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(54) Title: A NOVEL REFERENCE PLANT, A METHOD FOR ITS PRODUCTION, EXTRACTS OBTAINED THEREFROM AND THEIR USE

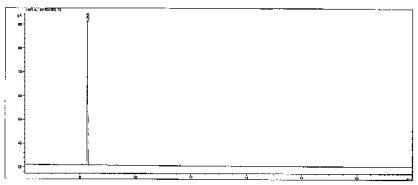

FIG 1A

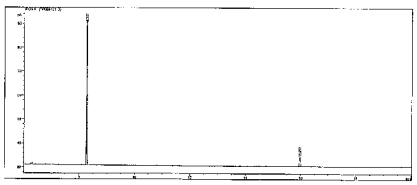

FIG 1B

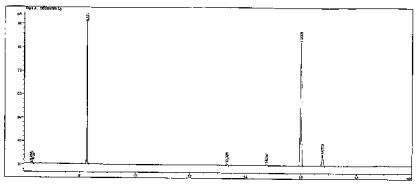

FIG 1C

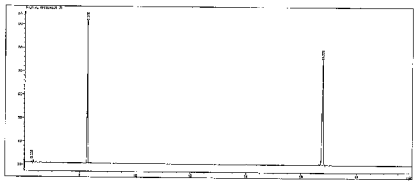

FIG 1 D

(57) Abstract: The present invention relates to a novel reference plant, a method for producing a novel reference plant, extracts free of a medicinally active compound or group of compounds obtained therefrom and their use. More particularly, the novel reference plant is a plant derived from a comparator plant. In an exemplifying embodiment the medicinal compounds, which are "knocked out", are one or more cannabinoids and the plant is a cannabis, *Cannabis sativa*, plant.

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A NOVEL REFERENCE PLANT, A METHOD FOR ITS PRODUCTION, EXTRACTS OBTAINED THEREFROM AND THEIR USE

Field of the Invention

The present invention relates to a novel reference plant, a method for producing a novel reference plant, extracts free of a medicinally active compound or group of compounds obtained therefrom and their use. More particularly, the novel reference plant is a plant derived from a comparator plant. In an exemplifying embodiment the medicinal compounds, which are "knocked out", are one or more cannabinoids and the plant is cannabis, *Cannabis sativa,* plant.

Background of the Invention

Many pharmaceuticals are derived from plants and indeed many plants or extracts obtained therefrom are taken as medicines. There are over 120 distinct chemical substances derived from plants that are considered as important drugs that are currently in use. The table below lists some of these substances.

There are many examples of plant-based substances that are known for their medicinal properties. For example a tropical plant, *Cephaelis ipecacuanha*, is known to produce the chemical emetine. A drug was developed from this substance called Ipecac; this was used for many years to induce vomiting. Another example of plant-based substances used as medicines is the plant chemical named taxol found in the Pacific Yew tree. The taxol molecule was produced synthetically to produce the drug Paclitaxel™, which is used in the treatment of various types of tumours.

The plant substance, cynarin, is a plant chemical found in the common artichoke (*Cynara scolymus*). A cynarin drug is sold for the treatment of liver problems and hypertension. The drug is simply an extract from the artichoke plant that has been standardized to contain a specific amount of cyanarin. Similarly the substance silymarin is a chemical found in the milk thistle plant and natural milk thistle extracts that have been standardized to contain specific amounts of silymarin are also used for the treatment of liver problems.

Some of the drugs/chemicals shown in the table below are sold as plant based drugs produced from processing the plant material. Many plant chemicals cannot be completely synthesised in the laboratory due to the complex nature of the plant extract. For example the tree *Cinchona ledgeriana* produces the substance quinine, which is used in to treat and prevent

malaria. Quinine is now chemically synthesised; however, another chemical in the tree called quinidine, which was found to be useful for the treatment of heart conditions, couldn't be completely copied in the laboratory. The tree bark is used to produce a quinidine extract.

The table below details some of the plant-based medicines that are in use today.

Drug/Chemical	**Action/Clinical Use**	**Plant Source**
Acetyldigoxin	Cardiotonic	*Digitalis lanata*
Adoniside	Cardiotonic	*Adonis vernalis*
Aescin	Anti-inflammatory	*Aesculus hippocastanum*
Aesculetin	Anti-dysentery	*Frazinus rhychophylla*
Agrimophol	Anthelmintic	*Agrimonia supatoria*
Ajmalicine	Circulatory Disorders	*Rauvolfia sepentina*
Allantoin	Wound healing	Several plants
Allyl isothiocyanate	Rubefacient	*Brassica nigra*
Anabesine	Skeletal muscle relaxant	*Anabasis sphylla*
Andrographolide	Baccillary dysentery	*Andrographis paniculata*
Anisodamine	Anticholinergic	*Anisodus tanguticus*
Anisodine	Anticholinergic	*Anisodus tanguticus*
Arecoline	Anthelmintic	*Areca catechu*
Asiaticoside	Wound healing	*Centella asiatica*
Atropine	Anticholinergic	*Atropa belladonna*
Benzyl benzoate	Scabicide	Several plants
Berberine	Bacillary dysentery	*Berberis vulgaris*
Bergenin	Antitussive	*Ardisia japonica*
Betulinic acid	Anticancerous	*Betula alba*
Borneol	Antipyretic, analgesic, anti-inflammatory	Several plants
Bromelain	Anti-inflammatory, proteolytic	*Ananas comosus*
Caffeine	CNS stimulant	*Camellia sinensis*
Camphor	Rubefacient	*Cinnamomum camphora*
Camptothecin	Anticancerous	*Camptotheca acuminata*
(+)-Catechin	Haemostatic	*Potentilla fragarioides*

Chymopapain	Proteolytic, mucolytic	*Carica papaya*
Cissampeline	Skeletal muscle relaxant	*Cissampelos pareira*
Cocaine	Local anaesthetic	*Erythroxylum coca*
Codeine	Analgesic, antitussive	*Papaver somniferum*
Colchiceine amide	Anti-tumour agent	*Colchicum autumnale*
Colchicine	Anti-tumour agent, anti-gout	*Colchicum autumnale*
Convallatoxin	Cardiotonic	*Convallaria majalis*
Curcumin	Choleretic	*Curcuma longa*
Cynarin	Choleretic	*Cynara scolymus*
Danthron	Laxative	*Cassia* species
Demecolcine	Anti-tumour agent	*Colchicum autumnale*
Deserpidine	Antihypertensive, tranquillizer	*Rauvolfia canescens*
Deslanoside	Cardiotonic	*Digitalis lanata*
L-Dopa	Anti-parkinsonism	*Mucuna* species
Digitalin	Cardiotonic	*Digitalis purpurea*
Digitoxin	Cardiotonic	*Digitalis purpurea*
Digoxin	Cardiotonic	*Digitalis purpurea*
Emetine	Amoebicide, emetic	*Cephaelis ipecacuanha*
Ephedrine	Sympathomimetic, antihistamine	*Ephedra sinica*
Etoposide	Anti-tumour agent	*Podophyllum peltatum*
Galanthamine	Cholinesterase inhibitor	*Lycoris squamigera*
Gitalin	Cardiotonic	*Digitalis purpurea*
Glaucarubin	Amoebicide	*Simarouba glauca*
Glaucine	Antitussive	*Glaucium flavum*
Glasiovine	Antidepressant	*Octea glaziovii*
Glycyrrhizin	Sweetener, Addison's disease	*Glycyrrhiza glabra*
Gossypol	Male contraceptive	*Gossypium* species
Hemsleyadin	Bacillary dysentery	*Hemsleya amabilis*

Hesperidin	Capillary fragility	*Citrus* species
Hydrastine	Hemostatic, astringent	*Hydrastis canadensis*
Hyoscyamine	Anticholinergic	*Hyoscyamus niger*
Irinotecan	Anticancer, anti-tumour agent	*Camptotheca acuminata*
Kaibic acud	Ascaricide	*Digenea simplex*
Kawain	Tranquillizer	*Piper methysticum*
Kheltin	Bronchodilator	*Ammi visaga*
Lanatosides A, B, C	Cardiotonic	*Digitalis lanata*
Lapachol	Anticancer, anti-tumour	*Tabebuia* species
a-Lobeline	Smoking deterrant, respiratory stimulant	*Lobelia inflata*
Menthol	Rubefacient	*Mentha* species
Methyl salicylate	Rubefacient	*Gaultheria procumbens*
Monocrotaline	Anti-tumour agent (topical)	*Crotalaria sessiliflora*
Morphine	Analgesic	*Papaver somniferum*
Neoandrographolide	Dysentery	*Andrographis paniculata*
Nicotine	Insecticide	*Nicotiana tabacum*
Nordihydroguaiaretic acid	Antioxidant	*Larrea divaricata*
Noscapine	Antitussive	*Papaver somniferum*
Ouabain	Cardiotonic	*Strophanthus gratus*
Pachycarpine	Oxytocic	*Sophora pschycarpa*
Palmatine	Antipyretic, detoxicant	*Coptis japonica*
Papain	Proteolytic, mucolytic	*Carica papaya*
Papavarine	Smooth muscle relaxant	*Papaver somniferum*
Phyllodulcin	Sweetner	*Hydrangea macrophylla*
Physostigmine	Cholinesterase Inhibitor	*Physostigma venenosum*
Picrotoxin	Analeptic	*Anamirta cocculus*
Pilocarpine	Parasympathomimetic	*Pilocarpus jaborandi*
Pinitol	Expectorant	Several plants

