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BIOMASS, MINERAL ELEMENTS AND PROTEIN CONTENTS OF SIX FRESHWATER MACROPHYTES FROM GHANA

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Abstract

The biomass, mineral elements and protein contents of six freshwater macrophytes found in Ghana are reported in this paper. The plants are *Ceratophyllum demersum* (a submerged plant), *Eichhornia crassipes* and *Pistia stratiotes* (free-floating plants), *Echinochloa pyramidalis* and *Typha domingensis* (emergent plants) and *Nymphaea lotus* (a floating-leaved plant). The fresh and dry weights of the plants were measured and the concentration of six elements: calcium, magnesium, nitrogen, phosphorus, potassium and sodium in the tissues of the plants were determined. Calcium and magnesium contents were determined by ethylenediamine tetraacetic acid (EDTA) titration, nitrogen by micro-Kjeldahl method, phosphorus as orthophosphate after reaction with molybdate by absorption spectrophotometry, and potassium and sodium by flame photometry. The fresh weight of the plants ranged from 22 to 57 t ha $^{-1}$ while the dry weight ranged from 1.2 to 12.5 t ha $^{-1}$. Mineral elements varied in the plants as follows: calcium, 0.6–2.2; magnesium, 0.4–2.7; nitrogen, 1.4–3.7; phosphorous, 0.2–0.8; potassium, 0.4–5.2; and sodium, 0.4–3.4 per cent dry weight. These values are within the ranges reported by other workers from comparable freshwater environments. The ethnobotany of the freshwater macrophytes studied was discussed.

Introduction

In many parts of tropical West African sub-region, including Ghana, a variety of freshwater bodies exists. Such freshwater bodies could be classified to include lakes (natural and man-made), reservoirs, ponds, streams, rivers, river-rapids including water falls, roadside ditches, marshes/ swamps, etc. In several of these freshwater bodies in Ghana, the dominant vegetation is aquatic macrophytes.The dominant species among them include *Azolla pinnata* subsp. *pinnata* R. Br., *Ceratophyllum demersum* L., *Ceratopteris cornuta* (P. Beauv.) Lepr., *Cyperus articulatus* L., *Echinochloa pyramidalis* (Lam.) Hitchc. & A. Chase, *Eichhornia crassipes* (Mart.-Solms.) Laubach., *Ipomoea aquatica* Forsk, *Ludwigia stolonifera* (Guill. & Perr.) Raven, *Ludwigia leptocarpa* (Nutt.) Hara, *Lemna perpusilla* Torrey, *Neptunia oleracea* Lour., *Nymphaea lotus* L., *Phragmites karka* (Retz.) Trin. ex Steud., *Pistia stratiotes* L., *Potamogeton octandrus* Poir., *Salvinia molesta* D. S. Mitchell, *Salvinia nymphylulla* Desv., *Spirodela polyrhiza* Schleid., *Typha domingensis* Pers., *Vallisneria aethiopica* Fenzl. and *Vossia cuspidata* (Roxb.) Griff. Some of these species are indigenous to Africa, e.g. *A. pinnata*, and *C. demersum* (Mitchell, 1985; Wagner, 1997) while others, e.g. *E. crassipes* and *S. molesta,* are recognised as introduced (de Graft-Johnson, 1988; Harley, 1992).

In many of the freshwater ecosystems in the country, both the indigenous and introduced macrophytes have reached weed status. Examples are the introduced *E. crassipes* and *S. molesta* in the Tano/Abbey/Ehy lagoon and river complex, and the indigenous *C. demersum* in the Barekese lake, and *A. pinnata*, *T. domingensis* and *C. demersum* in the Kpong head pond. The plants have become unsightly and interfere with beneficial uses of the water body, such as potable water production, fisheries, navigation and recreation.

When aquatic macrophytes reach weed status, they interfere with the intended use of a water body in a variety of ways. These include wasting water through excessive evapotranspiration and creating excellent conditions for the growth, proliferation and spread of vectors of some water-borne diseases by providing them with breeding grounds, protection against predators, sources of oxygen, and, in some cases, transporting them from one place to another. They also occupy useful volume for water storage in small reservoirs, interfere with boat movement for navigation and recreation, and hinder fish culture and fishing. Furthermore, they hamper collection and utilisation of water, e.g. in potable water production, and make water unpalatable and, hence, increase cost of potable water production. They also choke feeder streams, irrigation outlets and intakes; thus, impede water flow in rivers and canals and promote silting and sedimentation (Mitchell, 1985).

