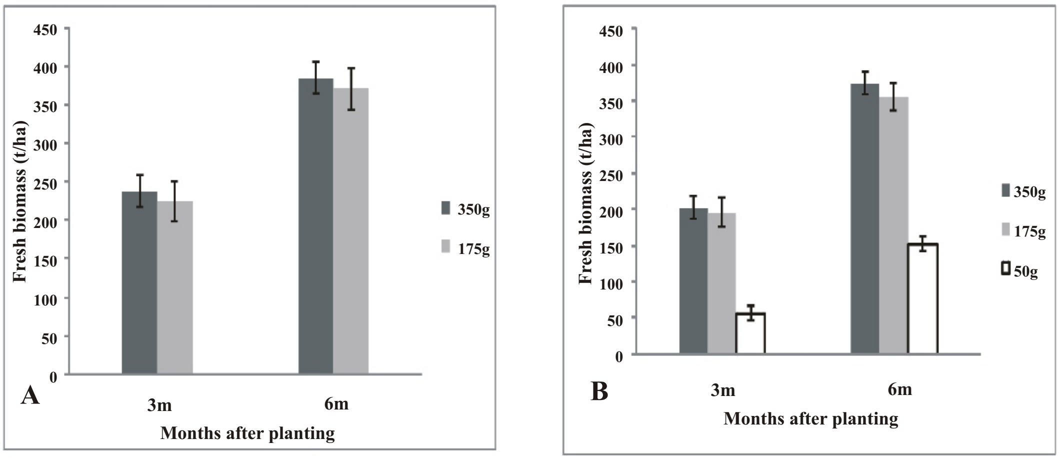

Figure 3: Effect of planted seed sett size on fresh leaf biomass of yam 3 and 6 months after planting at Fumesua and Ejura, 2014 (A) and 2015 (B) cropping season.

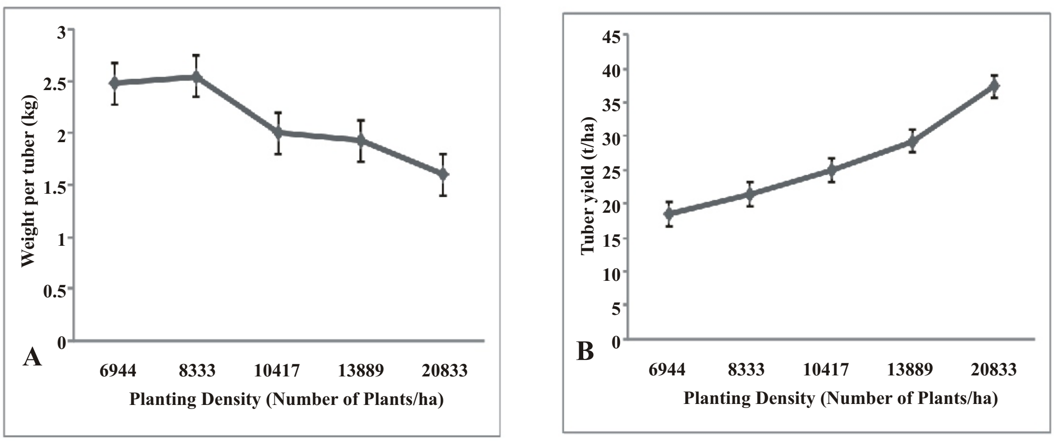

Figure 4: Effect of planting density on tuber size (A Weight per tuber) and yield (B) of yam at Fumesua and Ejura, 2014

333plt/ha) as compared to a range of 1.11 - 1.6kg/ha for the high planting densities (10417 - 20833plt/ha) in both years and locations (Figs. 4 & 5). The total tuber yields were reverse the tuber sizes, yields increased with the increasing planting density with 20833 plt/ha recording the significantly ($P < 0.05$) highest tuber yields in both locations and years (Figs. 4 & 5). Similar observation was made by Law-Ogboma and Osaigbovo (2014), that increasing planting density significantly increased tuber yields with the highest tuber yield recorded for 27778 plt/ha compared to 10000 plt/ha and 13333 plt/ha which were similar to that of 17778 plt/ha and 20000 plt/ha. The tuber sizes followed a

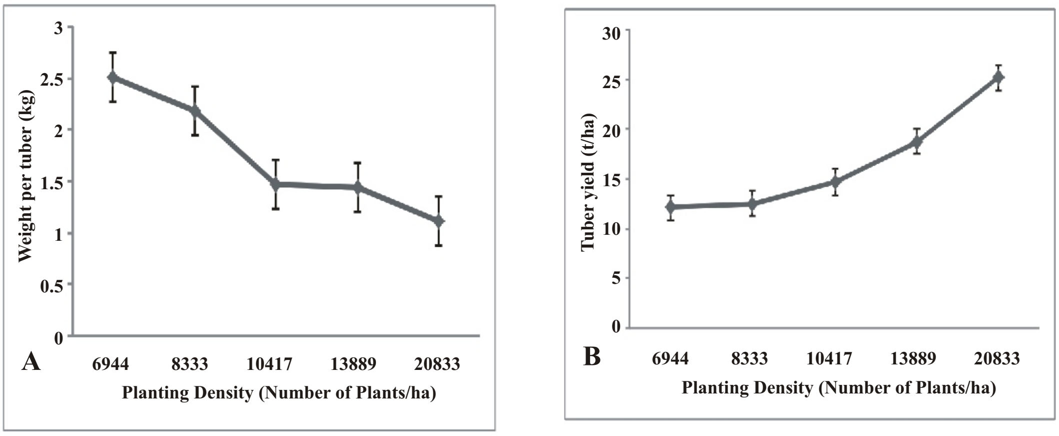

Figure 5: Effect of planting density on tuber size (A Weight per tuber) and yield (B) of yam at Fumesua and Ejura, 2015

