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Starch Yield and Mosaic Virus Infestation in Rainfed Cassava Genotypes in a Coastal Savannah Agro-Ecological Environment of Ghana

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Abstract: The influence of annual rainfall on dry matter and starch yield was studied using five cassava genotypes. The dry matter content and starch yield followed a bimodal trend with peak values in April and July when the amount of rainfall was low indicating the influence of rainfall on starch production. At the peak periods of production, Jamaicaso (JM) had the highest mean dry matter and starch content. However, Megyew ntem (MGN) produced the highest amount of starch in August when rainfall was low while JM had the lowest amount of starch for the same period. All the genotypes evaluated were susceptible to the African Cassava Mosaic Virus (ACMV). With the exception of Afisiafi (AFI), there was a negative correlation between ACMV infection and growth rate in the early development. Jamaicaso, AN and MGN which had a negative correlation between ACMV symptom severity and growth rate were able to recover from the disease, indicating that they are ACMV tolerant genotypes and thus could be incorporated into cassava breeding programmes. However, for maximum starch production by the starch industries, cassava should be harvested after the rainfall periods.

Key words: Cassava · Starch content · ACMV

INTRODUCTION

Cassava is the main energy source in many Ghanaian diets and currently, the most important crop in terms of production and contribution to agricultural gross domestic product-GDP [1]. Its production has been enhanced by the establishment of starch production factories in Ghana. Consequently, cassava has been transformed into an important foreign exchange earner with high potential for job creation and poverty alleviation particularly in the rural areas.

The storage root is the principal source of starch production used for food and non-food in agro-industries world-wide [2]. Structurally, starch is a mixture of two different polymers, amylose and amylopectin and each is known to play a critical role in its ultimate functionality. Viscosity, shear resistance, gelitinisation, texture, solubility, tackiness, gel stability, cold swelling and retrogradation all depend at least in part upon amylose/amylopectin ratio [2]. Thus, the ability to alter the size and shape of starch granules has significant implications for specific industrial utilisation. For example, the cosmetic industry requires starch with uniformly small granules.

The cooking quality of cassava is highly correlated with the quantity and quality of starch present in the storage roots. Thus, genotypes that maintain their starch quantity throughout the year are likely to maintain their good cooking quality. However, starches from cassava and other root and tuber crops such as potato and sweetpotato have large genotypic variation in terms of their functional properties [3]. This variation may be due to the age of the crop, maturation, plant architecture as well as other environmental factors such as rainfall which may modify the amylose/amylopectin ratio. Oates *et al.* [4] have shown that cassava starch extracted during the rainy season was structurally different from those harvested prior to the onset of the rains and also the amylose content changed with the time of harvest. Thus, it is very essential to evaluate cassava genotypes available in Ghana to know their peak level of starch production in relation to the rainfall pattern. Such a study will provide the necessary information on when to harvest cassava for the starch and other uses. Besides, it will lead to the identification of genotypes with good cooking varieties throughout the year and those that are good for industrial use only. The objectives of this study, therefore, were to assess the influence of rainfall pattern

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on starch yield and severity of the African Cassava Mosaic Virus disease and its effect on growth of selected cassava genotypes in a coastal savannah environment of Ghana.

MATERIALS AND METHODS

Field experiments were carried out at the BNARI Research Farm of the Ghana Atomic Energy Commission. The soil at the site is a Haatso soil series, a well-drained s andy loam described as Ferric Acrisol according to FAO/UNESCO [5]. The experimental site, which is about 76.0 m above sea level, is situated on latitude 05° 40'N and longitude 0° 13'W in the coastal savannah agro-ecological zone of Ghana. The annual rainfall at the experimental site is less than 1000 mm.

Experimental Design: Five cassava genotypes namely, 'Ankrah' (AN) which is serving as the control, 'Bosom nsia' (BN), 'Migyew ntem' (MGN), 'Jamaicaso' (JM) and an IITA introduced variety 'Afisiafi' (AFI) were planted on 2nd February 2004 using cassava nodal cuttings (10-15 cm long) at a planting distance of 1.0 m within rows and 1.0 m between rows. The experimental design used was the R andomised Complete Block design in four replications. The experimental plots were weeded when necessary. A micro weather station located at the experimental site recorded the seasonal rainfall. The number of stakes that germinated as well as weekly growth rate (measured as plant height) was recorded starting from 5 weeks after planting up to 15 weeks. Time to flowering after germination was also recorded for up to 16 weeks after planting.

