INDOOR PERFORMANCE OF PEPPERMINT (*Mentha piperita* L.) IN RESPONSE TO VERMICOMPOST AND LIGHT QUALITY

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CERTIFICATE

This is to certify that the thesis entitled ***"INDOOR PERFORMANCE OF PEPPERMINT (Mentha piperita L.) IN RESPONSE TO VERMICOMPOST AND LIGHT QUALITY"*** *submitted to the Department of Horticulture, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTERS OF SCIENCE (M.S.)*** *in* ***HORTICULTURE****, embodies the result of a piece of bonafide research work carried out by* ***BHRIGU RAM BARMAN****,* ***Registration No. 19-10353*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

Dated:

Dhaka, Bangladesh

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Research Supervisor

DEDICATED TO –

MY BELOVED PARENTS & RESPECTED TEACHERS

of

Sher-e-Bangla Agricultural University

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INDOOR PERFORMANCE OF PEPPERMINT (*Mentha piperita* L.) IN RESPONSE TO VERMICOMPOST AND LIGHT QUALITY

ABSTRACT

The present experiment was conducted at the "Horticultural Biotechnology and Stress Management Lab" of Dr M A Wazed Miah Research Center, Sher-e-Bangla Agricultural University, Dhaka during the period from November 2019 to March 2020 to evaluate the indoor performance of peppermint in response to vermicompost and light quality. The experiment consisted of two factors: Factor A: Vermicompost (4 levels) as V0 = 90 % cocopeat + 10 % broken bricks (Control)/pot, V1 = 30 % vermicompost + 60 % cocopeat + 10 % broken bricks/pot, V2 = 45 % vermicompost + 45 % cocopeat + 10 % broken bricks/pot, V3 = 60 % vermicompost + 30 % cocopeat + 10 % broken bricks/pot; and Factor B: Light quality (Monochromatic LED lights) as L1 = White light, L2 = Blue light, L3 = Red light, L4 = Combined red and blue light. The two factor experiment was laid out in Completely Randomized Design (CRD) with three replications. Vermicompost and light quality significantly influenced different growth and yield parameters of mint. In case of vermicompost, the highest fresh weight per plant (13.95 g) was found from V2 and the lowest fresh weight per plant (5.89 g) from V0. Considering the light quality application, L4 produced the highest fresh weight per plant (15.83 g) and the lowest fresh weight per plant (2.52 g) was from L3. Regarding the interaction effect, the highest fresh weight per plant (21.58 g) was obtained from treatment combination V2L4 and the lowest fresh weight per plant (1.87 g) from V0L3. So, the vermicompost dose, 45 % vermicompost + 45 % cocopeat + 10 % broken bricks/pot with combined red and blue light can be used for herbage production of peppermint.

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LIST OF ACRONYMS AND ABBREVIATIONS

BBS = Bangladesh bureau of statistics

CP = Cocopeat

CEC = Cation exchange capacity

et al. = And others

Ha = Hectare

HID = High intensity discharge

HPS = High pressure sodium

LED = Light emitting diode

UK = United Kingdom

USA = United States of America

WHC= Water holding capacity

Hr = Hour

Nm = Nanometer

Mg = Milligram

T = Ton

PPFD = Photosynthetic photon flux density

EC = Electrical conductivity

Chl= Chlorophyll

DAP= Days after planting

CHAPTER I
INTRODUCTION

Peppermint plant belongs to the family Lamiaceae. Peppermint (*Mentha piperita*, also known as *Mentha balsamea* Wild) is a hybrid mint, a cross between watermint and spearmint. Indigenous to Europe and the Middle East, the plant is now widely spread and cultivated in many regions of the world. It is occasionally found in the wild with its parent species. Although the genus *Mentha* comprises more than 25 species, the one in most common use is peppermint. While Western peppermint is derived from *Mentha piperita*, Chinese peppermint is derived from the fresh leaves of *Mentha haplocalyx*. *Mentha piperita* and *Mentha haplocalyx* are both recognized as plant sources of menthol and menthone, and are among the oldest herbs used for both culinary and medicinal products.

Peppermint (*Mentha piperita* L.) is a high demand aromatic and medicinal crop which is vegetatively propagated through stolon and rhizomes (Verma *et al.*, 2013). Peppermint oil is used both as a medicinal and flavoring agent in foods and confectionery (Milovanovic´ *et al.*, 2009). In Iran, peppermint is a perennial crop established with plantings in the spring and has an average stand life of about 6 years (Ayyobi *et al.,* 2013). Mint is also used as ornamental pot plants in several countries. Tea is prepared by using the mint leaves in a dry or fresh form. Its leaves can be used either in raw form or it can be cooked and it also contains the essential oil. The essential oil of the herb also used to season salad and other cooked food. Mint is usually taken after a meal for its credibility to reduce indigestion and colonic spasms by decreasing the gastro-cholic refluxes. Its pleasant taste makes it an excellent gastric stimulant (Williams, 2006).

Due to gradually increasing urbanization and reduction of agricultural land, production area of crops is decreasing day by day. In Bangladesh in the year of 1996 total cultivable land area was 9.762 million ha which in the year 2018 reduced to 8.577 million ha. Now the world is turning to new agricultural technologies like vertical farming and indoor crop production. Vertical farming is where crops are grown, usually indoors, in stacked layers. In vertical farming problems related to scarcity of agricultural land is met effectively. Currently, the country with the highest number of vertical farms is the USA. In Asia, the leading countries in the industry are Japan, China, Singapore, South Korea, Taiwan, and Thailand. In Europe, vertical farms can be found among others in Germany, France, UK, and the Netherlands. The farmer can control the environment- lighting, temperature and water provision without having to suffer the vagaries of the weather. In this case growing media, light quality and intensity are two main important factors.

Cocopeat is used globally in addition with vermicompost as growing media to replace soil. Cocopeat (CP) an organic byproduct from coir industry obtained after the extraction of fiber from the coconut husk is being viewed as a light weight substitute of sphagnum peat in ornamental plant nurseries (Yau and Murphy, 2000; Pickering, 1997). The CP is light in weight with low shrinkage, low bulk density and has slow biodegradation with longer decomposition time (10 years). The CP can be effectively recycled and has acceptable pH (5.2-6.8) (Evans *et al.,* 1996; Prasad, 1996). Cocopeat contains soluble salts of chloride and sodium as well as higher contents of K. The concentration of N (0.43%) and P (0.38%) have been reported in cocopeat, but nutrient content varies with the extent of decomposition and method of retting of CP (Solaimalai *et al.,* 2001).

Vermicompost can play a vital role in sustaining soil fertility and crop production more than the use of chemical fertilizers. Nutrient level of the vermicompost is about two times higher than that of ordinary poultry manure. Vermicompost is an excellent product because it tends to hold more nutrients over a longer period without adversely affecting the environment. Among the sources of available organic manures, vermicompost is a potential source due to the presence of readily available plant nutrient and number of beneficial micro-organisms such as N fixing, P solubilizing and cellulose decomposing organisms (Sultan, 1997). Vermicompost is a nutrient-rich, microbiologically active organic amendment which results from the interactions between earthworms and microorganisms in the breakdown of organic matter. It is a stabilized, finely divided peat-like material with a low C/N ratio and high porosity and water-holding capacity that contains most nutrients in forms that are readily taken up by plants (Dominguez J., 2004). Nutrients in vermicompost are present in readily available forms for plant uptake; e.g. nitrates, exchangeable P, K, Ca and Mg (Azarmy, R., 2009).

Light is an important factor affecting plant development and morphology (Avercheva *et al.*, 2014; Lee et al., 2016; Rehman et al., 2017). LED grow lights for vertical farming is the new trend of indoor farming, plants will not need sunlight or soil. Green leafy vegetables are grown on multiple floors using vertical farming led grow lights and indoor climate control systems. As one of the greatest achievements in agriculture, grow lights for vertical farming is dedicated to satisfying the food needs of people living in urban areas or high altitude areas, where it is cold all year round and lacks natural sunlight.

There are three basic types of grow lights that can be used for vertical farming: HPS or HID grow lights, Fluorescent grow lights, and LED grow lights. Among the three types of grow lights, LED growth lights is the most energy-saving. LEDs contain rich monochromatic light sources, and the wavelength coincides with the spectral range that causes plant morphogenesis (Manivannan *et al.*, 2017). Again LEDs have cold temperature compared other two types. It is known that light quality affects secondary metabolites, such as medicinal components in *Hypericum perforatum* (Nishimura *et al.*, 2007), plant pigments in red leaf lettuce (Ebisawa *et al*.,2008) and also volatile aromatic compounds in *Ocimum basilicum* (Johnson *et al*., 1999; loannidis *et al*., 2002; Amaki *et al*., 2009) and in *Perilla frutescens* (Ohashi-kaneko *et al*., 2013).

The leaves of peppermint are aromatic with sweet flavor. The fresh and dried leaves are the cooking source of mint. Mint was initially used as medicinal herb to cure stomach ache and chest pains. People also use mint leaves to flavor tea as well as indoor ornamental plants. The present experiment on peppermint has been undertaken with the following objectives:

1. To evaluate the effect of vermicompost level on growth and yield of peppermint.
2. To find out suitable light quality for indoor cultivation of peppermint.
3. To establish a protocol for indoor peppermint cultivation.

CHAPTER II

REVIEW OF LITERATURE

Mint is an important medicinal herb and popularly used as salad, herbal tea, condiments etc. in Bangladesh. It is useful in treating digestion related disorders and its shoots and leaves are used in flavoring food items. The literature about the response of vermicompost and light quality of peppermint is presented in this chapter. However, relative information on the effect of vermicompost and light quality on peppermint is not adequate, analogies from other crops have also been included to emphasize a certain point of view.

Literature related to the present study has been reviewed below-

2.1 Effect of vermicompost

Atiyeh, R. M. *et al.* (2000) confirmed that vermicompost have beneficial effects on plant growth in greenhouse and field studies examined the effects of vermicompost on cereals and legumes, vegetables and field crops.

Chaoui, H. I. *et al.* (2003) and Guerrero (2010) determined that vermicompost is a nourishing organic fertilizer having high amount of humus, nitrogen 2-3%, phosphorus 1.55-2.25%, potassium 1.85-2.25%, micronutrients, more beneficial soil microbes like nitrogen fixing bacteria and mycorrhiza fungi. Vermicompost has been scientifically proved as miracle plant growth enhancer.

Gutiérrez-Miceli, F. A. *et al.* (2007) investigated the effects of earthworm-processed sheep-manure (vermicompost) on the growth, productivity and chemical characteristics of tomatoes (*Lycopersicum esculentum*) (c.v. Rio Grande) in a greenhouse experiment. Five treatments were applied combining vermicompost and soil in proportions of 0:1, 1:1, 1:2, 1:3, 1:4 and 1:5 (v/v). Growth and yield parameters were measured 85 days and 100 days after transplanting. Addition of vermicompost increased plant heights significantly, but had no significant effect on the numbers of leaves or yields 85 days after transplanting. Yields of tomatoes were significantly greater when the relationship vermicompost : soil was 1:1, 1:2 or 1:3, 100 days after transplanting.

In a study Vijaya, D. *et al.*, (2008) found that vermicomposted cocopeat and cocopeat composted with microorganisms were used as a growth medium for growing the medicinal plant and *Rographis paniculata*. The results indicated that vermicomposted cocopeat could be helpful for the reclamation of soils from industrial sites in a small scale nursery

Abbey, L. *et al.* (2012) conducted an experiment in which treatments were cocopeat alone, commercial potting mix alone, and a vermicompost cocopeat mix in ratios of 2:1, 1:1, and 1:2. Plants in vermicompost had high amounts of N, P_2O_5 and K_2O compared to plants in cocopeat alone or the commercial potting mix. Addition of cocopeat increased the WHC of the mix. The WHC of coir alone and the 1:2 mix were over 80%. Water loss by evaporation was lowest in the 2:1 mix; evapotranspiration was highest due to active plant growth, which led to greater leaf expansion, increased leaf number, and harvest weight. Plants grown in cocopeat alone had the highest percentage of dry matter.

