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Variability on Growth and Storage Roots Yield in Cassava under Three Planting Methods

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Abstract: The increasing importation of starch in Malaysia for poultry and bio-processing industries is a call for concern. The development and released of improved cassava genotype (Sri Pontian) in 2003 by the Malaysian Agricultural Research and Development (MARDI) was a good step to enhance cassava productivity. Sri Pontian was reported to show higher yield than those of Manihot Mardi 92 and Sri Medan (the popular table variety). Such claim has not been verify in East Malaysia. This research was carried out to verify the aforementioned claim by comparing selected yields attributes of Manihot Mardi 92, Sri Medan and Sri Pontian at Bintulu, Sarawak, East Malaysia. This study was conducted at experimental field of University Putra Malaysia Bintulu Campus Sarawak from July to December, 2011. The experimental design was a randomized complete block with three replications. The three varieties evaluated were: Manihot Mardi 92, Sri Medanand Sri Pontian. These varieties were planted on ridges with three planting methods: Vertical planting (forming 90° angle to the ridges), incline planting (forming 45-60° angle to the ridges) and horizontal planting (forming 180° to the ridges). Variations among the varieties were observed for number of shoots retained per plant, leaf longevity, leaf area index, number of storage roots formation and fresh storage roots yield. Significant interaction effect between variety and planting method was observed for all the variables tested, except for number of shoots retained per plant and number of storage roots per plant. All varieties showed similar number of shoots per plant regardless of planting method except for Sri Pontian which had lowest effect with respect to number of storage roots formation per plant in incline planting. Similarly, leaf longevity in Sri Pontian was the lowest regardless of planting method. Sri Medan showed the greatest leaf area index, number of storage roots formation per plantand fresh storage roots yield. The effect of Manihot Mardi 92 in terms of leaf area index, number of storage roots formation per plantand total storage roots yield in vertical planting was comparable to that of Sri Medan. Sri Pontian had the lowest storage roots yield. This study showed in East Malaysia, Sri Medan was identified as the best genotype with good agronomic attributes. This variety has the potential to increase cassava productivity over a wide range of environmental conditions.

Key words: Cassava, planting methods, storage roots yield, yield attributes, East Malaysia

INTRODUCTION

Manihot esculenta, cassava or tapioca is a perennial starchy shrubs belonging to the dicotyledon (family Euphorbiaceae). The genus Manihot has about 100 species with cassava as the only commercially cultivated species (Alves, 2002). Cassava grows in a wide range of climatic conditions and it shows different behaviour in different locations due to variation in climatic and soil conditions. It grows very well in less fertile soil in contrast to many other plants that are highly vulnerable to environmental stresses, especially during their early growth stage (Ugorji, 1998). Despite the plant tolerance to low-input conditions, cassava responds well to higher agronomic management practices and yield increase by >100% (Leihner, 2002). Many of the yield and yield components in cassava are quantitatively inherited and are strongly influenced by both genetic and management practices. With limited land available for cassava cultivation, production increase must be based on improving productivity through the development of improved varieties and better crop management practices.

The storage root is the main economic organ for the direct production of cassava, its yield and quality reflects the productivity and the entire quality of the plant

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(Alves and Cameira, 2002). This crop organ serves as a staple food for almost 750 million people throughout the tropics (Nassar and Ortiz, 2010). The crop could be allowed to remain in the ground until needed, thereby providing a mean of storage (Benesi, 2005). It has been suggested that cassava is one of the cheapest and most reliable energy source for both human and animal nutrition (Tonukari, 2004). In South-East Asia, cassava plays an important role in starch and food processing industries (Ceballos, 2002). In Malaysia, the increasing demand for the crop in the poultry and raw material in starch processing industries coupled with the increasing importation of starch for the bio-processing industries have been highlighted (Aerni, 2006; Tan, 2007). However, the crop is facing some serious production constraints, such as lack of superior genotypes, high labour cost, low starch content, high cyanide contentand increasing competition for arable land from crops considered to be more profitable. Cock (1985) suggested that cassava yield in farmers' fields are low because of lack of suitable varieties and poor management practices. These production constraints must be address in order to revive interest in planting the cropand consequently change Malaysian current status of starch importer (Tan and Khatijah, 2002). The released of Sri Pontian by the Malaysian Agricultural Research and Development in 2003 is a good step in that respect. Sri Pontian was reported to show higher yield compared to those of Manihot Mardi 92 (released in 1992) and Sri Medan.

