YIELD, COMPOSITION AND *IN VITRO* DIGESTIBILITY OF *AMARANTHUS HYBRIDUS* SUBSPECIES *INCURVATUS*

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ABSTRACT

Amaranthus hybridus *subspecies* incurvatus *plots were sampled at 2-day intervals from* 38 *days after sowing to* 66 *days after sowing to determine dry matter production, chemical composition and in vitro dry matter digestibility.*

Dry matter yields exceeded 9,000 *Kg/ha when sampled* 66 *days after sowing.* In vitro *digestibility remained high over the duration of cutting, whole plant samples averaging* 82.1% *on day* 38 *and* 72.5% *on day* 66. *On the* 38*th day of growth after planting crude protein content in the plant, leaves and stems was* 27.7, 35.8 *and* 20.3%, *but by the end of harvest declined to* 11.3, 21.9 *and* 7.7%. *Over the period of harvest calcium averaged* 1.3, 2.2 *and* 0.8% *and phosphorus* 0.6, 0.7 *and* 0.5% *in whole plant, leaves and stems respectively. The mean oxalic acid content was* 6.7% *and its possible interference with dietary calcium utilization and toxicity are discussed.*

It is concluded that Amaranthus hybridus *subspecies* incurvatus *is potentially a valuable forage crop.*

INTRODUCTION

Livestock production on tropical forages in the humid tropical regions is low by temperate standards and this is usually ascribed to low dry matter, digestible energy or protein consumption or all of these (Hamilton *et al* 1971, Musangi 1969, Mugerwa *et al* 1973). Although there are 40 tropical grass cultivars and 23 legume cultivars currently available for planting (Stobbs 1971), there is a need to select forages of higher nutritive value.

Amaranthus species grow abundantly in Uganda, and are normally used as spinach for human consumption. Protein levels are high and the protein is highly digestible. *Amaranthus* contains higher levels of such essential amino acids as methionine and lysine than many other plants (Lexander *et al* 1970). This paper reports a cutting trial in which the yield, composition and digestibility of *Amaranthus* were determined.

EXPERIMENTAL PROCEDURE

The experiment was conducted at the Makerere University Farm, Kabanyolo, Uganda on a deep, well weathered and leached, fine-textured and well drained latosol.

The experimental site was prepared into a fine seed bed one week before planting. It was fertilized with 100 kg/ha of nitrogen as calcium ammonium nitrate, 112 kg/ha of P_2O_5 as single superphosphate and 112 kg/ha of K_2O as muriate of potash. It was then divided into three equal plots which served as replicates. On September 26th, 1972 seeds of *Amaranthus hybridus* subsp. *incurvatus* were sown into furrows, 30 cm apart and approximately 1 cm deep. The seeds were lightly covered with soil.

Good germination occurred within a week from planting followed by extremely vigorous growth. Weeding was done once during the third week and at the same time light thinning was carried out. Subsequent weeding was not necessary as the *Amaranthus* canopy scarcely permitted any weed growth to occur.

Harvesting was started 38 days after planting and continued a two-day intervals until the 66th day postplanting. The plants were cut at 2 to 3 cm above the soil surface.

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On the days of harvest, the plants were cut between 10.00 a.m. and 12.00 noon when all the dew had evaporated. A part of the harvested material from each of the three plots was separated into leaves and stems and a part was left intact.

The samples were oven dried at 65°C. Every fourth day a measured area in each of the three plots was harvested for the purpose of determining dry matter yields and amount of leaf on the plant.

Chemical analyses of dried samples of whole plant, leaf and stem were determined after grinding to pass a 1 mm sieve. Kjeldahl nitrogen, crude fibre, ether extract, N-free extracts and Organic matter were determined following the A.O.A.C. (1965) procedures. Acid detergent fibre, plant cell wall constituents, lignin and cellulose were assayed as described by Van Soest and Wine (1967). Calcium was determined titrimetrically and phosphorus by the molybdate method (A.O.A.C. 1965). The method of Moir (1953) was used in analysing for oxalic acid content.

In vitro dry matter digestibility determination on the dried samples was carried out by a modification of the Tilley and Terry (1963) two-stage technique, as described by Barnes (1969). The rumen fluid inoculum was obtained from a cow fitted with a permanent rumen fistula and grazing a predominantly *Chloris gayana* pasture.