Gholamnejad, S. *et al.* (2012) conducted a study in which vermicompost + cocopeat (3:1), vermicompost + cocopeat (1:3), vermicompost + cocopeat (1:1) (V/V) and normal soil of planting. The result showed that the highest fresh and dry weight of root and shoot, stem diameter, internode number, leaf area and height of planting were obtained in vermicompost + cocopeat (3:1).

Ram, M. *et al.* (2012) conducted a field experiment with peppermint (*Mentha piperita* L.) in a sandy loam soil at Lucknow, India where suggested to get sustainable production of peppermint, application of vermicompost 9 ton ha^{-1} along with 112.5 kg N ha^{-1} through synthetic fertilizer is recommended for light textured sandy loam soils as it produced maximum essential oil (94.3 kg ha^{-1}), increased the herb and essential oil yields by 104 and 89%.

Ayyobi, H., *et al.* (2013) conducted an experiment to determine effects of 7 Mt ha^{-1} of cow manure vermicompost, vermiwash prepared from 7 Mt ha^{-1} of vermicompost, leachate vermicompost + vermiwash, 50 Mt ha^{-1} municipal solid waste compost (MSWC), chemical fertilizer (NPK 50-0-300) and no fertilization as a control on peppermint yield and color. Fertilizer type affected all measured characteristics except number of nodes, stem fresh weight, total phenols and antioxidant capacity. Plants treated with vermicompost, vermiwash or leachate vermicompost + vermiwash were the tallest and had the highest levels of chlorophyll a, chlorophyll b, total chlorophyll and carotenoids. Plants treated with vermicompost or vermiwash had the highest total plant fresh weight, leaf fresh weight and total fresh yield. The leachate vermicompost, vermiwash and vermicompost can be used as organic fertilizers for sustainable peppermint cultivation.

Mahmoodabad, H. A. *et al.* (2014) investigated the changes in the yield and the growth of green mint under foliar application of urea and soil application of vermicompost showed the highest (295 g) and the lowest (217.33 g) plant dry weights, respectively in the application of vermicompost @10 ton ha^{-1} over the control treatment.

Suresh *et al.* (2018) studied on the organic nutrition for the growth and yield of the Japanese mint and pointed out that the application of vermicompost at the rate 2.5 ton ha^{-1} + humic acid 0.2% + panchagavya 3% resulted in improving the growth characteristics like plant height, plant spread, number of lateral branches, number of leaves and leaf area, the herbage yield and dry matter production as well.

Rawat, R. *et al.* (2020) studied that the treatment Soil + cocopeat (2:1) resulted significantly higher values of growth parameters in Rosemary and Cocopeat + vermicompost (2:1) recorded maximum values for Geranium cuttings, whereas cuttings grown with soil recorded minimum growth performance for both species.

Keshavarz-Mirzamohammadi, H. *et al.* (2021) conducted a field experiment to examine the influence of urea and vermicompost fertilizer on oil phytochemical properties of peppermint pH, soil cation exchange capacity (CEC) and organic carbon of experimental site under three irrigation regimes in 2018 and 2019. The experiments had three water deficit regimes (no stress, moderate, and severe drought stress) as a main plot. The subplot division consisted of six fertilizer treatments: unfertilized (control); 140 kg urea ha^{-1}; 105 kg urea ha^{-1} + 3.3 ton vermicompost ha^{-1}; 70 kg urea ha^{-1} + 6.6 ton vermicompost ha^{-1}; 35 kg urea ha^{-1} + 10 ton vermicompost ha^{-1}; and 13.5 ton vermicompost ha^{-1}. The maximum leaf area index (4.29) and dry matter weight (3,803 kg ha^{-1}) were observed in control irrigation, while the highest essential oil content (0.97%) could be seen under mild water deficit stress. Additionally, the highest organic carbon and CEC were obtained under well-watered conditions at 1.20% and 6.41 (meq 100 g $soil^{-1}$), respectively. Dry matter weight and essential oil content increased considerably in response to increasing vermicompost in fertilizer treatments, and the highest content of these traits were observed in 2019 and with 13.5 ton vermicompost ha^{-1}. The menthol content increases in response to deficit irrigation and integrated fertilizer. These data indicate that mild drought stress can increase the synthesis of medical compounds and vermicomposting can alleviate the impact of drought by conserving soil moisture as an acclimation mechanism to improve nutrient uptake and avoid yield losses.

2.2 Effect of light

Amaki, W. *et al.* (2009) conducted a study on sweet basil in which seedlings were grown under four monochromatic lights irradiated with blue, blue-green, green and red LEDs that have a peak wavelength of 470, 500, 525 and 660 nm respectively. A combined white light was simultaneously irradiated by white, blue, green and red LEDs (the PPFD ratio was 3:1:1:1). The treatment conditions of the LED lights consisted of 24±2°C at 50 μmol m^{-2} s^{-1} PPFD. After 70 days of the light treatment, plants were harvested so as to measure their biometric characteristics and essential oil contents in leaves. The results showed that the top fresh weight, total leaf weight and total leaf area were higher under green monochromatic light than under other lights. However, the total leaf weight and total leaf area of lateral shoots were the largest under blue light. The largest amount of essential oil was observed in leaves under blue light. The essential oil contents of plants grown under blue light were 1.2-4.4 times higher than those grown under white light. On the other hand, the contents of plants grown under red light were only 12.7-77.0% of that under white light.

Fan, X. *et al.* conducted an experiment on Chinese cabbage in which 6 treatments: red light (R), blue light (B), green light (G), yellow light (Y), red plus blue light (RB) and dysprosium lamp (CK). Lighting experiments were performed under controlled conditions (photon flux density 150 μmol m^{-2} s^{-1}; 12 hr photoperiod; 18-20℃). The fresh and dry mass were greatest under RB, which were significantly higher than other light treatments. The fresh mass under RB was almost twice higher compared to other light treatments. Plant height was higher under R treatment and was lowest under B. RB treatment also lowered the plant height significantly. The highest soluble sugar concentration was under treatment B. The soluble protein concentration was the greatest under RB. The R treatment was adverse to pigment accumulation. The concentration of photosynthetic pigments and chlorophyll biosynthesis precursors were higher under RB. The RB treatment was beneficial to pigment accumulation.

Sabzalian, M. R. *et al.* (2014) and Vu *et al.* (2014) showed blue light exposure has been reported to reduce leaf area and shoot dry weight of the *Asteraceae* plants, but to increase those of the *Solanaceae* plants.

Carvalho and Folta (2014); Xiaolong, F. *et al.* (2016); Maity, T. R. *et al.* (2016); Niizawa, I. *et al.* (2017); Marondedze, C. *et al.* (2018) conducted a meta-analysis to assess the effects of different colors of LED light on plant growth, development and various traits. Compared to the light from white fluorescent lamps, the red LED light significantly changed 4 out 26 plant characteristics by at least 37%, and blue LED light significantly increased 5 of 26 assessed characteristics by 37% or more. The combination of red/blue LED lights only significantly increased dry weight by 161% among 25 plant characteristics analyzed. Compared to the white LED light, red LED light significantly decreased 2 of 9 plant characteristics by at least 36%, and blue LED light significantly decreased only 1 of 9 plant characteristics, total chlorophyll content, by 42%. In the moderators analyzed, plant taxonomic families significantly influenced the effects of LED lights on shoot dry weight, and plant life cycles and plant taxonomic families significantly affected the effect on stomatal conductance. Through systematic meta-analysis, they found that the effect of LED on plant growth and quality traits was species-specific, and the effect was affected by the cultivation conditions. Therefore, they suggest that researchers be more targeted to experiment, and collect traits associated with practical production, especially related to the quality of product data, such as carotenoids, anthocyanin and other antioxidant compounds.

Manivannan, A. *et al.* (2015) and Wang *et al.* (2016) studied that in nature, because of the influence of clouds, rain and other weather factors, natural light is not often sufficient for optimal growth of plants. An artificial light source is supplemented in controlled facility cultivation to promote high yields and color products.

Sing, D. *et al.* (2015) examined LEDs can be adjusted to emit light in very specific parts of the spectrum. For example, chlorophyll absorbs mainly in the blue, green, and red parts of the spectrum but absorbs a very little in the orange and yellow. So, light should be produced only in these parts of the spectrum which is possible with the use of LEDs.

Arena, C. *et al.* (2016) studied the effect of different light qualities on growth, photosynthesis, leaf anatomy and isoprenoid emission in two different fast-growing plant systems: a herbaceous crop, tomato (*Solanum lycopersicum* L.), and a tree, oriental plane (*Platanus orientalis* L.). Both plant species were subjected to three different light quality regimes: RGB (Red 33%, Green 33%, Blue 33%) and RB (Red 66%, Blue 33%), provided by light emitting diodes (LED); and white light (WL), considered as a control and provided by white fluorescent lamps. Compared to WL, RGB and RB reduced plant height, plant biomass and leaf area. The CO_2 assimilation rate (A) was lower in tomato grown under WL than RGB and RB, while A was similar in oriental plane leaves exposed to the three light regimes. In tomato, stomatal (gs) and mesophyll (gm) conductance were higher under RGB and RB compared to WL. In plane, gs was also higher under RGB and RB, while g_m was not significantly influenced by different light qualities. In both species, leaf lamina thickness (LT) and stomata size were the anatomical traits most affected by the different light regimes. In tomato, leaf lamina thickness was significantly reduced in RGB and RB leaves, whereas in oriental plane leaf lamina thickness was significantly higher in RGB and RB than in WL leaves. In both species, RB leaves showed bigger stomata size than WL and RGB leaves. Light quality also affected photosynthesis-dependent volatile isoprenoids. In tomato, β-phellandrene was lower under RB and RGB compared to WL. However, RGB and RB stimulated α-pinene, carene and α-terpinene emissions. Oriental plane released about 14 nmol m^{-2} s^{-1} isoprene when growing at WL, while the emission was reduced under RGB and even more under RB. In summary, photosynthetic performance, leaf anatomy, biomass production, and volatile isoprenoids are affected by light quality differently in tomato and plane plants. Light quality control may have important applications to modulate plant productivity and increase biosynthesis of useful biochemical compounds.

Hernández, R. *et al.* (2016) evaluated cucumber (*Cucumis sativus*) seedlings physiological responses to different blue (B) and red (R) photon flux (PF) ratios using LEDs. Cucumber seedlings (cv. Cumlaude) were grown in a growth chamber until the second true leaf stage (17 days) with LED lighting and 18-h photoperiod. The treatments consisted of 100 μmol m^{-2} s^{-1} photosynthetic photon flux (PPF) with B:R PF ratios of 0B:100R%, 10B:90R%, 30B:70R%, 50B:50R%, 75B:25R%, 100B:0R%. Another treatment consisted of B, green (G) and R PF ratio of 20B:28G:52R%. Peak wavelengths of LEDs were 455 nm (B) and 661 nm (R) for the in the B:R treatments and 473 nm (B), 532 nm (G), 660 nm (R) in the B:G:R treatment. Hypocotyl length decreased with the increase of B PF up to the 75B:25R% treatment. Hypocotyl length in the 0B:100R% treatment was 164% greater than in the 75B:25R treatment. Plants under the 100B:0R% treatment had unexpected greater plant height, hypocotyl, and epicotyl length than plants under all other treatments. For example, the hypocotyl length under the 100B:0R% was 69% greater than in the 0B:100R treatment and 346% greater than in the 75B:25R% treatment. Leaf area decreased with the increase of B PF when plants were irradiated with the combination of B and R PF. The response of leaf area under the 100B:0R% treatment was unexpected since plants in the 100B:0R% treatment had 48% greater leaf area than plants in the 75B:25R% treatment. Chlorophyll content per leaf area, net photosynthetic rate, and stomatal conductance increased with the increase of B PF. Shoot dry and fresh mass decreased with the increase of B PF when plants were irradiated with the combination of B and R PF. Plants under 0B:100R% had the lowest dry and fresh mass from all the treatments and plants under 100B:0R% showed the greatest fresh mass from all the treatments and equal dry mass as the plants under 10B:90R% treatment. The addition of G PF to the spectrum did not have any influence in cucumber plant responses.