Podophyllotoxin	Anti-tumour, anticancer agent	*Podophyllum peltatum*
Protoveratrines A, B	Antihypertensive	*Veratrum album*
Pseudoephredrine*	Sympathomimetic	*Ephedra sinica*
Pseudoephedrine, nor-	Sympathomimetic	*Ephedra sinica*
Quinidine	Antiarrhythmic	*Cinchona ledgeriana*
Quinine	Antimalarial, antipyretic	*Cinchona ledgeriana*
Quisqualic acid	Anthelmintic	*Quisqualis indica*
Rescinnamine	Antihypertensive, tranquillizer	*Rauvolfia serpentina*
Reserpine	Antihypertensive, tranquillizer	*Rauvolfia serpentina*
Rhomitoxin	Antihypertensive, tranquillizer	*Rhododendron molle*
Rorifone	Antitussive	*Rorippa indica*
Rotenone	Piscicide, Insecticide	*Lonchocarpus nicou*
Rotundine	Analgesic, sedative, tranquilizer	*Stephania sinica*
Rutin	Capillary fragility	*Citrus* species
Salicin	Analgesic	*Salix alba*
Sanguinarine	Dental plaque inhibitor	*Sanguinaria canadensis*
Santonin	Ascaricide	*Artemisia maritma*
Scillarin A	Cardiotonic	*Urginea maritima*
Scopolamine	Sedative	*Datura* species
Sennosides A, B	Laxative	*Cassia* species
Silymarin	Antihepatotoxic	*Silybum marianum*
Sparteine	Oxytocic	*Cytisus scoparius*
Stevioside	Sweetener	*Stevia rebaudiana*
Strychnine	CNS stimulant	*Strychnos nux-vomica*
Taxol	Anti-tumour agent	*Taxus brevifolia*
Teniposide	Anti-tumour agent	*Podophyllum peltatum*
Tetrahydrocannabinol	Antiemetic, decrease ocular tension	*Cannabis sativa*

Tetrahydropalmatine	Analgesic, sedative, tranquilizer	*Corydalis ambigua*
Tetrandrine	Antihypertensive	*Stephania tetrandra*
Theobromine	Diuretic, vasodilator	*Theobroma cacao*
Theophylline	Diuretic, bronchodilator	*Theobroma cacao* and others
Thymol	Antifungal (topical)	*Thymus vulgaris*
Topotecan	Anti-tumour, anticancer agent	*Camptotheca acuminata*
Trichosanthin	Abortifacient	*Trichosanthes kirilowii*
Tubocurarine	Skeletal muscle relaxant	*Chondodendron tomentosum*
Valapotriates	Sedative	*Valeriana officinalis*
Vasicine	Cerebral stimulant	*Vinca minor*
Vinblastine	Anti-tumour, Antileukemic agent	*Catharanthus roseus*
Vincristine	Anti-tumour, Antileukemic agent	*Catharanthus roseus*
Yohimbine	Aphrodisiac	*Pausinystalia yohimbe*
Yuanhuacine	Abortifacient	*Daphne genkwa*
Yuanhuadine	Abortifacient	*Daphne genkwa*

There are many examples of extracts that are characterized by reference to a supposed active or marker. The principle described herein with reference to cannabis plants would thus be applicable to other plant types as are shown in the table above.

As an example of a botanical drug, *Cannabis sativa* has been used as a drug for centuries, although the precise basis for the plants activity is not known. Both THC and CBD, two of the plants cannabinoids, are known to have distinct pharmacological activities and Marinol® (THC) and Sativex® (an extract containing defined amounts of both THC and CBD) are approved products for various medical indications.

In the case of extracts it is of course unclear whether the efficacy of a botanical drug extract is attributable to the identified "active(s)" or "markers" and/ or other components present in

an extract which may provide an unidentified additive or synergistic effect or in fact be directly responsible for the activity.

In the case of cannabis the supposed actives, the cannabinoids, are produced through a series of enzymatic synthesis which are outlined below:

The first specific step in the pentyl cannabinoid biosynthesis is the condensation of a terpenoid moiety, geranylpyrophosphate (GPP), with the phenolic moiety, olivetolic acid (OA; 5-pentyl resorcinolic acid), to form cannabigerol (CBG). This reaction is catalysed by the enzyme geranylpyrophosphate:olivetolate geranyltransferase (GOT); [1]. Precursors for GPP are the C_5 isomers isopentenyl pyrophosphate (IPP) and dimethylallyl pyrophosphate (DMAPP). These compounds can originate from two different pathways:

- the mevalonate pathway (MVA) that is located in the cytoplasm; and
- the deoxyxylulose pathway (DOX) that operates in the plastid compartments.

According to Fellermeier *et al.* [2], the GPP incorporated into cannabinoids is derived predominantly, and probably entirely, via the DOX pathway of the glandular trichome plastids. The phenolic moiety OA is generated by a polyketide–type mechanism. Raharjo *et al.* [3] suggest that n-hexanoyl-CoA and three molecules of malonyl-CoA condense to a C_{12} polyketide, which is subsequently converted into OA by a polyketide synthase.

CBG is the direct precursor for each of the compounds THC [4], CBD [5] and CBC [6], [7] and [8]. The different conversions of CBG are enzymatically catalysed, and for each reaction an enzyme has been identified: THC acid synthase [4] CBD acid synthase [5] and CBC acid synthase [7] and [8].

Cannabinoids with propyl side chains, as identified by Vree *et al.* [9] and de Zeeuw *et al.* [10], result if GPP condenses with divarinic acid (DA; 5-propyl resorcinolic acid) instead of OA, into cannabigerovarin (CBGV). The condensation of n-hexanoyl-CoA and two, instead of three, molecules of malonyl-CoA, results in a C_{10} polyketide, which is subsequently cyclisised into DA by a polyketide [11]. The three cannabinoid synthase enzymes are not selective for the length of the alkyl side chain and convert CBGV into the propyl homologues of CBD, THC and CBC, which are indicated as cannabidivarin (CBDV), delta 9-tetrahydrocannabivarin (THCV) and cannabichromevarin (CBCV), respectively [12].

Summary of the Invention

The above pathway information is provided, as it will assist in an understanding of the probable mechanism - giving rise to the zero cannabinoid plants exemplifying the broader aspects of the invention.

Indeed it would be particularly useful to develop "knock out" plants in which the one or more "actives" or "markers" believed to be characteristic of a plants pharmaceutical activity are not expressed. Such plants would be useful in formulating "true" placebo extracts or comparator extracts for clinical trials and for producing extracts which could be used in pharmacological tests and experiments in order that a better understanding of an extract, and its perceived actives/ markers activity.

In the case of cannabis, the plant produces a vast array of cannabinoids (including THC and CBD – the main perceived cannabinoid actives) as well as a number of 'entourage' compounds. Entourage compounds are compounds which are related to cannabinoids but have little or no activity at the cannabinoid receptors. Such entourage compounds are thought to behave as modifiers of cannabinoid activity and therefore could enhance pharmacological efficacy. It would be useful to have a plant which did not produce the cannabinoids BUT which produced the entourage compounds and other significant compounds in combinations / amounts which at least substantially qualitatively and preferably also substantially quantitatively resembled that of a comparator plant, i.e. one which chemotypically bears a recognizable resemblance to the medicinal plants used to generate a pharmaceutical or medicine or a nutraceutical or functional food.

According to a first aspect of the present invention there is provided a reference plant which has been selected to:

a. not express a medicinally active compound or group of compounds; yet express, at least substantially qualitatively, most other non medicinally active compounds present in a therapeutically active comparator plant

such that the reference plant can be used to generate a reference extract with a reference chemical profile which resembles that of the comparator plant less the active compound or group of compounds and may thus be used as a placebo or to otherwise test the

hypothesis that the active compound or compounds are responsible for an extracts perceived medicinal activity.

The term "most other" is taken herein to refer to an amount of non medicinally active compounds expressed by the reference plant which is at least greater than 50% (w/w) of the total compounds in the plant. In specific embodiments the amount is greater than 60% (w/w) non medicinally active compounds, or the amount is greater than 70% (w/w) non medicinally active compounds, or the amount is greater than 80% (w/w) non medicinally active compounds, or the amount is greater than 90% (w/w) non medicinally active compounds, or the amount is greater than 95% (w/w) non medicinally active compounds,

Preferably the reference plant is a cannabis plant and the active compound or group of compounds are the cannabinoids.

The cannabis plant is preferably a *Cannabis sativa* plant containing a monogenic mutation that blocks the cannabinoid biosynthesis. Preferably the plant comprises a cannabinoid knock out factor governing a reaction in the pathways towards the phenolic moieties olivetolic and divarinic acid.

Significantly, the reference plant is characterised in that a homogenised bulk extract exhibits a profile of entourage compounds, which is quantitatively substantially similar to that of a reference plant; as for example is shown in Figure 3.

In one embodiment the homogenised bulk extract has a %v/w oil yield of greater than 0.14%, more preferably greater than 0.2%, through 0.3% to 0.4% or more.

A homogenised bulk steam distilled extract comprises both monoterpenes and sesquiterpines. The monoterpenes comprise detectable amounts of at least myrcene, alpha pinene and beta pinene. Preferably the combined myrcene, alpha pinene and beta pinenes comprise at least 50%, through 60% to at least 70% of the monoterpenes detected. Preferably it will also comprise one or more of limonine and optionally linalool and cis- and / or trans-verbenol.

The sesquiterpenes preferably comprise at least carophyllene and humulene and may further comprise carophyllene oxide.

Preferably humelene epoxide II is not detected in the reference plant.

The reference plants of the invention preferably comprise stalked glandular trichomes. These are present at a density comparable to those present in comparator drug type cannabinoid producing plants. The reference plants typically have small, grey, dull trichomes of various shapes (Fig. 2a). Some trichomes comprise headless; pinhead and/ or shrivelled trichomes, which may be, flat, convex or concave. They are also free of white trichome heads.

The reference plant may be further characterized in that it expresses monoterpenes, diterpenes, carotenoids, phytol and tetraterpenes. It additionally expresses sesquiterpenes, sterols and triterpenes.

The reference plant is further characterized in that it exhibits branching characteristic of a drug producing phenotype as opposed to a fibre producing phenotype and vigour, characterized in that the total above ground dry weight is comparable to drug producing phenotypes.

According to a further aspect of the present invention there is provided a method of producing a reference plant which does not express a medicinally active compound or group of compounds yet express, at least substantially qualitatively, most other non medicinally active compounds present in a therapeutically active comparator plant comprising:

a) Selecting a plant which does not express a medicinally active compound or group of compounds;
b) Selecting a therapeutically active comparator plant; and
c) Crossing the plant which does not express a medicinally active compound or group of compounds with the therapeutically active comparator plant to obtain an F1 progeny and self-crossing the F1 progeny to obtain an F2 progeny which is selected for the characteristics sought.

According to yet a further aspect of the present invention there is provided an extract obtainable from a reference plant of the invention.

According to yet a further aspect of the present invention there is provided an extract obtainable from a reference plant of the invention. Such extracts may be prepared by any method generally known in the art, for example by maceration, percolation, vaporisation, chromatography, distillation, recrystallisation and extraction with solvents such as C1 to C5 alcohols (ethanol), Norflurane (HFA134a), HFA227 and supercritical or subcritical liquid carbon dioxide. In particular embodiments the extracts may, for example, be obtained by the methods and processes described in International patent application numbers WO02/089945 and WO 2004/016277, the contents of which are incorporated herein in their entirety by reference.

