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# THE BOTANY & CHEMISTRY OF CANNABIS

*Proceedings of a Conference organized by The Institute for the Study of  
Drug Dependence at The Ciba Foundation 9-10 April 1969*

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# Contents

	<i>Page</i>
<i>Participants</i>	vii
<i>Foreword:</i> Sir Harry Greenfield, Chairman, International Narcotics Control Board, Geneva	ix
<i>Introduction:</i> C. R. B. Joyce and S. H. Curry	xi
 <i>Part One: BOTANY</i>	
1 The Cannabis Plant: Botanical Characteristics <i>W. T. Stearn</i>	1
2 Random Thoughts and Queries on the Botany of Cannabis <i>R. E. Schultes</i>	11
3 Some Ecological Implications of the Distribution of Hemp ( <i>Cannabis sativa</i> L.) in the United States of America <i>A. Haney and F. A. Bazzaz</i>	39
4 Changes with Maturation in the Amounts of Biologic- ally Interesting Substances of Cannabis <i>Z. Krejčí</i>	49
5 Constituents of Male and Female Cannabis <i>S. Agurell</i>	57
6 Microscopic Detection of Cannabis in the Pure State and in Semi-Combusted Residues <i>A. Nordal</i>	61
7 <i>Discussion I: Botanical Aspects</i>	
(a) Chemovars and Cultivars	69
(b) Determination of Geographical origins	71
(c) Sex	73
(d) Biosynthesis	74
(e) Forensic Identification of Cannabis	75
 <i>Part Two: CHEMISTRY</i>	
1 Synthesis of (-)-Tetrahydro-cannabinol and Analogous Compounds <i>T. Petržilka</i>	79

pollen-catching stigmas (Fig. 2G). The ovary has one ovule; after pollination the stigmas quickly fall off but the sheath increases in size. The *fruit* (Fig. 2K) is technically an achene, i.e. it contains a single seed with a hard shell tightly covered by the thin wall of the ovary, the whole being regarded in practice as a "seed". This is ellipsoid, slightly compressed, smooth, about 2.5-5 cm (1/8-3/16 in.) long, 2-3.5 mm (1/10 in.) in diameter, greyish or brownish or variously patterned. The embryo (Fig. 2N) within the seed is strongly curved with the two seed-leaves (cotyledons) packed together along one side and the potential root (radicle) up the other, together with a small food-supply (endosperm); they contain much oil.

*Cannabis* and *Humulus* (hop) are the only two genera of the family *Cannabaceae*. They lack the milky juice characteristic of the family *Moraceae* (mulberry family) and have quite different fruits. The generic name *Cannabis* goes back to Roman times; the Latin word *cannabis* (Greek: κένναβις) has accusative *cannabim*, genitive *cannabis*, ablative *cannabe*, and the now accepted family name *Cannabaceae* accordingly consists of the stem *Cannab-* plus the feminine plural adjectival ending *-aceae* (belonging to, have the nature of). The adjective *cannabinus* means "hemp-like". *Datisca cannabina* (family *Datisceae*) is a herbaceous perennial of hemp-like general appearance but with botanical characters quite different from those of *Cannabis*.

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## 2 Random Thoughts and Queries on the Botany of Cannabis

Richard Evans Schultes

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"The hemp plant grows in a wild or spontaneous state over so wide an area, but at the same time is always so closely associated with places that are or may have been inhabited or used as trade routes, that it is difficult to say where it originated".

Watt (1889)

### THE PLANT

It is a plant--this thing that we are about to discuss: a green plant, a very abundant and ubiquitous plant, an unusually valuable economic plant, possibly a dangerous plant, certainly in many ways a mysterious plant. Consequently, I am happy that this symposium, contrary to general procedure in such instances, will begin by considering the plant--some part of what we know about it, but, more important, some part of what we do not know botanically about it. For a thorough knowledge of *Cannabis sativa* as a plant must be basic to progress in studies of its derivatives and their significance to man and their effects on his life and social evolution. Its stature, its structure, its place, its life as a plant, these are all-important, and without a clear comprehension of them we flounder and are lost. So, let us now look at some aspects of this weedy organism as a plant. How much do we know? How little do we know?

The underlying theme of this symposium is, I believe, the consideration of what we really do not know or understand about *Cannabis* and its botany, chemistry and pharmacology. In fact what we do know and understand with certainty is much less than what still remains hidden in "a mist of uncertainty and conjecture". Oftentimes, indeed, we know far less about the botany of some of our important economic and agricultural plants than about some of the odd

and rare wild species of the Plant Kingdom. And of the major economic plants, *Cannabis* falls among those which, in many aspects of their botany, are least known—certainly an anomaly, in view of its antiquity, its diversity of uses and its success in spreading spontaneously over a large part of the earth's surface.

In a cursory panorama such as this talk must needs be, I cannot delve deeply into all of the poorly known or unknown aspects of the botany of *Cannabis*: first, for reasons of brevity; second, because I should consider primarily points bearing on the plant as the source of a narcotic; and third, because I must present the material in a form easily comprehended and pertinently meaningful to colleagues in chemistry, pharmacology and other fields of research often far removed from the plant itself. My principal aim is merely to stimulate thinking by presenting some of the unexplored aspects about *Cannabis* as a living, dynamic, complex chemical factory, concerning the life and evolution of which we should know more, whether we work with it in the laboratory as a dead, processed residue or in the field as an aggressive, plastic weed or cultigen. That so much is not known botanically may frustrate or discourage the chemist and pharmacologist, and justifiably so, but it is precisely such a danger that makes the interdisciplinary approach of this symposium so necessary and so fraught with potentialities.

## EVALUATION

At the start, we might do well to emphasize several points basic to any evaluation of *Cannabis* and concerning which there is no doubt.

*Cannabis sativa* is a triple-purpose economic plant. It has served man long and well as the source of fibre from its stem; of an oil from its seeds; of a narcotic drug from its resin. This diversity of its utilitarian interest to man has been responsible, perhaps more than any other circumstance, for the extraordinary differentiation of the species into so many races or strains throughout its long association with the human race.

