OFF-SEASON GROWTH AND YIELD PERFORMANCE OF TWO LETTUCE VARIETIES IN VERTICAL GARDEN INFLUENCED BY GROWTH MEDIA

RINITA ISLAM

DEPARTMENT OF HORTICULTURE

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

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By

RINITA ISLAM

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APPROVED BY:

Prof. Dr. A. H. M. Solaiman

Department of Horticulture

Supervisor

Prof. Dr. Mohammad Humayun Kabir

Department of Horticulture

Co-supervisor

Prof. Dr. Mohammad Humayun Kabir

Chairman

Examination Committee

DEPARTMENT OF HORTICULTURE

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

Ref. no.: *Date:*

CERTIFICATE

*This is to certify that thesis entitled, **"OFF-SEASON GROWTH AND YIELD PERFORMANCE OF TWO LETTUCE VARIETIES IN VERTICAL GARDEN INFLUENCED BY GROWTH MEDIA"** submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN HORTICULTURE,** embodies the result of a piece of bona fide research work carried out by **RINITA ISLAM,** Registration: **17-08287** 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.

Date: …………...

Dhaka, Bangladesh

……………………………….

Prof. Dr. A. H. M. Solaiman
Department of Horticulture
Sher-e-Bangla Agricultural University
Dhaka- 1207
Supervisor

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ABSTRACT

An experiment was conducted at Sher-e-Bangla Agricultural University to evaluate the influence of growth media on off-season growth and yield performance of lettuce varieties in vertical garden. The experiment comprised of two factors, viz., Lettuce varieties (Green wave,V_1 and New red fire, V_2) and Growth media (Control (100% Soil) P_0, SVC (40% Soil + 40% Vermicompost + 20% Cocodust) P_1, SV (50% Soil + 50% Vermicompost), P_2 and SVS (20% Soil + 40% Vermicompost + 40% Spent Mushroom Compost), P_3). Among the lettuce varieties, the highest yield per growth device (0.63 kg) was found from V_1 and the lowest (0.60 kg) from V_2. Considering the growth media, P_1 produced the highest yield per growth device (0.67 kg) and the lowest (0.57 kg) was from P_0. Regarding the interaction effect, the highest yield of individual growth device (0.71kg) was obtained from treatment combination V_1P_1 and the lowest (0.54 kg) from V_2P_0. According to single treatments and treatment combinations V_1, P_1 and V_1P_1 performed significantly better in terms of plant height, leaf number per plant, leaf area, circumference of canopy and fresh and dry weight of individual plants. V_2P_1 performed better than others for marketable qualities and safety parameter. The highest (17011BDT) and lowest (13440BDT) gross income was obtained from V_1P_1 and V_2P_0 treatment combination, respectively. The highest (1.37) and lowest (1.04) benefit cost ratio was noted for V_1P_1 and V_1P_3 treatment combination. So, Green Wave variety with SVC mixture (40% Soil + 40% Vermicompost + 20% Cocodust) can be economically used for summer lettuce production in vertical garden.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

SOME COMMONLY USED ABBREVIATIONS

Agroecological Zone	AEZ
and others	*et al.*
Centimeter	*cm*
Coefficient of variation	C.V.
Cultivar	cv.
Days After Sowing	DAS
Degree Celsius	^{0}C
Degree of freedom	df
East	E
Et cetra	etc.
Gram	g
Hydrogen ion conc.	pH
Journal	J.
Kilogram	kg
Least Significance Difference	LSD
Meter	m
Relative humidity	RH
Sher-e-Bangla Agricultural University	SAU
Soil Resources Development Institute	SRDI
Square centimeter	cm^2
Square meter	m^2

Chapter I

INTRODUCTION

Chapter I

INTRODUCTION

The inconsistency between food production and malnutrition in Bangladesh can be explained in three broad categories, i.e. - production technology and post-harvest handling of crops, food habit and lack of proper distribution of produced food. The focus of current production practices is to maximize crops which require usage of chemicals at various stages, often resulting in decreased nutritive value (Siddique, 2017). The local food habit is associated with excessive cooking and usage of spices that reduces the nutritional value of foods (Mepba *et. al.*, 2007). In order to maintain both productivity and nutritive status of food, organic production of highly nutritive crops, suitable for raw or minimally processed consumption, can be undertaken. Organically grown Lettuce can be an excellent fit in these criteria.

Lettuce (*Lactuca sativa* L.) is member of compositae family. It produces a cluster of leaves on a short stem. The leaves are delicate, crispy in texture and slightly bitter in fresh condition. They are consumed for a sweet-sour milky juice. In fact, it is globally the most requested crop for mixed salads (Fallovo, 2009) due to its high nutritive value. Generally, lettuce is low in calories, fat and sodium (Work, 1997) but rich in fiber, iron, folate, and vitamin C (Abu-Rayyan *et al*., 2004). It is also a good source of various other health-beneficial (anti-inflammatory, sedative, cholesterol-lowering, and anti-diabetic) bioactive compounds (Yakoot *et al.*, 2011).

Despite its popularity, lettuce is a rather unknown crop in Bangladesh (Jahan, 2017). Lettuce yield is much higher in leading lettuce growing countries than in Bangladesh (Lucic and Perkovic, 2013). The low yield of the produce can be attributed to a combination of factors, like- lack of suitable varieties and cultivars (Tsiakaras *et al*., 2014), nutritional management (Farag *et al*., 2013), environmental condition (Tudela *et al*., 2017) and growing season (Eden *et al*., 2009). Since lettuce varieties differ considerably in physical and chemical composition (Santamaria *et al.*, 2000; Boroujerdnia and Ansari, 2007) range of adaptable climatic condition (Leon *et al*., 2012), hardiness and yield performance. Lettuce yield can be improved in Bangladesh using suitable cultivars.

Another prominent constrain of lettuce production in Bangladesh is the environmental requirement of the crop and local cropping pattern. Lettuce is a cold loving crop (optimum temperature range is 18°C to 25°C) (Ryder, 1998). The crop climatic requirement coincides with Robi season. But it is already predominated and occupied by multiple numbers of vegetables (Tomato, potato, coal crops, beans, carrot etc.), cereal (boro rice, wheat, maize, barley etc.) and spices (onion, chili, coriander, garlic, zinger etc.) cultivation. Moreover, the climatic condition of Bangladesh is gradually changing. Therefore, selection of suitable varieties for off-season cultivation can boost the production as well as provide a mean to cope with environmental changes.

Judicious and timely application of all necessary nutrients is a pre-requisite for successful crop production (Islam, 2019). Inorganic fertilizers are convenient and quick provider of nutrients but they exhaust fast, particularly in terms of nitrogen (Jama *et al*., 1997). Moreover, chances of crop failure and residual effect of inorganic fertilizers (Relf *et al*., 2002) increases with the application of excessive doses chemical fertilizers (Fageria, 2009). Use of organic growth medias can be a safer alternative in this context.

Organic growth medias can be defined as combinations of fertilizers that are derivatives of complete or partially decomposed animal matter, animal excreta, human excreta, and different plant matter (Dittmar *et al*., 2009). It is a slow releaser of nutrients and do not effects crop adversely. Moreover, it improves soil structure, increase water holding capacity as well as facilitates aeration (Islam *et al.,* 2019). Nowadays, organic farming is appreciated by people for food safety and environmental concerns (Worthington, 2001). Recent studies showed that different organic supplements have positive effect on lettuce growth and yield (Polat *et al*., 2004; Mastouri *et al*., 2005) without any adverse effects. Thereby, production of organic lettuce can improve the nutritional status of people.

Bangladesh agriculture is characterized by gradual decrease of arable land. Annually 1% agricultural land is lost to industrialization and urbanization (Hasan *et al.*, 2013). Under such conditions, production of an apparently low yielding crop under organic cultivation can be threatening to the food self-sufficiency of Bangladesh. Incorporation of agriculture in urban areas may change this situation. According to

Wardard (2014) urban agriculture can be practiced on an estimated roof space of 10,000 ha in Dhaka city and fulfill over 10% nutritional demand of the inhabitants. Islam (2004) concluded in a survey that most of the roofs of Dhaka city are suitable for gardening without major modifications. According to Sajjaduzzaman *et al.*, (2005) roof top gardening is fairly profitable in self-owned buildings. But, the problem arises in shared apartment buildings as every resident owns the roof space. Each member has the legal rights of stopping others from using their space for gardening. Safayet *et al*, (2017) concluded that city dwellers are interested in roof top gardening but only over 50%, roof space. Hence, space management is a must in urban agriculture. Vertical gardening is the most space efficient gardening technique.

Vertical gardens imply moving the vegetation from the roof to the walls (Bass and Baskaran, 2003). It can also be set at verandas and balconies of the apartments. Moreover, a vertically grown garden can support great diversity of plant species and economic productivity (Timur and Karaca, 2013), especially for vegetables and salad crops (Utami and Jayadi, 2011). It also provides heat prevention, acoustics and aesthetical benefits (Perini and Novi, 2016). Therefore, vertical gardens can serve an excellent tool for environment friendly lettuce production in cities.

As lettuce leaves are consumed with minimal processing, the microbial safety level of the crop is a raising concern. Usually, foods that are consumed at fresh condition, (fruits and salad crops) contain a large number of bacterial populations as part of their natural micro-flora (*Anon.*, 2014). In addition, all manures serve as media for microbial population. Therefore, microbial contaminations are natural in organic lettuce. But some contaminations such as presence of *Salmonella spp.* is undesirable as they can cause serious food poisoning (Ceuppens *et al.*, 2014). Therefore, the microbial safety must be ensured in organically grown lettuce.

With conceiving the above scheme in mind, the present research work has been undertaken in order to fulfilling the following objectives:

- To evaluate the off-season growth and yield of different lettuce varieties;
- To determine the effect of different growth medias on off-season growth and yield of lettuce.
- To measure the effects of different growth medias on off-season growth and yield performance of lettuce varieties in vertical garden.

Chapter II

REVIEW OF LITERATURE

Chapter II

REVIEW OF LITERATURE

Some significant, informative and promising works and research findings related to the current study have been reviewed in this chapter.

2.1 Effect of different varieties on growth and yield of lettuce

Jahan (2017) undertook an experiment in the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka from November 2016 to February 2017. The experiment consisted of two factors, such as Factor A: Lettuce variety (3) as- V_1: Green wave, V_2: New red fire, V_3: Legacy and Factor B: Manure (3) as- M_0: 0 kg /ha (control), M_1: Cowdung @ 20 t/ha, M_2: Poultry manure @ 8 t/ha. The experiment was laid out in Randomized Complete Block Design with three replications. Lettuce variety and manure significantly influenced on different growth and yield parameter of lettuce varieties. In case of lettuce variety, the highest yield (20.49 t/ha) was found from V_1 and the lowest yield (17.66 t/ha) from V_2. Variety Green wave with Poultry manure @ 8 t/ha produced the best results for lettuce production.

The effect of nitrogen fertilizer level on growth and nitrate accumulation was studied in six lettuce cultivars (*Lactuca sativa* L.): 'Batavia rouge', 'Vitalia', 'Great Laks', 'Type Beurre', 'Romaine' and 'Romaine LO3' by M'Hamdi *et al.* (2014). Three nitrogen levels: 0, 120 and 240 $Kg.ha^{-}1$ was applied. During plant growth, agronomical parameters (leaves weight, root weight, dry matter, head diameter) and physiological parameters (nitrate concentration, chlorophyll fluorescence and sugar content) were evaluated. Results showed significant differences between cultivars and nitrogen treatment for the most agronomical (quantitative) and physiological (qualitative) parameters. The cultivars 'Great Laks' and 'Type beurre' accumulated the less and high nitrate concentration and yield, respectively.

Kerbiriou *et al.* (2014) investigated the impact of below-ground (root development and resource capture) on above-ground (shoot weight, leaf area) traits, different combinations of shoot and root growth were created using transplants of different sizes in three field experiments. Genetic variation in morphological and physiological below-and above-ground responses to different types of transplants hocks was assessed using four cultivars. The cultivars with overall larger root weight and rooting depth, “Matilda” and “Pronto,” displayed a slightly higher growth rate in the linear phase leading to better yields than “Mariska” which had a smaller root system and as lower linear growth despite a higher maximal exponential growth rate. “Nadine,” which had the highest physiological nitrogen-use efficiency (g dry matter produced per g N accumulated in the head) among the four cultivars used in these trials, gave most stable yields over seasons and trial locations.

Lucic and Perkovic (2013) conducted a three year study with three varieties of lettuce (Archimeds RZ, RZ Santoro, Kibo RZ). Each row with these varieties was exposed to the following variants of covering: control-planting on bare soil, mulching before sowing with PE-black foil, agro textile covering plants after planting with agro textile (17 g), a combination of mulching + agro textile. The results showed that the highest yield was recorded in agro textile variant (14 kg/10 m^2), and lowest in controls (9.31 kg/10 m^2). Throughout of all the three years of the trial, it was continuously evidenced that the variety Santoro had the biggest heads and the highest yield (15.33 kg/10 m^2), which lead to conclusion that the yield of lettuce is a varietal characteristics.

Maboko and Du-Plooy (2008) studied thirteen crisphead lettuce cultivars to evaluate in a gravel-film production system during the winter season at the experimental farm of the ARC-Roodeplaat. The experiment was laid out as a randomized complete block design with five replicates. For each cultivar, yield, internal quality, compactness, uniformity, ribbing, tip-burn, disease tolerance, bolting tolerance and number of days to maturity were recorded. Results showed clear differences between cultivars, with four cultivars, namely Del-Rio, Patagonia RZ, Winter haven and Winter Supreme, out yielding the rest of the cultivars. These four cultivars were also more tolerant to tipburn and disease, compared to most other cultivars included in the trial. Cultivars Annie, Del Rio, Supreme Plus and L425 showed the best core ratio, combined with a good colour and tip burn resistance. Results, thus, indicate that variability in yield and quality of crisphead lettuce are determined by cultivar differences, changes in environmental conditions, as well as different production systems utilized by farmers.

Maboko and Du-Plooy (2007) evaluated the performance of selected crisphead lettuce cultivars for summer production with regards to yield and quality in South Africa. During January to February 2007, 16 crisphead lettuce cultivars were grown using a gravel-film production system. The experiment was laid out as a randomized complete block design with five replicates. For each cultivar, compactness, uniformity, ribbing, tip-burn, disease tolerance, bolting tolerance and number of days to maturity were recorded. Cultivars evaluated demonstrated increased internal stem growth. The most promising cultivars for increased yield, improved harvest and improved quality were Aviram, Sahara, Lucy Brown, PF 1283, Robinson and Duke. Results, thus, indicate that improved yield and quality can be obtained by selecting the correct cultivars for summer production in a soilless medium.

