Effects of Harvest Date on the Contents of Sugar, Inorganic Phosphate and Vitamin C in *Amaranthus dubius*[1]

*A.O. Lawanson, B.E. Ayisire, S.F. Ikusebiala**

ABSTRACT

A study of the accumulation of inorganic phosphate, vitamin C and total free sugar by the leaves and stems or in the entire shoot of the leafy vegetable *Amaranthus dubius* during its mature stages was carried out. Maximum levels of inorganic phosphate were observed at the early stage of maturity of the plant in both leaves and stems, whereas the highest amount of total free sugar and vitamin C occurred in these organs at later stages. The stems tended to accumulate the nutrients investigated to a greater extent than the leaves.

COMPENDIO

Se estudió la acumulación de fosfato inorgánico, vitamina C y azúcares libres totales en las hojas y tallos de plantas de amaranto (*Amaranthus dubius*) durante diferentes etapas de maduración. Los niveles más altos de fosfato inorgánico se encontraron durante las primeras etapas de maduración de la planta, tanto en las hojas como en los tallos; mientras que los niveles más altos de azúcares libres y de vitamina C se dieron, en cambio, en las etapas más tardías de la maduración. Hubo mayor acumulación de los nutrimentos investigados en los tallos que en las hojas.

INTRODUCTION

Carbohydrate intake by many Africans has often been described as improportionately high compared with other nutrients and hence inimical. The two principal crops, found in most African countries, cassava and yam, are used as subsistence staples; they are starch-rich sources with disappointingly low contents of protein, sugar, vitamin C and minerals (10). There is thus a need to supplement the food product derived from these sources. This requirement appears to be met by many leafy vegetables used for making soups for eating the cassava- and yam-derived meals. Bassir (2) has demonstrated that several leafy vegetables contain significant amounts of minerals, vitamins and proteins; and many edible plants are potential sources of sugar (8) and dietary fibre (14).

The genus *Amaranthus* provides examples of leafy vegetables which are used for making various soups, particularly in West African countries. *Amaranthus* comprises about 800 species (9), many of which are cosmopolitan and widely-grown throughout the tropics and subtropics where one of the species, *A. hybridus* L., has been shown to have enhanced germination under water stress conditions (1).

In many cases leafy vegetables are harvested when they appear mature to the farmer, usually around the fifth week, which may or may not coincide with the time when they are most nutritive. In addition, many cultures show preferences for the leaves as opposed to the stem.

The aim of the present study was to determine the relative distribution of sugar, inorganic phosphate and vitamin C between the leaves and stems of *A. dubius* during its mature stages and hence identify the optimum time of harvest, and show whether or not there could be any scientific justification for descriminating against use of the stem.

MATERIALS AND METHODS

Seeds of *A. dubius*, locally obtained in the main market of Ile-Ife, in Southern Nigeria, were sown in washed sand in 15 cm-diameter plastic bowls perforated at the bottom to allow drainage. The bowls were then placed in a greenhouse, with temperatures between 22-28°C, and approximately 8 h of sunlight daily during the dry season when average sunlight intensity is about 9500 lux (6).

The bowls were irrigated with 50 ml water twice daily, first at 6 am and later at 6 pm prior to the germination of the seeds and at the early stage of germination. The seedlings were thinned at the fourth true-leaf stage to seven healthy uniform plants per bowl and were fed with 200 ml full-nutrient solution and water daily in the morning and evening respectively. The composition of the solution is based on the Long Ashton formula as modified by Hewitt (7).

---

1 Received for publication 15 March 1989.
We gratefully acknowledege the support, in form of a research grant, by University of Ife.

* Department of Botany, University of Ife, Ile-Ife, Nigeria.

Starting with 28-day-old plants, they were harvested at five-day intervals for a total of five harvests. On each occasion, 5 g fresh stem, leaf and entire shoot samples were obtained from three randomly-harvested plants, one per bowl. Each sample was chopped into pieces with a razor blade and then homogenized in distilled water (5 ml/g) with a mortar and pestle. The resulting extracts were then filtered through Whatman's No. 1 filter paper, and each filtrate, having been divided into two aliquots, was used for analyses of inorganic phosphate and free sugars. The method of Chen *et al.* (4) was adopted for the quantitative estimation of inorganic phosphate, while total free sugar was measured using the anthrone colorimetric procedure (5).

