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Biomass Production and Partitioning Pattern of Yam (*Dioscorea alata*)

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Abstract: There has been a decline in yam production relative to cassava and rice in Africa but yam is such a preferred staple food that, bearing in mind population increases, demand will remain and there will not be an absolute decline. Tuber yield of yam (*Dioscorea alata*) is determined by the total production of dry matter (DM) and its distribution within the crop. Dry matter partitioning is of great importance in crop production. Improvement of crop yield by plant breeding has resulted from higher harvest indices rather than improved DM production. However, there are limits to the fraction of assimilates that can be diverted to the harvestable organs. In this present study the effect of fertilizer on biomass production and the distribution of dry matter increments to the plant parts of white yam (*Dioscorea alata*) was determined by analysing data from field experiments set up in the Upper Oueme Basin, (Benin Republic) over two years (2005 and 2006) where yam was harvested periodically during the entire stages of its growth. It can be concluded that fertilizer application has highly positive significant effect on total biomass production of yam in both the years (an increase of 42 and 84% in total biomass production under fertilized condition was registered in year 2005 and 2006, respectively) and dry matter distribution tended to follow a regular pattern if expressed as a function of phenological growth phase of the crop in both fertilized and unfertilized management practice.

Key words: Phenological growth phase, biomass, yam, *Dioscorea alata*

INTRODUCTION

Tuber yield of yam (*Dioscorea alata*) is determined by the total production of dry matter (DM) and its distribution within the crop. Dry matter partitioning is of great importance in crop production. Improvement of crop yield by plant breeding has resulted from higher harvest indices rather than improved DM production (Cock and El-Sharkawy, 1988; Gifford *et al*., 1984). However, there are limits to the fraction of assimilates that can be diverted to the harvestable organs. A plant should invest sufficient assimilates in other plant parts to realize and maintain a high production capacity. The balance between assimilates for different plant parts is of importance for optimal crop production (Marcelis, 1994). In this present study the distribution of dry matter increments to the plant parts of white yam (*Dioscorea alata*) in relation to the application of mineral fertilizer was determined by analyzing data from field experiments set up in the Upper Oueme Basin (Benin Republic) over two years where yam was harvested periodically during the entire stages of its growth. The distribution tended to follow a regular pattern if expressed as a function of phenological growth phase of the crop.

MATERIALS AND METHODS

Field and plant sample preparation: The study was conducted as on-farm trials at Dogue village on latitude 9°05′N and longitude 01°55′E of Benin Republic. The village is characterized by a bimodal rainfall pattern with a short rainy season which usually starts in May and lasts till September. The soil was ploughed once and harrowed twice. Spade was used to manually establish 0.5 m high mounds spaced 1.0 m apart. Perennial weeds were controlled by weeding manually using hand hoe before planting and crop emergence. Sections from tubers heavier than 1 kg and without damages were used as planting material. In order to avoid heterogeneity, the "head" and "tail"of the tubers were eliminated. Thus only middle tuber sections were used as setts. At planting, setts were placed 10 cm deep at the top of the mounds with the epidermal tissue area facing down. The experiments were laid out as a randomized complete block design with three replications. Altogether there were six sub-plots of 8×8 m size (three main plots with 2 sub-plots within each main plot). Out of these six sub-plots, three were fertilized with 200 kg NPK ha^{-1} at planting, 100 kg NPK ha^{-1} (60 days after planting) and 100 kg ha^{-1} Urea (60 days after planting) for assuring that nutrients

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would not become a limiting factor for crop growth and development. The remaining 3 sub-plots were treated as control. Plants were allowed to grow in the field and four samples of crop were harvested at five different times i.e., first harvesting at 55th day after planting, 2nd at 126th day, 3rd at 154th day, 4th at 168th day and final harvest at 231st day after sowing from each sub-plot randomly. Aboveground plant parts were harvested by cutting the stem just above the soil surface. Fallen leaves were also collected. The plant tubers were harvested then put into a water bath, gently washing the soil and fine roots from the tubers. The tubers and shoots (leaves, fallen leaves, stems) were rinsed with deionised water before oven drying at 70°C to constant weight. Dry matter yield of tubers and shoots was determined by weighing.