There is, however dearth of information about the afforementioned claim from East Malaysia. It has been reported that improved genotype will have its maximum value in a particular environment (Dixon *et al*., 1994). The morphological and agronomic characteristics of cassava are highly variable due to intense interspecific hybridization and selection. The agronomic characteristics, such as leaf longevity, leaf area indexand storage roots indices are less heritable than morphological descriptors, suggesting strong influence of exogenous factors in their expression. These crop organs are directly related to storage root yields (Mahungu, 1993; Ntawuruhunga *et al*., 1998, 2001). The objective of the study was to compare the performance of Manihot Mardi 92, Sri Medanand Sri Pontian in terms of selected yield components in three different planting methods.

MATERIALS AND METHODS

Experimental site and soil sampling: This study was carried out at the experimental field of University Putra Malaysia Campus Bintulu (3°10'N; 113°2'E) Sarawak, Malaysia from June to November, 2011. The soil of the experimental area was classified as Bekenu series. Bekenu series is a member of the Bekenu family which is fine loamy, siliceous, isohypherthermic, red yellow to yellow Tipik Tualemkuts (Paramananthan, 2000). It is yellow to brownish in colour, deep and well drained. The average annual rainfall for Bintulu is between 2500-5000 mm with no month below 100 mm. The mean annual minimum temperature was 24°C and maximum 32°C with average relative humidity of 83% and sunshine hours (4.5-6.2). About 20 soil samples were taken at 0-15 cm depth using an augur for physico-chemical analysis. The samples were air dried, sieved to pass a 2 mm sieveand analysed for texture (Tan, 2005), pH (Peech, 1965), total N (Tan, 2005), available P (Murphy and Riley, 1962) and exchangeable K (Tan, 2005).

Experimental materials: The three cassava varieties used in the study were: Manihot Mardi 92, Sri Medanand Sri Pontian. Manihot Mardi 92 is a progeny of a cross between M 1362-6×CM 586-1 released in 1992 by the Malaysian Agricultural Research and Development Institute (MARDI). Manihot Mardi 92 is an early maturing variety with a tuberous yield of up to 35 ton ha^{-1} in 6 months, tolerant to drought and wide range of soil adaptation. It has a moderate level of cyanide root content. It has high fertilizer use efficiency with possible fertilizer reduction cost of up to 70%. Its demerits are low starch content of about 20%. Sri Pontian was introduced in 1992 as seedling clone of open-pollinated seeds from Centro International de Agricultura Tropical (CIAT) Columbia and release by MARDI in 2003. It outyields Sri Medan in total root production. It has up to 30% starch root which is higher than that of Manihot Mardi 92 (20%) and Sri Medan (24%). Sri Medan is believed to be originated from Indonesia, its tuberous yield is relatively low (25%) but has higher starch content (24%) than Manihot Mardi 92.

Experimental procedures: The experiment was carried out over a period of 5 months (June to November, 2011) in a 2×3 factorial in randomized complete block design with three replications. Treatments evaluated were: Manihot Mardi 92, Sri Medanand Sri Pontian). These cassava varieties were tested in three planting methods: Vertical planting (forming 90° angle to the ridges), inline planting (forming 45-60° angle to the ridges) and Horizontal planting (forming 180° to the ridges). Stem cuttings, 20 cm in length and approximately 6 cm in diameter selected from the tested varieties were planted on second June, 2011 in vertical, incline and horizontal positions. For vertical and incline plantings, cuttings were planted 5 cm deep in the soil while cuttings planted horizontally were buried to a depth of 2 cm from the surface. The main plot size of the