The pericyclic bast fibre provides true hemp. Strong and durable, composed of 70% cellulose and reaching lengths of from 3 to 15 feet, it is chiefly a substitute for flax. The drying oil, a greenish yellow fluid of disagreeable flavour, finds employment mainly as a substitute for linseed oil in the paint and varnish industry, but it is of value also in

soap-making, while the oil-cake is used as cattle feed, and, in eastern Europe especially, the seeds, containing sometimes up to 35% of oil, are roasted and consumed by man. The narcotic properties reside in a resin produced in glandular hairs on the leaves, stems and inflorescences. A number of closely related chemical constituents in the resin are responsible for the euphoric, hallucinogenic and other biodynamic activity of the several narcotic preparations of *Cannabis* which are eaten, drunk or smoked.

There is now ethnobotanically no way of ascertaining definitively which of these uses represents the earliest. Normally, however, the uses of a plant proceed historically from the simpler to the more complex. If this holds for *Cannabis*—and I see no reason why it should not—then we can assume that the plant was first valued in primitive society as a source of fibre. This would obviously be the most easily observed morphological characteristic of the plant, a characteristic which, when the stems rotted or were naturally retted, would have been difficult or impossible for man in an inquisitive stage of cultural development to have overlooked. We do know, from archaeological evidence, that in Europe and the near East, at least, the employment of *Cannabis* as a fibre source was perhaps the most ancient of the three uses. Next to have been discovered, perhaps, might have been the curiously narcotic effects of the resin when it was ingested—for we know that man in primitive societies experiments orally with almost any if not all plant tissues. We might logically argue that, at least in some regions, the narcotic use could have preceded all others, since magic is the essence of man's spiritual development, especially in primitive societies. The unearthly effects of the drug must early have assumed a magico-religious importance. The last and probably much more recent discovery could have been the value of the oil expressed from the seeds.

One supporting reason for this presumed sequence might be the geographical extent of these several uses. The use of *Cannabis* to produce fibre is more widespread than its employment as a narcotic or medicine which, in turn, is diffused over a larger area than the utilization of the seed as a source of oil.

## HISTORY

Whichever may have been its earliest economic significance, *Cannabis*

does represent one of man's oldest useful cultivated plants. In fact, I believe that it may represent actually one of our oldest non-food plants. Knowledge of its use by man goes back at least 6,000 years, and obviously man valued it long before our earliest records were made or our oldest archaeological remains were preserved. Archaeological specimens have been found in an Egyptian site of 3,000 to 4,000 years of age. Hempen fabrics have been excavated in sites near Ankara, Turkey, dated in the late 8th Century B.C. The Scythians, who burned *Cannabis* seed to produce an intoxicating smoke, grew hemp in the Volga region some 3,000 years ago. The plant was cultivated in Palestine and Mesopotamia at the time of Christ, but the earliest Roman mention of it was made about 100 B.C. Chinese tradition puts its date back some 4,800 years when Emperor Shen-Nung is credited with teaching his people to cultivate the plant for fibre. Although its value as a fibre plant dates back much earlier, the Indian medical writings, especially the *Susruta*, compiled before 1,000 B.C., report the therapeutic utilization of *Cannabis* resin, and as the nature of some of the vernacular names in India indicates, its narcotic properties were appreciated in the earliest Hindu writings.

Coarse hempen cloth, sometimes estimated to be 6,000 years of age, has turned up in some of the oldest sites of human habitation in Europe. Hempen textiles have been found in Romano-Gallic sites near Cologne, Germany, of the 3rd Century A.D. Seeds and leaves of *Cannabis*, indicating possibly its employment as a food, have been identified from a receptacle excavated near Berlin, Germany, and dated, albeit with some doubt, at about 500 B.C. Archaeological and historical evidence for early England is sparse, but specimens of hempen rope have been recovered from a Roman fort dated 140-180 A.D. In fact, there is very little evidence that *Cannabis* was cultivated, at least as a major plant, in western Europe before the Christian era, but from about 500 A.D. onward, the indications that it was, at least locally, an important crop plant in westernmost Europe are more abundant and trustworthy.

Palynological evidence, as shown by Godwin (1967), has been very helpful in tracing the path of *Cannabis* in western Europe and England and gives hope for similar studies elsewhere. A pollen diagram from an East Anglian lake, for example, indicated that from early Anglo-Saxon times there is a continuous curve for pollen of *Cannabis sativa* cultivated in ever-increasing amounts into late Saxon and Norman times.

*Cannabis* was introduced first to North America, north of Mexico, apparently by the Pilgrims of New England about 1632.

### ORIGINS

There appears to be general agreement that *Cannabis sativa* is an Old World plant, unknown in the Western Hemisphere before the 16th Century. No botanist has ever doubted this opinion, which has been held from the time of Linnaeus' formal naming of the species to Alphonse de Candolle's recognition of the Old and New World assemblages of cultivated plants as distinct and to the modern concepts of Vavilov, Schwanitz, Zhukovskii and other specialists on plant domestication.

There appears, furthermore, to be general agreement that *Cannabis* is Asiatic, and little doubt that it arrived comparatively late in Europe. Writing about 450 B.C., Herodotus stated that hemp "grows in Scythia; it is very like flax, only that it is a much taller and coarser plant. Some grows wild about the country; some is produced by cultivation . . . The Scythians take some of this hemp seed, and, creeping under felt coverings, throw it upon the red-hot stones; immediately it smokes and gives out such a vapour as no Grecian bath can excel". Most authorities feel that hemp was introduced into western Europe about 1500 B.C. by the Scythian invaders from Asia, that it did not come into Europe through the Mediterranean countries of the classical period, where it remained comparatively unknown until just prior to the beginning of the Christian Era. The plant was obviously spread westward in Europe by Teutonic peoples, as indicated in part by linguistic evidence. Most probably it was reintroduced to Europe many times and from sundry sources, if we may judge from the variety of races of the plant cultivated and spontaneous in different regions of Europe. It seems difficult to explain all the many races and their distribution on climatic or environmental selection alone. Boyce wonders, for example, if there might not have been an indigenous variety or race of hemp in Celtic Europe that crossed with one that was introduced originally from the Himalayan region. This is a unique, even though rather unorthodox idea, and one well worth considering, in view of the near-impossibility of explaining the complexity of modern European hemp on the basis of other factors alone.

Let us return, in greater detail, to the problem of where *Cannabis* originated, because if our experience in other economic crop plants

be a reliable guide, this aspect is basically and even perhaps exclusively important in understanding the plant in its present ubiquitous occurrence and complex diversity.

