INFLUENCE OF VARIOUS COMMERCIALLY AVAILABLE ORGANIC MANURES ON GROWTH, YIELD AND NUTRIENT ACCUMULATION IN MINT PLANTS (*Mentha* sp.)

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Abstract

A pot experiment was set up using completely randomized design (CRD) to compare the influences of different commonly available organic manures in the markets of Dhaka, Bangladesh on the growth parameters and nutrient contents in Mint plants (*Mentha* sp.). Eight different manures were used as treatments for the comparison, *viz*. ACI, Alo, Annopurna Vermicompost, Cow dung, Kazi, Mazim, Modern Vermicompost and Trichocompost GBD, along with a control, taking three replications of each treatment. After 2.5 months (75 days) the plants were harvested. Trichocompost GBD showed the highest average number of leaves (130.33 plant^{-1}), plant height (27.67 cm plant^{-1}), number of branches (11.00 plant^{-1}) and number of stolons at harvest (1.67 plant^{-1}). The maximum average single leaf area (2.01 cm^2 plant^{-1}) and fresh weight (1.68 g plant^{-1}) were observed in Kazi. ACI was observed to have the highest dry weight (0.26 g plant^{-1}), whereas cow dung had the longest root (8.57 cm plant^{-1}). Nutrient accumulation in leaf and stem exhibited the highest N in ACI, highest P and K in Alo, and highest S in Kazi. Correlation analysis of the explored traits with nutrient concentration of plant shoots was performed to elucidate the impact of plant nutrient contents on the analysed parameters.

***Key words*:** Organic manure; Mint; Growth; Yield; Nutrient accumulation.

INTRODUCTION

Fertilizer plays an important role in the cultivation of crops providing the required nutrition. In present day, cultivation relies on inorganic fertilizer to boost up the production. However, continuous use of inorganic fertilizers is unsustainable as it deteriorates soil health as well as has detrimental effects on the environment. As an alternative and sustainable source, there is a plethora of options of organic manures that can be used to get higher yield and meet the nutrient requirements of crops. Soil organic matter affects soil quality by enhancing nutrient processes by altering soil fertility, physical structure and soil nutrient availability (Qulsum *et al*. 2020). Experiments showed that organic manures and compost restore soil organic matter by improving nutrients and they significantly increase plant height, number of tillers, spike length, straw/grain yield (Ibrahim *et al*. 2008). A study confirmed that application of organic manures, especially into soil-root zones, helps to reduce agro-technological approach to increase soil fertility and minimize phytotoxicity (Liang *et al*. 2005). Additionally, organic manures are preferable over any chemical fertilizers owing to the fact that they can play a role in increasing the number of nitrogen fixing bacteria in the rhizosphere (Jilani *et al*. 2007). Organic fertilizers specially favour gram-negative bacteria and fungi since they quickly respond to organic carbon input and thus dominate over other microbial groups (Zhang *et al*. 2012).

Poor soil quality due to lack of soil organic matter is a major agricultural production impediment in Bangladesh. According to an estimation of expertise, about 7.0 million tons of organic fertilizers are produced from household waste, city waste, crop waste and animal waste annually (Islam 2006). This creates an opportunity for Bangladesh to extensively use low cost and sustainable organic fertilizer and get benefitted in the long run. Awareness among farmers and stakeholders, availability and large-scale practice of organic manures within the agricultural sector for different crops and medicinal plants can vastly minimize the threats of inorganic fertilizers along with increasing productivity.

Mint (*Mentha* sp.), commonly known as Pudina in Bengali, is a perennial plant that belongs to the family Lamiaceae. The genus contains several species and can be found in many environments (Brahmi *et al*. 2017). *Mentha* species are rich in polyphenols (Tafrihi *et al*. 2021) and therefore Pudina is an

essential medicinal plant (Rahman *et al*. 2014). It is used for the treatment of gastrointestinal disorders like flatulence, indigestion, nausea, vomiting, anorexia, and ulcerative colitis (Brahmi *et al*. 2017). *Mentha* has many versatile properties like antioxidant, antiallergic, antimicrobial, antiviral, antimycotic, anti-toxigenic, antifungal, antiparasitic, anti-inflammatory, antiseptic, insecticidal, anticancer and antitumor (Tafrihi *et al*. 2021). These properties contribute to its applications in pharmaceutical and food industries. In addition, it is one of the world's oldest and most popular herbs and are widely used in culinary purposes due to its strong scent and flavour.