In one embodiment the extract is used or formulated as a placebo. In particular embodiments such formulations and/or placebos may, for example, be formulated as described International patent application numbers WO01/66089, WO02/064109, WO03/037306 and WO04/016246, the contents of which are incorporated herein in their entirety by reference.

According to a further aspect of the present invention there is provided a method of testing a hypothesis that one or more compounds present in a plant extract are responsible or are solely responsible for the extracts pharmacological activity comprising:

i) selecting a plant according to the first aspect of the invention;
ii) obtaining an extract therefrom; and
iii) running comparative tests against the extract obtained from a comparator plant.

According to a further aspect of the present invention there is provided a method of producing a designer plant extract comprising the steps of:

i) selecting an extract obtainable from a reference plant according to the first aspect of the invention and
ii) combining the extract of (i) with one or more medicinally active components.

By "designer plant extract" is meant a plant extract which includes one or more medicinally active components which do not naturally occur in the reference plant of part i).

In specific embodiments, the medicinally active components may be purified naturally occurring compounds, synthetic compounds or a combination thereof. In a specific

embodiment the medicinally active components may be present in a plant extract. This plant extract may be an extract from a "drug producing" plant of the same species as the reference plant of part i). Typically this drug producing plant will not be the comparator plant to the reference plant of part i).

The invention is further described, by way of example only, with reference to novel *Cannabis sativa* plants (and not specific varieties), which do not express cannabinoids but which otherwise, resemble, chemotypically, medicinal cannabis plants.

The invention will be further described, by way of example only to the following figures in which:

Figs 1a - d are GC chromatograms from different chemotype segregants from a 2005.45.13 F_2.progeny (Table 2)

a: is from cannabinoid-free plants;

b: is from low content and THC predominant plants;

c: is from high content and THC predominant plants; and

d: is from high content and CBG predominant plants.

The peaks at 8.2, 16.0 and 16.7 min. represent the internal standard, THC and CBG, respectively;

Fig 2 a -d are microscopic images of the bracteole surfaces from different chemotype segregants from the 2005.45.13 F_2 progeny.

a: is from cannabinoid-free plants;

b: is from low content and THC predominant plants;

c: is from high content and THC predominant plants; and

d: is from high content and CBG predominant plants.

(The bar represents 500 μm) and

Fig 3 shows graphically, the chemical profile (both qualitatively and quantitatively) of respectively:

Top – a high cannabinoid bulk segregant;

Middle – a cannabinoid free bulk segregant of the invention; and

Bottom – a pharmaceutical production comparator (M3)

DETAILED DESCRIPTION

By way of introduction it should be noted that there are many different *Cannabis sativa* varieties and chemotypes. These include both wild type plants and cultivated varieties. The cultivated varieties include plants which have been cultivated as fibre producers (low THC varieties); those that have been bred (illegally) for recreational use (high THC) and more recently medicinal plants which have been selectively bred for their cannabinoid content (one or more cannabinoids predominate) and optionally the profile of e.g. entourage compounds.

In order to produce plants with the desired characteristics it was necessary to "knock out" the expression of cannabinoids in a manner, which did not detrimentally effect the production of e.g. entourage compounds in the medicinal plants. How this was achieved is set out below:

Identification of a cannabinoid-free chemotype plant.

Because in many countries cannabis cultivation is restricted to fibre hemp cultivars having specified "low" levels (typically below either 0.1 or 0.3% w/w of the dry floral tissue) of THC, several breeding programmes have been devoted to meeting these legal limits.

According to a survey of the European commercial fibre cultivars [13], the cultivars bred at the Ukrainian Institute of Fibre Crops (Glukhov, formerly, Federal Research Institute of Bast Crops) have the lowest THC contents and the lowest total cannabinoid contents. The cannabinoid breeding programme at this institute started in 1973. Their usual selective breeding methodology consists of family selection within existing cultivars with a high agronomic value and the elimination, before flowering, of plants with relatively high contents [14] and [15]. This effort has resulted in a gradual decrease of both THC content and total cannabinoid content.

Gorshkova *et al.* [16] evaluated the densities of sessile and stalked glandular trichomes on the bracteoles of various plants. They found that plants with stalked trichomes had relatively high cannabinoid contents and that their contents were positively correlated with the density of the stalked trichomes. Plants that had solely sessile trichomes always had low contents that were uncorrelated with the densities of the sessile trichomes. Gorshkova *et al.* [16] also mention plants without glandular trichomes that were found to be cannabinoid-free.

Since then, Ukrainian plant breeders have reported several times on the existence of cannabinoid-free breeding materials [15], [17] and [18]

Pacifico *et al.* [19] analysed individual plants from the Ukrainian cultivar USO 31 and found that one third of the individuals contained no cannabinoids. He also found that a minority of the plants (< 10%) in a French fibre cultivar, Epsilon 68, were cannabinoid-free.

The Ukrainian cultivar USO 31 is amongst several varieties of hemp that have been approved for commercial cultivation under subsection 39(1) of the Industrial Hemp Regulations in Canada for the year 2007.

These cannabinoid free plants are phenotypically and chemotypically different to those developed by the applicant through artificial manipulation and differ from those cannabinoid free plants that have been isolated in nature.

Theoretically, two different physiological conditions could make a plant cannabinoid-free:

(1) a disrupted morphogenesis of glandular trichomes that, according to Sirikantaramas *et al.* [20], appear to be essential structures for cannabinoid synthesis, and

(2) a blockage of one or more biochemical pathways that are crucial for the formation of precursors upstream of CBG.

The first condition would also seriously affect the synthesis of other secondary metabolites that are produced largely or uniquely in the glandular trichomes.

In 1991, field grown cannabinoid-free plants, resulting from Gorshkova *et al.* [16] programme were viewed and the bracts and bracteoles of these plants were apparently lacking glandular trichomes. Also, the plants did not exude the characteristic cannabis fragrance. This suggests that the volatile mono- and sesquiterpenes were not produced in these plants. Such cannabinoid free plants might therefore have been considered unsuitable for the purpose of breeding a cannabinoid free plant with typical entourage compounds.

The second condition could also affect metabolites other than cannabinoids, as in the case of an obstruction of the basic pathways of common precursors for different classes of end products.

The IPP incorporated, via GPP, into cannabinoids is derived from the DOX pathway in the plastids [2]. Monoterpenes, diterpenes, carotenoids, phytol and tetraterpenes are also uniquely synthesised in the plastids and one could therefore conclude that the IPP incorporated in these compounds, as with cannabinoids, is derived from the DOX pathway [21].

Sesquiterpenes, sterols and triterpenes are uniquely synthesised in the cytoplasm. Presumably they are synthesised from MVA derived IPP [21] and so do not share a fundamental pathway with the terpenoid moiety of cannabinoids.

Even so, according to Evans [22], there is also evidence for a cooperative involvement of the DOX- and the MVA pathway in the synthesis of certain compounds, through the migration of IPP from the plastids into the cytoplasm and *vice versa*.

The potentially wider chemical effect of engineering plants with the cannabinoid knockout factor yet which express selected entourage compounds has implications for pharmaceutical cannabis breeding. Cannabinoids, and THC in particular, are generally considered as the major pharmaceutically active components of *Cannabis*. Nevertheless, according to McPartland and Russo [23], the terpenoid fraction may modify or enhance the physiological effects of the cannabinoids, providing greater medicinal benefits than the pure cannabinoid compounds alone. As summarized by Williamson and Whalley [24], there are indications that the non-cannabinoid 'entourage' of constituents, such as:

- monoterpenes;
- sesquiterpenes; and
- flavonoids

modulate the cannabinoid effects and also have medicinal effects by themselves. Speroni *et al.* [25] reported an anti-inflammatory effect from an extract that was obtained from a cannabinoid-free chemotype.

Selection

Whilst USO-31 was selected as the source of a "knockout" gene to be introduced into pharmaceutical plants the challenge remained of achieving plants which were devoid of cannabinoids but which retained a good profile of selected entourage compounds (i.e. were broadly speaking comparable to plants grown to produce extracts for pharmaceutical use). In this regard USO-31 had a chemical profile, which was not similar to medicinal varieties in that it was lacking both in cannabinoids, and monoterpenes. Furthermore, the sesquiterpene profile also differed both quantitatively and qualitatively from that of plants used to produce pharmaceutical extracts.

EXAMPLE 1 - Breeding Programme

To overcome the problem of creating a reference plant which is, in the case of *Cannabis sativa*, free of cannabinoids BUT which had a chemical profile of entourage compounds resembling pharmaceutical cannabis, selective breeding programmes were undertaken.

A first cross was made between the selected cannabinoid free plant USO-31 and a plant having a high cannabinoid content of a given cannabinoid, in this case M35, a high THCV containing plant (83.4% by weight of cannabinoids THCV), and M84, a high CBD containing plant (92.4% by weight of cannabinoids CBD). The high cannabinoid plants were selected both for their high and specific cannabinoid contents and their vigour.

Alternatively, a direct cross with a selected pharmaceutical plant could have been made.

Table 1, bottom 2 rows, provides details of the cannabinoid composition of these parental clones:

Table 1. Characteristics of parental clones used in breeding experiments with cannabinoid-free materials.

Code	Generation/type	Source population	Cannabinoid content [a]	Cannabinoid composition [b]							
				CBDV	CBCV	THCV	CBD	CBC	CBGM [c]	THC	CBG
M3	Non-inbred clone	Skunk, marijuana strain	18			0.5		1.5		97.2	0.8
M16	Non-inbred clone	Turkish fibre landrace	12				91.5	2.6	1.3	3.8	0.8
M35	S_1 inbred clone	(California Orange x Thai), marijuana strains	14		1.0	83.4				15.6	
M84	F_1 hybrid clone	(Afghan x Skunk) x (Afghan x Haze), hashish and marijuana strains	15	1.0			92.4		1.0	3.7	1.9

[a] The total cannabinoid content (% w/w) of the floral dry matter assessed at maturity.

[b] The proportions (% w/w) of the individual cannabinoids in the total cannabinoid fraction assessed at maturity.

[c] Cannabigerol-monomethylether.

Of course other strains containing a high percentage of another cannabinoids e.g. THC, CBDV, CBG, CBGV, CBC, CBCV, CBN and CBNV could be used. By "high" is meant that the specific cannabinoid predominates and would typically comprise greater than 50% by weight of the total cannabinoids present, more particularly greater than 60%, through 70% and 80% to most preferably greater than 90% by weight.