It is not always easy to distinguish between wild, spontaneous, semi-cultivated, and cultivated plants. As Vavilov points out, specialists who have written on the occurrence of *Cannabis* in central Asia have had to employ such terms as *quasi-spontanea*, *subspontanea*, *spontanea videtur*, *erratica* when they were not certain, while others aggressively described that plant as *spontaneous*, *wild*, *running wild*, *almost wild*, or *escaped*. As a result, the literature might give the impression that hemp was "wild" over a greater area than really is true. I believe that we should use the term "wild" for a plant only when it grows wholly without man's care in what is thought to be its native area and that, in other regions, the terms *spontaneous* or *adventitious* might more appropriately be employed. But, as we search the literature of *Cannabis*, we must guard against the report of its growing "wild", because of the generally uncritical use of this term.

There is no agreement—except within extraordinarily large areas of Asia—as to where *Cannabis* really originated. Some authors assert that it is indigenous to the temperate parts of Asia near the Caspian Sea, southern Siberia, and the Kirghiz Desert, possibly including also parts of Persia. Other authorities have suggested northern India and the Himalayas. Alphonse de Candolle, the first serious student of the origin of cultivated plants, specifies that "the species has been found wild, beyond a doubt, to the south of the Caspian Sea, near the Irtysh, in the desert of Kirghiz, beyond Lake Baikal in Dahuria . . . Authors mention it throughout southern and central Russia and to the south of the Caucasus, but its wild nature is here less certain . . . The antiquity of the cultivation of hemp in China leads me to believe", he continues, "that its area extends further to the east, although this has not yet been proved by botanists."

Vavilov's meticulous work—a combination of critical sifting of the literature and extensive field observations—has accepted this general area. Zhukovskii, however, favours an area of origin in the Himalayas.

In connexion with the consideration of the native area of *Cannabis*, these three specialists handled the classification of the species very differently. De Candolle did not discuss variants of *Cannabis sativa* in his arguments. Vavilov insisted on recognizing the weedy hemp that has "run wild" as a true wild plant with characters sufficiently clear

to single it out confidently as a variety—*Cannabis sativa* var. *spontanea*—distinct from the cultivated type. Zhukovskii goes further in this direction, considering the weedy hemp occurring in a wild or spontaneous state in the steppes and cultivated fields of the upper and lower Volga region, western Siberia and central Asia and now spreading, he says, into more northern parts of European Russia, as a distinct species, *Cannabis ruderalis*. The cultivated hemp, which, he maintains, grows wild and as an escape in the Trans-Volga region, on the islands of the Volga Delta, in the mountains of Altai and Caucasus, and especially in Azerbaijan, as well as in the Himalayas, Hindu-Kush and Mongolia, he refers to as *Cannabis sativa*. He points out, however, that Nikiforov recognized taxonomically two races of the escaped, weedy form of this species: one large-fruited, the other small-fruited, with monoecious strains in both. The third species accepted by Zhukovskii, *Cannabis indica*, represents the plant cultivated for narcotic products in India, Iran, Turkey, Syria and North Africa and occurring "wild" in Pakistan and Kafiristan.

Obviously, neither Vavilov nor Zhukovskii envisage genetically stable "varietates" in these concepts, since both indicate that the main argument in their decisions concerning the origin of cultivated hemp is that this plant, even to-day, especially in central Asia, can be found in a truly wild state. Zhukovskii further supports his decisions with the belief that the species *Cannabis ruderalis* and *C. indica* cannot be ancestral types of the cultivated *C. sativa*. Mansfeld recognizes still different categories: *Cannabis indica* in India (especially northwestern India), Iran and eastern Afghanistan; and *C. sativa* with two sub-species: wild or cultivated subspecies, *spontanea* (or *C. ruderalis*) of Altai, Tienshan, Transcaucasia, Afghanistan, the Balkans and middle Europe; and *culta*, indigenous to Asia (northern Himalayas and Hindu-Kush to China), Europe, North Africa, North and South America, Australia.

It would seem that historical and ethnobotanical evidence must have greater weight perhaps—at least at the present state of our understanding—than the study of collections of wild, cultivated or spontaneous specimens. We must come to this conclusion in view of the diverse results that careful consideration of field data have led to in their evaluation by such scholars as Vavilov and Zhukovskii.

I cannot here refrain from emphasizing my conviction that much more thorough and critical search for an unquestionably wild and ancestral form of *Cannabis* must be attempted before we can truly

understand the modern cultigen. Vavilov's monumental work is now fully a third of a century behind us. Techniques for comprehension of the factors involved in plant domestication have greatly improved during the past few decades. Furthermore, methods of ecology are now far more sophisticated. Is it visionary to suggest that we re-examine the populations of *Cannabis* where we believe ancestral forms still thrive?

We are left without any very definite region for the origin of *Cannabis sativa* as a domesticate. This—like other critical aspects of the total study of the hemp plant—is intricately involved with a clearer study of its classification, its genetics and cytology and its ecology. I also strongly believe that a clear chemotaxonomic understanding of this important and possibly sinister economic plant must be sought. This may, in turn, aid in unravelling some of these mysteries, when we look at *Cannabis sativa* through less compartmentalized and monodisciplinary sights and when we go back to an analytical study of ancestral types.

#### DOMESTICATION

Wherever *Cannabis* may have been native, the problem of how it was domesticated still remains for us to consider. An understanding of this process bears directly on certain contemporary experimental enquiries into the behaviour of *Cannabis*.

How did early man begin domestication of plants? It is reasonable to suppose that the earliest steps in the case of both plants and animals were largely accidental. Early man did not sit down and muse: "Now I have reached a stage in culture when it behooves me to invent agriculture". He was probably led—perhaps almost forced—to the domestication of plants, especially his food plants, and by circumstances largely fortuitous. There must have been a gradual transition from the gathering of wild plants to the growing of cultivated ones.

We do have evidence from primitive yet still living cultures that this transition takes place. One of the best examples is in *Cannabis*. It is found in many parts of the world both cultivated and spontaneous. The spontaneous hemp is presumably escaping from the cultivated types. The reverse trend can likewise take place—cultivated types are being domesticated from wild or spontaneous hems. This two-way shift is, of course, recognized as taking place in other economic plants, notably in rice in India.

Wild and spontaneous *Cannabis* is not identical with cultivated

hemp: its seeds are smaller; most plants are deciduous, scattering their seed; many of the seeds have delayed germination.

