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Some Features of *Cannabis* Plants Grown in the United Kingdom from Seeds of Known Origin

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Abstract—The cannabinoid content of UK-grown plants (up to the 6th generation) from Moroccan, Sri Lankan and Zambian seedstock was determined by TLC, GLC and HPLC. All plants from the 5th and 6th series resembled their parents, and UK-grown plants were always much greener than those grown overseas. Cannabinoid content remained broadly typical of the source countries. However, tetrahydrocannabinolic acid (THCA) consistently predominated over tetrahydrocannabinol (THC) to a far greater extent than in the original plants; the THCA/THC ratio was 17 in UK-grown plants compared with 2·0 in the plants from the original areas. Two types of plant emerged from the Moroccan seedstock, one tending to increased cannabidiol (CBD), the other tending to zero levels of this component. The first generation Sri Lankan plants revealed one type of plant with an increased CBD/THC ratio (1·7 compared with 0·11) but this returned to the original value in the succeeding generations. Other Sri Lankan plants had low or undetectable levels of CBD. Moroccan and Sri Lankan CBD-rich plants did not contain cannabichromene, although this cannabinoid was found in THC-rich plants. Zambian plants did not appear to show such a pattern. Zambian seedstock plants had total tetrahydrocannabivarin (diol and acid) levels greater than THC but the ratio was progressively reversed in succeeding generations. The study concludes that the ratios of particular cannabinoids is greatly influenced by the environment.

This is part of a multi-generation study to monitor the physical and chemical characteristics of *Cannabis* grown in the UK from seedstock obtained from plants harvested in their countries of origin. Previous work at this Laboratory (Baker et al 1982, 1983; Taylor et al 1985) has shown that, although some changes do occur in successive generations, these are mostly in the chemical rather than physical characteristics of the plants. In most instances there is a strong morphological similarity between the successive generations. Further studies have now taken place and data are presented on two further growing seasons, covering the fifth and sixth generations of the plants.

Experimental

Selection of seeds

Seeds used in these two seasons were selected from plants from the previous year which showed cannabinoid distributions characteristic of each of the three countries under study. The plant reference numbers, which indicate the plant number in each successive generation in a given lineage, are listed in Table 1.

Two types of Moroccan plants have been identified over the period of the study. One contains tetrahydrocannabivarin (THV) but no cannabidiol (CBD), and the other the converse. In general, plants in which CBD was absent, contained cannabichromene (CBCh). Seeds from both types (derived from plants 1.2.3.2 and 1.2.3.4, respectively) were selected to provide the fifth generation plants (Table 1). Selection of seeds for the sixth generation plants was on the same basis, i.e. THV with low CBD (1.2.3.2.2), and high CBD but no THV (1.2.3.4.3). None of the fifth generation crop of Moroccan plants contained CBCh.

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In the fourth generation UK-grown Sri Lankan plants, only the females contained CBD. Seeds from a plant with high CBD (1.2.8.2), typical of these plants, were selected for the fifth season. Fifth generation plants with significantly different amounts of CBD were selected to provide seeds for the sixth season.

All the UK-grown Zambian plants from both the fourth and fifth generations had similar characteristics, and seed selection was straightforward. All contained THV and all except one in each year contained CBCh. No plants contained CBD.

Growing conditions

The plants were grown in greenhouses in south-east England, as far as possible under identical conditions over all six generations. Thus any differences observed between the original *Cannabis* material grown overseas and the sibling plants grown in the UK may be ascribed to the environmental differences between the country of origin and the UK. Over the fifth generation growing season there were 650 h of sunshine and a mean temperature of 18·5°C. For the sixth season, the figures were 619 h and 16·6°C.

Table 1. Selection of plants for pollination to provide seeds for planting in the subsequent year.

	Plant no.			
Country	Male	Female	Male	Female
Morocco	1.2.3.3	1.2.3.2 1.2.4.3	1.2.3.4.1	1.2.3.2.2 1.2.3.4.3
Sri Lanka	1.2.8.1	1.2.8.2	1.2.8.2.1	1.2.8.2.4 1.2.8.2.9
Zambia	3.1.7.4	3.1.7.2	3.1.7.2.7	3.1.7.2.2

The digits refer to the plant number in each successive generation in a given lineage.