For cucumber seedlings, morphological responses influenced plant growth since B PF responses in growth parameters (i.e., dry mass) closely matched those in morphological parameter (i.e., leaf area). He also suggested more research is needed to find the optimal spectrum for the growth and development of horticultural crops under sole source electrical lighting such as LEDs.

Noguchi, A. *et al*. (2016) conducted an experiment on mexican mint in which three monochromatic lights were irradiated with blue, green, or red LEDs which have the peak wavelength of 470, 525, or 660 nm, respectively. A combined light was simultaneously irradiated by white, blue, green, and red LEDs (the PPFD ratio was 3:1:1:1). The light treatment conditions were 24±2°C, 16 hr photoperiod at 100 µmol m^{-2} s^{-1} PPFD. Plants were cultivated under the respective light quality conditions for 70 days. The elongation of the main and lateral shoots was significantly reduced under blue and combined lights. The growth of lateral shoots was significantly reduced under the blue light. However, the thickness and fresh weight of leaves increased under the blue light.

Wang, S. *et al.* (2016) investigated the effects of different light qualities on chloroplast ultrastructure and photosynthesis efficiency, two grape cultivars 'Italia' (slower speed of leaf senescence) and 'Centennial Seedless' (faster speed of leaf senescence) grown under protected and delayed conditions were used. The three treatments, replicated three times, were control (no supplemental lighting), red light and blue light. Chlorophyll content, net photosynthetic rate, and the ratio of Fv/Fm significantly increased in red light relative to the control. The opposite trend was observed in blue light in the early phase of leaf senescence. At later stages, physiological indexes were gradually higher than that of control, resulting in a delay in leaf senescence. Compared to the control, red and blue light both significantly increased the chlorophyll a/b ratio. Electron microscopy showed that blue light caused severe damage to the fine structure of chloroplasts at early stages of leaf senescence, but effects at later stages of leaf senescence became less severe compared to the control. The degradation of chloroplast ultrastructure was apparently delayed in red light throughout the experimental timeframe compared to other treatments. In this experiment, 'Italia' showed higher chlorophyll content, net photosynthetic rate, ratios of Fv/Fm, chlorophyll a/b and better preserved chloroplast ultrastructure relative to 'Centennial Seedless', resulting in a slower rate of leaf senescence.

Li, Y. *et al.* (2017) evaluated the effects of different light qualities generated by light emitting diodes (LEDs) with the same photosynthetic photon flux density (PPFD), including monochromic light red (657 nm, R), blue (457 nm, B), purple (417 nm, P) or white (W), combination of R and B lights (R:B = 1:1, 1R1B and R:B = 3:1, 3R1B) on the net photosynthetic rate (Pn), growth rate, carbohydrate content and sucrose-metabolizing enzyme activities. The results showed that relative to W, the seedling plant height and stem diameter were significantly promoted by combination of R and B lights and monochromic R light. However, the level of root growth was lower under R and P light, and the seedling growth and Pn were significantly suppressed under the latter. Additionally, R light significantly increased the contents of fructose and glucose, and combination of R and B lights significantly enhanced total carbohydrate, starch and sucrose accumulation, especially for 3R1B treatment. Activity of sucrose synthase (SS) was promoted under the different treatments and reached its highest value under 3R1B, which appeared to be a major contributor to the significantly higher content of starch under this treatment. Furthermore, R, B and P light reduced activity of sucrose phosphate synthase (SPS). Activities of acid invertase (AI) and neutral invertase (NI) were significantly increased by R light, but were markedly reduced under P. The results presented here indicated that monochromic R and combination lights 3R1B, could regulate the plant morphology and photosynthesis by the effects on the metabolism of carbohydrate into fructose, glucose, sucrose and starch, mainly through the enhanced activities of AI and NI under the former treatment, while SS and SPS in the latter treatment, respectively. They also improved the end-product output in tomato leaves, and may ultimately improve the yield and quality of tomato fruit.

Nadalini, S. *et al.* (2017) in their experiment, the effects of three different lighting systems (LED blue, LED red and fluorescence neon tubes as control) on soilless cultivated strawberry growth and fruit quality were evaluated. Results showed that LED blue light (400-500 nm) induced a higher biomass accumulation, especially at root and crown level. Moreover, LED blue treated plants showed a 25% enhanced fruit set that caused a relevant higher final yield (65 g $plant^{-1}$) as compared to control and red LED treated plants (45 and 35 g $plant^{-1}$ respectively). Fruit main quality traits were not modified by treatments, the only differences being in fruit color (blue and red LED treated strawberries showed a less saturated color) and anthocyanin concentration (lower level of pelargonidin-3-glucoside in both blue and red LED treated fruits as compared to the control ones). Based on these results they suggested that the use of blue light can be feasible to enhance yield, while maintaining fruit quality, in protected strawberry cultivation systems.

Rehman, M. *et al.* (2017) revealed that spectral color of LEDs can have vivid effect on plant morphogenesis and anatomy. Red light wavelengths encouraged stem growth, flowering and fruit induction. Blue light wavelengths encourage strong vegetative growth by strong root growth and intense photosynthetic activity. A mixed red and blue light wavelengths improved photosynthetic activity to increase production and regulate plant morphogenesis.

Dimla, L. *et al.* (2020) showed that among different lights tested, the plant under sun light garnered the highest and most consistent observational value for positive features followed by the artificial light LED. In terms of negative features, the plant under fluorescent attained the most observed negative features to be followed by the incandescent lamp. In addition, heights of the plant were measured and the rankings from tallest to shortest were: sunlight, LED light, incandescent light, and fluorescent light.

Zou, T. *et al.* (2020) in a study, *Arabidopsis thaliana* (*Arabidopsis*) was used to investigate the effects of red, blue and green lights on the growth and development of plants from seed germination to seeding. Results demonstrated that red light showed a promotion effect but blue light a prohibition one in most stages except for the flowering time in which the effect of each light was just reversed. When mixed with red or blue light, green light generally at least partially cancelled out the effects caused by each of them. Results also showed that the same number of photons the plant received could cause different effects and choosing the right combination of different color of lights is essential in both promoting the growth and development of plants and reducing the energy consumption of lighting in plant factory.

Ma, Y. *et al.* (2021) studied compared to the light from white fluorescent lamps, the red LED light significantly changed 4 out 26 plant characteristics by at least 37%, and blue LED light significantly increased 5 of 26 assessed characteristics by 37% or more. The combination of red and blue LED lights only significantly increased dry weight by 161% among 25 plant characteristics analyzed. Compared to the white LED light, red LED light significantly decreased 2 of 9 plant characteristics by at least 36%, and blue LED light significantly decreased only 1 of 9 plant characteristics, total chlorophyll content, by 42%. In the moderators analyzed, plant taxonomic families significantly influenced the effects of LED lights on shoot dry weight, and plant life cycles and plant taxonomic families significantly affected the effect on stomatal conductance.

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out to assess the performance of peppermint production in response to vermicompost and light quality. The materials and methods i. e. experimental period, location, environmental condition and structure of experimental site, planting materials, design of the experiment, data collection and data analysis procedure that were used for conducting the experiment are presented in this chapter under the following headings and subheadings-

3.1 Experimental period

The experiment was conducted during the period from November 2019 to March 2020.

3.2 Experimental site

The present study was conducted at the laboratory of Dr M A Wazed Miah Research Center of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207.

3.3 Environmental condition

The experiment was conducted maintaining an optimum temperature of 25 ˚C and a photoperiod of 16 hours with LED lights by technical means.

3.4 Treatments of the experiment

The experiment consisted of two factors:

Factor A: Vermicompost

1. V_0 = 90 % cocopeat + 10 % broken bricks (Control)/pot
2. V_1 = 30 % vermicompost + 60 % cocopeat + 10 % broken bricks/pot
3. V_2 = 45 % vermicompost + 45 % cocopeat + 10 % broken bricks/pot
4. V_3 = 60 % vermicompost + 30 % cocopeat + 10 % broken bricks/pot

Factor B: Light quality

1. L_1 = White light (400 – 700 nm)
2. L_2 = Blue light (440 - 490 nm)
3. L_3 = Red light (620 - 700 nm)
4. L_4 = Combined red and blue light (620 - 700 nm & 440 - 490 nm)

3.5 Design and layout of the experiment

The experiment was laid out in a Completely Randomized Design (CRD) with three replications. The 96 plants were planted in the 48 plastic pots. Two plants were planted per pot.

3.6 Media preparation and pot filling

16″ × 8″ × 6″ pots were filled with cocopeat, vermicompost and broken bricks mixtures at required proportions (V_0 = 90 % Cocopeat (Control) + 10 % broken bricks/pot, V_1 = 30 % vermicompost + 60 % cocopeat + 10 % broken bricks/pot, V_2 = 45 % vermicompost + 45 % cocopeat + 10 % broken bricks/pot and V_3 = 60 % vermicompost + 30 % cocopeat + 10 % broken bricks/pot).

3.7 Planting materials

The stem cuttings of peppermint were collected from the Sobuj Bangla Nursery, Agargoan, Dhaka, during November, 2019. Then those cuttings were planted separately in pots to establish. In each pot 2 cuttings were placed maintaining a distance of 8 inch. After planting pots were placed in shelves maintaining a photoperiod of 16 hours. Average temperature of experimental site was around 25 °C. Watering was done 2 times a day until those produced new roots.

3.8 Arrangement of lights

LED lights were set in vertical shelves. Each shelf contained one type of colored lights. Two lights were used for each type of color. 4 shelves were arranged in this way containing colors - L_1 = white, L_2 = blue, L_3 = red, L_4 = red & blue. White papers were used as veil to avoid interruption among different colors.

3.9 Manure and fertilizer application

Mustard oil cake was used as nutrient supplement in every 15 days during experimental period. Each time about 150 g of cake was kept in water the day before application. The next day a solution was made with required amount of water and applied in every pot.

3.10 Intercultural operations

Intercultural operation i. e. irrigation was done whenever needed for better growth and development.

3.11 Pest control

Severe insect attack was not found during cropping duration and also there was no incidence of disease. So, no insecticide and fungicide were applied to the crop during the experimental period.

3.12 Harvesting

Harvesting was done on 24th March, 90 days after planting (DAP).

3.13 Data collection

Experimental data were recorded from 30 days after planting (DAP) and continued until the last harvest. The following data were recorded during the experimental period-

1. Plant height (cm)

2. Number of branches per plant

3. Number of leaves per plant

4. Leaf area (cm^2)

5. Chlorophyll a, b and total chlorophyll content of leaves (mg/g)

6. Leaf fresh weight/plant (g)

7. Fresh weight of Individual plant (g)

8. Dry weight of individual plant (g)

3.14 Procedure of recording data

3.14.1 Plant height

The plant height was measured from the sample plants in centimeter from the ground level to the tip of the highest leaf and the means value was calculated. To observe the growth rate plant height was recorded at 30, 60, and 90 days after planting.

