**Regulations of volatile oil production in irrigated ornamental plants with mannitol- induced short-term drought stress**

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**Regulations of volatile oil production in irrigated ornamental plants using mannitol- induced short-term drought stress**

**Abstract**

Drought stress is an environmental serious problem threatening cultivated ornamental plants in water-depleted regions. The aim was drought stress induction in three medicinal plants (*Ocimum basilicum*, B, *Mentha longifolia*, M and *Origanum majorana*, O) using 250 mM mannitol for ten days. The results viewed that proline level has increased in all drought-stressed plants compared to the control. Four protein bands (210, 70, 63 and 18 kDa) have disappeared in stressed B-plant, in addition to the newly expressed protein bands at low molecular weight ranges (16-78 kDa). The protein polymorphism varied and ranged from 16.66% to 54.54%. RAPD-DNA technique indicated high similarity of genomic DNA in stressed plants compared to control plants. GC-MS screened intensive fluctuations within the phytochemical compounds pool. The genomic DNA structure was stable under drought stress; undergo expression of new genes that mediated the expression of new proteins. The new proteins subsequently induced the induction of chemical compounds with antioxidant property to cope with the drought stress.

***Keywords*: essential oil; photosynthetic pigments; proline; RAPD-DNA; SDS-PAGE.**

***Abbreviation*: Basil, B; Mint, M; origanum, O; Stressed basil, BM; Mint, MM; origanum, OM.**

**Introduction**

Drought is the serious agricultural problem that had long considered as the other face of salinity 1. Drought known to contribute indirectly with water deficit due to temperature increase or directly due to lack of water resources supplying agricultural lands. In addition, drought increases osmotic stress in soil leading to salinity problems. Mannitol-mediates both drought and osmotic stresses and has been frequently utilized experimentally to exert incident drought stress on examined plants. Drought numerous impacts on morphological, physiological and biochemical traits of various ornamental plants genotypes have been studied 2. Furthermore, drought sensitivity in some plants encompasses inhibition of nutrient transport to the root, reduction of leaf expansion and subsequently leading to reduction of shoot length and root dry weight due to physiological inhibition of cellular elongation and suppression of cell wall carbohydrate synthesis (3, 4, 5, 6). Previous researcher blotted a linear relationship between the decreases of moisture contributed with decrease of seedling biomass against the increase of mannitol concentration 7. Proline is famous amino acid exploited in scientific research as biomarker of drought and other stresses. Proline is the transporter using phloem sap to reach root of aromatic plants. It synthesizes and accumulates under drought stress due to either injury or signals (8, 9). Thereby, progressive water deficit leads to intensive proline accumulation in ornamental plants (10, 11). Only few published reports

Indicated that protein was not affected in drought-stressed crop plants 5, whereas in others, protein profile under drought stress accounts for synthesis, expression and accumulation of new protein bands (12, 13). In the literature, expression of 50-78 new protein bands was observed in imposed-maize to drought stress ranging (9-200 kDa) nominated late embryogenesis abundant proteins (LEA), or dehydrin proteins (14,15). They are stable, cysteine-free, lysine-rich proteins, regarded as ABA-stimulators which manipulate osmotic stress and membrane stability (16, 17, 18). Synthesis and production of volatile oil compounds in subjected-ornamental plants to drought stress are relatively drought-resistant 19. Little reports are available regarding drought effects on aromatic medicinal plants; however, drought influences the vegetative stage of aromatic plants before flowering via reducing shoot growth and leaf area, declining dry matter due to less photosynthetic activities and insufficient light absorption by leaf. Furthermore, drought causes wilting, rolling, size reduction, and senescence. Short-term stressed ornamental plants before flowering are prone to grain yield decrease for drought hampering the physiologically important processes needed for flowering stage. In addition, shortens the time duration from vegetative to flowering stage, and hence decreasing grain filling which all lead to the harvest index to be reduced 20.

Photosynthetic pigments in drought-stressed *Catharanthus* *roseus* plants were generally reduce due to reduction of leaf area and shortened root and shoot. Likewise, in *Abelmoschus esculentus*, *Albizia*, *Eucalyptus*, *Ocimum basilicum*, *Thymus vulgaris*, *Mentha piperita* and *Cymbopogon* *nardus* (21; 22, 23, 24, 25, 26, 27). In contrast, high chlorophyll content was determined under drought in kakooti plant compared to unstressed plant 28.

Essential oils are unlike fatty acids; they enclose fragrance with unspecific chemical composition, and are industrial compounds involve in cosmetic, perfumes, drink and as falvor 29. Drought sometimes alters the oil chemical composition via varying the contribution ratio of volatile components in particular genera 28. Generally, essential oil yield decreases under drought stress; however, oil percentage suggested to be unaffected or even increased due to presence of stress antioxidant compounds that assist plants against stress conditions. In previous studies, essential oil increases under drought stress in *origanum maforanal* and *Origanum* *majorana* 30 and in *Salvia officinalis* along with calendula (31, 32). In critical cases, the essential oil could also diminish due to drought-mediates reduction of shoot yield, leaf number and /or leaf area 33. In addition, the leaf position whether plain or curly does not interfere with oil production under drought stress, although curly leaf in parsley found to produce higher amount of essential oil compared with plain leaf. Camphor, B, 1, 8-cineole and thujona were the chemical components that increase in ratio during moderate drought stress 2.

The random amplified RAPD-DNA is such a powerful technique widely known for being rapid, simple and consistent for a particular plant species regardless of its age or origin 34. RAPD-DNA elucidates variance of genetic relationship upon plants breeding and considered the molecular marker of phylogenic analyses of plants species. Furthermore, this protocol so far becomes substantial in clarifying the genetic diversity of endangered plants (35, 36). RAPD-DNA been exploited potentially in identification of medicinal and aromatic plants components 37. However, in some cases, the amplification products view similarity of DNA sequence between varied species, which likely ascribed to the significant similarity of the varied species regarding the primer's amplification sites.

The aim of this study is to identify drought impacts on photosynthetic pigments, volatile oil production, protein profile and the genomic-DNA of three medicinal plants grown for ten days only during their flowering stage with drought stress generated by D-mannitol.

**Materials and Methods**

**Plant Materials and Growth Conditions**

Three aromatic and medicinal plants (65 d-old) at the flowering stage *Ocimum basilicum* (B), *Mentha longifolia* (M), and *Origanum majorana* (O) were purchased from local market located at Kafr Hakeem, Giza, Egypt. The plants were divided into two sets: The first set was left to grow for ten days using regular irrigation water and the second set of plants (BM, MM, OM) was irrigated for ten days using 250 mM D-mannitol solution (M). At the end of the experiment, the vegetative leaves were detached from the plants and used for extraction and estimation of photosynthetic pigments, protein and RAPD-DNA. Two days over-dried leaves (70°C) were utilized for proline and GC-MS analyses. All data were mean of independent replicates from three separate experiments.

**Estimation of Proline**

Determination of free proline was conducted in dry leafs detached from the normally grown ornamentals*, Ocimum basilicum* (B), *Mentha longifolia* (M), and *Origanum majorana* (O) or drought-stressed ornamentals (BM, MM and OM) using acidic ninhydrin using the method described by 38.

**Estimation of Photosynthetic Pigments**

The photosynthetic pigments (chl *a*, chl *b* and carotenoids) were determined in the leaves of the investigated plant. The spectrophotometric method recommended by 39 was followed. 0.5 g fresh weight of leaves was homogenized in 85% aqueous acetone for 5 minutes. The homogenate was centrifuged and the supernatant was made up to volume with 85% aqueous acetone. The extinction was measured against a blank of pure 85% aqueous acetone at 3 wave lengths of 452.5, 644, 663 nm using Spectrocolourimeter DC Tiny 25III Model TUDC12B4. Taking into consideration the dilutions made of the pigment fraction, chl *a*, chl *b* and carotenoids were determined as µg/ml using the following equations:

Finally, the pigment contents were expressed as µg.g-1 fresh weight of leaves.

**GC-MS analysis**

For potential identification of the organic components present in dried leaf powder of the three medicinal plants, basil, mint and origanum grown normally or under drought stress, GC-MS analysis was performed on a HP 6890 Gas Chromatograph fitted with a SGE BPX5 fused-silica capillary column (15m × 220 µm×0.25 µm), and coupled to a HP 5973 mass selective quadrupole detector. The derivatized extracts were inoculated through Merlin Microseal™. High Pressure Septumin pulsed splitless mode (pulse pressure 17.6 Psi, 325°C). The column oven was programmed to be enhanced with an initial sothermal at 50°C for 2 min. The temperature was increased with 10°C perminute reaching 360°C, then remained at this temperature for 15 min. Helium was a carrier constant gas controlled using 2.0 ml/min flow. The ion source was maintained at 230°C, ionization and fragmentation were accomplished by electron impact (70 eV). The mass filter was scanned between m/z 50 and 700, with a scan rate of 2.29 scans per second.

**Protein analysis using SDS-PAGE technique**

Sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE) was performed according to the method of 40, which was later modified 41. Water soluble proteins (W.S.P) of studied varieties were taken from leaves of these plants. Then protein fractionations were performed exclusively on vertical slab gel (19.8 cm x 26.8 cm x 0.2 cm) using the electrophoresis apparatus manufactured by Cleaver, UK. The images were captured by digital camera (Sony, made in japan) and transferred directly to the computer.

**Molecular genetic studies (RAPD-DNA)**

DNA was isolated from young leaf located at the apex of shoot of the three medicinal plants: basil, mint and origanum following the manufacture manual of DNA isolation and extraction of Promega kits.

PCR amplification reaction for different isolated DNA was performed using selected five primers in 0.2 ml PCR eppendorf tube containing optimized mixture (40 μ total volumel) consisted of master mix solis primer (8 μl), Metabion German (2 μl) and Template DNA (2 μl) then completed up to 40μl by nuclease-free water. Amplification was performed in programed Thermocycler for 35 cycles as follows: denaturation, 94ᵒ C for 5 min (one cycle), annealing, 94ᵒ C for 1 min, 37ᵒC for 45 sec, and 72ᵒ C for 45 sec (35 cycles) then extension, 72ᵒC for 7 min (one cycle) then held at 4 ᵒC until use. Agarose (1.2%) was utilized for separating PCR products. It was placed in 1X TAE buffer then boiled in microwave. Ethidium bromide was added to the melted gel after the temperature become 55ᵒC. The melted gel was poured in the tray of midi-gel apparatus (horizontal electrophoresis apparatus manufactured by Cleaver, UK) and the comb was inserted immediately, then the comb was removed when the gel hardened. The electrophoresis buffer (1X TAE) was added and covered the gel. 8 µl of DNA amplified product was loaded in each well and run at 100 V for about 2 hours. DNA marker consisted of twelve DNA fragments was used for comparison (3000, 1500, 1000, 900, 800, 700, 600, 500, 400, 300, 200, and 100 bp). Image analysis was carried out on UV-transilluminator filter where the produced fragments from RAPD gels were visualized under UV light with polaroid film 667. The film was scanned using densitometer at 577 nm. The software data analysis for Bio-Rad model densitometer been used.

**Results**

Comparing the normally irrigated plants (control) with the imposed set of plants to short-term drought stress using mannitol soltution (250 mM) for irrigation, a remarkable increase in proline level was observed in mannitol-treated genotypes of the three medicinal plants: basil (*Ocimum basilicum*), mint (*Mentha longifolia*) and origanum (*Origanum majorna*). Increase of concentration and rate of proline compared to water-irrigated plants varies among genotypes (Figure 1). Mint (M) plant found to accumulate considerably high amounts of proline either under drought or in control conditions as compared to the other genotypes. On the other hand, basil (B) elicited sharp increase of proline value upon drought exposure. Proline concentration has increased to about 5.7, 1.57, and 4.16 time the control in basil, mint and origanum genotypes, respectively.

As shown in Fig. 2, the photosynthetic pigments (chl *a*, chl *b* and carotenoids) undergo alterations expressed as general decline of photosynthetic pigments under the effect of mannitol-mediated osmotic stress particularly in basil and origanum genotypes. The decrease in chl *a* in basil and origanum genotypes was up to 3.33 and 1.46 time the control, in Ch *b* was up to, 3.5 and 1.68 time the control and in carotenoids the decrease was up to 1.37 and 1.22 time the control, respectively. In contrast, chl *a*, chl *b* and carotenoids have increased by 3.3, 1.32, and 1.63 time the control in mint genotype, respectively.

Analysis of SDS-PAGE protein gel shows variations in protein banding pattern including protein intensity in stressed compared to unstressed genotypes after been subjected to drought stress for 10-d using mannitol in irrigation. In basil, the four disappeared bands were detected at 210 and 70, 63 and 18 kDa. In addition, newly expressed protein bands located at 78 and 16 were obtained in basil with 54.54% polymorphism. In drought stressed mint, six expressed protein bands observed at 190, 119, 45, 33, 32, and 16 kDa constituting total of 37.5% polymorphism. In origanum, three new protein bands have also appeared at 87, 23 and 18 kDa and the polymorphism was less than basil and origanum (16.66%). Under drought-stress, no protein band had disappeared in mint or in origanum plants (Figure3, Table 1).

The Random amplified polymorphic DNA (RAPD) primers is a technique used to evaluate drought effect in the three medicinal plants genotypes. The isolated DNA from each plant was amplified against five selected primers (OPA-1, CAGGCCCTTC, OPA-4, AATCGGGCTG, OPA-11, CAATCGCCGT, OPB-3, CATCCCCCTG, OPB-10, CTGCTGGGAC) and the pattern of DNA-RAPD product are illustrated in Figure 4. The produced fragments range between 380 and 1230 bp and the five primers from (a-e) used were not all successful in amplifying the DNA isolated from the studied plants as primer d (OPB-3) revealed ineffectiveness with amplification process. However, the polymorphism between drought-stressed and control genotypes was not detected (Figure 4).

At flowering stage, the simultaneous gas chromatography and mass spectrometry (GC-MS) analyses have been used to scan then identify the accumulated chemical compounds in essential oil of dry leaves of water irrigated ornamental plants *Ocimum basilicum* (B), *Mentha longifolia* (M) and *Origanum majorana* (O). The irrigated basil (BM), mint (MM) and origanum (OM) plants using 250 mM mannitol for short-term drought-stress were compared to the control plants. B-data indicates the presence of 126 compounds at different RTs, among the predominant compounds: 2-Propenoic acid (5.2 %), Eucalyptol (3.8%), 2-Bornanone (3.55), acetic acid, hydroxy[(1-oxo-2-propenyl)amino (3.17%) and 2-isopropyl-5-methyl-9-methylene (1.74%). Alternatively, the BM data detected the appearance of 129 compounds, with the predominant compounds: Propenoic acid (5.93%), Neophytadiene (3.16%), 9, 12, 15-Octadecatrienoic acid, (Z,Z,Z)-(2.84%), n-Hexadecanoic acid (2.26%), Bis(2-ethylhexyl) phthalate (2.6%) and Eucalyptol (1.85%). Linalool in B-plants (2.834%) is predominant over BM-plants (0.9311%). GC-MS data of normal growing M-plants determined 146 chemical compounds, the most predominant compounds: (Z)6,(Z)9-Pentadecadien-1-ol (6.05%), Methyl 8,11,14-heptadecatrienoate (3.75%), hydroxy[(1-oxo-2-propenyl)amino]-(3.26%), n-Hexadecanoic acid (3.05%), D-Carvone (2.5% ) and Nonacosane (2.17%). On the other hand, GC-MS data of mannitol-treated *Menthe* *longifolia* (MM) revealed the presence of 129 compounds, some of them exist with relatively high ratios: 1,2-Propanediamine (6.26%), n-Hexadecanoic acid (4.9%), ,12-Octadecadienoic acid (Z,Z)- (4.3%) and D-Carvone (3.3%). GC-MS data analysis of chemical composition of normal growing *Origanum majorana* (O) elicited the presence of 114 compounds at different RTs. Some of these compounds are detected in high proportions: Hydroquinone (3.77%), Octadecanamide (3.28%), hexacosane (2.7%), n-Hexadecanoic acid (2.68%) and 9,12,15-Octadecatrienoic acid, (Z,Z,Z)- (2.55%/). On the other hand, the chemical composition obtained from GC-MS analysis of mannitol-treated origanum plants (OM) shows 118 compounds where 9,12,15-Octadecatrienoic acid, (Z,Z,Z)-(4.7%), Cyclobutanol (3.3%), Hydroquinone (2.87%), 9-Hexacosene (2.6%) and n-Hexadecanoic acid (2.58%) were predominant.