Three main controls are used in attempts to eradicate or reduce infestation or rank growth of aquatic eradicate or macrophytic weeds. These are mechanical, chemical and biological control methods. In recent years, however, an integrated approach, involving the three methods, is practised.

There is enough evidence, however, to suggest that aquatic plants constitute free crop and have the potential to be exploited for the benefit of humans (Anon., 1976; Wagner, 1997). Aquatic macrophytes have found use as animal feed, soil additives (Frank, 1976), making paper and fibre pulps (Gupta & Lamba, 1976), food, leaf protein and carotene, medical ingredients, in wastewater treatment, and in fuel production (Anon., 1976; Mitchell, 1985). The plants have high turnovers. Data presented by Westlake (1981) gave the doubling times of *Eichhornia crassipes* and *Typha latifolia* L. as 13 and 15 days, respectively. The biomass of a mat of *E. crassipes* has been found to range from 660 to 3, 000 g m^{-2} (Lugo *et al.*, 1978). On the Volta Lake *Pistia stratiotes* has been shown to produce 500–690 g m^{-2} day^{-1} of vegetation per annum (Petr, 1968; Hall & Okali, 1974; Attionu, 1970). *Potamogeton pectinatus* has also been shown to produce almost 16 gm^{-2} day^{-1} of dry matter with an annual dry matter production of 2506 g m^{-2} yr^{-1} (Howard-Williams, 1978).

With such high turnovers, if aquatic plants become weeds requiring control, one means of control is to harvest and make use of them. However, aquatic weed harvesting and utilisation is not a control measure *per se*. Utilisation, however, enables part of the cost of harvesting to be recovered, and removes the risk of using chemicals which may pollute the water system, or introduce organisms that may themselves become pests.

The objectives of the study were to determine (i) the biomass, fresh and dry weights, and (ii) mineral elements and protein content, of six aquatic macrophytes that are dominant in many freshwater bodies in Ghana. It will enable the determination of the uses to which the plants can be put and, hence, lead to the formulation of strategies for their control or reduction in the population of the plants. The work forms part of efforts to investigate the ethnobotany of the dominant and weedy aquatic macrophytes in Ghana.

Experimental

The freshwater macrophytes used in the study were collected in September and October 2003, when the plants were in lush green condition, from two sites in Ghana as follows: (i) *Ceratophyllum demersum*, *Echinochloa pyramidalis*, *Nymphaea lotus* and *Typha domingensis* from the south-western parts of Weija lake; the lake lies between latitude 5^0 33' and 5^0 40' N and longitude 0^0 20' and 0^0 24' W. (ii)

Eichhornia crassipes and *Pistia stratiotes* from the Tano/Abbey/Ehy lagoon and river complex, (specifically the Dwueu lagoon 5^0 06' and 2^0 58' W and Nveye lagoon 5^0 06' N and 2^0 54'W) at the south western border with La Côte D'Ivoire. Sampling was done by locating quadrats at random for each species. Two sites of a rectangular area, 50 m $\times$ 30 m, containing nearly pure stands of the species were used as ordinates and co-ordinates and a table of random numbers (Fisher & Yates, 1963) was used to locate the approximate position of the quadrats.

The plant materials for analysis were obtained by hand cutting 10 quadrat samples, for each species, each quadrat of area 0.25 m^2. When necessary, root portions of plants were flushed in the water to remove soil and other debris. After flushing, the plants were wiped dry with a dry cloth for fresh weight determination as described by Gaudet (1977). The plants were weighed on a spring or top loading balance. They were then packed lightly into labelled polythene bags and transported to the laboratory. In the laboratory the various plant species were put into paper bags and dried in a Gallenkamp hot air circulating oven at 70 ^{0}C until constant dry weights were obtained, following the method of Gaudet (1977).