Mint is native to the Mediterranean and Western Asia. In Asia, India, Afghanistan, and Pakistan are main producers of mint (Sharangdhar 2008). The plants of this genus are used for essential oil production, mainly in USA, India, China, and Iran (Tafrihi *et al*. 2021). In Bangladesh, mint is grown all over the country, but at present there is no data available about area and production of mint (Tuly *et al.* 2015).

From recent search Pudina is found endangered in Bangladesh (Rahman *et al*. 2014). Therefore, it has been stated that it is important to take advantage of organic farming to enhance the cultivation of *Mentha* in Bangladesh at a large scale to restore the balance. It is also a highly profitable herb to grow for the farmers and hence its cultivation should be encouraged at a greater extent (Roy 2013).

On such grounds, this experiment was conducted to determine the effects of various commercially sold organic manures in Dhaka, Bangladesh on the growth, yield and nutrient contents of *Mentha*.

MATERIAL AND METHODS

Soil sample collection and analysis

The soil sample for the experiment was collected from a local dealer. It was a garden-mix soil processed from soils of Mithapukur (Rangpur) and Panchogram (Lalmonirhat). After collection, large soil clods were crushed to reduce their size. About 500 g soil was separately taken, that was air dried for two-three days, and any visible roots and debris were removed. The soil was passed through a 2mm sieve and preserved in labelled plastic bottles properly for further analysis of its physical, chemical and physico-chemical properties.

All analyses of physical and chemical properties were carried out at the Department of Soil, Water and Environment, University of Dhaka. The soil sample was found to be composed of 27.58 sand, 52.72 silt and 19.70% clay (Bouyoucos 1962), and it was silt loam in texture deduced from the USDA soil texture triangle using the proportion percentages. The particle density of the soil sample was determined by the pycnometer method (Huq and Alam 2005) and calculated as 2.38 g cm^{-3}. The matrix colour of the soil sample was evaluated visually in outdoor sunlight using a Munsell colour chart in both dry and moist conditions. The dry soil colour was 10YR 7/2 (D) (light grey), and the moist soil colour was 10 YR 5/3 (M) (light olive brown).

The pH and Electrical Conductivity (EC) of the soil samples were analysed by taking soil and distilled water in ratios 1:2.5 and 1:5, respectively (Jackson 1958). The pH of the soil sample was determined 5.37 using HANNA Instrument H12211ph (Orp Meter). The EC was measured by EC Eutech instruments CON 700, which gave a reading of 174.9µS/cm. For the organic carbon determination of the soil sample, Walkley and Black (1934)'s wet oxidation method was employed, and the organic matter (OM) was then calculated by multiplying the carbon content by Van Bemmelen factor of 1.72 (Huq and Alam 2005). The organic carbon and organic matter contents of the soil were 2.17 and 3.73%, respectively. The reason for having a high organic matter content could be due to the fact that processed garden mix soil was used which had additions of organic matter while processing. The soil sample collected was strongly acidic, and non-saline with high organic matter content (BARC 2018).

The total N, P, K, and S content of the soil sample were found to be 0.257, 0.156, 0.490 and 0.215%, respectively. For the analysis of total P, K and S, the soil sample was digested in nitric acid and perchloric acid (HNO_3: $HClO_4$ =2:1) (Huq and Alam 2005). The determination of total soil N was done by digesting soil sample separately using concentrated H_2SO_4 and digestion mixture and later distilling the digest following the Kjeldahl method (Jackson 1958). Total P was determined by the colourimetric method using a spectrophotometer following the Vanadomolybdophosphoric yellow colour method in nitric acid system method (Jackson 1958). Total K in a sample was evaluated by flame photometer and total S was determined by the spectrophotometry after developing turbid solutions using $BaCl_2$ and Tween-80 agents (Huq and Alam 2005).