**Discussion**

In the present study, three genotypes of medicinal plants were subjected to short-term drought stress using 250 mM mannitol solution for irrigation for 10-d. The spontaneous raise of proline level in all plants upon mannitol treatments manifests that drought stress is eventual in these genotypes; the result in concomitant with previous studies 42. Proline- the global stress indicator in plants increases in biosynthesis in stressed plants under various stress conditions depending on plant genotype and modulates its pathway via regulating enzymes of biosynthesis and degradation in addition, maintaining membrane stability required for osmotic stress tolerance 43. In a like manner, vitamin E (α-tocopherol), phenolic compounds and other antioxidant compounds are accumulated in higher amount in stressed medicinal genotypes. The result in 4corroboration to previous study 44 as appears from the polymorphism of high and low molecular weight proteins, regulation of metabolic activity occurs under drought stress is frequently associated with biosynthetic alterations of relevant protein in all the genotypes. In mint and origanum genotypes, six and two new protein bands expressed, respectively with no missing protein band. Among the six protein bands of mint, four were of low molecular weight (45, 33, 32 and 16 kDa) and in origanum, the low molecular weight expressed proteins were 87 and 18 kDa. In basil, four protein bands have disappeared and two have appeared at low molecular weight (78 and 16 kDa) under stress. These low molecular weight proteins are stress proteins function in maintaining osmotic homeostasis under stress 45 and responsible for production of organic antioxidant. Referred to DNA-RAPD, the genomic DNA under drought stress was structural stable but likely undergo variations of gene expression, as mannitol, and the short-term stress duration are not hazardous enough to cause mutation or breakdown of the medicinal plants genomic DNA. A study on tobacco plants shows that the genomic DNA under abiotic stress led to expression of 30 genes, among which twenty genes were defensive genes modified by methylation in relation to stress 46. Thus, essential oil pool of chemical compounds varies between control and stressed plants that confirms the protein bending modification likely due to gene expression. By comparing B-plants with BM-plants together, Ethylene oxide detected in B-plants at RT (0.89) with 1.6% ratio and in BM plants with 2.5% ratio at two RTs (1.08 and 1.22). Ethylene oxide is an insecticide and antimicrobial compound used for disinfection 47. Cyclobutanol was only detected in B-plants (1.021%) at two RTs and was absent in BM-plants along with 3-Furaldehyde (0.42%); the latter is inhibitory substance to mushroom tyrosinase 48, and traces of both Dimethyl aminomethyl and methylamine; the famous corrosive substances to eye and skin 49 were all absent in BM- plants. Although no bioactivity records are available for cyclotrisiloxane, it also detected in B-plants only. In contrast, furfural, the collagen stabilizer 50 detected in BM-plants (1.281%) and disappeared in B-plants. The acetic acid in B-plants has been detected at multiple RTs with total of (3.176%) ratio, and in BM-plants at two RTs with total ratio of (3.8512%). Linalool is antifungal and insecticidal natural product 51. Furthermore, acetic acid is a weak acid possesses antibacterial and antifungal properties and acts effectively as inhibitor of carbohydrate metabolism and on solubilization of cell membrane lipid causing subsequent death 52. Thus, the acetic acid raised in proportion in mannitol treated plants (BM) compared to the normal growing B-plants. The successive compounds, Bicyclo[3.1.1]heptane (0.58%) and Epianastrephin (0.12%) are biologically undefined substances, whereas the flavoring, antioxidant and food-additive beta-myrcene ( 0.55%, 53) characterizes B-plants only. Dimefox, the hazardous compound with insecticidal property (USA Emergency Planning and Community, 2017) is detected in small amounts in only B-plants. Allyldiethylamine found in B-plants (0.8076%) along with Eucalyptol which detected in B-plants in 3.7899% and in BM-plants (1.845%). Eucalyptol reported to kill infectious organisms preventing their spread 54. Allyldiethylamine present in B-plants is not biologically significant. In addition, (+)2- Bornanone (3.558%) is antioxidant and antibacterial compound inhibits the activity of harmful organisms 52 was solely found in B-plants. 2-Propenoic acid is powerful biocide 55 and is detected at frequent RTs with total (10.847%) ratio in B-plants and in total 9.4647%. ratio in BM-plants. The B-plants Bornyl acetate detected in 0.356% ratio. Pinocarvone found in B-plants only in trace amounts and functions as antioxidant, antibacterial and possesses other biological activities 56. The 4-Methylimidazole compound was found in 0.2445% ratio in B-plants and disappeared in BM-plants. Terpinen-4-ol presents in both B- and BM-plans and its effect is under investigation. Naphthalene induces oxidative stress in *Trifolium* plants 57, presents both in B-plants (2.256%) and in BM-plants (1.071%). 2-Methoxy-4-vinylphenol is a flavoring agent detected in both in B-plants (0.787%) and in BM-plants (1.48%). Myrtenol, the anti-inflammatory flavoring compound 58 been found in many plants and detected only in B-plants (0.4451%). Imidazole-4-carboxylic acid found in B-plants (0.3149%) and in BM-plants (0.4496%). Neophytadiene is bioactive lipid component 59 presents in B-plants (0.77%) as well as in BM-plants with higher ratio (3.164%). The tricosane is antibacterial substance 60 and was present in B-plants (1.08%) along with BM-plants (2.03%), whereas the hexacosane is potent antibacterial agent 61 present in B-plants only (1.389%). The α.-Tocopherol, known as vitamin E present in almost same ratio in B-plants (0.836%) and in BM-plants (0.9202%) plants. In addition, Stigmasta-3,5-diene, the derived steroid from plants particularly soybeans, was detected in B-plants (1.1%) and in BM-plants (1.3735%) and plays role as food additive, in lowering cholesterol absorption in the intestine and in cancer encounter 62. Gamma-Sitosterol found in B-plants (0.214%) and in BM-plants (0.6308%) as in all other plants as main plants sterol contributes to cell membrane. Squalane, the antioxidant, skin hydrator, detoxifier and drug carrier unsaturated hydrocarbon (3.47%, 63) and Bis(2-ethylhexyl) phthalate (2.59%) determined in BM-plants with high ratio although both were completely absent in B-plants. The detected chemical compounds in only BM-plants were Safrole (0.703%), the constituent of volatile oil acts as antifungal and considered carcinogenic compound 64. In addition to Olean-12-en-28-al (1.035%), 4H-Pyran-4-one (2.3%), aromandendrene (0.4%) the spice component and a natural oil compound of eucalyptus, D-limonene, the insecticidal natural product (0.7564%,50 and fumaric acid (0.7869%) involves in kreb's cycle, detrimental when releases to the environment and used in food preservation and in manufacture of paints and plastic (Pubchem).

M-and MM-plants show variations of total number of compounds per RT (146 for M-plants and 129 for MM-plants) and of chemical composition as detected by GC-MS. D-Carvone is a compound of volatile oil characterized by medicinal properties as antimicrobial 65 and detected in MM-plants in higher ratio (7.17%) as compared to M-plants. The5-Nonadecen-1-ol detected in M-plants (1.3384%) and in MM-plants (0.4452%).

The n-Hexadecanoic or palmitic acid is a saturated fatty acid detected at various RT, and presents in many plants and animal products. N-Hexadecanoic acid was detected both in M-plants (7.1903%) and in MM-plants. (Z)6,(Z)9-Pentadecadien-1-ol (6.05%) and L-cysteine (1.2557%) were found in M-plants only with considerably high proportion. 9-eicosyne is detected in M-plants (1.2155%) and is absent in MM-plants. In addition, Neophytadiene is found in M-plants (0.84%) along with MM-plants (0.66%). Vitamin E is found in both M- and MM-plants in similar ratios. Dihydrojasmone in M-plants (0.43%) and in MM-plants (0.4%), oxirane with 0.99% in M-plants and in 0.61% in MM-plants, Mepivacaine in M-plants (0.845%) with higher ratio in MM-plants (2.22%). 2-Cyclohexen-1-one was only found in M-plants (1.723%) as well as Resorcinol (0.46%), 6-Octen-1-ol (0.6%) and 1,4-Benzenediol which detected at varied RTs in 1.237% ratio in only M-plants.

GC-MS of normal growing *origanum* *majorana* plants (O) or grown plants under generated drought stress for

10-d using mannitol treatment (OM) shows variations of chemical compounds number and composition. Nonacosane found only in OM-plants with high ratio (3.5%). Hydroquinone, is naturally occurring antioxidant 52, found at relatively high ratio at successive RTs in O-plants (10.056%) and OM-plants (10.65%). The 9,12,15-Octadecatrienoic acid found in O-plants (2.5%) and in OM-plants (4.7%), Bis(2-ethylhexyl) phthalate in O-plants (1.7%) and in OM-plants (1.9%), hexacosane in O-plants (2.11%) and in OM-plants (1.1%), 2,5-Furandione, 3-dodecyl in O-plants (1.5%) and in OM-plants (4.3%), heptacosane in OM-plants (3.9%) and in O-plants (0.916%). Dihydrojasmone is flavoring component found in citrus and presents in O-plants (0.5%) and in OM-plants (0.37%). 3-Buten-2-one found in O-plants (0.656%) not OM-plants. Similarly, Docosane (1.8993%), Squalane (1.61%), Octadec-9-enoic acid (1.12%), -Hexadecenoic acid (2.0%), 1-(Adamantan-1-yloxy)-2-phenylhexahydropyrrolo[1,2-c][1,3,2]diazaphosphole (2.11%), Acetamide, 2-[2-(2H-1,2,3-benzotriazol-2-yl)-4-methylphenoxy]-N-(2-pyridinyl (0.965%), Nonadecanenitrile at two RTs (1.415%), 4-Benzyl-1-[N-methylsulfonyl-N-(3-chloro-2-methylphenyl)-aminoacetyl]piperidine (0.67%), Octadecanamide (3.3%). On the other hand, Tritriacontane was detected in OM-plants (0.82%).

**Conclusion**

In summary, effect of drought stress on tested ornamental plants appeared in elevation of proline level. Alterations of photosynthetic pigments and oil production accounts for gene expression-mediated new protein expression in water-deficit environment. Both the expressed stress proteins or the degrade proteins were induced under drought stress. Expression or degradation of proteins are responsible for numerous variation of chemical hydrocarbons constituting the essential oil. Ornamental plants to tolerate drought stress, they achieve gene and hence protein expressions, and ultimately undergo variations within the essential oil composition.

**Conflict of interest**

The authors declare that there is no conflict of interest

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**Figure Captions**

Fig. 1. Effect of drought-stress on proline level in 65-d old medicinal plants: *Ocimum basilicum*; Ocimum+mannitol, *Mentha longifolia*; Mentha+mannitol and *Origanum majorna*; Origanum+mannitol as compared to non-treated genotypes. Drought was induced for ten days using mannitol (250 mM) for irrigation. Each value is the mean of three replicates. The error bars represent ± standard deviation.

Fig. 2. . Effect of drought-stress induced by mannitol (250 mM) irrigation for ten days on chl *a*, *b* and carotenoids in 65-d old medicinal plants: *Ocimum basilicum*; Ocimum+mannitol, *Mentha longifolia*; Mentha+mannitol and *Origanum majorna*; Origanum+mannitol as compared to non-treated genotypes. Each value is the mean of three replicates. The error bars represent ± standard deviation.

Figure 3. SDS-PAGE electrophoresis of soluble protein extracted from apical detached-leaves from basil (B), mint (T) and origanum (O) plants grown for 10- d either under normal condition using water for irrigation, or with irrigation using 250 mM mannitol-induced drought stress (BM, MM, and OM).

Figure 4. Agarose gel electrophoresis of RAPD-PCR amplification fragments as products obtained from five primers: (A; OPA-1, B; OPA-4, C; OPA-11, D; OPB-3 (not successful), E; OPB-10) introduced to isolated DNA from medicinal plants grown for 10-d with or without drought stress: basil (B), stressed basil (BM), mint (T), stressed mint (TM), origanum (O) and stressed origanum (OM). M; marker ranges from 100-3000 b.

Table 1. Percentage of polymorphism of extracted soluble protein from leaves of drought stressed medicinal plants (Basil+M, Mint+M and origanum+M) using mannitol (260 mM) for 10-d irrigation compared to normally growing plants (Basil, Mint and Origanum).

Table 2. GC-MS of phytochemical compounds accumulated in dry leaves of 65-d old *Ocimum basilicum* (basil) plant at flowering stage. The plant was water-irrigated for 10-d before the analysis.

Table 3. GC-MS of phytochemical compounds accumulated in dry leaves of 65-d old *Ocimum basilicum* (basil) plant at flowering stage. The plant was 10-d irrigated using D-mannitol to induce drought stress before the analysis.

Table 4. GC-MS of phytochemical compounds accumulated in dry leaves of 65-d old *Mentha longiflia* (mint) plant at flowering stage. The plant was water-irrigated for 10-d before the analysis.

Table 5. GC-MS of phytochemical compounds accumulated in dry leaves of 65-d old *Mentha longifolia* (mint) plant at flowering stage. The plant was 10-d irrigated using D-mannitol to induce drought stress before the analysis.

Table 6. GC-MS of phytochemical compounds accumulated in dry leaves of 65-d old *Origanum majorana* (origanum) plant at flowering stage. The plant was water irrigated for 10-d before the analysis.

Table 7. GC-MS of phytochemical compounds accumulated in dry leaves of 65-d old *Origanum majorana* (Origanum) plant at flowering stage. The plant was 10-d irrigated using D-mannitol to induce drought stress before the analysis.