RESULTS

Dry matter and protein yields are shown in Table 1. Dry matter was accumulating at an average rate of 241 kg/ha/day from the date harvesting started. Assuming an average combustible energy of 4 Mcals/kg, plants were concentrating 964 Mcals/ha/day. In 66 days of growth dry matter yields of over 9000 kg/ha were produced. Plants were almost wholly leaf up to the 42nd day but thereafter the leaf to stem ratio widened. Plants were still in the vegetative phase after growing for 66 days. Crude protein production per hectare began declining after the 46th day of growth due to a rapid fall in crude protein content as the plant matured.

In vitro digestibility declined from a mean 82.1 at day 38 to 72.5 at day 66 (Table 1). Leaf digestibility declined more slowly than stem.

TABLE 1

Dry matter (DM) and protein yields and in vitro *DM digestibility of* Amaranthus hybridus *subsp.* incurvatus *with advancing maturation.*

Days of growth	38	42	46	50	54	58	62	66
D.M. Yield (kg/ha)								
Whole Plant	2,735	3,865	6,004	6,409	7,345	7,915	8,642	9,472
Leaf	1,477	1,971	2,522	3,076	2,644	3,483	3,284	3,789
Stem	1,258	1,894	3,482	3,333	4,701	4,432	5,358	5,683
Protein Yield (kg/ha)								
Whole Plant	758	1,016	1,561	1,154	1,278	1,187	1,072	1,198
Leaf	529	698	764	818	612	853	650	830
Stem	230	329	697	338	656	335	424	367
In vitro D.M. digestibility (%)								
Whole Plant	82.1	83.5	80.4	78.4	76.3	75.5	70.1	72.5
Leaf	82.2	82.5	77.9	76.2	77.7	79.4	79.4	79.0
Stem	82.8	79.0	72.4	72.3	69.6	68.3	64.6	61.3

The chemical composition of the different parts of the *Amaranthus* plant is shown in Table 2. Although organic matter differed only slightly between leaves and stems over the period of harvest, leaves contained on the average more organic matter. Leaves contained markedly more crude protein at all stages of growth than stems.

Similar trend was observed with ether and nitrogen-free extracts. Components of the fibrous fraction were much lower in leaves than in stems and all increased in leaf and stem as the plant matured.

The content of calcium and phosphorus in the *Amaranthus* plant is high and most is found in the leaves. There was a tendency for both calcium and phosphorus to decrease with the advancing maturity of the plant. Oxalic acid content was also extremely high.

TABLE 2

Mean values and ranges of the various chemical components of the different parts of Amaranthus hybridus *subsp.* incurvatus.

Component (% DM)	Whole Plant		Leaf		Stem	
	Mean	Range	Mean	Range	Mean	Range
Organic matter	79.4	77.0–82.7	82.8	80.8–84.1	77.8	73.8–83.0
Crude protein	19.4	11.3–27.7	27.6	19.8–36.3	12.8	7.7–20.3
Ether Extract	2.7	2.0– 3.7	4.3	2.3– 5.4	1.4	0.9– 2.1
Crude Fibre	23.6	12.5–31.8	10.8	8.1–12.0	30.9	18.5–38.7
Nitrogen Free Extract	33.7	28.8–39.2	40.2	31.3–47.4	32.7	26.9–38.7
Acid detergent Fibre	27.5	18.6–34.7	17.1	12.5–19.9	34.0	23.3–41.9
Lignin	6.0	4.0– 7.7	5.3	4.1– 6.8	7.6	5.8– 9.8
Cellulose	20.0	12.2–25.6	11.3	7.6–13.3	25.9	16.5–32.2
Cell wall constituents	42.9	28.7–52.3	38.5	21.8–46.1	45.5	29.1–58.4
Calcium	1.3	0.9– 1.7	2.2	1.6– 2.5	0.8	0.4– 0.7
Phosphorus	0.6	0.5– 0.7	0.7	0.6– 0.8	0.5	0.4– 1.2
Oxalic acid	6.7	6.1– 7.6	7.1	5.6– 9.6	5.8	5.0– 6.5

DISCUSSION

Insufficient digestible energy intake often coupled with a lack of protein are the major factors limiting animal production under practical farming conditions. In East Africa there is little surplus of cereal grains or grain legumes to be diverted from human needs to animal feeding. Supplementary feeding of cattle claims a very small share of this meagre surplus; the greater portion being fed to non-ruminants. These considerations have prompted investigations into the nutritive value of fodder crops with a potential for high dry matter and protein production per unit of land area.