Collection of organic manures

Eight different kinds of organic manures were collected which were commonly and commercially available in the local markets of Dhaka, Bangladesh. The names of these organic manures are as follows: ACI organic manure, Alo organic manure, Annopurna vermicompost, Locally-sold processed cow dung, Kazi organic manure, Mazim organic manure, Modern vermicompost and Garden BD Trichocompost. The information regarding the type of compost was confirmed by contacting with authorized personnel of each organic manure producer. A portion of each fertilizer was taken and analysed for its nutrient contents. The details of the compost type and nutrient contents of the organic manures used in the experiment are shown in Table 1.

Table 1. Nutrient contents of organic manures used in the experiment.

Treatments (10 ton ha^{-1})	Compost Type	Nutrient content (%)			
		N	P	K	S
ACI	Cow dung + Trichocompost	1.297^{d}	0.37^{h}	1.27^{d}	0.02^{f}
Alo	Trichocompost	1.335^{d}	1.75^{c}	0.35^{f}	0.07^{e}
Annopurna Vermi	Vermicompost	1.745^{c}	1.00^{e}	0.33^{f}	0.36^{b}
Cow dung	Cow dung	1.026^{f}	0.97^{f}	1.48^{c}	0.05^{e}
Kazi	Poultry Manure	2.537^{a}	1.80^{b}	3.18^{a}	0.61^{a}
Mazim	Trichocompost	1.217^{e}	1.31^{d}	1.73^{b}	0.23^{d}
Modern Vermi	Vermicompost	2.543^{a}	0.46^{g}	0.44^{e}	0.31^{c}
Trichocompost GBD	Trichocompost	1.835^{b}	2.33^{a}	0.11^{g}	0.22^{d}
LSD (5%)*	-	0.039	0.020	0.025	0.025

*Means bearing the same letters along the column are not significantly different ($p<0.05$) according to Fisher's Pair-wise Test

Distinguishing differences have been noticed within the nutrient contents of the organic manures that were used in this experiment. Annopurna and Modern, are vermicompost that enable the plant growth, suppress the diseases in plants, also increases porosity and microbial activities. Alo, Mazim and GBD Trichocompost are Trichocomposts that help in retaining water and nutrients, and also a good source of NPKS for plants. Cow dung is also a good source of minerals, especially nitrogen, phosphorus and potassium that allow the growth of beneficial microorganisms as well as improving the texture of the soil. ACI is a combination of cow dung and Trichocompost. Kazi is a poultry manure that is an excellent soil amendment that provides nutrients for growing crops and also improved soil quality as it has high nitrogen content.

The average range of N varies in the nutrient contents of manures from 1.026 -2.543% where Modern holds the highest value, with Kazi as a close second. The value of P ranges from 0.37-2.33%, where Trichocompost GBD has the highest amount. The average value of K varied from 0.11-3.18% and Kazi contains the highest. The average values of S in manures range from 0.02-0.61% where Kazi has the highest amount.

Pot Experiment

Pots with dimensions of 18 cm height and 21 cm diameter and drainage holes were taken. Five kilograms of grounded soil (making sure there was no big clod) was used per pot. A total of nine treatments which comprised of eight locally available commercial organic manures from different companies as noted before ACI, Alo, Annopurna vermicompost, locally sold processed cow dung, Kazi, Mazim, Modern vermicompost, Garden BD Trichocompost and a control without any treatment of organic manure were applied to the soil having three replications each treatment by arranging them in a complete randomized design such that each experimental pot had the same chance of getting any treatment. Each type of organic manure was added at a rate of 10 t ha^{-1}. The manures were added to the soil in the pots three weeks prior to planting the plant cuttings to give enough time for the manures to decompose. The experiment was set up in a shady place.

a. **b**.

Fig. 1. Pictorial view of Mint plants: **a**. Growing in a farm in Barisal; and **b**. Harvest with Trichocompost GBD treatment for this experiment.

The plants were planted by propagating cuttings of mint bought from a local market (Mohammadpur Bazaar). *Mentha* is not usually competent to reproduce by seeds, and therefore is propagated by stem cuttings (Thuraisingham and Seran 2019). Cuttings of 7-8 cm were made from mint stems and all the leaves were removed except the two at the top. The cuttings were submerged in fresh water for 7 days to allow rooting of the cuttings, changing the water every day. After 7 days when the cuttings had rooted, two cuttings per pot were transplanted on day 0 of this experiment. These cuttings were then allowed to grow with regular watering at 2-3 days interval and also frequent spraying of neem oil as natural pesticide after the plants were about one month old. Number of leaves, branches, plant height and leaf area were recorded at 15 days interval for 75 days. Number of leaves and branches were counted with tally counter and plant height was measured using a ruler from base to the tips of the plants, and leaf area was calculated from the measured length and width using the formula 'Length×Width'.