Vitamic C was also extracted from 5 g samples each of leaves stems and shoots obtained as previously described using 5% trichloro-acetic acid (TCA), 5 ml/g. The extracts were then filtered through Whatman's No. 1 filter paper and the resulting filtrates were used for the assay of vitamin C according to Plummer (12) with a slight modification. Five milliliters filtrate were mixed with 5 ml freshly prepared 0.1% dichlorophenol-indo-phenol (DCPIP) in a test tube and the mixture was incubated at room temperature for 30 minutes. After centrifugation at 600 rpm for 15 min, the OD of the resulting supernatant was read at 620 nm on a CE single-sample spectrophotometer. A standard curve was obtained with pure vitamin C solutions, using a mixture of TCA and DCPIP as blank.

Each of the assays was replicated three times and the results obtained were subjected to analyses of variance.

RESULTS

The analyses of inorganic phosphate (Fig. 1) showed that the stems of 28 and 33-day-old plants accumulated significantly higher amounts of the nutrient than the corresponding leaves. This difference, however, disappeared completely by 43 days after sowing since a more rapid decline in the level of inorganic phosphates was observed in the stems than in the leaves.

In contrast to the accumulation of inorganic phosphate, the levels of vitamin C (Fig. 2) was low in both the stem and leaf tissues of 28-day-old plants and remained so in both organs until 38 days after sowing. Thereafter, the concentrations of vitamin C rose to maximum levels of 78.5 and 80.9 nmoles/ml in the leaves and stems respectively before falling sharply in the parts of older plants.

No significant difference was found between the leaves and stems with respect to the levels of free sugars, except for the 28-day-old plants, throughout the experimental period, and the sugar distribution pattern in both plant organs consequently showed very close resemblance (Fig. 3).

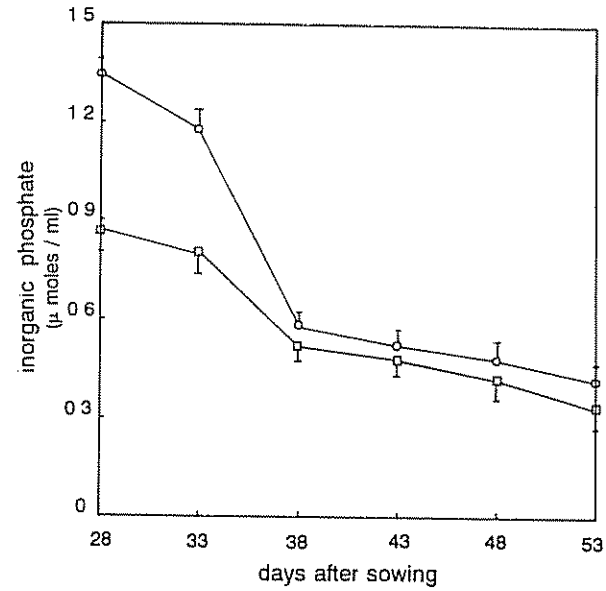

Fig. 1. Time-course of accumulation of inorganic phosphate in the leaves (□—□) and stems (O—O) of *Amaranthus dubius* during its mature stages of development.

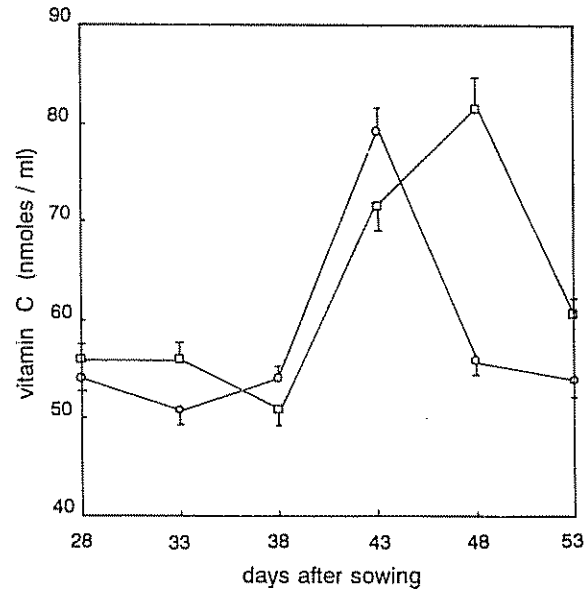

Fig. 2. Time-course of accumulation of vitamin C in the leaves (□—□) and stems (O—O) of *A. dubius* during its mature stages of development.