Chemical analysis of plant materials was done by using pooled samples, which included both old and young materials, as well as shoot and root portions of each species, as described by Gaudet (1977). These pooled samples were more representative of the plant, since they eliminate the wide variation in chemical composition often found between plant portions (Gaudet, 1976). The dried material was then dismembered enough to pass through the inlet of a laboratory mill. The chaffed material was ground in a Christy and Norris Junior Laboratory mill to pass a 1-mm sieve and stored in labelled specimen tubes.The ground material was re-dried for 3 h as done by Gaudet (1977). Three sub-samples of 500 mg each were then wet-digested in sulphuric acid, nitric acid and perchloric acid until clear (Piper, 1950; Jaiswal, 2003), and used in the determination of orthophosphate, calcium, magnesium, potassium and sodium.

Phosphate content in the digest was determined as orthophosphate (PO_4^--P) after reaction with molybdate by absorption spectrophotometry (Watanabe & Opsen, 1965). Calcium and magnesium contents were determined by ethylenediamine tetraacetic acid (EDTA) titration (Moss, 1961). Potassium and sodium were determined using a flame photometer (Jackson, 1962). Nitrogen content in the digest was determined by micro-Kjeldahl method (Jackson, 1962; AOAC, 1975). Crude protein was determined following the method of Boyd (1968) and Howard-Williams & Junk (1977), as percentage nitrogen multiplied by 6.25. According to Boyd (1970), such results correctly reflect the true protein content of aquatic macrophytes.

Results and discussion

Fresh and dry weights of six dominant freshwater macrophytes from Ghana

The biomass, fresh and dry weights of the six dominant aquatic macrophytes (*C. demersum*, *E. crassipes, E. pyramidalis, N. lotus, P. stratiotes* and *T. domingensis*), in lush green condition, from two major water bodies in Ghana are presented in Table 1. *P. stratiotes* had the highest fresh weight value of 56.9 t ha^{-1} while *E. crassipes* showed the lowest value of 21.8 t ha^{-1}. On dry weight basis, *T. domingensis* had the highest value of 12.5 t ha^{-1} and *E. crassipes* had the lowest value of 1.2 t ha^{-1}. The differences in fresh and dry weight values of the six species were significantly different from each other at the 95 per cent confidence level.

The fresh and dry weight values for the species were comparable to those reported for such plants elsewhere. In the Weija lake, for example, dry weight for *Pistia* plants was 4.5 t ha^{-1} (Ameka, 1987), and on the Volta lake a range of 5–7 t ha^{-1} was reported by Petr (1968), Attionu (1970) and Hall & Okali (1974). The maximum dry weight obtained for *E. pyramidalis* was 8 t ha^{-1} on Weija

TABLE 1

The fresh and dry matter content of six freshwater macrophytes from Ghana

Species	*Life form*	*Fresh weight t ha^{-1} (±S.E.)*	*Dry weight t ha^{-1} (±S.E.)*	*Dry weight as % of fresh weight*
C. demersum	Submerged	31.4 (±2.4)	1.6 (±0.4)	5.1
E. pyramidalis	Emergent	35.6 (±2.1)	9.8 (±1.1)	27.5
E. crassipes	Free-floating	21.8 (±1.9)	1.2 (±0.4)	5.5
P. stratiotes	Free-floating	56.9 (±2.2)	3.9 (±0.8)	6.8
N. lotus	Floating-leaved	33.3 (±2.1)	2.7 (±0.6)	8.1
T. domingensis	Emergent	49.8 (±3.1)	12.5 (±1.1)	25.3

TABLE 2

Protein content of six freshwater macrophytes from Ghana

Species	*Protein content (% dry weight)*
C. demersum	22.9
E. pyramidalis	10.4
E. crassipes	13.8
P. stratiotes	8.7
N. lotus	13.9
T. domingensis	12.1

lake (Ameka, 1987), and 54 t ha^{-1} on Lake Kainji in Nigeria (John, 1986). However, no meaningful comparisons can be made in terms of fresh and dry weights of the plants since they were growing in different environments. According to Sculthorpe (1967), different freshwater environments have large variations in habitat conditions and, as such, comparisons based solely on fresh and dry weights are not useful.