Boroujerdnia and Ansari (2007) carried out an experiment at Shahid Chamran University of Ahwaz, Iran to determine the effect of nitrogen fertilizer rates and cultivars on growth and critical yield of lettuce. The treatments included four nitrogen rates (0, 60, 120, and 180 kg N/ha) as the main plot and two lettuce cultivars ('Pich Ahwazi' and 'Pich Varamini') as the sub-plot. The criteria measured were plant length, fresh and dry weights of leaves, leaf area, number of leaves, crop growth rate (CGR), leaf area index (LAI) and yield. Results indicated that cultivar had a significant effect on growth characteristics, on fresh and dry weights of leaves and on leaf number but not on plant length and leaf area. The highest yield was obtained from 'Pich Ahwazi'. Also, it took 'Pich Varamini' longer to form a head and to flower than 'Pich Ahwazi'.

Parente *et al.* (2006) carried out an experiment to study production and accumulation of nitrate by new cultivars of lettuce in response to nitrogen doses applied to the soil. The main objective was to compare a Sunfertilized treatment with two nitrogen doses (75 and 150 kg/ha) applied by fertilization to different cultivars of lettuce belonging to the following types: Lollo Bionda, Canasta, Lollo Rossa, and, in the second trial, Oakleaf. The Lollo Rossa cultivars produced 26% and 56% less than the Canastatype, respectively in the first and the second year, probably due to the absence of a real head in the Lollo type.

Mantovani *et al.* (2005) carried out an experiment using pots under greenhouse conditions to evaluate the influence of nitrogen fertilizer application on the growth and nitrate accumulation of lettuce cultivars. Treatments consisted of five nitrogen rates (0, 141.5, 283.0, 566.0 and 1132.0 mg/pot N as urea) and five lettuce cultivars viz. Lucy Brown, Taina, Vera, Veronica and Elisa. Results revealed that Lucy Brown and Taina accumulated more nitrate than Vera,Veronica and Elisa cultivars.

An experiment was conducted by Al-Harbi (2001) to evaluate the growth and flowering of five commercially available lettuce (*Lactuca sativa* L.), cultivars 'Heavy Green (C1)', 'Murillo (C2)', 'Royal (C3)', 'Parris Island (C4)' and 'Valmaine (C5)' at four planting dates (23 Sep., 14 Oct., 4 Nov. and 25 Nov. 1995). The experiment was repeated the following year. The experiments determined head weight (g), head length (polar diameter [cm]), head diameter (lateral diameter [cm]), stalk length, dry matter percentage (%), yield per square meter (kg) and days from transplanting until 50% flowering. 'Heavy Green' and 'Murillo' (head lettuce types) had higher yield compared to other cultivars. Flowering of these two cultivars was less affected by planting date, while other cultivars ('Royal', 'Parris Island' and 'Valmaine') tended to flower sooner in the later planting dates.

2.2 Effect of different organic media on growth and yield of lettuce

A study was carried out for evaluation of the effects of agricultural waste composts on lettuce quality, yield and nutrient contents by Sönmez *et al.* (2018). In the study composts were consisted of different agricultural wastes such as pruning wastes-PW and spent mushroom composts-SMC. Five different compost medias were added to the pot soil (1 ton ha^{-1}) and composts effects on growth and nutrient contents of lettuce were determined. The study was carried out during two successive seasons (autumn and spring). The results showed that plant growth and yield were found higher in the compost applications than in control. Generally the highest values were obtained from Mix1 (80%SMC+20%PW) and Mix2 (70% SMC+30 PW) treatments for many parameters. Results, thus, indicate that improved yield and quality can be obtained by using agricultural waste composts.

Paredes *et al.* (2016) evaluated the effects of the addition of two types of spent mushroom substrate (SMS), SMS from an *Agaricus bisporus* crop (SMS1) and a media of SMSs from an *A. bisporus* crop and *A. pleurotus* crop (50% v/v each) (SMS2), on the characteristics of a calcareous clayey-loam soil and the yield and nutritional status of lettuce (*Lactuca sativa* L.), relative to crops receiving mineral fertilizer (M) and a S(C) without amendment. The application of SMS, especially SMS1, improved soil fertility compared with C and M soils. Moreover, the use of these organic substrates as soil amendments did not harm the plants and gave yields similar to that obtained with mineral fertilizer. The nutritional contents of the lettuce plants were greater than or similar to those of the plants from treatment C or M, except for the plant tissue concentrations of K, Fe and Zn, which were significantly reduced by SMS application. However, this latter fact did not reduce the lettuce yield in the amended soils. Therefore, the use of SMSs as organic amendments contributes to residue utilization, in an environmentally friendly way, and to improved soil fertility and crop yield.

Marques *et al.* (2014) conducted an experiment with the aims - (i) to evaluate the effects of substrates containing different proportions of spent mushroom compost on the growth of lettuce seedlings, and (ii) to determine the enduring effects of substrates containing spent mushroom substrate on the vigor of mature lettuce plants derived from such seedlings. The substrates employed in the germination and development of lettuce seedlings were obtained by mixing spent compost from the cultivation of *Agaricus subrufescens* and commercial vegetable substrate in different proportions. Seedlings were evaluated with respect to the number of leaves and the height, fresh mass and dry mass of the aerial parts, while mature plants were appraised according to stem height and circumference, fresh mass and dry mass of the lettuce head. Substrate containing between 42 to 48% spent mushroom substrate provided the most adequate conditions for the growth and development of crisphead lettuce seedlings and, consequently, of vigorous marketable plants. Under such conditions, the fresh mass of the aerial parts of seedlings attained a level of 0.89 g plant^{-1}, while the fresh mass of the marketable heads achieved a maximum of 233.45 g plant^{-1}. The data presented herein verified that top quality lettuce seedlings, yield high quality marketable heads, and that quality improvement could be brought about by the addition of spent mushroom substrate.

Ferdowsy (2013) conducted an experiment at the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka. In experiment, the treatment consisted of four organic manures viz. OM_0: no organic manure, OM_1: Cowdung, OM_2: Poultry manure, OM_3: Vermicompost and three spacing viz. S_1 (40 cm × 20 cm), S_2 (40 cm × 25 cm), S_3 (40 cm × 30 cm).Two factorial experiment was laid out in Randomized

Complete Block Design with three replications. Significant variations in all parameter were recorded due to effect of organic manure and spacing at different DAT (days after transplanting). In case of vermicompost, maximum gross yield (26.71 t/ha) was obtained from OM_3 and minimum (18.02 t/ha) was from OM_0. The highest benefit cost ratio (2.46) was obtained from OM_3S_2 and the lowest (1.78) was recorded from OM_0S_1. So, vermicompost with 40 cm × 25 cm spacing showed better performance.

An experiment was conducted in a field in Karaj-Iran to find out the effects of spacing, mulch and organic fertilizer on the growth and yield of lettuce by Khazaei *et al.*(2013).Four levels of spacing (40×40 cm,40×35 cm, 40×30 cm and 40×25 cm),two cultivation systems(mulch and no mulch) and two different types of organic fertilizers (humic acid and vitamint) were conducted on *Lactuca sativa* cv. Iceberg at the Engineer Zeraee's field. The treatments were set up in a split plot factorial design based on the randomized complete block design with three replications. According to results of experiment, stem length, stem diameter, stem weight, bud number, leaf dry weight and K% were significantly affected by organic fertilizer. However, organic fertilizer had no significant effect on total yield.

Islam *et al.* (2012) conducted a study to observe the effects of different organic fertilizers on the growth and yield of lettuce in the field conditions during the period from October 2011 to January 2012. The experiment was performed by randomized block design consisted of four factors as well as S(without fertilizer), poultry manure (chicken litter), cattle manure (cow dung) and commercial fertilizer. Under these four factors, eight treatments namely T_0 (control); T_1, T_2 and T_3 (10, 20, 30 ton/ha of poultry manure, , respectively); T_4, T_5 and T_6 (15, 25, 35 ton/ha of cattle manure, , respectively); and T_7 (10 ton/ha commercial fertilizer), with three replications were applied. The studies revealed that the highest production of lettuce was obtained by using eco-friendly organic fertilizer followed by commercial fertilizer than Sone. The average maximum number of leaves, root length and yield per plot were observed by using cow dung in T_6, while the lowest in T_0. The chicken litter fertilized plants had relatively higher average leaves length, leaves breadth and base diameter; while the maximum dry matter content and yield per hectare were found by applying cow dung in T_5. The highest gross return of BDT 1168800/ha and net return of BDT 683229/ha with the benefit cost ratio of 1.40 was obtained from T_5.

From the economic point of view, it is concluded that T_5 was the best dose of fertilizer for maximizing the growth and yield of lettuce.

León *et al.* (2012) carried out an experiment with the objective of evaluation of the effect of the application of vermicompost on the growth parameters of lettuce in two commercial types: leaf lettuce (cv Brisa) and butterhead (cv Daguan). Seedlings were produced in plastic trays and were transplanted when two leaves were completed expanded 30 days after sowing after that management was similar to a commercial one. The experimental design was a randomized complete block with four replications. During cultivation and at harvest measurements of fresh and dry weight, leaf number and area, nitrate and reducing sugar concentrations were made. Calculations for yield were performed. At harvest, vermicompost addition affected nitrate content in leaf lettuce (cv Brisa) increasing its concentration. Yield was not affected by vermicompost application.

Asaduzzaman *et al.* (2010) undertook an experiment in the field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to find out the combined effect of mulch materials and organic manure on the growth and yield of lettuce. Four levels of mulch materials viz. Mo = No mulching, M_1 = Dry water hyacinth, M_2 = Black polythene and M_3 = Dry rice straw and four levels of organic manure viz. OM_0 = no organic manure, OM_1 = Cow dung (20 t /ha), OM_2 = Poultry manure (10 t/ ha) and OM_3 = Vermicompost (10 t/ ha) were also used as experimental variables. The results showed that most of the growth parameters were influenced by the mulch materials and organic manure. All the parameters viz. number of leaves plant $^{-1}$, leaf length (cm), leaf breath (cm), dry matter accumulation (%), yield (g plant $^{-1}$) and yield (t ha $^{-1}$) performed better in case of M_2 OM_3 (Black polythene + vermicompost: 10 t /ha), while the minimum growth and yield parameter were obtained from M_0OM_0(control) at each observation stage.

A greenhouse study was conducted to evaluate the effect on total growth and leaf nutritional content in lettuce (*Lactuca sativa* L.) at the Agrotechnology Sciences Department of the Universidad Autonoma de Chihuahua, Mexico by Hernández *et al.* (2010). Three types of fertilization treatments were analyzed: two organic and one conventional or inorganic.Both vermicompost and compost were produced from cattle manure in a 25-wk process. The study included 12 experimental units made up of lettuce plantlets var. Great Lakes. A linear model was fitted for statistical analysis using a completely randomized experimental design. ANOVA was performed and means were compared by orthogonal contrasts. Results showed differences in weight and leaf content for the N and K variables, and the highest mean values for these variables were in the urea treatment. Leaf content of Ca, Mg, and Mn showed higher values in organic fertilization treatments. The vermicompost treatment showed a higher contribution of Mg, Fe, Zn, and Cu, and lower Na in lettuce leaf content when compared to compost usage.

Rana (2009) experimented with four types of mulching; M_0: No mulching (control), M_1: Dry water hyacuith: M_2: Black polythene and M_3: Dry rice straw and Four types of organic manure: OM_0: No organic manure (Control); OM_1: Cowdung (20 t/ha); $0M_2$: Poultry manure (10 t/ha); $0M_3$: Vermicompost (10 t/ha) in the field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The two factor experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. In case of organic manure, the highest result (45.25 t/ha) was found from $0M_3$ and lowest (34.38 t/ha) from control. So, poultry manure was more effective for growth and yield of lettuce.

2.3 Microbial safety of organically grown lettuce

Ceuppens et al. (2014) detected the microbiological quality and safety of lettuce during primary production in Brazil by enumeration of hygiene indicators *Escherichia coli*, coliforms and enterococci and detection of enteric pathogens *Salmonella* and *E. coli* O157:H7 in organic fertilizers, soil, irrigation water, lettuce crops, harvest boxes and worker's hands taken from six different lettuce farms throughout the crop growth cycle. Generic *E. coli* was a suitable indicator for the presence of *Salmonell*a and *E. coli* O157:H7, while coliforms and enterococci were not. Few pathogens were detected: 5 salmonellae and 2 *E. coli* O157:H7 from 260 samples, of which only one was lettuce and the others were manure, soil and water. Most (5/7) pathogens were isolated from the same farm and all were from organic production. Statistical analysis revealed the following environmental and agro-technical risk factors for increased microbial load and pathogen prevalence in lettuce production: high temperature, flooding of lettuce fields, application of contaminated organic fertilizer, and irrigation with water of inferior quality and large distances between the field and toilets. Sof the composting process of organic fertilizers and the irrigation water quality appeared most crucial to improve and/or maintain the microbiological quality and safety during the primary production of lettuce.

Maffei et al., 2013 analyzed 130 samples of different organic and conventional vegetable varieties sold in Brazil were analyzed for mesophilic aerobic bacteria, yeasts and molds, total coliforms, *Escherichia coli* and *Salmonella* spp. Most of the mesophilic aerobic bacteria counts in organic and conventional vegetables ranged from 6 to 7 $\log_{10}$ CFU/g; most of the yeasts and molds counts ranged from 5 to 6 $\log_{10}$ CFU/g and most of the total coliforms counts ranged from 4 to 5 $\log_{10}$ CFU/g. *E. coli* was found in 41.5% of the organic and 40.0% of the conventional vegetables, and most samples had counts ranging from 1 to 2 log10 CFU/g. *Salmonella* spp. was not found in any sample. Comparative analyses of the microbial counts of organic and conventional vegetables showed that some organic varieties had greater counts. However, the global results showed that this was not a trend. These results indicated the need of good farming practices, and proper sanitization before consumption, to ensure food quality and safety.

Oliveira *et al.* (2010) stated that previously there was no available information on the levels of indicator bacteria and the prevalence of pathogens in fresh lettuce grown in organic and conventional farms in Spain. A total of 72 lettuce samples (18 farms for 4 repetitions each) for each type of the agriculture were examined in order to assess the bacteriological quality of the lettuces, in particular the prevalence of selected pathogens. The lettuce samples were analyzed for the presence of aerobic mesophilic, psychrotrophic microorganisms, yeasts and moulds, *Enterobacteriaceae*, mesophilic lactic acid bacteria, *Pseudomonas* spp. and presumptive *Escherichia coli*, *Salmonella* spp. and *Listeria monocytogenes*. The mean aerobic mesophilic counts (AM) were $6.35 \pm 0.69 \log_{10}$ cfu g^{-1} and $5.67 \pm 0.80 \log_{10}$ cfu g^{-1} from organic and conventional lettuce, , respectively. The mean counts of psychrotrophic microorganisms were $5.82 \pm 1.01 \log_{10}$ cfu g^{-1} and $5.41 \pm 0.92 \log_{10}$ cfu g^{-1} from organic and conventional lettuce, , respectively. Yeasts and moulds (YM) mean counts were $4.74 \pm 0.83 \log_{10}$ cfu g^{-1} and $4.21 \pm 0.96 \log_{10}$ cfu g^{-1} from organic and conventional lettuce, , respectively. Lactic acid bacteria (LAB) were present in low numbers and the mean counts were $2.41 \pm 1.10 \log_{10}$ cfu g^{-1} and

$1.99 \pm 0.91 \log_{10}$ cfu g^{-1} from organic and conventional lettuce, , respectively. *Pseudomonas* spp. mean counts were $5.49 \pm 1.37 \log_{10}$ cfu g^{-1} and $4.98 \pm 1.26 \log_{10}$ cfu g^{-1} in organic and conventional lettuce, , respectively. The mean counts for *Enterobacteriaceae* were $5.16 \pm 1.01 \log_{10}$ cfu g^{-1} and $3.80 \pm 1.53 \log_{10}$ cfu g^{-1} in organic and conventional lettuce, , respectively. *E. coli* was detected in 22.2% (16 samples) of organic lettuce and in 12.5% (9 samples) of conventional lettuce. None of the lettuce samples was positive for *E. coli* O157:H7, *L. monocytogenes* and *Salmonella* spp. From the samples analyzed by principal component analysis (PCA) a pattern with two different groups (conventional and organic) can be observed, being the highest difference between both kinds of samples the *Enterobacteriaceae* count.