Evaluation for African Cassava Mosaic Virus (Acmv) Symptom Severity: African Cassava Mosaic virus symptom expressions were scored weekly by visually observing the chlorotic pattern on young leaves of 24 plants for each of the cassava genotypes in each replication using a scale of 0 (no symptom) to 5 (highly chlorotic [6].

Harvesting of Cassava Storage Roots: Cassava roots were harvested from four plants per sub-plot every month, starting from 12 months after planting, up to six months. Cassava roots were subsequently weighed using a domestic scale immediately after harvesting. The mean number of roots and weight per st and or plant were recorded.

Dry Matter Determination: Harvested cassava roots were peeled after which approximately fifty gram (W_1) of peeled root tubers were chopped into small pieces and oven-dried at a temperature of 105°C in an oven until constant weight. The dried chopped roots were cooled in a desiccator and weighed (W_2). The percentage dry matter was calculated as the ratio of W_2 to W_1 multiplied by 100.

Starch Extraction: Starch was extracted using the method described by Wiessenborn *et al.* [7] with modifications. Five hundred grammes (500 g) of peeled cassava roots were blended with 500 mL water in a Waring blender. The suspension was allowed to st and for 20 minutes, the supernatant blended again for 45 seconds and added to the sediment and allowed to st and again for 40 minutes. The supernatant was discarded and the sediment was suspended in 500 mL of water, sieved with a U.S. No 20 mesh and the residue washed again with 300 mL of water. The sediment was re-suspended in 400 mL water, blended and sieved again with the same mesh. The residue was further washed with 2 L of water, sieved and allowed to st and for 45 minutes and the supernatant decanted. The starch obtained was re-suspended in 500 mL water, allowed to settle and decanted. The starch was finally washed three times in 2 L of water, pulverised and sun-dried on aluminium trays for three days and weighed.

Statistical Analysis: Statistical analyses were done using Microsoft Excel and means were separated using Tukey's pairwise comparison.

RESULTS

Growth Rate and Flowering: The mean percentage sprouting in all the cassava genotypes was very high, ranging from 93.5% to 100% (Table 1), which indicates high sprouting potential among the cassava genotypes. All the planted stakes of AN sprouted while sprouting of stakes of the other cassava genotypes ranged from 98.9% for JM to 93.5% for BN (Table 1). Shoots of all the cassava genotypes grew vigorously; however, there were differences in plant height 16 weeks after planting (Table 1). The cassava genotype AN showed the fastest rate of growth, attaining about 140.0 cm plant height 16 weeks after planting while the growth rate of AFI was the lowest, reaching a plant height of 86.8 cm 16 weeks after planting (Fig. 1).

Table 1: Mean percentage germination, plant height at 4 MAP and percentage of plants with flowers at 3 MAP.

Cassavagenotype	Mean germination (%)	Plant height at 4 MAP (cm)	Flowering at 3 MAP (%)
AFI	97.7	86.8	42.7b
AN	100.0	136.9	29.5c
BN	93.5	117.6	76.9a
JM	93.8	123.6	6.5d
MGN	98.9	91.8	8.8d

Numbers in a column with the same letters are not significantly different.

