Copper Tolerance in *Becium homblei*

A ZAMBIAN flowering plant *Becium homblei* of the family labiatae grows on soils rich in copper[1], and it has been shown to accumulate heavy metals[2-4]. Other plants also have this characteristic, and their ability to immobilize in insoluble form and to regulate internal distribution of absorbed metals has been noted[5,6]. We agree that these two properties are important in *B. homblei*, but also suggest that an extrinsic factor, peculiar to the derived savanna vegetation of south-central Africa, must be taken into account.

B. homblei is a small plant which forms a clump of unbranched stems, about 18 inches high, from a perennial rootstock. Stems and leaves usually appear early in September before the end of the dry season. Young leaves are dark green, though a few may be yellow. The number of chlorotic leaves increases, until by the end of the growing season (April or May) 60% of the plants may show signs of chlorosis. The leaves wither in the dry season and stems and leaves are usually burned away in bush fires.

Analyses show that *B. homblei* has apparently no mechanism for limiting copper uptake. As growth proceeds, the concentration of metal increases in leaves and stems. We have recorded, during 1 month, an average increase of 75% in total leaf copper. We have also shown, by paper and thin-layer chromatography, that none of this copper is ionic but exists in complexed forms. Fractionation of plant tissue into extractive-free, detergent residue and H_2SO_4-insoluble residue, represent-soluble, cell wall and lignin fractions[7,8] indicates that much of the copper is bound to structural material of the cells. As is also seen from Table 1, the difference between normal and chlorotic leaves seems to lie not in total copper content, but in the amount extractable in water and organic solvents. There is, moreover, a significant difference between the amount of extractable material in root and leaf tissues. We suggest that these differences, in conjunction with the extrinsic factor of regular bush fires, were important factors in the evolution of this copper-resistant species of *Becium*.

If roots of *B. homblei* are cut in the dry season, they ooze a considerable amount of sap which undoubtedly permits new growth to take place before the rains begin. This root water contains little copper, and thus copper toxicity is unlikely to occur in new leaves. When the rains begin, copper contaminated water passes from the soil to stems and leaves. Much of the copper is rendered insoluble, but enough remains in solution to produce toxic effects. Thus chlorosis develops with the increasing uptake of copper. With leaf fall and subsequent burning, the plant is freed from the bulk of its accumulated copper. Thus, at the beginning of the new growth season, the plant develops new leaves and produces flowers and seeds, before it is affected by the copper.

Table 1 Distribution of Copper in Fractions of Leaf and Root of *B. homblei*

	Copper (mg/kg dry wt.)		
	Leaf		Root
	Normal	Chlorotic	
Total	20.2 ± 5.8	16.6 ± 1.4	9.9 ± 2.2
Extractive-free	12.2 ± 3.9	5.8 ± 1.0	7.9 ± 1.2
% of total extracted by water/organic solvents	40	65	20
Acid detergent residue	4.5 ± 0.9	4.0 ± 1.3	2.6 ± 1.8
% of total extracted by detergent	37	11	50
H_2SO_4	1.3 ± 0.5	0.6 ± 0.6	0.9 ± 0.4
% of total extracted by H_2SO_4	16	20	22

Results are related to original dry tissue and are the mean of five observations ± standard deviation. The figures given for the amount of copper extracted by the different treatments are expressed as the approximate percentage of the total copper originally present in the tissue. The acid detergent was 1% (w/v) cetyl trimethyl ammonium bromide in 1 N H_2SO_4 and extraction was for 2 h. Extractive-free residue was prepared by exhaustive refluxing with water and ethanol : benzene (1 : 2, v/v) mixture. H_2SO_4 residue was what remained after overnight treatment of acid detergent residue with 72% (w/v) sulphuric acid.

When stems are clipped from a clump of *B. homblei* in the dry season and early sprouting is induced by watering the roots, the new leaves are nearly always chlorotic. This phenomenon is apparently caused by contaminated water reaching the developing leaves. When, as sometimes happens, some stems survive the dry season and are protected from fire, the new leaves which sprout from them are usually chlorotic also. Again, this could be explained on the assumption that water supplied from the root, though initially non-toxic, is contaminated with soluble copper on its way through the stems.

As Bradshaw *et al.*[9] wrote of adaptation to metal toxicity in *Agrostis tenuis*, it is tempting to believe that purely Darwinian (selective) processes are insufficient to explain the phenomenon, and that the tolerance is Lamarckian (acquired) in origin. In the light of such a surmise, it would be interesting to see whether prolonged protection of *B. homblei* from the external influence of fire would finally result in the complete disappearance of the plant as a result of the uninterrupted accumulation of toxic concentrations of copper in leaves and stems.

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Estimation of Ecological Production where Age of the Population is Unknown

HITHERTO methods of production estimation[1] have presupposed the estimation of the age of animals, from population data, from laboratory observations on growth rates, or from periodic marks found in hard structures of the body[2]. Frequently no such method is suitable and it becomes impossible to estimate production.

An estimate of production (P) can be derived from knowledge of G, the instantaneous growth rate[3], and the mean biomass, $\bar{B}$:

$$P = G\bar{B} \qquad (1)$$

This assumes that G is constant for individuals of different sizes and ages; errors will be small if production is calculated for separate size or age classes, whose width is small. We shall calculate production for 1 yr, the time interval most frequently used by fishery biologists. P may also be estimated graphically from Allen curves[4].

The value of G decreases with age unless animals enter a new growth stanza[5], or stop growing altogether. Greze[6] has related variation of G to percentage final body weight (*%FBW*). This procedure has the advantages of excluding consideration of absolute body weight and of permitting us to consider relations between relative size and growth rate. Greze used