3.14.2 Number of branches per plant

The number of branches per plant was counted from the sample plants and total branches were counted from each plant of each pot considering each replication and mean value was calculated. The number of leaves per plant was recorded at 30, 60, and 90 DAP.

3.14.3 Number of leaves per plant

The total number of leaves per plant was counted from each pot at 30, 60, and 90 DAP.

3.14.4 Leaf area (cm^2)

Leaf length (cm) and breadth (cm) were measured by meter scale and was expressed in cm from fully expanded leaves of each plant of each pot. Then area of leaf was calculated. It was measured at 90 DAP.

3.14.5 Chlorophyll a content of leaves (mg/g)

Spad value of leaves was taken at 90 days after planting. Then chlorophyll a content of leaves was calculated by the following formula-

Chlorophyll a content = 0.0346X – 0.1933

Here, X= spad meter reading

3.14.6 Chlorophyll b content of leaves (mg/g)

Spad value of leaves was taken at 90 days after planting. Then chlorophyll b content of leaves was calculated by the following formula-

Chlorophyll b content = 0.0115X – 0.0936

Here, X= spad meter reading

3.14.7 Total chlorophyll content of leaves (mg/g)

Spad value of leaves was taken at 90 days after planting. Then total chlorophyll content of leaves was calculated by the following formula-

Total chlorophyll content = chlorophyll a + chlorophyll b

3.14.8 Weight of fresh leaves

Weight of fresh leaves of individual plant was recorded from each plant in gram (g) with a beam balance at final harvest.

3.14.9 Weight of fresh plant

Weight of individual fresh plant was recorded from each plant in gram (g) with a beam balance at final harvest.

3.14.10 Weight of fresh plant

Weight of individual dry plant was recorded from each plant after sundry in gram (g) with a beam balance at final harvest.

3.15 Statistical Analysis

The recorded data on different parameters were statistically analyzed using MSTATC software to find out the significance of variation resulting from the experimental treatments. The mean for the treatments was calculated and analysis of variance for each of the characters was performed by F (variance ratio) test. The differences between the treatment means were evaluated by the LSD test at 5% probability (Gomez and Gomez, 1984).

CHAPTER IV
RESULT AND DISCUSSION

The present experiment was conducted to determine the response of vermicompost and light quality on peppermint. This chapter comprises the arrangement and discussion of the results obtained due to the application of different vermicompost level and light quality applications on peppermint. The analyses of variance (ANOVA) of the data on different components are given in Appendix II to XII. The results have been presented, discussed, and possible interpretations have been given under the following headings:

4.1 Plant height (cm)

In terms of plant height at different growth stages in relation to different vermicompost doses, results were varied significantly under the trial (Fig. 1 and Appendix II). Results revealed that the highest plant height (31.66, 37.52 and 43.03 cm at 30, 60 and 90 DAP, respectively) was found from the treatment V_2 followed by V_3 and V_1. The shortest plant height (14.11, 17.44, and 21.63 cm at 30, 60, and 90 DAP, respectively) was obtained from the control treatment V_0. Under the present study, control treatment also showed comparatively better results, might be due to the presence of nutrients in cocopeat (appendix I) and mustard oil cake solution which was up taken by the root system of peppermint. The results indicated gradually increased plant height was achieved with increased levels of vermicompost from treatment V_1 to V_2 but in case of further increase in treatment V_3 it reduced. It is because vermicompost increases pH value of the growing media which ultimately results in increased cation exchange capacity (CEC) reducing the availability of phosphorus and other micronutrients such as Cl, Mo, S, B, NO_3^- etc. As a result growth become restricted at high level of vermicompost doses. The tallest plant was produced at different growth stages by the application of 45% vermicompost than that of others with ensuring better growth and development. An almost similar result was also observed by Gholamnejad S. *et al*. (2012) and Rawat R. *et al*. (2020) which supported the present study.

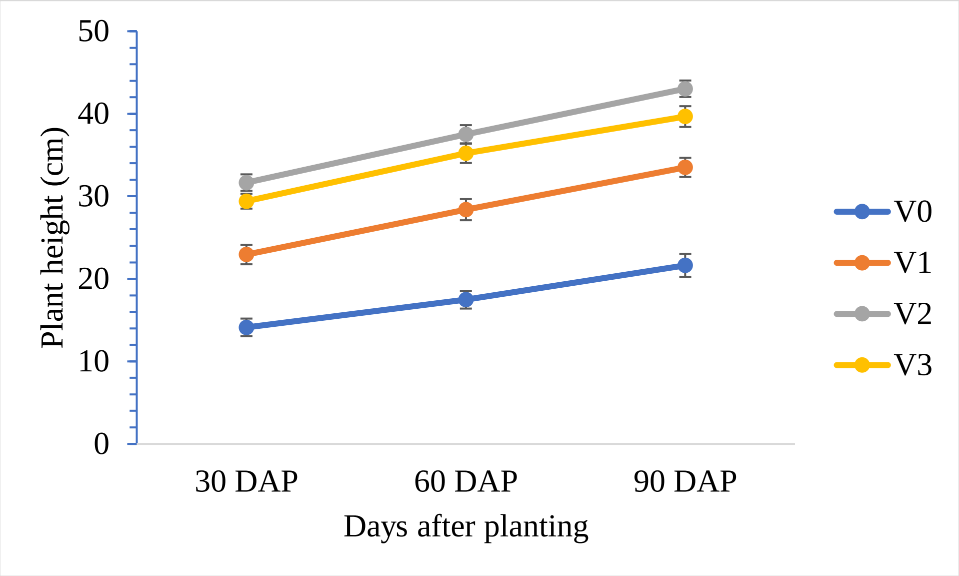

Figure 1. Plant height of peppermint as influenced by vermicompost ($LSD_{0.05}$ = 31.66, 37.52 and 43.03 cm at 30, 60 and 90 DAP, respectively)

(V_0 = 90% Cocopeat (Control) + 10% broken bricks/pot, V_1 = 30% vermicompost + 60% cocopeat + 10% broken bricks/pot, V_2 = 45% vermicompost + 45% cocopeat + 10% broken bricks/pot and V_3 = 60% vermicompost + 30% cocopeat + 10% broken bricks/pot)

Remarkable variation was observed on plant height at different growth stages influenced by light wavelength applications (Fig. 2 and Appendix II). Results showed that the highest plant height (30.83, 36.56, and 40.80 cm at 30, 60, and 90 DAP, respectively) was found from the treatment L_3 whereas the shortest plant height (21.15, 25.53, and 30.24 cm at 30, 60 and 90 DAP, respectively) was obtained from the treatment L_4. The results indicated that the tallest plant at different growth stages was produced by the application of L_3 followed by, L_1 and L_4. Almost same result was also observed by Fan X. *et al.* (2013), Rehman M. *et al.* (2017) and Noguchi *et al.* (2016) and they found that plants treated with red light encouraged stem growth while blue and combined light treatments reduced main and lateral shoot growth.

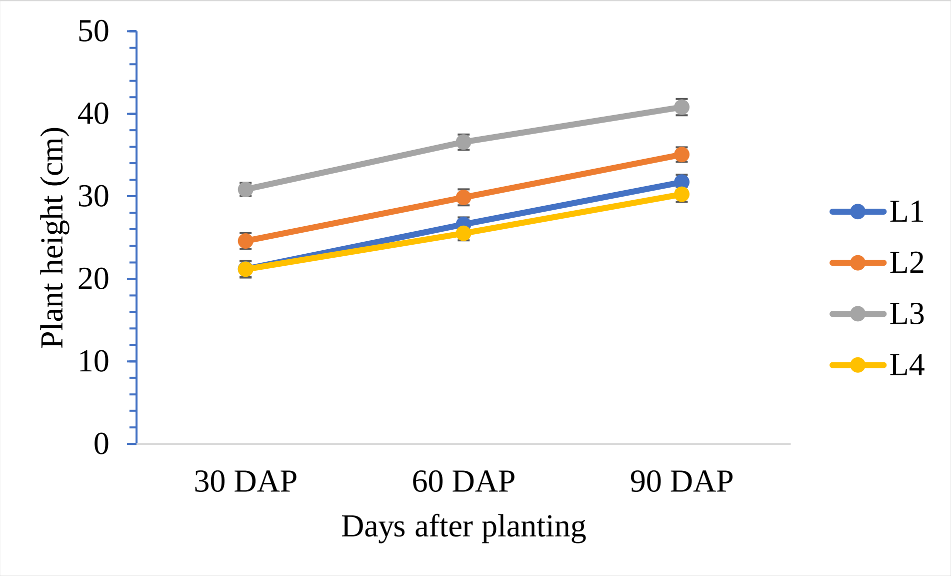

Figure 2. Plant height of peppermint as influenced by light quality ($LSD_{0.05}$ = 30.83, 36.56, and 40.80 cm at 30, 60 and 90 DAP, respectively)

(L_1 = White light, L_2 = Blue light, L_3 = Red light and L_4 = Combined Red and Blue light)

There was a significant variation found on peppermint height at different growth stages influenced by the interaction of vermicompost and light quality (Table 1 and Appendix II). It was observed that the highest plant height (46.02, 52.72, and 56.20 cm at 30, 60, and 90 DAP, respectively) was found from the treatment combination of V_2L_3 which was significantly different from all other treatment combinations. The lowest plant height (8.76, 10.33, and 14.30 cm at 30, 60, and 90 DAP, respectively) was obtained from the treatment combination of V_0L_4 which was also significantly different from all other treatment combinations. The results indicated that the combination of vermicompost and light quality ensures the optimum condition for the growth and development of peppermint and the ultimate result is the longest plant at different growth stages.

Table 1: Interaction effect of vermicompost and light quality on plant height (cm) of peppermint*

Treatments	Plant height (cm) at different DAP		
	30 DAP	60 DAP	90 DAP
V_0L_1	13.37 i	17.40 j	21.13 k
V_0L_2	15.18 h	19.35 i	22.87 j
V_0L_3	19.15 g	22.78 h	28.22 i
V_0L_4	8.767 j	10.33 k	14.30 l
V_1L_1	21.15 f	27.35 g	32.78 h
V_1L_2	23.17 e	27.58 g	34.05 g
V_1L_3	25.43 d	31.50 f	35.10 g
V_1L_4	22.02 ef	27.10 g	32.05 h
V_2L_1	21.93 ef	27.62 g	34.07 g
V_2L_2	31.92 b	38.03 b	44.95 b
V_2L_3	46.02 a	52.72 a	56.20 a
V_2L_4	26.77 cd	31.70 ef	36.90 f
V_3L_1	28.32 c	34.03 cd	38.85 d
V_3L_2	28.08 c	34.53 c	38.37 de
V_3L_3	32.75 b	39.25 b	43.70 c
V_3L_4	27.07 cd	33.00 de	37.72 ef
$LSD_{0.05}$	1.765	1.417	1.074
CV (%)	4.34	2.87	1.88

*In a column, means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

(V_0 = 90% Cocopeat (Control) + 10% broken bricks/pot, V_1 = 30% vermicompost + 60% cocopeat + 10% broken bricks/pot, V_2 = 45% vermicompost + 45% cocopeat + 10% broken bricks/pot and V_3 = 60% vermicompost + 30% cocopeat + 10% broken bricks/pot; L_1 = White light, L_2 = Blue light, L_3 = Red light and L_4 = Combined Red and Blue light)

4.2 Number of branches per plant

In terms of number of branches per plant at different growth stages in relation to different vermicompost doses, results were varied significantly under the trial (Fig. 3 and Appendix III). Results revealed that the highest branch number (7.17, 13.96 and 21.92 at 30, 60 and 90 DAP, respectively) was found from the treatment V_2 followed by V_3 and V_1. The lowest branch number (3.46, 6.92, and 11.92 at 30, 60, and 90 DAP, respectively) was obtained from the control treatment V_0. Under the present study, control treatment also showed comparatively better results, might be due to the presence of nutrients in cocopeat (Appendix I) and mustard oil cake which was up taken by the root system of peppermint. The highest branch number was produced at different growth stages by the application of 45% vermicompost than that of others with ensuring better growth and development. A similar result was also observed by Suresh *et al.* (2018) and Rawat R. *et al*. (2020) which supported the present study.