Hemp does best on a fertile, well drained soil. It is a heavy feeder and a soil-depleting crop. The high fertility requirements of *Cannabis* are so notorious that in Italy where fine hemp fibre is grown there is a proverb that "it will *grow* anywhere, but without manure will be fit for no use, though planted in heaven itself". Darlington calls hemp a "dung hill plant"; Edgar Anderson, a typical "camp follower".

Whatever we call it, *Cannabis* not only prefers but almost demands rich soils and, as a consequence, encroaches naturally on man's dwelling space where rubbish, garbage and excrement accumulate. Man will then eventually recognize the value of the fibres and oil of the plant growing in his very dooryard, especially in times of food shortage, and soon he will himself be sowing and caring for it. Disturbances of natural habitats have been greatly accelerated since man began to live on the earth; and he has constantly created new ecological niches for plants either native to the area or brought with him in his restless roving from unfamiliar and foreign environments. "As he unconsciously bred the quick-growing weeds capable of utilizing soils high in nitrogen, he also unconsciously carried them about from place to place and gave them previously unparalleled opportunities to . . . build up into super-weeds". Domesticated hemp definitely started in this way. Under cultivation, the large-seeded, non-deciduous forms—the seed of which all germinates simultaneously—forms arising from mutation—are at a distinct advantage. These soon replace the small-seeded forms with delayed or variable germination. It is really not even necessary for man to select for this character himself. These steps in domestication of hemp have been observed and reported by Vavilov in Altai in central Asia. Many of the other characteristics brought to the fore in cultivated forms—absence of a large perianth and thin seed coat—are recessive characters.

The domestication of *Cannabis* came about probably in several localities more or less simultaneously, as indicated by the great diversity of geographical and morphological types amongst cultivated forms. The germ plasm represented by these numerous types must have been very ample to have permitted, in subsequent times, the extraordinary morphological plasticity that we now see in *Cannabis* and its almost unique geographical and climatic adaptability over a great part of the world.

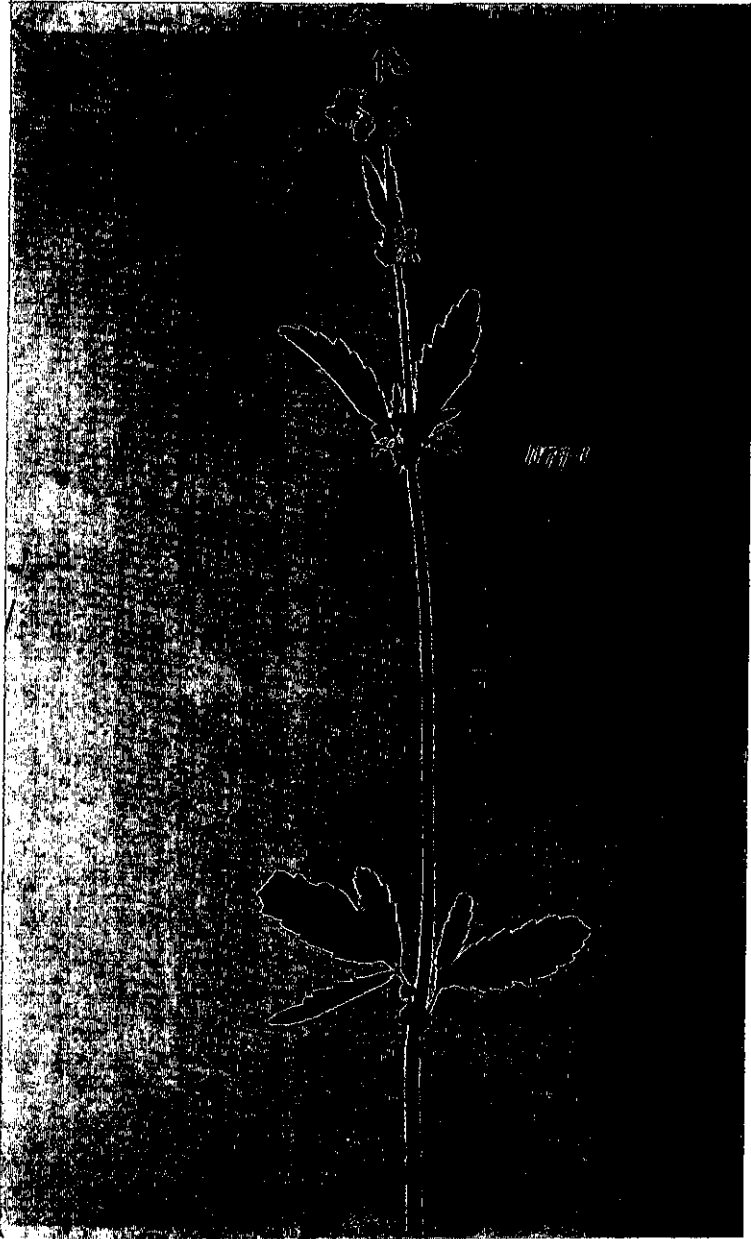
Palynology has been helpful in tracing the path of *Cannabis* as a domesticate and has shown that it was cultivated for fibre and oil in western Asia some 900 years B.C.