The initial cross generated an F1 progeny (Table 2 rows 1 and 2) which were then self crossed to generate an F2 progeny from which plants having the desired characteristics (zero cannabinoid/ good entourage compound chemotype profile) were selected for back crossing to pharmaceutical varieties.

The selected zero-cannabinoid plant, USO-31, was monoecious. i.e. it has unisexual reproductive units (flowers, conifer cones, or functionally equivalent structures) of both sexes appearing on the same plant. In order to self-fertilise USO-31 and mutually cross female plants, a partial masculinisation was chemically induced. Self-fertilisations were performed by isolating plants in paper bags throughout the generative stage. The USO-31 source plants were evaluated for their drug type habit. Inbred seeds from the best individual apparently devoid of cannabinoids and another with only cannabinoid traces were pooled.

i) Crosses of low/zero cannabinoid USO-31 offspring with M35 and M84

Twenty-four plants of the 2003.8 F_1 (table 2, row 2) were evaluated.

Table 2. Pedigrees and codes of the progenies studied for chemotype segregation.

Seed parent[a]	Pollen parent [b]	F_1 code	F_2 code [c]
M35 (THCV)	USO-31 (low/zero)	2003.17	2003.17.19
M84 (CBD)	USO-31 (low/zero)	2003.8	2003.8.21
M3 (THC)	2003.8.21.76 F_3 (zero)	2005.45	2005.45.13
M16 (CBD)	2003.8.21.76 F_3 (zero)	2005.46	2005.46.27
M3 (THC)	2003.17.19.67 F_3 (zero)	2005.47	2005.47.9
M16 (CBD)	2003.17.19.67 F_3 (zero)	2005.48	2005.48.7

[a] Of the parents with cannabinoids present, the major one is indicated in brackets.

[b] The USO-31 pollinators were two plants with very low cannabinoid content and/or true cannabinoid absence. The other pollinators were F_3 lines confirmed to be devoid of cannabinoids.

[c] The underlined ciphers in the F_2 codes indicate the single F_1 individual that was self-fertilised to produce the F_2 generation. The majority of the plants had 'normal' cannabinoid contents, falling within a Gaussian distribution range from 1.13 to 4.56%. Three plants had only trace amounts of cannabinoids, ranging from approximately 0.02 up to 0.15%.

Similarly, the 19 plants of the 2003.17 F_1 comprised a majority of individuals with a cannabinoid content in the range of from 1.69 to 13.76%, and two plants with cannabinoid traces of only ca. 0.02%.

From both F_1s, an individual with only trace cannabinoid amounts was self-fertilised to produce an inbred F_2 2003.8.21 and 2003.17.19. Both F_2s comprised plants that were confirmed to be devoid of cannabinoids.

The remaining plants, those with cannabinoids present, could be assigned to two categories on the basis of a discontinuity in the cannabinoid content range:

- a group with low contents ranging from trace amounts up to roughly 0.6%; and
- a group with higher contents.

The newly obtained cannabinoid-free plants designated 2003.8.21 and 2003.17.19 F_2 had more branching (typical of a drug type phenotype and in contrast to that of a fibre type phenotype), a stronger fragrance (due to the presence / increase in the terpenes and sesquiterpenes) and higher trichome density (determinable on examination) than the original USO-31 plants.

The cannabinoid-free F_2 individuals with the best drug type plant habit, 2003.8.21.76 and 2003.17.19.67, were self-fertilised to produce fixed cannabinoid-free F_3 inbred lines (Table 2, rows 3-6, col 2) for use in a backcrossing programme with pharmaceutical production clones M3 (High THC 97.2%) and M16 (High CBD 91.5%) (Table 1, top 2 rows).

Backcrosses were performed in order to obtain cannabinoid-free material, more closely resembling (both qualitatively and quantitatively) the pharmaceutical production clones by way of their non-cannabinoid profile, particularly those of the entourage compounds.

All the clones listed in Table 1 were true breeding for their chemotype.

ii) Backcrossing of cannabinoid-free lines to pharmaceutical production clones M3 and M16

The cannabinoid-free lines 2003.8.21.76 and 2003.17.19.67, (Table 2, column 2, last 4 rows) were then back crossed with pharmaceutical production clones M3 and M16 and the resulting F1's crossed to generate an F2 progeny.

The resulting progeny had their cannabinoid content evaluated as shown in Table 3 below.

Table 3. Total cannabinoid contents of F_1 progenies resulting from crosses between two cannabinoid-free inbred lines (P1) and two high content clones (P2).

			Total cannabinoid content (% w/w)			
F_1 progeny	No. of F_1 plants evaluated	F_1 individual self-fertilised	P1	P2	F_1 range Min-avg-max	F_1 individual self-fertilised
2005.45	57	2005.45.13	0	18	0.22-0.58-1.09	0.89
2005.46	57	2005.46.27	0	12	0.16-0.46-1.00	0.47
2005.47	57	2005.47.9	0	18	0.24-0.45-0.75	0.36
2005.48	57	2005.48.7	0	12	0.10-0.42-1.25	0.83

Within the F_1s the cannabinoid contents showed a single Gaussian distribution. The F_1 contents were much lower than the parental means and therefore much closer to the cannabinoid-free parent than to the production parent. The F_1s were well covered with trichomes and were quite fragrant.

In respect of the cannabinoid composition, the 2005.45 F_1 segregated into two chemotypes: THC predominant plants and mixed CBD/THC plants, in a 1:1 ratio.

The 2005.46 F_1 had a uniform CBD chemotype.

The 2005.47 F_1 was uniform and consisted of THC plants, all with a minor proportion of THCV.

The 2005.48 F_1 was uniform and consisted of CBD/THC plants that also had minor proportions of CBDV and THCV.

Per F_1, one individual was selected on the basis of criteria such as 'drug type morphology' (e.g. branching) and minimal monoeciousness to produce back cross generations. These individuals were used for a repeated pollination of M3 or M16, which is not discussed here.

To examine chemotype segregation, the selected F_1 individuals were also self- fertilised to produce large inbred F_2s.

Figure 1 shows chromatograms of different chemotype segregants from the 2005.45.13 F_2. Fig 1a is the chromatogram for a zero cannabinoid plant.

The different chemotype segregants were microscopically compared. The cannabinoid-free plants of each progeny all had small, grey, dull trichomes of various shapes (Fig. 2a). Some were headless; some were pinhead and shrivelled, either flat, convex or concave.

By way of contrast:
The high content CBD- and/or THC- predominant individuals of each group all had big, round clear heads that sparkled under the lamp (Fig. 2b);

The low content plants from each progeny were almost indistinguishable from the cannabinoid-free plants except that there was an occasional small but bright trichome in some (Fig. 2c); and

The high content CBG predominant plants from the 2005.45.13 F_2 had big, round, opaque white heads (Fig. 2d), clearly distinct from the transparent ones occurring on the THC predominant plants of the same progeny.

The low content CBG predominant 2005.45.13 plants did not show opaque white trichome heads and were indistinguishable from the low content THC predominant plants. Neither were white trichome heads observed in any of the cannabinoid-free plants of this progeny.

As an indication of their vigour, the total above ground dry weights of all the cannabinoid-free- and the high content segregants were assessed. Per progeny, per segregant group the weights showed a Gaussian distribution.

For the 2005.45.13, 2005.46.27 and the 2005.47.9 progenies the cannabinoid-free individuals on average had a ca. 10% higher dry weight than the high content individuals.

In the 2005.48.7 progeny however, the average weight of the high content group exceeded that of the cannabinoid-free group by about 10%.

In order to characterize the plants a chemical analysis of both the cannabinoid content, and selected other chemicals, was undertaken as set out below:

EXAMPLE 2

i) Analysis of cannabinoid content and other chemicals

Mature floral clusters were sampled from every individual plant considered in the breeding experiments. Sample extraction and GC analysis took place as described by de Meijer *et al.* [26].

The identities of the detected compounds were confirmed by GC-MS. Cannabinoid peak areas were converted into dry weight concentrations using a linear calibration equation obtained with a CBD standard range. The contents of the individual cannabinoids were expressed as weight percentages of the dry sample tissue. The total cannabinoid content was

calculated and the weight proportions of the individual cannabinoids in the cannabinoid fraction were used to characterize the cannabinoid composition.

ii) Chemical comparison of bulk segregants

Each of the six F_2s listed in Table 2 segregated into:

- cannabinoid-free plants;
- plants with cannabinoid traces; and
- plants with high cannabinoid contents.

In each case, per F_2, the floral leaves, bracts and bracteoles of all the cannabinoid-free plants were pooled and homogenised, as was the floral fraction of all the plants belonging to the group with high cannabinoid contents. The different bulks from the:

- 2005.45.13 (from M3 – THC),
- 2005.46.27 (from M16 –CBD),
- 2005.47.9 (from M3- THC) and
- 2005.48.7 (from M16-CBD) F_2

were steam-distilled and the essential oil yields were assessed.

The monoterpene and sesquiterpene composition of these essential oils was analysed by Gas Chromatography with Flame Ionisation Detection (GC-FID).

The relative amounts of a wide range of entourage compounds in the bulk homogenates of:

- 2003.8.21 (from M84 – CBD) and
- 2003.17.19 (from M35 THCV) F_2s

were also compared by using the following analytical techniques:

a) Gas Chromatography – Mass Spectrometry (GC-MS)

To obtain comparative fingerprints, GC-MS analyses were performed on a HP5890 gas chromatograph, coupled to a VG Trio mass spectrometer. The GC was fitted with a Zebron fused silica capillary column (30m x 0.32mm inner diameter) coated with ZB-5 at a film thickness of 0.25μm (Phenomenex). The oven temperature was programmed from 70°C to 305°C at a rate of 5°C/min. Helium was used as the carrier gas at a pressure of 55 kPa. The injection split ratio was 5:1.

b) Gas Chromatography with Flame Ionisation Detection (GC-FID)

GC profiles of terpenoids were generated in the splitless mode with a HP5890 gas chromatograph. The GC was fitted with a Zebron fused silica capillary column (30m x 0.32mm inner diameter) coated with ZB-624 at a film thickness of 0.25µm (Phenomenex). The oven temperature was held at 40°C for 5 minutes, programmed to 250°C at a rate of 10°C/min then held at 250°C for 40 minutes. Helium was used as the carrier gas at a pressure of 9.2 psi. The injection split ratio was 10:1.

c) High-Performance Liquid Chromatography (HPLC) with Ultra-Violet (UV) detection

HPLC profiles were obtained using methods specific to a variety of compound classes. All samples were analysed using Agilent 1100 series HPLC systems

(i) **Cannabinoid profiles** were generated using a C_{18} (150 x 4.6mm, 5µm) analytical column. The mobile phase consisted of acetonitrile, 0.25% w/v acetic acid and methanol at a flow rate of 1.0 ml/min and UV profiles were recorded at 220nm.

