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Plant Materials (BOT-300)

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Section - 1

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This report aims to provide the reader a comprehensive set of information about the genus, *Mentha* L. Commonly known as the 'mint' genus; plants of the mint genus are known for their immense versatility. Hopefully, this term paper will be a small, but successful step in illuminating and exposing the reader to the same.

Acknowledgements

First and foremost, I would like to thank Almighty, because without His grace and blessings, this report would have been impossible.

Secondly, my deepest respects and regards go to my professor, Dr. Manar Bani Mfarrej, whose excellent guidance and support motivated me to do my best.

Lastly, I would also like to extend my heartfelt gratitude to my parents for their painstaking efforts to ensure that their children have the best of everything in life.

Abstract

This term paper aims to shed light on the many aspects of mint plants of the genus *Mentha* L. It provides accurate and sufficient insight on the historical usage and importance of mint plants, while also taxonomically classifying them. Several other aspects such as diseases and vulnerabilities and the economic, culinary, medicinal, and therapeutic uses have also been discussed in detail. It also analyzes a case study done to find out more about the viral infections prominently seen in many species of *Mentha* L.

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Introduction

Source: http://www.backyardnature.net/n/h/spermint.htm

Mint is one of the most versatile herbs one can find. Its uses are simply too many to list, whether that is deodorizing your room, freshening your breath, brewing teas that rejuvenate your senses, prepare finger-licking zesty dishes, or making boring salads lively (Lee, 1977).

Figure 1: Leaves of *Mentha spicata* - spearmint. Source: http://en.wikipedia.org/wiki/File:Minze.jpg

Mint (*Mentha L.*) genus has several different species (over the 600 known varieties, the most popular ones include: *M. spicata* – spearmint, *M. x piperita* – peppermint, *M. x piperita* var. citrate – Orange/Bergamot mint, *M. suaveolens* 'Variegta' – pineapple mint, *M. x gracilis* – red stemmed apple mint, and *M. pulegium* – pennyroyal (South Texas Unit of The Herb Society of America , 2013)) – and most of these have immense importance in our daily lives; in fact, it is safe to say that the mint family's (Lamiaceae) most important genus is *Mentha* L. thanks to its many species of perennial nature [plants that live for more than two years (Mfarrej M. B., 2013)]. Species such as *M. pulegium* L. (Pennyroyal), *M. spicata* L. Spearmint), and *M. piperita* L. have been used since ancient times as medicine, as noted in (Baytop, 1999) to cure different ailments such as nausea, flatulence, headache, and muscle pain (Folk Remedies, 2011). Species of the '*Mentha* L.' genus have been termed as antioxidant, anti – inflammatory, anti – microbial analgesic, and even anti – carcinogenic by researchers (Pereira

Figure 2: Ice limonana, mint lemon drink popular in Israel Source: http://food.lizsteinberg.com/2010/07/04/ice-limonana-mint-lemonade-the-drink-of-the-israeli-summer/

& Cardoso, 2013). All species under the '*Mentha* L.' genus mandatorily have the 'mint' suffix added to them, such as peppermint, spearmint, etc.

Figure 3: Map of the Old World. Source: http://ideawallpaper.com/old-world-map-wallpaper/

The *Mentha* genus has twenty – five (25) species of aromatic (having a pleasant smell) herbs mainly native in temperate Eurasia [continent combining Europe and Asia], North America, southern Africa, and Australia (Encyclopædia Britannica, 2013). However, mint's natural surroundings mainly occur in North America, from where it is widespread all over tropical/sub – tropical regions of the world with concentrations in the temperate regions of Europe – Asia, and Africa (A.K.A. the Old World) (Encyclopædia Britannica, 2013).

Review of Literature

Historical Background

Figure 4: Hades and Persephone with their dog, Cerberus. Source: http://piperbasenji.blogspot.ae/2013/03/cerberus.html

The name '*mentha*' is derived from the Greek word '*Minthê*'. The name can be attributed to an event in the Greek mythology: *Minthê* was a nymph (women in service of Gods and Goddesses) in the court of Hades (ruler of the kingdom of dead in Greek mythology (GreekMythology, 2010)) who was given high regard; legend has it that on a certain occasion she proclaimed herself to be more able than Persephone (wife of Hades, She exercises power over the dead), who got furious upon hearing this; in a fit of rage, she turned *Minthê* into a pile of dust. However, Hades did not of what happened to Minthê and therefore gave her life again by causing a plant to sprout out of the dust; therefore, bring the 'mint' plant into existence; although He was unsuccessful in granting her former appearance, He made sure that she was never forgotten, therefore granting the plant immense versatility and fragrance. This is how the '*Mentha*' name of the genus came into being (Theoi Greek Mythology, 2011).

Figure 5: An ancient Egyptian scroll, depicting the apothecary providing vials of medicine to the patient(s). Mint was widely used for medicinal uses back then. Source: http://www.messagetoeagle.com/prehherbmedicine.php#.UnVXPvmAJ-F

Figure 6: An Egyptian mummy; several provisions [which included dried mint leaves] were kept for them in their coffin or around it to help them in their journey in the afterlife. Source: http://www.weekendnotes.co.uk/the-british-museum-egypt/

Mint (*Mentha L.)* has a long history in the dawn of civilization. One of the earliest civilizations: the Egyptian civilization (the beginning i.e. pre-dynastic period dates back to as old as ~3500 B.C. as stated by (The British Museum - Ancient Egypt, 1999)) found extensive uses for mint plants. However, mint plants back then were not as well categorized and researched upon, as they are, today. Nevertheless, there are evidences that the Egyptians were among the first ones to cultivate *Mentha piperita* (peppermint) in (Grieve, 2013); Egyptian tombs as old as 1000 B.C. contained remains of *Mentha piperita* (peppermint), as cited in (Esoteric Oils, 2013) and (The Wisconsin Mint Industry, 2013); the presence of dried mint leaf remains in mummy tombs give an impression of mint also being used by the Egyptians to support the dead in the journey of after-life, as quoted by (Gerritsen, 2010). An ancient Egyptian

Figure 7: A scroll of the Ebers Papyrus; one of the oldest literature on medicine and surgery. Source: http://www.crystalinks.com/egyptmedicine.html

scripture, *Ebers Papyrus* (one of the oldest medical papyri of Ancient Egypt, currently it's kept in the Library of Leipzig, Germany), which dates back to 1550 B.C. states peppermint (*Mentha piperita*) as being capable of relieving flatulence, indigestion, and nausea while also being an excellent breathe freshener (CrystalLinks - Metaphysics and Science Website, 2013). In fact, one scripture says that mint was considered to be so valuable in ancient Egypt that it was used as a very prominent form of currency (InDepthInfoPepperMint, 2013).

Figure 8: Greek salad; the Greek cuisine also makes extensive use of whole, fresh mint leaves in their dishes. Source: http://au.lifestyle.yahoo.com/food/galleries/photo/-/19174585/how-to-cook-greek-food-like-a-pro/19174596/

Figure 9: Greek mint tea; it's prepared from crushing powdered mint leaves and mixing them with warm water. Mint plants in Greece are known to have a stronger aroma. Source: http://www.thatsgreece.com/info/greek-cuisine-beverages-infusions-Diosmos-Spearmint

After the Egyptians, the Greeks were the ones who found a large number of applications for the mint plants; mainly in their cuisine [between 1700 B.C. – 1400 B.C., the usage of mints was thoroughly integrated into the Greek cuisines, as quoted by (Hill & Barclay, 1998)]; such as using them in fermented barley drinks (wiseGEEK, 2013). Apart from this, mint plants are also traditionally considered to be a sign of hospitality by the Greeks, the Romans, and the medieval monks, who also used mint to keep their teeth clean and polished (InDepthInfoPepperMint, 2013); the Greeks especially, would brush their banqueting tables with mints and add crushed mint paste to their baths as its effects were rejuvenating to the body (FreshHerbs, 2013). Also, the Greeks used them for funeral rites (due to the fragrance effect mainly, which was seen as a way to respect the dead) (wiseGEEK, 2013). Greek philosopher Aristotle and Greek physician Hippocrates (also known as the Father of Medicine) both argued that mint plants (with *Mentha piperita* in specific) discouraged procreation and sexual intercourse, but some others seemed to favor the contrast – saying that consumption of mint herbs of any species stimulates the body, therefore increasing the probability of it engaging in a sexual event; soldiers, therefore, were not allowed to consume mint before wars as a

Figure 10: A modern herb garden; even in the medieval times, monks had gardens around monasteries and mint was one of the more important and sought-after plants. Source: http://thecatholicbeat.sacredheartradio.com/2013/04/25/monastery-garden-herbs-dipping-oil/

Figure 11: A sketch depicting ancient Greek soldiers at war. Physical fitness of soldiers was an important issue, and so they weren't allowed to consume mint before battles. Source: http://karenswhimsy.com/ancient-greek-soldiers.shtm

Figure 12: A photograph of what remains of Charlemagne's gardens. Although in-evident from the picture, Charlemagne's gardens contained a great number of herbs. Source: http://www.flickr.com/photos/sarisetiogi/2554431996/

means of preventing any incident which could increase the probability of a failure due to a drop in the physical prowess. Roman philosopher, Pliny the Elder, suggested that mint leaves had rejuvenating effects on not just the body, but also on the mind and soul of the person; so, mint leaves were also bound to crowns of kings and princes. He also believed that mint could increase the appetite due to its pleasant taste and fragrance in the dinner table (InDepthInfoPepperMint, 2013). Frank Emperor, Charlemagne (742 A.D. – 814 A.D.), who is known to be the Father of Europe (The History Channel Website, 2013), wrote in his books that mint plants required wide attention due to their extensive therapeutic capabilities and healing effects, particularly to aid the soldiers (Hein & Rose, 2004). Subsequently, two years before his death, he ordered several acres of his land to be used for mint plant cultivation, which in all happens to be a vast collection of lands growing as many as seventy – eight (78) kinds of herbs across various levels in the modern day taxonomic classification (GardenAction - The Premier Gardening Information Source, 2011).

Mint plants also seem to have earned honorable mentions in Icelandic pharmacopoeias (encyclopedias with instructions to create drugs) in the thirteenth (13th) century and sometime even before that; pharmacopoeias dating back to as early as 1240 A.D. contain references of mint plants as a herbal and culinary herb. This was also popularized by the monks of middle ages who used mint to clean their teeth (InDepthInfoPepperMint, 2013).

Figure 13: Powdered mint, made from dried mint leaves. In the past, monks used powdered mint to keep their teeth clean and healthy. Source: http://chezshuchi.com/How%20to%20make%20Mint%20Powder.html

Figure 14: A medieval church in England. Mint leaves were scattered during Bible sessions and prayers to purify the air. Source: http://www.rgbstock.com/bigphoto/mkTxYQ4/Village+Church

However, it wasn't until seen widely in use until the mid – eighteenth (mid – 18th) century in West Europe, when many researchers and botanists had turned themselves to discovering more about the *Mentha L.* genus and its many species of miraculous herbs (Grieve, 2013). Nicholas Culpeper, an English botanist, herbalist, physician, and astrologer in the seventeenth (17th) century, wrote that the effects of mint reinforcing effects on the sex – hormones, therefore increasing the likelihood of intercourse between couples; this confirmed the previous norm in Roman armies where mint was forbidden for consumption by the soldiers (GardenAction - The Premier Gardening Information Source, 2011). The Romans were the ones who introduced the mint plants to England, where it was first used (in the Old World). In England, mint was mainly used in the churches where mint leaves (and armloads of it) were scattered around to purify the air and lighten the atmosphere for sacred ceremonies (Hanna, 2013).