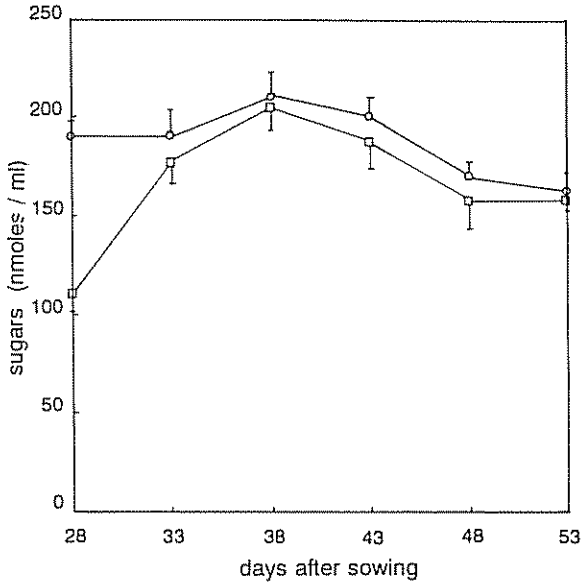

Fig. 3. Time-course of accumulation of free sugars in the leaves (□—□) and stems (O—O) of *A. dubius* during its mature stages of development.

Fig. 4 shows the time course of accumulation of inorganic phosphate, vitamin C and total free sugar in the entire shoot during the mature stages. Examination of the results showed that the level of inorganic phosphate in the shoot was highest in 28-day-old plants whereas maximal accumulation of vitamin C and free sugars occurred at later development stages, 43 and 38 days after sowing respectively.

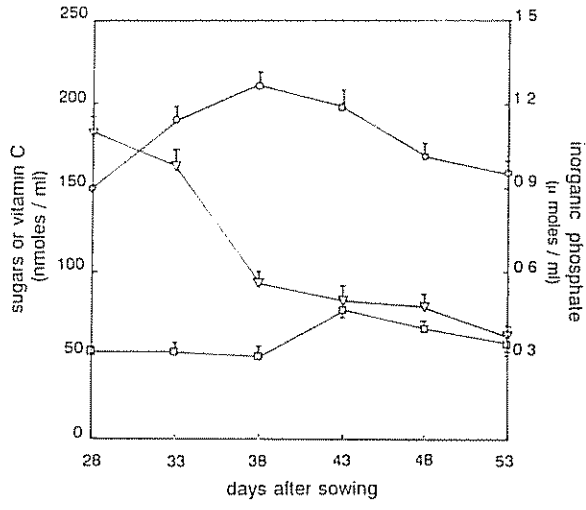

Fig. 4. Time-course of accumulation of inorganic phosphate (Δ—Δ), free sugars (O—O), and vitamin C (□—□) in the shoots of *A. dubius* during its mature stages of development.

DISCUSSION

At the early maturity stage, distribution of sugar in the leaves and stems was similar, rising in each case to a peak before declining at later phases of development. This observation is consistent with the general notion that the extent to which plant organs are supplied with assimilate relates to their rate of growth or storage capacity.

Thus, at the early mature stages the levels of sugar in the leaves and stems were high as growth was still taking place; whereas the period of decline in sugar contents of these same parts could be a reflection of a diversion of a major percentage of the assimilates away from them at floral evocation (3) and during subsequent development. The significantly low levels of sugar in the leaves of 28-day-old plants compared with the stems could be due to the fact that this stage of development, marked by newly fully-expanded leaves with well-differentiated vasculature, is also the period of maximum exportation of sugar by the leaves. The stems, however, at this period, which were still growing required more assimilate or constituted stronger sinks.