Harvesting

After 75 days of transplanting, the plants were harvested. Whole plant was uprooted and then leaves, stem and roots were separated. Then root length and number of runners were measured and observed at harvest. The plant samples were transferred to poly bags and then carried to laboratory. These were then washed with tap water and with distilled water. Fresh weights of the samples were taken. After that the samples were air-dried in the room temperature and then oven-dried at 65°C for 72 hours. The dry

weight of the samples was recorded and then these were grounded with a mechanical grinder. The grounded samples were stored in plastic bottles for further chemical analysis.

Chemical analysis

The organic manures used as treatments and harvested mint plants were further chemically analysed for their total nutrient (nitrogen, phosphorus, potassium and sulphur) contents in the laboratory of the Department of Soil, Water and Environment, University of Dhaka.

Statistical analysis: Analysis of Variance (ANOVA), Fisher's Least Significant Difference (LSD) test and Pearson's correlation analysis were carried out with the results obtained. Other statistical analysis was done using Minitab 17 and MS Excel 2016.

RESULTS AND DISCUSSION

Plant growth assessment

Plant growth was assessed in terms of morphological characters, such as height of plants (Table 2), number of leaves (Table 2), number of branches (Table 3) and leaf area (Table 3). All the parameters were compared to that of the control experiment results which is the treatment without the addition of any organic manure.

Table 2. Effects of organic manures on the height of plant plant^{-1} and number of leaves plant^{-1} of Mint plants.

Treatments (10 ton ha^{-1})	Height of plant (cm)				Number of leaves			
	30d	45d	60d	75d	30d	45d	60d	75d
Control (-OM)**	14.93^{bc}	17.07^{bc}	18.77^{c}	20.43^{c}	21.67^{d}	24.00^{d}	27.67^{d}	30.33^{d}
ACI	14.03^{cd}	18.20^{b}	22.40^{b}	26.60^{ab}	34.00^{c}	52.00^{c}	71.33^{bc}	88.33^{bc}
Alo	11.90^{de}	13.50^{d}	14.97^{d}	16.17^{d}	29.00^{cd}	47.33^{c}	64.67^{c}	83.00^{c}
Annopurna Vermi	14.13^{cd}	17.37^{bc}	20.20^{bc}	23.43^{bc}	44.33^{b}	71.67^{ab}	94.33^{ab}	118.00^{ab}
Cow dung	17.17^{ab}	18.63^{b}	20.23^{bc}	22.17^{c}	32.67^{c}	51.67^{c}	71.33^{bc}	88.33^{bc}
Kazi	12.63^{cde}	15.47^{cd}	18.10^{c}	21.50^{c}	53.00^{a}	79.33^{a}	104.00^{a}	127.33^{a}
Mazim	7.87^{f}	8.83^{e}	9.73^{e}	10.53^{e}	30.33^{c}	43.67^{c}	59.00^{c}	71.00^{c}
Modern Vermi	10.43^{e}	10.80^{e}	11.10^{e}	11.47^{e}	47.33^{ab}	59.00^{bc}	68.67^{c}	81.00^{c}
Trichocompost GBD	19.40^{a}	22.00^{a}	25.37^{a}	27.67^{a}	45.67^{ab}	77.00^{a}	103.33^{a}	130.33^{a}
LSD (5%)	2.40	2.54	2.74	3.69	8.42	16.53	24.91	33.75

**-OM means the absence of any organic manure treatment

The mean plant height in all the treatments increased with time. The maximum height recorded was 27.67 cm plant^{-1} in Trichocompost GBD after 75th day which is followed by ACI. Using Mazim organic manure, the least height after 75 days was obtained, which was statistically the same as Modern vermicompost. Trichocompost GBD gave the greatest mean plant height at harvest. An experiment on tomato showed that Trichoderma-enriched biofertilizer produced significantly higher plant height in tomato (Molla *et al.* 2012). They also reported that Trichoderma enhances the nitrogen use efficiency and can solubilize a number of poorly soluble nutrients, such as Mn^{4+}, Fe^{3+}, and Cu^{2+}, etc. On the other hand, it reduces the concentrations of substances in soil that are inhibitory to plant which could be why Trichocompost gave a good response.