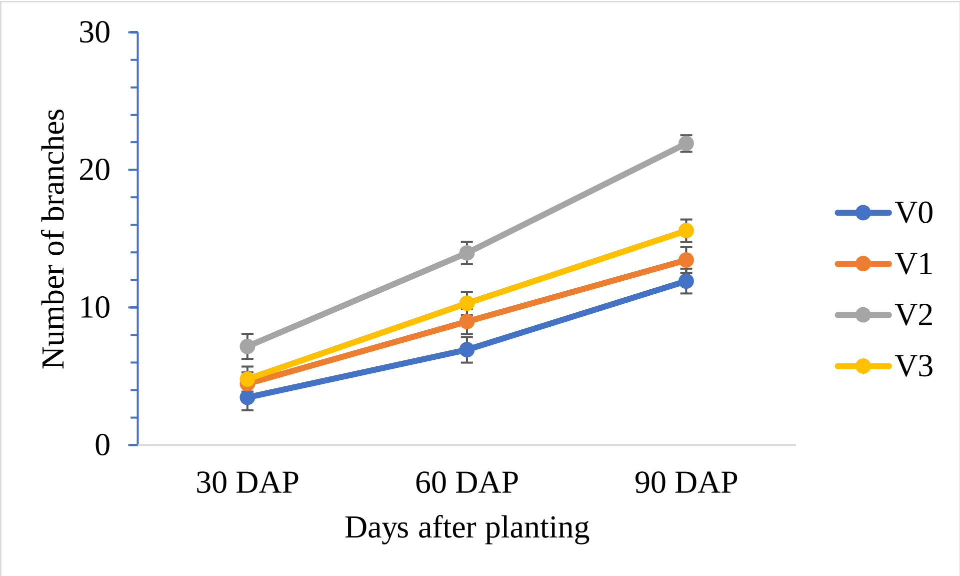

Figure 3. Number of branches per plant of peppermint as influenced by vermicompost ($LSD_{0.05}$ = 7.17, 13.96 and 21.92 at 30, 60 and 90 DAP, respectively)

(V_0 = 90% Cocopeat (Control) + 10% broken bricks/pot, V_1 = 30% vermicompost + 60% cocopeat + 10% broken bricks/pot, V_2 = 45% vermicompost + 45% cocopeat + 10% broken bricks/pot and V_3 = 60% vermicompost + 30% cocopeat + 10% broken bricks/pot)

Variation was observed on branch number at different growth stages influenced by light wavelengths applications (Fig. 4 and Appendix III). Results showed that the highest branch number (9.12, 18.54, and 28.52 at 30, 60, and 90 DAP, respectively) was found from the treatment L_1 whereas the lowest branch number (0.21, 0.50, and 1.04 at 30, 60 and 90 DAP, respectively) was obtained from the treatment L_3. The results indicated that highest branch number at different growth stages was produced by the application of L_1 followed by L_4, L_2 and L_3. Almost same result was also observed by Rehman M. *et al*. (2017) and Noguchi *et al.* (2016).

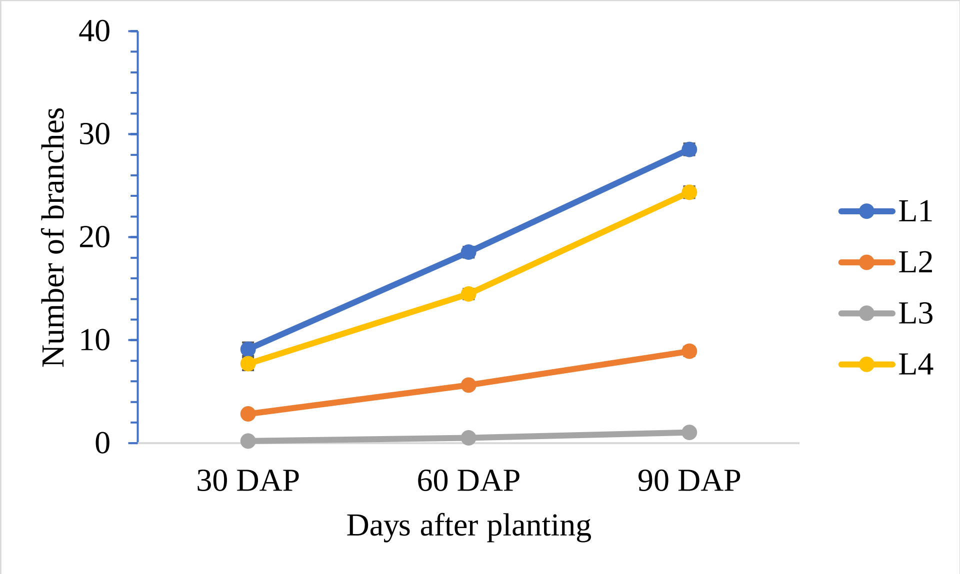

Figure 4. Number of branches per plant of peppermint as influenced by light quality ($LSD_{0.05}$ = 9.12, 18.54, and 28.52 at 30, 60 and 90 DAP, respectively)

(L_1 = White light, L_2 = Blue light, L_3 = Red light and L_4 = Combined Red and Blue light)

There was a significant variation found on peppermint branch number per plant at different growth stages influenced by the interaction of vermicompost and light quality (Table 2 and Appendix III). It was observed that the highest branch number (13.33, 25.33, and 37.67 at 30, 60, and 90 DAP, respectively) was found from the treatment combination of V_2L_1 which was significantly different from all other treatment combinations. The lowest branch number (0.00, 0.16, and 0.5 at 30, 60, and 90 DAP, respectively) was obtained from the treatment combination of V_0L_3 which was also significantly different from all other treatment combinations. The results indicated that the combination of vermicompost and light quality ensures the optimum condition for the growth and development of peppermint and the ultimate result is the highest branch number per plant at different growth stages.

Table 2: Interaction effect of vermicompost and light quality on number of branches per plant of peppermint*

Treatments	Number of branches per plant at different DAP		
	30 DAP	60 DAP	90 DAP
V_0L_1	6.167 e	13.17 f	22.00 ef
V_0L_2	2.500 h	4.833 i	7.333 i
V_0L_3	0.0000 i	0.1667 j	0.5000 k
V_0L_4	5.167 f	9.500 g	17.83 g
V_1L_1	8.000 d	16.50 d	24.28 d
V_1L_2	2.500 h	4.667 i	8.000 i
V_1L_3	0.0000 i	0.1667 j	0.5000 k
V_1L_4	7.333 d	14.59 e	21.00 f
V_2L_1	13.33 a	25.33 a	37.67 a
V_2L_2	3.667 g	8.333 h	12.67 h
V_2L_3	0.5000 i	0.8333 j	2.000 j
V_2L_4	11.17 b	21.33 b	35.33 b
V_3L_1	9.000 c	19.17 c	30.17 c
V_3L_2	2.667 h	4.667 i	7.667 i
V_3L_3	0.3333 i	0.8333 j	1.167 jk
V_3L_4	7.167 d	12.50 f	23.30 de
$LSD_{0.05}$	0.906	1.158	1.457
CV (%)	10.97	7.11	5.55

*In a column, means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

(V_0 = 90% Cocopeat (Control) + 10% broken bricks/pot, V_1 = 30% vermicompost + 60% cocopeat + 10% broken bricks/pot, V_2 = 45% vermicompost + 45% cocopeat + 10% broken bricks/pot and V_3 = 60% vermicompost + 30% cocopeat + 10% broken bricks/pot; L_1 = White light, L_2 = Blue light, L_3 = Red light and L_4 = Combined Red and Blue light)

4.3 Number of leaves per plant

In terms of number of leaves per plant at different growth stages in relation to different vermicompost doses, results were varied significantly under the trial (Fig. 5 and Appendix IV). Results revealed that the highest leaves number (60.58, 139.58 and 185.63 at 30, 60 and 90 DAP, respectively) was found from the treatment V_2 followed by V_3 and V_1. The lowest leaves number (35.07, 68.65, and 97.00 at 30, 60, and 90 DAP, respectively) was obtained from the control treatment V_0. Under the present study, control treatment also showed comparatively better results, might be due to the presence of nutrients in cocopeat (Appendix I) and mustard oil cake which was up taken by the root system of peppermint. The highest leaves number was produced at different growth stages by the application of 45% vermicompost than that of others with ensuring better growth and development. A similar result was also observed by Suresh *et al.* (2018) and Rawat R. *et al*. (2020) which supported the present study.

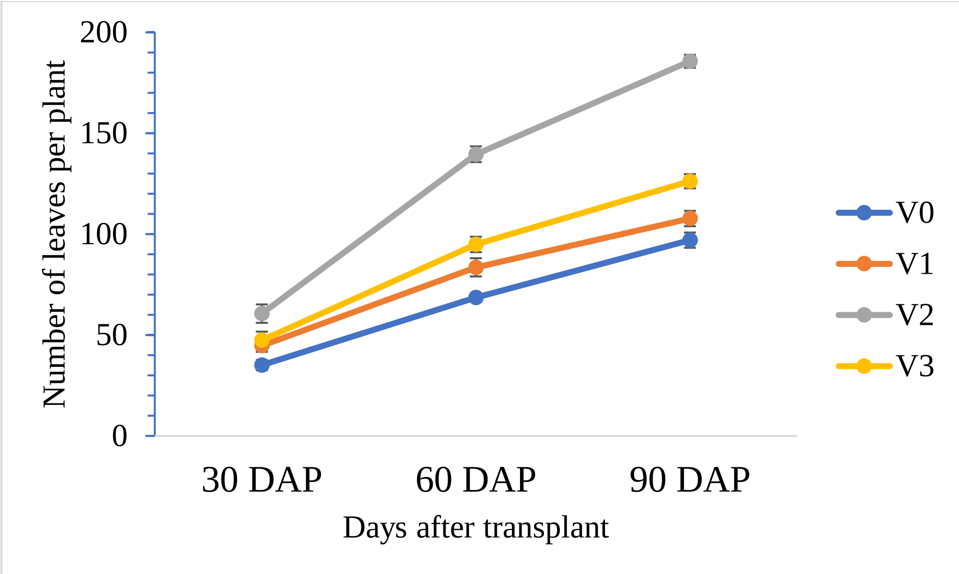

Figure 5. Number of leaves per plant of peppermint as influenced by vermicompost ($LSD_{0.05}$ = 60.58, 139.58 and 185.63 at 30, 60 and 90 DAP, respectively)

(V_0 = 90% Cocopeat (Control) + 10% broken bricks/pot, V_1 = 30% vermicompost + 60% cocopeat + 10% broken bricks/pot, V_2 = 45% vermicompost + 45% cocopeat + 10% broken bricks/pot and V_3 = 60% vermicompost + 30% cocopeat + 10% broken bricks/pot)

Variation was observed on leaf number at different growth stages influenced by light wavelength applications (Fig. 6 and Appendix IV). Results showed that the highest leaves number (71.41, 153.20, and 199.75 at 30, 60, and 90 DAP, respectively) was found from the treatment L_4 whereas the lowest leaves number (13.61, 26.25, and 35.04 at 30, 60 and 90 DAP, respectively) was obtained from the treatment L_3. The results indicated that highest branch number at different growth stages was produced by the application of L_4 followed by L_1, L_2 and L_3. Almost same result was also observed by Rehman M. *et al*. (2017) and Noguchi *et al.* (2016).

