CANNABINOID CONTENT OF INDIVIDUAL PLANT ORGANS FROM DIFFERENT GEOGRAPHICAL STRAINS OF *CANNABIS SATIVA* L.

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ABSTRACT.—Individual plant organs from different geographical strains of *Cannabis sativa* L. were analyzed for their cannabinoid content by gas-liquid chromatography. Analyses showed that different plant parts from each strain varied quantitatively in their cannabinoid content. However, each plant part possessed a cannabinoid profile which characterized the chemical phenotype of that strain. Accumulation of a specific cannabinoid in high quantities that was uncharacteristic of that strain was found. Factors such as maturity of plant organ, sex of the plant, location of the plant organ on the plant and sampling procedures influenced the accumulation of cannabinoids. Pollen grains and seeds (intact or crushed) were found to lack detectable levels of cannabinoids. Based on these results, precautions that should be taken when accumulating data on the chemical phenotype of a *Cannabis* plant are discussed.

Cannabinoids represent a distinctive class of compounds found only in *Cannabis sativa* (1). These C_{21} compounds which consist of the carboxylic acids, analogs and transformed products belong to the chemical class of natural terpenophenols (2). Several studies have identified different chemical phenotypes of *Cannabis* distinguishable from each other by their cannabinoid content (3, 4). These chemical classifications of the various strains were based upon gas-liquid chromatographic analyses of cannabinoids from manicured marihuana samples (3, 4). Other investigators have reported variation in cannabinoid content (5, 6) as well as morphological characters (7) within and between strains of diverse geographical origins. Previous work in our laboratory also has demonstrated a degree of variation in cannabinoid content in specific organs on several clones of *Cannabis* (8). These reported differences in cannabinoid profiles may be related to variations in cannabinoid content of specific organs, possibly influenced by organ development. The present study, therefore, represents an attempt to compare cannabinoid profiles of specific plant organs from several strains and clones of *Cannabis* to determine whether cannabinoid variability exists in different organs and during different phases of organ development and whether variability, if present, influences the phenotypic classification of the plant.

MATERIALS AND METHODS

PLANT MATERIAL.—Seeds of *Cannabis sativa* L. from different geographical sources and chemical types were employed in this study (table 1). Plants were either germinated from seed or derived from cloned pistillate plants by vegetative reproduction (8) and were grown under greenhouse conditions. Organ samples were harvested from several different plants of a strain or clone in the flowering stage. Bract and floral leaf samples were harvested at specific times and consisted of a mixed population of young to mature organs; calyx-anther samples were collected after anthesis. Pollen grains were harvested by gently tapping the staminate flowers to allow the pollen grains to fall through a 1 mm^2 mesh screen into collecting beakers. Screens were washed rigorously with organic solvents prior to each sample collection to prevent contamination between samples. For the axillary study of leaves of different ages, samples were collected from both the floral and vegetative portion of the plant at one time during the day. The manicured samples consisted of the flowering tops from these plants and were harvested at the same time. For the analyses of leaves of different lengths, center leaflets of compound leaves were collected from vegetative plants. Plant organs were immediately dehydrated by oven-drying (65°) overnight; pollen grains were air-dried.

Analyses by Gas-liquid Chromatography (glc). Samples were weighed and extracted (3X) with chloroform (spectranalyzed) for at least 1 hr per extraction at 4°. Combined aliquots were filtered and concentrated to dryness by gentle nitrogen evaporation. Dried

residue from the excised plant parts was taken up in 1 ml of chloroform containing eicosane (0.25 mg/ml) as the internal standard. One microliter of this solution followed by 1 μl of chloroform as a washing solution was injected into the chromatograph.

Analyses were performed with a glc (Hewlett-Packard 5701A) equipped with a hydrogen flame-ionization detector and operated by programming from 200–240 C (2/min). Nitrogen (20 ml/min) was used as the carrier gas. The injection port and detector temperatures (C) were 250 and 300, respectively. Glass columns, pretreated with dimethyldichlorosilane in toluene (10%, v/v), were packed with 3% OV-1 Supelcoport (80/100 mesh). Quantitative data of identified cannabinoids (cannabidiol, CBD; cannabichrome, CBC; Δ^5- and Δ^9-tetrahydrocannabinol, Δ^8- and Δ^9-THC; cannabinol, CBN) in each sample were determined with an integrator (Hewlett-Packard 3380A).