The dry matter (dry weight as a percentage of the fresh weight) values obtained for the free-floating, submerged and the floating-leaved plants ranged from 5.1 to 8.2 per cent and were considerably lower than those obtained for the emergent plants which ranged from 25 to 28 per cent (Table 1). The dry matter values obtained for the free-floating freshwater plants, *E. crassipes* and *P. stratiotes*, fell well within the range 5 – 9 per cent reported by Guadet (1974) for such plants. Also the values for the emergent species *E. pyramidalis* and *T. domingensis* (25 – 28%), were comparable to the range 25 – 40 per cent reported by Sculthrope (1967) for emergent plants. The values for *C. demersum* and *N. lotus* (5 – 8%) also fell within the range (5 – 14.5%) obtained in the Kpong head pond and Weija lake in Ghana for the two species (de Graft-Johnson, unpublished). Boyd (1968) obtained a dry matter of 13.7 per cent for *C. demersum* plants from Alabama, in the USA.

The difference in dry matter values for submerged and free-floating plants, on one hand, and emergent types, on the other hand, was striking. The low dry matter value for the floating and submerged was due to the high water content and, in some cases, the extensive lacuna system. Such plants are necessarily buoyant. The surrounding water reduces the need for supporting tissue, so that the plant contains very little dry matter. Emergents, on the other hand, contain much more dry matter. Data presented by Gaudet (1974) support this statement for both temperate and tropical climates.