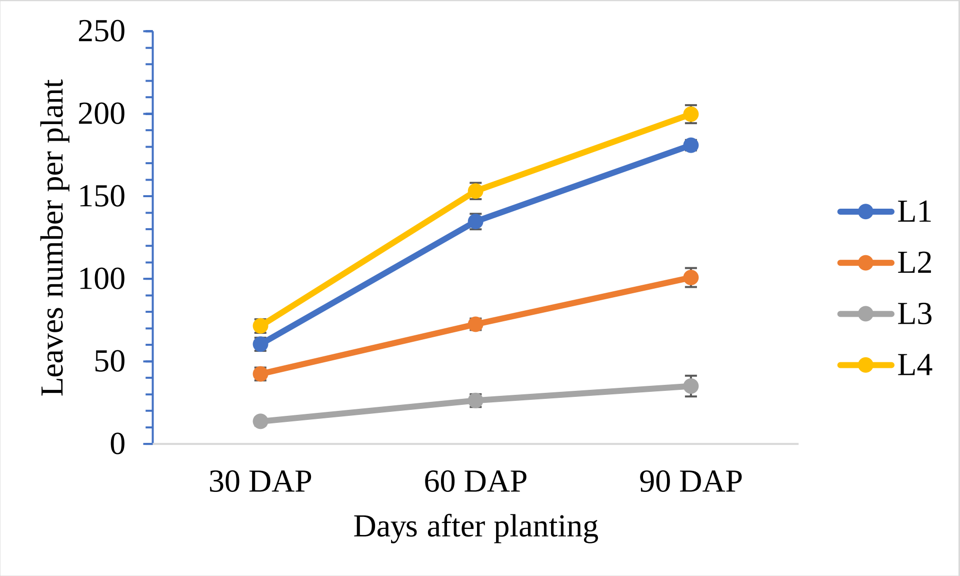

Figure 6. Number of leaves per plant of peppermint as influenced by light quality ($LSD_{0.05}$ = 71.41, 153.20, and 199.75 at 30, 60 and 90 DAP, respectively)
(L_1 = White light, L_2 = Blue light, L_3 = Red light and L_4 = Combined Red and Blue light)

There was a significant variation found on peppermint leaf number per plant at different growth stages influenced by the interaction of vermicompost and light quality (Table 2 and Appendix IV). It was observed that the highest leaves number (91.83, 239.3, and 318.2 at 30, 60, and 90 DAP, respectively) was found from the treatment combination of V_2L_4 which was significantly different from all other treatment combinations. The lowest leaves number (12.96, 24.50, and 34.83 at 30, 60, and 90 DAP, respectively) was obtained from the treatment combination of V_0L_3 which was also significantly different from all other treatment combinations. The results indicated that the combination of vermicompost and light quality ensures the optimum condition for the growth and development of peppermint and the ultimate result is the highest leaves number per plant at different growth stages.

Table 3: Interaction effect of vermicompost and light quality on number of leaves per plant of peppermint*

Treatments	Number of leaves per plant at different DAP		
	30 DAP	60 DAP	90 DAP
V_0L_1	44.00 g	95.17 g	131.0 f
V_0L_2	31.50 i	52.77 j	92.17 h
V_0L_3	12.96 kl	24.50 lm	34.83 ij
V_0L_4	51.83 f	102.2 f	130.0 f
V_1L_1	59.50 e	113.8 e	149.0 e
V_1L_2	40.13 h	75.00 i	98.17 h
V_1L_3	14.33 jk	28.83 kl	35.83 ij
V_1L_4	64.83 d	116.5 e	147.8 e
V_2L_1	73.83 c	204.8 b	269.0 b
V_2L_2	59.83 e	83.83 h	115.2 g
V_2L_3	16.83 j	30.33 k	40.17 i
V_2L_4	91.83 a	239.3 a	318.2 a
V_3L_1	64.17 d	125.0 d	174.8 d
V_3L_2	38.00 h	78.33 i	97.67 h
V_3L_3	10.33 l	21.33 m	29.33 j
V_3L_4	77.17 b	154.8 c	203.0 c
$LSD_{0.05}$	2.699	4.408	7.416
CV (%)	3.46	2.74	3.45

*In a column, means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

(V_0 = 90% Cocopeat (Control) + 10% broken bricks/pot, V_1 = 30% vermicompost + 60% cocopeat + 10% broken bricks/pot, V2 = 45% vermicompost + 45% cocopeat + 10% broken bricks/pot and V_3 = 60% vermicompost + 30% cocopeat + 10% broken bricks/pot; L_1 = White light, L_2 = Blue light, L_3 = Red light and L_4 = Combined Red and Blue light)

4.4 Leaf area (cm^2)

In terms of area of leaves in relation to different vermicompost doses, results were varied under the trial (Table 4 and Appendix V). Results revealed that the highest leaf area (4.65 cm^2 at 90 DAP) was found from the treatment V_2 followed by V_3 and V_1. The lowest leaf area (4.30 cm^2 at 90 DAP) was obtained from the treatment V_0. Under the present study, control treatment also showed comparatively better results, might be due to the presence of nutrients in cocopeat (Appendix I) and mustard oil cake which was uptaken by the root system of peppermint. A similar result was also observed by Suresh *et al.* (2018) and Rawat R. *et al*. (2020) which supported the present study.

Table 4: Effect of vermicompost on leaf area (cm^2) of peppermint

Treatments	Leaf area (cm^2)
V_0	4.304 c
V_1	4.383 c
V_2	4.647 a
V_3	4.487 b
CV (%)	2.42

*In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

(V_0 = 90% Cocopeat (Control) + 10% broken bricks/pot, V_1 = 30% vermicompost + 60% cocopeat + 10% broken bricks/pot, V_2 = 45% vermicompost + 45% cocopeat + 10% broken bricks/pot and V_3 = 60% vermicompost + 30% cocopeat + 10% broken bricks/pot)

Remarkable variation was observed on leaf area influenced by light wavelengths applications (Table 5 and Appendix V). Results showed that the highest leaf area (8.10 cm^2 at 90 DAP) was found from the treatment L_4 whereas the lowest leaf area (0.60 cm^2 at 90 DAP) was obtained from the treatment L_3. The results indicated that highest leaf area was produced by the application of L_4 followed by L_1, L_2 and L_3. Almost same result was also observed by Noguchi *et al.* (2016) and Rehman M. *et al.* (2017).

Table 5: Effect of light quality on leaf area (cm^2) of peppermint

Treatments	Leaf area (cm^2)
L_1	4.733 b
L_2	4.379 c
L_3	0.6037 d
L_4	8.104 a
CV (%)	2.42

*In a column, means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

(L_1 = White light, L_2 = Blue light, L_3 = Red light and L_4 = Combined Red and Blue light)

There was variation found on peppermint leaf area influenced by the interaction of vermicompost and light quality (Table 6 and Appendix V). It was observed that the highest leaf area (8.48 cm^2 at 90 DAP) was found from the treatment combination of V_2L_4 which was significantly different from all other treatment combinations. The lowest leaf area (0.55 cm^2 at 90 DAP) from treatment combination of V_0L_3. The results indicated that the combination V_2L_4 of vermicompost and light quality ensures the optimum condition for the growth and development of peppermint.

Table 6: Interaction effect of vermicompost and light quality on leaf area (cm^2) of peppermint*

Treatments	Leaf area (cm^2)
V_0L_1	4.690 ef
V_0L_2	4.173 h
V_0L_3	0.5525 i
V_0L_4	7.800 c
V_1L_1	4.845 de
V_1L_2	4.407 g
V_1L_3	0.6300 i
V_1L_4	8.065 b
V_2L_1	4.873 d
V_2L_2	4.557 fg
V_2L_3	0.6773 i
V_2L_4	8.479 a
V_3L_1	4.522 fg
V_3L_2	4.380 g
V_3L_3	0.5550 i
V_3L_4	8.074 b
$LSD_{0.05}$	0.182
CV (%)	2.42

*In a column, means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

(V_0 = 90% Cocopeat (Control) + 10% broken bricks/pot, V_1 = 30% vermicompost + 60% cocopeat + 10% broken bricks/pot, V_2 = 45% vermicompost + 45% cocopeat + 10%

broken bricks/pot and V_3 = 60% vermicompost + 30% cocopeat + 10% broken bricks/pot; L_1 = White light, L_2 = Blue light, L_3 = Red light and L_4 = Combined Red and Blue light)

4.5 Chlorophyll a, b and total chlorophyll content of leaves (mg/g)

In terms of Chlorophyll a content of leaves in relation to different vermicompost doses, results were varied under the trial (Table 7 and Appendix VI). Results revealed that the highest Chlorophyll a, b and total chlorophyll content (1 mg/g, 0.297 mg/g, 1.298 mg/g respectively at 90 DAP) was found from the treatment V_2 followed by V_3 and V_1; the lowest (0.87 mg/g, 0.26 mg/g and 1.135 mg/g at 90 DAP) was obtained from the treatment V_0. Under the present study, control treatment also showed comparatively better results, might be due to the presence of nutrients in cocopeat (Appendix I) and mustard oil cake which was up taken by the root system of peppermint. A similar result was also observed by Ayyobi, H. *et al.* (2013) which supported the present study.

Table 7: Effect of vermicompost on chlorophyll a, b and total chlorophyll content (mg/g) at 90 DAP of peppermint leaves*

Treatments	Chlorophyll a content (mg/g)	Chlorophyll b content (mg/g)	Total chlorophyll content (mg/g)
V_0	0.8750 c	0.2600 b	1.135 d
V_1	0.9375 b	0.2817 ab	1.220 c
V_2	1.000 a	0.2975 a	1.298 a
V_3	0.9742 a	0.2900 a	1.264 b
CV (%)	2.82	3.39	2.69

*In a column, means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

(V_0 = 90% Cocopeat (Control) + 10% broken bricks/pot, V_1 = 30% vermicompost + 60% cocopeat + 10% broken bricks/pot, V_2 = 45% vermicompost + 45% cocopeat + 10% broken bricks/pot and V_3 = 60% vermicompost + 30% cocopeat + 10% broken bricks/pot)

Variation was observed on chlorophyll content (mg/g) influenced by light wavelengths applications (Table 8 and Appendix VI). Results showed that the highest chlorophyll a, b and total chlorophyll content (0.9825 mg/g, 0.2925 mg/g and 1.275 mg/g respectively at 90 DAP) was found from the treatment L_4 whereas the lowest (0.91 mg/g, 0.2733 mg/g, 1.188 mg/g respectively at 90 DAP) was obtained from the treatment L_3. The results indicated highest chlorophyll content was produced by the application of L_4 followed by L_1, L_2 and L_3. Almost same result was also observed by Fan, X. *et al.* (2013) that red light treatment was adverse to pigment accumulation and the concentration of photosynthetic pigments and chlorophyll biosynthesis precursors were higher under red and blue light treatment. Ma, Y. *et al.* (2021) found that combination of blue and red light increased chlorophyll content compared to other lights. This is because Blue light improves gene expression of MgCH, GluTR and FeCH which regulates synthesis of chlorophyll (Wang *et al.* 2009) and promotes chlorophyll synthesis (Poudel *et al.* 2008; Kurilcik *et al*. 2008). Red light is not conducive to the formation of chlorophyll, because of the reduction in tetrapyrrole precursor 5-aminolevulinic acid (Tanaka et al. 1998; Sood *et al.* 2005).