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Table 1. Percentage of polymorphism of extracted soluble protein from leaves of drought stressed medicinal plants (Basil+M, Mint+M and origanum+M) using mannitol (260 mM) for 10-d irrigation compared to normally growing plants (Basil, Mint and Origanum).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Band No. | RF | MW | Medicinal Plants | | | | | |
| Basil | Basil+M | Mint | Mint+M | Origanum | Origanim+M |
| 1 | 0.043 | 230 | - | - | + | + | - | - |
| 2 | 0.052 | 210 | + | - | - | - | - | - |
| 3 | 0.058 | 190 | - | - | - | + | - | - |
| 4 | 0.104 | 119 | - | - | - | + | - | - |
| 5 | 0.115 | 110 | - | - | - | - | + | + |
| 6 | 0.124 | 105 | - | - | + | + | - | - |
| 7 | 0.147 | 87 | - | - | + | + | - | + |
| 8 | 0.160 | 78 | - | + | - | - | - | - |
| 9 | 0.175 | 70 | + | - | + | + | + | + |
| 10 | 0.241 | 63 | + | - | + | + | + | + |
| 11 | 0.271 | 60 | + | + | + | + | + | + |
| 12 | 0.311 | 52 | - | - | + | + | - | - |
| 13 | 0.329 | 49 | - | - | - | - | + | + |
| 14 | 0.352 | 45 | - | - | - | + | + | + |
| 15 | 0.372 | 42 | - | - | - | - | + | + |
| 16 | 0.390 | 40 | + | + | + | + | + | + |
| 17 | 0.408 | 38 | - | - | - | - | + | + |
| 18 | 0.444 | 35 | - | - | - | - | + | + |
| 19 | 0.481 | 33 | - | - | - | + | + | + |
| 20 | 0.503 | 32 | - | - | - | + | + | + |
| 21 | 0.546 | 29 | - | - | + | + | + | + |
| 22 | 0.600 | 25 | + | + | + | + | + | + |
| 23 | 0.629 | 23 | - | - | - | - | - | + |
| 24 | 0.674 | 20 | + | + | + | + | + | + |
| 25 | 0.702 | 19 | - | - | + | + | - | - |
| 26 | 0.732 | 18 | + | - | + | + | - | + |
| 27 | 0.816 | 17 | + | + | + | + | + | + |
| 28 | 0.856 | 16 | - | + | - | + | - | - |
| 29 | 0.881 | 15 | + | + | + | + | + | + |
| 30 | 0.937 | 12 | + | + | + | + | + | + |
| **Bands number** | | | **11** | **9** | **16** | **22** | **18** | **21** |
| **% Polymorphism** | | | **-** | **54.54** | **-** | **37.50** | **-** | **16.66** |

Table 2. GC-MS of phytochemical compounds accumulated in dry leaves of 65-d old *Ocimum basilicum* (basil) plant at flowering stage. The plant was water-irrigated for 10-d before the analysis.

|  |  |  |  |
| --- | --- | --- | --- |
| Serial no. | RT | % | Chemical compound |
| 1 | 0.2415 | 0.0097 | Carbon dioxide |
| 2 | 0.8929 | 1.6027 | Ethylene oxide |
| 3 | 1.0411 | 0.996 | Cyclobutanol |
| 4 | 1.1523 | 3.1733 | Acetic acid, hydroxy[(1-oxo-2-propenyl)amino]- |
| 5 | 3.8953 | 0.025 | Cyclobutanol |
| 6 | 4.0647 | 0.0295 | Cyclotrisiloxane, hexamethyl- |
| 7 | 5.0179 | 0.4246 | 3-Furaldehyde |
| 8 | 5.3356 | 0.0319 | N-Dimethylaminomethyl-N-methylformamide |
| 9 | 5.3727 | 0.039 | N-Dimethylaminomethyl-N-methylformamide |
| 10 | 5.4786 | 0.0601 | Methylamine, N,N-dimethyl- |
| 11 | 5.5633 | 0.0534 | Methylamine, N,N-dimethyl- |
| 12 | 5.6375 | 0.0923 | Bicyclo[3.1.0]hex-2-ene, 2-methyl-5-(1-methylethyl)- |
| 13 | 5.7222 | 0.1757 | (1S)-2,6,6-Trimethylbicyclo[3.1.1]hept-2-ene |
| 14 | 5.8016 | 0.4894 | Acetic acid |
| 15 | 5.9234 | 1.6299 | Camphene |
| 16 | 6.0823 | 1.2153 | Acetic acid |
| 17 | 6.167 | 0.101 | Acetic acid |
| 18 | 6.2676 | 0.5841 | Bicyclo[3.1.1]heptane, 6,6-dimethyl-2-methylene-, (1S)- |
| 19 | 6.4211 | 0.5515 | .beta.-Myrcene |
| 20 | 6.58 | 0.1226 | Epianastrephin, (-) |
| 21 | 6.6383 | 0.1279 | Dimefox |
| 22 | 6.956 | 3.7899 | Eucalyptol |
| 23 | 7.1519 | 0.1944 | .gamma.-Terpinene |
| 24 | 7.3531 | 0.1603 | Bicyclo[3.1.0]hexan-2-ol, 2-methyl-5-(1-methylethyl)-, (1.alpha.,2.alpha.,5.alpha.)- |
| 25 | 7.4961 | 0.8076 | Allyldiethylamine |
| 26 | 7.7979 | 2.8341 | Linalool |
| 27 | 7.925 | 0.3496 | m-Guaiacol |
| 28 | 8.1262 | 3.5579 | (+)-2-Bornanone |
| 29 | 8.2269 | 0.0771 | Pinocarvone |
| 30 | 8.2904 | 0.1497 | (1-Ethyl-2-pyrrolidinyl)methanol |
| 31 | 8.3645 | 0.9486 | Terpinen-4-ol |
| 32 | 8.4545 | 0.1653 | 5-Caranol, (1S,3R,5S,6R)-(-)- |
| 33 | 8.5075 | 0.2264 | Terpinyl formate |
| 34 | 8.5552 | 0.226 | .alpha.-Terpineol |
| 35 | 8.624 | 0.4451 | (-)-Myrtenol |
| 36 | 8.7617 | 0.1045 | Imidazole-4-carboxylic acid, 1-methyl- |
| 37 | 8.8411 | 0.1699 | Imidazole-4-carboxylic acid, 1-methyl- |
| 38 | 8.8835 | 0.118 | Pterin-6-carboxylic acid |
| 39 | 8.9258 | 0.1089 | 4-Methylimidazole-2,5-diethanol |
| 40 | 8.9629 | 0.1926 | Butanal, dimethylhydrazone |
| 41 | 9.0476 | 0.1356 | 4-Methylimidazole-2,5-diethanol |
| 42 | 9.1006 | 0.3562 | Bornyl acetate |
| 43 | 9.3706 | 2.6643 | 2-Propenoic acid, 3-phenyl-, methyl ester |
| 44 | 9.4554 | 0.7155 | 2-Propenoic acid, 3-phenyl-, methyl ester |
| 45 | 9.5401 | 0.2802 | .alpha.-Cubebene |
| 46 | 9.6883 | 0.7874 | 2-Methoxy-4-vinylphenol |
| 47 | 9.7625 | 0.3722 | Copaene |
| 48 | 9.8843 | 1.0759 | 2-Propenoic acid, 3-phenyl-, methyl ester |
| 49 | 9.9849 | 5.1995 | 2-Propenoic acid, 3-phenyl-, methyl ester, (E)- |
| 50 | 10.1861 | 1.1925 | 2-Propenoic acid, 3-phenyl-, methyl ester |
| 51 | 10.3026 | 0.3527 | .gamma.-Muurolene |
| 52 | 10.3714 | 0.4583 | cis-.alpha.-Bisabolene |
| 53 | 10.4191 | 0.5208 | Bicyclo[4.4.0]dec-1-ene, 2-isopropyl-5-methyl-9-methylene- |
| 54 | 10.525 | 0.6671 | (S,1Z,6Z)-8-Isopropyl-1-methyl-5-methylenecyclodeca-1,6-diene |
| 55 | 10.6468 | 0.6494 | Naphthalene, decahydro-4a-methyl-1-methylene-7-(1-methylethenyl)-, [4aR-(4a.alpha.,7.alpha.,8a.beta.)]- |
| 56 | 10.7421 | 1.0933 | Naphthalene, 1,2,3,4,4a,5,6,8a-octahydro-7-methyl-4-methylene-1-(1-methylethyl)-, (1.alpha.,4a.beta.,8a.alpha.)- |
| 57 | 10.7898 | 0.2404 | cis-Calamenene |
| 58 | 10.8639 | 0.3553 | Cyclopentanol, 2-cyclopentylidene- |
| 59 | 10.9222 | 0.1863 | Cadala-1(10),3,8-triene |
| 60 | 11.0387 | 0.5657 | 2-Methyl-oct-2-enedial |
| 61 | 11.1446 | 0.3515 | Methylpropargyl-.beta.-phenylpropionate |
| 62 | 11.2452 | 1.6488 | 1H-Cycloprop[e]azulen-7-ol, decahydro-1,1,7-trimethyl-4-methylene-, [1ar-(1a.alpha.,4a.alpha.,7.beta.,7a.beta.,7b.alpha.)]- |
| 63 | 11.3564 | 0.1858 | Aristolene epoxide |
| 64 | 11.4093 | 0.9143 | Epicubenol |
| 65 | 11.5841 | 1.746 | Bicyclo[4.4.0]dec-1-ene, 2-isopropyl-5-methyl-9-methylene- |
| 66 | 11.6794 | 0.6998 | (1R,9R,E)-4,11,11-Trimethyl-8-methylenebicyclo[7.2.0]undec-4-ene |
| 67 | 11.7535 | 0.6269 | 2-(4a,8-Dimethyl-1,2,3,4,4a,5,6,7-octahydro-naphthalen-2-yl)-prop-2-en-1-ol |
| 68 | 11.8277 | 0.4555 | Caryophyllene oxide |
| 69 | 11.9336 | 0.7038 | (1aR,4aS,8aS)-4a,8,8-Trimethyl-1,1a,4,4a,5,6,7,8-octahydrocyclopropa[d]naphthalene-2-carbaldehyde |
| 70 | 12.0236 | 0.568 | 2-Butanone, 4-(2,6,6-trimethyl-1-cyclohexen-1-yl)- |
| 71 | 12.1401 | 0.5388 | Spiro[2,4,5,6,7,7a-hexahydro-2-oxo-4,4,7a-trimethylbenzofuran]-7,2'-(oxirane) |
| 72 | 12.3095 | 0.3208 | Spiro[2,4,5,6,7,7a-hexahydro-2-oxo-4,4,7a-trimethylbenzofuran]-7,2'-(oxirane) |
| 73 | 12.3731 | 0.2412 | Spiro[2,4,5,6,7,7a-hexahydro-2-oxo-4,4,7a-trimethylbenzofuran]-7,2'-(oxirane) |
| 74 | 12.4578 | 0.7704 | Neophytadiene |
| 75 | 12.5108 | 0.2764 | Cyperadione |
| 76 | 12.5743 | 0.3684 | 9-Nonadecyne |
| 77 | 12.6855 | 0.7846 | Heptadecanal |
| 78 | 12.7543 | 0.1791 | Cyclohexane, 1,1,2-trimethyl-3,5-bis(1-methylethenyl)-, (2.alpha.,3.alpha.,5.beta.)- |
| 79 | 12.7914 | 0.5136 | Naphthalene, 2-(1,1-dimethylethyl)decahydro-4a-methyl- |
| 80 | 12.9026 | 0.5147 | 2-Butanone, 4-(2,2,6-trimethylcyclohexyl)- |
| 81 | 13.0244 | 0.3471 | 2-Butanone, 4-(2,2,6-trimethylcyclohexyl)- |
| 82 | 13.1144 | 0.4839 | Cyclohexane, 1,1,2-trimethyl-3,5-bis(1-methylethenyl)-, (2.alpha.,3.alpha.,5.beta.)- |
| 83 | 13.1832 | 0.2743 | 5-(Diethylamino)-2-nitrosophenol |
| 84 | 13.2256 | 0.2782 | 3-(4-Methoxyphenyl)-5-ethyl-2-(1,2,4)-oxadiazoline |
| 85 | 13.3527 | 1.5942 | n-Hexadecanoic acid |
| 86 | 13.4745 | 0.5183 | n-Hexadecanoic acid |
| 87 | 13.5751 | 0.3786 | C(14a)-Homo-27-nor-14.beta.-gammaceran-3.alpha.-ol |
| 88 | 13.6175 | 0.2556 | Aromadendrene oxide-(1) |
| 89 | 13.6863 | 1.1054 | Z-8-Methyl-9-tetradecenoic acid |
| 90 | 13.9564 | 1.3707 | Acetic acid, 1-methyl-3-(2,6,6-trimethylcyclohex-1-enyl)propyl ester |
| 91 | 14.3006 | 2.3952 | (Z)-9-octadecen-4-olide |
| 92 | 14.4859 | 1.0614 | Cyclohexene, 1-pentyl-4-(4-propylcyclohexyl)- |
| 93 | 14.6024 | 1.1867 | Undec-10-ynoic acid, hexadecyl ester |
| 94 | 14.9201 | 3.5506 | Benzenamine, N,N-dibutyl- |
| 95 | 15.0366 | 2.7078 | 1,3-Benzodioxole, 5-(1-propenyl)- |
| 96 | 15.2167 | 0.928 | 4-Methoxycinnamaldehyde |
| 97 | 15.4497 | 1.0821 | Tricosane |
| 98 | 15.5661 | 0.8013 | Cyclopropaneoctanal, 2-octyl- |
| 99 | 15.6297 | 0.8321 | Pteridin-4(3H)-one, 2-amino-6-isobutenyl-, 8-oxide |
| 100 | 15.7621 | 1.1806 | Phthalic acid, hexyl 3-methoxy-4-nitrobenzyl ester |
| 101 | 15.8415 | 1.3897 | Hexacosane |
| 102 | 16.0586 | 1.4293 | Alloaromadendrene |
| 103 | 16.2069 | 2.5534 | Tetratriacontane |
| 104 | 16.4928 | 0.7195 | Furo[2,3-H]coumarine, 1,2-dihydro-2-(3-acetoxy-4-nitrobenzylideno)-6-methyl-1-oxo- |
| 105 | 16.6093 | 0.5661 | Docosane |
| 106 | 16.8211 | 1.636 | 13-Docosenamide, (Z)- |
| 107 | 16.9059 | 1.0103 | 3-OXO-18-NOR-ENT-ROS-4-ENE-15.beta.,16-ACETONIDE |
| 108 | 17.1177 | 1.2354 | Heneicosane |
| 109 | 17.3454 | 0.4659 | 2,6-Dimethylbenzaldehyde carbamoylhydrazone |
| 110 | 17.4566 | 0.6659 | pentanamide, N-(2-chloro-5-nitrophenyl)-2-[(4-hydroxyphenyl)imino]-4,4-dimethyl-3-oxo- |
| 111 | 17.6048 | 1.0307 | Triacontane |
| 112 | 18.0284 | 0.7771 | 3-Methyl-4-(phenylthio)-2-prop-2-enyl-2,5-dihydrothiophene 1,1-dioxide |
| 113 | 18.325 | 1.7009 | Heneicosane |
| 114 | 18.3991 | 0.1784 | 3-Methyl-4-(phenylthio)-2-prop-2-enyl-2,5-dihydrothiophene 1,1-dioxide |
| 115 | 18.468 | 0.1434 | Disiloxane, 1,3-diethoxy-1,1,3,3-tetramethyl- |
| 116 | 18.5474 | 0.2731 | Stigmasta-5,22-dien-3-ol, acetate, (3.beta.)- |
| 117 | 18.6957 | 0.5862 | Stigmasta-3,5-diene |
| 118 | 18.8069 | 0.8363 | dl-.alpha.-Tocopherol |
| 119 | 18.9763 | 0.8208 | Hexacosane |
| 120 | 19.4794 | 0.2174 | Eicosyl isopropyl ether |
| 121 | 19.5959 | 0.0888 | benzenesulfonyl fluoride, 4-(hexadecyloxy)-3-nitro- |
| 122 | 19.9718 | 1.6744 | Heneicosane |
| 123 | 20.1466 | 0.24 | Stigmasterol |
| 124 | 20.7238 | 0.6142 | Tritriacontane, 3-methyl- |
| 125 | 20.7873 | 0.2143 | .gamma.-Sitosterol |
| 126 | 20.9356 | 0.1623 | Tetratriacontane |

Table 3. GC-MS of phytochemical compounds accumulated in dry leaves of 65-d old *Ocimum basilicum* (basil) plant at flowering stage. The plant was 10-d irrigated using D-mannitol to induce drought stress before the analysis.