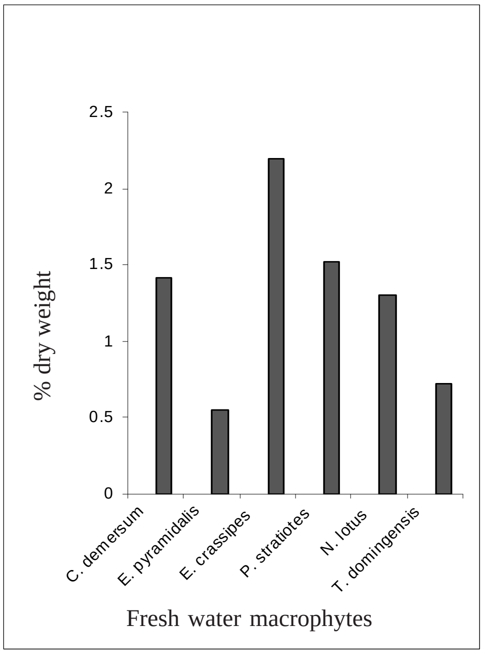

Fig. 1. Calcium content of six freshwater marcrophytes from Ghana

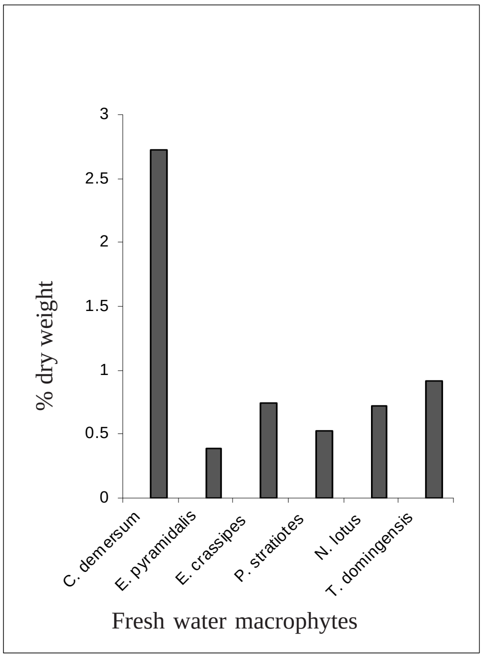

Fig. 2. Magnesium content of six freshwater marcrophytes from Ghana

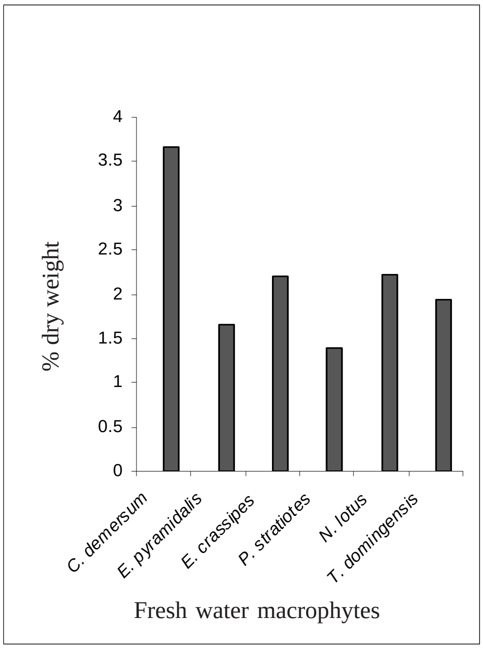

Fig. 3. Nitrogen content of six freshwater marcrophytes from Ghana

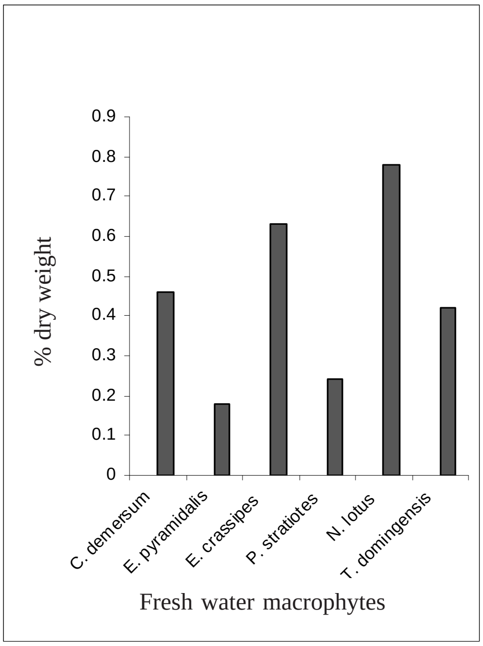

Fig. 4. Phosphorous content of six freshwater marcrophytes from Ghana

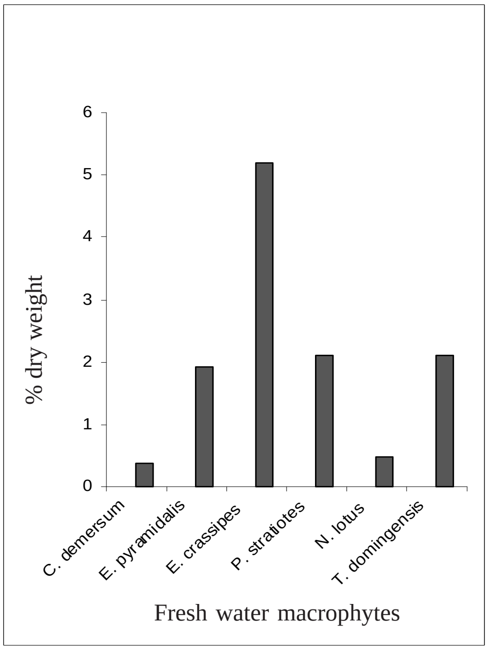

Fig. 5. Potassium content of six freshwater marcrophytes from Ghana

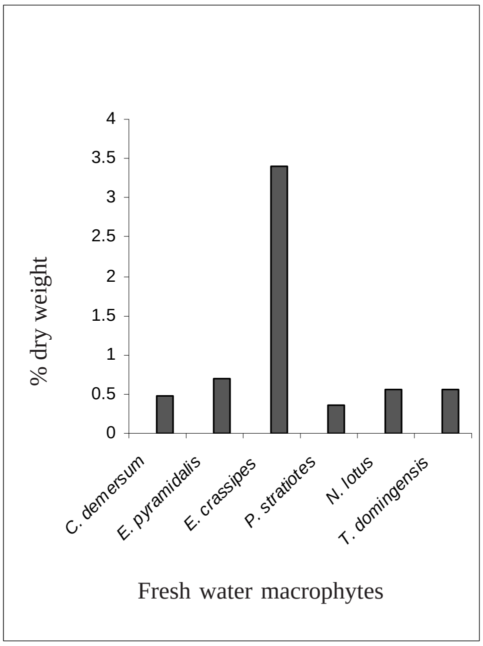

Fig. 6. Sodium content of six freshwater marcrophytes from Ghana

Mineral elements and protein contents of six freshwater macrophytes occurring in Ghana