Table 8: Effect of light quality on chlorophyll a, b and total chlorophyll content (mg/g) of peppermint leaves at 90 DAP*

Treatments	Chlorophyll a content (mg/g)	Chlorophyll b content (mg/g)	Total chlorophyll content (mg/g)
L_1	0.9575 ab	0.2858 a	1.243 b
L_2	0.9325 bc	0.2775 a	1.210 c
L_3	0.9142 c	0.2733 a	1.188 c
L_4	0.9825 a	0.2925 a	1.275 a
CV (%)	2.82	3.39	2.69

*In a column, means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

(L_1 = White light, L_2 = Blue light, L_3 = Red light and L_4 = Combined Red and Blue light)

Interaction effect of different vermicompost doses and light quality showed differences in terms of chlorophyll content of peppermint under the present trial (Table 9 and appendix VI). The highest chlorophyll a, b and total chlorophyll content (1.04 mg/g, 0.31 mg/g and 1.35 mg/g respectively at 90 DAP) was observed from V_2L_4 and the lowest (0.84 mg/g, 0.25 mg/g and 1.09 mg/g respectively at 90 DAP) was found from V_0L_3 treatment combination. V_2L_4 produces highest chlorophyll content due to activation of specific phytochromes and light receptors as Ayyobi, H. *et al.* (2013) and Fan X. *et al.* (2013) also reported that.

Table 9: Interaction effect of vermicompost and light quality on chlorophyll a, b and total chlorophyll content (mg/g) at 90 DAP of peppermint leaves*

Treatments	Chlorophyll a (mg/g)	Chlorophyll b content (mg/g)	Total chlorophyll content (mg/g)
V_0L_1	0.8800 fgh	0.2600 ab	1.140 fgh
V_0L_2	0.8700 gh	0.2600 ab	1.130 gh
V_0L_3	0.8400 h	0.2500 b	1.090 h
V_0L_4	0.9100 efg	0.2700 ab	1.180 efg
V_1L_1	0.9400 de	0.2833 ab	1.223 cde
V_1L_2	0.9300 def	0.2800 ab	1.210 de
V_1L_3	0.9100 efg	0.2733 ab	1.187 ef
V_1L_4	0.9700 bcd	0.2900 ab	1.260 bcd
V_2L_1	1.010 ab	0.3000 ab	1.310 ab
V_2L_2	0.9800 bcd	0.2900 ab	1.270 bc
V_2L_3	0.9700 bcd	0.2900 ab	1.260 bcd
V_2L_4	1.040 a	0.3100 a	1.350 a
V_3L_1	1.000 abc	0.3000 ab	1.300 ab
V_3L_2	0.9500 cde	0.2800 ab	1.230 cde
V_3L_3	0.9367 de	0.2800 ab	1.217 de
V_3L_4	1.010 ab	0.3000 ab	1.310 ab
$LSD_{0.05}$	0.052	0.053	0.052
CV (%)	2.82	3.39	2.69

*In a column, means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

(V_0 = 90% Cocopeat (Control) + 10% broken bricks/pot, V_1 = 30% vermicompost + 60% cocopeat + 10% broken bricks/pot, V_2 = 45% vermicompost + 45% cocopeat + 10% broken bricks/pot and V_3 = 60% vermicompost + 30% cocopeat + 10% broken bricks/pot; L_1 = White light, L_2 = Blue light, L_3 = Red light and L_4 = Combined Red and Blue light)

4.6 Weight of fresh leaf per plant, fresh plant and dry plant (g)

In terms of fresh leaf, fresh plant and dry plant weight in relation to different vermicompost doses, results varied significantly under the trial (Table 10 and Appendix VII). Results revealed that the highest fresh leaf, fresh plant and dry plant weight (6.88 g, 13.95 g and 5.737 g, respectively at 90 DAP) was found from the treatment V_2 followed by V_3 and V_1; the lowest (2.65 g, 5.89 g and 2.3 g, respectively at 90 DAP) was obtained from the treatment V_0. Under the present study, control treatment also showed comparatively better results, might be due to the presence of nutrients in cocopeat (Appendix I) and supplied mustard oil cake solution which was up taken by the root system of peppermint. Though V_3 contained higher amount of vermicompost it showed poor result compared to V_2 treatment may be due to the reduced porosity of the growing media and decreased mobility of the nutrients as media V_3 was more compact than V_2. An almost similar result was also observed by Ayyobi *et al.* (2013) and Rawat R. *et al*. (2020) which supported the present study.

Table 10: Effect of vermicompost on fresh leaf, fresh plant and dry plant weight (g) of peppermint*

Treatments	Leaf fresh weight (g)	Plant fresh weight (g)	Plant dry weight (g)
V_0	2.659 d	5.892 c	2.303 d
V_1	4.716 c	10.20 b	3.967 c
V_2	6.889 a	13.95 a	5.737 a
V_3	5.487 b	11.22 b	4.548 b
CV (%)	6.86	3.71	9.08

*In a column, means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

(V_0 = 90% Cocopeat (Control) + 10% broken bricks/pot, V_1 = 30% vermicompost + 60% cocopeat + 10% broken bricks/pot, V_2 = 45% vermicompost + 45% cocopeat + 10% broken bricks/pot and V_3 = 60% vermicompost + 30% cocopeat + 10% broken bricks/pot)

Remarkable variation was observed on fresh leaf, fresh plant and dry plant weight (g) influenced by light wavelength applications (Table 11 and Appendix VII). Results showed that the highest fresh leaf, fresh plant and dry plant weight (7.39 g, 15.83 g and 6.31 g respectively at 90 DAP) was found from the treatment L_4 whereas the lowest (1.16 g, 2.53 g and 1.01 g respectively at 90 DAP) was obtained from the treatment L_3. The results indicated that highest weight was produced by the application of L_4 followed by L_1, L_2 and L_3. Almost same result was also observed by Noguchi *et al.* (2016), Fan X. *et al.* (2013) and Ma, Y. *et al.* (2021) that increased leaf area, chlorophyll content, thereby increased photosynthetic efficiency and higher carbohydrate assimilation increased biomass in case of combined red and blue light treatment.

Table 11: Effect of light quality on fresh leaf, fresh plant and dry plant weight (g) of peppermint*

Treatments	Leaf fresh weight (g)	Plant fresh weight (g)	Plant dry weight (g)
L_1	6.118 b	12.89 b	5.169 b
L_2	4.284 c	9.983 c	4.055 c
L_3	1.157 d	2.527 d	1.014 d
L_4	7.393 a	15.83 a	6.316 a
CV (%)	6.86	3.71	9.08

*In a column, means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

(L_1 = White light, L_2 = Blue light, L_3 = Red light and L_4 = Combined Red and Blue light)

Interaction effect of different vermicompost doses and light quality showed significant differences in terms of fresh leaf weight of individual plant of peppermint under the present trial (Table 12 and appendix VII). The highest fresh leaf, fresh plant and dry plant weight (10.76 g, 21.58 g and 8.933g respectively at 90 DAP) was observed from V_2L_4 and the lowest fresh leaf, fresh plant and dry plant weight (0.907 g, 1.873 g and 0.86 g respectively at 90 DAP) was found from V_0L_3 treatment combination. V_2L_4 produces highest fresh weight due to increased leaf area, chlorophyll content as Raghava (2003) and Fan X. *et al.* (2013) also reported that higher fresh weight production may be due to increased leaf area, chlorophyll content, thereby increased photosynthetic efficiency and higher carbohydrate assimilation.

Table 12: Interaction effect of vermicompost and light quality on fresh leaf, fresh plant and dry plant weight (g) of peppermint*

Treatments	Weight of fresh leaf (g)	Weight of fresh plant (g)	Weight of dry plant (g)
V_0L_1	3.117 g	6.593 g	2.577 h
V_0L_2	3.090 g	6.758 g	2.557 h
V_0L_3	0.907 h	1.873 i	0.8600 i
V_0L_4	3.823 f	8.130 f	3.217 g
V_1L_1	6.193 d	12.50 d	5.243 e
V_1L_2	3.933 f	7.563 f	3.313 g
V_1L_3	1.170 h	2.337 hi	0.9863 i
V_1L_4	7.567 c	15.29 c	6.250 cd
V_2L_1	8.243 b	16.91 b	6.877 b
V_2L_2	7.307 c	14.70 c	5.990 d
V_2L_3	1.250 h	2.613 h	1.147 i
V_2L_4	10.76 a	21.58 a	8.933 a
V_3L_1	7.317 c	14.75 c	5.980 d
V_3L_2	5.207 e	10.67 e	4.360 f
V_3L_3	1.200 h	2.387 hi	1.063 i
V_3L_4	8.223 b	16.71 b	6.863 bc
$LSD_{0.05}$	0.566	0.62	0.624
CV (%)	6.86	3.71	9.08

*In a column, means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

(V_0 = 90% Cocopeat (Control) + 10% broken bricks/pot, V_1 = 30% vermicompost + 60% cocopeat + 10% broken bricks/pot, V_2 = 45% vermicompost + 45% cocopeat + 10% broken bricks/pot and V_3 = 60% vermicompost + 30% cocopeat + 10% broken bricks/pot; L_1 = White light, L_2 = Blue light, L_3 = Red light and L_4 = Combined Red and Blue light)

CHAPTER V
SUMMARY AND CONCLUSION

Summary

The experiment was carried out in the Horticultural Biotechnology and Stress Management Lab of Dr M A Wazed Miah Research Center, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from November 2019 to March 2020 to find out the effect of vermicompost and light quality on growth and yield of mint. The experiment consisted of two factors; Factor A: Vermicompost (4 levels) as- V_0 = 90% Cocopeat (Control) + 10% broken bricks, V_1 = 30% vermicompost + 60% cocopeat/pot + 10% broken bricks, V_2 = 45% vermicompost + 45% cocopeat/pot + 10% broken bricks and V_3 = 60% vermicompost + 30% cocopeat/pot + 10% broken bricks and Factor B: Light quality (4 levels) as- L_1 = White light, L_2 = Blue light, L_3 = Red light and L_4 = Combined Red and Blue light. The two factors experiment was laid out in Completely Randomized Design (CRD) with three replications. data were recorded for different growth and yield parameters and significant variation was recorded for different treatment. The collected data were statistically analyzed for evaluation of the treatment effect.