Data analysis: Treatment effects were determined by analysis of variance by ANOVA using computer package SPSS version 11 (SPSS Inc.©2002, Chicago, Illinois, USA). Significance was regarded at $p \leq 0.05$.

RESULTS AND DISCUSSION

The effect of fertilizer treatment on yam (*Dioscorea alata*) biomass production: There is highly positive significant effect of fertilizer on biomass production of yam in year 2005 and 2006 ($p<0.001$). In year 2005, under fertilized condition, an increase of 44% in tuber yield and 42% in total biomass production of yam had been registered, whereas it was higher in year 2006, which accounted 85 and 84% of increase in tuber yield and total biomass production, respectively when compared with control (without fertilizer) (Fig. 1). The stronger effect in year 2006 could be explained by the better water use efficiency (WUE) of the crop as this year was dry (Average rainfall 328 mm) and mineral nutrition may improve the stomata regulation and the metabolic efficiency as higher nutrient availability may enhance the uptake of nutrients under lower soil moisture condition (Payne *et al.*, 1992).

Normally yam is grown just after fallow and no fertilizer is applied to this crop. The poor biomass production in yam under unfertilized condition could be explained by the negative nutrient balance in the crop because of high removal of nutrients through the harvested tuber. The poor performance of yam in terms of total biomass production in year 2006 compared with the total biomass production in year 2005 could be explained by the shorter vegetation period due to erratic distribution of rainfall in the year 2006 (Table 1).

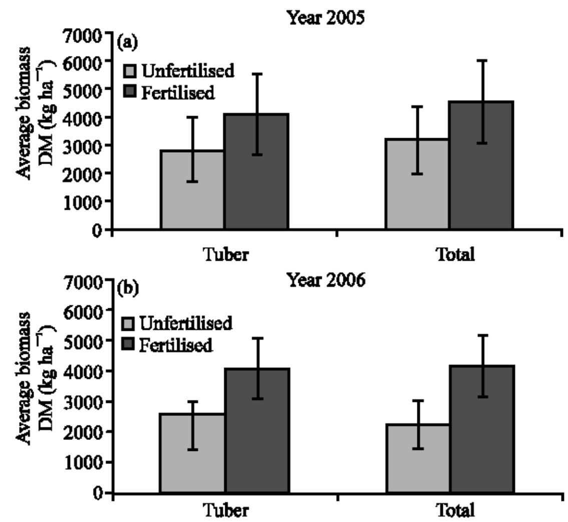

Fig. 1(a, b): Comparison of total biomass and tuber biomass production of Yam under control and fertilized conditions in year 2005 and 2006

Table 1: Total biomass yield at five harvesting dates in relation to the application of mineral fertilizer ($p<0.05$) in year 2005 and 2006

Days after planting (DAP)	Control	Fertilized	Level of significance (p)
Year 2005			
57	327	196	0.012
126	1482	2257	0.052
154	3313	5921	0.002
168	3501	5527	0.021
231	3217	4553	0.002
Year 2006			
55	532	988	0.028
125	2325	4094	0.0002
155	3845	6168	0.0005
165	4760	7381	0.0005
216	2254	4142	0.00001

Relative dry matter distribution: Partitioning is the differential distribution and deposition of assimilates among tissues. Because in yams the tuber yield is more relevant than the total dry matter yield, it is important to study the distribution of the produced dry matter among the different plant parts.

Figure 2 shows the partitioning rates of leaves, stems and tubers in year 2005. The proportion of leaves and stems was increasing until 57th day after planting and gradual decrease can be observed until day of final harvest (i.e., 231st Days after planting). By contrast, the tuber partitioning rate was always positive, increasing rapidly during the period between 57 and 126 Days after planting. There was no effect of fertilizer observed on the partitioning pattern within the crop.