Leaf number is one of the significant characteristics that basically influence plant productivity and yield. It is stimulated with the application of different fertilizers. From Table 2, it can be seen that among the organic manures, Trichocompost GBD has shown the production of the highest number of leaves after 75 days. The minimum values of leaf numbers were recorded in the control at harvesting suggesting that the application of organic manure makes a difference in vegetative growth which

corroborates with studies which show the application of different organic manures, increased leaf number and other plant growth parameters (Khadir *et al*. 1989, Qulsum *et al*. 2020).

Table 3. Effects of organic manures on number of branches plant^{-1} and average single leaf area leaf^{-1} of Mint plants.

Treatments (10 ton ha^{-1})	Number of branches				Average single leaf area (cm^{2}leaf^{-1})			
	30d	45d	60d	75d	30d	45d	60d	75d
Control (-OM)	1.00^{d}	1.00^{e}	1.00^{e}	1.00^{e}	1.34^{abc}	1.37^{bc}	1.23^{b}	1.40^{b}
ACI	2.33^{bcd}	3.00^{bcd}	4.00^{bcd}	5.00^{bcd}	1.17^{bcd}	1.37^{bc}	1.19^{b}	1.16^{bc}
Alo	1.67^{cd}	2.33^{de}	3.33^{cde}	4.00^{cde}	1.34^{abcd}	1.01^{cde}	1.04^{bc}	1.11^{c}
Annopurna Vermi	2.67^{bc}	4.33^{bc}	6.00^{b}	8.33^{ab}	1.56^{ab}	1.14^{cd}	1.15^{bc}	1.21^{bc}
Cow dung	2.67^{bc}	3.67^{bcd}	5.33^{bc}	6.67^{bc}	1.01^{cde}	0.87^{de}	0.93^{bc}	1.03^{c}
Kazi	3.33^{ab}	4.67^{ab}	6.00^{b}	7.00^{bc}	1.48^{ab}	1.64^{ab}	1.77^{a}	2.01^{a}
Mazim	2.67^{bc}	2.67^{cde}	2.67^{de}	2.67^{de}	0.87^{de}	0.35^{f}	0.42^{d}	0.50^{d}
Modern Vermi	2.33^{bcd}	3.67^{bcd}	4.67^{bcd}	5.33^{bcd}	0.66^{e}	0.69^{ef}	0.40^{d}	0.38^{d}
Trichocompost GBD	4.33^{a}	6.33^{a}	8.67^{a}	11.00^{a}	1.78^{a}	1.87^{a}	0.84^{c}	0.97^{c}
LSD (5%)	1.48	1.75	2.54	3.35	0.47	0.38	0.31	0.28

There is a remarkable difference among the treatments after 15, 30, 45, 60 and 75 days after transplant in respect of branch number (Table 3). For all organic including the control manure treatments, the number of branches increased throughout the timespan of the experiment, with very high increase in the Trichocompost GBD and the Annopurna vermicompost from the initial number of branches suggesting maximum new growth. The Trichocompost GBD showed the maximum number of branches after 75 days and the control had the lowest. Trichoderma produce the compounds that stimulate growth and plant defense mechanisms. A study by Singh and Singh (2004) shows an increase in herb yield in Trichoderma inoculated treatments.