The mineral element levels in the freshwater macrophytes studied are shown in Fig. 1–6. Calcium content of the plants ranged from 0.6 per cent in *E. pyramidalis* to 2.2 per cent dry weight in *E. crassipes*. The values of magnesium ranged from 0.4 per cent in *E. pyramidalis* to 2.7 per cent dry weight in *C. demersum*. Nitrogen was 3.7 per cent in *C. demersum*, which was the highest value, and 1.4 per cent dry weight in *P. stratiotes*, the lowest value. *N. lotus* showed the highest value of phosphorus with a value of 0.8 per cent while the lowest value of 0.2 per cent dry weight was obtained in *E. pyramidalis*. *E. crassipes* had the highest potassium content of 5.2 per cent and the lowest value of 0.4 per cent dry weight was observed in *C. demersum*. Sodium levels in the plants varied from 3.4 per cent, the highest, in *E. crassipes* to 0.4 per cent dry weight, the lowest, in *P. stratiotes*. These values agreed with data obtained by Okali & Attionu (1974) for *Pistia* plants on the Volta lake in Ghana and work by Howard-Williams & Junk (1977) on plants in South America.

The protein content of the macrophytes studied is presented in Table 2. The highest protein level (22.9% dry weight) was obtained in *C. demersum* while the lowest (8.7% dry weight) was in *P. stratiotes*. The values obtained in the study were similar to those obtained for *C. demersum* (21.7%), *Nymphaea odorata* (16.6%) and *Typha latifolia* (10.3%) species from S. E. Alabama, USA by Boyd (1968).

In the past, aquatic weeds were considered a nuisance and must be destroyed or eradicated. There is, however, a growing interest, even in developing countries, in the potential use of aquatic weeds in a variety of ways to benefit humans. This interest dates as far back as the 1970's as shown by publications such as those by the US National Academy of Sciences. Other publications relating to utilisation of aquatic plants include those by Boyd (1972, (1974), Gaudet (1974), Morton (1975), Little (1979), Gopal & Sharma (1981), and Mitchell (1985). The general trend, which has emerged from such studies on utilisation of aquatic plants is that the plants, could be used as food for humans or other animals, as fertilizer, for pulp and paper, for wastewater treatment, and for energy production.

From the foregoing, based on chemical analysis, the aquatic macrophytes studied could be used in the local communities in which they occur as high protein content roughage in the diet of humans and livestock. The plants also contain mineral elements, which could possibly be used as mineral supplements. The actual biological values for the plants must be determined in feeding trials. The use of aquatic weeds as food supplement could reduce protein shortages in local communities but it is doubtful if the plants could contribute significantly to the total food security of any country or region.

Again, based on chemical analysis, the plants contain fair amounts of plant nutrients and could, therefore, be used as compost, fertilizer, mulch or other forms of soil additives in the local communities where the plants exist. Eddowes (1976) gave the recommended levels of nitrogen (N), phosphorous (P) and potassium (K) for maize and carrots as follows: maize, N (1.0 – 1.5), P (0.6 – 0.9) and K (0.6 – 0.9); carrots, N (0.6 – 0.8), P (0.6 – 0.8) and K (1.0 – 1.5). In the communities around the Weija lake, maize and carrots are commonly grown, while maize is the predominant crop in the Tano/Abbey/Ehy lagoon and river complex area. With regard to N, all the six aquatic plants (*C. demersum*, *N. lotus*, *E.crassipes*, *P. stratiotes*, *E. pyramidalis* and *T. domingensis*) had values higher than the recommended values for both crops.

Phosphorous levels were lower than the recommended values in *E. crassipes* and *N. lotus* for both crops, but the other four plants had higher values. Potassium levels in *C. demersum* and *N. lotus* were lower than the recommended values for both crops. However, the other plants had values above the recommended range. The levels of N, P and K in *P. stratiotes*, *E. pyramidalis* and *T. domingensis* (Fig. 3, 4 and 5) were above the recommended levels and, thus, can be used as soil additives for maize and carrot. With the other three plants (*C. demersum*, *E. crassipes* and *N. lotus*), addition of P and K from other sources could enable them to be used as soil additives or amendments.

Clearly the prospects of utilising aquatic weeds for the benefit of humans are exciting. However, more experimental work (e.g. feeding trials) and field work/trials (e.g. use of plants in the field as soil additives) need to be done, particularly in the developing countries. This is because it is in the developing countries that the need to eradicate the plants is more urgent, and the need to use the plants as food for humans and animals, for energy, and as soil amendments can not be over stated. Yet it is in these countries that very little work has been done in this direction.

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