Harvesting

The fifth and sixth generation plants were harvested at maturity. For the fifth generation, as in previous years, the maturation order was Morocco, Sri Lanka and Zambia, with the males generally flowering first. The final month of maturation of the fifth generation was disrupted both by the loss of some immature plants and attack by spider mite on those that remained. The sixth generation Zambian plants

Table 2. Quantitative data on fifth generation *Cannabis* plants.

Country of origin and plant no.	Harvesting date	Sex	Weight of cannabis (g)	Content (% by weight) CBD[a]	THC[a]	THV[a,b]	THCA	THC	CBCh	THCA/THC	CBD[a]/THC[a]
Morocco											
1.2.3.2.2	September	Female	—	0·07	0·83	0·27	0·78	0·05	ND	16	0·08
1.2.3.4.1	September	Male	25	1·10	0·47	0·25	0·44	0·03	ND	16	2·3
1.2.3.4.3	September	Female	28	0·95	0·07	ND	0·06	0·02	ND	3	13
Sri Lanka											
1.2.8.2.1	September	Male	25	0·19	1·66	0·07	1·42	0·24	ND	6	0·11
1.2.8.2.2	September	Female	38	0·79	0·46	0·02	0·41	0·06	ND	7	1·7
1.2.8.2.3	September	Female	36	0·09	1·45	0·04	1·31	0·14	ND	9	0·06
1.2.8.2.4	September	Female	37	1·25	0·83	0·03	0·75	0·08	ND	19	1·5
1.2.8.2.5	September	Female	38	0·08	1·77	0·03	0·54	0·023	ND	7	0·05
1.2.8.2.6	September	Male	26	0·03	0·50	ND	0·41	0·08	ND	5	0·06
1.2.8.2.7	September	Immature	22	0·12	1·61	0·05	1·55	0·06	ND	26	0·07
1.2.8.2.8	September	Male	25	0·20	2·12	0·08	1·89	0·23	ND	8	0·09
1.2.8.2.9	September	Male/female	24	0·18	1·15	0·19	0·93	0·22	<0·2%	8	0·16
Zambia											
3.1.7.2.1	September	Female	34	ND	1·59	0·28	1·49	0·10	0·08	15	—
3.1.7.2.2	September	Female	32	ND	0·59	0·24	0·50	0·09	0·00	5	—
3.1.7.2.3	September	Female	25	ND	0·67	0·26	0·62	0·05	0·08	12	—
3.1.7.2.4	September	Female	31	ND	0·66	0·44	0·58	0·08	0·07	7	—
3.1.7.2.5	September	Female	38	ND	0·43	0·22	0·34	0·09	0·04	3	—
3.1.7.2.6	September	Female	39	ND	1·07	0·44	0·90	0·17	0·05	5	—
3.1.7.2.7	September	Male	12	ND	0·21	0·05	0·17	0·04	0·02	4	—

[a] As determined by GLC (includes decarboxylated acid). [b] Where no value is quoted, THV«THC. ND = not detectable (<0·02%).

Table 3. Quantitative data on sixth generation *Cannabis* plants.