Average single leaf area is used as another reliable parameter which indicates the growth performance of a plant. On the day of transplantation, there were insignificant differences ($p < 0.05$) among the treatments. After 15 days of transplanting, there were no significant differences in plants in the control and those treated with ACI, Cow dung, and Trichocompost. The ACI had the highest mean leaf area per leaf, while the Mazim had the least leaf area per leaf. However, on 30th and 45th days, the Trichocompost GBD dominated having the highest leaf area per leaf, while the Modern and the Mazim in the corresponding days were with the least leaf area per leaf. At the day of harvest, the Kazi showed largest leaf area per leaf, being the only treatment, which showed a general increasing trend in leaf area per leaf in comparison to other treatments. There were significant differences of the Kazi with all other treatments on both 60th and 75th day indicating that the Kazi showed the best result in terms of leaf area per leaf. The Kazi is composed of poultry manure, which had one of the highest total nitrogen content (2.54%) among all organic manures. Adequate nitrogen helps promoting the vegetative growth of plants by increasing the synthesis of proteins. This result of poultry manure resonates with the findings of Rahman *et al*. (2014) which showed that poultry manure produced near maximum values for the mint plant parameters. It has been stated that sufficient nitrogen in organic manures increases the apical growth as well as the length and breadth of leaf (Rahman *et al*. 2014). No treatment consistently had the highest and lowest leaf area from 15th day till 75th day as can be seen in Table 3. The inconsistent results of leaf area may have arose from the fact that some large leaves at the bottom had shed off throughout the experiment's timespan and also due to plants not getting proper and even sunlight throughout the experiment.

Yield assessment

Yield was determined in terms of fresh and dry weight of leaves, stems, roots separately and of total plant (Table 4).

Table 4. Effects of different organic manures on the fresh weight and dry weight of Mint plants (g plant^{-1}).

Treatments (10 ton ha^{-1})	Fresh weight (g plant^{-1})				Dry weight (g plant^{-1})			
	Leaves	Stem	Root	Total	Leaves	Stem	Root	Total
Control (-OM)	0.12^{e}	0.45^{cd}	0.09^{de}	0.66^{de}	0.05^{cd}	0.16^{a}	0.03^{cd}	0.23^{ab}
ACI	0.43^{bc}	0.57^{bc}	0.26^{a}	1.25^{b}	0.07^{bc}	0.12^{b}	0.07^{a}	0.26^{a}
Alo	0.33^{cd}	0.32^{de}	0.08^{e}	0.73^{de}	0.04^{cd}	0.04^{e}	0.03^{bcd}	0.11^{d}
Annopurna Vermi	0.54^{ab}	0.54^{c}	0.11^{de}	1.19^{b}	0.08^{ab}	0.07^{cd}	0.03^{bcd}	0.18^{c}
Cow dung	0.39^{bc}	0.53^{c}	0.21^{b}	1.13^{bc}	0.06^{bc}	0.09^{c}	0.06^{a}	0.21^{bc}
Kazi	0.71^{a}	0.75^{a}	0.22^{ab}	1.68^{a}	0.10^{a}	0.08^{c}	0.04^{b}	0.22^{abc}
Mazim	0.13^{de}	0.22^{e}	0.04^{f}	0.39^{e}	0.03^{d}	0.06^{d}	0.02^{d}	0.10^{d}
Modern Vermi	0.19^{de}	0.49^{cd}	0.12^{d}	0.80^{cd}	0.02^{d}	0.05^{de}	0.03^{cd}	0.10^{d}
Trichocompost GBD	0.47^{bc}	0.73^{ab}	0.16^{c}	1.36^{ab}	0.08^{ab}	0.11^{b}	0.03^{bc}	0.22^{abc}
LSD (5%)	0.20	0.18	0.03	0.39	0.03	0.02	0.01	0.05

The total fresh weight and dry weight and that of leaves, stem and roots, shoot yield and leaves yield at 75 days has been shown in Table 4. The highest total fresh weight was found in the pots treated with the Kazi which is processed poultry manure and lowest was of the Mazim. The highest fresh weight of leaves and stem was also obtained from the plants grown in the pots with the Kazi treatment. The fresh weight of roots of plants grown with the Kazi was not the highest, yet statistically the same with the highest of that of the ACI. In case of dry weight, the maximum total weight was obtained from the pot treated with the ACI which were statistically the same as the Control, Kazi and Trichocompost GBD. The highest dry weight of leaves was obtained from the plant grown with the Kazi treatment even though the highest dry weight of stem was of the plant grown in the control pot without any manure and highest dry weight of root was cow dung treated plant. A previous study reported that the maximum fresh leaf weight was in the cow dung treatment at a rate of 5t ha^{-1} followed by a close second of that of poultry manure at a rate of 4t ha^{-1} (Rahman *et al*. 2014). Even though the results of this experiment do not quite coincide with Rahman *et al.* (2014) because Kazi poultry manure gave better leaf weight than cow dung, it still suggests both of them are good treatments as both the Kazi and cow dung were statistically first and second in rank, respectively.