Phloem translocation of minor components such as mineral ions is controlled by sugar, the principal phloem solute (11). The observation in this study that maximum levels of vitamin C occurred in the stem and leaf parts within the period of high levels of distribution of sugars in these organs supports this thesis. The situation is not quite the same, however, as regards the accumulation of inorganic phosphate in the stem and leaf parts of *A. dubius*, where high concentrations were recorded at the early mature stage of the vegetable and therefore additional factors are to be considered. The most likely explanation is that at the plant's early maturity phase, the roots are relatively young and active so maximum absorption of nutrients from the culture medium occurs. In *A. viridis* and some other leafy vegetables, nutrient uptake was found negligible in the first three weeks of growth whereas over 70% took place in the two weeks before harvest (13).

This investigation has demonstrated that there is no scientific justification for either harvesting *A. dubius* 35 days (5 weeks) after planting, or preferring the leaves to the stems. Timing of the harvest and the choice of leaves or stems must therefore be a question of convenience in both cases. The optimum date of harvest should be determined by the nutritive value and the harvestable part desired. For the purpose of supplementing carbohydrate-rich diets, consumption of leaves as well as stems, harvested at different times, should be encouraged.

LITERATURE CITED

1. ADEBONA, A.C.; AYISIRE, B.E. 1979. Effect of polyethylene glicol-induced moisture stress on the germination of some tropical seeds. Turrialba 29(4):318-320.

2. BASSIR, O. 1980. The nutritive value of some Nigerian leafy green vegetables. Food Chemistry 5:231-235.

3. BODSON, M.; OUTLAW, W.C. 1985. Elevation in the sucrose content of the shoot apical meristem of *Sinapsis alba* at floral evocation. Plant Physiology 79:420-424.

4. CHEN JUNIOR, P.S.; TORIBARA, T.Y.; WARNER, H. 1956. Microdetermination of phosphorus. Analytical Chemistry 28:1756-1758.

5. CLARK, M.J. 1964. Experimental biochemistry. W.H. Freeman (Ed.). San Francisco. p. 12-14.

6. EZE, J.M. 1986. Growth of *Amaranthus hybridus* (African spinach) under different day light intensities in the dry season in Southern Nigeria. Experimental Agriculture 23:195-200.

7. HEWITT, E.G. 1952. Sand water culture methods used in the study of plant nutrition. Commonw. Bur. Hort. Plantation Crops. Technical Communication no. 22.

8. LAWANSON, A.O.; AKINDELE, B.B.; FASALAJO, P.B.; AKPE, B.L. 1975. Time course of sugar accumulation during deficiences of nitrogen, phosphorus and potassium in seedlings of *Zea mays* L. var. N.S.1. Phyton. Revista Internacional de Botánica Experimental 33(22):179-182.

9. LASSAILLY, F. 1986. Amarante: Vénérée, oubliée, retrouvée. Inter. Tropiques Agricultures (France) 15:16-18.

10. ONWUEME, I.C. 1978. Tropical tuber crops. Wiley (Ed.). p. 84-145.

11. PATRICK, W. 1987. Hormonal control of assimilate partitioning - mini review. News Bulletin British Plant Growth Regulator Group 8(3):1-15.

12. PLUMMER, D.T. 1971. An introduction to practical biochemistry. London, McGrawHill. p. 363.

13. PURUSHOTHAMAN, V.; RAVOOF, A.A. 1980. Micronutrient and removal by four tropical leaf vegetables in Malaysia. Vegetables for the Hort. Humid Tropics 5:26-38.

14. SELVENDRAN, R.R.; STEVENS, B.J.H.; O'NEIL, M.A. 1985. Developments in the isolation and analysis of cell walls from edible plants. **In** Biochemistry of Plant Cell Walls. C.T. Brett *et al.* (Eds.). p. 39-78.

LIBRO RECOMENDADO

Botánica de los Cultivos Tropicales. J. León. Instituto Interamericano de Cooperación para la Agricultura. 445 p. ISBN 92-9039-132-4.

Presenta los conceptos básicos sobre el origen, diversidad, forma y estructura de los cultivos tropicales y su aplicación en las fases de mejoramiento y manejo. Se presenta un ordenamiento sistemático de los cultivos por familia y especies, según el sistema de clasificación fitogenética de J. Hutchinson. Su propósito es servir de material de consulta sobre las regiones tropicales de Latinoamérica.

US$18.00

Ver lista de publicaciones disponibles para la venta y boleta de solicitud en la última sección de la revista Turrialba.