TABLE 1. Chemical types and geographical origin of different *Cannabis* strains.

Strain	Chemical Type	Geographical Location	Seed Source	Ref.
79	Non-drug	USA	E. Small	(16)
87	Fiber	Hungary	E. Small	(16)
152	Drug	Japan	E. Small	(16)
150	Fiber	Germany	E. Small	(16)
Turkish [TU-A(2); C-71]	—	Turkey	C. E. Turner	(5)
Mexican	Drug	Police-seizure	P. G. Mahlberg	(10, 17)
Mexican [ME-A(3); C-72]	Drug	Acapulco	C. E. Turner	(5)
Russ 106	—	Yuyraja Krasnadarskaya	[a]	—
Russ 126	—	The Ukraine	[a]	—
Russ 311	—	Yuynaja cerkasskaja	[a]	—
Russ 391	—	Yuynaja toyreva-jutcajy 6 (FS 6)	[a]	—
Russ 405	—	Arhonskaya	[a]	—

[a]The N. I. Vavilov All-Union Institute of Plant Industry, Leningrad, USSR.

RESULTS

ANALYSES OF ORGANS FROM PLANTS OF DIFFERENT GEOGRAPHICAL ORIGINS.—Cannabinoid content varied quantitatively and qualitatively in different organs from staminate and pistillate *Cannabis* plants of different geographical origins. Glc analyses of terpenophenolic extractions of organs from pistillate plants revealed a characteristic cannabinoid profile for each strain (table 2). For example, high levels of both CBD(CBC) and Δ^9-THC were present in bracts of non-drug 79 (clone), Russ 106, Russ 391 and Russ 405. In comparison, bracts of fiber 87 (clone), fiber 150, Turkish, Russ 126 and Russ 311 possessed predominantly CBD and low levels of Δ^9-THC, while bracts from the drug-type plants (both Mexican strains and clone 152) contained high levels of Δ^9-THC with low concentrations of CBD(CBC). In most strains, bracts contained low levels of CBN and only trace quantities of Δ^8-THC, if present at all.

Intact seeds from both Mexican strains, drug 152 (clone) and non-drug 79 (clone) were carefully separated from dried bracts and analyzed and were found to lack detectable levels of cannabinoids. Crushed seeds harvested from dried bracts of the Mexican [ME-A(3); C-72] and non-drug 79 strains also lacked cannabinoids. However, expanding cotyledons from growing seedlings of the Mexican strain (police-seizure) grown in our greenhouses have been shown to accumulate cannabinoids.

Floral leaves which subtend aggregates of pistillate flowers were generally found to possess cannabinoid profiles similar to bracts from the same strain

TABLE 2. Cannabinoid content of organs from pistillate plants of different *Cannabis* strains.

Strain	Organ	Cannabinoid (mg/100 mg dry wt)[a]				
		CBD	CBC	Δ^8-THC	Δ^9-THC	CBN
Non-drug 79 (clone)	Bract	2.79	tr	—	1.70	0.09
	Floral leaf	0.48	0.35	—	1.60	0.08
Fiber 87 (clone)	Bract	3.67	—	0.04	0.20	0.10
	Floral leaf	1.44	—	0.01	0.08	0.02
Drug 152 (clone)	Bract	0.01	0.19	0.08	1.14	0.06
	Floral leaf	0.01	0.11	0.06	0.55	0.03
Fiber 150	Bract	2.16	—	—	0.07	0.01
	Floral leaf	0.87	—	—	0.03	0.01
Turkish	Bract	3.47	—	0.03	0.13	0.05
[TU-A(2); C-71]	Floral leaf	0.91	—	tr	0.04	0.01
Mexican	Bract	0.02	0.20	—	3.00	0.07
	Floral leaf	0.01	0.11	—	1.09	0.03
Mexican	Bract	—	0.15	—	3.41	0.09
[ME-A(3); C-72]	Floral leaf	—	0.05	—	0.72	—
Russ 106	Bract	0.72	0.46	—	0.93	0.05
	Floral leaf	0.37	0.22	—	0.47	0.02
Russ 126	Bract	1.57	—	—	0.05	0.01
	Floral leaf	0.46	—	—	0.01	tr
Russ 311	Bract	2.09	—	0.01	0.39	0.03
	Floral leaf	0.92	0.03	tr	0.20	0.01
Russ 391	Bract	1.84	—	0.01	0.66	0.07
	Floral leaf	3.53	—	—	0.16	0.05
Russ 405	Bract	4.01	—	—	1.27	0.11
	Floral leaf	2.14	—	—	0.57	0.06

[a]Each datum value represents the mean of at least three replicates. tr; trace quantities detected (less than 0.01 mg/100 mg dry wt).