Bohaychuk *et al.* analyzed 673 fresh produce samples collected from Alberta public and farmer's markets in Canada (including organic produce) during 2009 and observed that the levels of *E. coli* in organically and conventionally grown produce was not significantly different ($p < 0.05$).

To investigate bacteriological quality in organically grown leaf lettuce, including the presence of selected pathogenic bacteria, and to obtain information about organic lettuce production, including fertilizing regimes Loncarevic *et al.* (2005) conducted a study. Altogether 179 samples of Norwegian organically grown lettuce were collected from 12 producers. *Escherichia coli* was isolated from 16 of the lettuce samples, but in 12 of these contamination was sufficiently low (<100 CFU g^{-1}) that they would be considered to be of acceptable bacteriological quality. *Escherichia coli* O157 and *Salmonella* were not detected in any of the samples. *Listeria monocytogenes* serogroups 1 and 4 were isolated from two samples. The results showed that contamination of organic lettuce with *E. coli* and *L. monocytogenes* occured occasionally. It was concluded that organically grown lettuce may be contaminated with *E. coli* and *L. monocytogenes* during cultivation.

Johannessen et al. (2004) carried out an experiment to investigate the bacteriological quality, and the occurrence of selected pathogenic bacteria from organically grown Iceberg lettuce fertilized with bovine manure in the form of compost, firm manure and slurry in a 2-year field trial. Samples of soil, fertilizer, fertilized soil, seedlings and lettuce were analyzed for aerobic plate counts (APC), thermotolerant coliform bacteria (TCB), *Escherichia coli*, *E. coli* O157:H7, *Salmonella* spp. and *Listeria monocytogenes*. No difference in bacteriological quality could be shown in lettuce at harvest, however, APC varied significantly from year to year in the study. The various treatments gave significantly different APC and numbers of TCB isolated from fertilized soil. *Escherichia coli* O157:H7 was isolated from firm manure and slurry, and soils fertilized with the respective fertilizers the second year, but were not recovered from the lettuce. No difference in bacteriological quality could be detected in lettuce at harvest after application of various types of manure-based fertilizers grown under Norwegian conditions. The results indicated that the use of manure did not have considerable influence on the bacteriological quality of organic lettuce.

Mukherjee *et al.* (2004) analyzed 476 organic and 129 conventional produce samples from farms in Minnesota, USA, and found greater prevalence of *E. coli* in organic vs. conventional samples. The largest prevalence of *E. coli* was in organic lettuce (22.4% of samples).

2.4 Effect of growing seasons on growth and yield of lettuce

Souza *et al.*, (2017) conducted a study where agronomic indicators were evaluated in lettuce fertilized with different amounts of roostertree biomass; fertilizer was incorporated into the soil at distinct times and seedlings were planted in two cropping seasons (spring and autumn-winter) in Serra Talhada, Pernambuco state, Brazil. The experimental design consisted of randomized complete blocks with three replications and treatments arranged in a 4 x 4 factorial scheme. The first factor was the amounts of roostertree biomass (5.4, 8.8, 12.2, and 15.6 t ha -1 on a dry basis) and the second the manure incorporation times (0, 10, 20, and 30 days before lettuce transplanting). The variables evaluated in the lettuce crop were: plant height and diameter, number of leaves per plant, productivity of green mass, and dry shoot mass. Maximum productivity and dry shoot mass were obtained using fertilization with 15.6 t ha -1. A synchrony between supply of nutrients by green manure and the period of maximum demand by lettuce was observed in the incorporation times of 10 (spring) and 20 (autumn-winter) days before transplanting. Cultivation in the spring resulted in higher vegetative growth.

Lafta and Mou (2013) experimented to identify heat-tolerant lettuce genotypes based on their ability to germinate under high-temperature stress. Twenty-four to 26 genotypes were selected from each lettuce types (crisphead, romaine, butterhead, loose leaf, and wild species) and their seeds were placed in petri dishes to test their ability to germinate at high temperatures (29 and 34℃) as compared with controls at 24℃. Some lettuce genotypes showed thermotolerance to 34℃ (less than 20% reduction in germination) such as Elizabeth, PI 342533, PI 358025, Florida Buttercrisp, Kordaat, FL 50105, PRO 425, PI 278070, Noemie, Picarde, Gaillarde, *L. serriola* (PI 491112, UC96US23, PI 491147), *L. virosa* (PI 274378 D), *L. saligna* (PI 491159), and primitive (PI 187238 A, PI 289063 C). The germination rates were consistent with the germination percentage at the high temperatures. Seed germination in the field was very low and positively correlated with seed germination at 29 and 34 ℃. The highest field germination percentages (greater than 40%) were observed in Belluro, Mantilia, Mid Queen, Headmaster, PRO 874, PRO 425, FL 50105, Corsair, Romaine SSC 1148, Romaine Romea, Green Forest, Grenadier, Squadron, Xena, Noemie, Green Wave, Picarde, and Red Giant. The results of this study indicated that lettuce genotypes differ greatly in their ability to germinate at high temperatures as determined by the percentages and the rates of germination.

In an experiment Konstantopoulou *et al.*, (2012) had grown Lettuce (*Lactuca sativa* L., *cv.* 'Parris Island') hydroponically in autumn, winter and spring under five levels of nitrogen (N) fertilization. Plant biomass was highest in spring and lowest in autumn at N rates of 200 and 260 mg L^{-1}, respectively. Increasing N application correlated positively with rates of photosynthesis, transpiration, stomatal carbon dioxide (CO_2) conductance and leaf chlorophyll concentration. Photosynthetic rate, stomatal CO_2 conductance, and chlorophyll a/b ratio were higher in spring than in autumn or winter. Nitrate concentrations within the leaves increased with increasing N application in all seasons. It is concluded that lettuce growth and yield is higher in spring than in winter or autumn due to enhanced photosynthesis thanks to increasingly favorable photoperiod.

Eden *et al.* (2009) carried out an experiment with the aim of investigating the effect of macro-anion (NO_3^-, $H_2PO_4^-$, and SO_4^{2-}) and macro-cation (K^+, Ca^{2+} and Mg^{2+}) proportions in the nutrient solution during two consecutive growing seasons (spring and summer) on yield and leaf quality (chlorophyll content, color parameters,carbohydrates and mineral composition) of *Lactuca sativa* L. var.

acephala grown in a floating system. Marketable yield, shoot biomass and leaf area index were unaffected by nutrient solution composition. A high proportion of calcium in the nutrient solution increased the quality attributes in particular calcium, chlorophyll, glucose and fructose concentrations. Plants grown in the spring season exhibited a lower yield, growth (total dry biomass and leaf area index), leaf mineral content (N, K and Mg), total carotenoids and water use efficiency than those grown in the summer season but were influenced positively by some quality parameters (higher content of glucose and fructose and lower nitrate content). The results demonstrated, that the effect of growing season on leafy lettuce performance (yield and quality) was more pronounced than the effect of nutrient solution composition.

2.5 Productivity of vertical gardens

Nwosisi *et al.,* (2017) conducted a study on cultivar trials in organic vertical system on the certified organic farm of the Tennessee State University, Nashville. Several cultivars of lettuce, chard, kale, mustard-green, basil and coriander were grown in the vertical-grow system and were harvested successfully. Automated system called 'Drip Organics' provided organic nutrients to the plants. Perlite and coco fiber media was used in the stacked pots. It was concluded that although modern organic farming would remain a widely used food production method as evidenced by its global acceptance and steady growth, organic vertical farming would have a potential to provide food security, year-round produce and ease transportation of food within urban and semi urban areas.

Al-Chalabi (2015) prepared a paper with the purpose to examine the feasibility and plausibility of the vertical farming concept from socio technical, mixed methods, research perspective. It included (1) examining energy requirement to power such a building and probability of renewable energy to meet the onsite demands of the building by constructing an energy model, (2) quantifying the carbon footprint of vertically grown produce and subsequently comparing that to conventionally grown produce, and (3) conducting interviews to explore how relevant stakeholders perceive the concept of vertical farming in order to identify the barriers and opportunities towards possible uptake of the technology. The findings indicated that vertical farming could be used as a tool to supply food to cities in a sustainable manner depending on the location and design.

Banerjee and Adenaeuer (2013) carried out a study to construct a Vertical Farm and thereof investigate the economic feasibility of it. In a concurrent Engineering Study initiated by DLR Bremen, a farm, 37 floors high, was designed and simulated in Berlin to estimate the cost of production and market potential of this technology. It yielded about 3,500 tons of fruits and vegetables and 140 tons of tilapia fillets, 516 times more than expected from a footprint area of 0.25 ha due to stacking and multiple harvests. The investment costs added up to € 200 million, and it required 80 million liters of water and 3.5 GWh of power per year. The produced food ranged between € 3.50 and € 4.00 per kilogram. In view of its feasibility, they estimated a market for about 50 farms in the short term and almost 3000 farms in the long term.

An experiment about vertical garden was done at the Centre for Land Resources, Gadjah Mada University, Yogyakarta, Indonesia by Utami and Jayadi (2012). Raised beds (shelf, a place holder) or growing beds were the basic unit of an intensive garden. Several of these beds were made with 6 levels of $6\times4\ m^2$ and 4 levels of $4\times1.72\ m^2$. Nutrients were supplied by organic matter (manure and compost), while water was supplied as treated wastewater. Then several vegetables (Chinese cabbage, lettuce, water spinach, chili red) and fruits (lemon, guava, mango, passion fruit) were planted. The results showed that vertical gardening were best suited for plants that required maximum sunlight such as fruit and also several vegetables. Plants grown in a vertical garden were less accessible to diseases and pests, and crop harvesting and cultivation was easier. Vertical gardening provided adequate aeration to the plants and also increased the beauty of the garden. Overall, the yield of vertical gardening was higher than traditional plantation methods.

Above cited reviews revealed that organic manure is one of the important factors for attaining optimum growth and yield of lettuce. In addition to that it is also evident that varieties can significantly influence the production of lettuce under optimum growing seasons. The above cited results also point out that the productivity of lettuce can improve vastly in vertical gardening under the agro-climate of Bangladesh.

Chapter III

MATERIALS AND METHODS

Chapter III

MATERIALS AND METHODS

This chapter includes a brief description of different materials and methodologies followed during the experiment.

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted during the period from May to July 2019.

3.1.2 Climatic condition

The monthly average temperature, humidity and rainfall during the crop growing period were collected from "Monthly Weather Report" on AccuWeather website and presented in Appendix I. During this period the maximum highest temperature (37℃) and the minimum lowest (28℃) was recorded in May and June 2019, respectively. The maximum rainfall 30 mm and highest humidity (78%) was recorded in the month of July 2019.

3.1.3 Experimental location

The experiment was conducted on a wall at the Sher-e-Bangla Agricultural University Horticulture Farm, Dhaka, Bangladesh. It is located at 90°22′ E longitude and 23°41′N latitude at an altitude of 8.6 meters above the sea level.

3.2 Experimental details

3.2.1. Treatments

The experiment comprised of two factors:

Factor A: Two lettuce varieties

1. $V_1 \Rightarrow$ Green Wave
2. $V_2 \Rightarrow$ New Red Fire

Factor B: Four types of growth media

1. $P_0 \Rightarrow$ Control (100% Soil),

2. $P_1 \Rightarrow$ SVC (40% Soil + 40% Vermicompost + 20% Cocodust)
3. $P_2 \Rightarrow$ SV (50% Soil + 50% Vermicompost); and,
4. $P_3 \Rightarrow$ SVS (20% Soil + 40% Vermicompost + 40% Spent Mushroom Compost)

There were 8 (2 × 4) treatment combinations, namely- V_1P_0, V_1P_1, V_1P_2, V_1P_3, V_2P_0, V_2P_1, V_2P_2 and V_2P_3.

3.2.2. Design and layout of the experiment

The experiment was laid out in a randomized complete block design (RCBD) having thirty two experimental units (8 treatment combinations with four replications). The experiment was carried out on a hardboard wall (8.2×3.2 m^2). The total area of the hardboard was first divided into four blocks which was considered as replication and each block was further divided into 8 plots. The block to block distance was 1m.No space was provided within plots as vertical gardening does not require any space for intercultural operations. Each of the plots was mounted with a growth device with the help of electric borer, iron threads and ladder.

3.2.3. Preparation of vertical growth device

The growing device is made of a 4 inch (0.1016 m) diameter PVC Pipe. Three 30 feet long and one ten feet long 4 inch PVC pipes were brought from local market and cut into 1.0 m long pieces with electric saw. A rectangle (0.70×0.15 m^2) was drawn on the outer surface of the pipes and this rectangular portion was cut out from the pieces. Both ends of each piece were covered with pipe-end caps to complete the device. The 1m long devices weighted around 0.75 kg each. The devices were hung on the hardboard wall in such a manner that the bottom of the part of the devices from fourth replication was placed at a height of 0.5 m from the ground level. A picture of the growth device and a part of the experimental set up are added in Appendix II and Appendix III.

