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Gibberellic acid and CCC effects on sugar composition and tuber yield in Yam Bean (*Pachyrhizus erosus*, Urban)

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Yam bean is a tropical tuber and grain legume that needs to be better known as a crop for human consumption and animal feed. The seeds are poisonous but can be used for planting. The tuber is edible and can be eaten as a fresh vegetable or cooked. Large tubers and better fruiting occurred when the growing season coincided with long days, but marketable tubers were produced, especially under short days. In all cases tuber production competes with seed production. Investigations were undertaken to study the effects of foliar application of GA3 and CCC on growth, sugar composition and tuber yield of yam bean under short days. GA3 promoted shoot growth, tuber enlargement, yield increase, sucrose accumulation and starch content increase. CCC did not consistently affect growth, but reduced tuber size, increased starch content, therefore reduced tuber and starch yields per plant. Foliar applications of GA3 might be used to increase tuber and starch yields per plant under short days. This result was obtained because of a partial or total inhibition of flowering and seed set by that growth substance.

Keywords: *Pachyrhizus*; Yam Bean; Growth Regulators; Gibberellic Acid; CCC

Introduction

Mexican Yam bean, (*Pachyrhizus erosus* Urban), is a tropical root crop that deserves to be better known in the Caribbean. It is today widely disseminated in the tropical regions of China, India, Indonesia and the Philippines (Schroeder, 1967; Srivastava et al., 1973). It belongs to the family Papilionaceae and produces tubers and pods. Although the seeds are not suitable for human consumption because they contain rotenone, a respiratory inhibitor (Hansberry et al., 1947), they are used to propagate the plant. The edible tubers are therefore available as food. The chemical composition indicates a well balanced protein content (Marta Evans et al. 1977). The tuber contains 84.5 percent water. Glucose, fructose, sucrose and starch are the main sugars.

As a legume, yam bean can supply its own nitrogen needs by biological dinitrogen fixation and leave in the soil an appreciable amount of nitrogen that is usable by the next crop. In addition the tops are rich in proteins, and can be used for forage or as green manure. (Cortes, 1970).

Tuber yield depends on climatic conditions and cultural practices. The best yields are obtained if vegetative growth occurs under long day conditions. The yield can be increased twofold if the plant is prevented from fruiting by an early pruning (Zepeda, 1971). Tuber size, yield and sugar composition may also be modified by use of growth regulators. This article reports the result of the application of different concentrations of gibberellic acid (GA3) and chlorocholine chloride (CCC) during the growth of yam bean.

Materials and methods

Yam bean seeds (kindly supplied by Dr. Steele of IITA, Ibadan, Nigeria) were sown in October and grown under field conditions. The plants received basic slag containing 70 kg of P_2O_5/ha and potassium sulphate (120 kg K_2O/ha.). The plant did not receive any nitrogen fertilization. The nodulating rhizobium was present and efficient in the soil.

Beginning six weeks after sowing, five applications of growth hormones were made at two week intervals to plots of 200 plants. Treatments were gibberellic acid at 50 ppm (GA 50) and 200 ppm (GA 200), chlorocholine chloride at 1000 ppm (CCC 1000) and 5000 ppm (CCC 5000); control plants were sprayed with water. Ten plants of each set were harvested weekly to follow growth characteristics and carbohydrate content. Only the results at harvest are reported here. Yield of yam bean tubers was taken after 5 months of growth on a sample of 50 plants.

At harvest, plants were individually separated into various constituents; leaves were counted and dry weights of different parts were determined after 48 hours of drying at 80^{o}C.

Tubers of 5 plants randomly harvested were washed, cut into pieces and oven dried at 80^{o}C for 48 hours. The dried material was ground to pass a 0.4mm sieve. Soluble sugars (sucrose and reducing sugars) were extracted in ethanol-water (80:20) (Cerning-Beroard, 1975). Total ethanol-water soluble carbohydrates were estimated in sulfuric acid with orcinol (Tollier and Robin, 1979); sucrose, glucose and fructose according to the enzymatic methods of Bergmeyer (1979). Starch was extracted as described by Thivend et al. (1965) and determined according to Bergmeyer (1979).Starch was extracted as described by Thivend et al. (1965) and determined according to Bergmeyer (1979).

Results

Effect of GA3 and CCC on aerial organs

Leaf number: Gibberellic acid, at both 50 and 200 ppm, increased leaf number compared to the control. The effect was observed from the beginning of the treatment. At harvest, the leaf number for GA 50 treatment was twice that of the control. CCC did not significantly affect leaf number (Table 1).

Leaf Dry Matter: Only GA 50 treatment had a large effect on leaf dry matter accumulation at harvest (Table 1). Although GA 50 and CCC 1000 treatments increased leaf dry matter up to pod set, levels declined thereafter in the CCC 1000 treatment. Other treatments showed little effect.

Stem and Petiole Dry Matter: All treatments showed increased dry matter accumulation over the control (Table 1). The effect was greatest with GA 50 treatment and as with the GA 200 treatment, resulted from increased internode length. CCC increased dry matter by increasing development of floral organs.