TABLE 3. Cannabinoid content of organs from staminate plants of different *Cannabis* strains.

Strain	Organ	Cannabinoid (mg/100 mg dry wt)[a]				
		CBD	CBC	Δ^8-THC	Δ^9-THC	CBN
Non-drug 79	Calyx-anther	—	0.10	—	2.36	0.24
	Pollen	—	—	—	0.26	—
Fiber 87	Calyx-anther	1.48	0.38	0.06	0.07	0.04
	Pollen	0.05[b]	—	—	tr	—
Drug 152	Calyx-anther	—	0.29	0.19	1.11	0.08
	Pollen	0.02	0.04	0.02	0.15	0.01
Fiber 150	Calyx-anther	1.29	—	—	0.04	0.02
	Pollen	0.15[b]	—	—	0.07	0.05
Turkish	Calyx-anther	0.38	0.35	0.02	1.58	0.18
[TU-A(2); C-71]	Pollen	tr	tr	—	0.03	tr
Mexican	Calyx-anther	—	1.43	—	1.92	0.15
	Pollen	—	0.20	—	0.22	0.03
Mexican	Calyx-anther	—	0.47	—	1.36	0.07
[ME-A(3); C-72]	Pollen	—	—	—	0.06	—
Russ 106	Calyx-anther	0.64	0.95	—	0.03	tr
Russ 126	Calyx-anther	0.35	0.49	—	0.04	tr
Russ 311	Calyx-anther	0.63	0.35	0.03	0.13	0.01
Russ 391	Calyx-anther	0.14	0.09	—	0.06	tr
Russ 405	Calyx-anther	0.33	1.15	—	0.33	0.02

[a]Each datum value represents the mean of at least three replicates. tr; trace quantities detected (less than 0.01 mg/100 mg dry wt).

[b]Includes both CBD and CBC, as resolved on 6% OV-1.

(table 2). However, this organ contained lower concentrations of total cannabinoids than bracts for each strain, with the exception of the Russ 391 strain where the concentration levels were reversed.

Flowers of staminate plants (calyx-anthers) also were found to possess a characteristic cannabinoid profile as indicated by the terpenophenolic composition of each phenotype (table 3). Based on dry weight values, staminate flowers contained lower levels of total cannabinoids than bracts of pistillate plants. Staminate flowers from the Turkish and non-drug 79 strains contained a higher level of Δ^9-THC than CBD and CBC, whereas the ratio was reversed in the bracts (table 2). Staminate flowers from both Mexican strains contained high levels of CBC as well as Δ^9-THC (table 3). Also, staminate flowers from most strains contained both CBD and CBC while bracts possessed predominantly CBD. Similar levels of CBN and Δ^8-THC were found in the staminate flowers as found in bracts of pistillate flowers (table 2). In most strains, the presence of these