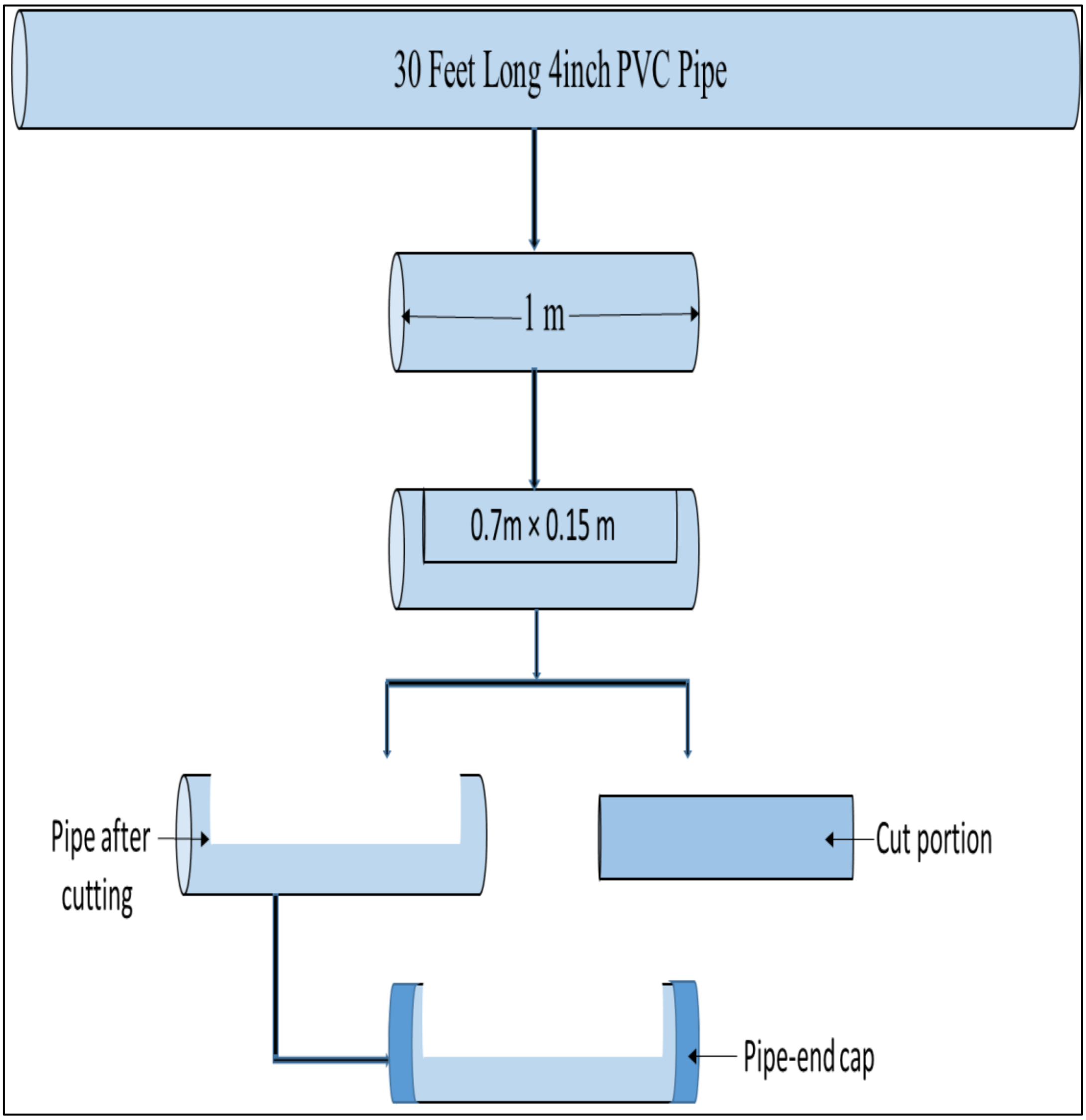

Plate 1. Schematic Representation of Growth Device Making Process

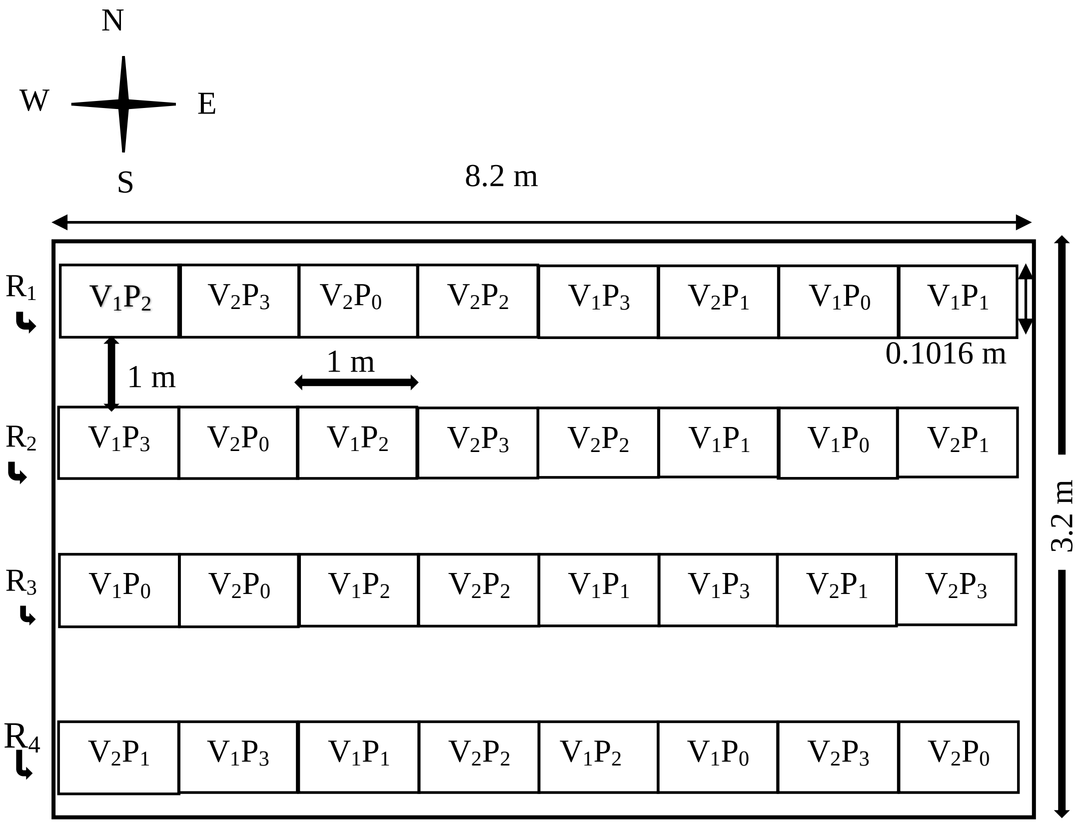

Figure 1: Schematic Layout of Experimental Set-up

Here, Wall size: 8.2 × 3.2 m^2
Number of Blocks: 4 Block spacing: 1 m
Number of Device: 32
Device size: 1×0.1016 m^2
Factor A: Variety
- V_1: Green Wave
- V_2: New Red Fire

Factor B: Growth media
- P_0: Control (100% soil)
- P_1: SVC (40% Soil + 40% Vermicompost + 20% Cocodust)
- P_2: SV (50% soil + 50% Vermicompost)
- P_3: SVS(20% Soil + 40% Vermicompost + 40% Spent Mushroom Compost)

3.3 Cultivation of crop

3.3.1. Collection of planting materials

Seeds of the three varieties of lettuce *viz*. Green Wave and New Red Fire were collected from the local seed market to be used as plant materials.

3.3.2. Seed tray preparation for seed germination

An aluminum seed tray (1x1 m^2) was used for seed germination. A locally used pot mix was used to fill the seed tray. This media contained thoroughly mixed fine grain soil, vermicompost and cocodust. After filling the tray, the surface of the media was leveled with a stick. The seed tray was divided into two equal portions and separated by cardboards to accompany the seeds of varieties.

3.3.3. Seed germination

100 seeds of each variety (Green Wave and New Red Fire) were mixed with a little amount of pot media and broadcasted on one portion of the seed tray for uniform distribution. Each portion was marked according to the variety followed by light irrigation. The tray was places on roof and covered with nets to avoid direct sunlight and stormy winds.

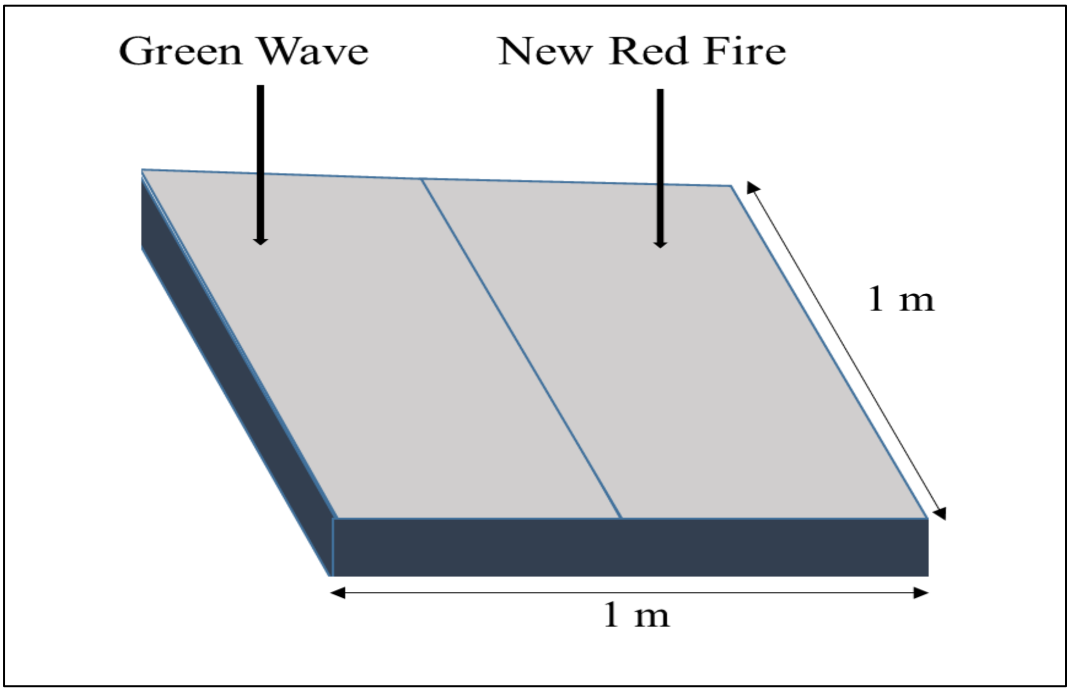

Plate 2. Schematic Representation of Germination Test

3.3.4. Seedling emergence

The apparent, fifty and ninety percent seedling emergence took place within 3, 6 and 8 days after sowing, respectively for Green Wave and New Red Fire varieties.

3.3.5. Collection of organic manures

Vermicompost and spent mushroom compost was used as organic manures in current study. The growth media comprised of soil, coco-dust, vermicompost and spent mushroom compost which were collected from Horticulture Farm, SAU.

3.3.6. Preparation of growth media / pot mix

Four different growth media (pot mix) was used in this experiment. The first pot media contained only regular nursery soil. While the second pot media comprised of soil, vermicompost and cocodust. The third pot media was made of only soil and vermicompost. In addition to soil and vermicompost, the forth pot media contained spent mushroom substrates. The physiochemical properties of soil, vermicompost and spent mushroom compost are attached in Appendix-III. Pictures of growth media are added in Appendix V-VI.

3.3.6.1. Preparation of control media

The control media was prepared from light textured local sandy-loam soil. The soil was rich in nutrients and dark in color due to presence of higher organic matter. The pH of the soil was 6.5. Loose friable soil was poured in eight growing devices, leaving the top most 5 cm of each device empty for irrigation and facilitation of other intercultural operation. The individual device weighted about 4.5 kg.

3.3.6.2. Preparation of SVC media

The soil, vermicompost and coco-dust media (SVC media) was prepared by thoroughly mixing 4 kg, 4 kg and 2 kg of the respective components at 2:2:1 ratio (weight basis). It was rich in nutrients but light in color due to presence of cocodust. In addition, it was slightly alkaline (pH 7.5) with great drainage property and very light texture. The media was poured in eight growing devices excluding the top most 5 cm of every device empty for irrigation and intercultural operations. The final weight of each device was 2 kg.

3.3.6.3. Preparation of SV media

The SV media was prepared by thoroughly mixing 12kg soil with 12 kg vermicompost at 1:1 ratio (weight basis). SV media was rich in nutrients and dark in color due to presence of vermicompost. The media had alkaline pH (7.5) with good drainage property abut heavy texture due to presence soil. The media was poured in eight growing device, leaving the top most 5cm of each device empty for irrigation and facilitation of other intercultural operation. The individual device weighted about 3.7 kg.

3.3.6.4. Preparation of SVS media

The SVS media was prepared by thoroughly mixing 4 kg soil, 8.5 kg vermicompost and 8.5 kg spent mushroom compost at 1:2:2 ratio (weight basis). SVC media is rich in nutrients due to presence of both vermicompost and spent mushroom. SVC media is more acidic (pH 6.0) and darker in color than SV media. This media has good drainage property and relatively light texture in comparison with SV media. The media was poured in eight growing device, leaving the top most 5cm of each device empty for irrigation and facilitation of other intercultural operation. The individual device weighted about 3.4 kg.

3.3.7. Intercultural operation

All necessary intercultural operations viz. – transplanting, gap filling, weeding, irrigation and pest and disease Swere carried out for better performance of lettuce seedlings. A ladder was used to carry out these operations on the higher replications.

3.3.7.1. Transplanting

Healthy and uniform sized, ten days old seedlings were transplanted on June 7, 2019. Irrigation was stopped one day prior to transplanting. The seed tray was wetted thoroughly in the afternoon and transplanting was done. After the seedlings were transplanted in the growing devices, light irrigation was provided for their better establishment. The seedlings were transplanted in a single row 15 cm apart in the growing device. Shed was provided to protect the transplanted seedlings from scorching sunlight in the following five days.

3.3.7.2. Gap filling

New vigorous seedlings from the stock on germination tray were used to replace dead, injured and weak seedlings of the growth devices.

3.3.7.3. Weeding

The hand weeding was done according to necessity of keeping the devices free from weeds and to avoid crop-weed competition. Total four weeding was carried out.

3.3.7.4. Irrigation

Irrigation was given on third day using a watering pot. Approximately 125ml water was provided each of the growing devices. To avoid run off of irrigation water and leaching of nutrients into the lower devices of vertical gardening, water was sprinkled on each device in two split doses. A thin layer (1 cm) of foam was also provided at the bottom of the growing device for the same purpose before the pouring with pot media.

3.3.7.5. Pest and disease control

There was no incidence of insects during the experimental duration. However, **s**ome plants were infected by *Alternaria* leaf spot diseases onset of harvesting. The diseased leaves were also removed from the infested plant.

3.4 Harvesting

Lettuce was harvested at 40 Days after Transplanting. Five plants were randomly harvested from each treatment combination and were used for data observation and recording regarding yield performance.

3.5 Data collection

Four plants were randomly selected from each of the treatment combination. Data on different growth parameter, such as- plant height, number of leaves/plant, leaf length and length breadth and circumference of canopy were collected at 20, 30, 40 and 50 days after sowing (DAS). Yield parameters were recorded at harvest which included fresh weight and yield per device. Total yield was calculated from yield per device. Dry weights of individual plant were recorded after harvest.

3.5.1 Plant height

The distance between the tips of the highest leaf from ground was considered as plant height and measured with a meter scale from five randomly selected plants at 10 days interval beginning at 20 days after sowing (DAS) and continued till harvest. The units were expressed in cm.