Taxonomical Classification

Before we start discussing about the 'Mint' family, it would be helpful to provide a brief overview of the background, so that the reader does not feel unfamiliar when he/she comes across any word or term that he might read in the following paragraphs. So, let's start from the taxonomical classification in Plant Biology or Botany.

The taxonomical classification in botany is done by an international group of botanists known as the "International Association for Plant Taxonomy" or IAPT in short (International Association For Plant Taxonomy - IAPT, 2011). In the year 1930, the taxonomists finalized their report on the International Code of Botanical Nomenclature. Every six (6) years, the Code is given a revision by the taxonomical experts, but these are often minor with respect to the overall structure of the provisions of the Code (Utah State University Intermountain Herbarium, 2002). Summarizing the Code gives us the following levels of classification which were then used for classification of any and every organism that fell within the Plant kingdom:

Rank	**Ending**	**Examples**
Division/Phylum	-phyta	Pinophyta, Magnoliophyta
Class	-opsida	Pinopsida, Liliopsida,, Magnoliopsida
Order	-ales	Pinales, Liliales, Magnoliales
Family	-aceae	Pinaceae, Liliaceae, Magnoliaceae
Tribe	-eae	Pineae, Lilieae, Magnolieae
Genus	A noun	*Pinus*, *Lilium*, *Magnolia*
Species	Varies	*Pinus flexilis,Lilium grandiflorum, Magnolia grandiflora*
Variety	Varies	*Pinus flexilis* var. *humilus*
Form	Varies	

Table 1: 1930 Taxonomical Classification Style as per the International Code of Botanical Nomenclature. Source: http://herbarium.usu.edu/teaching/4420/botnom.htm#Family

However, in the present day world, there have been several changes in the botanical nomenclature; also, there are several different types of classifications. For instance, earlier, everything that did not fall in the animal kingdom was included in the plant kingdom, but now, they are differently classified: microbiology for viruses and bacteria, phycology for algae, and mycology for fungi; in addition to that, there's always the chance of new features being discovered in the same plants which later causes them to be grouped/categorized different (Mfarrej M. B., What Is Botany?, 2013). There is no strict universal taxonomical classification rule for botany now; different institutions have different criteria for classifying the plants. This report describes two taxonomical classification styles - from the National Center for Biotechnology Information (NCBI) and the Natural Resources Conservation Service (NRCS). The NCBI style is much more detailed compared to the NRCS style of classification, but both of them provide appropriate and adequate classification details for the plant. Both the taxonomical styles will be discussed in detail; although the NCBI style is more detailed than the NRCS style of classification, it is still a good idea to give more than one classification style for an analogy. Both are given below:

Tribe recognized by NCBI Taxonomy:

- Cellular organisms +
  - Eukaryota +
    - Viridiplantae +
      - Streptophyta +
        - Streptophytina +
          - Embryophyta +
            - Tracheophyta +
              - Euphyllophyta +
                - Spermatophyta +
                  - Magnoliophyta +
                    - Eudicotyledons +
                      - Core eudicotyledons +
                        - Asterids +
                          - Lamiids +
                            - Lamiales +
                              - Lamiaceae +
                                - Nepetoideae +
                                  - **Mentheae**

Figure 16: National Center of Biotechnology Information (NCBI) Taxonomical Classification of *Mentha* L. genus. Source: *http://eol.org/pages/11885868/overview*

Rank	Scientific Name and Common Name
Kingdom	Plantae – Plants
Subkingdom	Tracheobionta – Vascular plants
Superdivision	Spermatophyta – Seed plants
Division	Magnoliophyta – Flowering plants
Class	Magnoliopsida – Dicotyledons
Subclass	Asteridae
Order	Lamiales
Family	Lamiaceae – Mint family
Genus	*Mentha* L. – mint

Figure 15: Natural Resources Conservation Service (NRCS) Taxonomical Classification of *Mentha* L. genus. Source: *http://plants.usda.gov/core/profile?symbol=MENTH*

**Since the NCBI taxonomy style is detailed beyond the scope of this term paper, the NRCS style will be followed and explained.*

The Mint genus or *Mentha L.* falls under the kingdom 'Plantae'. Kingdom is often considered to be the highest taxonomic rank (at least in this taxonomic classification style) (Mfarrej M. B., What Is Botany?, 2013). The main criteria which decide whether or not an organisms belongs under the 'Plantae' kingdom include being able to produce their own food through photosynthesis, having a well – developed nucleus and cell organelles i.e. being eukaryotic, and having more than one cell i.e. multi – cellular; if any of the following criteria is not satisfied by the organism, then it isn't considered to be a 'plant' (Central Yukon Species Inventory Project (CYSIP), 2011).

Figure 17: 'Plantae' kingdom is characterized their autotrophic ability, presence of a cell wall, and being eukaryotic. Source: http://upload.wikimedia.org/wikipedia/commons/3/3f/Ferns 02.jpg

Then within the kingdom 'Plantae', plants in the 'Sub-kingdom' are further classified on either presence or absence of a developed vascular system; those with no true vascular system [refers to well – developed system of xylem and phloem tissues; those make up the vascular part of the plant (Mfarrej M. B., What Is Botany?, 2013)] are termed as Bryophyta or 'non-vascular plants' whereas those with a well – developed vascular system [system of xylem and phloem] are given the scientific name of Tracheobionata/Tracheophyta or 'vascular plants'. *Mentha L.* falls under this category.

Figure 18: *Podocarpus acutifolius*, a tracheophyte only found in New Zealand. Source: http://4.bp.blogspot.com/-1vuDtiecBrE/TrGzOj4DmII/AAAAAAAAIIc/axzEgzFVO-M/s1600/Podocarpus+acutifolius.JPG

Figure 19: Barbarea vulgaris (Yellow rocket); a spermatophyte. The spermatophytes carry out their reproduction process through seeds. Source: *http://www.synodresourcecenter.org/pg/devotions/0007/0051/picture2.jpg*

Figure 20: A moss specimen under sub-kingdom 'Bryophyta'; Bryophytes lack a true vascular system. Source: http://www.bryophyta.ca/wp-content/uploads/2013/03/bryophyta_mousse1.jpg

Going one level down to the 'Super-division', plants are classified according to their method of reproduction and type of stem; the category Spermatophya refers to plants which are able to reproduce through seeds and have either herbaceous or woody stems: mint plants can reproduce through seeds and have herbaceous stems, so they are spermatophytes (Central Yukon Species Inventory Project (CYSIP), 2011).

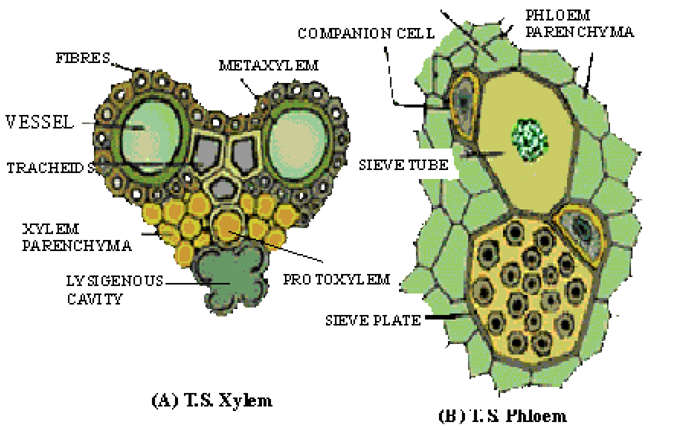

Figure 21: The vascular system consisting of xylem and phloem which distinguishes bryophytes from tracheophytes. Source: http://www.pinkmonkey.com/studyguides/subjects/biology-edited/chap15/b1515501.asp

Figure 22: Flowers of *Primula hortensis* [Primrose]; primroses are ornamental flowers mainly found in China; they belong to magnoliophyta i.e. have true flower [they also have seeds within the ovary.] Source: http://upload.wikimedia.org/wikipedia/commons/thumb/c/c9/Primula_aka.jpg/800px-Primula_aka.jpg

In the 'division' taxon, Mint plants fall under the 'Magnoliophyta' or 'flowering plants' category; plants in this group are identified by the presence of a true flower, which is believed to be a well – developed shoot or a condensed and reduced strobilus [a cone-like structure]. The flowers have parts such as sepals, petals, stamens, and carpels; those are termed as the 'floral parts' (Department of Botany - University of Wisconsin-Madison, 2013).

The next lower taxon is 'Class' which classifies plants as either having one or two cotyledons [a major part of the embryo present in the seed of the plant which forms the first leaves of a seedling during the growth or germination period (ScienceDaily, 2013)]. Plants with one cotyledon are termed as 'liliopsida' or 'monocotyledons' whereas plants with two cotyledons are termed as 'magnoliopsida' or 'dicotyledons' (Study of Northern Virginia Ecology, 2013), and mint plants are classed under magnoliopsida.

Descending further, we find that Mint genus belongs to the 'sub-class', Asteridae. Plants within the Asteridae sub-class have sympetalous (fused petals) flowers. The stamens here are isomerous (equal in number) and found alternatively to corolla lobes (or fewer). Asteridae sub-class is the most specialized group in the class of Magnoliopsida (University of Wisconsin Plant Teaching Collection, 2012).

Figure 23: French marigold (*Tagetes Patula*); they belong to the class Magnoliopsida i.e. dicotyledons. Source: http://2.bp.blogspot.com/-EgbNv5B3S60/ULQ6S_GjL0I/AAAAAAAAAJQ/IbboW1OyJnI/s1600/Tagetes+patula.jpg

The Asteridae subclass deepens into the 'Lamiales' order i.e. the Mint order of flowering plants. Lamiales has twenty – four (24) families, one thousand fifty – nine (1,059) genera, and greater than twenty – three thousand and eight hundred (800) species. The Lamiales order includes plants which have opposite leaves and often show bilateral symmetry with the number of petals being more than that of stamens. The Lamiales orders houses species, most of which have ovaries with two locules or valves/chambers and each is representative for one carpel (Berry, 2013).