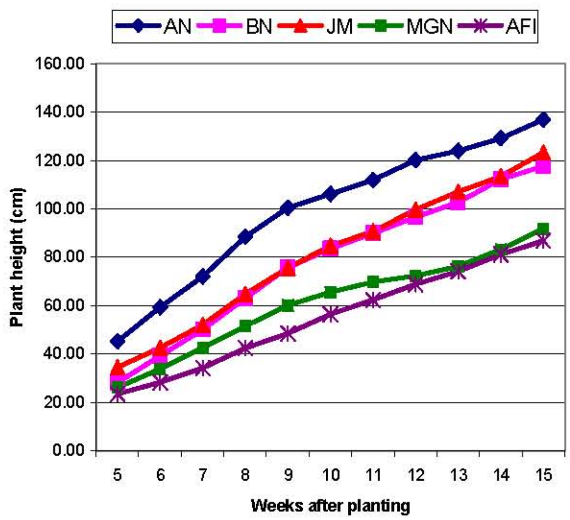

Fig. 1: Growth rate of five cassava genotypes fifteen weeks after planting

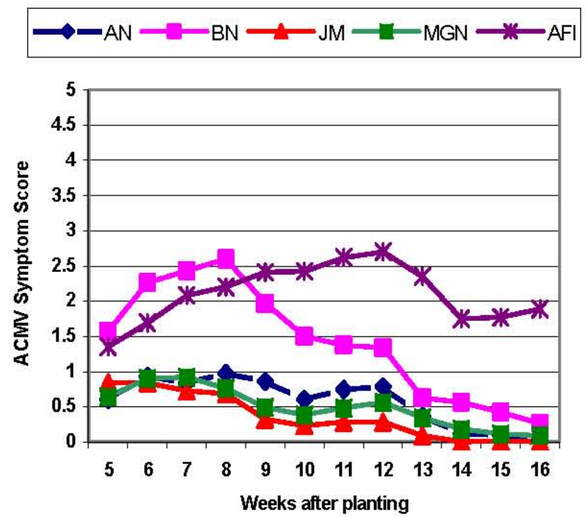

Fig. 2: Time course of ACMV symptom expression score on five cassava genotypes

More than 75% of BN plants flowered 12 weeks after planting, suggesting early bulking which was significantly higher (P=0.05) than the percent number of plants that flowered for each of the other cassava genotypes. The cassava genotype JM had the least percentage of plants flowering (6.5%) by 12 weeks after planting which suggests late bulking.

ACMV Susceptibility: All the cassava genotypes were susceptible to the ACMV infection as shown by visual observation of chlorotic patterns on the leaves. The severity of ACMV symptom was highest on the cassava genotype BN followed by that of AFI for the period from five weeks to eight weeks after planting (Fig. 2). The severity of ACMV symptom on BN reached at about 2.5 eight weeks after planting but decreased gradually to about 0.4 sixteen weeks after planting. Generally, the severity of ACMV symptom was highest on AFI, compared to the severity of ACMV symptom on the other cassava genotypes, from 8 weeks to 16 weeks after planting (Fig. 2), it reached at 2.7 on the eighth week after planting after which it declined but remained between 1.5 and 2.0 values (Fig. 2). Also, the severity of ACMV symptom on the cassava genotypes AN, BN and JM was fairly constant, ranging between zero and one, for the period between five weeks and sixteen weeks after planting (Fig. 2).

All the cassava genotypes, except AFI, showed a negative correlation between ACMV and growth rate. The high ACMV symptom expression of 2.7 on AFI, however, was poorly correlated ($r = 0.316$) with the growth rate. For AN the correlation coefficient between ACMV infection and growth rate was - 0.337, indicating a non-significant relationship while for BN, MGN and JM correlation coefficient ranged between -0.787 and -0.968 for which coefficient of determination (r^2) values ranged between 61.0% and 93.7%, indicating good dependence of ACMV on growth rate. The cassava genotypes JM and MGN were able to recover completely from ACMV fifteen weeks after planting indicating high tolerance to the virus (Fig. 2).