Figure 3 shows the partitioning rates of leaves, stems and tubers in year 2006. In case of 2006, we observed the same pattern of dry mater distribution in yam crop as we

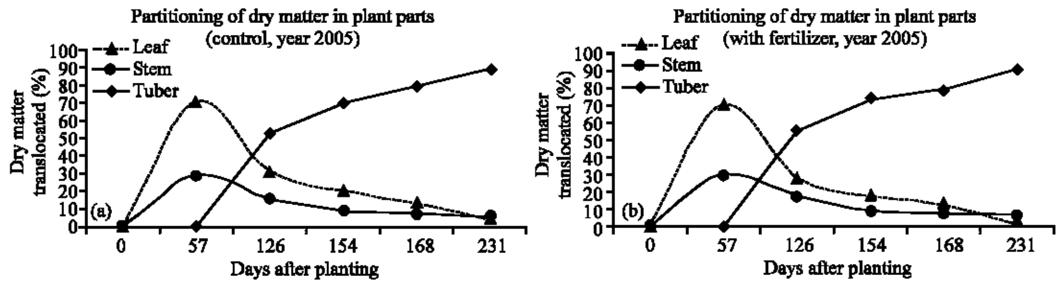

Fig. 2: Comparison of partitioning rate of dry matter in different yam tissues under (a) control and (b) fertilized condition in year 2005

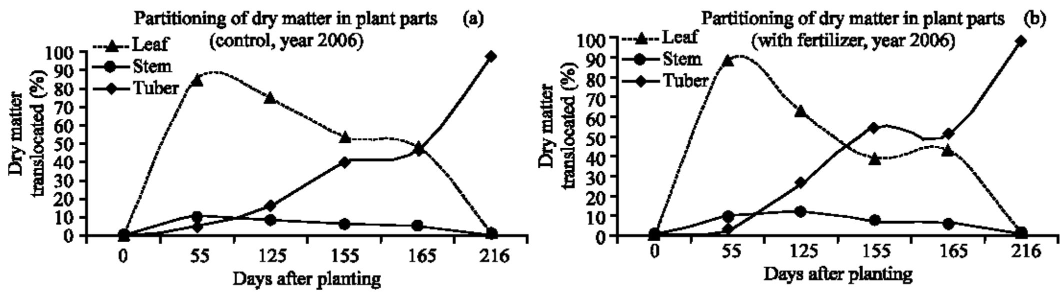

Fig. 3: Comparison of partitioning rate of dry matter in different yam tissues under (a) control and (b) fertilized condition in year 2006

saw in year 2005. There was a gradual decrease in leaves and stem partitioning rates after about 55th DAP, whereas it was positive until 55th DAP. However, tuber partitioning rate followed always positive trend and registered a rapid increase during the period between 55 and 155 DAP. The probable reason for the decrease in tuber dry matter partitioning between 155 and 165 DAP is yet not known. No fertilizer effect on partitioning rate of dry matter within the crop was observed. In case of tubers, environmental factors such as light and temperature contributed less to explain DM accumulation than time. As in potatoes, tuber production in yams is determined by time of tuber initiation and bulking rate (Bremner and Taha, 1966; Enyi, 1972a, b). According to Milthorpe (1963), the bulking rate is the first derivative of tuber growth which in our experiment rapidly increased after about 55 DAP (Fig. 2 and 3).

Haynes *et al.* (1967) for another yam species (*Dioscorea alata*) showed that leaf area declines as tuberization begins. An adequate balance between shoot, root and tuber growth should be achieved in order to obtain high yields, as it has been proposed by Osaki *et al.* (1996). They found that high productivity root crops are able to maintain a balance between root and shoot activity because since in root crops the main sink is underground, photosynthates are actively distributed also to roots. Additional information is needed to optimize shoot-root, shoot-tuber and root-tuber interactions in root crops such as yam.

CONCLUSION

We can conclude from the conducted experiment that fertilizer application has highly positive significant effect on total biomass production and tuber yield of yam crop (*Dioscorea alata*) in both years of study (year 2005 and 2006). Regarding partitioning pattern in yam crop, no effect of fertilizer has been noticed, the crop behaves identically (i.e; partitioning rate) in both fertilized and unfertilized management practice.

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