Figure 25: *Lysimachia vulgaris* (Garden Loosestrife) belongs to the Asteridae sub-class; notice the petals fused to one another. Source: http://content63.eol.org/content/2011/11/01/14/93289_580_360.jpg

Figure 26: Beautyberry bush (*Callicarpa dichotoma*) belongs to Order Lamiales. Notice the opposite leaves. Source: http://farm1.staticflickr.com/109/264530560_1ec106ef60.jpg

Figure 24: Common selfheal (*Prunella vulgaris*), a member of the Lamiaceae (Mint) family. Source: http://farm4.staticflickr.com/3574/3801519723_81897bbe9f.jpg

The Mint genus belongs to one of the most important families in the Lamiales order i.e. the Lamiaceae family. The Lamiaceae family is characterized by leaves arranged in an opposite fashion, flowers being bilaterally symmetric, and two (2) to four (4) stamens/androecium. The ovary here consists of two (2) carpels [it has two (2) chambers, and as mentioned earlier, this corresponds to two (2) carpels]. Most members (including *Mentha L.* genus) of the Lamiaceae family are of perennial nature i.e. they survive for more than two (2) years. The Lamiaceae family is known for its genera which displays the characteristic of saw – toothed leaves and aromatic nature (with the Mint genus being particularly important) (Berry, 2013). The commonly observed patterns of the Mint family Lamiaceae are given below:

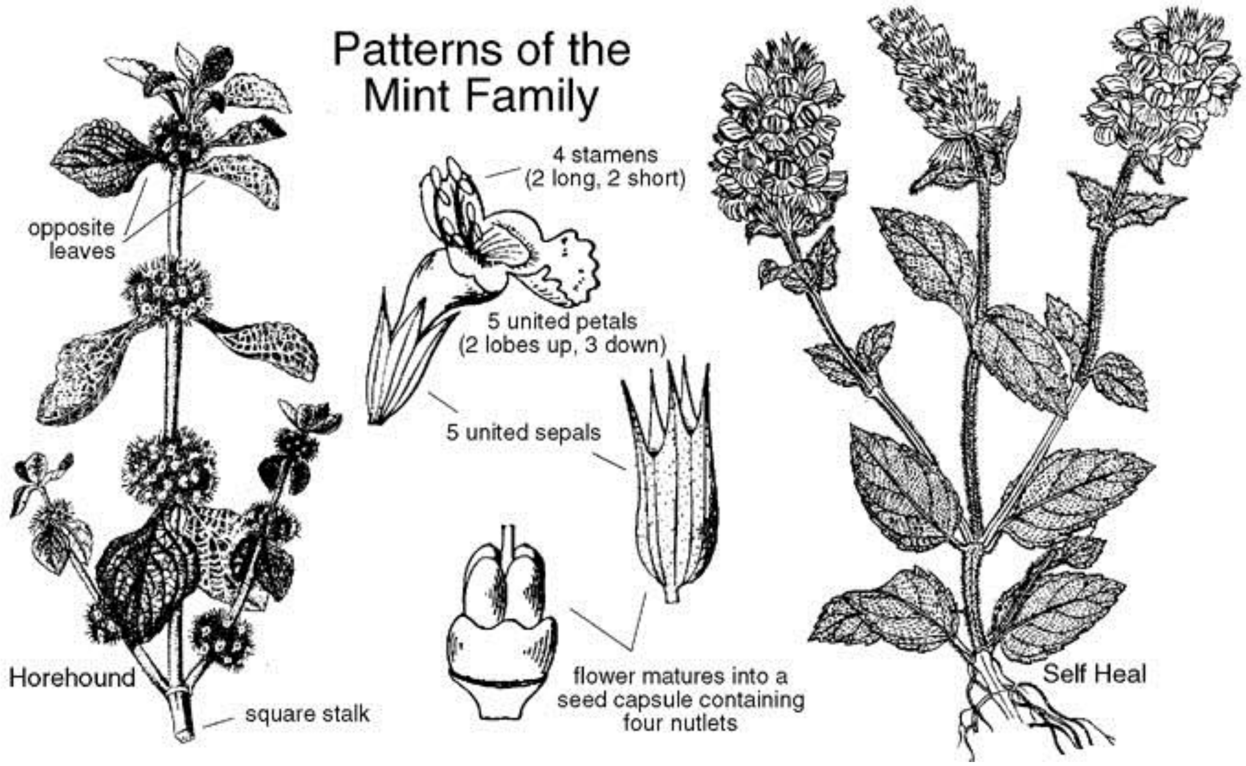

Figure 28: Commonly observed characteristics of family Lamiaceae/Labiatae (Mint family). Source: http://www.wildflowers-and-weeds.com/Plant_Families/Lamiaceae_pics/Lamiaceae.jpg

Figure 27: Spearmint (*Mentha spicata*) leaves. Spearmint is one of the most important species under genus Mentha L. Source: http://content65.eol.org/content/2012/01/25/02/25795_orig.jpg

Finally, the Lamiaceae family of flowering plants narrows down to the *Mentha L.* or mint genus of plants. This shall be the main focus of our study in the term paper. *Mentha L.* is different from other genera under Lamiaceae family because it exhibits extensive hybridization and vegetative propagation. The genus itself has four (4) sections: Pulegium, Tubulosae, Eriodontes, and *Mentha* itself

(Tarimcilar, Yilmaz, Daskin, & Kaynak, 2012). True mints fall (square shaped stems, opposite leaves with aromatic features with small flowers that grow in clusters) in the *Mentha* category (Encyclopædia Britannica, 2013).

Part – Wise Classification

Now that the general/overall taxonomical classification of the genus is known to us, it's only imperative that we go into further details about the parts of plants belong to the Mint genus, which brings us to the part – wise classification.

Part – Wise Classification: Leaves

Mentha genus consists of plants with leaves arranged in an opposite manner and per node, there are two (2) leaves along the stem of the plant (New England Wild Flower Society, 2013); their shapes range from oblong (elongated shape with the sides being slightly parallel to each other) to lanceolate (lance – shaped; wider in the middle and pointed near the ends). The color of the leaf usually varies from dark green and gray – green to purple, blue and even pale yellow (Absolute Astronomy, 2013). Also, the leaves may have stalks (like in peppermint i.e. [*M. piperita*]) or stalk-less (like in spearmint which is [*M. spicata*]) (Encyclopædia Britannica, 2013). Mint leaves usually have serrated edges, like tooth. This is with the exception of the 'curly mint' *(M. spicata* variety *crispii),* which has curly leaves as opposed to the usual serrated shape (Enclycopedia of Plants and Flowers, 2010). Also, the leaves are highly aromatic; in fact, the aroma of mint leaves is what helps distinguish between plants of the Lamiaceae family and other families within the same order Lamiales of flowering plants. For example, the Verbena genus from Verbenaceae

Figure 30: Wild Mint (*Mentha arvensis*). Notice the leaves' opposite arrangement and the shape. Source: http://content65.eol.org/content/2009/07/24/03/43465_580_360.jpg

Figure 29: Leaves of Spearmint (*Mentha spicata*); notice the serrated edges. Source: http://newfs.s3.amazonaws.com/taxon-images-1000s1000/Lamiaceae/mentha-spicata-le-jlindsey.jpg

family (U.S. Dept. of Agriculture - Natural Resources Conservation Service NRCS, 2013) has plants with apperances of leaves similar to that of the mint genus in terms of square stems and opposite leaves, but their leaves do NOT have the mint aroma. Same goes for species like *coleus*; the leaves might look similar to mint, but they lack the scent (Elpel, 2013). The leaves of the mint plants differ in their sizes, albeit over a small magnitude; the leaves of the *Mentha arvensis* L. (wild mint) has leaves ranging from two (2) to eight (8) centimeters (cm) long and six (6) to forty (40) millimeters (mm) wide (Montana Plant Life, 2013), similarly, Spearmint (*Mentha spicata* L.) has leaves which are about 2 -7 centimeters long and 0.8 – 2.5 centimeters wide (Montana Plant Life, 2013).

Figure 31: Curly Mint's (*M. spicata variety crispii*) leaves are rather curly than straight, as seen in other mint plants. Curly mint does not possess a strong minty aroma, but it still is a good garnishing ingredient. Source: http://store.wickleinswatergardens.com/menthaaquaticacrispa-curlymint.aspx

Part – Wise Classification: Flowers

Mint flowers usually are seen in Plants of *Mentha* genus exhibit flowers with characteristics not common or typical to other members of the Lamiaceae family (mint family), for they four instead of five fused/united petals. The flowers of the *Mentha* genus have characteristics over a wide range of color, size, orientation, and even structure, and are comparatively smaller than the leaves (EOL - Encyclopedia of Life, 2013). In most cases, however, the flowers range from pale purple to pink or even white colors, among these there are colors such as blue, purple, white, and pink to red (New England Wild Flower Society, 2013); the bright colors are vital to their characteristics, for they invite the insects, which

Figure 32: Flowers of Spearmint (*Mentha spicata*). The important features to note here are the flower colour and arrangement. Source: http://newfs.s3.amazonaws.com/taxon-images-1000s1000/Lamiaceae/mentha-spicata-fl-ahaines-b.jpg

Figure 33: Flowers of Wild Mint (*Mentha arvensis*); notice the arrangement of flowers in ball-like clusters. Source: http://newfs.s3.amazonaws.com/taxon-images-1000s1000/Lamiaceae/mentha-arvensis-fl-mlovit-a.jpg

Figure 34: Flowers of American Wild Mint (*Mentha canadensis*). The flower cluster arrangment is a characteristic property in the genus. Source: https://gobotany.newenglandwild.org/species/mentha/canadensis/

help them pollinate (Science Encyclopedia, 2013). In normal cases, the number of stamens/androecium for tem is (4) which are almost equal to each other and push-out; the anther (part that contains the pollen and constitutes the upper part of the stamen (Eucalypts of Australia, 2013)) is elliptical in shape, with the thecae (plural for 'theca' meaning the covering of pollen sac (GardenWeb, 2002)) are parallel and distinct, and the stigma-lobes are sub-equal (Mentha L., 2013). They are found together in clusters (tight clusters, often giving them arrangements that look like balls, which are spaced along the stem (Morhardt, 2004), which might either have separate whorls (the flowers are

Figure 35: Flowers of Pennyroyal (*Mentha pulegium*). Source: http://content60.eol.org/content/2012/05/23/18/11386_580_360.jpg

Figure 36: A closer look at the flowers of Pennyroyal (*Mentha pulegium*). Source: http://content62.eol.org/content/2012/01/14/02/06282_580_360.jpg

Figure 38: Flowers of American wild mint (Mentha canadensis). Flowers are small and in clusters; source: http://newfs.s3.amazonaws.com/taxon-images-1000s1000/Lamiaceae/mentha-canadensis-fl-ahaines-b.jpg

Figure 37: A closer look at the flowers of American wild mint; source: http://newfs.s3.amazonaws.com/taxon-images-1000s1000/Lamiaceae/mentha-canadensis-fl-dcameron-b.jpg

arranged in false whorls known as 'verticillasters' (EOL - Encyclopedia of Life, 2013)) or occur together (Encyclopædia Britannica, 2013). The calyx (sepals of the flower) are actinomorphic and have five (usually) lobes (Mentha L., 2013). The calyx may be pubescent (have hairs) as seen in water mint (*Mentha aquatica* L.) or glabrous (without hairs) as seen in spearmint (*Mentha spicata* L.) (New England Wild Flower Society, 2013). Here again, the different species under the genus have variations in their features; such as the spearmint (*M. spicata*) grows pink to lilac flowers which has the characteristic scent of mint; similarly, peppermint (*M. piperita*) has reddish lilac – colored flowers which have a stronger scent than spearmint (Encyclopædia Britannica, 2013). The flower symmetry is actinomorphic or radial (more than two (>2) ways that divide the flower evenly), but it is more commonly known to be zygomorphic or bilateral (two ways (2) that divide the flower evenly) (New England Wild Flower Society, 2013). Another notable feature of the mint plants is that they have bisexual flowers (flowers which possess both male (such as androecium or stamens) as well as female (gynoecium or carpels) reproductive parts; they are also called 'perfect flowers' (Cactus Art - The World of Cactus and Succulents, 2013)) (Science Encyclopedia, 2013).