experimental area was 108 m^2. A replicate size of 36 m^2 comprising 9 ridges, each measuring 4 m long and at 1 m intervals was established. Planting distance of 1×1 m was adopted. First weeding using a hoe was done at 1 month after planting while subsequent weeding were carried out by hand to minimize roots injury. A commercial fertilizer blue fertilizer N:P:K:Mg 12:12:17:2 at the rate of 400 kg ha^{-1} (Mbah *et al*., 2008) was applied in 2 equal split doses (1 and 2 months after planting). The sampling unit consisted of 2 central plants of each treatment of which 2 plants from each treatment were excluded in data collection (guard rows). Watering was done when necessary to complement rainfall in period of drought. No insecticide or herbicide was applied throughout the experimental period.

Data collection: Data were collected at harvest (5 months after planting). Number of shoots retained per plant was counted manually at harvest, leaf area index were computed using LAI 2000 canopy analyser, number of leaf fall per plant was estimated by counting the number of leaf scars at harvest, number of storage roots per plant was counted manuallyand storage root yield (ton ha^{-1}) was measured on fresh weight basis using a weighing balance. Data collected were analysed and treatment effects were detected using factorial Analysis of Variance (ANOVA). Means found to be significant were compared using Duncan's new multiple range test at $p \leq 0.05$. Statistical analysis was carried out using the Statistical Analysis System version 9.2.

RESULTS AND DISCUSSION

The results of the soil analysis before planting and after harvest are shown in Table 1. The soil pH decreased by 0.19. The observed soil acidification after harvesting cassava could be due to the application of nitrogenous fertilizer and subsequent leeching of ammonium in form of nitrate and crop removal of lime-like elements (e.g., Ca and Mg) at harvest (Gazey, 2009). Available P increased by 0.86% whereas total exchangeable K decreased by 739.2%. The texture of the soils remained unchanged and it was classified as sandy loam. Howeler (1991) reported that for each tonne of cassava root dry matter produced, 4.5 kg of N, 0.83 kg of P and 6.6 kg of K are removed. Similar results were earlier reported (Amarasiri and Perera, 1975). According to Putthacharoen *et al*. (1998) with an average root yield of 11 ton ha^{-1}, cassava removes lower N and P than those of other cropsand while K removal was similar to those of other crops and lower than that removed by pineapple.

Table 1: Means±SE of selected physico-chemical characteristics of Bekenu series before and after planting cassava

Physico-chemical properties	Before planting	After planting
Sand (%)	67.00±0.87	68.50±0.29
Silt (%)	16.00±0.29	16.17±0.72
Clay (%)	17.00±0.29	15.33±0.73
Soil texture	Sandy loam	Sandy loam
pH (H_2O)	4.94±0.12	5.13±0.19
Total nitrogen (N) (%)	0.19±0.01	0.19±0.02
Available phosphorus (P) (mg L^{-1})	13.30±0.06	14.16±0.17
Exchangeable potassium (K) (mg L^{-1})	1686.20±70.69	947.0±13.32

Shoots number per plant: Number of shoots retained per plant referred to total number of stems counted at harvest. In vertical planting, Manihot Mardi 92 showed the highest shoots number (2.36 per plant), followed by Sri Medan (1.98 per plant) and Sri Pontian (1.94 per plant) (Fig. 1). Sri Medan and Sri Pontian were statistically similar when cuttings were vertically planted. In incline planting, significant differences on number of shoots among the three varieties were observed. Manihot Mardi 92 had the highest shoots number per plant (2.29), followed by Sri Medan (2.00) and Sri Pontian (1.79). In horizontal planting, the mean shoots number recorded for Manihot Mardi 92 (2.11 per plant) and Sri Medan (2.19 per plant) were statistically similar whereas that of Sri Pontian (1.79 per plant) the lowest. It is important to mention that shoots and roots growth occurred simultaneously in cassava, thereby competing for the partitioning of the photosynthates. As such, excessive shoot development may have negative effect on tuberous root yield. Thus, it is necessary to select the variety in which multiple shoots retention could be optimum for functional equilibrium of biomass allocation between above-ground and below-ground organs. In a related study Okoro *et al*. (2009), found significant differences among cassava genotypes on shoots number retention.