|  |  |  |  |
| --- | --- | --- | --- |
| Serial no | RT | % | Chemical Compound |
| 1 | 1.0835 | 1.5224 | Ethylene oxide |
| 2 | 1.2212 | 0.9939 | Ethylene oxide |
| 3 | 1.2953 | 2.3546 | Ethyne, fluoro- |
| 4 | 4.1601 | 0.0158 | Amphetamine |
| 5 | 4.8326 | 0.5757 | Furfural |
| 6 | 4.859 | 0.1413 | Furfural |
| 7 | 4.9067 | 0.1066 | Furfural |
| 8 | 4.9384 | 0.4574 | Furfural |
| 9 | 5.378 | 2.4671 | Acetic acid |
| 10 | 5.4521 | 0.6538 | 2-Propanone, 1-hydroxy- |
| 11 | 5.5474 | 0.1891 | 1,3-Butanediol |
| 12 | 5.6745 | 0.0934 | 3(2H)-Furanone, dihydro-2-methyl- |
| 13 | 5.7592 | 0.2136 | (1R)-2,6,6-Trimethylbicyclo[3.1.1]hept-2-ene |
| 14 | 5.8545 | 0.2369 | Butanenitrile, 2,3-dioxo-, dioxime, O,O'-diacetyl- |
| 15 | 5.9498 | 0.4071 | Camphene |
| 16 | 6.0293 | 0.0726 | N-Methoxy-1-ribofuranosyl-4-imidazolecarboxylic amide |
| 17 | 6.2358 | 0.2709 | Spiro ( 6,6-dimethyl-2,3-diazobicyclo [3.1.0] hex-2-ene-4,1'-cyclopropane ) |
| 18 | 6.2782 | 0.3715 | Cyclohexene, 4-methylene-1-(1-methylethyl)- |
| 19 | 6.4317 | 0.4905 | 2-Furancarboxaldehyde, 5-methyl- |
| 20 | 6.5906 | 0.1485 | 2-Furancarboxaldehyde, 5-methyl- |
| 21 | 6.7336 | 0.169 | 2-Carene |
| 22 | 6.8712 | 0.7564 | D-Limonene |
| 23 | 6.9613 | 1.8451 | Eucalyptol |
| 24 | 7.0248 | 0.1845 | 3-(5-Bromo-3-nitro-1H-1,2,4-triazol-1-yl)-6,8-dioxabicyclo[3.2.1]octan-4-one |
| 25 | 7.1413 | 0.2866 | .gamma.-Terpinene |
| 26 | 7.3531 | 0.3411 | Cyclohexanol, 1-methyl-4-(1-methylethenyl)-, cis- |
| 27 | 7.4272 | 0.0972 | Cyclohexene, 3-methyl-6-(1-methylethylidene)- |
| 28 | 7.4696 | 0.1977 | Benzene, 1-methyl-4-(1-methylethenyl)- |
| 29 | 7.6867 | 0.9311 | Linalool |
| 30 | 7.7238 | 0.1684 | Bicyclo[3.1.0]hexan-2-ol, 2-methyl-5-(1-methylethyl)-, (1.alpha.,2.alpha.,5.alpha.)- |
| 31 | 7.782 | 0.1307 | Bicyclo[4.1.0]heptane, 7-(1-methylethylidene)- |
| 32 | 7.8985 | 0.595 | d-Ribitol, 1-deoxy-1-heptylamino- |
| 33 | 8.0998 | 2.4931 | (+)-2-Bornanone |
| 34 | 8.1633 | 0.3517 | (+)-2-Bornanone |
| 35 | 8.2427 | 0.1549 | Undecanal |
| 36 | 8.3116 | 0.4646 | Terpinen-4-ol |
| 37 | 8.3963 | 0.5141 | 3-Cyclohexen-1-ol, 4-methyl-1-(1-methylethyl)-, (R)- |
| 38 | 8.5181 | 0.3771 | Cyclopentanone, dimethylhydrazone |
| 39 | 8.6557 | 0.4496 | Imidazole-4-carboxylic acid, 1-methyl- |
| 40 | 8.6981 | 0.592 | 4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl- |
| 41 | 8.8464 | 0.2809 | 4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl- |
| 42 | 8.9364 | 0.488 | 4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl- |
| 43 | 9.0211 | 0.2151 | 4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl- |
| 44 | 9.0847 | 0.3421 | 4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl- |
| 45 | 9.1323 | 0.3807 | 4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl- |
| 46 | 9.27 | 0.6385 | 2-Propenoic acid, 3-phenyl-, methyl ester |
| 47 | 9.3653 | 2.9077 | 2-Propenoic acid, 3-phenyl-, methyl ester |
| 48 | 9.6566 | 1.4857 | 2-Methoxy-4-vinylphenol |
| 49 | 9.7572 | 0.3175 | Copaene |
| 50 | 9.8684 | 1.068 | 2-Propenoic acid, 3-phenyl-, methyl ester, (E)- |
| 51 | 9.9849 | 5.9291 | 2-Propenoic acid, 3-phenyl-, methyl ester |
| 52 | 10.1543 | 0.5911 | (1R,2S,6S,7S,8S)-8-Isopropyl-1-methyl-3-methylenetricyclo[4.4.0.02,7]decane-rel- |
| 53 | 10.2179 | 0.1561 | 2-Propenoic acid, 3-phenyl-, methyl ester |
| 54 | 10.2497 | 0.318 | (Z)-2-Methoxycinnamaldehyde |
| 55 | 10.3185 | 0.3124 | 2,4-Hexadiene, 2,5-dimethyl- |
| 56 | 10.3714 | 0.2791 | 1H-Cyclopropa[a]naphthalene, 1a,2,3,5,6,7,7a,7b-octahydro-1,1,7,7a-tetramethyl-, [1aR-(1a.alpha.,7.alpha.,7a.alpha.,7b.alpha.)]- |
| 57 | 10.4509 | 0.2411 | 11-Oxatricyclo[6.2.1.0(1,6)]undec-9-en-2-one |
| 58 | 10.4879 | 0.2005 | Naphthalene, 1,2,3,5,6,8a-hexahydro-4,7-dimethyl-1-(1-methylethyl)-, (1S-cis)- |
| 59 | 10.5409 | 0.1529 | Naphthalen-4a,8a-imine, octahydro- |
| 60 | 10.5833 | 0.1505 | 4-Methyl-1,3-heptadiene |
| 61 | 10.6256 | 0.2059 | 3-Cyclopentylpropionic acid, but-3-yn-2-yl ester |
| 62 | 10.705 | 0.5918 | Naphthalene, 1,2,3,4,4a,5,6,8a-octahydro-7-methyl-4-methylene-1-(1-methylethyl)-, (1.alpha.,4a.beta.,8a.alpha.)- |
| 63 | 10.7633 | 0.2685 | cis-Calamenene |
| 64 | 10.8533 | 0.2293 | Benzene, 1,4-dimethoxy- |
| 65 | 10.9116 | 0.2105 | 3-Buten-2-ol, 4-(2,6,6-trimethyl-2-cyclohexen-1-yl)-, (3E)- |
| 66 | 11.0228 | 0.5353 | Benzene, 1,4-dimethoxy- |
| 67 | 11.1234 | 0.2914 | Benzene, 1,4-dimethoxy- |
| 68 | 11.2293 | 1.3462 | Caryophyllene oxide |
| 69 | 11.3722 | 0.771 | Spiro[2.5]octane, 5,5-dimethyl-4-(3-oxobutyl)- |
| 70 | 11.5311 | 1.8884 | Bicyclo[4.4.0]dec-1-ene, 2-isopropyl-5-methyl-9-methylene- |
| 71 | 11.7376 | 0.5576 | Z-8-Hexadecen-1-ol acetate |
| 72 | 11.8171 | 0.5704 | 3-buten-2-one, 4-(5,5-dimethyl-1-oxaspiro[2.5]oct-4-yl) |
| 73 | 11.9653 | 0.629 | 2-Butanone, 4-(2,6,6-trimethyl-1-cyclohexen-1-yl)- |
| 74 | 12.4578 | 3.1642 | Neophytadiene |
| 75 | 12.5107 | 0.3088 | Ethanone, 1-(4,5-dihydro-2-thiazolyl)- |
| 76 | 12.569 | 0.7147 | Ethanone, 1-(4,5-dihydro-2-thiazolyl)- |
| 77 | 12.6643 | 1.3283 | Tetradecanal |
| 78 | 12.7649 | 0.7416 | 12-Bromododecanoic acid |
| 79 | 13.0985 | 0.518 | Tetradecanal |
| 80 | 13.1462 | 0.2082 | Z-8-Methyl-9-tetradecen-1-ol acetate |
| 81 | 13.3368 | 2.2625 | n-Hexadecanoic acid |
| 82 | 13.5169 | 0.2968 | n-Hexadecanoic acid |
| 83 | 13.5592 | 0.2167 | n-Hexadecanoic acid |
| 84 | 13.6439 | 0.5955 | n-Hexadecanoic acid |
| 85 | 13.7181 | 0.6972 | Oleic Acid |
| 86 | 13.7922 | 0.1766 | 3-[(E)-2-Chloro-1-methyl-1-butenyl]-3-methyl-1,2,4-trioxolane |
| 87 | 13.824 | 0.2233 | 3-[(E)-2-Chloro-1-methyl-1-butenyl]-3-methyl-1,2,4-trioxolane |
| 88 | 13.8716 | 0.2687 | L-(+)-Threose, tris(trimethylsilyl) ether, methyloxime (anti) |
| 89 | 13.9352 | 1.0324 | 2,9-Heptadecadiene-4,6-diyn-8-ol, (Z,E)- |
| 90 | 14.2264 | 2.8413 | 9,12,15-Octadecatrienoic acid, (Z,Z,Z)- |
| 91 | 14.4065 | 1.3841 | (1,6,6-Trimethyl-5-oxospiro[2.5]oct-1-en-4-yl)-acetic acid, methyl ester |
| 92 | 14.613 | 0.4289 | Z-8-Methyl-9-tetradecen-1-ol acetate |
| 93 | 14.9466 | 3.8314 | 1,3-Benzodioxole, 5-(1-propenyl)- |
| 94 | 15.0631 | 2.3115 | 2-Propenoic acid, 3-phenyl-, methyl ester |
| 95 | 15.116 | 0.703 | Safrole |
| 96 | 15.3014 | 0.4554 | 2-heneicosanone, 1,1,1-trifluoro- |
| 97 | 15.3702 | 0.5328 | N-Isobutylundeca-2(E)-en-8,10-diynamide |
| 98 | 15.4338 | 0.4651 | Docosane |
| 99 | 15.5132 | 0.9457 | 9-Octadecenoic acid (Z)-, 2,3-dihydroxypropyl ester |
| 100 | 15.582 | 1.0351 | Olean-12-en-28-al |
| 101 | 15.7409 | 2.5904 | Bis(2-ethylhexyl) phthalate |
| 102 | 15.9686 | 0.4389 | 2-Dodecen-1-yl(-)succinic anhydride |
| 103 | 16.0586 | 1.1871 | Alloaromadendrene |
| 104 | 16.1698 | 0.3975 | Aromandendrene |
| 105 | 16.2333 | 2.0322 | Tricosane |
| 106 | 16.5246 | 0.7666 | Octacosane, 2-methyl- |
| 107 | 16.6358 | 0.7694 | 2-Methyl-cis-7,8-epoxynonadecane |
| 108 | 16.8158 | 3.47 | Squalene |
| 109 | 17.1018 | 1.0617 | Nonacosane |
| 110 | 17.3454 | 0.5097 | Propenone, 3-(4-chlorophenyl)-1-(2-methylphenyl)- |
| 111 | 17.4936 | 0.7206 | 2-Methyltriacontane |
| 112 | 17.6419 | 0.5745 | Triacontane |
| 113 | 17.7531 | 0.5489 | Stigmastan-3,5-diene |
| 114 | 17.8696 | 0.7177 | 10,11-(3'-6'-Dihydrobenzo)[3.2]paracyclophane-4'-carboxylic acid |
| 115 | 18.0073 | 0.7869 | Fumaric acid, hexadecyl octyl ester |
| 116 | 18.3091 | 1.9097 | Triacontane |
| 117 | 18.4044 | 0.4001 | Benzoic acid, 4-(1,3-dioxolan-2-yl)-, methyl ester |
| 118 | 18.505 | 0.321 | Eicosanoic acid, 2,2,2- trifluoroethyl ester |
| 119 | 18.6692 | 0.8246 | Stigmasta-3,5-diene |
| 120 | 18.8121 | 0.9202 | Vitamin E |
| 121 | 18.9975 | 0.716 | Tricosane |
| 122 | 19.4529 | 0.1696 | 9,19-Cyclolanost-24-en-3-ol, acetate, (3.beta.)- |
| 123 | 19.9612 | 1.7412 | Heneicosane |
| 124 | 20.0671 | 0.3128 | Pentatriacontane |
| 125 | 20.4113 | 0.1116 | 9,19-Cycloergost-24(28)-en-3-ol, 4,14-dimethyl-, acetate, (3.beta.,4.alpha.,5.alpha.)- |
| 126 | 20.4696 | 0.0775 | 1.alpha.,2.alpha.-Epoxy-1.beta.-methylcholesta-4,6-dien-3-one |
| 127 | 20.6496 | 0.4079 | .gamma.-Sitosterol |
| 128 | 20.6973 | 0.2229 | .gamma.-Sitosterol |
| 129 | 20.8879 | 0.172 | Tetratriacontane |

Table 4. GC-MS of phytochemical compounds accumulated in dry leaves of 65-d old *Mentha longiflia* (mint) plant at flowering stage. The plant was water-irrigated for 10-d before the analysis.