Part – Wise Classification: Fruits/Seed

Figure 39: Fruits of water mint (*Mentha aquatica*). Their apperance is similar to that of nutlets. Source: http://newfs.s3.amazonaws.com/taxon-images-1000s1000/Lamiaceae/mentha-aquatica-fr-kuleuven.jpg

Figure 40: Fruits of wild mint (*Mentha arvensis*). Source: http://newfs.s3.amazonaws.com/taxon-images-1000s1000/Lamiaceae/mentha-arvensis-fr-jlindsey.jpg

Plants belonging to the *Mentha* L. genus have the general dry type of fruits; these, however, do not split up and open when ripe, as commonly seen in horse mint (*Mentha longifolia* L.), water mint (*Mentha aquatica* L.) and ginger/wild mint (*Mentha arvensis* L.); then there are other species in the genus which consist of sterile (not producing fruits) plants, such as American wild mint (*Mentha canadensis* L.), peppermint (*Mentha piperita* L.), and spearmint (*Mentha spicata* L.) (National Herbarium of NSW, 2013). For the plants that bear fruits, these are usually nutlets (a small, nut-like part of a compound [divided into smaller parts] fruit) (GardenWeb, 2013). Each nutlet may contain anywhere from one (1) to four (4) seeds (NatureWatch NZ, 2013).

Part – Wise Classification: Stem

Mentha L. plants generally have stems herbaceous in nature (Conrad, 2013); these are frail and can be broken easily since they do not have the lignified layers of cells which add toughness, as opposed to woody stems seen in trees (Botanical-Online, 2013). Mint plants have stolons/runners or "lateral stems" which forms vast and extensive networks of plants between them (New World Encyclopedia, 2008). Mint plants characteristically have square shaped stems which bear resemblance similar to that of rhizomes [forming roots at the notes and going erect at the apex (GardenWeb, 2013)]; the internodes [distance between two (2) nodes; node is the part on a stem where the leaf is attached to the stem (Mfarrej M. B., Plant Materials BOT-300, 2013)) of the stems vary from normal length (as seen in *Mentha canadensis* L. [American wild mint] and *Mentha*

Figure 41: Stem of American wild mint (Mentha canadensis); notice the hairy stem. Source: http://newfs.s3.amazonaws.com/taxon-images-1000s1000/Lamiaceae/mentha-canadensis-st-atal.jpg

arvensis L.[ginger/wild mint]), to shortened (as seen in *Mentha aquatica* L. [water mint]) (GoBotany, 2013). Apart from the usual stalk-like stem nature, there are anomalies seen in *Mentha* L. genus plants too; for example, *Mentha pulegium* L. (Pennyroyal) has a vine-like stem which helps it to climb on structures; therefore it is categorized as a "creeper" and does not exhibit the usual minty scent seen in the other species of the genus (Encyclopædia Britannica, 2013). The stems too may either have hairs (pubescent) or be devoid of them (glabrous); plants with pubescent stems include species such as *Mentha arvensis* L. (ginger/wild mint) and *Mentha longifolia* L. (horse mint); *Mentha spicata* L. (spearmint), on the other hand, has glabrous stems (GoBotany, 2013).

Figure 42: Stem of spearmint (*Mentha spicata*); notice the lack of stem hairs here. Source: http://newfs.s3.amazonaws.com/taxon-images-1000s1000/Lamiaceae/mentha-spicata-st-ahaines-c.jpg

Part – Wise Classification:
Roots/Allelopathic Nature

The mint plants have roots called rhizomes; the roots grow vast networks among them in a relatively short period of time; this creates a dense area of tangled roots [runners to be precise] in the soil which leaves other plants in the vicinity with little to no nutrients to absorb. For example, both peppermint (*Mentha piperita* L.) and spearmint (*Mentha spicata* L.) can form a five (5) inch thick mat of runners in a matter of weeks, given the space and water (Homegrown, 2010). Due to their nature of indefinitely spreading over an area, they are considered to be invasive to other species of plants. Also, mint plants secret certain chemicals in the soil which make the existence of other plants in the area around them virtually impossible. These growth inhibition chemicals ensure its survival and even domination over other species of plants around; the property is known as allelopathy; therefore, mint plants are allelopathic in nature (Mfarrej M. , 2013).

Figure 43: Mint plants often grow rapidly and develop thick mat-like networks of underground stolons, this leaves other plants in vicinity with scarce resources. Source: http://2.bp.blogspot.com/-5wlkvra-uAk/TVk1soMafwI/AAAAAAAAEjY/s1qzwxwpls4/s1600/Mint37.JPG

Habitat & Growing Conditions

Plants of the *Mentha* L. genus grow in a wide range of habitats; as such, they are said to be cosmopolitan in nature. They are distributed across Europe, Africa, Asia, Australia, and North America; they do well in wet environments with moist soils, since they grow quickly and therefore need more resources to accomplish their needs. Some of the more popular ones in the genus like *Mentha arvensis* L. [wild mint/ginger mint] has a circumboreal distribution (area around the boreal zone of Eurasia [Europe and Asia] and North America; the region includes Canada, Alaska, Russia, and North Anatolia along with northern New England, Michigan, and Minnesota in U.S.A), and are native to the temperate [region of the world lying between tropics and poles] parts of Europe and Eastern Siberia; *Mentha longifolia* L. bears characteristics similar to these, but it is also prevalent in southern Africa (AbsoluteAstronomy, 2013). Some growing conditions, are, however, specific to certain species of mint plants; for example, *Mentha aquatica* L. [water mint] grows well around water or places close to water bodies like shores, springs, ditches, wet meadows, and inland ends of sea inlets, but it can also grow in relatively dry areas in roads and fields; sometimes, a particular species (or sub-species or variety) may have unusual habitats due to deliberate efforts by humans. For example, the species has been extended from North America to South America as a result of it being carried by people due to its usefulness (NatureGate, 2013); similarly, ginger mint has a tendency to grow around old, often deserted areas, for example the border where earlier the division of Finland took place in 1743 between Sweden and Russia is still solely marked by the spread of ginger mint plants. Their vague features often make classification difficult, even for skilled botanists (NatureGate, 2013); likewise, [whorled mint] *Mentha x verticillata* (hybrid between *Mentha aquatica* L. and *Mentha arvensis* L.) is mainly found along the banks of waterways (NatureGate, 2013) . This list goes on.

Diseases and Vulnerabilities

While the mint genus plants are excellent dominators in their area thanks to their invasive nature, they are still susceptible to some pests and agents which can be severely detrimental to their development, if left unchecked; some of the more common diseases have been listed and explained in brief below:

1. *Verticillium* wilt (strain *Verticillium albo – atrum*)

   Verticillium wilt is a fungal infection which eats away at the leaves of the mint plant and causes them to lose their color and photosynthetic properties; the beginning starts with the leaves at the apex turning from green to yellow to bronze, followed by their change in shapes straight to twisted or curved; the plant does not receive enough organic food due to lack of green leaves to perform photo-synthesis. This will affect the growth of the plant, stunting it. The lack of food causes the remaining leaves to turn brown and eventually fall off; subsequently, the entire plant dies. It is important to note that a particular strain of *Verticillium*, *Verticillium albo – atrum,* is harmful for mint genus plants; it doesn't affect other genera as severely. Even after the plant dies, the fungus still persists in the soil; this is why once the mint plants get affected in a certain part of land, that land is declared as unfit for any more cultivation over an indefinite period of time. (Maloy & Skotland, 2013). *Verticillium* wilt's main process of infection is through infected plants; often it happens that among dense patches of the land, the symptoms aren't easily seen [since they happen gradually; the leaves at first turn dull green from green, for instance] (Maloy & Skotland, 2013). If an infected plant is introduced in a new piece of land, then the fungus spreads rapidly over that area through the soil into the roots; therefore, the

Figure 45: Reddish colored peppermint leaves; notice the loss of green color of their leaves and their disfigured nature. Source: http://www.apsnet.org/edcenter/intropp/lessons/fungi/ascomycetes/Article%20Images/VerticilliumWilt03.jpg

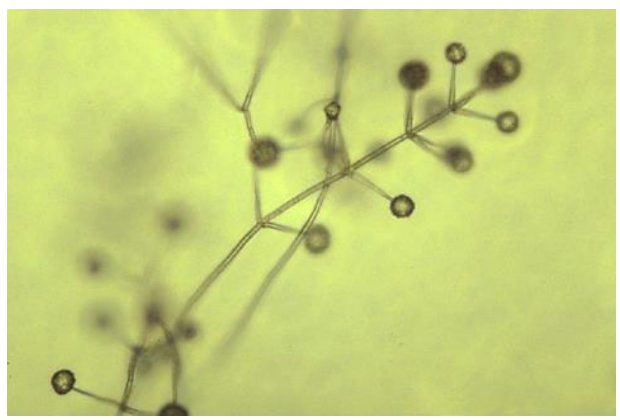

Figure 44: *Verticillium* under microscope. Seen in this picture is the long segment known as hyphae, from which branches called 'conidiophores' arise in opposite directions, each conidophore as a bunch of phialide arranged in a whorl, each of which contain conidia (fungal spores). Source: http://www.cals.ncsu.edu/course/pp728/alboatrum/Verticillium_albo-atrum.html

land is wasted. *Verticillium* is so named due to its phialides which form whorls (or verticillates) Once the *verticillium* wilt has started, there is no way known to stop or mitigate its damages; preventive measures can be taken to ensure that the soil stays fungi – free and that plants (if any) are brought from certified lands, so that they aren't infected. The mint plant most affected by *verticillium albo – atrum* is *Mentha pipertia* L. (peppermint) and the plant resistant to it is *Mentha spicata* L. (spearmint); other species show variable amounts of damage to it; however, in the long run, the fungi ultimately kills the plant if left unchecked (VanSickle, 2013).

2. Powdery Mildew

Another fungal infection observed commonly in the *Mentha* L. genus; powdery mildew is caused by the fungus *Erysiphe cichoracearum*. Compared to *verticillium albo – strum*, this disease is relatively easier to identify; if a mint plant has a white (sometimes, the color of the dust may be gray or even black (VanSickle, 2013)), powdery – coating of some substance on its stem and leaves, it's most likely suffering from powdery mildew; if the disease is severe, the fungus will kill the leaves, turning them yellow and eventually be shed by the plant (Maloy & Skotland, 2013). The plants at the biggest risk here are peppermint plants (*Mentha piperita* L.), for the fungus specifically targets them more than other species; this is thought to be because, in the winter months, the peppermint plant provides all the resources the fungus needs to survive (VanSickle, 2013).