Country of origin and plant no.	Harvesting date	Sex	Weight of cannabis (g)	Content (% by weight) CBD[a]	THC[a]	THV[a,b]	THCA	THC	CBCh	THCA/THC	CBD[a]/THC[a]
Morocco											
1.2.3.2.2.1	August	Female	25	ND	1·00	0·46	0·96	0·04	ND	24	—
1.2.3.2.2.2	August	Male	16	ND	0·97	0·10	0·92	0·05	ND	18	—
1.2.3.2.2.3	August	Female	38	ND	0·84	ND	0·78	0·06	ND	13	—
1.2.3.2.2.4	August	Female	33	ND	0·16	0·99	0·16	<0·01	ND	—	—
1.2.3.4.3.1	August	Female	18	0·49	1·30	0·27	1·28	0·02	ND	64	0·4
1.2.3.4.3.2	August	Male	15	2·23	0·99	0·07	0·93	0·06	ND	16	2·3
1.2.3.4.3.3	August	Female	16	2·00	1·38	0·06	1·26	0·12	ND	11	1·4
1.2.3.4.3.4	August	Male	19	2·17	0·81	0·07	1·73	0·08	ND	22	2·7
Sri Lanka											
1.2.8.2.4.1	August	Female	40	1·04	0·43	0·45	0·41	0·02	ND	21	2·4
1.2.8.2.4.2	August	Female	32	1·90	1·20	0·11	1·17	0·03	ND	39	1·6
1.2.8.2.4.3	August	Female	31	1·26	0·69	0·67	0·68	0·01	ND	68	1·8
1.2.8.2.4.4	August	Female	41	0·27	1·76	0·94	1·74	0·02	ND	87	0·2
1.2.8.2.9.1	August	Female	27	ND	1·94	1·36	1·89	0·05	<0·2%	38	—
1.2.8.2.9.2	August	Female	44	ND	0·25	1·12	0·25	<0·01	<0·2%	—	—
1.2.8.2.9.3	August	Female	42	ND	1·41	0·30	1·33	0·08	<0·2%	17	—
1.2.8.2.9.4	August	Male	8	ND	3·49	0·17	3·35	0·14	<0·2%	24	—
Zambia											
3.1.7.2.2.1	August	Male	5	—	2·09	0·78	2·02	0·07	0·27	29	—
3.1.7.2.2.2	August	Female	27	ND	0·80	0·95	0·77	0·03	0·08	26	—
3.1.7.2.2.3	August	Male	8	ND	0·49	0·21	0·46	0·03	0·07	15	—
3.1.7.2.2.4	August	Female	29	ND	1·12	1·09	1·08	0·04	0·05	28	—
3.1.7.2.2.5	August	Male	7	ND	1·23	1·06	1·20	0·03	0·11	40	—
3.1.7.2.2.6	August	Female	30	ND	0·91	0·59	0·86	0·05	0·11	17	—
3.1.7.2.2.7	August	Female	31	ND	1·27	0·50	1·23	0·04	0·08	31	—
3.1.7.2.2.8	August	Female	30	ND	0·97	0·81	0·94	0·03	0·11	31	—

[a] As determined by GLC (includes decarboxylated acid). [b] Where no value is quoted, THV«THC. ND = not detectable (<0·02%).

matured much earlier than in previous years. The cool summer combined with an infestation on some of the plants, resulted in reduced yields of cannabis.

Analysis

After harvesting and air drying, the larger stalks and stems were removed and the remainder weighed. Samples of cannabis from each plant were chopped and mixed to give a homogeneous material for analysis by TLC (Fowler et al 1979), GLC (Baker et al 1980a) and HPLC (Baker et al 1980b). The analyses were carried out within one month of harvesting. The results are given in Tables 2 and 3 for the fifth and sixth generations, respectively.

Results and Discussion

As in previous years, all plants from the fifth and sixth seasons physically resembled their parents. The harvested material was of a green or yellow/green, friable nature. Mean values for the yields of cannabis are given in Table 4 and are the lowest obtained in the study. For all countries, the females again generally gave a greater yield than the corresponding males. Tetrahydrocannabinol (THC) contents for plants derived from all three countries continued to be lower than in the original foreign grown plants, although the combined content of THC and its acid (THCA) was little different from that in the original plants.

Morocco

Many of the fifth generation Moroccan plants were lost before reaching maturity and therefore it was not possible to identify any trends. However, the plant (1.2.3.2.2) whose mother contained THV and no CBD, itself contained THV and low CBD. On the other hand, plants whose parents contained some CBD and no THV, themselves contained CBD. Only in the female offspring (1.2.3.4.3) was THV absent. The sixth generation plants were again of two types, those with no detectable CBD (from parents of low CBD) and those with substantial quantities of CBD (as had their parents). Taking all the sixth generation Moroccan plants, there was no correlation between CBD and THV levels, although as before there were instances of particular plants having no CBD but high THV. None of the fifth or sixth seasons crop contained any detectable CBCh.