The rapid growth, tremendous dry matter yield per unit area and per unit time and the high protein content make *Amaranthus* species worthy of investigation as a forage crop.

In 66 days of growth *Amaranthus hybridus* subsp. *incurvatus* produced over 9000 kg DM/ha. Henderlong (unpublished data) has investigated the productivity of a number of tropical grasses and legumes at this station, but none of these have yielded so much dry matter in a period of two months. Van Eijnatten (1970) reported that during the rainy seasons in tropical areas the production of green leaves from some *Amaranthus* species could reach 12–17 tonnes/ha. Moreover, the protein content of *Amaranthus hybridus* subsp. *incurvatus* is much higher than that found in most tropical grasses and a number of legumes of the same stage of growth. However, one of the factors likely to limit its dry matter intake in the fresh form is its high moisture content (up to 90%), especially in the stems in the early stages of growth. Because of its rapid growth, it would be possible in East Africa to harvest two crops of *Amaranthus* in a growing season. In the two rainy seasons in Uganda, four crops and yields exceeding 40 metric tons of dry matter per year are possible. With selective breeding, it is hoped that even greater productivity can be achieved.

The fibrous fraction is much lower in *Amaranthus* than that found in most tropical grasses and legumes at the same stage of growth. This may partially explain the high *in vitro* dry matter digestibility of all parts of the plant. It should, however, be recognized that *in vitro* results merely give an indication of the likely *in vivo* results.

The tendency for the *in vitro* digestibility coefficients to underestimate *in vivo* digestibility of tropical forages has been reported (Long 1967, McLeod and Minson 1969, Reid *et al* 1973). The magnitude of underestimation differs between plant species (Reid *et al* 1973). Quantitative agreement would be difficult to achieve since *in vivo* data are normally derived under conditions where the animals have an opportunity to select their feed. As to how closely the *Amaranthus in vitro* digestibility data would estimate animal data is not currently known.

Of particular interest is the high content of calcium and phosphorus in the species of *Amaranthus* reported here. These levels are similar to those of most forage legumes and much higher than those found in the gramineous forages. Oxalic acid content is extremely high (Table 2). The relationship between oxalic acid content of a feed and dietary calcium availability and metabolism and toxic effects of oxalic acid rich plants have been investigated over the last thirty odd years. Several workers agree that the rumen micro-organisms have the ability to decompose to a considerable degree ingested oxalates (Morris and Garcia-Rivera 1955, Manoharjit *et al* 1971 and Negi 1971), especially when habituated (Watts 1957). The presence of excess calcium decreased the amount decomposed (Watts 1957). In his later work Watts (1959) observed subacute oxalic acid poisoning in sheep drenched with 10.5—21 gm of oxalic acid per day, but those animals in good nutritional status achieved by feeding additional source of protein in the form of lucerne hay and calcium tolerated even larger doses. Mathams and Sutherland (1952) observed no ill-effects in sheep receiving 0.28 to 0.32 gm of sodium oxalate per kg of body weight. Poisoning occurred only on those plants containing over 8% oxalic acid on a dry matter basis. When *Oxalis cernua* Thumb was the only feed to sheep no signs of toxicity were noted by Maymone *et al* (1961), although there were deposits of oxalic acid crystals in the renal tubules. In our preliminary feeding trials with sheep consuming between 700–1200 gm/day of *Amaranthus* dry matter (c. 40–90 gm of oxalic acid), no clinical signs of ill-effects have been observed. However, the ratio of insoluble to soluble oxalates has not been determined yet. It is possible that the high protein and calcium contents of *Amaranthus* may help to overcome toxic effects (Watts 1959) but further animal experimentation is required.

It is concluded that *Amaranthus* species are capable of producing high yields of apparently highly nutritious herbage and this preliminary study suggests that further investigations to measure their usefulness for increasing animal production are warranted.

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REFERENCES

A.O.A.C. (1965)—Official methods of analysis. Association of Official Agricultural Chemists. Washington D.C. U.S.A.