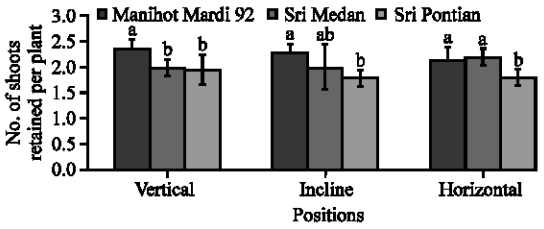

Fig. 1: Variability among the three cassava varieties on number of shoots retained per plant. Bars denote the Standard Error (SE) of the means and n = 6. Letters above columns within the same planting positions which are different represent significant differences among the three tested varieties at $p \leq 0.05$ according to Duncan's new multiple range test

Leaf fall rate per plant: Regardless of planting method, Sri Pontian showed the highest leaf fall rate (63.89-71.25 per plant) compared to those of Manihot Mardi 92 (48.56-59.19 per plant) and Sri Medan (45.98-52.81 per plant) (Fig. 2). Manihot Mardi 92 and Sri Medan were not significantly different except for vertical planting where Sri Medan had the lowest leaf fall rate (48.48 per plant). The importance of leaf fall determination in cassava lies in its effect on duration of photosynthetic activity and as an integral part of selection strategy for storage root yields (Osiru *et al*., 1995; Cock and El-Sharkawy, 1988; El-Sharkawy *et al*., 1990). According to Lim *et al*. (2007) and Yoshida (2003), leaf senescence is influenced by endogenous and exogenous factors including plant growth regulators, starvation, woundand environmental stresses.

Leaf Area Index (LAI): Regardless of planting method, Sri Medan was the most efficient (LAI of 2.56-2.81) (Fig. 3).

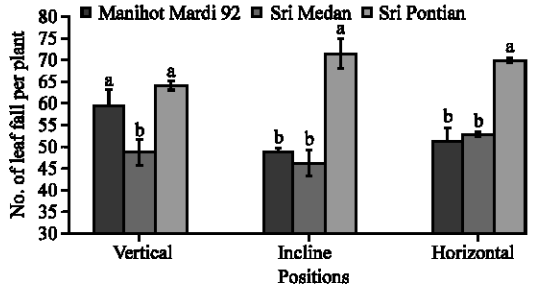

Fig. 2: Variability among the three cassava varieties on number of leaf fall per plant. Bars denote the Standard Error (SE) of the means and n = 6. Letters above columns within the same planting positions which are different represent significant differences among the three tested varieties at $p \leq 0.05$ according to Duncan's new multiple range test

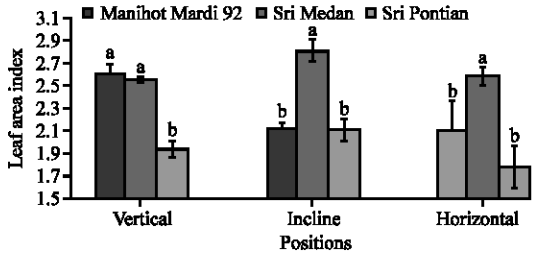

Fig. 3: Variability among the three cassava varieties on leaf area index. Bars denote the Standard Error (SE) of the means and n = 6. Letters above columns within the same planting positions which are different represent significant differences among the three tested varieties at $p \leq 0.05$ according to Duncan's new multiple range test

However, the effect of Manihot Mardi 92 (LAI of 2.61 per plant) was not significantly different from that of Sri Medan (LAI of 2.56 per plant) in vertical planting. On the other hand, Manihot Mardi 92 and Sri Pontian showed similar effect irrespective of planting method except for vertical planting where Sri Pontian had the lowest effect (LAI of 2.11 per plant). The importance of LAI determination lies on its direct effect on carbon fixation capacity and sink strength. Jonik *et al*. (2012), reported tuber yield increase in potato when sink strength was elevated. In another study, Begum and Paul (2005) found a positive relationship between LAI and tuber yield in cassava.