(ii) **Carotenoid profiles** were generated using a Varian Polaris C_{18} (250 x 4.6mm, 5µm) analytical column. The mobile phase consisted of acetonitrile: methanol: dichloromethane: water at a flow rate of 1.2 ml/min and UV profiles were recorded at 453nm.

(iii) **Chlorophyll profiles** were generated using the same column, mobile phase and flow rate described for carotenoids. UV profiles were recorded at 660nm.

(iv) **Non-polar compound profiles** (triglycerides, sterols etc) were generated by a gradient LC method using a Phenomenex Luna C_{18} (2) (150 x 2.0mm, 5µm) analytical column. The mobile phase consisted of solvent A (acetonitrile: Methyl-tert-butyl-ether (9:1)) and solvent B (water) with the proportion of B decreased linearly from 13% to 0% over 30 minutes then held constant for 20 minutes at a flow rate of 1.0 ml/min. The flow rate was then increased linearly to 1.5 ml/min over 40 minutes and UV profiles were recorded at 215nm.

(v) **Polar compound profiles** (phenolics) were generated by a gradient LC method using an Ace C_{18} (150 x 4.6mm, 5µm) analytical column. The mobile phase consisted of solvent A

(acetonitrile: methanol, 95:5) and solvent B (0.25% w/v acetic acid: methanol, 95:5). The proportion of B was decreased linearly from 75% to 15% over 30 minutes then held constant for 10 minutes at a flow rate of 1.0 ml/min and UV profiles were recorded at 285nm.

RESULTS

Chemical comparison of cannabinoid-free- and high content bulks

The yields and compositions of steam-distilled essential oils from bulked cannabinoid-free- and bulked high content segregants of the four F_2 progenies are presented in Table 4 below.

A	B	C	D	E	F	G	H	I
		Parent	Parent	Parent	Intermediate	Intermediate	Back cross parent	Back cross parent
		USO-31	**M35**	**M84**	**USO-31 x M35 F2**	**USO-31 x M84 F2**	**M16**	**M3**
		Zero cannabinoid **Control 1**	83.4% THCV	92.4%CBD	Table 5	Table 5	91.5% CBD **Control 2**	97.2% THC **Control 3**
	Weight of material (g)	73.8g					117.7g	120.5g
	Volume of oil (ml)	0.10ml					0.3	0.95
	% OIL (%v/w)	0.14%					0.25	0.79
R/T								
	MONOTERPENES							
10.3	alpha-pinene	UDL					7.3	4.95
11.8	beta-pinene	UDL					2.65	3.58
12.2	myrcene	UDL					42.55	39.02
13.7	limonene	UDL					5.27	6.66

14.2	beta-ocimene	UDL	2.5	UDL
16	Linalol	UDL	3.68	4.65
17.8	cis-verbenol	UDL	UDL	UDL
18	trans-verbenol		UDL	UDL
	TOTAL	0	63.95	58.86
	SESQUITERPENES			
28.8	caryophyllene trans alpha	33.02	25.11	16.44
28.9	bergamotene	5.75	UDL	2.45
29.2	(z)-beta farnesene	9.34	UDL	4.25
29.8	humulene	11.96	8.71	7.65
30.7	Unidentified	5.95		
30.8	(e)-beta farnesene	1.59	2.23	UDL
31.1	gamma gurjunene	4.01	UDL	UDL
31.3	delta guaiene		UDL	UDL
31.6	Unidentified	1.03		
32.3	(e)-nerolidol	0.98	UDL	5.31
32.7	unknown		UDL	5.03
33.6	Unidentified	1.91		
33.8	caryophyllene oxide	6.42	UDL	UDL

34.5	humulene epoxide II	3.17	UDL	UDL	
36.4	alpha bisabolol		UDL	UDL	
47.5	Unidentified	7.48			
	TOTAL	92.61	36.05		41.13

A	B	J	K	L	M	N	O	P	Q
		Final zero		Final zero		Final zero		Final zero	
		2005.45.13	**2005.45.13**	**2005.46.27**	**2005.46.27**	**2005.47.9**	**2005.47.9**	**2005.48.7**	**2005.48.7**
		M3 backcross		M16 backcross		M3 backcross		M16 backcross	
		zero	high	zero	high	zero	high	zero	high
	Weight of material (g)	104.5g	88.1g	95.1	92.2	87.1	86.4	85.2	123.6
	Volume of oil (ml)	0.68	0.5	0.64	0.8	0.24	0.74	0.35	0.78
	% OIL (%v/w)	0.65	0.57	0.67	0.87	0.28	0.87	0.41	0.63
R/T									
	MONOTERPENES								
10.3	alpha-pinene	16.64	11.83	28.53	26.8	10.27	2.86	33.52	22.53
11.8	beta-pinene	7.65	6.58	12.6	9.37	5.57	2.22	15.51	8.98
12.2	myrcene	51.1	42.11	34.16	42.86	19.84	41.45	24.82	36.47
13.7	limonene	4.76	4.53	6.41	7.41	7.27	5.54	5.17	4.58
14.2	beta-ocimene	UDL	UDL	UDL	UDL	UDL	9.58	UDL	8.6
16	Linalol	1.62	2.78	UDL	UDL	10.48	2.95	2.91	UDL

17.8	cis-verbenol	UDL	UDL	UDL	UDL	UDL	UDL	1.73	UDL
18	trans-verbenol	UDL	UDL	UDL	UDL	3.31	UDL	2.61	UDL
	TOTAL	81.77	67.83	81.7	86.44	56.74	64.6	86.27	81.16
	SESQUITERPENES								
28.8	caryophyllene trans alpha	3.9	12.25	7.28	8.35	7.97	15.93	4.73	9.84
28.9	bergamotene	3.86	3.71	1.71	UDL	UDL	UDL	UDL	UDL
29.2	(z)-beta farnesene	4.83	6.05	2.78	1.95	UDL	3.48	UDL	1.86
29.8	humulene	3.04	6.83	3.27	3.26	7.88	7.68	2.12	3.69
30.8	(e)-beta farnesene	UDL	1.69	UDL	UDL	UDL	UDL	UDL	UDL
31.1	gamma gurjunene	UDL	UDL	UDL	UDL	UDL	1.78	UDL	UDL
31.3	delta guaiene	UDL	UDL	UDL	UDL	3.64	4.67	1.67	3.44
32.3	(e)-nerolidol	UDL	1.65	UDL	UDL	UDL	UDL	UDL	UDL
32.7	unknown	UDL	UDL	UDL	UDL	UDL	1.86	UDL	UDL
33.8	caryophyllene oxide	2.62	UDL	3.25	UDL	13.43	UDL	5.19	UDL
34.5	humulene epoxide II	UDL	UDL	UDL	UDL	6.06	UDL	UDL	UDL
36.4	alpha bisabolol	UDL	UDL	UDL	UDL	4.27	UDL	UDL	UDL
	TOTAL	18.25	32.18	18.29	13.56	43.25	35.4	13.71	18.83

In three (2005.46.27, 2005.47.9, and 2005.48.7), the cannabinoid-free bulks contained less essential oil than the high content ones.

In 2005.45.13 however, the cannabinoid-free bulk was slightly richer.

No significant qualitative differences in the essential oil composition were found, only minor quantitative ones, which generally did not show a systematic pattern.

The only consistent quantitative difference between the low and high content progeny was difference was found for caryophyllene oxide that in all four progenies, reached a higher proportion in the cannabinoid-free bulks than in the high content bulks.

When the zero cannabinoid backcross plants of the invention were compared to control 1 (the original zero cannabinoid plant which was also devoid of monoterpenes) and controls 2 and 3 (the pharmaceutical plants with a high cannabinoid content and a range of entourage compounds) the following differences were observed:

1. The volume of oil (%) obtained by steam distillation in the zero cannabinoid plants of the invention was on average 0.50%. By way of comparison control 1 is 0.14%, and the mean of control 2 and 3 was 0.52%. In other words the % oil is representative of the pharmaceutical clones.

2. The total measured monoterpene fraction in the zero cannabinoid plants of the invention was on average about 76. By way of comparison control 1 is 0, and the mean of control 2 and 3 was about 61. In other words the monoterpene fraction is representative of the pharmaceutical clones.

3. Within the monoterpence fraction in the zero cannabinoid plants of the invention the predominant terpene was myrcene, followed by alpha pinine and beta pinine with smaller amounts of limonine and linalol. Whilst quantitatively there were differences compared to the pharmaceutical controls there was, broadly speaking, a qualitative relationship.

4. The total measured sesquiterpene fraction in the zero cannabinoid plants of the invention was on average about 23. By way of comparison, control 1 is about 93, and the mean of controls 2 and 3 was about 39. In other words the sesquiterpene fraction is much more representative of the pharmaceutical clones than control 1.

5. Within the sesquiterpene fraction in the zero cannabinoid plants of the invention the predominant sesquiterpene were carophyllene, humulene and carophyllene oxide (accounting for more than 50% of the sesquiterpence fraction). Whilst there were differences compared to the pharmaceutical controls (where quantitatively carophyllene and humulene were again the most significant sesquiterpenes but carophyllene oxide was absent) there was, broadly speaking a qualitative, if not quantitative relationship between the plants of the invention and the pharmaceutical plants as compared to the starting zero cannabinoid plants which had much higher levels of sesquiterpenes and a wider detectable range of sesquiterpenes.

By way of comparison Table 5 gives some analytical data on the intermediate plants generated. It is a comparison of the different segregant bulks from 2003.8.21 and 2003.17.19 for a variety of compound classes.

Table 5: The composition of bulked cannabinoid-free- (Zero) and bulked high content segregants of two intermediate F_2 progenies.