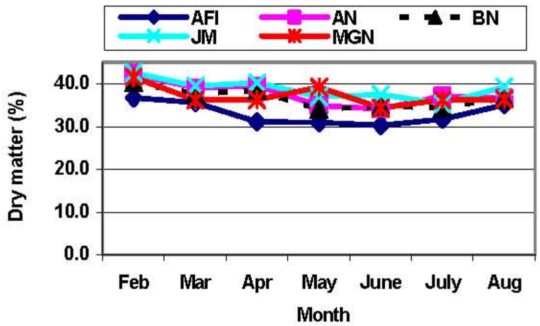

Fig. 3a: Time course of dry matter content of five cassava genotypes in the year 2005

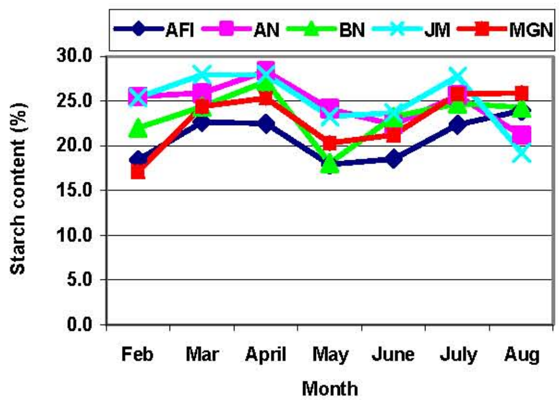

Fig. 3b: Time course of starch content of five cassava genotypes in the year 2005

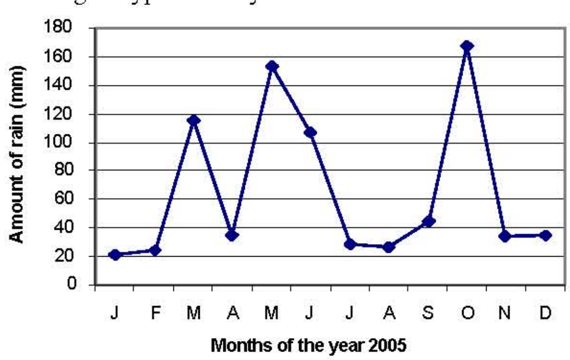

Fig. 3c: Rainfall during the year 2005.

Fresh Root Weight, Dry Matter and Starch Yield: The mean number of storage roots produced per st and ranged from 6.82 in JM to 9.67 in AFI (Table 2) but there were no significant differences (P=0.05) between the cassava genotypes. Similarly, the mean fresh root weight of the cassava genotypes varied with BN having significantly higher (P=0.05) mean fresh root weight (4.05 kg per st and) than the other cassava genotypes indicating a potential for higher yield and early bulking or maturity while MGN had the lowest mean fresh root weight of 1.77 kg per st and (Table 2).

Table 2: Mean number of roots and fresh root weight of the cassava genotypes

Cassava genotype	Mean number of roots	Mean fresh root weight (kg)
AFI	9.67 ± 1.40a	2.89 ± 0.27a
AN	8.78 ± 0.87a	2.88 ± 0.26a
BN	7.85 ± 1.09a	4.05 ± 0.71b
JM	6.62 ± 0.93a	3.45 ± 0.34b
MGN	7.53 ± 0.81a	1.77 ± 0.31c

Numbers in a column with the same letters are not significantly different

The amount of dry matter and the corresponding starch obtained from cassava roots averaged over the harvesting period are shown in Fig. 3. Both the dry matter and starch yield were influenced by the amount of rainfall (Fig. 3) throughout the study period. Generally, dry matter and starch yields were low when the rainfall was high and vice versa (Fig.3). Throughout the study period, JM produced the highest percentage dry matter of 38.5% while AFI produced the lowest (33.0%) as shown in Fig. 3. However, in May when the rainfall was high, MGN produced the highest amount of dry matter (Fig.3).

The amount of starch produced showed a bimodal peak following the rainfall pattern; it was high in April and July and low in May and June when the highest amount of rainfall was recorded (Fig.3). However, starch production in AFI declined to the lowest value of about 18.0% and 20.0% in the months of May and June of the year 2005, respectively (Fig.3). In contrast, starch production in MGN started rising in June (2005) and it reached the highest value of 27.0% in August 2005 when rainfall for the month was about 27.0 mm and comparatively low (Fig. 3).