### TAXONOMY

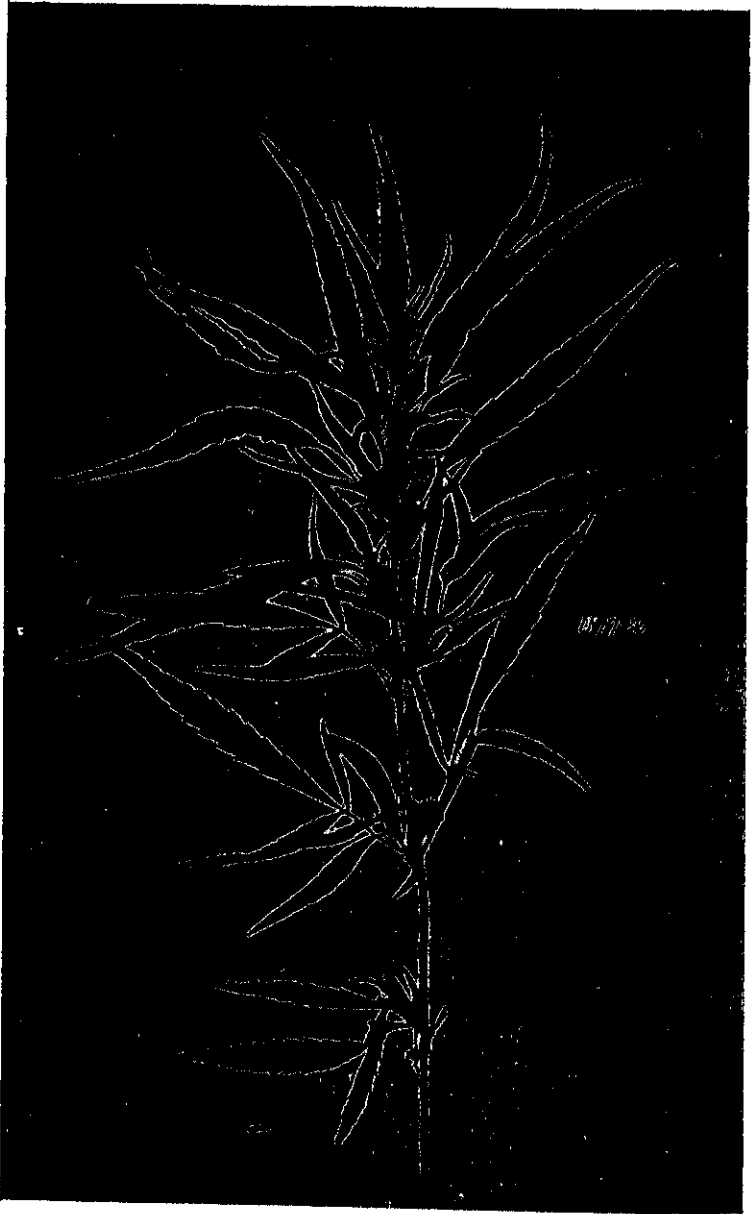
The life of *Cannabis* in modern botanical nomenclature and taxonomy began when Linnaeus set up the genus in 1735. It was based, however, on pre-Linnaean concepts, and the name *Cannabis* itself was taken from ancient vernacular usage going back even to Sanskrit roots.

It would be extremely interesting to review the ancient literature concerning the hemp plant. Until the 17th Century, botany and medicine in European literature were, for all practical purposes, one. Consequently, all of the ancient literature would be medico-botanical. However, we cannot here take time for an excursion into this earlier phase of *Cannabis* literature but must be content with a passing mention of Dioscorides' discussion of the plant, in the 1st Century A.D. as, translated by Goodyer: "Cannabis is a plant of much use in this life for ye twistings of very strong ropes, it bears leaves like to the Ash, of a bad scent, long stalks, empty, a round seed, which being eaten of much doth quench geniture, but being juiced when it is green is good for the pains of the ears". This description, like those of most if not all of the early medico-botanical writers, stresses the useful qualities of the plant and lacks almost wholly the morphological details upon which modern botany has built its systems of classification. The conspicuous absence of any references to the intoxicating qualities of the plant do not fail to engage the reader's attention, however, and it is generally believed that at this early period knowledge of the narcotic use of *Cannabis* had not reached the Mediterranean area.

Even more significant is the lack of mention of any narcotic properties in Rabelais's remarkably detailed account in 1546 of the celebrated 'Pantagruelion' herb (Book 3, chapters 49-51), i.e. hemp, wherein he refers to the seeds beloved by finches and also eaten by Greeks and its fibres hated by robbers which made them end their lives high and quickly. Had even a hint of its hallucinogenic powers reached that inquisitive and exuberant scholar, he would certainly have expounded such exciting matters at length.



*Fig. 1.* Specimen No. 1177.1 of *Cannabis sativa* L. in the Linnean Herbarium. Courtesy: Linnean Society of London.



*Fig. 2. Specimen No. 1177.2 of Cannabis sativa L. in the Linnean Herbarium. Courtesy: Linnean Society of London.*

The name *Cannabis sativa* was used by Caspar Bauhin in 1623 but its first publication as a deliberate binomial dates from Linnaeus's *Species Plantarum* of 1753, which is the internationally accepted starting point for modern botanical nomenclature. Linnaeus listed under this binomial several pre-Linnaean synonyms: his own *Cannabis foliis digitatis* used in his *Hortus Cliffortianus* (1738), *C. sativa* and *C. erratica* of Caspar Bauhin (1623), *C. mas* and *C. femina* of D'Aléchamps (1587).

The Linnean Society of London preserves in Linnaeus' herbarium two specimens of *Cannabis sativa*. One specimen, No. 1177.1 (Fig. 1), is labelled "*sativa*" in Linnaeus' handwriting and represents a staminate plant, with much more abbreviated leaves than is usual in the genus. No. 1177.2 (Fig. 2), without a specific epithet written on the sheet, represents a pistillate plant with the lanceolate leaves that are normal for the species. There are, of course, no locality data on these two specimens, although in *Species Plantarum*, Linnaeus offers the information that the species has a "habitat in India". In his annotated copy of *Species Plantarum*, which is preserved at the Linnean Society, Linnaeus had written, in his own hand, as a note for a further edition, the word "Persia" as an additional habitat.

Botanists now generally agree that *Cannabis* is a monotypic genus, a genus with one species: *C. sativa*; that there cannot be recognized any true botanical varieties within this species; and that this one species has diversified into a great number of ecotypes and cultivated races. Modern taxonomists, thus, are in agreement with Linnaeus' treatment of the genus.

Nevertheless, a number of binomials have been legitimately published for distinct concepts once thought to deserve nomenclatorial recognition. These are *Cannabis chinensis* Delile; *C. erratica* Siev.; *C. foetens* Gilib.; *C. indica* Lam.; *C. Lupulus* Scop.; *C. macrosperma* Stokes; *C. americana* Pharm. ex Wehmer; *C. generalis* E. H. L. Krause; *C. gigantea* Crevost; *C. ruderalis* Janischewskii; and a hybrid, *C. X interstitia* Sojak.

As early as 1869, de Candolle recognized several varieties of *Cannabis sativa*, offering very detailed descriptions of each one:  $\alpha$  *Kif*;  $\beta$  *vulgaris*;  $\gamma$  *Pedemontana*;  $\delta$  *Chinensis*.

Although none of these is accepted by most modern taxonomists, confusion of nomenclature still reigns in the non-technical literature.