|  |  |  |  |
| --- | --- | --- | --- |
| Serial no | Rt. | % | chemical compound |
| 1 | 1.0729 | 0.8187 | Nitrous oxide |
| 2 | 1.0941 | 0.283 | Nitrous oxide |
| 3 | 1.1629 | 0.2011 | Mercaptamine |
| 4 | 1.2476 | 0.2169 | Acetic acid, hydroxy[(1-oxo-2-propenyl)amino]- |
| 5 | 1.2635 | 0.0837 | Acetic acid, hydroxy[(1-oxo-2-propenyl)amino]- |
| 6 | 1.29 | 3.262 | Acetic acid, hydroxy[(1-oxo-2-propenyl)amino]- |
| 7 | 3.3552 | 0.1915 | 1,2-Ethanediamine, N-(2-aminoethyl)- |
| 8 | 4.1654 | 0.0387 | 1-Octanamine, N-methyl- |
| 9 | 5.0549 | 0.3024 | Furfural |
| 10 | 5.1026 | 0.2369 | Furfural |
| 11 | 5.3144 | 0.1327 | 2,4-Dimethylfuran |
| 12 | 5.7434 | 0.1663 | (1R)-2,6,6-Trimethylbicyclo[3.1.1]hept-2-ene |
| 13 | 5.9022 | 0.0199 | 4-(2-Methylamino)ethyl)pyridine |
| 14 | 6.2623 | 1.3357 | Bicyclo[3.1.1]heptane, 6,6-dimethyl-2-methylene-, (1S)- |
| 15 | 6.3523 | 0.1867 | Acetic acid |
| 16 | 6.4158 | 1.0831 | Acetic acid |
| 17 | 6.5324 | 0.7866 | (5-Nitro-1H-1,2,4-triazol-3-yl)acetic acid |
| 18 | 6.6647 | 0.7584 | 1,3,8-p-Menthatriene |
| 19 | 6.903 | 1.5562 | D-Limonene |
| 20 | 6.9189 | 0.863 | D-Limonene |
| 21 | 6.993 | 0.3986 | Eucalyptol |
| 22 | 7.0195 | 0.0496 | 1,3,6-Octatriene, 3,7-dimethyl-, (Z)- |
| 23 | 7.1042 | 0.2226 | Butyrolactone |
| 24 | 7.189 | 0.3046 | Carbamic acid, 2-(dimethylamino)ethyl ester |
| 25 | 7.3213 | 0.0813 | 3-Azabutyl-1-ol, 4-cyclopropyl-3,3-dimethyl-, bromide |
| 26 | 7.512 | 0.2331 | Benzene, 1-methyl-4-(1-methylethenyl)- |
| 27 | 7.7026 | 0.7489 | Piperidine, 1,2-dimethyl- |
| 28 | 7.7291 | 0.4454 | 1-n-Butoxy-2,2,3,3-tetramethylaziridine |
| 29 | 7.9621 | 0.3241 | Piperidine, 1-ethyl- |
| 30 | 7.9886 | 0.2919 | 2,2,6,6-Tetramethyl-4-piperidylamide, N-piperidinoacetic acid |
| 31 | 8.0415 | 0.138 | Pyrimidine, 5-methyl- |
| 32 | 8.1474 | 0.7372 | 1,3-Dimethylimidazole-2(3H)-thione |
| 33 | 8.4439 | 0.6554 | Pyrrolin-2-one-5-methanol, N-methyl- |
| 34 | 8.5975 | 0.5841 | 2-Cyclopenten-1-one, 3-ethyl-2-hydroxy- |
| 35 | 8.6663 | 0.182 | Cyclohexanamine, N-3-butenyl-N-methyl- |
| 36 | 8.9152 | 2.5059 | D-Carvone |
| 37 | 8.9841 | 0.4268 | D-Carvone |
| 38 | 9.0423 | 0.678 | D-Carvone |
| 39 | 9.0688 | 1.0062 | D-Carvone |
| 40 | 9.1482 | 0.763 | D-Carvone |
| 41 | 9.233 | 0.5355 | D-Carvone |
| 42 | 9.3018 | 0.1113 | Dichloropropylphosphine |
| 43 | 9.3283 | 0.2678 | 1-methyl-4-(prop-1-en-2-yl)-7-oxabicyclo[4.1.0]heptan-2one |
| 44 | 9.4024 | 0.2944 | Piracetam |
| 45 | 9.4553 | 0.4095 | (-)-8-p-Menthen-2-yl, acetate, trans |
| 46 | 9.556 | 0.9747 | (-)-8-p-Menthen-2-yl, acetate, trans |
| 47 | 9.5877 | 0.5222 | 2-Cyclohexen-1-ol, 2-methyl-5-(1-methylethenyl)-, acetate, cis- |
| 48 | 9.6936 | 0.5125 | 2-Cyclohexen-1-ol, 2-methyl-5-(1-methylethenyl)-, acetate |
| 49 | 9.7837 | 1.3515 | 2-Cyclohexen-1-ol, 2-methyl-5-(1-methylethenyl)-, acetate |
| 50 | 9.879 | 0.4576 | (-)-.beta.-Bourbonene |
| 51 | 9.9002 | 0.2946 | Cyclohexane, 1-ethenyl-1-methyl-2,4-bis(1-methylethenyl)-, [1S-(1.alpha.,2.beta.,4.beta.)]- |
| 52 | 9.9584 | 0.6201 | 2,6-Dimethyl-1-nonen-3-yn-5-ol |
| 53 | 10.1226 | 0.7443 | Caryophyllene |
| 54 | 10.1702 | 0.4202 | Aciphyllene |
| 55 | 10.2179 | 0.2809 | Cyclohexanol, 2,3-dimethyl- |
| 56 | 10.2338 | 0.172 | Cyclohexanol, 2,3-dimethyl- |
| 57 | 10.2549 | 0.2996 | Cyclohexanol, 2,3-dimethyl- |
| 58 | 10.3185 | 0.613 | Cyclohexanol, 2,3-dimethyl- |
| 59 | 10.3661 | 0.1862 | Cyclohexanol, 2,3-dimethyl- |
| 60 | 10.4032 | 0.3848 | (+)-.beta.-Himachalene oxide |
| 61 | 10.435 | 0.6448 | (+)-epi-Bicyclosesquiphellandrene |
| 62 | 10.5303 | 0.441 | 1H-Pyrazole, 1,3,5-trimethyl- |
| 63 | 10.5886 | 0.5686 | 1H-Pyrazole, 1,3,5-trimethyl- |
| 64 | 10.6786 | 0.1221 | Dihydrojasmone |
| 65 | 10.7051 | 0.2382 | Naphthalene, 1,2,3,4,4a,5,6,8a-octahydro-7-methyl-4-methylene-1-(1-methylethyl)-, (1.alpha.,4a.beta.,8a.alpha.)- |
| 66 | 10.7739 | 0.5059 | Naphthalene, 1,2,3,4-tetrahydro-1,6-dimethyl-4-(1-methylethyl)-, (1S-cis)- |
| 67 | 10.8427 | 0.7384 | Azulene, 1,2,3,3a,4,5,6,7-octahydro-1,4-dimethyl-7-(1-methylethenyl)-, [1R-(1.alpha.,3a.beta.,4.alpha.,7.beta.)]- |
| 68 | 10.9963 | 0.2738 | 2(1H)-Naphthalenone, octahydro-8a-methyl-, trans- |
| 69 | 11.0704 | 0.2934 | 7a-Methyl-3-methylenehexahydrobenzofuran-2-one |
| 70 | 11.2293 | 0.8341 | 1,4-Benzenediol, 2,5-dimethyl- |
| 71 | 11.2452 | 0.2392 | 1,4-Benzenediol, 2,5-dimethyl- |
| 72 | 11.2928 | 0.1635 | 1,4-Benzenediol, 2,5-dimethyl- |
| 73 | 11.3828 | 0.7944 | Epicubenol |
| 74 | 11.4623 | 0.4599 | Resorcinol |
| 75 | 11.5364 | 0.3861 | 2-Cyclohexen-1-one, 2-methyl-5-(1-methylethenyl)-, O-methyloxime, (+)- |
| 76 | 11.5629 | 0.1542 | 2-Cyclohexen-1-one, 2-methyl-5-(1-methylethenyl)-, O-methyloxime, (+)- |
| 77 | 11.5841 | 0.2206 | 2-Cyclohexen-1-one, 2-methyl-5-(1-methylethenyl)-, O-methyloxime, (+)- |
| 78 | 11.6317 | 0.4834 | .alpha.-Cadinol |
| 79 | 11.6741 | 0.1997 | 2-Cyclohexen-1-one, 2-methyl-5-(1-methylethenyl)-, O-methyloxime, (+)- |
| 80 | 11.7323 | 0.4294 | Dihydrojasmone |
| 81 | 11.7588 | 0.1874 | 7a-Methyl-3-methylenehexahydrobenzofuran-2-one |
| 82 | 11.8171 | 0.7456 | 7a-Methyl-3-methylenehexahydrobenzofuran-2-one |
| 83 | 11.8912 | 0.763 | 2-Cyclohexen-1-one, 2-methyl-5-(1-methylethenyl)-, O-methyloxime, (+)- |
| 84 | 12.1348 | 0.6207 | Spiro[2,4,5,6,7,7a-hexahydro-2-oxo-4,4,7a-trimethylbenzofuran]-7,2'-(oxirane) |
| 85 | 12.246 | 0.3782 | Spiro[2,4,5,6,7,7a-hexahydro-2-oxo-4,4,7a-trimethylbenzofuran]-7,2'-(oxirane) |
| 86 | 12.336 | 0.5985 | 6-Octen-1-ol, 3,7-dimethyl-, acetate |
| 87 | 12.3731 | 0.2844 | 2-Butanone, 4-(2,6,6-trimethyl-1-cyclohexen-1-yl)- |
| 88 | 12.4631 | 1.9551 | Neophytadiene |
| 89 | 12.5796 | 0.768 | Neophytadiene |
| 90 | 12.7067 | 1.3384 | 5-Nonadecen-1-ol |
| 91 | 12.7649 | 0.2411 | 4-Isopropyl-5,10-dimethyl-decalin-1,3-dione |
| 92 | 12.7914 | 0.6621 | 9-Octadecen-1-ol, (Z)- |
| 93 | 12.8444 | 0.3769 | cis-11-Hexadecenal |
| 94 | 12.9079 | 1.2557 | L-Cysteine, N-acetyl- |
| 95 | 13.035 | 0.3913 | 1,3-Propanediol, 2-amino-1-(4-nitrophenyl)-, (R\*,R\*)-(.+/-.)- |
| 96 | 13.1091 | 0.8415 | 9-Nonadecyne |
| 97 | 13.1568 | 0.327 | 4-Isopropyl-5,10-dimethyl-decalin-1,3-dione |
| 98 | 13.1991 | 0.6257 | Cyclohexanecarbonitrile, 1-(1-piperidinyl)- |
| 99 | 13.4268 | 2.2684 | n-Hexadecanoic acid |
| 100 | 13.5063 | 3.0539 | n-Hexadecanoic acid |
| 101 | 13.7075 | 0.7103 | n-Hexadecanoic acid |
| 102 | 13.8028 | 1.155 | n-Hexadecanoic acid |
| 103 | 13.9034 | 1.2617 | Z-8-Methyl-9-tetradecenoic acid |
| 104 | 14.3112 | 6.0524 | (Z)6,(Z)9-Pentadecadien-1-ol |
| 105 | 14.4859 | 0.9273 | Methyl 8,11,14-heptadecatrienoate |
| 106 | 14.5441 | 3.7557 | Methyl 8,11,14-heptadecatrienoate |
| 107 | 14.9201 | 1.2155 | 9-Eicosyne |
| 108 | 15.349 | 1.3716 | 5-Decenedioic acid, 5,6-dimethyl-, dimethyl ester |
| 109 | 15.3808 | 0.5459 | 5-Decenedioic acid, 5,6-dimethyl-, dimethyl ester |
| 110 | 15.4602 | 0.6877 | Docosane |
| 111 | 15.5873 | 0.4529 | 3a,9-Dimethyldodecahydrocyclohepta[d]inden-3-one |
| 112 | 15.6244 | 0.5411 | 3a,9-Dimethyldodecahydrocyclohepta[d]inden-3-one |
| 113 | 15.7621 | 1.2157 | 2,4,7,14-Tetramethyl-4-vinyl-tricyclo[5.4.3.0(1,8)]tetradecan-6-ol |
| 114 | 15.8362 | 0.6539 | Heptacosane |
| 115 | 15.8786 | 0.6347 | Heptacosane |
| 116 | 15.958 | 0.8786 | Triacontane |
| 117 | 16.0586 | 1.3049 | 9-Methyl-Z-10-tetradecen-1-ol acetate |
| 118 | 16.2174 | 0.7285 | Heptacosane |
| 119 | 16.2492 | 1.3578 | 5-Decenedioic acid, 5,6-dimethyl-, dimethyl ester |
| 120 | 16.5563 | 0.8409 | Neophytadiene |
| 121 | 16.6252 | 0.5637 | Octacosane |
| 122 | 16.8264 | 1.7905 | Squalene |
| 123 | 16.9217 | 1.1604 | Octacosane, 2-methyl- |
| 124 | 17.1336 | 2.175 | NonacosanFe |
| 125 | 17.3877 | 0.2745 | 5-Decenedioic acid, 5,6-dimethyl-, dimethyl ester |
| 126 | 17.4566 | 0.5858 | Fumaric acid, isobutyl tridecyl ester |
| 127 | 17.6101 | 0.5027 | Triacontane |
| 128 | 17.7478 | 0.7761 | Androst-5-en-3-ol, 4,4-dimethyl-, (3.beta.)- |
| 129 | 17.9014 | 0.279 | 10,11-(3'-6'-Dihydrobenzo)[3.2]paracyclophane-4'-carboxylic acid |
| 130 | 18.0284 | 0.9261 | 2-Methyltriacontane |
| 131 | 18.3462 | 1.3679 | Nonacosane |
| 132 | 18.4362 | 0.2962 | Bicyclo[10.1.0]trideca-4,8-diene-13-carboxylic acid (2-hydroxy-4-nitrophenyl)amide |
| 133 | 18.5421 | 0.3493 | 2H-Cyclopropa[g]benzofuran, 4,5,5a,6,6a,6b-hexahydro-4,4,6b-trimethyl-2-(1-methylethenyl)- |
| 134 | 18.7115 | 0.6125 | Stigmasta-3,5-diene |
| 135 | 18.8439 | 0.8453 | Vitamin E |
| 136 | 18.9763 | 0.5223 | Hentriacontane, 3-methyl- |
| 137 | 19.527 | 0.4152 | Dotriacontane, 2-methyl- |
| 138 | 19.5959 | 0.164 | Fumaric acid, hexadecyl octyl ester |
| 139 | 19.9189 | 0.7227 | Nonacosane |
| 140 | 19.9877 | 0.0696 | (Z)-Decyl icos-9-enoate |
| 141 | 20.0513 | 0.0353 | 3-Methyl-4-(phenylthio)-2-prop-2-enyl-2,5-dihydrothiophene 1,1-dioxide |
| 142 | 20.1148 | 0.1142 | i-Propyl 5,9,17-hexacosatrienoate |
| 143 | 20.4166 | 0.0454 | 2,5-Furandione, 3-dodecyl- |
| 144 | 20.602 | 0.0266 | 3-Methyl-4-(phenylthio)-2-prop-2-enyl-2,5-dihydrothiophene 1,1-dioxide |
| 145 | 20.8032 | 0.4018 | .gamma.-Sitosterol |
| 146 | 20.8879 | 0.0599 | benzenesulfonyl fluoride, 4-(hexadecyloxy)-3-nitro- |

Table 5. GC-MS of phytochemical compounds accumulated in dry leaves of 65-d old *Mentha longifolia* (mint) plant at flowering stage. The plant was 10-d irrigated using D-mannitol to induce drought stress before the analysis.