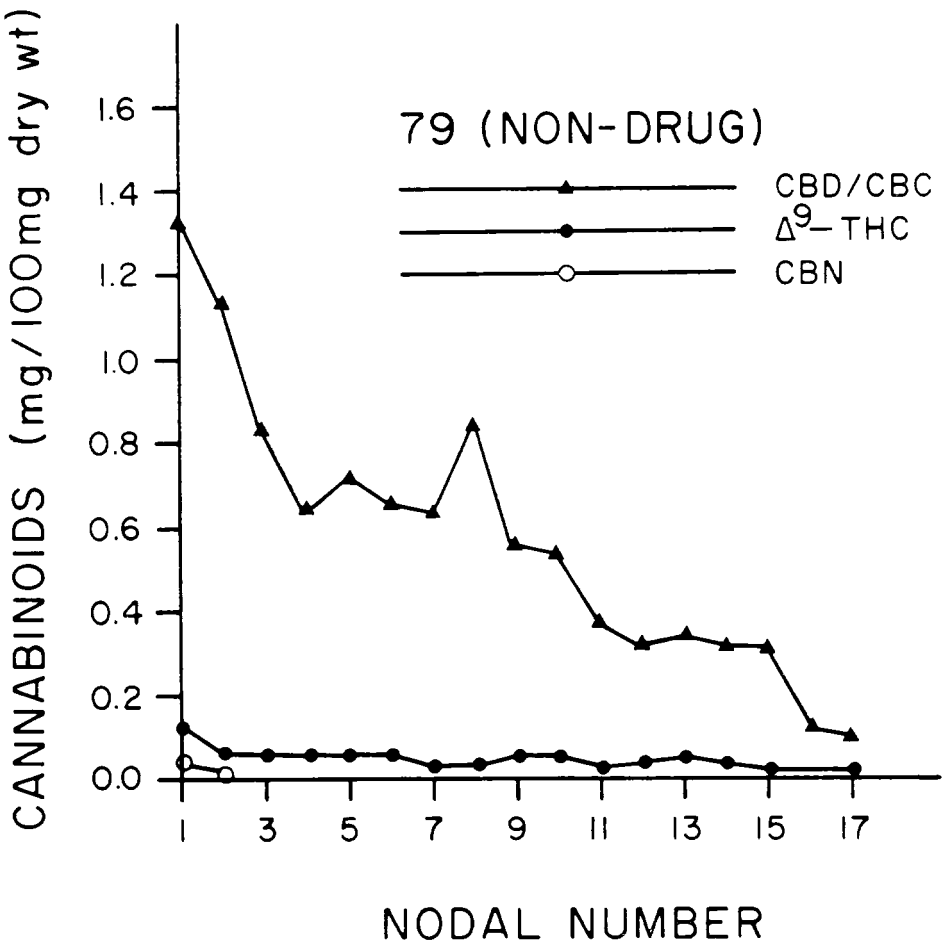

FIG. 1. Cannabinoid content of *Cannabis* leaves from successive nodes of pistillate plants of non drug 79. Small floral leaves consisted approximately of the top 7 nodes. Manicured samples were taken from this floral region.

cannabinoids (CBN and Δ^8-THC) appeared to be positively correlated with the level of Δ^9-THC present in the plant organ.

Pollen grains from mature staminate flowers were found to contain cannabinoids, although the concentrations were lower than levels found in floral parts of the staminate plant (table 3). Characteristic cannabinoid profiles were found in pollen grain samples collected from drug 152, Mexican [ME-A(3); C-72] and two fiber strains (87 and 150), whereas this was not found for the other Mexican strain (police-seizure), the non-drug 79 and the Turkish strain. When examined by scanning electron microscopy, pollen grain samples were found to contain epidermal glandular trichomes (heads) intermixed with the pollen grains.

ANALYSES OF LEAVES AT SUCCESSIVE NODES.—Leaves of different ages from three strains were analyzed to determine whether age affected the cannabinoid content of these organs (figs. 1–3). The youngest leaves from the uppermost nodes of the flowering pistillate plants of non-drug 79, fiber 87 and Mexican (police-seizure) strains contained the highest level of their characteristic cannabinoid (figs. 1–3). The concentrations of these C_{21} compounds found in non-drug 79 (CBD/CBC) and fiber 87 (CBD) were shown to decrease progressively in successively older leaves along the axis with the lowest level of cannabinoids present in the mature senescing leaves. The Δ^9-THC concentration was low in leaves at all nodal positions; CBN was not detected or was present in only trace amounts (figs. 1–2); Δ^8-THC was not detected. In contrast, the characteristic