	F_2 progenies	2003.8.21		2003.17.19	
	Segregant bulks	Zero	High	Zero	High
(i)	**Cannabinoids** [c]				
	CBDV	-	0.00566	-	-
	THCV	-	-	-	0.08814
	CBGV	-	-	-	0.01157
	CBD	-	0.47868	-	-
	CBC	-	0.04855	-	0.02771
	CBGM	-	0.00671	-	-
	THC	-	0.01605	-	0.32459
	CBG	-	0.20785	-	0.05573
	CBN	-	-	-	0.01179
	Triterpenes [b]				
	Squalene	4.1×10^7	7.9×10^7	2.1×10^7	1.9×10^7
	Unidentified hydrocarbon	5.2×10^8	5.4×10^8	1.1×10^8	1.6×10^8
	Unidentified alcohol 1	3.8×10^8	5.1×10^8	1.1×10^8	3.3×10^8
	Unidentified alcohol 2	1.3×10^8	1.3×10^8	5.5×10^7	1.4×10^8
	Diterpenes [c]				
	Phytol	0.0587	0.0591	0.0511	0.0487
	Sesquiterpenes [c]				
	Beta-caryophyllene	0.0043	0.0105	0.0022	0.0102
	Alpha-caryophyllene	0.0022	0.0037	0.0027	0.0035
	Caryophyllene oxide	0.0049	0.0041	0.0020	0.0041
	Nerolidol	0.0030	0.0024	0.0043	0.0027
	Monoterpenes [c]				
	Alpha-pinene	0.0010	0.0015	0.0015	0.0085
	Myrcene	0.0017	0.0057	0.0024	0.0180
	Limonene	-	0.0011	-	0.0015
	Linalol	0.0030	0.0053	0.0035	0.0053
	Long-chain alkanes [b]				
	Nonacosane	1.1×10^9	9.5×10^8	2.0×10^8	4.7×10^8
	Heptacosane	1.5×10^8	1.8×10^8	5.5×10^7	4.7×10^7
	Pentacosane	2.5×10^7	2.0×10^7	1.3×10^7	7.4×10^6
	Hentriacontane	2.7×10^8	1.6×10^8	4.2×10^7	7.3×10^7
	Sterols [b]				
	Sitosterol	2.3×10^8	1.5×10^8	7.6×10^7	2.9×10^8
	Campesterol	6.6×10^7	4.0×10^7	1.3×10^7	5.9×10^7
	Stigmasterol	5.1×10^7	3.3×10^7	8.1×10^6	4.6×10^7
	Fatty acids [a]				
	Palmitic acid	√	√	√	√
	Linoleic acid	√	√	√	√
	Oleic acid	√	√	√	√
	Stearic acid	√	√	√	√
	Linolenic acid	√	√	√	√
	Aldehydes [b]				
	Octadecanal	2.4×10^7	5.5×10^7	8.1×10^7	6.9×10^7
	Vitamins [b]				
	Vitamin E	1.6×10^7	2.1×10^7	1.2×10^7	1.3×10^7
(ii)	**Carotenoids** [a]				
	Beta-carotene	√	√	√	√
(iii)	**Chlorophylls** [a]				
	Chlorophyll a	√	√	√	√
	Triglycerides [d]				
	GGL	49. 13	22.67	39.07	32.81
	GLL	19.40	7.00	9.71	7.03
	OLLn	39.37	22.87	48.23	39.36
	OLL	20.14	6.21	15.53	10.80

[a] compounds scored as present (√) or absent (-). [b] quantities expressed as GC-MS peak areas.
[c] quantities expressed as w/w contents.
[d] quantities expressed as HPLC-UV peak areas.

In general the differences between the entourages of the cannabinoid-free and the high content bulks were only quantitative. Limonene was an exception, as it was not detected in the cannabinoid-free bulks whereas a minor presence was found in both of the high content bulks.

However, the essential oil data in Table 4 does not confirm this finding for the other F_2s. Likewise, Table 5 does not show the difference in caryophyllene oxide as it appears in Table 4.

Both progenies in Table 5 had consistently higher levels of four different triglycerides in the cannabinoid-free bulks than the high content bulks. The occurrence of none of the entourage compounds listed in the Tables 4 and 5 appears to be critically associated with the presence or absence of cannabinoids.

With the reported exception of the triglycerides, the quantitative differences in the entourage compounds does not show a consistent trend between cannabinoid-free- and high content bulks.

This is most clearly seen in Fig 3, which compares high cannabinoid bulks with cannabinoid free bulks. It also shows an M3 pharmaceutical bulk. What is apparent from a comparison of these extracts is that the profiles between the high content bulk and the cannabinoid free bulk of the segregating plants are very similar and that further more there is substantial similarity to the pharmaceutical extract M3, particularly at the earlier retention times (less than 30 minutes).

DISCUSSION

The cannabinoid-free segregants resulting from backcrosses with high content drug clones had glandular trichomes in normal densities but the trichome heads were dull and much smaller than those of high cannabinoid content sister plants. Nevertheless the trichomes of cannabinoid-free segregants appear to be functional metabolic organs, as the chemical comparison of contrasting segregant bulks did not reveal big differences in the content and composition of volatile terpenes, which are also produced in the trichomes. The absence of cannabinoids probably causes the small trichome heads, rather than being a result of them.

The abundant presence of apparently functional trichomes on the cannabinoid-free plants rules out that the absence of cannabinoids is due to a disrupted morphogenesis of the glandular trichomes. It thus appears that the cannabinoid knockout factor is not derived from the gland free plants selected by Gorshkova et al [16].

It is more plausible that the absence of cannabinoids is attributable to the blockage of one or more biochemical pathways that are crucial for the formation of precursors upstream of CBG. As the chemical entourage of cannabinoid-free plants is intact, the obstacle is probably not in the MVA and DOX pathways towards IPP.

A blocked MVA pathway would not affect cannabinoid synthesis [2], but it should reduce levels of sesquiterpenes, sterols and triterpenes [21].

A blockage of the DOX pathway would obstruct the synthesis of the terpenoid moiety of cannabinoids [2] but it should also negatively affect the synthesis of monoterpenes, diterpenes, carotenoids, phytol and tetraterpenes [21].

An alternative is that the knockout allele encodes a defective form of the enzyme GOT [1] that catalyses the condensation of resorcinolic acids (OA and DA) with GPP into CBG. However, with such a mechanism one would expect an accumulation of the phenolic moieties OA and/or DA in the cannabinoid-free segregants. Our GC method for cannabinoid analysis detects the decarboxylated forms of both acids but they were observed in none of the cannabinoid-free plants' chromatograms.

The most plausible hypothesis for the absence of cannabinoids appears to be a blockage in the polyketide pathway towards the phenolic moieties OA and DA. Whatever the working mechanism of the cannabinoid knockout factor is, one would expect that a functional synthase dominates a non-functional version, and so it remains obscure as to why the heterozygous genotypes (*O/o*) have such a strongly suppressed cannabinoid synthesis.

The essential oil comparison and the chromatographic fingerprinting of contrasting segregant bulks demonstrated that except the cannabinoids, all the monitored compound classes were present in both segregant groups. The relative levels of the compound classes did vary between the contrasting segregant groups but not usually in a systematic way.

The quantitative differences between contrasting bulks could be attributable to the fact that in cannabinoid-free plants the trichome heads, as the metabolic centres for a range of end products, are not inflated with cannabinoids. This may change the physical environment in which the reactions occur so that it quantitatively affects the synthesis of entourage compounds. The fact that large amounts of basic cannabinoid precursors are not incorporated may also affect equilibriums of other biosynthetic reactions.

A further benefit of the plants of the present invention is that they can be used to create plant extracts containing cannabinoids in quantities / purities, which could not be achieved naturally. Such plant extracts providing the benefits arising from the presence of one or more selected entourage compounds. The cannabinoids, which could be introduced to the cannabinoid free extracts, could include one or more natural cannabinoids, synthetic cannabinoids or biosynthetic cannabinoids (modified natural cannabinoids). This would produce a "designer" plant extract that could be used in clinical trials or as medicines.

The benefits of natural or biosynthetic cannabinoids over synthetic cannabinoids lies in the fact that all of the cannabinoids are in the active form as opposed to a racemic mixture.

Other aspects of the invention will be clear to the skilled artisan and need not be repeated here. Each reference cited herein is incorporated by reference in its entirety for the relevant teaching contained therein.

The terms and expressions that have been employed are used as terms of description and not of limitation, and there is no intention in the use of such terms and expressions of

excluding any equivalents of the features shown and described or portions thereof, it being recognized that various modifications are possible within the scope of the invention.

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CLAIMS

1. A reference plant which has been selected to:

    a) not express a medicinally active compound or group of compounds; yet

    b) express, at least substantially qualitatively, most other non medicinally active compounds present in a therapeutically active comparator plant

such that the reference plant can be used to generate a reference extract with a reference chemical profile which resembles that of the comparator plant less the active compound or group of compounds and may thus be used as a placebo or to otherwise test the hypothesis that the active compound or compounds are responsible for an extracts perceived medicinal activity.

2. A reference plant as claimed in claim 1 which is a cannabis plant and the active compound or group of compounds are the cannabinoids.

3. A reference plant as claimed in claim 2 which contains a monogenic mutation that blocks the cannabinoid biosynthesis in *Cannabis sativa*.

4. A reference plant as claimed in claim 2 or claim 3 wherein the reference plant comprises a cannabinoid knock out factor governing a reaction in the pathways towards the phenolic moieties olivetolic and divarinic acid.

5. A reference plant as claimed in any of the preceding claims characterised in that a homogenised bulk extract exhibits a profile of entourage compounds which is quantitatively substantially similar to that of a reference plant.

6. A reference plant as claimed in claim 5 wherein the homogenised bulk extract has a %v/w oil yield of greater than 0.14%, more preferably greater than 0.2%, through 0.3% to 0.4% or more.

7. A reference plant as claimed in any of the preceding claims characterised in that a homogenised bulk steam distilled extract comprises both monoterpenes and sesquiterpine.

8. A reference plant as claimed in claim 7 wherein the monoterpenes comprise at least myrcene, alpha pinene and beta pinene.

9. A reference plant as claimed in claim 8 wherein the myrcene, alpha pinene and beta pinene comprise at least 50%, through 60% to at least 70% of the monoterpenes detected.