In agricultural, horticultural, chemical and pharmacological publi-

cations, it is not uncommon to find in use Latin binomials that have no validity, since they were never validly published. The binomial *Cannabis indica* is, however, frequently employed as though it represented a species-concept distinct from *C. sativa* and most often to indicate a race native to India and usually high in concentration of intoxicating principles. Even more frequently, pharmacological writings use the name *Cannabis sativa* var. *indica* in the belief that there exists a definitive "*varietas*" of Indian origin that may be distinguished taxonomically by having a higher content of the narcotic constituents: a physiological race or chemovar which, it is often asserted, cannot long be maintained in an inappropriate climate and environment. Some have gone even beyond this to distinguish nomenclatorially other varieties. There is still so much confusion that some pharmacological reports have even used the epithets "*Cannabis indica*" and "*C. sativa* var. *indica*" as though the two were distinct concepts!

Morphological or taxonomic botanists cannot accept true varieties within *Cannabis sativa*, simply because they cannot define them. On the basis of cytological studies, Postma concluded that there was only one species which might be split into many kinds of "subspecies", but that perhaps it might be better to speak of two types of *Cannabis sativa*: the northern, to which the Russian hems might be relegated; and the southern, to which belong the Indian hems. Agricultural and horticultural specialists are prone to recognize different species and varieties, but admit that they are not stable. We are here speaking about two very distinct concepts: the true "*varietas*", which is genetically distinct; and the non-genetical response to environmental and other factors, concepts which are better called "races", "ecotypes", "cultivars", "chemovars" or other appropriate terms.

One of the most succinct summaries—and this from an agriculturist, not from a taxonomist—is that of the American fibre specialist, Dewey. "Hemp, cultivated for three different products", he wrote, "has developed into three rather distinct types of groups of forms. The extreme forms of each group have been described as different species, but the presence of intergrading forms and the fact that the types do not remain distinct . . . under new conditions make it impossible to regard them as valid species. There are few recognized varieties in either group. Less than 20 varieties of fibre-producing hemp are known, although hemp has been cultivated for more than 40 centuries, or much longer than either cotton or corn, both of which now have hundreds of named varieties".

One cause of the chaos in taxonomic and nomenclatorial recognition of polymorphism in *Cannabis sativa* has been misunderstanding of species delimitation in cultivated plants. No botanist can draw a sharp line between a cultivated and a wild or spontaneous plant. It is probable that most of the changes that occur with cultivated plants occur likewise in the wild representatives. True species do occur amongst cultigens; but, with cultivated forms, the differences, in contrast to those recognized in wild or spontaneous populations, are usually minor and often not of a genetic or hereditary nature. These minor variations often have agricultural, commercial or other practical significance and, consequently, may be considered of greater importance than more basic differences in wild populations. It is often most convenient to distinguish a cultigen by glorifying it with a binomial, with the result that there have been, as indicated previously, many Latin binomials applied to cultigens.

The recognition of races, ecotypes and other kinds of convivia with Latin designations in the rank of species for convenience confuses classification, since the minor concepts—e.g. *Cannabis indica*—are not the equivalent of a Linnean species. Vavilov pointed out that the study of cultivated plants “. . . sometimes made it necessary to postulate late large Linnaean species. We are coming to the concept of a Linnaean species as a definite, discrete, dynamic system differentiated into geographical and ecological types and comprising sometimes an enormous number of varieties”. Even these “geographical” and “ecological types” cannot be treated as true botanical varieties.

## VARIATIONS

It is now quite generally accepted that *Cannabis* tends to resemble or differ from a parental or ancestral strain according to environmental conditions under which it is grown. Is this really invariably true, however, or are a few striking examples being overemphasized? Have controlled experiments on a large scale ever been done to back up this belief? And what are the kinds of difference—morphological, physiological, chemical, etc.—that are connected with phytobiotic factors? What are the principal environmental factors that do influence this polymorphism: climatic factors, such as sunlight, length of day, wind, variation in humidity; lithospheric and hydrospheric influences like water content, nutritive content, temperature and other characteristics of the soil; vegetational factors, such as humus formation; and pyric

factors of both the anthropic and non-anthropic or natural environment?

The plasticity of *Cannabis* has long been recognized but has never been truly understood. Charles Darwin was impressed by this aggressive weed. Plants long cultivated "can", he wrote, "generally endure with undiminished fertility various and great changes", and hemp may be "so much affected that the proportions and the nature of their chemical ingredients are modified". The *Report of the Indian Hemp Drugs Commission* attempted in 1894 to set forth definitive thoughts on this aspect of the plant after an exhaustive survey by questionnaire. It stated that in India the only differences recognized by the people (and botanists should heed folk classifications more frequently) are between the *wild* and *cultivated* plant, the male and female plants and certain colour differences; and that, while the inherent potentiality of the seed to develop a plant closely resembling the parents must be admitted, there is no evidence of racial speciality or differentiation of definitive forms. In India, the Commission found, the plant cultivated for fibre yields the narcotic, and evidence was strong that the wild plant also yields the intoxicating resin. *Cannabis* grown for production of the narcotic *ganja* or *bang* yielded fibre as well, even though, in India, fibre production was a very limited activity. Chopra and Chopra write that "even the plant growing under different climatic conditions in the vast Indo-Pakistan sub-continent shows remarkable variations in appearance; those variations at first may give the impression of separate species".

The plasticity of *Cannabis* was shown experimentally by Christison and Hope as early as 1847, by J. Bouquet in 1912 and, more recently, by others: plants grown in England and France from seed imported from India were, after several generations, morphologically indistinguishable from the races long acclimatized to European conditions. Further experiments indicated that conversely the same holds true of European material planted out for several generations in dry, warm areas such as Egypt and Tunisia. Another interesting indication of this susceptibility to environment is the experience in Egypt when hemp seed procured from Europe and planted to supply cordage for an incipient navy soon changed, making it imperative to import new seed periodically, since the quality of the fibre steadily degenerated, while the plants began to produce more and more intoxicating resin.

Although the pharmaceutical literature long persisted—and still

often does so—in recognizing the Indian *Cannabis* as distinct, botanists such as Watt early pointed out that although “the European form of the plant was supposed to be distinct from the Asiatic, the chief value of the latter consisting in its narcotic properties . . . this distinction has now disappeared from the literature of the subject, since it could not be supported by botanical characters. The reduction became the more necessary when it was fully understood that, according to climate and soil, the Indian plant varied in as marked a degree as it differed from the European”. Watt further pointed out that *Cannabis sativa*, in high mountainous areas of India, yields a superb fibre; that, in Kashmir, it was valued for the resin exuding from the stem and leaves just before maturation of the flowers; that, in the plains, instead of secreting resin from splits in the bark, the plant produces it in the young pistillate flowers and twigs; that, in other parts of India, the narcotic principle is not developed until the fertilized ovaries are nearly mature. “We have here”, Watt says, “. . . one of the most notable illustrations of the effect of climate in changing the chemical processes . . . of a plant”.