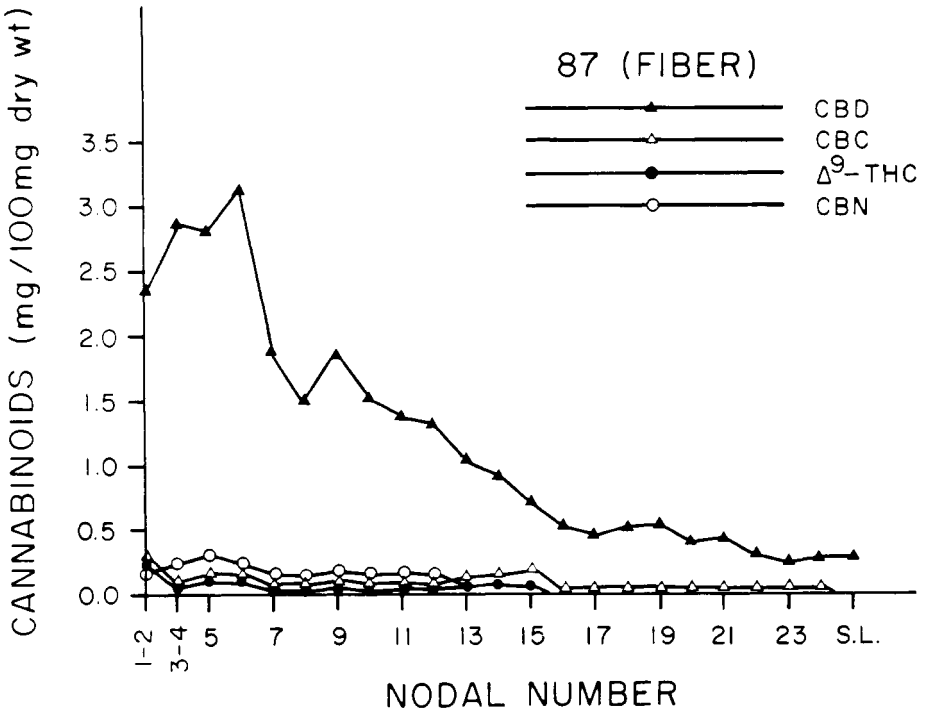

FIG. 2. Cannabinoid content of *Cannabis* leaves from successive nodes of pistillate plants of fiber 87. Small floral leaves consisted approximately of the top 7 nodes. Manicured samples were taken from this floral region.

cannabinoid (Δ^9-THC) of the Mexican strain, a drug type, decreased in concentration progressively to node 7 whereupon the Δ^9-THC level increased slightly in concentration in successively older leaves. Low levels of CBC and CBN were found in leaves at all nodal positions (fig. 3), whereas Δ^8-THC was not detected.