10. A reference plant as claimed in claim 8 or 9 further comprising limonine and optionally linalol.

11. A reference plant as claimed in claim 10 further comprising cis- and / or trans-verbenol.

12. A reference plant as claimed in claim 7 wherein the sesquiterpenes comprise at least carophyllene and humulene.

13. A reference plant as claimed in claim 12 further comprising carophyllene oxide.

14. A reference plant as claimed in claim 12 in which humelene epoxide II is not detected.

15. A reference plant as claimed in any of claims 2 to 14, substantially comprising stalked glandular trichomes.

16. A reference plant as claimed in claim 15 wherein the density of the stalked glandular trichomes is comparable to a cannabinoid producing plant.

17. A reference plant as claimed in claim 15 or 16 comprising small, grey, dull trichomes of various shapes (Fig. 2a).

18. A reference plant as claimed in claim 17 in which some trichomes comprise headless; pinhead and/ or shrivelled trichomes which may be flat, convex or concave.

19. A reference plant as claimed in claim any of claims 15-17 in which the trichomes are free of white trichome heads.

20. A reference plant as claimed in any of the preceding claims characterized in that it expresses monoterpenes, diterpenes, carotenoids, phytol and tetraterpenes.

21. A reference plant as claimed in any of the preceding claims characterized in that it expresses sesquiterpenes, sterols and triterpenes.

22. A reference plant as claimed in claim 20 or 21 which expresses entourage compounds selected from one or more of: monoterpenes; sesquiterpenes; and flavonoids.

23. A reference plant as claimed in any of the preceding claims having branching characteristic of a drug producing phenotype as opposed to a fibre producing phenotype.

24. A reference plant as claimed in any of the preceding claims exhibiting vigour, characterized in that the total above ground dry weight is substantially equivalent to that of comparator drug producing plants.

25. A method of producing a reference plant which does not express a medicinally active compound or group of compounds yet express, at least substantially qualitatively, most other non medicinally active compounds present in a therapeutically active comparator plant comprising:

    a) Selecting a plant which does not express a medicinally active compound or group of compounds;
    b) Selecting a therapeutically active comparator plant ; and
    c) Crossing the plant which does not express a medicinally active compound or group of compounds with the therapeutically active comparator plant to obtain an F1 progeny and self crossing the F1 progeny to obtain an F2 progeny which is selected for the characteristics sought.

26. A method as claimed in claim 25 further comprising successive back crosses with a comparator plant to selectively breed for the desired characteristics.

27. An extract obtainable from a reference plant as claimed in any of claims 1-24.

28. A placebo comprising an extract as claimed in claim 27.

29. A method of testing a hypothesis that one or more compounds present in a plant extract are responsible or are solely responsible for the extracts pharmacological activity comprising:

i) selecting a plant as claimed in any of claims 1-24;

ii) obtaining an extract therefrom; and

iii) running comparative tests against the extract obtained from a comparator plant.

30. A method of producing a designer plant extract comprising the steps of:

iii) selecting a plant extract as claimed in claim 27; and

iv) combining the extract of (i) with one or more medicinally active components.

FIG 1A

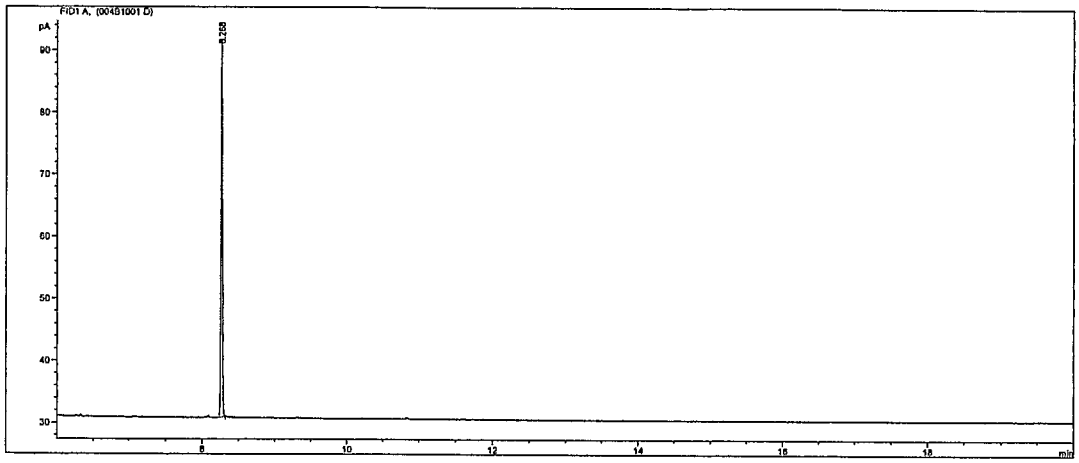
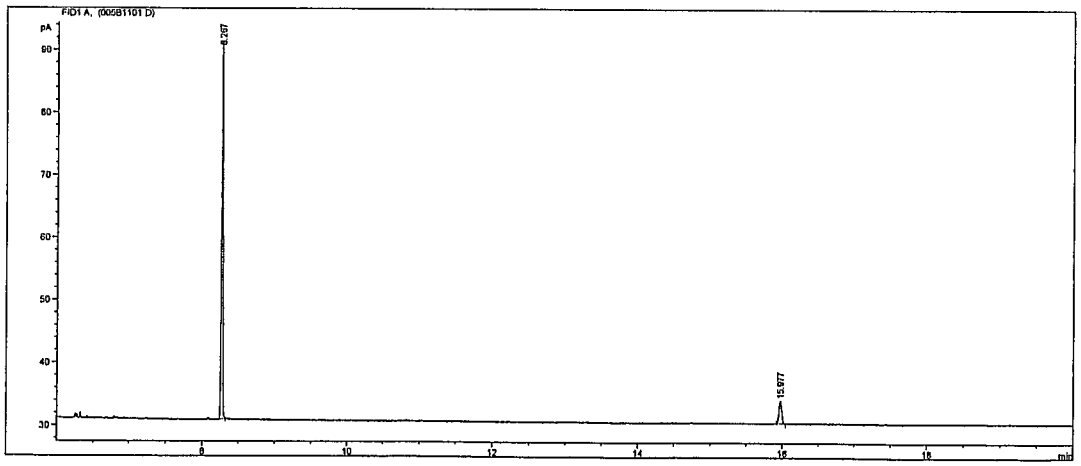
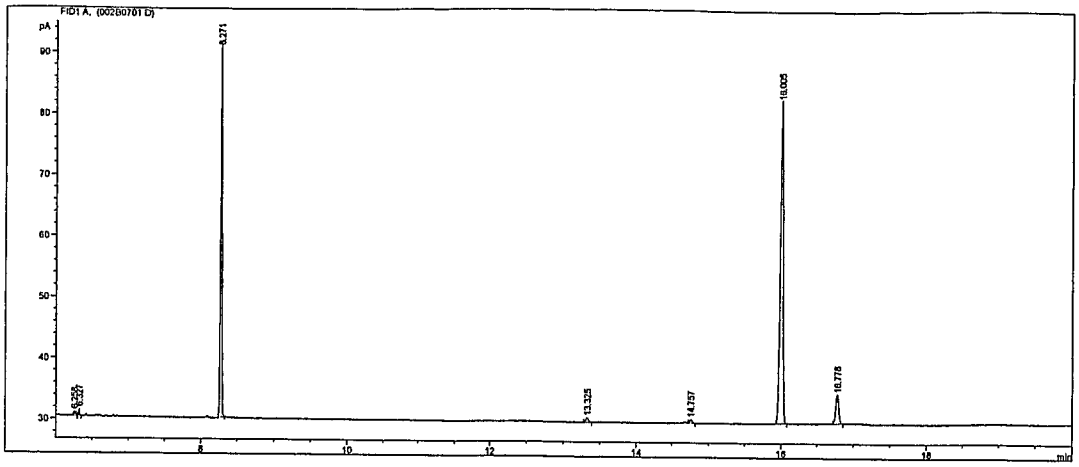


FIG 1B



b

FIG 1C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70
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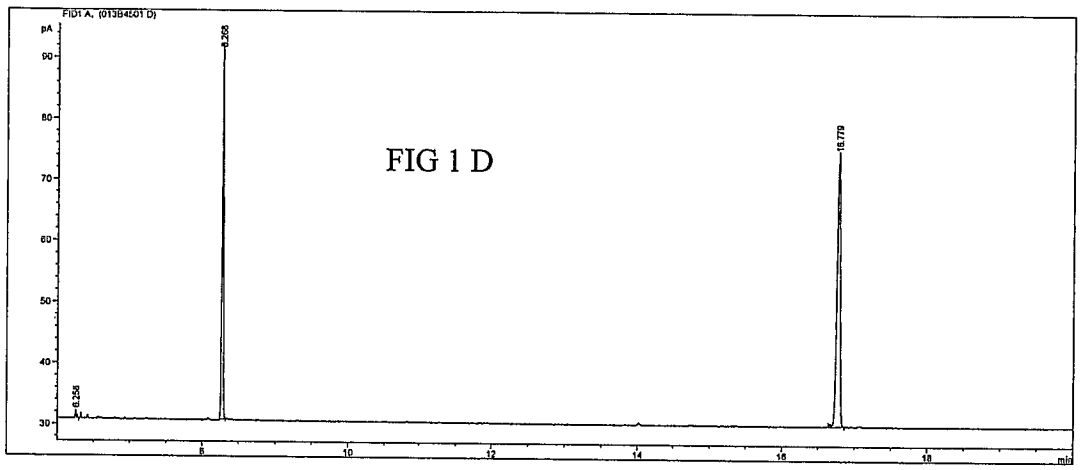
8
10
12
14
16
18
min