3.5.2 Number of leaves per plant

Number of leaves per plant was counted from five randomly selected plants at 10 days interval starting from 20 days after sowing (DAS) and continued upto 40 DAS and at harvest and their mean was recorded.

3.5.3 Leaf length

The leaf length (distance from tip of the leaf to leaf-stalk base) was measured from randomly selected five plants with meter scale in centimeter at 10 days interval beginning at 10 days after transplanting (DAT) and continued upto 40 DAT.

3.5.4 Leaf breadth

Leaf breadth was counted from five plants selected randomly from each treatment combination at every 10 days starting from 20 DAS and continued upto 50 DAS and at harvest and their mean value was calculated and recorded.

3.5.5 Leaf area

Leaf area was estimated by multiplying leaf length and leaf breadth. It was expressed in unit, cm^2.

3.5.6. Circumference of lettuce canopy

The four diameter of the canopy were with a meter scale. The average diameter was used to calculate the circumference (cm) of lettuce canopy by geometrical formula.

3.5.7 Weight of individual plant

Weight of individual plant was recorded was measured from four randomly selected plants in grams (g) with an electric balance.

3.5.8 Dry matter content per plant

At first selected plant were collected, cut into pieces and sun dried for 72 hours followed by drying in an oven at 70°C for 72 hours. The weight of the oven dried sample was taken and express in gram.

3.5.9 Yield/Device

Yield of lettuce/Device was recorded as the leaf of whole plant at final harvest within a plot and was expressed in kilogram per m^2.

3.6 Statistical analysis

The data obtained for different characters were statistically analyzed to find out the significance of the difference for different lettuce variety and manure on growth and yield of lettuce. The mean values of all the recorded characters were evaluated and analysis of variance was performed. The significance of the difference among the treatment combinations of means was estimated by Least Significant Difference (LSD) value at 5% level of probability.

3.7 Organoleptic test

A 25 member judge panel was formed. They evaluated the marketable qualities such as - crispness, sweetness, sourness, bitterness and appearance of lettuce leaf based on its acceptability. Scoring was done on the three categories, namely- Highly Acceptable (HA), Slightly Acceptable (SA) and Not Acceptable (NA) for all characters (Villared *et al*., 1979). Finally, acceptability score was done by using the following formula-

$$\text{Highly Acceptable (HA)} = \frac{\text{Number of score} \times 100}{\text{Total number of Judges}} \times 7$$

$$\text{Slighly Acceptable (SA)} = \frac{\text{Number of score} \times 100}{\text{Total number of Judges}} \times 5$$

$$\text{Not Acceptable (NA)} = \frac{\text{Number of score} \times 100}{\text{Total number of Judges}} \times 2$$

Finally, the lettuce leaves were sorted into three categories on the basis of score.

3.8 Safety test

The microbiological quality of the produce was conducted in Molecular and Environmental Microbiology Laboratory, BRAC University. Approximately, 10 g of fresh lettuce leaves for each of the samples was aseptically cut, weighed and transferred onto sterile mortar and pestle alone 20 mL of sterile distilled water (Total volume 30 mL). The leaves were crushed until they were homogenized. Two subsamples were taken from this homogenate; one for primary enrichment in Tryptic Soy Broth (TSB), and another for direct enumeration of fecal indicator bacteria (FIB) using selective media.

3.8.1. Enumeration of FIB

Enumeration of FIB was performed on bacteriological agar media using spread plate method. Nutrient Agar (NA) was used for enumeration of total heterotrophic plate count (HPC); McConkey Ager was used for total coliform count (TC); Hi-Chrome Agar was used for detection and enumeration of *E. coli*, *Klebsiella* spp., and enterococci; and Hi-Chrome Bacillus Agar was used for detection and enumeration of *Bacillus* spp. An aliquot of 100 µL was collected from the lettuce homogenate was spread on 90 mm plates containing solid media and incubated at 37 °C for 24 hrs in aerobic condition. Detection and enumeration of the presumptive colonies relied on characteristic colony appearances (Abrahamovich, and Alippi, 2019).

3.8.2. Detection of *Salmonella* spp.

For detection of *Salmonella* spp., aliquots of 5 mL lettuce homogenate (described earlier) was added to 45 mL TSB in 250 mL conical flasks for primary enrichment; the primary culture was incubated at 37 °C for 12 hrs without shaking in aerobic condition. After primary enrichment, approximately 10 µL aliquots for each of the samples were subcultured on Xylose-Lysine-Deoxycholate (XLD) agar media using streak plate method. The XLD plates were then incubated for 24 hrs at 37 °C in aerobic conditions. Detections were made based on appearance of black center colonies with clear margins characteristic of *Salmonella* spp.

Calculation of bacterial loads was done using the following formula:

$$\text{Final CFU count (per gm lettuce)} = \frac{30\ \times 10 \times \text{CFU count on plate}}{10}$$

3.9 Economic analysis

The economic analysis was done by calculation of production cost and price of the produce in order to find out the most economic combination of different lettuce variety and manure for lettuce cultivation in vertical garden. All input cost and interests on running capital was included in computing the cost of production. The interests were calculated @ 12% in simple rate. The market price of lettuce was considered for estimating the gross and net return. Economic analyses were done according to the procedure of Alam *et al*. (1989). The benefit cost ratio (BCR) was calculated as follows:

$$\text{Benefit Cost Ratio (BCR)} = \frac{\text{Gross return (tk)}}{\text{Total cost of production (tk)}}$$

Chapter IV

RESULTS AND DISCUSSIONS

Chapter IV

RESULTS AND DISCUSSIONS

An experiment was conducted to evaluate the qualitative and quantitative effect of different organic manures on off-season growth and yield performance of two lettuce varieties. Data were collected on various growth and yield indicator and data was statistically analyzed with Statistix10.0 software. Appendices VII-XIV contains the analysis of variance (ANOVA) of the data on different growth and yield parameters. Figures, graphs and tables were used to discuss the findings of the study as well as their most probable interpretation in this chapter under the following headings.

4.1. Plant height

Plant height of lettuce exhibited significant differences due to various growth medias at 20, 30, 40 and 50 DAS (Figure 2). The highest plant height at 20 DAS (5.50 cm) was recorded for P_2 which was statistically identical with P_0 (5.35 cm). P_1 produced the tallest plants at 30 DAS (22.04 cm) and 40 DAS (27.35 cm). At 50 DAS the longest (31.18 cm) plant was obtained from P_0 which had statistical similarity with P_1 (30.61cm). The lowest plant heights were recorded for P_3 (4.25cm, 14.64 cm and 17.79 cm) and P_0 (11.48 cm) at 20, 40, 50 and 30 DAS, respectively.

Significant varietal variation was calculated on plant height at different DAS (20, 30, 40 and 50). While V_1 generated taller plants (5.16 cm, 17.50 cm, 24.91 cm, and 28.39 cm) than V_2 (4.80 cm, 14.20 cm, 19.13 cm and 24.26 cm) at all stages, it was statistically identical at 20 DAS (Figure 3). Jahan (2017) concluded that both organic manures and variety influenced length of lettuce plants significantly.

Combined effect of variety and growth medias produced a statistically significant variance on plant height at 20, 30, 40 and 50 DAS (Table 1). The length of the tallest plants at 20, 30, 40 and 50 DAS were noted for V_1P_2 (5.88 cm) and V_1P_1 (25.88 cm, 32.45 cm and 34.88 cm) , respectively. The shortest plants were detected under varied treatment combinations at various growth stages. While V_1P_3 and V_1P_0 was responsible for the shortest plants at 20 DAS (3.75 cm) and 30 DAS (11.25 cm) correspondingly, V_2P_3 accounted for the lowest plant lengths at 40 DAS (12.53 cm) and 50 DAS (16.95 cm).

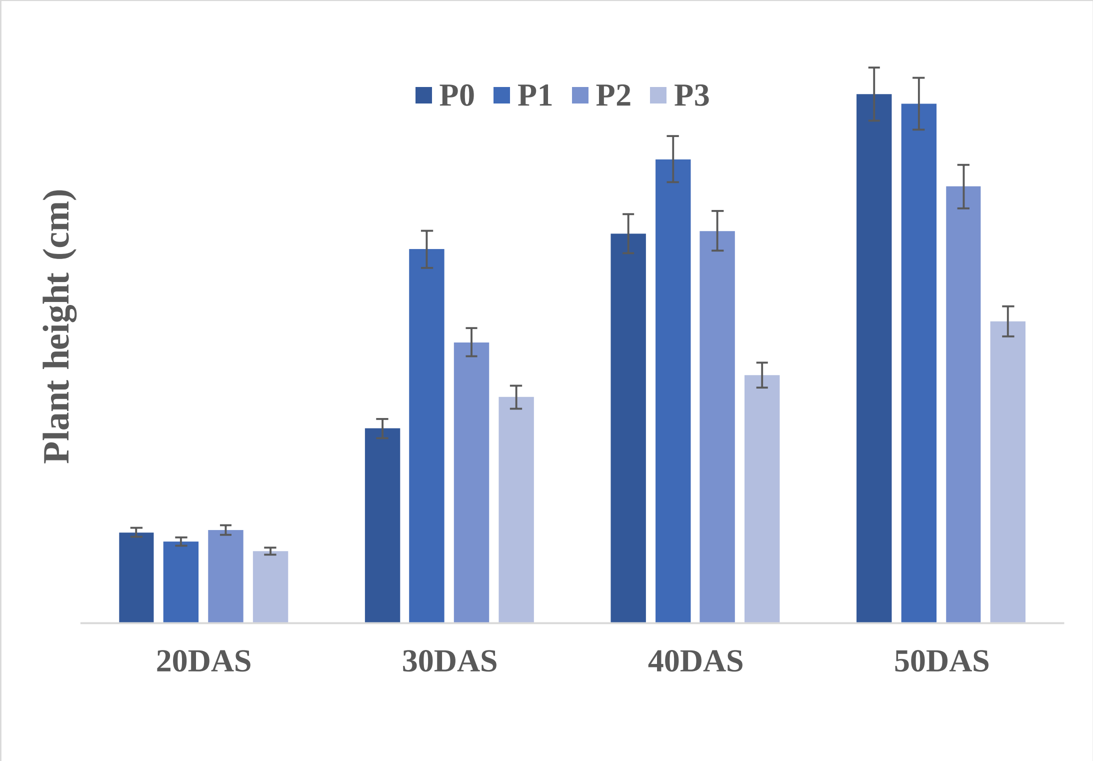

Figure 2. Effect of Organic Manures on Plant Height of Lettuce

Here, P_0 ⇒ Control, P_1⇒ SVC, P_2 ⇒SV, P_3 ⇒ SVS; DAS⇒ Days after Sowing; Vertical bars represent error

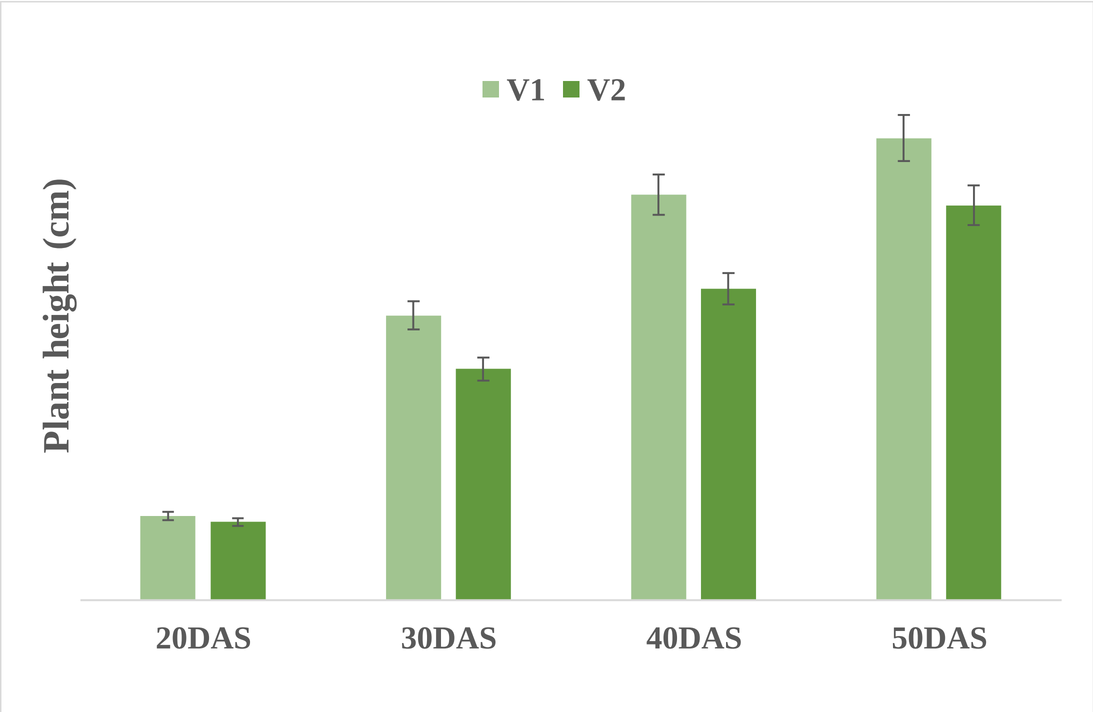

Figure 3. Effect of Varieties on Plant Height of Lettuce

Here, V_1⇒ Green Wave and V_2 ⇒ New Red Fire; DAS⇒ Days after Sowing; Vertical Bars represents error

Table 1. Interaction Effect of Growth Media on Plant Height of Two Lettuce Varieties at Different Days After Sowing (DAS)

Treatment Combinations	Plant Height (cm)			
	20	30	40	50
V_1P_0	5.50 ab	11.25 d	24.95 b	31.95 b
V_1P_1	5.50 ab	25.88 a	32.45 a	34.88 a
V_1P_2	5.88 a	19 b	25.50 b	28.13 c
V_1P_3	3.75 d	13.88 c	16.75 d	18.63 e
V_2P_0	5.20 ab	11.70 d	21c	30.40 b
V_2P_1	4.13 cd	18.20 b	22.25 bc	26.35 c
V_2P_2	5.13 ab	14.13 c	20.75 c	23.35 d
V_2P_3	4.75 bc	12.78 cd	12.53 e	16.95e
LSD (0.05)	0.934	1.70	3.56	1.85

Here, $V_1 \Rightarrow$ Green Wave and $V_2 \Rightarrow$ New Red Fire; $P_0 \Rightarrow$ Control, $P_1 \Rightarrow$ SVC, $P_2 \Rightarrow$SV, $P_3 \Rightarrow$ SVS;
Means in same column with different letter(s) are significant at 0.05 level of probability.

4.2. Leaf number per plant

Significant variation due to growth medias on number of leaf per plant was observed at different days after sowing (Figure 4). The highest leaf number per plant was produced by P_2 (6.88 at 20 and 14.88 at 30 DAS) and P_1 (19.63 at 40 and 21.50 at 50 DAS). The least number of leaves per plant were recorded for P_3 (5.00) and P_0 (10.88, 16.85 and 19.50) at 20, 30, 40 and 50 DAS, respectively. Masarirambi *et al.* (2012) reported that lettuce provided with 60 t/ha of Nitrogen exhibited higher values in number of leaves per plant of lettuce.