For a long while, the *United States Pharmacopoeia* insisted that medically active hemp could be supplied officially only by the Indian plant or “*Cannabis indica*”. The 8th edition of the *Pharmacopoeia*, for example, specified that “*Cannabis indica* shall consist of the dried prepared tops of the pistillate plant of *Cannabis sativa* grown in the East Indies . . .”. So far afield did the pharmaceutical literature stray that the *National Standard Dispensatory* reported that “the rich soil and cool climate suitable for the production of hemp fibre will not develop the medicinal properties . . .”.

Following a spirited argument in the literature, Hamilton and others showed conclusively that American-grown hemp did contain the active constituents; that, if equal care were exercised in selecting the proper part of the drug for extraction, no material difference in activity would be found between Indian and American hemp; and that, since *Cannabis* grown in various localities in the United States and Mexico was fully as active as the best imported Indian material, there was no valid reason why American hemp could not replace the imported Asiatic product. Furthermore, the work of Sabalitschka indicated that high resin content perhaps may not wholly be due to climate, since seeds of common European hemp taken to India failed there to produce a higher resin content.

While these and other specialists can cite statistical studies to the contrary, there is ample evidence, equally reliable, that *Cannabis sativa* does indeed change drastically, though impermanently, in response to environmental factors. Adams, for example, asserted that "the amount of resin depends almost entirely on the climate, the largest . . . in hot dry climates such as Chinese Turkestan and the smallest in temperate climates where there is plenty of moisture". I could cite any number of additional specialists who accept this contention, and I tend to believe it to be true, with certain limitations, although large-scale controlled plantings alone can experimentally answer these questions with finality and apparently such experiments have never been carried out. They may never be attempted. It is to be hoped, however, that they will be—not only because of the immediate understanding of a plant that, although important to man, may become a danger to his health and well-being, but because of the insights that such a study will provide for a fuller understanding of some of our other basic economic plants. It is here that the joint efforts, fully integrated, of botanists, ecologists, agronomists, horticulturists, chemotaxonomists, phytochemists and pharmacologists are sorely needed.

It is obvious that what has interested certain investigators most avidly is the possible creation of chemovars with high concentration of the intoxicating principles. What about gross morphology? There seems, from the reliable literature, to be every probability that environmental conditions can influence rapidly and significantly the morphology of the plant. Adams, for example, is very explicit about this point when he says that "the morphological characters . . . are modified very easily—one variety to another—merely by a change in climatic conditions". It is very definitely known, for example, that the tallest forms of fibre-yielding *Cannabis sativa* are produced in China and Japan, where the plants have slender, sparsely branched internodes 8 to 10 inches long; that the European types have shorter, more rigid stems and require two weeks less time to mature than the Asiatic forms. There seems, on the surface, to be little doubt that this is true—but again: what *are* the changes induced and what *factors* are active in bringing about these modifications? Camp grew, under controlled conditions, a number of so-called varieties, the original seed of which came from different parts of the world. Sown in adjacent plots over several years in garden and greenhouse, they showed difference in size, time of flowering, seed productivity, fibre quality and drug content; but,

except for one known mutant, he found no difference sufficiently stable and important to separate them into distinct groups. One proof of the truly monotypic nature of *Cannabis* is this basic similarity in forms, despite its cultivation and differential selection by various and widespread racial groups since antiquity.

One aspect of the polymorphism resulting from the plasticity of *Cannabis* and which, I believe, is not sufficiently stressed in the agricultural and botanical literature has to do with its manipulation by man for so long a time. *Cannabis* is such an ancient economic plant, has been subjected over so many millenia by man to subconscious and conscious selection, that a bewildering array of cultivars has appeared. Obviously many of the cultivars that have appeared have disappeared. When man was interested primarily in production of a strong and long fibre, selection tended to proceed along lines that would produce cultivars with superior fibres; and the same has been true in parts of the world where a major interest was directed towards greater intoxicating properties. It is often the case that, when a plant is intensively selected for one characteristic, other characteristics suffer or even disappear. In *Cannabis sativa*, races of unusually high yield of seed oil or superior fibre have been developed which are either inferior in narcotic principles or wholly devoid of them—yet these races are reported as growing in the same region, sometimes even in adjacent fields! On the contrary, highly narcotic races are reported in which the quality of fibre is decidedly inferior, so much so that these strains are commercially worthless—yet they may, too, grow in the same region. Do we really know—are we really certain—that the deductions from uncontrolled commercial plantings that have led to these propositions are reliable and definitive? Have scientists made these pronouncements—or are they promulgated by production managers and government statistics agents? Or have the results of what experimental data we do have been interpreted under the shadow of prejudice from what we know in the case of other cultivated plants? Is it wise to assume that *Cannabis* will follow the norms of other cultivated plants in its much more complicated, geographically more extensive and economically more diverse nature? These are basic questions that we must consider, if we are to learn more about the plant and its idiosyncrasies. Much of a basic nature certainly remains for scientists to authenticate along these lines, yet we must always bear in mind that in *Cannabis sativa* it will be hard—especially in cultivated and even escaped or spontaneous

populations—to avoid the results of the complicating finger of man.

There is one point, however, on which we can here be certain: the inadvisability of using technical Latin nomenclature to designate the minor variants of *Cannabis sativa*. It is, of course, accepted practice in horticulture and agriculture to designate definite cultivars with vernacular names. Many of the cultivars of *Cannabis sativa* have been so designated. Man has selected hundreds of strains, races or other types of cultivars during the millenia that he has had to manipulate this economic plant, and in modern times he has engaged in conscious and purposeful selection. Until recently, hemp has been essentially a cultivated wild plant, but through appropriate modern methods and selection, the fibre content has been increased 100% in some strains, up to 200% in others. The greatest emphasis, naturally, has been given to the variants of hemp as a fibre plant, but selection has had effects also in strains for narcotic constituents and for oil content.