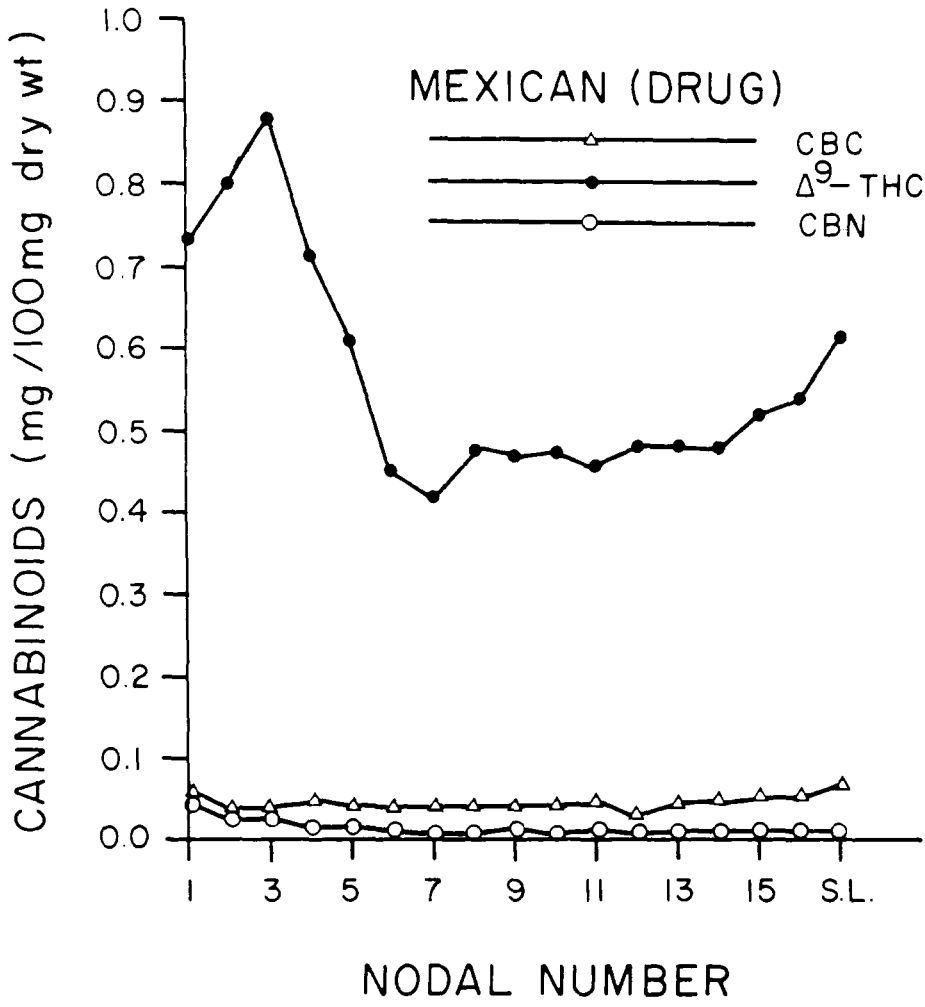

FIG. 3. Cannabinoid content of *Cannabis* leaves from successive nodes of pistillate plants of Mexican strains. Small floral leaves consisted approximately of the top 7 nodes. Manicured samples were taken form this floral region.

Flowering tops from these pistillate plants were harvested as manicured samples at the same time as the leaf samples were taken and analyzed to compare the cannabinoid content of the floral region (table 4) with leaves from the floral and vegetative portions of the plant (figs. 1–3). Small floral leaves (approx. top 1–7 nodes) of all three strains contained a higher level of their characteristic cannabinoid than the leaves of the vegetative portion of the plant (figs. 1–3). However, the manicured sample (table 4) of the Mexican strain contained a higher

level of its characteristic cannabinoid (Δ^9-THC) than the small floral leaves of the same strain. In comparison, similar levels of CBD were found in these two samples of non-drug 79 and fiber 87.

TABLE 4. Cannabinoid content of manicured samples of *Cannabis*.

Strain	Cannabinoid (mg/100 mg dry wt)[a]				
	CBD	CBC	Δ^8-THC	Δ^9-THC	CBN
Non-drug 79	0.98[b]	—	—	0.03	—
Fiber 87	2.30	0.13	—	0.11	0.13
Mexican	—	0.08	—	1.42	0.02

[a]Each datum value represents the mean of at least three replicates.
[b]Includes both CBD and CBC, as resolved on 6% OV-1.

ANALYSES OF LEAFLETS OF DIFFERENT LENGTHS.—The central leaflet of vegetative leaves of increasing lengths from three cloned strains (non-drug 79, fiber 87 and drug 152) were examined for their cannabinoid content (table 5). Characteristic cannabinoids were found for all strains [non-drug 79 (clone) and fiber 87 (clone), CBD; drug 152 (clone), Δ^9-THC] as found in floral organs (tables 2 and 3) and vegetative leaves (figs. 1–3), however the quantitative level of the characteristic cannabinoid was different in each cloned strain at each leaf age. All cannabinoids found in the center leaflet decreased with leaf age. Leaflets from drug 152 (clone) contained Δ^8-THC, whereas this C_{21} compound was not detected in leaves of non-drug 79 (clone) and fiber 87 (clone). The high levels of CBN in these leaf samples could represent the overlapping of cannabigerol with CBN. We have found that CBN and cannabigerol are not resolved on 3% OV-1 under the chromatographic conditions employed in this study. High levels of CBN also could result from oxidation of Δ^9-THC (9).

TABLE 5. Cannabinoid content of central leaflets of leaves of different lengths from *Cannabis* plants that were grown under long day conditions.

Strain	Length of center leaflet (cm)	Cannabinoid (mg/100 mg dry wt)[a]				
		CBD	CBC	Δ^8-THC	Δ^9-THC	CBN
Non-drug 79 (clone)	2.5	6.45	0.95	—	0.39	0.57
	5.0	4.09	0.71	—	0.29	0.19
	7.5	3.65	0.56	—	0.19	0.09
	10.0	1.97	0.35	—	0.11	tr
	12.5	1.60	0.27	—	0.15	tr
Fiber 87 (clone)	2.5	4.36	0.52	—	0.28	0.55
	5.0	2.07	0.20	—	0.10	0.03
	7.5	2.00	0.22	—	0.10	0.10
	10.0	1.45	0.15	—	0.07	tr
	12.5	1.32	0.15	—	0.07	—
	15.0	1.00	0.12	—	0.07	—
Drug 152 (clone)	2.5	tr	0.53	0.51	4.35	0.47
	5.0	—	0.25	0.26	2.58	0.14
	7.5	—	0.20	0.22	1.99	tr
	10.0	tr	0.13	0.09	1.39	tr
	12.5	tr	0.12	0.08	1.10	tr

[a]Each datum value represents the mean of at least two replicates. tr; trace quantities detected (less than 0.01 mg/100 mg dry wt).