Figure 46: Powdery mildew on leaves of *Monarda* (Bee Balm). Source: http://www.obsessiveneuroticgardener.com/2013/09/powdery-mildew-on-monarda-bee-balm.html

The disease in most cases, isn't severe or contagious enough to cause large – scale damage, but still regular check-up of the soil helps keep things under control (Maloy & Skotland, 2013). In case there's mildew already on a mint plant, the easiest and most readily available solution is to remove the affected parts of the plant and expose the plant to bright sunlight in a well – circulated environment. Extreme

Figure 47: Powdery mildew as seen on leaves of mint plants. Source: http://www.allposters.com/-sp/Powdery-Mildew-Erysiphe-Orontii-Infection-on-Mint-Leaves-Posters_i6017003_.htm

cases can be treated with sulfur; however, doing so renders the plant unfit for any kind of use or consumption (VanSickle, 2013).

3. Mint Stolon Decay

   This mainly occurs to mint plants in the muck soils; stolons present in the transition zone of warm and frozen/extremely cold soil are susceptible to the growth of white molds. Eventually, the stolons infected become brown – black colored and eventually die out; causing the entire plant to collapse. This is a fungal infection as well which happens mainly due to the action of *Rhizoctonia* and *Sclerotinia* species (Lundy, Grey, & Rivera-Smith, 2013).

4. Black Stem

   Black steam disease is caused by *Phoma strasseri,* a fungal pathogenic organism that mainly affects plants. The stem of the mint plant(s) are targeted and affected in this disease; high humidity and rainfall during winter and early spring are ideal conditions for the fungi to infect the host plants. Characteristic symptoms of the disease include black cankers and lesions on the stems and rhizomes (Lundy, Grey, & Rivera-Smith, 2013).

Figure 48: Peppermint plant infected with the black stem/rhizome rot disease, caused by fungi *Phoma strasseri*. Source: http://www.science.oregonstate.edu/bpp/Plant_Clinic/images/peppermint,%20phoma08-0919.jpg

5. Mint Rust

   Rust is a common disease seen in a variety of plants spawning across an array of genera, families, and classes. *Mentha L.* genus is no exception; rust is again a fungal infection caused by the fungus named *Puccinia menthae* (Royal Horticultural Society , 2013). Conditions that favor the growth of the fungi on the plants is a humid environment with excess water in the soil and not enough sunlight and a lack of air circulation (VanSickle, 2013). The symptoms of rust continue from spring till autumn; they are first observed early in spring season, and then steadily degrade the plant if left

Figure 49: Mint plant affected by mint rust; notice the fungal infection on the stem. Source: http://apps.rhs.org.uk/advice/ACEImages/SCN0000193_976019.jpg

unchecked. In the first stage, the leaves of the plant display light yellow colored pustules; once they mature and develop, they break open, releasing spores known as 'aeciospores', these then infect the young and developing leaves, killing them. Infected plants lose their flexibility and become brittle, making them susceptible to breaking off easily. As summer passes, the leaves and stems develop brown lesions (cinnamon – brown), mainly on the underside of the leaves. Both ways, the leaves die and fall off from the plant; and a plant without functional leaves can do little than wither away due to lack of nutrients. In the terminal stage of fall, the spots turn from brown to black; along with this black spores (teliospores) might also be seen on stems and leaves. Following this stage, the plant dies and new infections spread by pores to nearby plants. There are two different kinds of rust (caused by the same fungus though) which affect *Mentha piperita* L. [peppermint] and *Mentha spicata* L. [spearmint]; the types are mutually exclusive in nature. Spearmint is a little more susceptible to mint rust than peppermint for various reasons; the other species such as wild mint and water mint are more seen in the wild, and so are not as vulnerable. In any case, prevention is the best option; plants which show early symptoms such as light yellow blisters must be dealt with by killing the first

Figure 50: Mint rust symptoms seen on a peppermint leaf. Source: http://mint.ippc.orst.edu/images/mintrust.jpg

Figure 51: A closer look at the pustules formed due to mint rust on the surface of the leaves. Source: http://www.forestryimages.org/images/768x512/2174049.jpg


Figure 52: Mint rust (*Puccinia menthae*) on leaves of Horse mint (*Mentha longifolia*). Source: http://www.naturefg.com/images/b-fungi/puccinia-menthae.jpg

shoots which can be seen in the beginning of the spring season; this can be done both by flaming and contact herbicides (Maloy & Skotland, 2013). If this isn't possible, then the affected plants must be immediately removed from the area before the spores can spread to neighboring plants; however, if the black spores are visible or have been formed, then there is a good chance that the soil also has been contaminated. In this case the only option is to search carefully and dig out unaffected rhizomes (roots) and plant them to a new location and start anew. The flame treatment suggested earlier is nowadays often not a viable choice, for the money could be simply expended for new plants (Royal Horticultural Society , 2013). In dire cases, sulfur fungicides can be used to kill the rust, but like all cases, it is not safe anymore for consumption, so the only time when this measure may be used is when the plants serve more of an ornamental value than culinary (VanSickle, 2013).

6. <u>Parasitic Nematodes</u>

Parasitic nematodes are quite potent as parasites and are counted as one of the main reasons as to why mint plant harvests fail each year.

Nematodes are a very diverse group of multicellular (having more than a single cell), invertebrate organisms; there are more than fifteen thousand (15,000) species worldwide, out of the total estimated two hundred to five hundred thousand species (200,000 – 500,000). They can survive within a large range of environments. Fifteen percent (15%) of them are parasitic to animals, 10 percent (10%) to plants, twenty – five percent (25%) are found freely in soil and freshwater [although these are beneficial, especially to the soil; they help in retaining the soil's fertility], and fifty percent (50%) are marine i.e. found in seas and oceans. Their diets include

Figure 54: Dagger nematode (*Xiphinema*); it is up to 5 mm long and is classed under migratory ecto-parasites. Source: http://ocid.nacse.org/nematodes/images/xiphinema.JPG

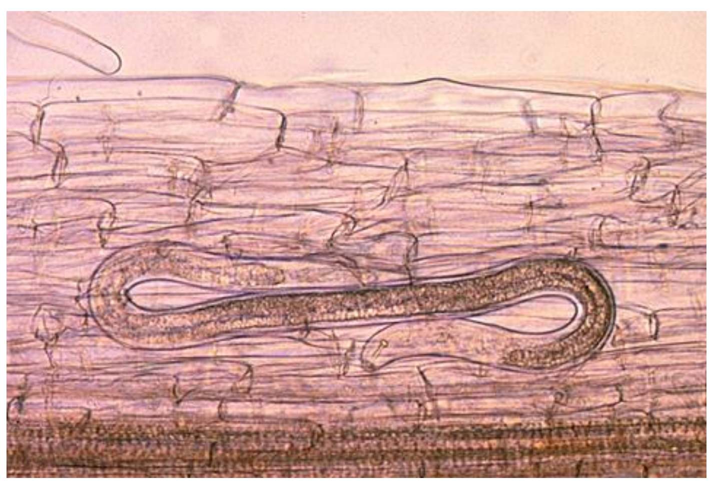

Figure 53: A root-lesion nematode inside the root tissue of the plant. Source: https://www.apsnet.org/edcenter/intropp/lessons/Nematodes/Article%20Images/LesionNematode02.jpg

bacteria, fungi, diatoms, and algae. Those parasitic in nature feed on the host organism, be that an animal or plant. In case of animals, they particularly dwell in an organ of the body and feed from there, but for plants, they can absorb nutrients from any part of the plant. As opposed to annelids [phylum of "ringed worms" in kingdom Animalia], nematodes are un-segmented worms which have developed digestive, reproductive, and nervous systems. They do not have a circulatory or respiratory system, however. The lengths might be anywhere between 0.003 in. to 27 feet; plant – pathogenic nematodes range from 0.01 – 0.22 inches. The reproduction takes place through two (2) methods: amphimixis [when males and females mate], and parthenogenesis [happens in absence of males; females fertilize females, in this method, males aren't necessary]. In plant nematodes, they are differentiated by their location and feeding behavior. Based on location, they are classified as either ecto-parasites [nematode remains outside the plant tissues] or endo-parasites [nematode enters the plant tissues], and based on their feeding behavior, they are classified as either migratory [move around in their environment], or sedentary [stay in one location or habitat throughout life]. Crossing the two factors, four types of plant parasitic nematodes can be obtained:

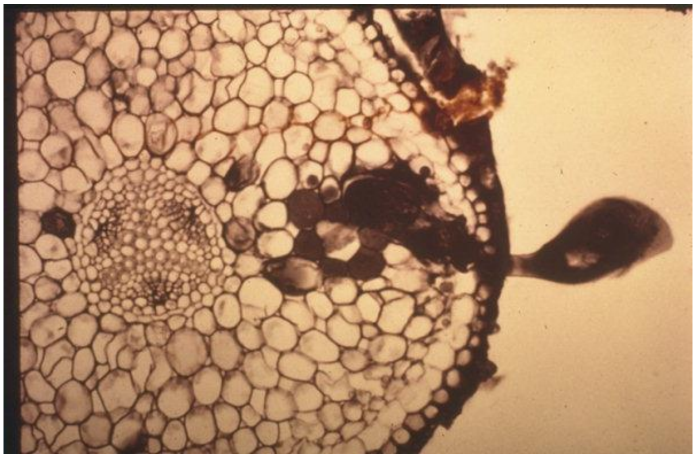

Figure 55: A female citrus nematode with the head inside root tissue and body jutting out. Source: http://www7.inra.fr/hyppz/IMAGES/7033330.jpg

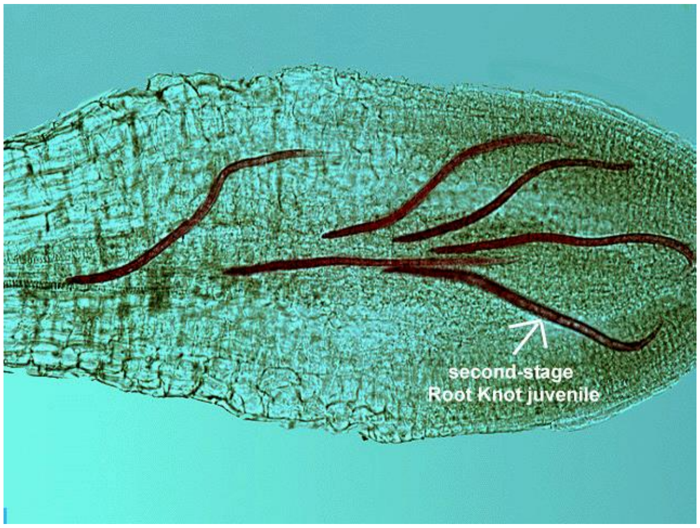

Figure 56: A root-knot nematode juvenile inside root tissues of tomato plant. Source: http://nematology.umd.edu/images/eis145.gif

a. Migratory Ecto-parasites:
   They do not enter the root plant tissue, but remain outside it while moving from cell – to – cell as a part of their feeding behavior. Example: dagger nematode (Department of Botany and Plant Pathology, 2010).
b. Sedentary Ecto-parasites:

The head of the nematode enters the root tissue before it starts feeding, but the rest of the body remains outside, showing no movement. Example: citrus nematode (Department of Botany and Plant Pathology, 2010).

c. Migratory Endo-parasites:

They tunnel their way through the root tissues of the plant and move freely after getting in, both between new roots and the soil. Example: root-lesion nematode (Department of Botany and Plant Pathology, 2010).

d. Sedentary Endo-parasites:

The nematode penetrates the root tissue and enters it fully; once in, it designates a specific site from where it feeds on. Female nematodes cause the roots to rupture as they grow bigger; eventually, the eggs are released. Example: root – knot nematodes and cyst nematodes (Department of Botany and Plant Pathology, 2010).