Sri Lanka

All the fifth generation Sri Lankan plants contained CBD. All except one contained THV, and only one contained CBCh. The results for Sri Lanka for the sixth season were clear cut. Only those plants whose parents had high CBD contained CBD themselves. CBCh was absent from this group. For the plants grown from parents of low CBD, no CBD at all was found. CBCh was found in all of these plants, which is again consistent with previously published observations (Fairbairn & Rowan 1975). THV was present in almost all of the Sri Lankan plants.

Zambia

The Zambian plants were similar to their parents and the fifth and sixth generations were again characterized by the absence of CBD.

Conclusions

Examination of the results over the entire study shows that all generations of plants physically resembled the plants of the originating country, with the major exception that all UK-grown plants were much greener than those encountered overseas. Yields have varied substantially from year to year (Taylor et al 1985), but do not correlate with hours of sunshine or temperature. Although the cannabinoid distribution has remained broadly typical of the source countries, there have been some notable changes. Tables 5–8 summarize the major observations relating to the cannabinoid distributions over the entire study. The THC levels have varied widely, but THCA has consistently predominated over THC to a far greater extent than in the plants providing the original seedstock. The THCA/THC ratios in plants grown in various overseas countries have previously been determined by Baker et al (1981). The mean value for 62 plants was 1·7. In the present study, the mean THCA/THC ratio for the original plants grown overseas was 2·0. The mean for the UK-grown siblings was 17. That this ratio is clearly dependent on climatic conditions can be seen even within the UK, as there were considerable variations over the six seasons involved. Taking all countries, the lowest ratio was observed in the fourth season, which had a higher total period of sunshine and higher mean temperature than any of the other years. Conversely, the highest ratios were observed in the first and sixth seasons, both of which had low mean temperatures.

Fairbairn & Liebmann (1974) have concluded that the total CBD/THC ratios (i.e. those calculated from the combined diol and acid content) are independent of the environment and suggested that there are two chemical races of plant, one being rich in CBD and the other in THC. In the present study two types of plant emerged from Moroccan seedstock, one with the percentage total CBD a little greater than total THC for all generations and the other type with no CBD (very low CBD in the fifth generation). If these authors

Table 4. Mean yields of *Cannabis*[a] (g).

	Fifth generation		Sixth generation	
	(mean)	(s.d.)	(mean)	(s.d.)
Morocco	27	—	23	8·7
Sri Lanka	30	7·0	33	12
Zambia	30	9·3	21	12
Mean	29		26	

[a] Data for 1980–1983, see Taylor et al (1985).

Table 5. Mean value of THCA/THC ratios[a].

	Generation		
Country	Original plant	Fifth	Sixth
Morocco	3·1	11·7	24·0
Sri Lanka	1·7	8·0	42·0
Zambia	1·2	7·3	27·1

[a] Data for 1980–1983, see Taylor et al (1985).

Table 6. Cannabinoids in Moroccan plants grown in the UK (all generations).

Generation	Number of plants	THCA/THC	CBD/THC[a]	CBCh	THV/THC[a]	Total THC[a] (% weight)
Original		> 1	< 1	Yes	< 1	1·5
1	1/3	> 1	≫ 1	Yes	< 1	0·3
	2/3	> 1	No CBD	Yes	< 1	4·3
2	1/6	> 1	= 1	No	< 1	0·4
	5/6	> 1	No CBD	Yes	< 1	0·7
3	1/8	> 1	> 1	No	< 1	0·9
	7/8	> 1	No CBD	Yes (3/8)	< 1	1·2
4	2/8	> 1	No CBD	Yes	≪ 1	0·7
	6/8	> 1	> 1	Low	No THV	0·8
5	1/3	> 1	≫ 1	No	No THV	0·1
	1/3	≫ 1	> 1	No	< 1	0·5
	1/3	≫ 1	≪ 1	No	< 1	0·8
6	1/8	≫ 1	< 1	No	≪ 1	1·3
	3/8	≫ 1	> 1	No	≪ 1	1·1
	4/8	≫ 1	No CBD	No	Variable	0·7

[a] Determined by GLC (includes the decarboxylated acid).