Analyses of leaflets of different lengths were extended to include comparisons of leaflets on the same compound leaf of drug 152 (clone) (table 6). For 7.5 cm trifoliate leaves, both the central leaflet and the two lateral leaflets contained similar quantities of Δ^9-THC on a dry weight basis. In a similar manner, the central leaflet of a 10 cm leaf contained quantities of Δ^9-THC comparable to the adjacent pair and proximal pair of leaflets. Therefore, these data suggest that all leaflets of a compound leaf from drug 152 (clone) are quantitatively and qualitatively similar in their cannabinoid content.

TABLE 6. Cannabinoid content of leaflets from different aged compound leaves of *Cannabis*, drug 152 (clone).[a]

Compound leaves	Cannabinoid (mg/100 mg dry wt)				
	CBD	CBC	Δ^8-THC	Δ^9-THC	CBN
7.5 cm Leaf					
a. Central leaflet	tr	0.17	tr	1.80±0.23	tr
b. Lateral leaflet pair	—	0.15	tr	1.74±0.17	tr
10.0 cm Leaf					
a. Central leaflet	tr	0.10	tr	1.01±0.13	tr
b. Proximal pair of leaflet to central leaflet	tr	0.08	tr	0.99±0.13	tr
c. Distal pair of leaflets to central leaflet	tr	0.07	tr	0.96±0.17	tr

[a]Each datum value represents the mean of at least three replicates. Standard error is given for Δ^9-THC value. tr; trace quantities detected (less than 0.01 mg/100 mg dry wt).

DISCUSSION

Data presented in this report showed that different plant parts from a given strain or clone of *Cannabis* contained different concentrations of cannabinoids. However, each of these plant parts, in most cases, possessed a cannabinoid profile which characterized the chemical phenotype of that strain. For example, samples of either leaves or flower parts (bracts or calyx-anthers) from the drug plants (both Mexican strains and drug 152) contained a cannabinoid profile which included high levels of Δ^9-THC, whereas, organs from fiber or non-drug strains possessed an abundance of CBD(CBC) as their characteristic cannabinoid. The other major cannabinoids present in plant parts of each strain were usually found in relatively low quantities. Also, comparable or intermediate levels of both CBD(CBC) and Δ^9-THC were found in specific plant organs of several strains. In addition, the cannabinoid profile found in leaves of different ages also was indicative of the chemical phenotype of that strain, although the quantitative levels of the individual cannabinoids were lower. In a few cases, high levels of non-characteristic cannabinoids were found. This was true for the calyx-anther complex of staminate plants of the Turkish and non-drug 79 strains plus the floral parts of the pistillate plants of the non-drug 79 (clone) as well as vegetative leaves (10) of the Mexican (police-seizure) and Turkish strains. The accumulation of these non-characteristic cannabinoids in specific organs suggests that some cross-pollination might have occurred, environmental factors might influence cannabinoid accumulation and/or the existence of a cyclic pattern (5) in the biosynthetic pathway of these C_{21} compounds in all cannabinoid accumulating organs of *Cannabis* plants. Therefore, whether the accumulation of these non-

characteristic compounds in high quantities influenced the determination of the phenotypic classification of *Cannabis* strains or not, was of interest.

Two procedures for classifying the cannabinoid phenotype have been described for *Cannabis* (3, 4, 11). Essentially, these systems are based on the CBD and Δ^9-THC ratios in manicured samples. Using the cannabinoid values found for samples of specific plant parts, we have calculated the cannabinoid phenotype using both of these classification methods (table 7). As expected, most samples indicated the same phenotypic category as determined from manicured samples. However, non-drug 79 (clone) was an exception. Cannabinoid profiles of the plant parts varied sufficiently to place this strain into different phenotypic categories depending upon which plant part was analyzed. Similar results were found for organs of pistillate and staminate plants of the Turkish and Russ 106 strains. Deviation in cannabinoid formation could possibly be influenced by organ ontogeny (this report, 12) as well as gland type and stage in gland development (8). These data emphasize the importance of maintaining uniform sampling procedures of organs of comparable maturity when determining the cannabinoid phenotype of a *Cannabis* strain.