c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16
18
min

d

FIG 1 D

FIG 2A

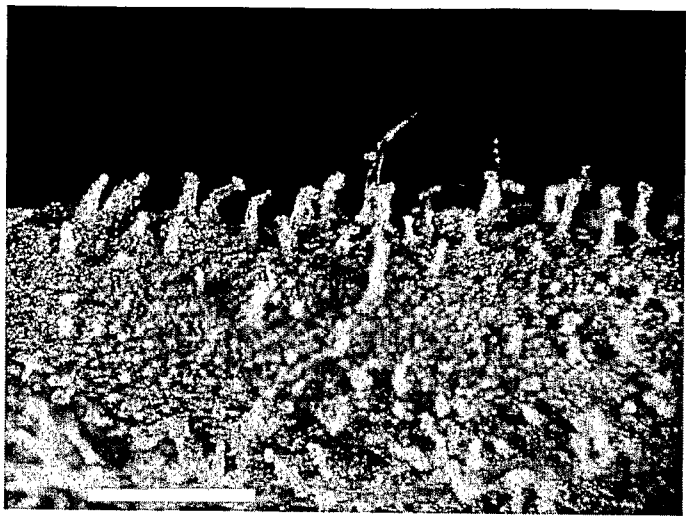


FIG 2B

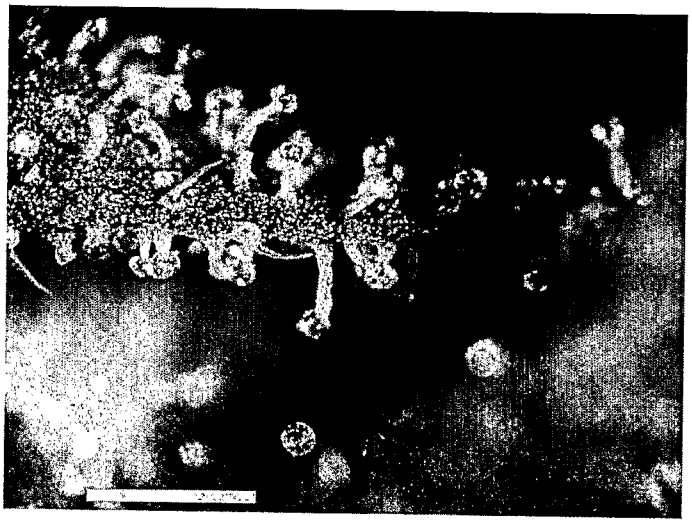


FIG 2C

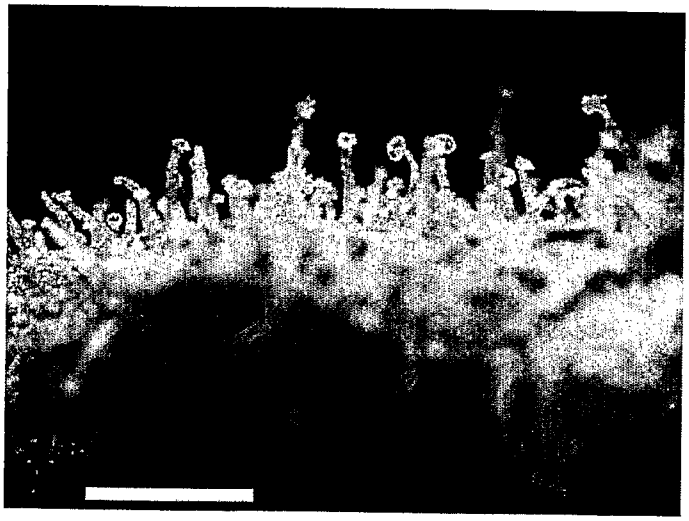


FIG 2D

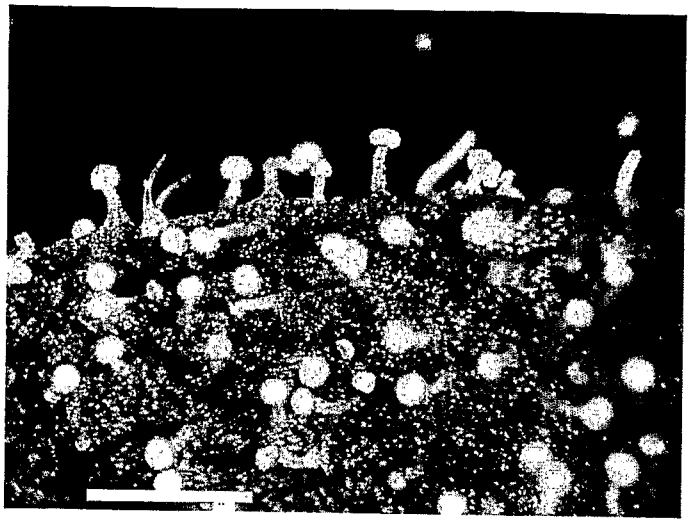
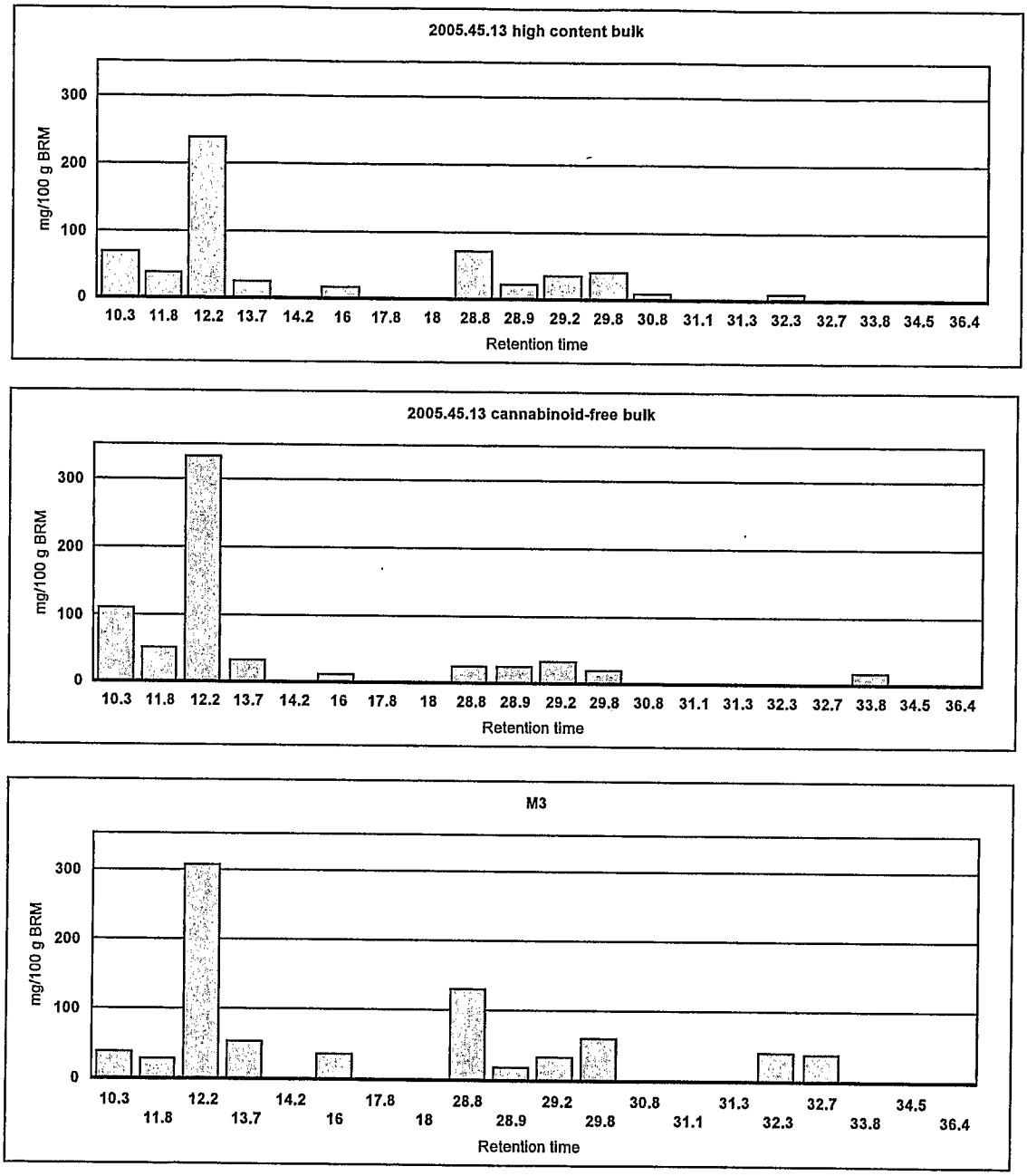


Fig 3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300
200
100
0
10.3 11.8 12.2 13.7 14.2 16 17.8 18 28.8 28.9 29.2 29.8 30.8 31.1 31.3 32.3 32.7 33.8 34.5 36.4
Retention time
2005.45.13 cannabinoid-free bulk
mg/100 g BRM
300
200
100
0
10.3 11.8 12.2 13.7 14.2 16 17.8 18 28.8 28.9 29.2 29.8 30.8 31.1 31.3 32.3 32.7 33.8 34.5 36.4
Retention time
M3
mg/100 g BRM
300
200
100
0
10.3 11.8 12.2 13.7 14.2 16 17.8 18 28.8 28.9 29.2 29.8 30.8 31.1 31.3 32.3 32.7 33.8 34.5 36.4
Retention time

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2008/001837

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61K36/185

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DANIELA PACIFICO ET AL: "Genetics and Marker-assisted Selection of the Chemotype in Cannabis sativa L" MOLECULAR BREEDING, KLUWER ACADEMIC PUBLISHERS, DO, vol. 17, no. 3, 1 April 2006 (2006-04-01), pages 257-268, XP019258788 ISSN: 1572-9788 page 262, paragraph 3; figure 1; table 1 ----- -/--	1-24, 27-30

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 August 2008	22/08/2008

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Krüger, Julia

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2008/001837

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	VIROVETS VG ET AL: "Selektion auf niedrigen Gehalt der Cannabinoid und hohe Produktivität im Schaffungsprogramm von Hanfsorten (Cannabis sativa L.), die keine narkotische Aktivität besitzen" TAGUNGSBAND ZUM/PROCEEDINGS OF THE SYMPOSIUM BIOROHSTOFF HANF, NOVA-INSTITUT FÜR POLITISCHE UND ÖKOLOGISCHE INNOVATION, HÜRTH, 1 January 1997 (1997-01-01), pages 135-153, XP009103931 page 3, paragraph 2; table 3	1-24, 27-30
X	SMALL ERNEST ET AL: "Tetrahydrocannabinol levels in Hemp (Cannabis sativa) germplasm resources" ECONOMIC BOTANY, NEW YORK BOTANICAL GARDEN, BRONX, NY, US, vol. 57, no. 4, 1 January 2003 (2003-01-01), pages 545-558, XP009103921 ISSN: 0013-0001 figures 2,3; table 1	1-24, 27-30

INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB2008/001837

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [X] Claims Nos.: 25, 26
because they relate to subject matter not required to be searched by this Authority, namely:

Rule 39.1(ii) PCT - Essentially biological process for the production of plants

2. [ ] Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. [ ] As all required additional search fees were timely paid by the applicant, this international search report covers allsearchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this international search reportcovers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

[ ] The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

[ ] No protest accompanied the payment of additional search fees.