Pods and Seeds: Fruiting was completely inhibited by GA 200 as compared to GA 50 and the control (Table 1). CCC had an inverse effect, enhancing pod and seed production.

Effect of GA3 and CCC on tuber yields

Yam bean generally bears one tuber (exceptionally two). In our experiments the application of growth regulators began after the start of tuberization. So our results concerned the tuber development rather than tuberization.

At harvest, tuber dry matter of the GA 50 and GA 200 treatments was respectively, 2.7 and 1.8 times higher than that of the control (Table 1). The opposite effect was found under CCC treatments where the CCC 1000 and CCC 5000 treatments yielded respectively, 78% and 37% that of the control. Tuber fresh weights followed closely the trends in dry weight. On the basis of 200,000 plants per hectare the highest tuber yield was around 70 t/ha (GA 50), while control plots yielded 24 t/ha (Table 1).

Effect of GA3 and CCC on tuber composition.

Soluble carbohydrates: Tuber analysis at harvest showed that sugar composition was affected by applications of the growth regulators (Table 2). As compared to the control plants, GA 200 maintained soluble sugars content but GA 50 and CCC 1000 treatments decreased it. All treatments modified the ratio of soluble sugars analysed. Sucrose was not found in control tubers. Studies are under way to identify the other soluble sugars.

Table 1 Growth characteristics of yam bean at harvest under GA3 and CCC treatments (weights in g/plant).

Growth Characteristics	Treatments				
	Control	GA 50	GA 200	CCC 1000	CCC 5000
Leaf number	31.0	61.0	50.0	34.0	31.0
Dry Weights					
Leaves	28.0	50.8	37.4	31.6	26.6
Stems & Petioles	24.9	48.4	32.1	34.3	30.0
Pods & seeds	93.6	71.0	9.5	162.0	153.0
Tuber	109.0	300.0	200.0	84.5	40.8
Fresh Weight					
Tuber (Mean)	1200	3500	1800	900	430
(Range ±)	200	800	300	250	130
Yield (t/ha)	24.0	70.0	36.0	18.0	8.6

Table 2 Carbohydrate composition of yam bean tuber at harvest under GA3 and CCC treatments. Carbohydrate expressed as % dry matter.

Carbohydrate Composition	Treatments			
	Control	GA 50	GA200	CCC 1000
Soluble sugars	30.2 (0.9)	16.5 (1.0)	31.1 (0.6)	24.8 (0.9)
Glucose	6.7 (0.5)	2.0 (0.2)	10.4 (0.6)	5.7 (0.5)
Fructose	9.8 (0.6)	6.8 (0.5)	13.7 (0.7)	5.7 (0.5)
Sucrose	0	7.6 (0.5)	6.0 (0.5)	6.4 (0.5)
Starch	12.5 (0.5)	18.9 (0.8)	17.2 (0.7)	17.5 (0.5)

Range (±) given in brackets, ( )

Starch: Both GA3 and CCC increased starch content in the tubers, irrespective of concentration used. The improvement varied from 37.5% for GA 200 to 51% for GA 50. GA3 not only improved starch content in the tuber, but also increased starch yield per plant. Taking into account the dry matter produced by each treatment, starch yields were 14, 56, 34 and 15g/plant for control, Ga 50, GA 200, and CCC 1000 treatments, respectively.

Discussion and conclusions

The results generally indicate opposite effects from GA3 and CCC foliar applications to yam bean:

- GA3 promoted shoot growth, whereas CCC had no significant effect.

- GA3 reduced flowering and seed production, whereas CCC improved flowering and increased seeding.

- GA3 promoted tuber enlargement, whereas CCC treatments reduced tuber production.

- Both growth regulators, however, increased starch levels in the tuber generally resulting in increased starch yields per plant.

The promotion of shoot growth by GA3 and the inhibition of flowering for some species has been reported by Sachs and Hackett (1969 and 1977). The antagonistic effects of GA3 and CCC are similar to reports by many authors. Tuber enlargement was not found in other tuber plants (Okazawa, 1960; Kumar and Wareing, 1975). This was attributed to an inhibition of photoassimilate translocation into tubers and the hydrolysis of sucrose into reducing sugars, thus preventing its conversion into starch (Lovell and Booth, 1967).

A full discussion of the results reported on yam bean was given elsewhere (Zinsou et al, 1987a and b). It was suggested that GA3 and CCC activated photosynthesis and increased assimilate production, by inducing a greater top growth (GA3) and improving chlorophyll and carotenoid levels as reported by Prokhorchik and Mashtokov (1972) in El-Abd et al, 1980). Other possible effects of the growth substances were modifications of the distribution pattern between the different sinks. GA3 reduced or suppressed the pod and seed sinks and favoured tuber enlargement, whereas CCC improved seed production by reducing assimilates allocated to the tuber.

Finally, the results are interesting for practical application. Foliar application of GA3 at 50 ppm may triple tuber yield while allowing sufficient seed production for crop propagation.

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