TABLE 7. Comparison of cannabinoid phenotypes of different organs from *Cannabis* strains according to two major classification procedures.

Strain	Small and Beckstead (15)			Fetterman et al. (3)		
	Bract	Floral leaf	Calyx-anther	Bract	Floral leaf	Calyx-anther
Non-drug 79 (clone)	II	I	I[a]	II	I	I[a]
Fiber 87 (clone)	III	III	III[a]	II	II	II[a]
Drug 152 (clone)	I	I	I[a]	I	I	I[a]
Fiber 150	III	III	III	II	II	II
Turkish [TU-A(2); C-71]	III	III	I	II	II	I
Mexican	I	I	I	I	I	I
Mexican [Me-A(3); C-72]	I	I	I	I	I	I
Russ 106	II	II	III	II	II	II
Russ 126	III	III	III	II	II	II
Russ 311	III	III	III	II	II	II
Russ 391	III	III	III	II	II	II
Russ 405	III	III	III	II	II	II

[a]Non-cloned material.

Previous studies on pollen have suggested the presence of cannabinoids in pollen grains (13). We have found the cannabinoid level to be low in pollen samples and not reproducible between different harvests from any one strain. Microscopic examination (SEM) of pollen samples revealed the presence of individual glandular trichomes (heads) distributed among the pollen grains. The existence of gland heads, known to contain cannabinoids (8, 14), suggests that the low level of cannabinoids represent a contaminant derived from glands rather than from pollen grains.

A general trend of decreasing cannabinoid content in leaves of increasing stages of maturity from pistillate plants (grown from seeds) was found in two strains (non-drug 79 and fiber 87), but was not as evident in the Mexican strain. This progressive decrease of cannabinoid content in leaves of different ages differs

from leaflets of a particular leaf where the cannabinoid concentration remains relatively constant between the leaflets. Young floral leaves, those within the first several nodes of the shoot apex, possessed a higher concentration of cannabinoids than older vegetative leaves. These results suggest that the formation rate of cannabinoids may be metabolically altered during leaf maturation. The cannabinoid content of the uppermost floral leaves can exceed that for manicured floral parts of a pistillate plant as indicated by non-drug 79 and fiber 87. Since manicured samples most likely contain different ratios of bracts, floral leaves and some vegetative leaves, and small stems, cannabinoid values of these samples, therefore, represent a mean estimate of the total cannabinoid profile within the flowering portion of the plant. Cannabinoid values of specific plant parts are, in turn, more indicative of the metabolic and/or accumulative centers of these C_{21} compounds in the *Cannabis* plant.

Several investigators (4, 5, 15) have reported the presence of different cannabinoid levels in manicured samples from pistillate and staminate plants of different *Cannabis* strains. Manicured samples from both sexes of plants originating north of latitude 30° N were found to contain comparable levels of total cannabinoids while for strains originating south of latitude 30° N, the female plants possessed higher levels of cannabinoids than male plants (4, 15). When flower parts of a Mexican strain were compared, the bracts of pistillate plants contained more than twice the drug (Δ^9-THC) content of the calyx-anthers of staminate plants (3). Different levels of Δ^9-THC also were found in flower parts of pistillate and staminate plants of both Mexican strains grown in our laboratory; however, another drug type (152) was found to possess similar drug content in both the pistillate and staminate flower parts. It has been suggested these differences in cannabinoid content, as described above involve seed differences in cannabinoid formation during organ ontogeny more than environmental control (8, 15, 18).

Our studies indicate that plant parts of a *Cannabis* strain may differ quantitatively and, in some cases, qualitatively in cannabinoid content from each other and that each organ also can contain different levels of cannabinoids as regulated by its degree of maturity and the sex of the plant. These variations, therefore, emphasize the need for uniform sampling procedures of organs of comparable maturity when accumulating data on a particular strain and when comparing data between strains. It is desirable, therefore, that analyses include information on the specific organ and relative stage of development. Additional studies also are necessary to determine the influence of environmental factors on both quantitative and qualitative levels of cannabinoids in specific plant organs.

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