WORLD'S MOST IMPORTANT PLANT-PATHOGENIC NEMATODES

Common Name	Genus	Life Cycle Strategy	Weighted Importance Ranking
Root-knot	*Meloidogyne*	Sedentary Endoparasite	1375
Root-lesion	*Pratylenchus*	Migratory Endoparasite	782
Cyst	*Heterodera*	Sedentary Endoparasite	606
Stem & Bulb	*Ditylenchus*	Diverse Strategies	251
Potato Cyst	*Globodera*	Sedentary Endoparasite	244
Citrus	*Tylenchulus*	Sedentary Ectoparasite	233
Dagger	*Xiphinema*	Migratory Ectoparasite	205
Burrowing	*Radopholus*	Migratory Endoparasite	170
Reniform	*Rotylenchulus*	Sedentary Ectoparasite	142
Spiral	*Helicotylenchus*	Migratory Ectoparasite	122

Figure 57: Some of the world's most important (and damaging) plant-pathogenic nematodes. Source: http://bpp.oregonstate.edu/files/bpp/webfm/pdf/bot350~/Lecture%2025-%202012.pdf

To give an estimate of how damaging they can be, a survey conducted at the Oregon State University from leads all over the world brought forth the conclusion that each year, one hundred billion ($100,000,000,000) worth of harvests are lost worldwide due to the detrimental effects of the tiny multicellular organisms (Department of Botany and Plant Pathology, 2010).

Returning to the effect of parasitic nematodes on mint plants, there are three (3) main nematodes known to be especially harmful to the *Mentha* L. genus; these are the root – knot nematode (*Meloidogyne hapla*), root – lesion nematode (*Pratylenchus minyus*), and the pin nematodes (*Paratylenchus hamatus*). All three (3) nematodes cause stunted growth with unhealthy appearances in the plants they infect. Out of the trio, the most dangerous nematode seems to be the root – knot nematode, since it has the ability to infect a wide range of hosts; it is easily recognizable due to the galls (small, white colored swellings found on the roots of the infected plants; these are thought to be produced by the female nematode and contain eggs which hatch into larvae); the root – lesion nematode on the other hand, is only dangerous because it makes the mint plant much more susceptible to the effects of *Verticillium albo – atrum;* plants affected with the root – lesion nematode start showing the symptoms of *verticillium albo - atrum* much earlier and the effects are way more severe (Maloy & Skotland, 2013).

Managing nematodes is difficult, mainly because of nematodes like root – knot nematodes which can infect a variety of crops; crop rotation is often not a viable option for this reason. However, careful planning where resistant varieties are included can help reduce the potency of nematodes. Susceptible plants such as those of the *Mentha* L. genus can be grown after a period of growing non-susceptible crops, such as tomato varieties with VFN (*Verticillium, Fusarium*, and Nematodes) are great for nematode – susceptible soils; therefore, crop rotation in which one season VFN tomatoes are grown and the next goes for mint plants is a feasible idea of keeping the nematode invasion in check. The best strategy would be to provide sufficient sunlight and air/water to the plants such that the nematodes aren't given favorable conditions to breed; it also helps to buy saplings from certified nurseries which are free of nematode infestation (UC IPM Online - Statewide Integrated Pest Management Program, 2010). Soil fumigation is a costly alternative, but it still works very well to curb the invasion once it has started (Maloy & Skotland, 2013).

7. <u>Excessive Salinity</u>

There are ideally two (2) types of plants: the ones which can withstand salinity and the ones that cannot; the ones that withstand soil salinity either do so by salt – inclusion or salt – exclusion (Sykes, 1992); salt – excluders can give out salts from the whole plant or from certain organs; in these kind of scenarios, the selectively permeable membrane absorbs potassium ions (K^+) over sodium ions (Na^+); as a result, the excluder crops have low sodium and chlorine ion (Na^+) and (Cl^-) concentrations. Salt – acceptor plants, on the other hand, either seem to have resistant cell membranes which remain unaffected by high levels of salts, or they discard the excess salts entering the plant, although the salt ions can be taken up by their roots (Badr & Shafei, 2002). In most cases, faulty irrigation techniques result in the excessive build-up of salts in the soil; mint plants aren't able to withstand high soil

Figure 58: A leaf from the soyabean plants showing the symptoms of what is known as the "salt injury". Notice the wilting of the leaves and discoloration. Source: http://louisianacrops.com/wp-content/uploads/2012/06/Salt-injury_12.jpg

salinity levels, and as such are killed due to salt deposits when they occur in the soil at the bed of the mint plants (Maloy & Skotland, 2013).

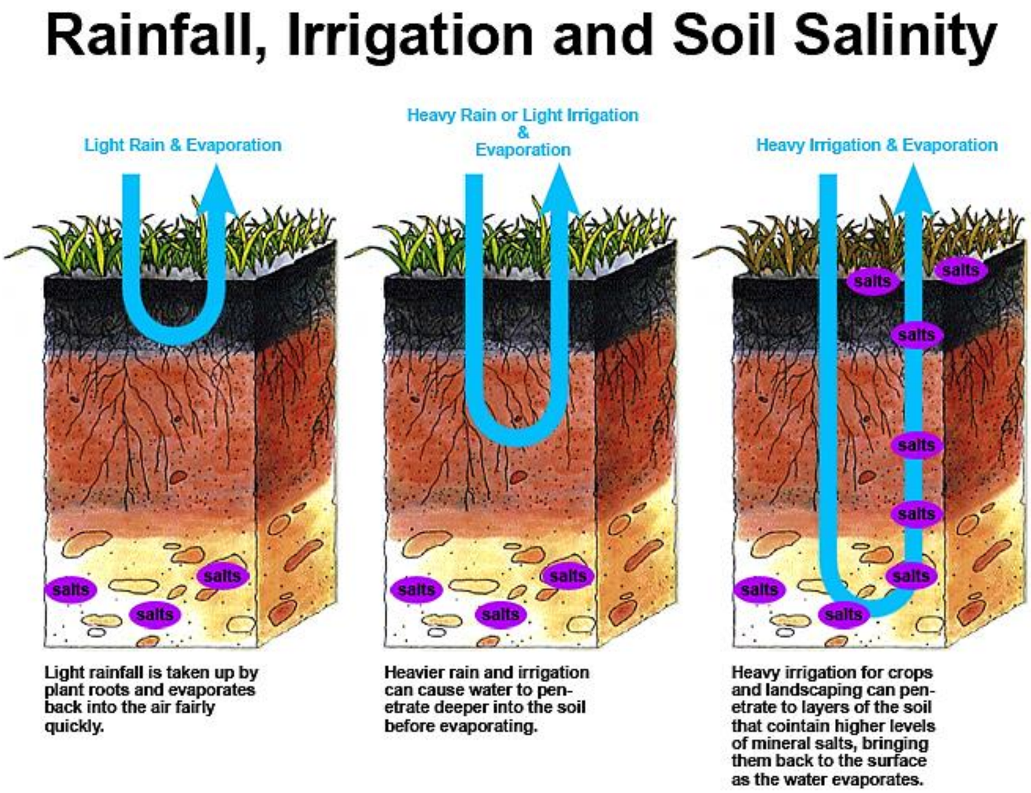

Figure 59: An illustration showing how irrigation can contribute to increased soil salinity. Source: http://www.biosci.ohio-state.edu/~plantbio/osu_pcmb/pcmb_lab_resources/images/pcmb101/soilSalinity/SoilSalinity_watermovement.jpg

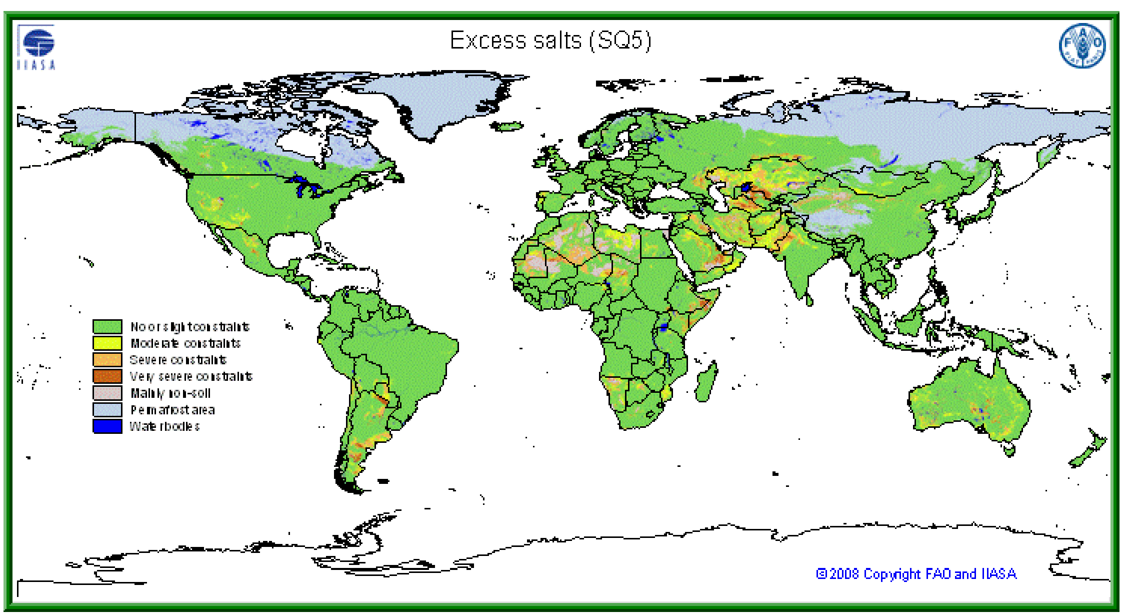

Figure 60: A map showing the regions with different levels of excess salt concentrations (levels go down the legend). Source: http://www.fao.org/fileadmin/templates/nr/documents/HWSD/soil_quality/SQ5.gif

Economic Importance of Mint

Mint is also very important in terms of trade and economy; every year, the amount of oils extracted from the four major species under *Mentha* L. (including peppermint, spearmint, scotch spearmint (*Mentha* x *gracilis*), and corn mint) exceed $400 million (Lawrence B. M., 2006)Since old times, the *Mentha* L. genus has been a genus of vast economic importance due to its immense versatility. Its plants play a significant role in the world's economy, particularly in the market of essential oils. For instance, peppermint (*Mentha* x *piperita* L.) is one of the plants of great economic importance due to its main components being methanol and menthone (Gul, 1994); the oil of peppermint is used in many industries for flavoring and pharmaceutical companies for oral drug/medicine preparations; on a smaller scale, Japanese mint, Scotch spearmint, and bergament mint are used for their essential oils as well. Similarly, corn mint is also used as a rich source of natural menthol (Sharma & Tyagi, 1991) [it might be useful to note that corn mint is cultivated solely due to the oil that it gives (Small, 1997); species like *Mentha spicata* L. [spearmint] are rich in carvone and are widely used for spices, therefore being cultivated on a large scale in several countries (Aflatuni, 2005). In 1984, China produced ~1700 and the United States of America produced approximately 3000 tons of mint oil for export (Lawrence B. , 1985). The United States of America is one of the largest producers of mint oil worldwide; having exported eight thousand five hundred (8,500) tons of mint oil in year 2002 – 2003, India too is a major exporter of mint oils (Raja & Arockiasamy, 2008). In 1984, the total mint productions summed up to: 2.2 Mtons of peppermint, 2.1 Mtons of corn mint, and 1.4 Mtons of spearmint (Lawrence B. , 1985).