The reason for not coinciding could be that the rate, at which each manure was applied, was different from Rahman *et al*. (2014) (cow dung was applied at a higher rate) and also both the rates were lower (4 t ha^{-1} and 5t ha^{-1} vs. 10 t ha^{-1} in this experiment). The lowest for leaves was in the control and the lowest for fresh stem, fresh root, fresh total, dry root and dry total were for the Mazim. The lowest dry leaves and dry stem weight were observed in the Modern vermicompost and the Alo, respectively. The Modern vermicompost also had the lowest total dry weight.

Other growth parameters at harvest

Additionally, various different parameters observed during harvest (Root length, numbers of stolons) and some parameters calculated from the obtained results (root/shoot ratio and dry matter percentage) have been taken into account. The root-shoot ratio is the ratio of the dry weight biomass of root divided by that of shoot which is the ratio of the amount of plant tissues that have supportive functions to the amount of those that have growth functions. Plants with a higher proportion of roots can compete more effectively for soil nutrients, while those with a higher proportion of shoots can collect more light energy. It is an important index for assessing plant health (Agathokleous *et al*. 2019). Another notable parameter measured was the number of stolons at harvest. The species of Mentha genus usually produces long stolons which are basal branch disposed to roots or more simply particular “stems” that point downwards, aiming to the soil (Tucker and Naczi 2006). Once they reach the soil, they will spread

horizontally (either slightly below the surface or above), and, from time to time, it will produce upright stems which will become new mint plants and form new roots.

Table 5. Effects of different organic manures on root length and number of stolons of Mint plants at harvest.

Treatments (10 ton ha^{-1})	Root length (cm)	Number of stolons (No. plant^{-1})
Control (-OM)	1.53^{h}	0.00^{c}
ACI	6.77^{c}	1.00^{b}
Alo	4.50^{e}	0.00^{c}
Annopurna Vermi	4.40^{e}	0.00^{c}
Cow dung	8.57^{a}	0.00^{c}
Kazi	5.83^{d}	1.00^{b}
Mazim	1.80^{g}	0.00^{c}
Modern Vermi	3.03^{f}	0.00^{c}
Trichocompost GBD	7.60^{b}	1.67^{a}
LSD (5%)	0.15	0.33

The highest root/shoot ratio was that of cow dung, and lowest was that of Trichocompost GBD. The maximum root length observed was for cow dung and the lowest was for control (Table 5). Most treatments did not grow any stolons in the experiment's time period but ACI, Kazi and Trichocompost GBD, grew some with the highest in the Trichocompost GBD (Table 5).

Nutrient assessment

Total nutrient concentration in plant leaf and stem was determined to assess the nutrient accumulation in Mint plants for the macronutrients, *viz*. N, P, K and S.

Table 6. Effects of different organic manures on the nutrient concentrations of the leaf and stem of Mint plants.

Treatments (10 ton ha^{-1})	Nutrient concentration (%)			
	N	P	K	S
Control	2.715^{d}	0.413^{c}	4.23^{d}	0.25^{d}
ACI	3.710^{a}	0.243^{g}	2.80^{h}	0.40^{b}
Alo	2.468^{f}	0.808^{a}	6.67^{a}	0.15^{e}
Annopurna Vermi	1.710^{g}	0.462^{b}	3.78^{f}	0.09^{f}
Cow dung	1.779^{g}	0.171^{h}	1.76^{i}	0.15^{e}
Kazi	2.840^{c}	0.365^{e}	4.50^{b}	1.20^{a}
Mazim	3.325^{b}	0.404^{d}	3.71^{g}	0.09^{f}
Modern Vermi	0.983^{h}	0.283^{f}	3.83^{e}	0.16^{e}
Trichocompost GBD	2.589^{e}	0.401^{d}	4.45^{c}	0.33^{c}
LSD (5%)	0.081	0.003	0.017	0.099

From Table 6, it is observed that there are significant differences among the control experiment and other treatments in respect of nutrient concentration of plants. The average N concentration in the plants ranged from 0.983 to 3.710%. The average P concentration in the plants ranged from 0.171 to 0.808%. The average K concentration in the plants ranged from 1.76 to 6.67 %. The average S concentration in the plants ranged from 0.09 to 0.40%. The ACI had the highest N content whereas the Modern vermicompost had the lowest value. P content was highest in the Alo and lowest in the cow dung. The highest value and the lowest value of K content were found within the Alo and the cow dung, respectively. The Kazi contained the highest value of S while the Annopurna and the Mazim contained the lowest S content.