Storage roots formation per plant: Significant differences in number of storage roots formation among the test varieties were observed across all planting methods examined except for vertical planting (Fig. 4). In both incline and horizontal planting methods, Sri Medan showed the highest rate of storage roots formation (14.87 per plant) whereas Manihot Mardi 92 (13.00 per plant) the lowest. However, the effect of Manihot Mardi 92 and Sri Pontian were not significantly different irrespective of planting method. The outstanding performance of Sri Medan in formation of storage roots was a demonstration of positive relationship existed between source and sink organs, in view of the variety's excellent performance in leaf longevity and LAI (Fig. 2 and 3). The obtained result is consistent with those of the previous reports (Lapointe, 2001; Paul and Foyer, 2001). The researchers highlighted that increase sink activity reduces leaf senescence and increase biomass yield. According to Keutgen *et al*. (2002), storage root growth depends on the sink strength, the potential of leaves to export photosynthesis and photosynthetic efficiency of leaves.

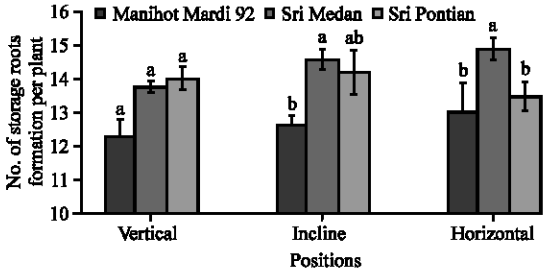

Fig. 4: Variability among the three cassava varieties on number of storage roots formation per plant. Bars denote the Standard Error (SE) of the means and n = 6. Letters above columns within the same planting positions which are different represent significant differences among the three tested varieties at $p \leq 0.05$ according to Duncan's new multiple range test

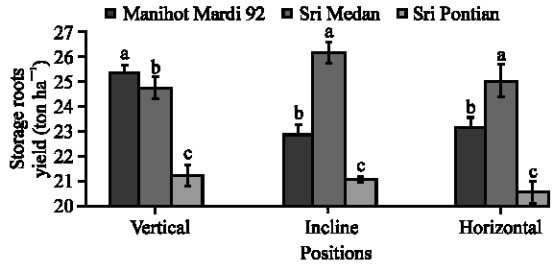

Fig. 5: Variability among the three cassava varieties on storage roots yield formation per plant. Bars denote the Standard Error (SE) of the means and n = 6. Letters above columns within the same planting positions which are different represent significant differences among the three tested varieties at $p \leq 0.05$ according to Duncan's new multiple range test

Storage roots yield: The storage root yields (ton ha^{-1}) of the 3 varieties were significantly different (Fig. 5). In vertical planting, Manihot Mardi 92 showed the highest yield (25.33 ton ha^{-1}), followed by Sri Medan (24.73 ton ha^{-1}) and Sri Pontian (21.24 ton ha^{-})^{1}in that order. However in both incline and horizontal planting methods, Sri Medan out-yielded Manihot Mardi 92 and Sri Pontian. The poor yield of Sri Pontian could be attributed to excessive leaf fall as shown in Fig. 2. It can be summarized that cassava yield components comprise of leaf longevity, leaf area index, number of storage roots and storage roots weight. Ntawurunhunga *et al.* (2001) reported storage root number, storage root weight, storage root girthand total leaf area as yield components explaining 72% of storage root yield in cassava.

CONCLUSION

The current study has established phenotypic variability among cassava varieties. It also showed the usefulness of evaluating newly improved genotypes in a wide range of environments. Based on the findings of this experiment, Sri Medan is the most suitable material for storage root yields at Bintulu, East Malaysia. In areas where vertical planting method is desired, Manihot Mardi 92 was comparable to Sri Medan in terms of storage root yields and therefore recommended for farmers.

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