Culinary Uses

Out of the different species of *Mentha* L., the two most widely used species of mint in cuisines are *Mentha piperita* (peppermint) and *Mentha spicata* (spearmint). Also, different countries use them in different ways; for example, in the United States, peppermint is mainly used to add flavor to desserts, such as mint syrup, mint tea, and peppermint cream [served with hot chocolate]; confectionary such as peppermint cookies and candies are quite popular as well. Some of the major chewing gum companies such as Wrigley's, are

Figure 61: Albondigas, a Mexican speciality. Mint leaves are used for garnishing as well as flavor. Source: http://www.weheartfood.com/wp-content/uploads/blogger/_aR7uIk5VS2Y/R4G3ST6tKEI/AAAAAAAACD0/cipf55PQf-c/s1600/seafoodalbondigassoup.jpg

based in U.S.A and primarily use peppermint oil for making mint chewing gums. In Mexico, mint [*Mentha piperita* or *Mentha spicata*] is used for a soup, known as '*albondigas*'. The Brazilian cuisine makes extensive use of peppermint for its omelets, crackers, sauces, and even meats; traditionally, meat cutlets or other meat dishes are served with mint jelly, known as "*geléia de hortelã".* In Austria, big dumplings, stuffed with cheese, potatoes, and a number of different herbs, called "*Kärntner Kasnudeln"* counts in peppermint and spearmint as a vital ingredient. The British are known for their ingenious variety of potato and pea – containing dishes which have a fine taste of mint, along with some of the earliest peppermint candy factories back then; they used mint sauce mainly for dressing lamb dishes. In France, since medieval times, crushed peppermint was used as the main ingredient for making *"saumon à la Humbertier*", or poached salmon. *Pfefferminzlikör*, is a cordial immensely popular in Germany, is prepared from peppermint. There are many German brands known for their flavorful peppermint schnapps [German term for strong, alcoholic beverages], such as Rumple Minze®. In Greece, since ancient times, mint is primarily used for a lot of different foods; in fact, as mentioned before, the Greek cuisine revolves around the usage of mint plants, primarily due to their enormous significance in the Greek mythology [see Section-1]; a pie dish known as *"hortopitta",* primarily served in with spinach and rice, also includes mint. Along with this, the famous Greek variety of cheese, *haloumi,* also has mint. Italians used peppermint leaves [dried] as spices and condiments. Scottish folk are renowned for their *Jeddart snails* [dark brown toffees], and *cheugh* [chewy] toffees, made from peppermint. The Chinese use young shoots of peppermint for tea flavoring and also in the kitchen as spices. The world – famous Indian chutney, is prepared from Pudina [Hindi name for peppermint]; it is served with a wide assortment of fried snacks and local delicacies; mint also finds itself in the South Indian recipes such as coconut chutney [which is served with Idlis (or steamed rice cakes)]; In the MENA (Middle East and North Africa) region, mint is used mainly to complement dishes containing falafel [Middle Eastern delicacy prepared from fava beans], in form of fillings, or yogurts, and also for dressing salads and dishes containing eggs and meat (Natural Standard -The Authority on Integrative Medicine, 2011).

Figure 62: Peppermint oil capsules are sold as over-the-counter medicine. Source: http://www.helpforibs.com/shop/suplmts/pepcappic.asp

Medicinal Uses

Mint has innumerable uses when it comes to health and medicine; as previously mentioned in the report, traditionally, before synthetic medicines were brought into existence, men relied on herbal remedies to cure their ailments. Even today, a large number of pharmaceutical companies dedicated a section of their infrastructure and funding to botanical research centers in attempts to exploit the immense versatility of *Mentha* L. Mint oils are of prime importance in cough syrups and lozenges due to their cooling and throat – soothing properties. Tablets containing peppermint extracts are sold in the market today for those with digestion problems, for they cure and relax the sphincter muscles. Mint oils also possess antibacterial and antiviral properties (The Romanian Mint Rubbing Association, 2004).

Figure 64: Peppermint oil is a widely used ingredient in many medicines. Source: http://www.buzzle.com/articles/how-to-make-peppermint-oil.html

Figure 63: Mint oils are also used to prepare medicinal lozenges such as cough drops. Source: http://www.walmart.com/ip/Fishermans-Friend-Menthol-Cough-Suppressant-Lozenges-Sugar-Free-Refreshing-Mint-6-Pack/26967271

Figure 66: Peppermint oil is used for cough syrups as well. Source: http://www.yumtrade.com.sg/shopexd.asp?id=1453

Therapeutic Actions

Figure 65: Popular over-the-counter pain relieving medication such as Tiger balm also contains menthol (organic compound derived from mint). Source: http://www.st-sm.com/07SM/en/pain-relieving-ointment-/114-tiger-balm-ultra-strength-white-194g-8851990210298.html

Mint leaves have analgesic [painkiller], anti-inflammatory [reduces inflammation (body's attempt to fight back foreign microbes during an injury; causes symptoms like redness, pain, heat, and swelling), and anti-ulcer properties, they are nerve strengthening, and also have digestive properties. Apart from this, they help the gastrointestinal (GI) tract stay healthy, dissolve gall stones, reduce the chance of acid reflux, and kill several micro – organisms such as (Candida albicans, Herpes simplex, Influenza A virus, Mumps virus, Pseudomonas acruginosa, Streptococcus pyogenes, and Staphylococcus aureus) (The Romanian Mint Rubbing Association, 2004).

Case Study under Focus

Identification, detection and transmission of a new vitivirus from *Mentha*

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Objectives & Aim

Though *Mentha* L. enjoys a great deal of importance in many aspects of our life, it remains highly vulnerable from many different agents [biotic and abiotic] found in the environment [see Diseases and Vulnerabilities]. From these, although many fungal pathogens have been subjected to extensive research and study, viral pathogens have received comparatively less attention, and even out of these most pertain to concluding the known fact of mint being a host to many viruses. The research under analysis was an attempt to find out more about the viruses which infect the mint

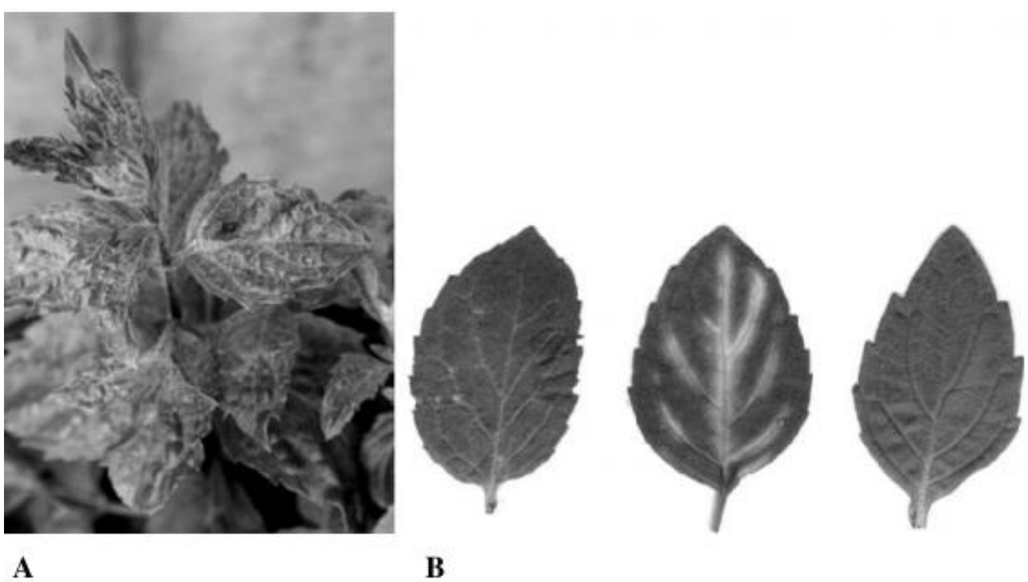

Figure 67: A shows the crinking symptoms seen in the leaves of Oregon Ginger Mint [OGM], while B compares the symptoms of OGM and GGM; the left leaf shows symptoms on OGM, middle of GGM, and right of a virus-free variation of ginger mint [ginger mint NCGR 454.002]. Source: http://link.springer.com/article/10.1007%2Fs00705-007-1030-1

plants, by using their phenotypic symptoms as clues, mainly in *Mentha* x *gracilis* 'Variegata' [also known as 'golden ginger mint'], where viral infection produces phenotypic symptoms perceived as ornamental (Tzanetakis, Postman, & Martin, 2007).

Current Scenario & Justification

Golden ginger mints display bright – yellow vein bands which are lost to the environment after summer months and eliminated after heat therapy [also known as thermotherapy in plant virology; generally used for virus eradication for plants such as strawberry and citrus; plants are heated in growth chambers at high temperatures, which when combined with meristem culture, helps separate the virus (Information Technology Unit, 2001)]. Those have given rise to further study of virus's set of causes or factors that trigger the infection. In this process, three viruses were identified in the golden ginger mint (GGM); six more clones were acquired to help better correlate the virus with its symptoms; however, one clone brought in from an Oregon nursery did not show the typical symptoms [such as the vein bands, as was evident in the other golden ginger mint clones]. This golden ginger mint was termed as Oregon Ginger Mint [OGM]. The OGM had distorted leaves, but no bright yellow vein banding. So, investigation of which other viruses caused the symptoms seen in the OGM was the main justification for the report.

Materials & Methods

Two viruses were identified in the experiment, which belonged to the Closteroviridae family, named 'mint-virus-1 [MV-1] and Flexiviridae family, termed 'mint-virus-2' [MV-2].