Plant leaf number of lettuce showed significant differences due to influence of variety at 20, 30, 40 and 50 DAS (Figure 5). Though number of leaves per plant was greater in V_1 (5.81, 13.75, 18.44 and 21.06) than V_2 (5.75, 13.19, 18.00 and 20.00) at all cases, it were statistically significant only at 50 DAS.

Plant leaf number exhibited significant differences due to combined influence of growth medias and variety at variable DAS (Table 2).The highest leaf numbers were 7.25(V_1P_2), 15.75 (V_1P_3), 19.75 (V_2P_1) and 21.5 (V_1P_1 and V_2P_1) at 20, 30, 40 and 50 DAS , respectively. 4.75(V_1P_3), 10.25(V_1P_0), 16(V_1P_0) and 18.75 (V_2P_0) was the lowest number of leaf per plant from 20, 30, 40 and 50 DAS.

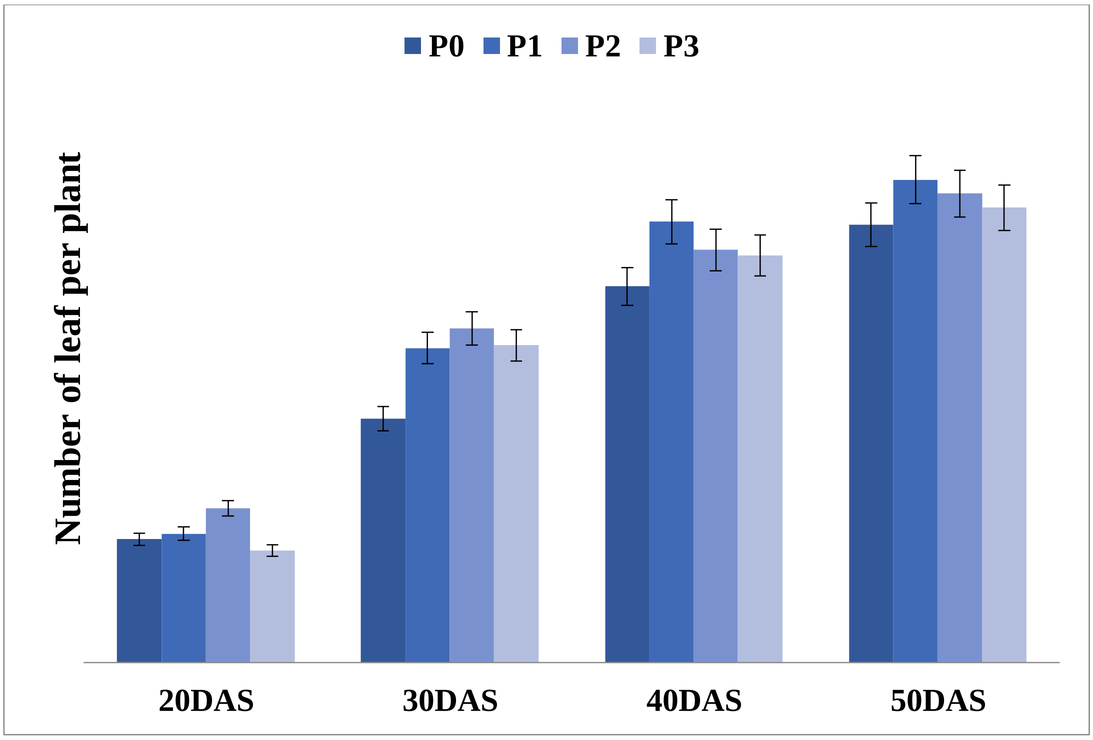

Figure 4. Effect of Growth Medias on Leaf Number per Plant of Lettuce

Here, $P_0 \Rightarrow$ Control, $P_1 \Rightarrow$ SVC, $P_2 \Rightarrow$SV, $P_3 \Rightarrow$ SVS; DAS$\Rightarrow$ Days after Sowing; Vertical bars represent error

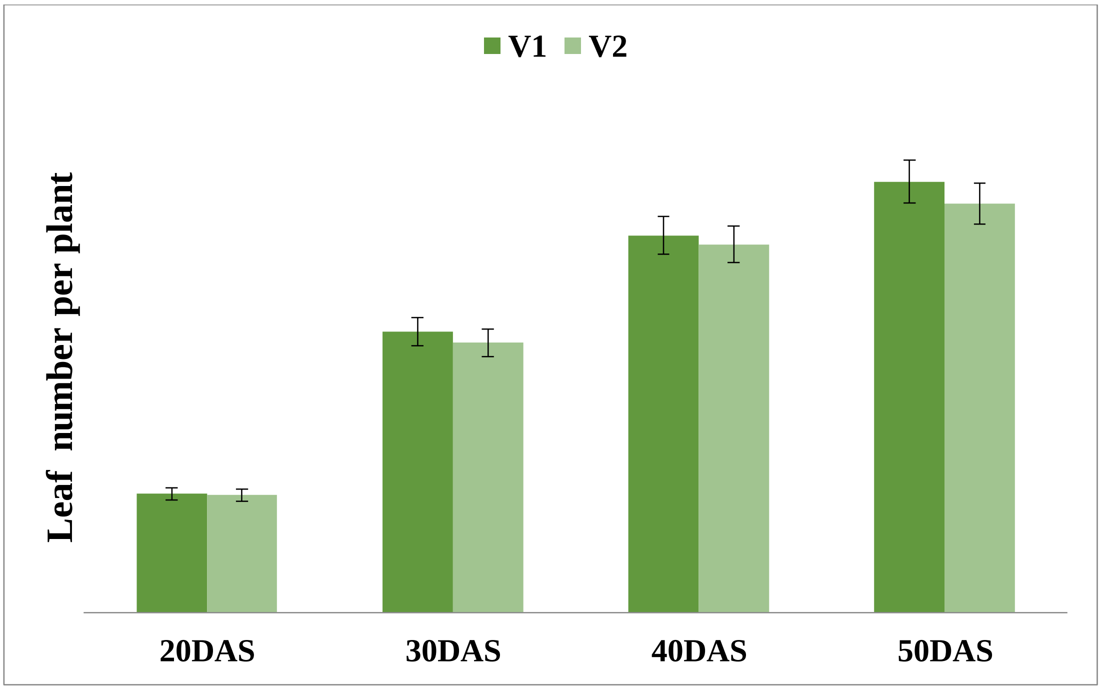

Figure 5. Effect of Varieties on Leaf Number per Plant of Lettuce

Here, $V_1 \Rightarrow$ Green Wave and $V_2 \Rightarrow$ New Red Fire; DAS$\Rightarrow$ Days after Sowing Vertical bars represent error

Table 2. Interaction effect of Growth Medias on Number of Leaf per Plant of Two Lettuce Varieties at different Days After Sowing (DAS)

Treatment Combination	Number of Leaf per Plant			
	20	30	40	50
V_1P_0	5.50 bc	10.25 e	16d	20.25ab
V_1P_1	5.75 bc	13.75 bc	19.5ab	21.5a
V_1P_2	7.25 a	15.25 ab	19abc	21.25a
V_1P_3	4.75 c	15.75 a	19.25abc	21.25a
V_2P_0	5.50 bc	11.50 de	17.5 cd	18.75b
V_2P_1	5.75 bc	14.25 abc	19.75a	21.5a
V_2P_2	6.50 ab	14.50 ab	17.75 bcd	20.5ab
V_2P_3	5.25 c	12.50 cd	17d	19.25b
LSD (0.05)	1.11	1.98	1.98	1.96

Here, $V_1 \Rightarrow$ Green Wave and $V_2 \Rightarrow$ New Red Fire; $P_0 \Rightarrow$ Control, $P_1 \Rightarrow$ SVC, $P_2 \Rightarrow$SV, $P_3 \Rightarrow$ SVS;
Means in same column with different letter(s) are significant at 0.05 level of probability.

4.3. Leaf length

The leaf length of plant was significantly varied with variation in growth media at different days after sowing (Figure 6).The highest leaf length (8.31 cm) was obtained from P_2 which was statistically identical to P_1 (8.13 cm) and P_3 (8.19 cm) at 20 DAS. P_1 generated the tallest leaves (15.78 cm, 17.60 cm and 19.95 cm) at 30, 40 and 50 DAS, respectively. The shortest leaves were always recorded for P_0 (6.06 cm, 6.58 cm, 8.24cm and 17. 75 cm).

Varieties significantly altered the lettuce leaf height at all DAS (Days after Sowing) expect 20 DAS (Figure 7). Leaf height calculated from V_1 (7.78 cm, 12.98 cm, 15.22 cm and 18.82 cm) outperformed the leaf height recorded from V_2 (7.56cm, 11.65cm, 13.40 cm and 17.20 cm) at all DAS. Santamaria *et al.* (2000) reported similar results. According to them, longifolia cultivars produced higher leaf length than capitata and crispa cultivars.

Mixed effect of variety and growth mix had a significantly variable influence on leaf height at 20, 30, 40 and 50 DAS (Table 3). The tallest leaves at 20, 30, 40 and 50 DAS were noted for V_1P3 (8.50 cm) and V_1P_1 (16.35 cm, 18.50 cm and 21.05 cm), respectively. The shortest leaves were detected under V_2P_0 at 20 DAS (5.63 cm), 30 DAS (6.33cm) and 40 DAS (7.15 cm) as well as V_2P_3 at and 50 DAS (14.08 cm).

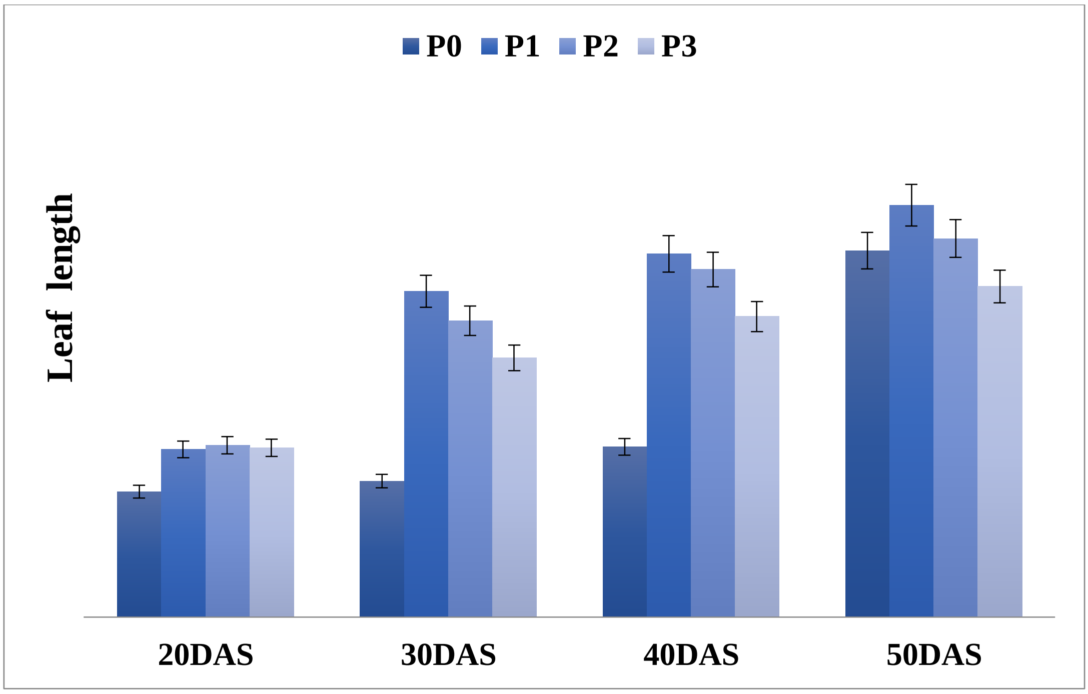

Figure 6. Effect of Organic Manures on Leaf Length of Lettuce

Here, P_0 ⇒Control, P_1⇒ SVC, P_2 ⇒SV, P_3 ⇒ SVS; DAS⇒ Days after Sowing; Vertical bars represent error

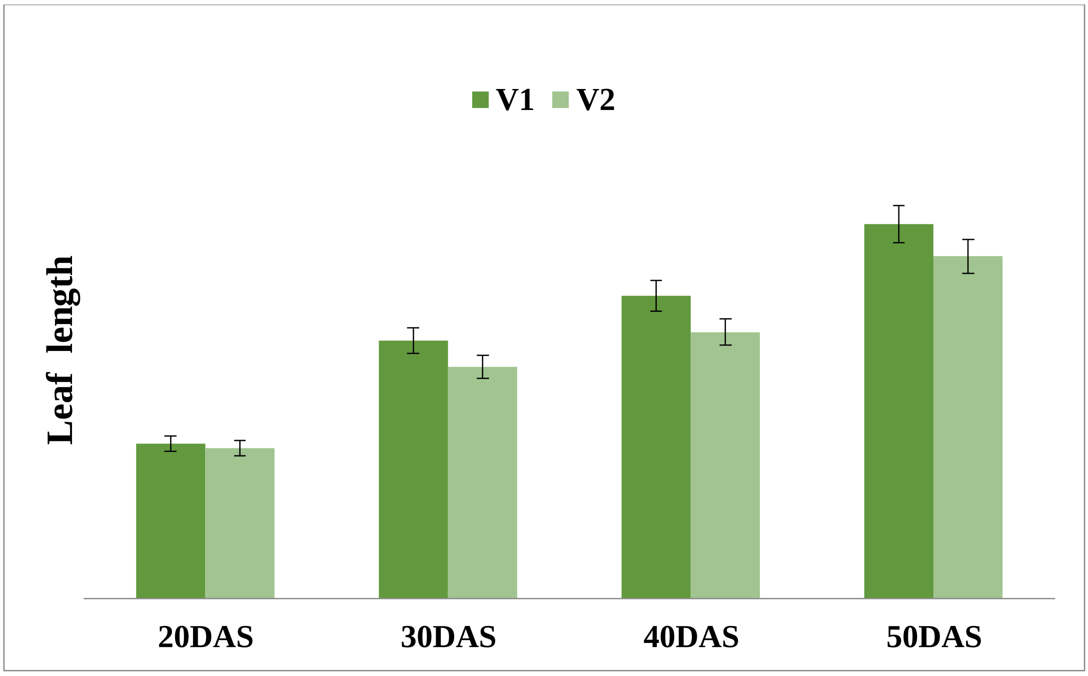

Figure 7. Effect of Varieties on Leaf Length of Lettuce

Here, V_1⇒ Green Wave and V_2 ⇒ New Red Fire; DAS⇒ Days after Sowing; Vertical bars represent error

Table 3. Interaction Effect of Growth Media on Leaf Length of Two Lettuce Varieties at Different Days After Sowing (DAS)

Treatment Combination	Leaf Length (cm)			
	20	30	40	50
V_1P_0	6.50b	6.83d	9.33d	18.20bc
V_1P_1	7.88a	16.35a	18.50a	21.05a
V_1P_2	8.25a	13.33b	16.10b	18.08bc
V_1P_3	8.50a	15.40a	16.95ab	17.95bc
V_2P_0	5.63b	6.33d	7.15e	17.30c
V_2P_1	8.38a	15.20a	16.70b	18.85b
V_2P_2	8.38a	15.38a	17.58ab	18.58bc
V_2P_3	7.88a	9.70c	12.18c	14.08d
LSD (0.05)	1.18	1.66	1.78	1.44

Here, $V_1 \Rightarrow$ Green Wave and $V_2 \Rightarrow$ New Red Fire; $P_0 \Rightarrow$ Control, $P_1 \Rightarrow$ SVC, $P_2 \Rightarrow$SV, $P_3 \Rightarrow$ SVS;
Means in same column with different letter(s) are significant at 0.05 level of probability.