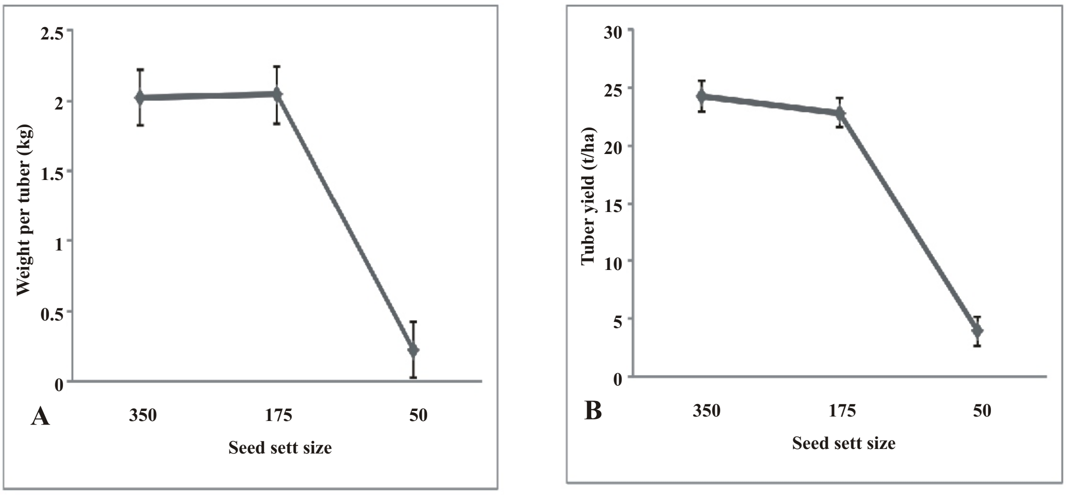

Figure 6: Effect of planted seed sett size on yam tuber size (A Weight per tuber) and yield (B) at Fumesua and Ejura for the 2015 cropping season.

reverse trend of the tuber yield as also observed in this study. Average tuber size decreased with increasing plant density (Figs. 4 & 5). The decrease in tuber sizes resulting from the increasing planting density could be due to competition between the stands for soil nutrients. The planting densities of this current study produced tubers which fits the tuber size categories of the Ghana Standard Authority (GSA). According to the GSA root and tuber specification for fresh yams, tubers are categorized into extra small, small, medium, large and extra-large sizes corresponding to tuber sizes ranging from 0.5 - 0.9

kg, 1.0 - 1.5 kg, 1.6 - 3.5 kg, 3.6 - 5 kg and above 5 kg respectively (GSA, 2011). It can be observed that whiles the low planting densities (6944 - 8333 plt/ha) had tuber sizes ranged (2.19 - 2.55 kg) mainly within the medium (1.6 - 3.5kg) category the high planting densities (10417-20833 plt/ha) had tuber sizes range (1.11- 2 kg) mainly with in the small (1 - 1.5kg) and medium (1.6 - 3.5kg) category (Fig 4 & 5). On planted seed sett sizes farmers' sett size 350 g and half farmers' size 175 g had similar and bigger average tuber sizes of 2.04 kg/tuber and 2.02 kg/tuber (medium) respectively whiles the mini sett 50g had tuber size of 0.22kg (out of extra small range) (Fig. 6). Thus, the mini sett 50g had tuber sizes not suitable for the export market. The tuber yields followed similar trend with farmers' sett size 350 g and half farmers' size 175 g recoding similar and significantly higher yield of 24.23 t/ha and 22.85t/ha compared to mini-sett 50 g which had lower yield of 3.94 t/ha (Fig. 6). The above trend could be attributed to the biomass accumulation patterns of the planted sett size (Fig. 3). The similar high biomass accumulation of the farmers' sett size 350 g and half farmers' size 175 g resulted in similar tuber size and yield whiles the low biomass accumulation of the mini-sett 50g resulted in tiny and low tuber size and yield respectively (Fig. 6). Yam production has been noted to provide cash income for a wide range of small holders, including many women as producers, processors and traders (Asiedu, 2003; MoTI, 2013). Therefore, improving yam productivity can increase food production and farmers' income in the producing areas, particularly in West Africa. The increasing global demand for yams coming from Europe, the U.S., neighboring African countries and the local market indicates there is potential for higher production and export volumes (MoTI, 2013). However, competition for fertile land to expand the area under yam cultivation to certify the demand for yam domestically and internationally is likely to add to land and soil degradation attributed to yam production (Ennin *et al.,* 2014; Owusu Danquah *et al.,* 2015). This study has demonstrated cost of production can be reduced whiles increasing productivity per unit area by reducing the current seed sizes used by farmers to about half and planting on ridges at about 208833 plt/ha. This would help sustain crop production per unit area instead of increasing area under crop production.

Conclusion

This study has shown yam production can be increased and sustained with the use of improved agronomic practices on continuously cropped fields. This would help address the problem of deforestation and land degradation associated with yam production

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