|  |  |  |  |
| --- | --- | --- | --- |
| Serial No. | RT | % | Chemical Compound |
| 1 | 0.5169 | 0.0351 | Carbon dioxide |
| 2 | 1.02 | 2.2593 | Ethylene oxide |
| 3 | 1.1206 | 0.242 | Carbon dioxide |
| 4 | 1.2371 | 6.2645 | 1,2-Propanediamine |
| 5 | 4.1442 | 0.0541 | Cyclotrisiloxane, hexamethyl- |
| 6 | 4.8644 | 0.3522 | 3-Furaldehyde |
| 7 | 4.8908 | 0.0896 | 3-Furaldehyde |
| 8 | 4.9491 | 0.4208 | Furfural |
| 9 | 5.3357 | 0.1284 | Phenylephrine |
| 10 | 5.6746 | 2.3855 | Acetic acid |
| 11 | 5.7434 | 1.1982 | Acetic acid |
| 12 | 5.8228 | 0.5818 | Acetic acid |
| 13 | 5.8652 | 1.2033 | Acetic acid |
| 14 | 5.9764 | 0.8773 | Acetic acid |
| 15 | 6.2835 | 0.4092 | .beta.-Pinene |
| 16 | 6.3841 | 0.1766 | D-Streptamine, O-2-amino-2-deoxy-.alpha.-D-glucopyranosyl-(1-4)-O-(3-deoxy-4-C-methyl-3-(methylamino)-.beta.-L-arabinopyranosyl-(1-6))-2-deoxy- |
| 17 | 6.4371 | 0.4475 | 2-Furanmethanol |
| 18 | 6.5059 | 0.6133 | 2-Furanmethanol |
| 19 | 6.633 | 0.7805 | 1,3,8-p-Menthatriene |
| 20 | 6.7813 | 0.264 | 2-Acetonyl-9-[3-deoxy-.beta.-d-ribouranosyl]hypoxanthine |
| 21 | 6.8925 | 1.7168 | D-Limonene |
| 22 | 6.9507 | 0.9417 | Eucalyptol |
| 23 | 7.0195 | 0.1177 | Octanal |
| 24 | 7.1414 | 0.0581 | Heptanal |
| 25 | 7.2049 | 0.0923 | Heptanal |
| 26 | 7.4961 | 1.033 | Mepivacaine |
| 27 | 7.5861 | 1.1927 | Mepivacaine |
| 28 | 7.6815 | 0.1212 | Acetic acid, phenyl ester |
| 29 | 7.7821 | 0.5006 | 2-Cyclopenten-1-one, 2-hydroxy-3-methyl- |
| 30 | 7.8721 | 0.3786 | 2-Propenoic acid, 3-(dimethylamino)-, methyl ester |
| 31 | 8.0098 | 0.9098 | 4-Isothiazolecarboxamide |
| 32 | 8.1792 | 0.1169 | Ethanol, 2-bromo- |
| 33 | 8.2375 | 0.0789 | Ethanol, 2-bromo- |
| 34 | 8.3434 | 0.7783 | 1,3-Cyclopentanedione |
| 35 | 8.4758 | 0.4325 | Imidazole-4-carboxylic acid, 1-methyl- |
| 36 | 8.5446 | 0.5246 | N-methylene-n-octadecylamine |
| 37 | 8.6134 | 0.2017 | Imidazole-4-carboxylic acid, 1-methyl- |
| 38 | 8.7776 | 2.1187 | Cyclohexanol, 2-methyl-5-(1-methylethenyl)- |
| 39 | 8.9576 | 3.3083 | D-Carvone |
| 40 | 9.0212 | 1.9679 | D-Carvone |
| 41 | 9.0477 | 1.9026 | D-Carvone |
| 42 | 9.2171 | 0.222 | Ethanol, 2-bromo- |
| 43 | 9.2595 | 0.1975 | Butanal, dimethylhydrazone |
| 44 | 9.323 | 0.3069 | Nanofin |
| 45 | 9.3601 | 0.2211 | 3,3-Bis(carbamino)diaziridine |
| 46 | 9.4183 | 0.5804 | (-)-8-p-Menthen-2-yl, acetate, trans |
| 47 | 9.4607 | 0.9627 | (-)-8-p-Menthen-2-yl, acetate, trans |
| 48 | 9.5031 | 0.7522 | 2-Cyclohexen-1-ol, 2-methyl-5-(1-methylethenyl)-, acetate, cis- |
| 49 | 9.5931 | 0.3046 | 2-Cyclopenten-1-one, 2-(2-butenyl)-3-methyl-, (Z)- |
| 50 | 9.7255 | 2.521 | trans-Carveyl acetate |
| 51 | 9.8525 | 0.7167 | (-)-.beta.-Bourbonene |
| 52 | 9.8737 | 0.468 | Aciphyllene |
| 53 | 9.9373 | 0.5506 | 1-Methyl-2-methylenecyclohexane |
| 54 | 10.0485 | 0.7043 | Furan, 2-ethyl-5-methyl- |
| 55 | 10.1067 | 0.7451 | 1H-Pyrazole, 1,3,5-trimethyl- |
| 56 | 10.1544 | 0.3111 | 7-Azabicyclo[4.1.0]heptane, 2-methyl-5-(1-methylethyl)- |
| 57 | 10.2232 | 0.5996 | 1H-Pyrazole, 1,3,5-trimethyl- |
| 58 | 10.2656 | 0.3865 | .gamma.-Muurolene |
| 59 | 10.3026 | 0.2853 | Phenyl-1-thio-.alpha.-d-glucopyranoside |
| 60 | 10.3397 | 0.2399 | 4-Methyl-2-oxo-(1H)-pyrimidine |
| 61 | 10.3927 | 0.6416 | cis-Muurola-4(15),5-diene |
| 62 | 10.5145 | 0.4058 | Dihydrojasmone |
| 63 | 10.5939 | 0.4729 | (+)-.beta.-Himachalene oxide |
| 64 | 10.6892 | 0.3128 | Naphthalen-4a,8a-imine, octahydro- |
| 65 | 10.7475 | 0.4111 | trans-Calamenene |
| 66 | 10.8216 | 0.3987 | Benzisoxazole-2-acetic acid, hydrazide |
| 67 | 11.0069 | 0.4951 | Benzene, 1,4-dimethoxy- |
| 68 | 11.2134 | 1.2756 | Naphthalen-4a,8a-imine, octahydro- |
| 69 | 11.3723 | 0.6988 | Azulene, 1,2,3,3a,4,5,6,7-octahydro-1,4-dimethyl-7-(1-methylethenyl)-, [1R-(1.alpha.,3a.beta.,4.alpha.,7.beta.)]- |
| 70 | 11.4782 | 0.1824 | 6-Acetyl-4,4,7-trimethylbicyclo[4.1.0]heptan-2-one |
| 71 | 11.6265 | 1.0401 | Naphthalene, 2-(1,1-dimethylethyl)decahydro-4a-methyl- |
| 72 | 11.7377 | 0.4066 | 3-buten-2-one, 4-(5,5-dimethyl-1-oxaspiro[2.5]oct-4-yl) |
| 73 | 11.8277 | 0.3139 | Dihydroedulan IIA |
| 74 | 11.9177 | 0.9752 | 1,3-Benzenediol, 2-methyl- |
| 75 | 12.013 | 0.323 | 1H-Pyrazole, 3,5-bis(1,1-dimethylethyl)-4-methyl- |
| 76 | 12.066 | 0.2654 | 1H-Pyrazole, 3,5-bis(1,1-dimethylethyl)-4-methyl- |
| 77 | 12.1242 | 0.5873 | Benzaldehyde, 6-hydroxy-4-methoxy-2,3-dimethyl- |
| 78 | 12.3784 | 0.2593 | 2,6-Octadiene, 2,6-dimethyl- |
| 79 | 12.442 | 1.2241 | Neophytadiene |
| 80 | 12.4949 | 0.2495 | 2,2,4-Trichloro-1,3-cyclopentenedione |
| 81 | 12.5584 | 0.4452 | 5-Nonadecen-1-ol |
| 82 | 12.6749 | 0.9125 | Heptadecanal |
| 83 | 12.7438 | 0.1354 | 2,6,10-Dodecatriene, 12-acetoxy-6-hydroxymethyl-2,10-dimethyl-, (E,E)- |
| 84 | 12.7808 | 0.1748 | Aristolene epoxide |
| 85 | 12.8179 | 0.2754 | 2-(3-Hydroxybutyl)cyclooctanone |
| 86 | 12.9026 | 0.441 | 2-Butanone, 4-(2,2,6-trimethylcyclohexyl)- |
| 87 | 13.035 | 0.215 | 2-Butanone, 4-(2,2,6-trimethylcyclohexyl)- |
| 88 | 13.125 | 0.3243 | Spiro[5.6]dodecane-1,7-dione |
| 89 | 13.3845 | 4.9422 | n-Hexadecanoic acid |
| 90 | 13.6863 | 0.5681 | 2- Chloropropionic acid, hexadecyl ester |
| 91 | 13.7287 | 0.2861 | Spiro[4.5]decan-7-one, 1,8-dimethyl-8,9-epoxy-4-isopropyl- |
| 92 | 13.7658 | 0.5298 | 2(1H)-Benzocyclooctenone, decahydro-4a-methyl-, trans-(-)- |
| 93 | 13.8505 | 1.5867 | 2(1H)-Naphthalenone, octahydro-4a,7,7-trimethyl-, trans- |
| 94 | 14.3271 | 4.2971 | 9,12-Octadecadienoic acid (Z,Z)- |
| 95 | 14.4648 | 1.939 | Methyl 5,11,14,17-eicosatetraenoate |
| 96 | 14.6501 | 1.746 | Farnesol isomer a |
| 97 | 14.8566 | 2.3441 | Cyclopentadecanone, 2-hydroxy- |
| 98 | 15.0155 | 0.8272 | 1-Bromo-11-iodoundecane |
| 99 | 15.1479 | 0.4418 | 3a,9-Dimethyldodecahydrocyclohepta[d]inden-3-one |
| 100 | 15.4232 | 0.6513 | Pentacosane |
| 101 | 15.4868 | 0.3736 | Ursodeoxycholic acid |
| 102 | 15.5291 | 0.394 | 5-Decenedioic acid, 5,6-dimethyl-, dimethyl ester |
| 103 | 15.7568 | 1.6991 | Diisooctyl phthalate |
| 104 | 15.8257 | 0.6189 | 2-Dodecen-1-yl(-)succinic anhydride |
| 105 | 16.0216 | 0.9259 | Cyclopropaneoctanal, 2-octyl- |
| 106 | 16.0639 | 0.4954 | Cyclopentadecanone, 2-hydroxy- |
| 107 | 16.2122 | 1.0763 | Tetratriacontane |
| 108 | 16.2863 | 0.9605 | 3-Methyl-4-(phenylthio)-2-prop-2-enyl-2,5-dihydrothiophene 1,1-dioxide |
| 109 | 16.5352 | 0.6659 | Neophytadiene |
| 110 | 16.6041 | 0.3137 | Docosane |
| 111 | 16.8 | 1.3841 | Squalene |
| 112 | 16.8953 | 0.2314 | E-8-Methyl-9-tetradecen-1-ol acetate |
| 113 | 17.123 | 1.1886 | Nonacosane |
| 114 | 17.393 | 0.0238 | Fumaric acid, heptadecyl hexyl ester |
| 115 | 17.4566 | 0.0594 | 3-Methyl-4-(phenylthio)-2-prop-2-enyl-2,5-dihydrothiophene 1,1-dioxide |
| 116 | 17.5996 | 0.2668 | Triacontane |
| 117 | 17.7055 | 0.193 | 2-[4-methyl-6-(2,6,6-trimethylcyclohex-1-enyl)hexa-1,3,5-trienyl]cyclohex-1-en-1-carboxaldehyde |
| 118 | 17.9755 | 0.3074 | 2-Methyltriacontane |
| 119 | 18.3039 | 1.7348 | Heneicosane |
| 120 | 18.3833 | 0.0994 | 9,19-Cycloergost-24(28)-en-3-ol, 4,14-dimethyl-, acetate, (3.beta.,4.alpha.,5.alpha.)- |
| 121 | 18.5051 | 0.1693 | Stigmasta-5,22-dien-3-ol, acetate, (3.beta.)- |
| 122 | 18.6639 | 0.5467 | Stigmasta-3,5-diene |
| 123 | 18.8016 | 0.9102 | Vitamin E |
| 124 | 18.9393 | 0.3731 | Nonacosane |
| 125 | 19.4529 | 0.2235 | Dotriacontane, 2-methyl- |
| 126 | 19.866 | 0.9076 | Hexacosane |
| 127 | 20.0937 | 0.3229 | i-Propyl 5,9,17-hexacosatrienoate |
| 128 | 20.3902 | 0.1765 | i-Propyl 5,9,19-octacosatrienoate |
| 129 | 20.7132 | 0.9848 | .gamma.-Sitosterol |

Table 6. GC-MS of phytochemical compounds accumulated in dry leaves of 65-d old *Origanum majorana* (origanum) plant at flowering stage. The plant was water irrigated for 10-d before the analysis.

|  |  |  |  |
| --- | --- | --- | --- |
| Serial no | RT | % | Chemical compound |
| 1 | 0.9458 | 1.3849 | Acetamide, 2,2-dichloro- |
| 2 | 1.1259 | 1.7106 | Hydroxyurea |
| 3 | 3.5406 | 0.0342 | Cyclobutanol |
| 4 | 4.1601 | 0.0069 | Cyclotrisiloxane, hexamethyl- |
| 5 | 4.7479 | 0.3142 | Furfural |
| 6 | 4.9915 | 0.1028 | Cyclohexan-1,4,5-triol-3-one-1-carboxylic acid |
| 7 | 5.1344 | 0.0817 | Tetramethylammonium perchlorate |
| 8 | 5.378 | 0.3626 | Acetic acid |
| 9 | 5.754 | 2.2686 | Bicyclo[3.1.0]hex-2-ene, 2-methyl-5-(1-methylethyl)- |
| 10 | 5.8069 | 0.7746 | (1R)-2,6,6-Trimethylbicyclo[3.1.1]hept-2-ene |
| 11 | 6.167 | 0.1044 | 2,3-Dihydrooxazole, 2-t-butyl-4-(1-hydroxy-1-methylethyl)-3-methoxycarbonyl-5-methyl- |
| 12 | 6.3418 | 2.0266 | .gamma.-Terpinene |
| 13 | 6.4847 | 0.3689 | .beta.-Myrcene |
| 14 | 6.6383 | 0.4077 | .alpha.-Phellandrene |
| 15 | 6.7972 | 1.2636 | Cyclohexene, 1-methyl-4-(1-methylethylidene)- |
| 16 | 6.9295 | 1.3753 | Cyclohexane, 1-methylene-4-(1-methylethenyl)- |
| 17 | 7.0831 | 0.0348 | .beta.-Ocimene |
| 18 | 7.242 | 1.4244 | Tricyclo[2.2.1.0(2,6)]heptane, 1,3,3-trimethyl- |
| 19 | 7.4326 | 1.2617 | Bicyclo[3.1.0]hexan-2-ol, 2-methyl-5-(1-methylethyl)-, (1.alpha.,2.alpha.,5.alpha.)- |
| 20 | 7.4961 | 0.625 | Cyclohexene, 1-methyl-4-(1-methylethylidene)- |
| 21 | 7.7927 | 2.3765 | Bicyclo[3.1.0]hexan-2-ol, 2-methyl-5-(1-methylethyl)-, (1.alpha.,2.alpha.,5.alpha.)- |
| 22 | 7.9198 | 0.127 | 1,3,8-p-Menthatriene |
| 23 | 8.0786 | 0.1408 | Phenylethyl Alcohol |
| 24 | 8.2163 | 0.1204 | 8-Thiabicyclo[3.2.1]oct-2-ene |
| 25 | 8.2639 | 0.082 | Benzen-d5-amine |
| 26 | 8.3804 | 0.7432 | Terpinen-4-ol |
| 27 | 8.534 | 0.6658 | .alpha.-Terpineol |
| 28 | 8.5923 | 0.2031 | Cyclohexanol, 1-methyl-4-(1-methylethylidene)- |
| 29 | 8.8676 | 1.2465 | Cyclohexanol, 1-methyl-4-(1-methylethylidene)-, acetate |
| 30 | 9.0424 | 0.0438 | t-Butoxycarbonylalanylalanamide |
| 31 | 9.1059 | 0.0891 | 2-Cyclopentene, 4-(hydroxymethyl)-1,1,2,3-tetramethyl- |
| 32 | 9.2171 | 0.6085 | (1R)-2,6,6-Trimethylbicyclo[3.1.1]hept-2-ene |
| 33 | 9.3336 | 0.1034 | Benzenemethanamine, N-methyl- |
| 34 | 9.4078 | 0.2057 | Cyclohexane, 1-ethenyl-1-methyl-2-(1-methylethenyl)-4-(1-methylethylidene)- |
| 35 | 9.4925 | 0.6465 | 1,5,5-Trimethyl-6-methylene-cyclohexene |
| 36 | 9.5613 | 0.2092 | Indole |
| 37 | 9.6513 | 0.3046 | Catechol |
| 38 | 9.8155 | 0.8561 | Phenol, 2,6-dimethoxy- |
| 39 | 9.9055 | 0.2873 | Catechol |
| 40 | 9.9849 | 0.2448 | Catechol |
| 41 | 10.1014 | 0.6597 | Caryophyllene |
| 42 | 10.1756 | 0.2579 | Pyrrolidine, 1-(1-pentenyl)- |
| 43 | 10.3185 | 0.3111 | cis-.alpha.-Bisabolene |
| 44 | 10.4668 | 0.2093 | (1R,4R,5S)-1,8-Dimethyl-4-(prop-1-en-2-yl)spiro[4.5]dec-7-ene |
| 45 | 10.5145 | 0.1197 | 4-(2,6,6-Trimethylcyclohexa-1,3-dienyl)but-3-en-2-one |
| 46 | 10.6045 | 0.3199 | (1S,2E,6E,10R)-3,7,11,11-Tetramethylbicyclo[8.1.0]undeca-2,6-diene |
| 47 | 10.7316 | 0.3967 | Benzene, 1,4-dimethoxy- |
| 48 | 10.991 | 2.2491 | Hydroquinone |
| 49 | 11.0652 | 0.856 | Hydroquinone |
| 50 | 11.1711 | 3.7757 | Hydroquinone |
| 51 | 11.4941 | 1.0656 | Hydroquinone |
| 52 | 11.6053 | 0.7783 | Hydroquinone |
| 53 | 11.7112 | 1.0405 | Hydroquinone |
| 54 | 11.8859 | 0.2917 | Hydroquinone |
| 55 | 11.9548 | 0.6192 | Ethyl 5-methyl-3-isoxazolepropanoate |
| 56 | 12.0872 | 0.3423 | 1-Methoxybicyclo[2,2,2]oct-5-en-2-yl methyl ketone |
| 57 | 12.1507 | 0.4983 | Dihydrojasmone |
| 58 | 12.2672 | 0.6338 | Cyclononasiloxane, octadecamethyl- |
| 59 | 12.3731 | 0.325 | Glutaric acid, 3-chlorophenyl 2-isopropoxyphenyl ester |
| 60 | 12.4473 | 1.2142 | Neophytadiene |
| 61 | 12.5585 | 0.3651 | 1,4-Eicosadiene |
| 62 | 12.6697 | 0.8901 | Eicosen-1-ol, cis-9- |
| 63 | 12.765 | 0.6024 | Undecanoic acid |
| 64 | 12.8867 | 0.6207 | 2-(3,4-Dimethyl-.alpha.-thiosemicarbazonobenzyl)benzoic acid |
| 65 | 13.088 | 0.5729 | Cyclononasiloxane, octadecamethyl- |
| 66 | 13.1515 | 0.3209 | Pentadeca-2,3,6,9,12,13-hexaen-8-one, 2,5,5,11,11,14-hexamethyl- |
| 67 | 13.3739 | 2.6808 | n-Hexadecanoic acid |
| 68 | 13.5063 | 0.6714 | Fumaric acid, 2,4-dimethylpent-3-yl tridecyl ester |
| 69 | 13.6016 | 0.656 | 3-Buten-2-one, 3-methyl-4-(1,3,3-trimethyl-7-oxabicyclo[4.1.0]heptan-1-yl)- |
| 70 | 13.7022 | 0.5835 | Z-8-Methyl-9-tetradecenoic acid |
| 71 | 13.787 | 0.7316 | 2,4-Dihydroxybenzoic acid, 3TMS derivative |
| 72 | 13.8505 | 1.8993 | Docosane, 2,21-dimethyl- |
| 73 | 14.1841 | 1.1892 | Octadec-9-enoic acid |
| 74 | 14.3059 | 2.5547 | 9,12,15-Octadecatrienoic acid, (Z,Z,Z)- |
| 75 | 14.4701 | 1.8402 | Hexasiloxane, tetradecamethyl- |
| 76 | 14.6289 | 1.0376 | 8-Methylenecyclooctene-3,4-diol |
| 77 | 14.7454 | 0.5609 | Methyl 2-tetradecyloxiranecarboxylate |
| 78 | 14.8513 | 2.0011 | 6-Hexadecenoic acid, 7-methyl,methyl ester (E) |
| 79 | 15.0314 | 1.0281 | Eicosyl isopropyl ether |
| 80 | 15.0896 | 0.5262 | Z-8-Methyl-9-tetradecenoic acid |
| 81 | 15.2167 | 2.1111 | 1-(Adamantan-1-yloxy)-2-phenylhexahydropyrrolo[1,2-c][1,3,2]diazaphosphole |
| 82 | 15.3967 | 0.4917 | Benzamide, 3-methoxy-N-[4-(1-methylcyclopropyl)phenyl]- |
| 83 | 15.4762 | 0.9653 | Acetamide, 2-[2-(2H-1,2,3-benzotriazol-2-yl)-4-methylphenoxy]-N-(2-pyridinyl)- |
| 84 | 15.5556 | 0.6229 | Nonadecanenitrile |
| 85 | 15.6244 | 0.6792 | 4-Benzyl-1-[N-methylsulfonyl-N-(3-chloro-2-methylphenyl)-aminoacetyl]piperidine |
| 86 | 15.7568 | 1.7111 | Bis(2-ethylhexyl) phthalate |
| 87 | 15.8468 | 0.792 | Nonadecanenitrile |
| 88 | 16.0533 | 3.282 | Octadecanamide |
| 89 | 16.2069 | 0.9164 | Heptacosane |
| 90 | 16.3128 | 1.6438 | Docosane |
| 91 | 16.4981 | 0.8008 | Tricyclo[6.3.0.0(5,7)]undecane, 1,8-epoxy-2,6,6,9-tetramethyl- |
| 92 | 16.6041 | 1.2005 | 2-heneicosanone, 1,1,1-trifluoro- |
| 93 | 16.7047 | 0.6036 | 4-Methyl-3-(4-nitrophenyl)-6-p-tolyl-5,6-dihydro-4H-[1,2,4,5]oxatriazine |
| 94 | 16.8318 | 1.6158 | Squalene |
| 95 | 16.9589 | 1.3343 | Docosane |
| 96 | 17.1336 | 2.1164 | Hexacosane |
| 97 | 17.3507 | 0.8051 | Benzoic acid, 2-[6-(ethylamino)-3-(ethylimino)-2,7-dimethyl-3H-xanthen-9-yl]-, ethyl ester |
| 98 | 17.4725 | 1.162 | 17,21-Dimethylheptatriacontane |
| 99 | 17.6208 | 1.0813 | Tetratriacontane |
| 100 | 17.7426 | 0.6407 | 2,5-Furandione, 3-dodecyl- |
| 101 | 17.8749 | 0.5295 | 2,5-Furandione, 3-dodecyl- |
| 102 | 18.0126 | 1.0062 | 2-Methyltriacontane |
| 103 | 18.1397 | 0.3727 | 13-Methyl-Z-14-nonacosene |
| 104 | 18.3303 | 1.9021 | Hexacosane |
| 105 | 18.4415 | 0.9649 | Methoxyacetic acid, heptadecyl ester |
| 106 | 18.6745 | 0.5314 | 13-Methyl-Z-14-nonacosene |
| 107 | 18.8546 | 1.6049 | dl-.alpha.-Tocopherol |
| 108 | 19.024 | 0.7535 | 2-Methylpentacosane |
| 109 | 19.1193 | 0.4656 | Cyclononasiloxane, octadecamethyl- |
| 110 | 19.3629 | 0.3202 | 2,5-Furandione, 3-dodecyl- |
| 111 | 19.6224 | 0.9754 | 3-Methyldotriacontane |
| 112 | 20.099 | 2.7409 | Tricosane |
| 113 | 20.3796 | 0.0242 | 1-Bromo-11-iodoundecane |
| 114 | 20.7821 | 0.6986 | 2-Methyltriacontane |