Overall Assessment

Table 7 shows Pearson's correlation analysis results of various growth parameters observed and measured in the experiment with the nutrient concentration of the plants for different treatments. The correlation interpretations were done following Uddin and Uddin (2020).

Table 7. Correlation analysis of various explored traits with leaf and stem nutrient concentration of Mint plants.

Features of plants and organic manures (OM)	Correlation analysis			
	N	P	K	S
Number of leaves	-0.024	-0.008	0.126	0.563
Height of plants	0.246	-0.223	-0.237	0.292
Number of branches	-0.259	-0.174	-0.084	0.207
Single leaf area	0.288	0.095	0.153	0.807
Fresh weight	0.066	-0.301	-0.150	0.730
Dry weight	0.369	-0.474	-0.441	0.486
Root length	0.076	-0.360	-0.362	0.260
Root/ Shoot ratio	-0.171	-0.065	-0.145	-0.180
Number of stolons	0.470	-0.179	0.042	0.560
OM nutrient	-0.381	-0.330	-0.229	-0.021

Because nitrogen is important for a plant's vegetative growth, leafy vegetables or spices tend to have a high requirement for nitrogen. *Mentha* sp. is usually grown for its leaves and hence better growth is expected with increased shoot nitrogen content. From Table 7, it is seen that none of the growth parameters has a strong correlation with the nitrogen content of plants. Number of leaves had a very weak negative correlation with shoot nitrogen content. Fresh weight and root length had a very weak positive correlation with nitrogen content of plants. Height of plants, leaf area and dry weight of plants had a weak positive correlation with nitrogen content of the plants, whereas number of branches, root/shoot ratio and organic manure nitrogen content had a weak negative correlation. The only parameter to have a moderate correlation with the plants' nitrogen content was number of stolons, with a positive relationship. Stolons are the important physiological part of *Mentha* sp. plants which forms new mint plants from the original one by spreading horizontally (Tucker and Naczi 2006). If nitrogen content of plants affected this parameter moderately, then definitely there is somewhat increase in vegetative growth with increased N content as number of runners moderately increased with nitrogen content.

The linear relationships of phosphorus content in plant sample with various features explored in this experiment indicating their growth performance given in Table 7 indicates that all of the features except number of leaves and leaf area have negative correlations with their corresponding P contents. The number of leaves has the lowest correlation coefficient value suggesting that there is no correlation between this plant feature and P-content. The dry weight of the plants is negatively correlated with P-content having a moderate correlation between them. There are very weak relationships of number of branches, leaf area, root/shoot ratio, and number of runners with the Phosphorus contents in the shoots of the Mint plants. Weak negative correlations of fresh weight, root length, organic manure nutrient and height of plants with phosphorous content are also observed from Table 7.

It can also be discerned that none of the analyzed parameters has strong correlation with potassium. There was a very weak positive correlation between number of leaves, leaf area and number of stolons and potassium. The dry weight of the plants was correlated with K-content having the highest negative coefficient indicating a moderate negative correlation between them. Height of plants, root length, and organic manure nutrient had weak negative correlation. Number of branches, fresh weight, and root/ shoot ratio had very weak negative correlation with potassium.

In case of sulphur, height of plants, number of branches and root length has a weak positive correlation. Number of leaves, dry weight and number of stolons show moderate positive correlation. Moreover, leaf area and fresh weight have strong positive relationship with sulphur content of plant. On the other hand, root/shoot ratio and organic manure nutrient content had very weak negative relationship with plant sulphur content.

The reason for most of the growth parameters having a weak correlation could be that the plants were harvested immaturely (75 days). If the plants were allowed to grow for a longer period, the effect could have been more prominent.

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