Table 7. Cannabinoids in Sri Lankan plants grown in the UK (all generations).

Generation	Number of plants	THCA/THC	CBD/THC[a]	CBCh	THV/THC[a]	Total THC[a] (% weight)
Original		< 1	= 1	No	< 1	1·0
1	1/3	≫ 1	No CBD	Yes	< 1	3·1
	2/3	> 1	≫ 1	Low	< 1	2·4
2	2/6	≫ 1	≫ 1	No	< 1	0·9
	4/6	> 1	> 1	No	< 1	0·7
3	1/8	> 1	≫ 1	No	< 1	0·2
	2/8	> 1	No CBD	Yes (1/2)	< 1	2·6
	5/8	> 1	> 1	No	< 1	1·2
4	3/8	> 1	No CBD	Yes	≪ 1	2·8
	5/8	> 1	> 1	Low	≪ 1	1·7
5	2/9	> 1	> 1	No	≪ 1	0·6
	7/9	> 1	≪ 1	No	≪ 1	1·5
6	1/8	≫ 1	< 1	No	< 1	1·8
	3/8	≫ 1	< 1	No	< 1	0·8
	4/8	≫ 1	No CBD	Yes	< 1	1·8

[a] Determined by GLC (includes the decarboxylated acid).

Table 8. Cannabinoids in Zambian plants grown in the UK (all generations).

Generation	Number of plants	THCA/THC	CBD/THC[a]	CBCh	THV/THC[a]	Total THC[a] (% weight)
Original		= 1	No CBD	No	> 1	1·5
1	3/3	≫ 1	No CBD	No	> 1	0·8
2	6/6	> 1	No CBD	No	> 1	0·7
3	1/8	> 1	No CBD	No	< 1	0·3
	7/8	≫ 1	No CBD	No	> 1	1·7
4	2/8	> 1	No CBD	Yes	> 1	1·1
	6/8	> 1	No CBD	Yes	< 1	0·5
5	1/8	> 1	No CBD	No	< 1	0·6
	7/8	> 1	No CBD	Yes	< 1	0·7
6	5/8	≫ 1	No CBD	Yes	< 1	1·1

[a] Determined by GLC (includes the decarboxylated acid).

are correct, then the seedstock itself must have been derived from both types of plant, which is not very probable because of the manner in which the seeds were selected (Baker et al 1982). Further, based on the examination of several hundred cannabis products from Morocco, plants grown in Morocco are typified by the presence of CBD. Two types of plant also emerged from Sri Lankan seedstock. In one type there was a dramatic change between the CBD/THC ratio in the seedstock plants and the first generation. The ratio decreased over the five generations by an order of magnitude, to revert to the value of the seedstock plants. For all years some Sri Lankan plants had a much lower or undetectable amount of CBD, even though the parents contained CBD. No Zambian plants over the whole study contained CBD. Fairbairn & Rowan (1975) and Rowan & Fairbairn (1977) also observed that CBD rich plants did not contain CBCh, whereas this cannabinoid was present in THC rich plants. This (and the converse) was found to be true for all generations of Sri Lankan plants and for the majority of Moroccan plants in all generations. No such pattern was apparent for Zambian plants.

It has previously been reported by Boucher et al (1977) that southern African plants rich in THVA gave rise to THCA rich plants in subsequent generations grown in a temperate climate. The experience in the present study exactly follows this pattern. Zambian plants providing the seedstock for the study had a total (diol and acid) THV level greater than total THC. By the third generation, one plant out of eight showed the converse and by the fifth generation all plants had become THC rich. This strongly supports the argument that the ratio of these cannabinoids is affected by the environment. The study also demonstrates that the ratio of the diol to its acid for a given cannabinoid is significantly affected by the environment.

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