Table 7. GC-MS of phytochemical compounds accumulated in dry leaves of 65-d old *Origanum majorana* (Origanum) plant at flowering stage. The plant was 10-d irrigated using D-mannitol to induce drought stress before the analysis.

|  |  |  |  |
| --- | --- | --- | --- |
| Serial no | RT | % | Chemical compound |
| 1 | 1.2157 | 3.2928 | Cyclobutanol |
| 2 | 2.1636 | 0.0865 | Cyclobutanol |
| 3 | 2.1953 | 0.1472 | Cyclobutanol |
| 4 | 2.8149 | 0.0661 | Cyclobutanol |
| 5 | 3.4239 | 0.021 | 4-Fluorohistamine |
| 6 | 4.1334 | 0.0503 | Cyclohexan-1,4,5-triol-3-one-1-carboxylic acid |
| 7 | 4.61 | 0.6519 | Acetic acid |
| 8 | 4.6788 | 0.6884 | Acetic acid |
| 9 | 4.8536 | 0.1683 | Acetic acid |
| 10 | 5.0283 | 0.2479 | Acetic acid |
| 11 | 5.0601 | 0.116 | Acetic acid |
| 12 | 5.1342 | 0.1948 | Acetic acid |
| 13 | 5.3249 | 0.5712 | Acetic acid |
| 14 | 5.5896 | 0.0747 | Acetic acid |
| 15 | 5.7538 | 1.3743 | Bicyclo[3.1.0]hex-2-ene, 2-methyl-5-(1-methylethyl)- |
| 16 | 5.8068 | 0.1729 | .alpha.-Pinene |
| 17 | 5.8968 | 0.0855 | Propanoic acid, 2-oxo-, ethyl ester |
| 18 | 6.0186 | 0.2104 | 2-Furanmethanol |
| 19 | 6.3363 | 2.1707 | .gamma.-Terpinene |
| 20 | 6.4898 | 0.4618 | .beta.-Myrcene |
| 21 | 6.564 | 0.0315 | Piperidine, 3-(bromomethyl)- |
| 22 | 6.6328 | 0.3938 | .alpha.-Phellandrene |
| 23 | 6.8023 | 1.3882 | Cyclohexene, 1-methyl-4-(1-methylethylidene)- |
| 24 | 6.9082 | 0.7521 | Cyclopropane, 1,1-dimethyl-2-(3-methyl-1,3-butadienyl)- |
| 25 | 6.9399 | 0.802 | Cyclohexane, 1-methylene-4-(1-methylethenyl)- |
| 26 | 7.0935 | 0.0268 | .beta.-Ocimene |
| 27 | 7.2418 | 1.5581 | Tricyclo[2.2.1.0(2,6)]heptane, 1,3,3-trimethyl- |
| 28 | 7.3106 | 0.1783 | Mepivacaine |
| 29 | 7.4324 | 0.9065 | Bicyclo[3.1.0]hexan-2-ol, 2-methyl-5-(1-methylethyl)-, (1.alpha.,2.alpha.,5.alpha.)- |
| 30 | 7.4959 | 0.8274 | Cyclohexene, 1-methyl-4-(1-methylethylidene)- |
| 31 | 7.7342 | 1.3162 | Bicyclo[3.1.0]hexan-2-ol, 2-methyl-5-(1-methylethyl)-, (1.alpha.,2.alpha.,5.alpha.)- |
| 32 | 7.8613 | 1.586 | Bicyclo[3.1.0]hexan-2-ol, 2-methyl-5-(1-methylethyl)-, (1.alpha.,2.alpha.,5.alpha.)- |
| 33 | 7.9778 | 0.0671 | Ethanol, 2-bromo- |
| 34 | 8.0678 | 0.0866 | Ethanol, 2-bromo- |
| 35 | 8.1526 | 0.0591 | Ethanol, 2-bromo- |
| 36 | 8.2002 | 0.0833 | Pyrazole-5-carboxamide, 4-amino- |
| 37 | 8.2532 | 0.1253 | Cyclohexanone, 2-ethyl- |
| 38 | 8.375 | 0.5529 | Terpinen-4-ol |
| 39 | 8.4226 | 0.3411 | Terpinen-4-ol |
| 40 | 8.5074 | 0.177 | .alpha.-Terpineol |
| 41 | 8.5709 | 0.8166 | .alpha.-Terpineol |
| 42 | 8.6556 | 0.0572 | Ethanedial, bis(dimethylhydrazone) |
| 43 | 8.7033 | 0.0666 | Ethanedial, bis(dimethylhydrazone) |
| 44 | 8.7509 | 0.0888 | 2-Propyl-tetrahydropyran-3-ol |
| 45 | 8.8727 | 0.9617 | Cyclohexanol, 1-methyl-4-(1-methylethylidene)-, acetate |
| 46 | 8.8992 | 0.6877 | Cyclohexanol, 1-methyl-4-(1-methylethylidene)-, acetate |
| 47 | 9.0316 | 0.0889 | Benzenemethanamine, N-methyl- |
| 48 | 9.111 | 0.1812 | (-)-cis-Myrtanyl acetate |
| 49 | 9.2222 | 0.7162 | (1R)-2,6,6-Trimethylbicyclo[3.1.1]hept-2-ene |
| 50 | 9.3175 | 0.1035 | N-Isopropyl-N-methyl aminoethyl-2-chloride |
| 51 | 9.4076 | 0.2777 | Camphene |
| 52 | 9.4446 | 0.0757 | 1-[2-Deoxy-.beta.-d-erythro-pentofuranosyl]pyrrole-2,4-dicarboxamide |
| 53 | 9.4923 | 0.7606 | 1,5,5-Trimethyl-6-methylene-cyclohexene |
| 54 | 9.5717 | 0.2796 | Indole |
| 55 | 9.6564 | 0.4862 | Catechol |
| 56 | 9.7517 | 0.4472 | Catechol |
| 57 | 9.7888 | 0.7015 | 2-(2-Hydroxyethoxy)phenol |
| 58 | 9.9053 | 0.4197 | 2-Isopropoxyphenol |
| 59 | 9.9847 | 0.2505 | 7-Azabicyclo[4.1.0]heptane, 2-methyl-5-(1-methylethyl)- |
| 60 | 10.096 | 0.8781 | Caryophyllene |
| 61 | 10.1595 | 0.1508 | 1-Methoxy-1,4-cyclohexadiene |
| 62 | 10.2072 | 0.2434 | 2-Isopropyl-5,5-dimethylcyclohex-2-enone |
| 63 | 10.3078 | 0.3227 | 1H-Benzocycloheptene, 4,4a,5,6,7,8,9,9a-octahydro-4a-methyl-, trans- |
| 64 | 10.4613 | 0.7868 | Hydroquinone |
| 65 | 10.5143 | 0.3439 | Hydroquinone |
| 66 | 10.599 | 0.8586 | Hydroquinone |
| 67 | 10.7208 | 1.121 | Hydroquinone |
| 68 | 10.7526 | 0.3113 | Hydroquinone |
| 69 | 10.8691 | 1.4176 | Hydroquinone |
| 70 | 10.975 | 1.866 | Hydroquinone |
| 71 | 11.0703 | 1.0721 | Hydroquinone |
| 72 | 11.1868 | 2.871 | Hydroquinone |
| 73 | 11.8222 | 0.3693 | Dihydrojasmone |
| 74 | 12.034 | 0.959 | 1H-Imidazole, 2-octanoyl- |
| 75 | 12.1505 | 0.4373 | Phenanthrene, 9,10-dihydro-1-methyl- |
| 76 | 12.4576 | 2.4057 | Neophytadiene |
| 77 | 12.5635 | 0.5357 | 5-Nonadecen-1-ol |
| 78 | 12.6642 | 1.6191 | 3,7,11,15-Tetramethyl-2-hexadecen-1-ol |
| 79 | 12.8866 | 0.4665 | 2-(3-Hydroxybutyl)cyclooctanone |
| 80 | 13.1143 | 0.6608 | Oleyl alcohol, methyl ether |
| 81 | 13.1619 | 0.231 | 2(1H)-Naphthalenone, octahydro-4a-methyl-7-(1-methylethyl)-, (4a.alpha.,7.beta.,8a.beta.)- |
| 82 | 13.3949 | 2.5814 | n-Hexadecanoic acid |
| 83 | 13.7179 | 2.5969 | 9-Hexacosene |
| 84 | 13.8556 | 1.9658 | Ethanone, 1-cyclododecyl- |
| 85 | 14.3163 | 4.6934 | 9,12,15-Octadecatrienoic acid, (Z,Z,Z)- |
| 86 | 14.4593 | 1.5124 | 2(1H)-Naphthalenone, octahydro-4a-methyl-7-(1-methylethyl)-, (4a.alpha.,7.beta.,8a.beta.)- |
| 87 | 14.6287 | 1.8075 | 2-Heptadecenal |
| 88 | 14.8776 | 1.8705 | 9-Eicosyne |
| 89 | 15.0471 | 0.6957 | 3a,9-Dimethyldodecahydrocyclohepta[d]inden-3-one |
| 90 | 15.0947 | 0.5466 | 2,5-Furandione, 3-dodecyl- |
| 91 | 15.2324 | 2.4121 | 2,5-Furandione, 3-dodecyl- |
| 92 | 15.4177 | 1.5195 | 3-Methyl-4-(phenylthio)-2-prop-2-enyl-2,5-dihydrothiophene 1,1-dioxide |
| 93 | 15.7407 | 1.9106 | Bis(2-ethylhexyl) phthalate |
| 94 | 15.8308 | 0.6003 | Heptacosane |
| 95 | 15.9208 | 1.5266 | Tetratriacontane |
| 96 | 16.0373 | 1.0589 | 8-Methylenecyclooctene-3,4-diol |
| 97 | 16.1591 | 0.3215 | 5-Decenedioic acid, 5,6-dimethyl-, dimethyl ester |
| 98 | 16.2226 | 0.7682 | Muscone |
| 99 | 16.3073 | 1.3457 | 2,5-Furandione, 3-dodecyl- |
| 100 | 16.5033 | 0.7869 | (5-Isopropyl-2-methyl-phenoxy)-acetic acid (2-bromo-benzylidene)-hydrazide |
| 101 | 16.6145 | 0.7988 | 2-heneicosanone, 1,1,1-trifluoro- |
| 102 | 16.821 | 2.7178 | Squalene |
| 103 | 17.1122 | 1.4064 | Nonacosane |
| 104 | 17.4829 | 1.9789 | Stanolone |
| 105 | 17.6259 | 0.7299 | Tritriacontane |
| 106 | 17.7477 | 0.9483 | 8-Methylenecyclooctene-3,4-diol |
| 107 | 17.9807 | 0.8717 | 2-Methyltriacontane |
| 108 | 18.3301 | 2.0399 | Nonacosane |
| 109 | 18.4943 | 0.2697 | Cholestan-3-ol, 4,4-dimethyl-, (3.beta.,5.alpha.)- |
| 110 | 18.7114 | 0.6933 | Stigmasta-3,5-diene |
| 111 | 18.8756 | 1.658 | dl-.alpha.-Tocopherol |
| 112 | 19.0185 | 1.0935 | Hexacosane |
| 113 | 19.4845 | 0.1745 | Dotriacontane, 2-methyl- |
| 114 | 19.5851 | 0.371 | Dotriacontane, 2-methyl- |
| 115 | 20.1041 | 3.3487 | Heptacosane |
| 116 | 20.2259 | 0.0441 | E-8-Methyl-9-tetradecen-1-ol acetate |
| 117 | 20.39 | 0.0073 | 6-(5-Bromo-2-methoxy-phenyl)-5-nitro-piperidin-2-one |
| 118 | 20.766 | 0.8209 | Tritriacontane, 3-methyl- |

Fig. 1. Effect of mannitol induced 10-d drought stress on proline level in 65-d old *Ocimum basilicum*, *Mentha longifolia* and *Origanum magorana* medicinal plants. Error bars designate ±SD of the mean.