Virus purification and electron microscopy

MV-2 was purified by the Martin and Bristow method; the virus was then negative stained with 2% of molybdenum acetate which helped to visualize the virions [refers to a single, whole virus particle; it consists of an outer protein shell, known as 'caspid' which covers the inner core that has either ribonucleic or deoxyribonucleic acid. The core gives the infective property to the virus, while the shell assigns a specific location for the same (Encyclopædia Britannica, Inc., 2013)].

Nucleic acid extractions and cloning

The double – stranded RNA [dsRNA] isolations were cloned. During this process, recombinant plasmids were identified through the help of polymerase chain reactions (PCRs) through *Taq* polymerase [a polymerase isolated/acquired from thermophilic bacterium *Thermus aquaticus*. Thermus aquaticus is a bacterium which lives in hydrothermal vents and hot springs; it was first isolated by Thomas D. Brock in year 1965; it is used in polymerase chain reactions for amplifying short segments of DNA (Chien, Edgar, & Trela, 1976)] and M13 forward and reverse primers [a primer is a simple strand of nucleic acid that initiates a DNA synthesis; they are needed for DNA replication (TheFreeDictionary, 2000)]. The sequencing of plasmids was done in an ABI3730 XL automatic DNA sequencer. Following this, the MV-2 sequence (initially deposited in Genbank) was acquired as mentioned for mint vein banding virus (Tzanetakis, Postman, & Martin, 2007).

Detection

MV-2 was detected the same way/through same procedures as MV-1. Primers used for detection were MV-2F (5' CCAGCAGACTTACAACTTGGT 3') [where C stands for Cytosine, A for Adenine, T for Thymine, and G for Guanine; they are the constituent bases of DNA], and MV-2R (5' TGGGGTCCGAATCTACATAGCA 3'), that amplified a certain polymerase in the virus. There was a forward and backward primer; the forward primer was (5' GGACTCCTGACGTATACGAAGGATC 3') and the reverse primer was (5' AGTAGATGCTATCACACATACAAT 3'), these two (2) primers were special in the sense that they allowed the amplification of polymerase than normal scenarios. Those primers, also known as 'internal control primers' have been previously used with many plant genera such as *Rubus*, *Ribes*, *Fragaria*, and *Vaccinium* (Tzanetakis, Postman, & Martin, 2007).

Transmission Studies

For the study, a total of thirteen (13) herbaceous plant species - Chenopodium, Ch. Amaranticolor, Cucumis sativus, Nicotiana benthamia, N. tabacum, N. occidentalis, Phaseolus vulgaris, Tetragonia tetragonioides, Vigna sinesis, Brassica rapa, Spinacia oleracea, Capsicum capsa, and Gomphrena globosa and a virus-free clone of *Mentha* x *gracilis* were implanted with tissues obtained from Oregon Mint Ginger through mechanical means. Out of these, five (5) herbaceous plants and fifteen (15) plants of the Oregon Ginger Mint (OGM) were checked and analyzed for the presence of MV-2 (Tzanetakis, Postman, & Martin, 2007).

To derive conclusions, mint aphids (*Ovatus crataegarius*) were allowed to feed on the leaves of the Oregon Ginger Mint (OGM) or other MV-2 infected for the period of a week. Following which, ten (10) aphids from the Oregon Ginger Mint (OGM) and twenty (20) aphids from the other MV-2 infected plants [sampled earlier] were taken and transferred into virus-free clones of golden ginger mint [*Mentha* x *gracilis*] for a week to allow the virus to spread into their systems, this was done prior to treating them with a systemic insecticide. Five (5) plants of OGM were selected for four (4) trials and ten (10) plants from the other MV-2 infected plants were taken for two (2) trials; this was done in order to find out the effects of the pesticide applied earlier (Tzanetakis, Postman, & Martin, 2007).

Genome analysis

Open reading frames (ORF) acquired and encoded by the MV-2 were studied and identified by the help of FGENESV0 and ORF finding software, such as http://www,softberry.com and http://wwww.ncbi.nlm.nih.gov/gorf/gorf.html along with multiple sequence alignment programs used for both deoxyribonucleic acids [DNA] and proteins, such as ClustalW2 - http://www.ebi.ac.uk/Tools/msa/clustalw2/ [Now Clustal Omega] (Tzanetakis, Postman, & Martin, 2007).

Results and Observations

Virus analysis

The purification of the MV-2 after negative staining revealed virus – like particles under the electron microscope; the virions' width is recorded to be of around 13 nanometers [1 nanometer = 10^{-9} meters], the length was variable, though the longest virions were about 550 nanometers long (Tzanetakis, Postman, & Martin, 2007).

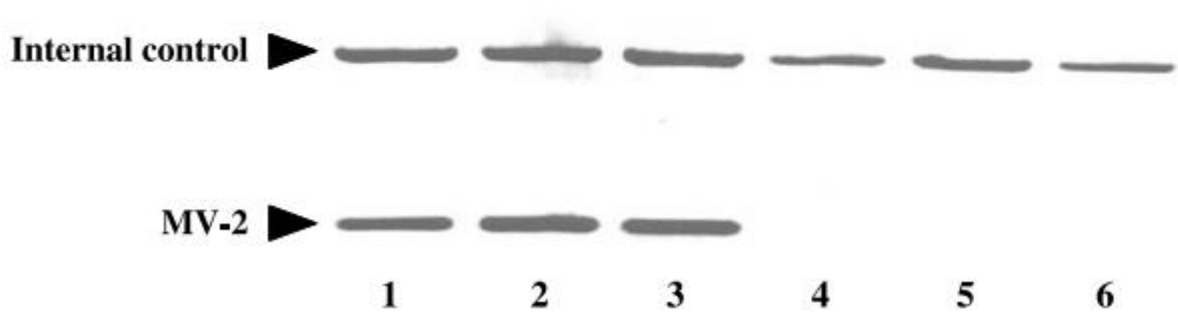

Figure 68: The reverse transcription PCR used for detection of MV-2. The (1) in MV-2 represents OGM, 2 and 3 represent plants infected with MV-2 subsequent to aphid transmission from OGM, 4 is for MV-1 infected plant, 5 is the mint banding associated with the plant infected by virus, and 6 is the NCGR 454.002 (healthy control) plant. [Notice that 4, 5, and 6 are only seen in the internal control band]. Source: http://link.springer.com/article/10.1007%2Fs00705-007-1030-1

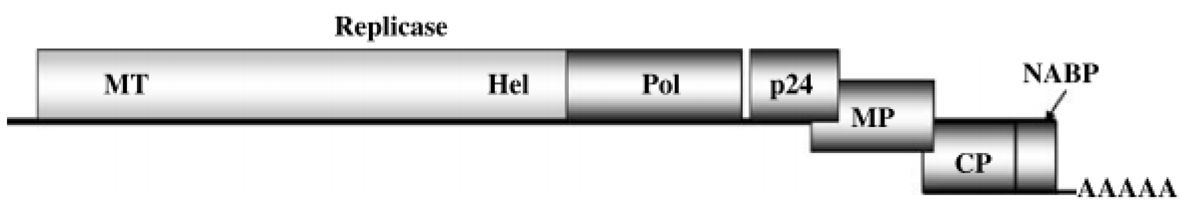

Figure 69: Genomic organization of MV-2. The darker region shows sequenced region; MT represents the Methyltransferase, Hel stands for helicase, Pol for RNA-dependent RNA polymerase, MP for movement proteins, CP for coat protein, and NABP is for nucleic – acid – binding protein. Source: http://link.springer.com/article/10.1007%2Fs00705-007-1030-1

Detection

MV-2 was successfully detected by employing a RT-Polymerase Chain Reaction [RT-PCR] test, which also detected the host internal control mRNA. Another test, the enzyme – linked immunosorbent assay [ELISA] test was, however, tried but unsuccessful at generating satisfactory results (Tzanetakis, Postman, & Martin, 2007).

Transmission Studies

None of the herbaceous and mint plants mechanically inoculated were found to be positive for the presence of MV-2 by RT-PCR, inferring that the virus may not be mechanically transmissible, or may not be done so easily. When the Oregon Ginger Mint (OGM) was used for transmission of aphid experiments, three (3) out of total twenty (20) plants were successfully infected with MV-2. However, when one (1) of these three (3) plants were used to further transmit the virus, the results were negative, implying that the virus wasn't transmitting by aphids (Tzanetakis, Postman, & Martin, 2007).

Discussions

This study was a specific case that included only two members of genus *Vitivirus*, which added to the knowledge extracted about the group of viruses, therefore identifying a new virus under the genus which infects mint plants. *Vitivirus* includes viruses which have positive – sense, single – stranded Ribonucleic acid [RNA] genomes and form filament-like [filamentous] particles ranging from 800 x 12 nanometers. The purification done for MV-2 yielded a few virions with thirteen (13) nanometers and variable lengths (Tzanetakis, Postman, & Martin, 2007).

MV-2 sequence was responsible encoding the virus RNA-dependent RNA polymerase. The transmission studies conducted showed that MV-2 can be transmitted by aphids, albeit only with the help of a helper virus [such as MV-1], a case similar to that of Heracleum latent virus [HLV]. Although the infection conditions for both MV-1 and MV-2 were identical, the aphid – implanted MV-2 plants were not infected with the helper virus MV-1, though it helped in the process. This is thought to be a surprising phenomenon, since the helper virus MV-1 was previously believed to intricately present in the whole process (Tzanetakis, Postman, & Martin, 2007).

Also, MV-2 was a very potent virus, its effects were significant, as observed in the aphid transmission studies. It wasn't however, the casual agents of symptoms seen in Oregon Ginger Mint [OGM] (Tzanetakis, Postman, & Martin, 2007).

MV-2 bears close resemblance in characteristics and properties to another vitivirus, peppermint stunt virus [PmSV]. Previously discovered, PmSV and MV-2 are very similar to each other, though both are from different species. They share ~70% of nucleotide sequence identity (and 75% amino acid identity); both more or less stunt the growth of the plants and are difficult to be purified. The case of Oregon Ginger Mint [OGM] remains yet to be thoroughly researched, for the viruses which cause the exact symptoms are still unknown (Tzanetakis, Postman, & Martin, 2007).

Conclusion

As we reach to an end of the term – paper, the all rounded importance and value of mint plants is seen clearly. Right from the beginning till the current day, they are one of the fundamental herbs that drive forward the biggest innovation and discovery, particularly in pharmaceutical and industrial aspects. It has a plethora of health benefit and therapeutic applications which still makes it one of the drastically important genera in the Lamiaceae family. Apart from this, there are various cuisines which extensively rely on mint plants for imparting a refreshing aroma to it. Also, every year, companies worldwide make billions of wealth thanks to the trade of mint oils, which are considered to be important for almost a big majority of medicines being manufactured today.

Despite its invasive nature, mint plants are the cornerstone of the modern healthcare and medicine. Few plants have such immense versatility like mint. It will not be surprising to see further research and study being done to extensively understand its characteristics at large, so that we may successfully utilize the benefits of this miraculous herb gifted to us by nature to its maximum efficiency.

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