A number of named variants of hemp are recognised, especially in the fibre industry. Although the statement that there are 20 or fewer “varieties” of *Cannabis* cultivated for fibre is often quoted, there are in reality many more. The fibre hemp grown in the United States in colonial times was of European origin, but the type basic to modern American fibre production—commonly known as “Kentucky”—was originally from China. Selection for improved fibre quality and production has been carried on in a number of countries. In the United States, for example, it has resulted in at least one widely grown cultivar called “Kymington”. In Europe, five or six varieties are considered outstanding. A recent chemical and biological evaluation of the resin of hemp grown for seed in Russia enumerates 19 named “varieties”. More attention must, however, be given to the classification of these agronomic variants. The need for an intensive study of this kind on highly intoxicating races in India is most to be desired.

### CLASSIFICATION

In the classification of such an ancient, economically diversified and geographically extended plant, one might be justified in expecting some taxonomic accord as to its position in the dicotyledons. One may well be dismayed that we still have not reached universal agreement about the family position of *Cannabis*.

*Cannabis* is closely allied to *Humulus*, the genus of the hop plant.

Botanists group them together, usually with *Cannabis* as a monotypic genus and *Humulus* with three species, although some authorities believe that all three of the species of *Humulus* are referable to *H. lupulus*.

Early taxonomists tended to place *Cannabis* and *Humulus* in the *Urticaceae* or Nettle Family, although it was not uncommon, early in the 19th Century, to find the genus collocated in the *Moraceae* or Fig Family. Both families belong, of course, to the Order *Urticales* and are, to be sure, closely related. A number of earlier botanists felt constrained to create for *Cannabis* and *Humulus* a distinct family: *Cannabaceae* or Hempwort Family, still accommodated in the *Urticales* and patently allied to both the *Urticaceae* and the *Moraceae*. The family name is sometimes written *Cannabiaceae*, *Cannabidaceae* or, most often, *Cannabinaceae*. When *Cannabis* and *Humulus* were included within the *Urticaceae* or the *Moraceae*, however, a separate subfamily or other sectional distinction (e.g. *Cannaboideae*) was usually made. Whatever we call these two genera—separate family or section of *Urticaceae* or *Moraceae*—there is evidence that they are evolutionarily relatively highly advanced.

If I were to generalize, I would say that the earliest trend in taxonomic works was to include *Cannabis* in the *Urticaceae*; that in the last half of the last century and the early part of this century, most authorities favoured the *Moraceae*; that the modern tendency appears to maintain the family *Cannabaceae* as separate from these. Recent studies in morphology and chemistry likewise support the separation of *Cannabis* into a distinct family. In modern agricultural and horticultural writings, *Cannabis* is usually assigned to the *Moraceae*.

Even though in writing about *Cannabis* as a narcotic I have myself usually preferred to assign it to the *Moraceae*, I must agree that a critical evaluation of the taxonomic characters convinces me that there is ample evidence on which to accept the *Cannabaceae* as a discrete family concept that represents—in *Cannabis* and *Humulus*—a distinct trend in urticalean evolution and that there is both a morphological and chemical basis for this point of view.

The *Cannabaceae* appear to be more closely allied to the *Urticaceae* than to the *Moraceae*, although in many respects this small family is intermediate between the other two larger families. Hegnauer intimates, from chemical evidence, a closer alliance with *Moraceae*.

From the *Urticaceae*, it differs in its erect (instead of inflexed or

coiled) anther filament in bud; in its hanging (instead of erect) ovule; in the aromatic quality of the plants; and in the lack of stinging hairs, while urticaceous plants often possess urticant pilosity. These represent major and basically significant differences.

The *Cannabaceae* differ from the *Moraceae* most conspicuously in the form of flowers and fruit; in the latter, the flowers are numerous on or inside a large receptacle and the achenes are enclosed in a fleshy calyx or are aggregated into a spherical mass or else borne inside a large fleshy or leathery receptacle that forms usually a hollow fruit known as a cynconium or fig; in the former, the flowers are not borne on the inside of a receptacle, and the sepals are not fleshy nor do they envelop the achene in fruit. These, too, are meaningful differences. The *Moraceae* are nearly all trees and shrubs with conspicuous milky latex, whereas the *Cannabaceae* are herbs or vines, not woody, and are devoid of a milky latex, although *Cannabis* does have unbranched, unicellular latex vessels.

There is still much to resolve regarding the taxonomic position and relationships of *Cannabis*, but only a fundamental integration of morphology, anatomy, cytology and chemistry with what is now known taxonomically can take us nearer to a meaningful understanding of the true phylogenetic position of this anomalous plant.

There are many problems demanding study in a variety of aspects of the botany of *Cannabis*. I have been derelict in not delving into many of them, but they are too numerous and complex to discuss lightly. Ecology—especially as it concerns the spread of spontaneous hemp and its successful survival as a weed—will certainly be most illuminating once a basic program is started. Just what is the secret of the aggressiveness of *Cannabis*? How much of the success that this plant has had in spreading can be attributed to chemical or other characteristics of the soil? What effect do fungal, insect or other diseases have on its spread? Why does it do better under drier conditions? Although preliminary cytological studies have been carried out, showing that this 20-chromosome species is an allopolyploid, more intensive and extensive investigations may throw much light on the taxonomic position and biology of *Cannabis sativa*. We have really considered little or nothing of the tremendous variation in chemical constituents—the intoxicating principles and sundry others—in relation to the total life of the plant. What, if anything, does the botany of *Cannabis* have to do with the biogenetic pathways of some of the

chemical constituents? What purpose does the resin produced by the secretory glands of the flowering tops and leaves have in the living plant? Is it truly a protection against dry atmosphere and high temperature, or is it in some way concerned physiologically with maturation of the fruit? And why is this resin often produced so much more abundantly by the pistillate plant? What is the purpose to the plant, if any, of the intoxicating constituents found in the resin? How much more study must be placed on the genetics of *Cannabis*! One problem concerns the complexities of sex determination in *Cannabis*, for, while the plant is dioecious, the monoecious condition, which occasionally appears and which has been explained on a genetic basis, can be experimentally induced. Furthermore, sex reversal is still something of a mystery, for plants may occasionally be made to reverse their sex by varying growth conditions. These and many other purely botanical problems await the searchlight of modern research methods.

I trust that, in this brief and admittedly superficial collection of thoughts and queries, I may have awakened in the minds of some of my colleagues in other fields of research germs of ideas which might in some way initiate new chemical and pharmacological research or aid in pursuing older investigations to more productive ends. It is time that one of man's oldest cultivated plants was honoured with the kind of scientific attention that its place in human history and culture merits for it.

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