Significant variations were observed due to different treatments such as plant height of mint (31.66, 337.52 and 43.03 cm at 30, 60 and 90 DAP, respectively) was recorded from V_2 (45% vermicompost + 45% cocopeat/pot + 10% broken bricks) and the shortest plant (14.11, 17.44, and 21.68 cm at 30, 60, and 90 DAP, respectively) was found from V_0 (90% cocopeat + 10% broken bricks); the highest number of branches/plant (7.17, 13.96 and 21.92 at 30, 60 and 90 DAP, respectively) was found from V_2 (45% vermicompost + 45% cocopeat/pot + 10% broken bricks) whereas the lowest branch number/plant (3.36, 6.92, and 11.92 at 30, 60, and 90 DAP, respectively) was found from V_0 (90% cocopeat + 10% broken bricks); the highest number of leaves/ plant (60.58, 139.58 and 185.63 at 30, 60 and 90 DAP, respectively) was recorded from V_2 (45% vermicompost + 45% cocopeat/pot + 10% broken bricks) and the lowest number of leaves/ (35.07, 68.65, and 97.00 at 30, 60, and 90 DAP, respectively) was found from V_0 (90% cocopeat + 10% broken bricks); the highest leaf area (4.65 cm^2 at 90 DAP) was recorded from V_2 (45% vermicompost + 45% cocopeat/pot + 10% broken bricks) and whereas the lowest leaf area (4.30 cm^2 at 90 DAP) was found from V_0 (90% cocopeat + 10% broken bricks); the

highest chlorophyll a content (1 mg/g at 90 DAP) was recorded from V_2 (45 % vermicompost + 45 % cocopeat + 10% broken bricks) and whereas the lowest chlorophyll a content (0.87 mg/g at 90 DAP) was found from V_0 (90 % cocopeat + 10% broken bricks); the highest chlorophyll b content (0.297 mg/g at 90 DAP) was recorded from V_2 (45 % vermicompost + 45 % cocopeat + 10% broken bricks) and whereas the lowest chlorophyll b content (0.26 mg/g at 90 DAP) was found from V_0 (90 % cocopeat + 10% broken bricks); the highest total chlorophyll content (1.29 mg/g at 90 DAP) was recorded from V_2 (45 % vermicompost + 45 % cocopeat + 10% broken bricks) and whereas the lowest total chlorophyll content (1.13 mg/g at 90 DAP) was found from V_0 (90 % cocopeat + 10% broken bricks). The highest fresh weight of leaf (6.88 g at 90 DAP) was found from V_2 (45 % vermicompost + 45 % cocopeat + 10% broken bricks) while the lowest fresh leaf weight (2.65 g at 90 DAP) was observed from V_0 (90 % cocopeat + 10% broken bricks); the highest fresh weight of individual plant (13.95 g at 90 DAP) was found from V_2 (45 % vermicompost + 45 % cocopeat + 10% broken bricks) while the lowest fresh plant weight (5.89 g at 90 DAP) was observed from V_0 (90 % cocopeat + 10% broken bricks); the highest dry weight of individual plant (5.73 g at 90 DAP) was found from V_2 (45 % vermicompost + 45 % cocopeat + 10% broken bricks) while the lowest dry weight (2.30 g at 90 DAP) was observed from V_0 (90 % cocopeat + 10% broken bricks).

In terms of plant height of mint highest (30.83, 36.56, and 40.80 cm at 30, 60, and 90 DAP, respectively) was recorded from L_3 (Red light) and the shortest plant (21.15, 25.53, and 30.24 cm at 30, 60 and 90 DAP, respectively) was found from L_4 (Blue and red light); the highest number of branches/plant (9.12, 18.54, and 28.52 at 30, 60, and 90 DAP, respectively) was found from L_1 (White light) whereas the lowest branch number/plant (0.21, 0.50, and 1.04 at 30, 60 and 90 DAP, respectively) was found from L_3 (Red light); the highest number of leaves/ plant (71.41, 153.20, and 199.75 at 30, 60, and 90 DAP, respectively) was recorded from L_4 (Combined Red and blue light) and the lowest number of leaves/plant (13.61, 26.25, and 35.04 at 30, 60 and 90 DAP, respectively) was found from L_3 (Red light); the highest leaf area (8.10 cm^2 at 90 DAP) was recorded from L_4 (Combined Red and blue light) and whereas the lowest leaf area (0.60 cm^2 at 90 DAP) was found from L3 (Red light); the highest chlorophyll a content (0.98 mg/g at 90 DAP) was recorded from L_4 (Combined red and blue light) whereas the lowest chlorophyll a content (0.91 mg/g at 90 DAP) was found from L_3 (Red light); the highest chlorophyll b content (0.292 mg/g at 90 DAP) was recorded from L_4 (Combined red and blue light) whereas the lowest chlorophyll b content (0.273 mg/g at 90 DAP) was found from L_3 (Red light); the highest total chlorophyll content (1.27 mg/g at 90 DAP) was recorded from L_4 (Combined red and blue light) whereas the lowest total chlorophyll content (1.18 mg/g at 90 DAP) was found from L_3 (Red light). The highest weight of fresh leaf (7.39 g at 90 DAP) was found from L_4 (Combined red and blue light) while the lowest fresh leaf weight (1.15 g at 90 DAP) was observed from L_3 (Red light); the highest fresh weight of individual plant (15.83 g at 90 DAP) was found from L_4 (Combined red and blue light) while the lowest weight (2.52 g at 90 DAP) was observed from L_3 (Red light); the highest dry weight of individual plant (6.316 g at 90 DAP) was found from L_4 (Combined red and blue light) while the lowest dry weight (1.01 g at 90 DAP) was observed from L_3 (Red light).

Interaction effect of different vermicompost doses and light treatment showed statistically significant variation in terms of plant height of mint at 30, 60, 90 DAP. At 30, 60, 90 DAP, the tallest plant 46.02 cm, 52.72 cm, and 56.20 cm, respectively was observed from V_2L_3 (45% vermicompost + 45% cocopeat/pot + 10% broken bricks with red light) and the shortest plant 8.70 cm, 10.33 cm and 14.30 cm respectively was found from V_0L_4 (90% Cocopeat (Control) + 10% broken bricks with combined red and blue light) treatment combination. The highest branch number/plant 13.33, 25.33 and 37.67, respectively was observed from V_2L_1 (45% vermicompost + 45% cocopeat/pot + 10% broken bricks with white light) and the lowest branch number/plant 0.00, 0.16 and 0.5, respectively was found from V_0L_3 (90% Cocopeat (Control) + 10% broken bricks with red light) treatment combination. The highest number of leaves/ plant 91.83, 239.3 and 318.2 respectively was observed from V_2L_4 (45% vermicompost + 45% cocopeat/pot + 10% broken bricks with combiner blue and red light) and the lowest number of leaves/plant 12.96, 24.50 and 34.83 respectively was found from V_0L_3 (90% cocopeat/pot + 10% broken bricks with red light) treatment combination. The highest leaf area (8.48 cm^2 at 90 DAP) was observed from V_2L_4 (45% vermicompost + 45% cocopeat/pot + 10% broken bricks with combined blue and red light) and the shortest leaf area (0.55 cm^2 at 90 DAP) was found from V_0L_3 (90% Cocopeat (Control) + 10% broken bricks with red light) treatment combination. The highest chlorophyll a content (1.04 mg/g at 90 DAP) was observed from V_2L_4 (45% vermicompost + 45% cocopeat/pot + 10% broken bricks with combined blue and red light) and the lowest chlorophyll a content (0.84 mg/g at 90 DAP) was found from V_0L_3 (90% cocopeat/pot + 10% broken bricks with red light) treatment combination; the highest chlorophyll b content (0.31 mg/g at 90 DAP) was observed from

V_2L_4 (45% vermicompost + 45% cocopeat/pot + 10% broken bricks with combined blue and red light) and the lowest chlorophyll b content (0.25 mg/g at 90 DAP) was found from V_0L_3 (90% cocopeat/pot + 10% broken bricks with red light) treatment combination; the highest total chlorophyll content (1.35 mg/g at 90 DAP) was observed from V_2L_4 (45% vermicompost + 45% cocopeat/pot + 10% broken bricks with combined blue and red light) and the lowest total chlorophyll content (1.09 mg/g at 90 DAP) was found from V_0L_3 (90% cocopeat/pot + 10% broken bricks with red light) treatment combination. The highest weight of fresh leaf (10.76 g) was observed from V_2L_4 (45% vermicompost + 45% cocopeat/pot + 10% broken bricks with combined blue and red light) and the lowest fresh leaf weight (0.90 g) was found from V_0L_3 (90% Cocopeat (Control) + 10% broken bricks with red light) treatment combination; the highest weight of individual fresh plant (21.58 g) was observed from V_2L_4 (45% vermicompost + 45% cocopeat/pot + 10% broken bricks with combined blue and red light) and the lowest weight (1.873 g) was found from V_0L_3 (90% Cocopeat (Control) + 10% broken bricks with red light) treatment combination; the highest dry weight of individual plant (8.93 g) was observed from V_2L_4 (45% vermicompost + 45% cocopeat/pot + 10% broken bricks with combined blue and red light) and the lowest dry weight (0.86 g) was found from V_0L_3 (90% Cocopeat (Control) + 10% broken bricks with red light) treatment combination.

Conclusion

Considering the above mentioned findings, it can be concluded that the 45% vermicompost + 45% cocopeat + 10% broken/pot bricks with combined blue and red light treatment on peppermint plant was most effective for vegetative growth and as well as quantitative yield of its fresh herbage.

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APPENDICES

Appendix I. Chemical properties of cocopeat

pH	6.10
EC	0.63
N (%)	0.41
P (%)	0.81
K (%)	1.32
Ca (%)	0.21
Mg (%)	0.31
Fe (ppm)	23.00
Zn (ppm)	22.00
Mn (ppm)	17.00
Cu (ppm)	5.00

Source: Rainbow and Wilson (1997)

Appendix II. Analysis of variance of the data on plant height of peppermint at different days after planting (DAP) as influenced by different vermicompost doses and light quality

Sources of variation	Degrees of Freedom	Mean Square of plant height at		
		30 DAP	60 DAP	90 DAP
Factor A	3	728.844**	971.084**	1064.052**
Factor B	3	249.192**	296.330**	263.889**
AB	9	53.539**	61.880**	52.653**
Error	32	1.126	0.726	0.417

NS = Non-significant, * = Significant at 5% level, ** = Significant at 1% level

Appendix III. Analysis of variance of the data on branch number per plant of peppermint at different days after planting (DAP) as influenced by different vermicompost doses and light quality

Sources of variation	Degrees of Freedom	Mean Square of branch number at		
		30 DAP	60 DAP	90 DAP
Factor A	3	29.616**	106.136**	232.257**
Factor B	3	208.005**	808.987**	2002.142**
AB	9	6.038**	19.795**	36.850**
Error	32	0.297	0.485	0.767

NS = Non-significant, * = Significant at 5% level, ** = Significant at 1% level

Appendix IV. Analysis of variance of the data on leaf number per plant of peppermint at different days after planting (DAP) as influenced by different vermicompost doses and light quality

Sources of variation	Degrees of Freedom	Mean Square of leaf number at		
		30 DAP	60DAP	90 DAP
Factor A	3	1328.812**	11206.137**	18765.783**
Factor B	3	7644.310**	40747.340**	69316.144**
AB	9	160.548**	2593.961**	4830.306**
Error	32	2.634	7.023	19.885

NS = Non-significant, * = Significant at 5% level, ** = Significant at 1% level

Appendix V. Analysis of variance of the data on leaf area of peppermint at different days after planting (DAP) as influenced by different vermicompost doses and light quality

Sources of variation	Degrees of Freedom	Mean Square of leaf area
Factor A	3	0.263**
Factor B	3	112.934**
AB	9	0.046**
Error	32	0.012

NS = Non-significant, * = Significant at 5% level, ** = Significant at 1% level

Appendix VI. Analysis of variance of the data on chlorophyll content of peppermint leaves at 90 days after planting (DAP) as influenced by different vermicompost doses and light quality

Sources of variation	Degrees of Freedom	Mean Square of chlorophyll a	Mean Square of chlorophyll b	Mean Square of total chlorophyll
Factor A	3	0.035**	0.003**	0.059**
Factor B	3	0.011**	0.001	0.017**
AB	9	0.001**	0.001*	0.001**
Error	32	0.001	0.001	0.001

NS = Non-significant, * = Significant at 5% level, ** = Significant at 1% level

Appendix VII. Analysis of variance of the data on leaf fresh weight, plant fresh weight and plant dry weight of peppermint at different days after planting (DAP) as influenced by different vermicompost doses and light quality

Sources of variation	Degrees of Freedom	Mean Square of leaf fresh weight	Mean Square of plant fresh weight	Mean Square of plant dry weight
Factor A	3	35.609**	130.264**	24.486**
Factor B	3	91.930**	388.411**	62.286**
AB	9	4.688**	20.363**	3.083**
Error	32	0.116	0.139	0.141

NS = Non-significant, * = Significant at 5% level, ** = Significant at 1% level