Barnes, R. F. (1969)—Collaborative research with the two-stage *in vitro* technique. Proceedings of the National Symposium on Forage Quality and Utilization, Lincoln, Nebraska.

Hamilton, R. I., Lambourne, L. J., Roe, R., and Minson, D. J. (1971)—Quality of tropical grasses for milk production. Proceedings of the XI International Grassland Congress. Queensland pp. 860-4.

Lexander, K., Carlsson, R., Simonsson, A., and Lundborg, T. (1970)—Quantities and qualities of leaf protein concentrates from wild species and crop species grown under controlled conditions. *Annals of Applied Biology* **66**: 193-216.

LONG, M. I. E. (1967)—Investigations on the *in vitro* techniques used under East African conditions. *East Africa Agriculture and Forestry Journal* **33**: 166-9.

MAYMONE, B., TIBERIO, M., DITTILO, M., and GIACOMINI, A. (1961)—*Oxalis cernua* Thumb as a winter feed for dairy cows in the southern regions. *Nutritional Abstracts and Reviews* **31**: 1011-2.

MATHAMS, R. H., and SUTHERLAND, A. K. (1952)—The oxalate content of some Queensland pasture plants. *Queensland Journal of Agricultural Science* **9**: 317-9.

MCLEOD, M. N., and MINSON, D. J. (1969)—Sources of variation in the *in vitro* digestibility of tropical grasses. *Journal of British Grassland Society* **24**: 244-9.

MOIR, K. W. (1953)—The determination of oxalates in plants. *Queensland Journal of Agricultural Science* **10**: 1-4.

MONOHARJIT, KAUR, PUNJ, M. L., and BHATIA, I. S. (1971)—*In vitro* breakdown of oxalates by rumen microorganisms. *Indian Journal of Animal Science* **41**: 802-4.

MORRIS, M. P., and GARCIA-RIVERA, J. (1955)—The destruction of oxalates by the rumen contents of cows. *Journal of Dairy Science* **38**: 1169.

MUGERWA, J. S., LAWRENCE, MARY P., and CHRISTENSEN, D. A. (1973)—Utilization of urea-molasses for dairy cattle feeding. II Urea-molasses as a supplement for lactating dairy cows grazing improved pastures in Uganda. (In Press).

MUSANGI, R. S. (1969)—The utilization of improved pastures in Uganda. I. Beef steers. *East African Agriculture and Forestry Journal* **34**: 306-11.

NEGI, S. S. (1971)—Calcium assimilation in relation to metabolism of soluble and insoluble oxalates in the ruminant system. A reappraisal. *Indian Journal of Animal Science* **41**: 913-21.

REID, R. L., POST, AMY J., OLSEN, F. J., and MUGERWA, J. S. (1973)—Studies on the nutritional quality of grasses and legumes in Uganda. I Application of *in vitro* digestibility techniques to species and stages of growth effects. *Tropical Agriculture (Trinidad)* **50**: 1-15.

STOBBS, T. H. (1971)—Quality of pasture and forage crops for dairy production in the tropical regions of Australia. *Tropical Grasslands* **5**: 159-69.

TILLEY, J. M. A., and TERRY, R. A. (1963)—A two-stage technique for *in vitro* digestion of forage crops. *Journal of British Grassland Society* **18**: 104-11.

VAN EIJNATTEN, C. L. M. (1970)—Freedom from hunger campaign. Report to the Government of Nigeria. Home gardens for improved human nutrition. Royal Tropical Institute, 63 Mauritskade, Amsterdam.

VAN SOEST, P. J., and WINE, R. H. (1967)—Use of detergents in the analysis of fibrous feeds. IV Determination of plant cell-wall constituents. *Journal of the Association of Official Agricultural Chemists* **50**: 50.

WATTS, P. S. (1957)—Decomposition of oxalic acid *in vitro* by rumen contents. *Australian Journal of Agricultural Science* **8**: 266.

WATTS, P. S. (1959)—Effects of oxalic acid ingestion by sheep. II Large doses to sheep on different diets. *Journal of Agricultural Science* **52**: 250-5.

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CORRECTION

The first line of the INTRODUCTION on page 305 of Vol. 7, No. 3 should read "Greenleaf (*Desmodium intortum*)† is one of two *Desmodium* cultivars recom—"