Fig. 2. . Effect of drought-stress induced by irrigation sing mannitol (250 mM) for ten days on chl *a*, *b* and carotenoids in 65-d old medicinal plants: *Ocimum basilicum*, *Mentha longifolia*, and *Origanum majorna*. Each value is the mean of three replicates. The error bars represent ± standard deviation.

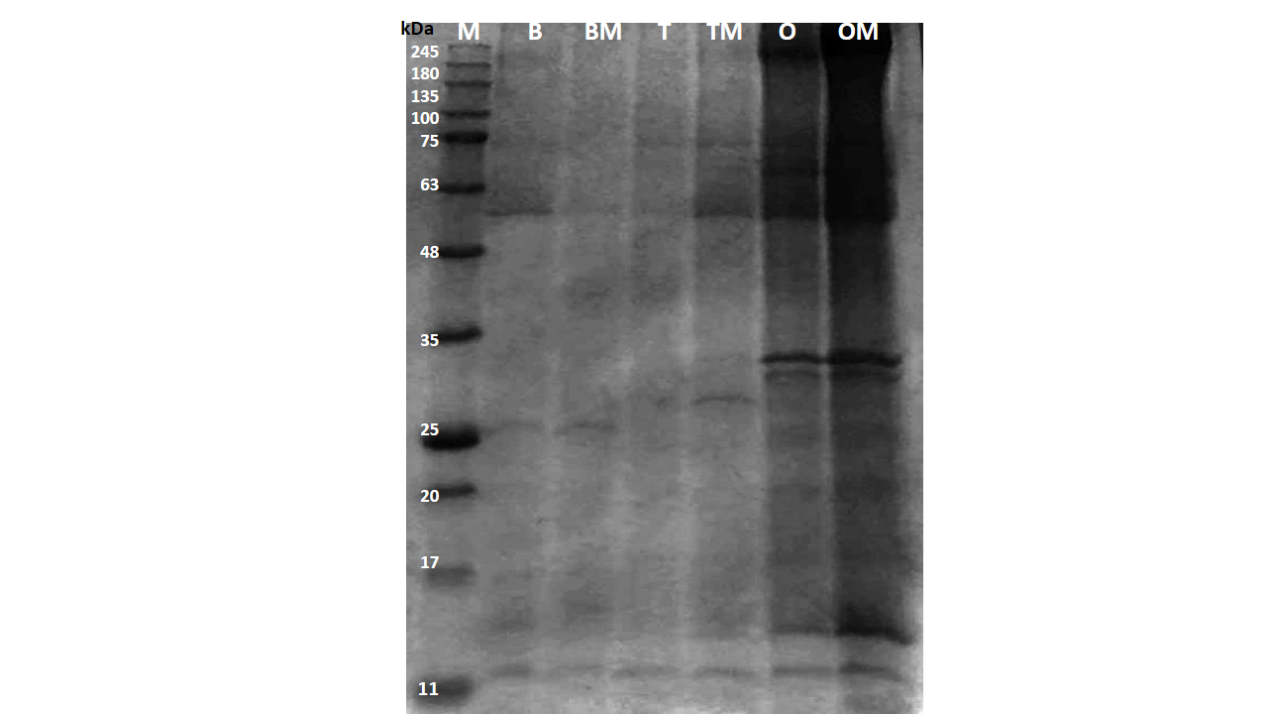
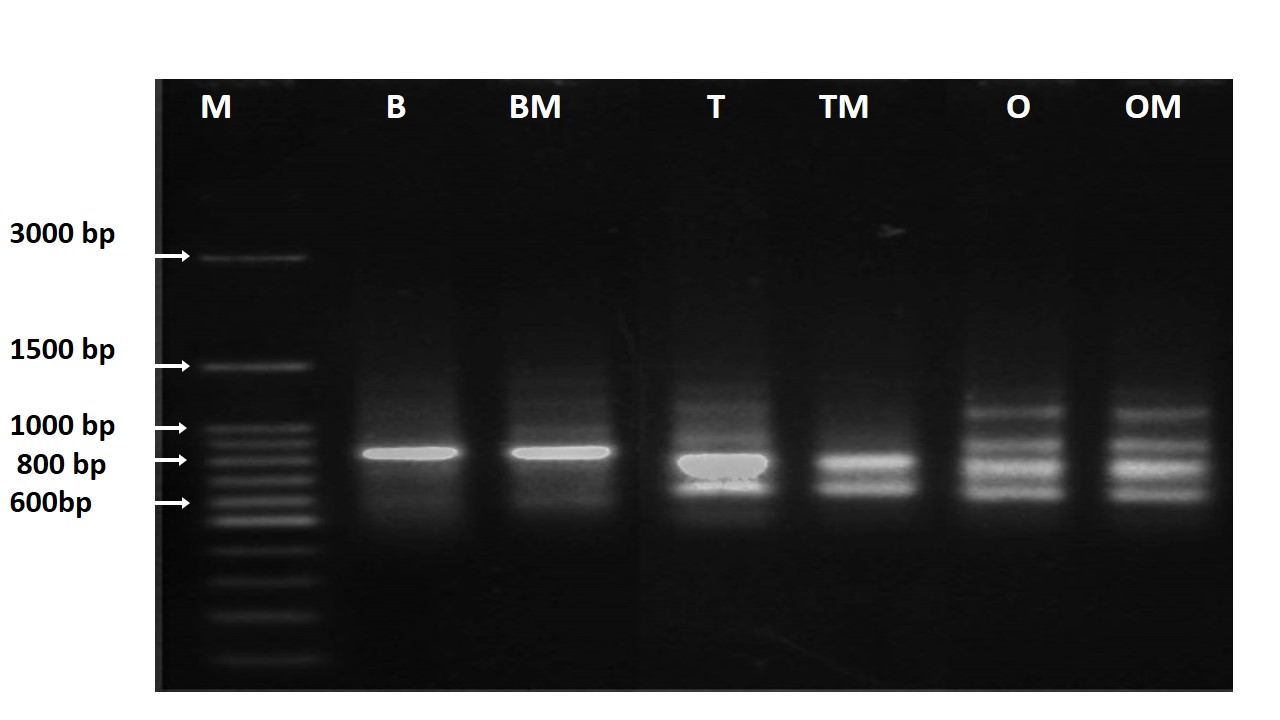
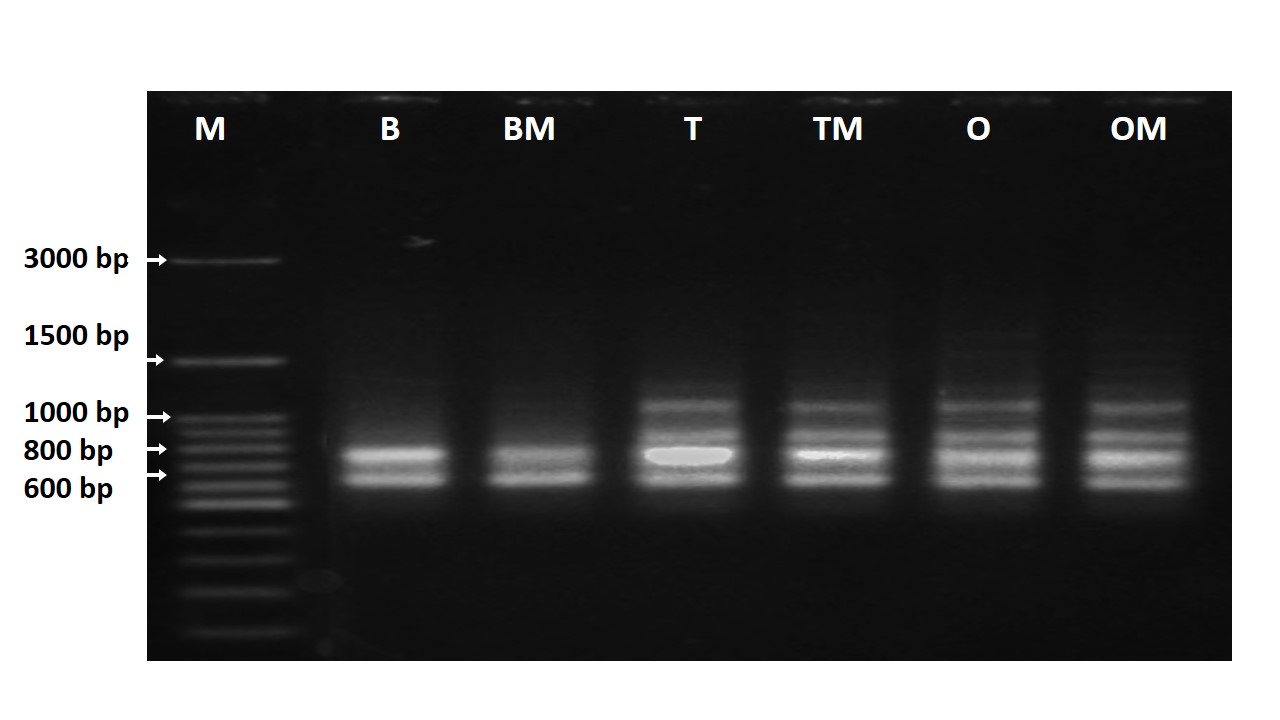
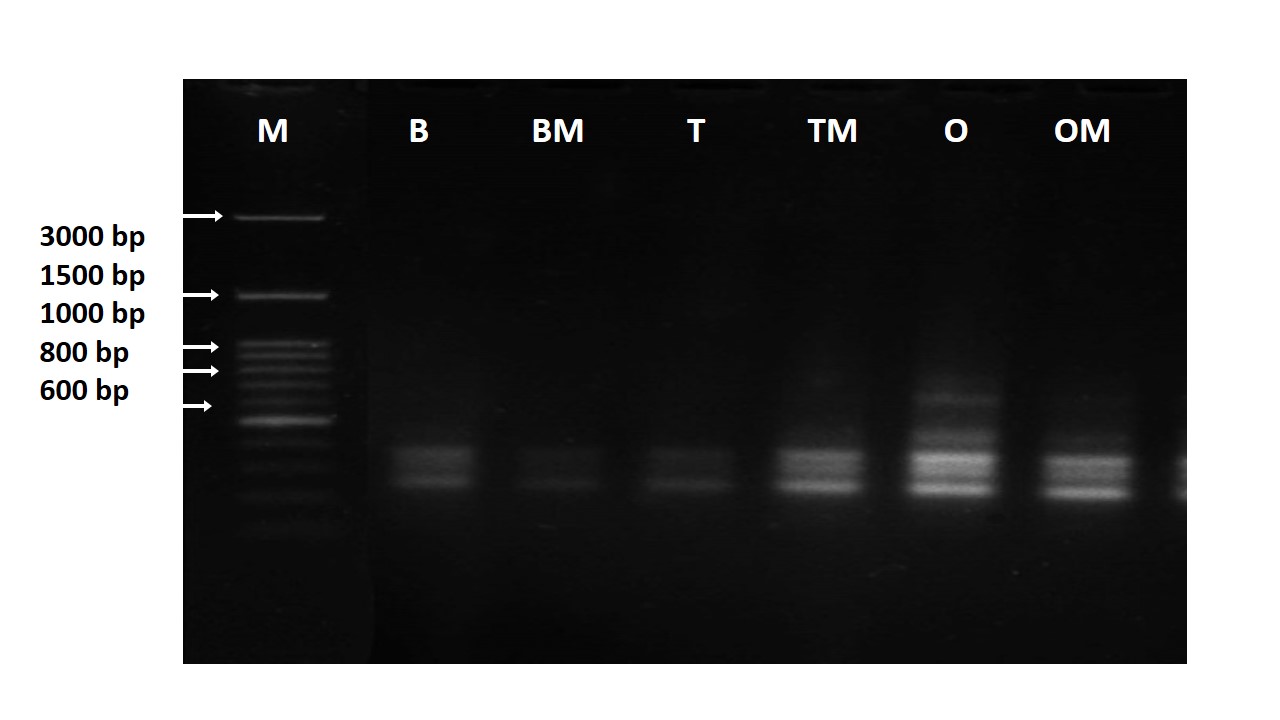


Fig 3. SDS-PAGE electrophoresis of soluble protein extracted from apical leaf detached from basil (B), mint (T) and origanum (O) plants grown for 10- d either under normal irrigation condition using water or with irrigation using 250 mM mannitol-induced drought stress (BM, MM, and OM). 

**A**



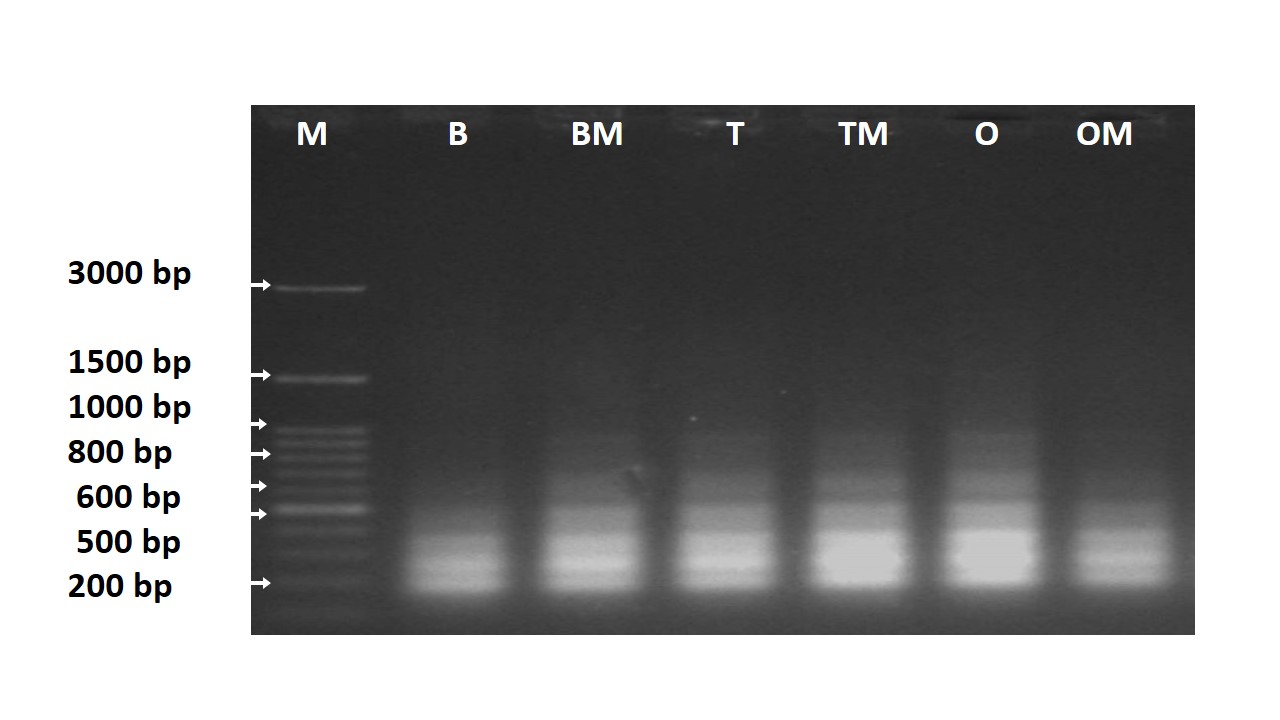
**B**



**C**



**D**



**E**

Fig 4. Agarose gel electrophoresis of RAPD-PCR amplification fragments as products obtained from five primers: (A; OPA-1, B; OPA-4, C; OPA-11, D; OPB-3 (not successful), E; OPB-10). The primers introduced to isolated DNA from medicinal plants grown for 10-d with or without drought stress: basil (B), stressed basil (BM), mint (T), stressed mint (TM), origanum (O) and stressed origanum (OM). M; marker ranges from 100-3000 b.