# SOME RESULTS OF THE INVESTIGATION OF THE DYNAMICS OF THE ACCUMULATION AND FORMATION OF ALKALOIDS AND THEIR ROLE IN PLANTS

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Before the appearance in print of our review "The dynamics of the accumulation and formation of alkaloids and their role in plants" [1] none of the investigations in this field indicated at what period of vegetation and at what site the plant was collected, and it was never stated from what organ the alkaloid was extracted. Consequently, in spite of the enormous amount of accumulated material it was impossible to draw any conclusion whatever about the dynamics of the accumulation and formation of alkaloids and their role in the plant. Now numerous investigators are filling this gap.

We study all plants for their alkaloid content with respect to the vegetation periods of various organs and their various growth sites. We have analyzed 3589 species (more than 30 000 analyses). These included 316 species with a high alkaloid content, 227 with a moderate content, 687 with a low content, and 682 species with traces of alkaloids. The alkaloids have been determined quantitatively in 397 species (848 analyses). From 100 plants, belonging to 20 families, 201 alkaloids have been isolated [2], of which 100 proved to be new. The structures of 51 alkaloids have been established. We have found new sources for the production of 101 alkaloids discovered by other authors, including galanthamine [3], cytisine [4], papaverine [5], and others.

The results of our experiments and literature data, and ideas associated with them, have enabled the following conclusions to be drawn. Alkaloids fulfil different functions in different organs of a plant in different periods of its vegetation and therefore there can be no plant containing only one alkaloid in all the vegetative organs during the whole vegetation period. If only one alkaloid or one isomer has been isolated from the whole plant (epigeal and hypogeal parts) this means that the plant has not been investigated completely.

The maximum total amount of alkaloids is contained in the green part of an alkaloid-bearing plant at an early period of the growth of the stem and leaves, while there is a minimum amount in the hypogeal part and the bark at the same period. Practically no alkaloids remain in parts of the plant that have died off naturally. Their amount begins to decrease in the earlier-formed parts of the plant, the alkaloids passing into the over-wintering parts of the plant necessary for the subsequent generation: seeds, hypogeal part, and, in woody species, into the bark. Consequently, the maximum amount of the mixture of bases accumulates in these parts at the end of the vegetation period, which is why ripe seeds contain more alkaloids than unripe seeds.

However, at this period of vegetation these organs of the plant do not always contain the maximum amount of individual alkaloids; this depends on the role that a particular alkaloid plays. In some cases, for this reason, at the end of the vegetation period alkaloids are concentrated in the seeds, the root system and the bark simultaneously.

At the beginning of the vegetation period, when the leaves appear, the alkaloids from the roots, seeds, and bark migrate, partially in the final form, into the shoots. In the hypogeal parts of the plants the number and the total amount of alkaloids decrease, while in the bark the number remains as before but the total amount decreases. The qualitative and quantitative changes in the alkaloids continue during the whole of the vegetation period. This phenomenon can be used to determine the accumulation of the maximum amount of alkaloids useful in practice, for the separation of complex mixtures of bases, and also to explain the genesis and role of alkaloids in the plant.

The alkaloid-bearing properties of plants are determined by ecological, geographical and other factors. A change in the type and amount of the alkaloids in the individual shrubs is determined mainly by the composition of the soil. The alkaloid content of the individual organs of the plants depends on the vegetation period.

With a change in the conditions of growth of the plant and other factors, the alkaloids change more rapidly than the morphological characteristics. Consequently, one and the same species may contain different alkaloids or other substances under different growth conditions.

In general, the relative number of alkaloid-bearing plants varies as a function of the conditions of their growth. In some species the alkaloids may be replaced by other substances and in other species they appear as a new substance. Consequently, to ascribe alkaloid-bearing properties and a definite alkaloid or group of alkaloids to only certain species or families of plants is incorrect: the presence of alkaloids, or one definite alkaloid, depends on the condition of growth in the various species of several families of plants. But, because of differences in external and internal factors, all species of a single family may not contain alkaloids simultaneously.

The number of alkaloid-bearing plants and their alkaloid content increase from north to south. This is due, in the first place, to the fact that the number of species and the diversity of plants increases towards the south, and in the second place, to the more intensive metabolism of substances in plants in which alkaloids act as biochemical catalysts. In addition to this, alkaloids fulfil various functions. Thus, for example, the alkaloids present in the leaves may be carrier-activators of oxygen, (in the peroxy-N-oxide form), and glucoalkaloids fulfil an active function in the synthesis of polysaccharides. In the hypogeal parts and the seeds, on the other hand, these alkaloids regulate the metabolism, the growth of the root system, and other processes. One alkaloid which fulfils the function mentioned in the leaves is, at a definite period of vegetation and with a further change in the state of the plant, converted into another alkaloid or isomer, migrates to another organ of the plant, and fulfils a new function. In these circumstances, the alkaloids may be converted partially or completely into substances of nonalkaloid character, and vice versa. In this case, during the growth period of the plant there are no alkaloids in its green part, but substances of a nonalkaloid character are present which, at the end of the vegetation period, are converted into alkaloids which accumulate in the hypogeal parts or the seeds. At the end of the vegetation period, the alkaloids present in the green parts may be converted into other substances which accumulate in the appropriate organs.

Nitrogen-containing intermediates necessary for the formation of alkaloids in the leaves are synthesized in the roots of the plant. Depending on the structure of the intermediates, the environment, and the phase of development of the plant, different alkaloids and other substances are synthesized in the leaves. The main intermediates are not so diverse in nature as the alkaloids. From a single main intermediate arising from the root system, many related alkaloids are synthesized in the epigeal parts of various plants.

The elucidation of these principles, on the one hand, has enabled us readily to discover alkaloid-bearing plants and their alkaloids; on the other hand, poor alkaloid-bearing plants have become rich in alkaloids, inaccessible or difficulty accessible alkaloids have become readily accessible, and so on.

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