4.4. Leaf breadth

Leaf breadth of lettuce exhibited significant difference due to influence of various growth mix at 20, 30, 40 and 50 DAS (Figure 8). The highest plant leaf breadth at 20 DAS (5.69 cm) and 30 DAS (9.04 cm) was recorded for P_2. P_1 produced the widest plant leaves at 40 DAS (15.50 cm) and 50 DAS (17.05 cm). The narrowest leaf breadth were recorded for P_0 (3.63 cm, 4.20cm, 4.92 cm and 12.20 cm) at 20, 30, 40, and 50 DAS, respectively.

Significant varietal variation was calculated on leaf breadth at different growth stages (20, 30, 40 and 50 DAS). While V_1 generated wider leaves (4.56 cm, 6.91 cm, 11.66 cm, and 14.72 cm) than V_2 (4.53 cm, 7.04 cm, 10.94 cm and 13.66 cm) at all stages, however, these were statistically different at 40 and 50 DAS (Figure 9). Jahan (2017) reported similar findings from her experiments and concluded that both organic manures and variety influenced breadth of lettuce leaves significantly.

Combined effect of variety and growth medias produced a statistically significant alteration on leaf breadth at each DAS (Table 4). While V_2P_2 and V_1P_2 was responsible for the widest leaves at 20 DAS (5.75 cm) and 30 DAS (11.25 cm) correspondingly, V_1P_1 accounted for the highest leaf width at 40 DAS (17.75 cm) and 50 DAS (18.88 cm). The least breadth of leaf (3.50 cm, 3.93 cm and 4.75cm) Was recorded for V_1P_0 in all DAS except 50 DAS , in which it was credited to V_2P_0 (12.15 cm).

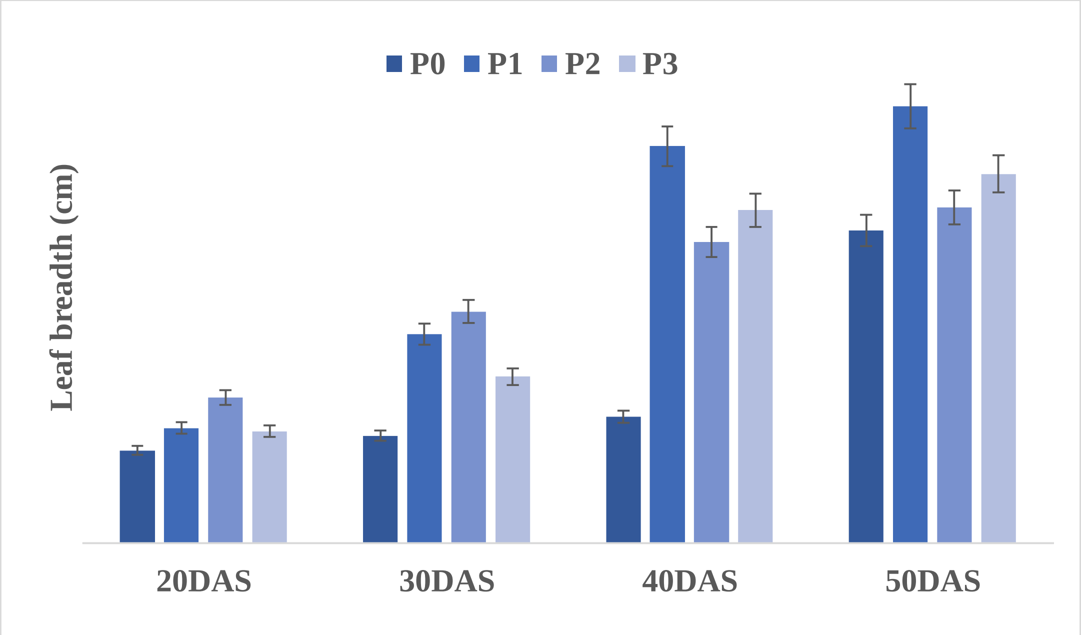

Figure 8. Effect of Organic Manures on Leaf Breadth of Lettuce

Here, P_0 ⇒Control, P_1⇒ SVC, P_2 ⇒SV, P_3 ⇒ SVS; DAS⇒ Days after Sowing; Vertical bars represent error

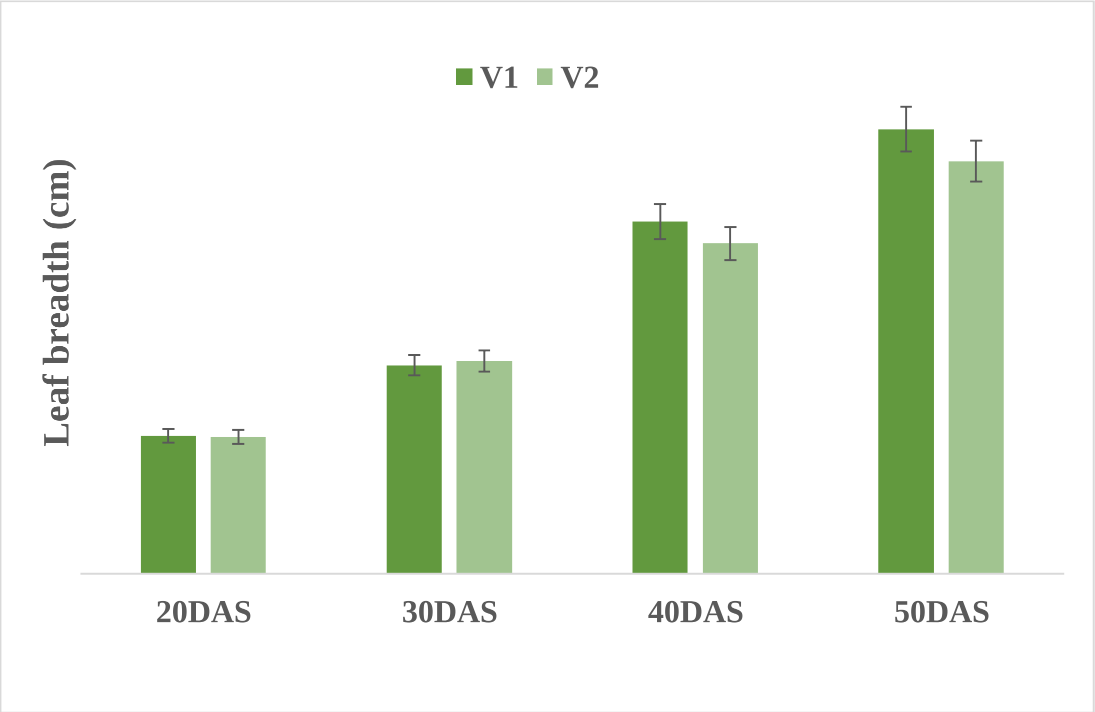

Figure 9. Effect of Varieties on Leaf Breadth of Lettuce

Here, V_1⇒ Green Wave and V_2 ⇒ New Red Fire; DAS⇒ Days after Sowing; Vertical bars represent error

Table 4. Interaction effect of growth medias on leaf breadth of two lettuce varieties at different Days After Sowing (DAS)

Treatment Combination	Leaf Breadth (cm)			
	20	30	40	50
V_1P_0	3.50c	3.93d	4.75d	12.25d
V_1P_1	4.75ab	8.45a	17.75a	18.88a
V_1P_2	5.63a	9.13a	11.38c	13.08cd
V_1P_3	4.38bc	6.13c	12.75 bc	14.68b
V_2P_0	3.75 bc	4.48d	5.13d	12.15d
V_2P_1	4.25bc	7.88ab	13.25b	15.23b
V_2P_2	5.75a	8.95a	12.13bc	13.13cd
V_2P_3	4.38bc	6.88bc	13.25b	14.15bc
LSD (0.05)	1.21	1.32	1.42	1.42

Here, $V_1 \Rightarrow$ Green Wave and $V_2 \Rightarrow$ New Red Fire; $P_0 \Rightarrow$ Control, $P_1 \Rightarrow$ SVC, $P_2 \Rightarrow$ SV, $P_3 \Rightarrow$ SVS;
Means in same column with different letter(s) are significant at 0.05 level of probability.

4.5. Leaf area

The leaf area of plant was significantly varied with variation in organic growth medias at different days after sowing (Figure 10). P_1 and P_2 produced the highest leaf area (129.51cm^2) at 30 DAS. While P_2 was accounted for the highest leaf area (47.00 cm^2) at 20 DAS, P_1 was responsible for the highest leaf area at 40DAS (274.58 cm^2) and 50 DAS (342.11 cm^2). The lowest leaf area was recorded for P_0 at all DAS (21.88 cm^2, 27.55 cm^2, 40.45 cm^2, and 216.61 cm^2 at 20, 30, 40 and 50 DAS , respectively). Ferdowsy (2013) concluded in her research findings that, organic manures had significant effect on leaf area of lettuce and vermicompost produced the best results.

Variety had significantly altered leaf area of lettuce at 40 and 50DAS (Figure 11). Even thought, varietal influence was insignificant at 20 and 30 DAS, nonetheless, V_1 (36.11 cm^2, 95.26 cm^2, 192.97cm^2 and 280.12 cm^2) performed better at all DAS than V_2 (34.77 cm^2, 88.35 cm^2, 157.79 cm^2 and 234.88 cm^2).

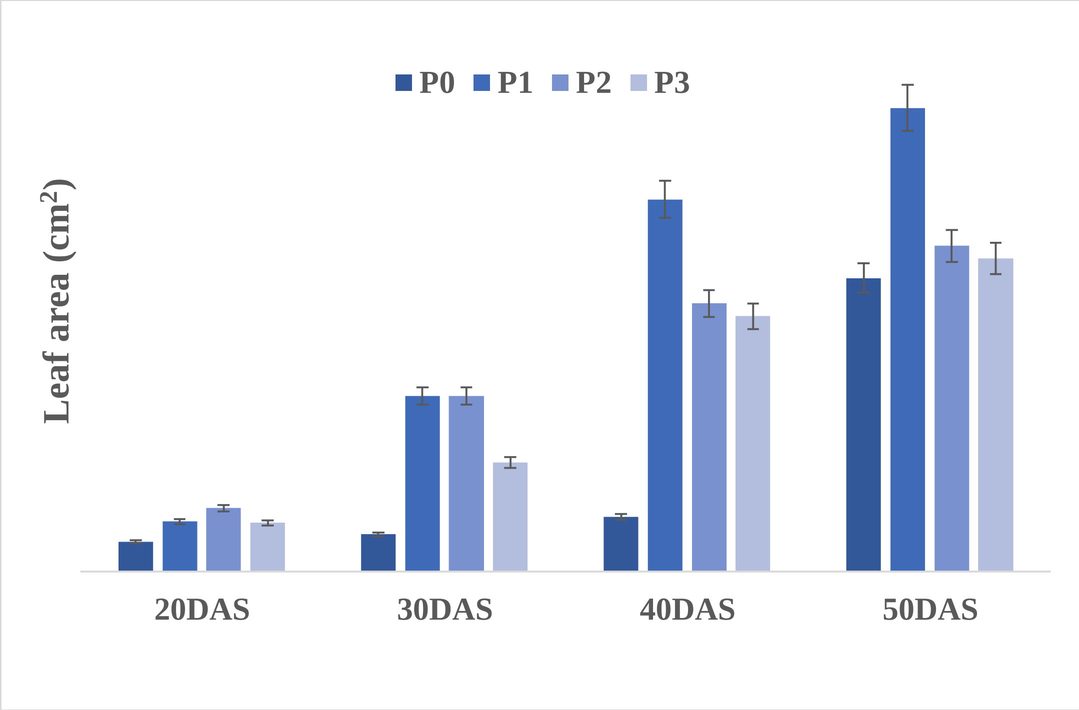

Figure 10. Effect of Organic Manures on Leaf Area of Lettuce

Here, P_0 ⇒ S, P_1⇒ SVC, P_2 ⇒SV, P_3 ⇒ SVS; DAS⇒ Days after Sowing; Vertical bars represent error

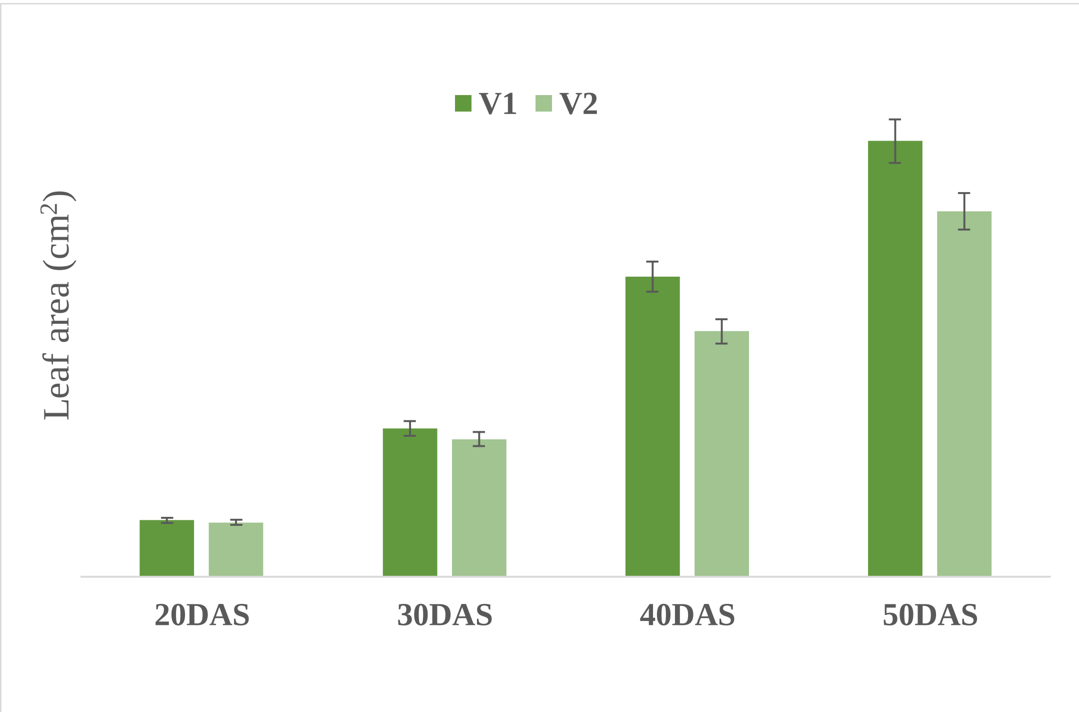

Figure 11. Effect of varieties on leaf area of lettuce

Here, V_1⇒ Green Wave and V_2 ⇒ New Red Fire; DAS⇒ Days after Sowing; Vertical bars represent error

Table 5. Interaction Effect of Growth Medias on Leaf Area of Two Lettuce Varieties at Different Days After Sowing (DAS)

Treatment Combination	Leaf Area (cm^2)			
	20	30	40	50
V_1P_0	22.69c	26.78d	44.24d	223.23 def
V_1P_1	38ab	137.96 a	328.13a	397.38 a
V_1P_2	46.50a	121.85a	183.59c	236.64 cde
V_1P_3	37.25ab	94.45b	215.91b	263.25 bc
V_2P_0	21.06c	28.32d	36.66d	210 ef
V_2P_1	35.88ab	121.05a	221.02b	286.84 b
V_2P_2	47.50a	137.18 a	212.33b	243.83 cd
V_2P_3	34.63b	66.85 c	161.16c	198.84 f
LSD (0.05)	11.73	24.58	28.72	32.78

Here, $V_1 \Rightarrow$ Green Wave and $V_2 \Rightarrow$ New Red Fire; $P_0 \Rightarrow$ Control, $P_1 \Rightarrow$ SVC, $P_2 \Rightarrow$SV, $P_3 \Rightarrow$ SVS;
Means in same column with different letter(s) are significant at 0.05 level of probability.