DISCUSSION

Cassava is a heterozygous crop and therefore exhibits different morphological traits which have been used by farmers for botanical nomenclature, ethnobotanical classification as well as selection. A morphological trait such as flowering may give an indication of early bulking or tuberisation of the crop. Of all the genotypes evaluated BN showed early flowering at three months after planting, indicating early maturity or bulking. Besides, there was a positive correlation between early flowering and bulking/tuberisation and in the final tuber yield in BN. Thus, the early maturation or bulking of the cassava genotype BN is evidenced by the fact that the root weight per plant within the first three months (February to April) of sampling was comparatively higher than the remaining cassava genotypes (data not shown).

In contrast, MGN had the second highest mean weight of roots per plant within the first two months of harvesting but did not show early flowering. This observation suggests that the presence of flowering may not necessarily indicate early tuberisation in cassava and that other factors may play significant role.

All the cassava genotypes evaluated were susceptible to ACMV but there were differences in the severity of virus symptoms. With the exception of AFI which showed a poor correlation with plant growth rate, all the remaining cassava genotypes showed a negative correlation between ACMV infection and growth rate at early developmental stages. It was also observed that cassava genotypes AN, JM and MGN were able to recover fully fifteen weeks after planting, indicating that these cassava genotypes are highly tolerant to ACMV. In contrast, the cassava genotypes AFI and BN which had high severity of ACMV symptom are highly susceptible to the disease.

Until now, there is no record of a single ACMV resistant cassava genotype in Africa [8], thus the yield of cassava keeps declining as propagation through cutting keeps multiplying the virus population leading to total crop failure in some countries [9]. Consequently, all efforts are therefore being made either to select for ACMV tolerant genotypes or breed for resistant cultivars. Thus, the full recovery from the ACMV infection showed by AN, JM and MGN fifteen weeks after sprouting makes them suitable c andidates for use in cassava improvement programmes. The complete absence of the ACMV symptoms on leaves of AN, JM and MGN 15 weeks after sprouting could be attributed to increased synthesis of laticiferous or other compounds, which prevent whitefly (*Bemisia tabaci*), the vector of ACMV, from feeding on them, thus limiting the expression of ACMV symptom.

The mean dry matter ranged from 33.0 to 38.7% with highly significant differences between the cassava genotypes. The mean dry matter content reported here is similar to that of Sarmento *et al.* [10] who reported a mean dry matter of 36.6% sixteen months after planting in four South American cassava genotypes. However, dry matter production in this study was negatively affected by the rainfall pattern; low at high rainfall and high at low rainfall. This observation may be due to physiological changes such as active shoot development during the rains leading to the breaking down of stored starch for mobilisation for growth and thus depleting root dry matter and consequently low dry matter content.

As indicated above, peak starch production in this study was identified to be in the months of April and July, corresponding also to periods of low rainfall during the rainy season. This confirms findings by Bonierbale *et al.* [2] that environmental factors such as rainfall affect the yield and quality of starch. Oates *et al.* [4] have also confirmed structural differences in starch production as a result of rainfall seasonality. Although, the exact cause of low starch production during the high rainfall periods is not known, it may be attributed to its breakdown to release metabolites for growth and development.

The ability to alter the size and shape of starch granules has significant implications for specific industrial utilisation of the crop [2]. For example, the cosmetic industry requires starch with uniformly small size granules. Although, the size of starch granules could be changed by molecular modifications, the requirement for specific amylose/amylopectin ratio for specific industrial utilisation could be achieved depending on the rainfall pattern, the time of harvesting and the search for cassava l andraces with different starch profiles. Significant differences in starch production among the cassava genotypes studied support this proposition as Collado and Corke [3] have confirmed that starch from cassava and other root and tuber crops such as potato and sweetpotato shows large genotypic variation in their functional properties.

Traditionally, AN used to be the most preferred cassava genotype for cooking but it has become highly susceptible to the ACMV and has long bulking period. Thus, the observation in this study that MGN and BN are early maturing genotypes and produce appreciable amount of starch provides alternate cassava genotype with good cooking quality for farmers who prefer to grow cassava for domestic consumption. The low severity of ACMV symptom coupled with high starch production by MGN after the rainfall in August suggests that this cassava genotype could have good cooking quality and thus could be suitable for consumption throughout the year. However, harvesting of MGN and all the remaining genotypes for the starch industries should be done after the rainfall in order to maximise starch yield.

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