The interaction of growth medias and lettuce varieties generated markedly different statistical alteration in terms of leaf area (Table 5). At 20 DAS the highest leaf area was recorded from V_2P_2 (47.50 cm^2) which was statistically similar to V_1P_2 (46.59 cm^2), V_1P_3 (37.25 cm^2) and V_2P_1 (35.88 cm^2). V_1P_1 (137.96 cm^2) was attributed to the highest leaf are at 30 DAS. V_1P_2 (121.85 cm^2), V_2P_1 (121.05 cm^2) and V_2P_2 (137.18 cm^2) were fund to have statistically similarity with V_1P_1. V_1P_1 also produced the maximum leaf area at 40 (328.13 cm^2) and 50 DAS (397.38 cm^2). V_2P_0 (21.06 cm^2), V_1P_0 (26.78 cm^2), V_2P_0 (36.66 cm^2) and V_2P_3 (198.84 cm^2) was noted to had the least leaf area at 20, 30, 40 and 50 DAS, respectively.

4.6. Circumference

Circumference or core diameter of lettuce canopy had significantly varied due to different growing medium (Figure 12).The highest circumference (37.84 cm) was calculated for P_1 and P_2 at 20 DAS. P_1 (48.59 cm) was responsible for the highest lettuce canopy at 30 DAS. Statistical similarity was found between P_1 (52.95 cm) and P_2 (53.31 cm) at 40 DAS and P_2 (56.76 cm) and P_1 (54.53 cm) at 50 DAS. Elgubshawi and Attia (2019) concluded that Leaf area index, Avg. core length and yield (marketable yield) were significantly responded to relatively higher amounts of organic manures (24t/acre) in a sand soil.

Varieties influenced circumference at 30, 40 and 50 DAS, however, it did not generated significant variation at 20 DAS (Figure 12). The higher value was always recorded from V_1 (35.35 cm, 40.74 cm, 47.57cm and 51.32 cm) in comparison with V_2 (32.91cm, 38.60cm, 45.49cm and 48.93 cm).

Circumference of lettuce was significantly varied due to interactive effect of growth medium on two lettuce varieties (Table 6). While longest circumference at 20 DAS and 30 DAS was found for V_1P_1 (38.07 cm and 49.46 cm , respectively), it was obtained from V_1P_2 at 40 DAS (56.76 cm) and 50 DAS (59.97 cm). The shortest circumference was recorded for V_2P_0 at 20, 30, 40 and 50 DAS (25.04 cm, 26.61cm, 37.84cm and 42.78 cm , respectively).

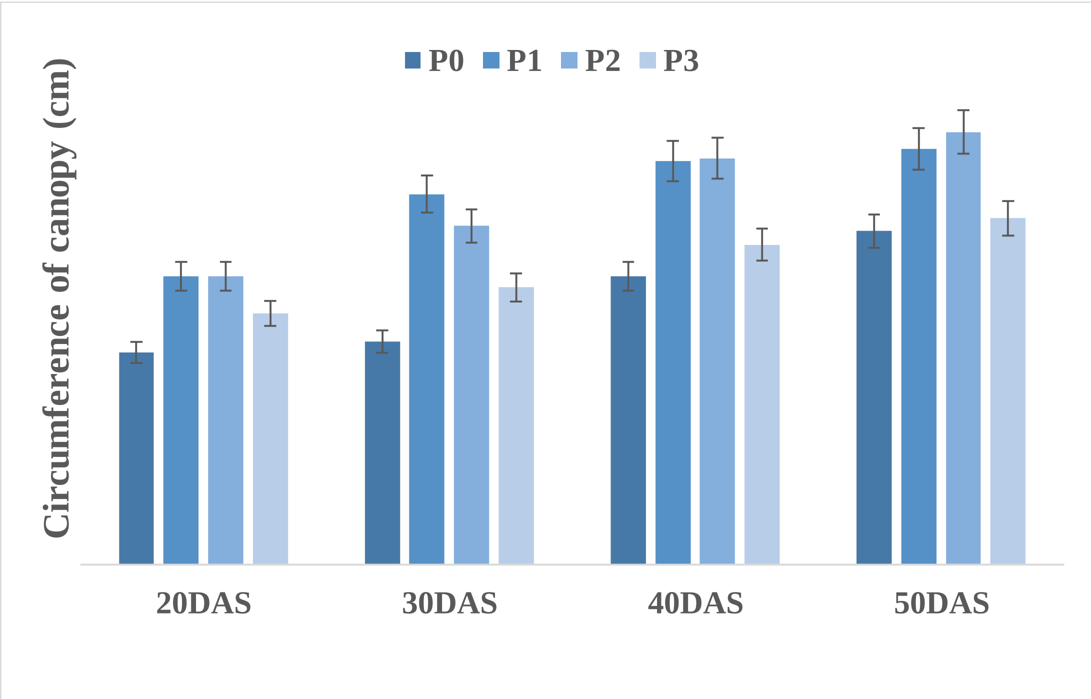

Figure 12. Effect of Growth Media on Circumference of Canopy

Here, $P_0 \Rightarrow$ Control, $P_1 \Rightarrow$ SVC, $P_2 \Rightarrow$SV, $P_3 \Rightarrow$ SVS; DAS$\Rightarrow$ Days after Sowing; Vertical bars represent error

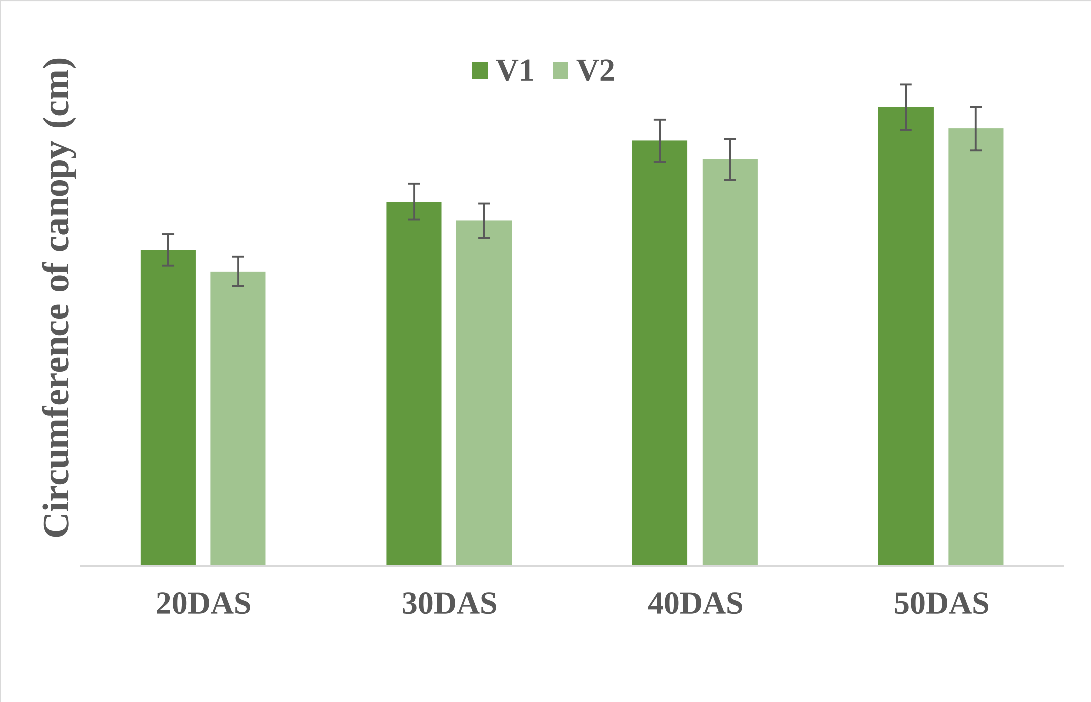

Figure 13. Effect of Varieties on Circumference of Lettuce

Here, V_1⇒ Green Wave and V_2 ⇒ New Red Fire; DAS⇒ Days after Sowing; Vertical bars represent error

Table 6. Interaction effect of Growth Medias on Circumference of Two Lettuce Varieties at Different Days After Sowing (DAS)

Treatment Combination	Circumference (cm)			
	20	30	40	50
V_1P_0	30.72b	31.95d	37.92d	44.75 c
V_1P_1	38.07a	49.46a	53.40ab	55.15 b
V_1P_2	37.68a	44.98 b	56.76a	59.97a
V_1P_3	34.93ab	36.58 c	42.23c	45.40 c
V_2P_0	25.04c	26.61e	37.84d	42.78 c
V_2P_1	37.60a	47.73ab	52.50 b	53.90 b
V_2P_2	37.99a	43.88 b	49.86b	53.55 b
V_2P_3	31.01b	36.19 cd	41.75 c	45.50 c
LSD (0.05)	4.46	4.43	3.71	3.76

Here, V_1⇒ Green Wave and V_2 ⇒ New Red Fire; P_0 ⇒ Control, P_1⇒ SVC, P_2 ⇒SV, P_3 ⇒ SVS;
Means in same column with different letter(s) are significant at 0.05 level of probability.

4.7. **Yield parameters**

4.7. 1. Fresh weight per plant

Significant varietal variation was calculated on fresh weight of each plant at harvest (Table 7). V_1 generated significantly heavier plants (126.8 g) than V_2 (120.69g). Tsiakaras *et al*. (2014) reported that cultivars had significant effect on fresh weights of individual plants.

Fresh weight of per lettuce plant exhibited significant differences due to influence of various organic growing medium at harvest (Table 7). The healthiest plant (134.63 g) was recorded for P_1. The least heavy plant was observed for P_0 (113.19 g).

Combined effect of variety and growing media produced a statistically significant variance on fresh weight of plant at harvest (Table 7). The weight of the healthiest plants at harvest was noted for V_1P_1 (141.75 g). The least heavy plant at fresh condition was detected at V_2P_0 (112.00g) which was statistically similar to V_1P_0 (114.37 g).

4.7.2. Dry weight per plant

Varieties significantly altered the dry weight of individual lettuce plant (Table 7). V_1 (14.53g) significantly outperformed the dry mass of individual plant recorded from V_2 (13.08g).

The individual dry weight of plant was significantly varied with a variation in growth medias (Table 7). The highest and lowest dry weight was obtained from P_1 (16.71 g) and P_0 (11.19 g), respectively. Masarirambi *et al.* (2012) concluded that lettuce provided with 60 t/ha of vermicompost exhibited higher values in individual plant dry mass.

Interacting effect of variety and growth medias had a significantly variable influence on individual plant dry mass (Table 7). The greatest dry mass per plant was noted for V_1P_1 (17.65 g). The plant with least dry mass was detected under V_2P_0 (10.19g).

4.7.3. Individual of yield growth device

Varieties influenced individual yield per growth device significantly (Table 7). The higher value was recorded from V_1 (0.63 kg) in comparison with V_2 (0.60 kg).

Individual growth device yield of lettuce was significantly varied due to different organic manures (Table 7). The highest yield (0.67 g) was measured for P_1 and P_0 (0.57 g) was responsible for the lowest yield per growth device. Elgubshawi and Attia (2019) concluded that Leaf yield per plot (marketable yield) was significantly responded to relatively higher amounts of organic manures (24t/acre) in a sand soil.

Yield of lettuce from individual growth device was significantly varied due to interactive effect of organic manure on two lettuce varieties (Table 7). While V_1P_1 produced the highest yield (0.71 g), V_2P_0 was the least yield (0.56 g) producing combination.

Table 7. Effect of Growth Medias, Varieties and Interaction of Growth Medias And Varieties on Yield Contributing Characteristics and Yield of Lettuce

	Yield Parameters		
	Fresh Weight per Plant (g)	Dry Weight per Plant (g)	Yield per device (kg)
Variety			
V_1	126.38a	14.53a	0.63a
V_2	120.69b	13.08b	0.60 b
LSD (0.05)	1.61	0.69	0.008
Organic Manure			
P_0	113.19d	11.19d	0.57 d
P_1	134.63a	16.71a	0.67a
P_2	124.44b	14.18b	0.62b
P_3	121.88 c	13.14c	0.61c
LSD (0.05)	2.28	0.98	0.01
Treatment Combination			
V_1P_0	114.37 d	11.48de	0.57d
V_1P_1	141.75 a	17.65a	0.71a
V_1P_2	127.62 b	15.90b	0.62b
V_1P_3	121.75 c	13.08c	0.61c
V_2P_0	112.00 d	10.90e	0.56d
V_2P_1	127.50 b	15.78b	0.64b
V_2P_2	121.25 c	12.45cd	0.61c
V_2P_3	122.00 c	13.20c	0.61c
LSD (0.05)	3.23	1.37	0.02

Here, $V_1 \Rightarrow$ Green Wave and $V_2 \Rightarrow$ New Red Fire; $P_0 \Rightarrow$ Control, $P_1 \Rightarrow$ SVC, $P_2 \Rightarrow$SV, $P_3 \Rightarrow$ SVS;
Means in same column with different letter(s) are significant at 0.05level of probability.

4.8. Organoleptic test

Marketable parameters such as- crispness, sweetness, bitterness, sourness and appearance of lettuce leaf influence its acceptability to consumer. These qualitative parameters were analyzed by organoleptic test. A 25 member judge panel was created from of the students of Sher-e-Bangla Agricultural University, Dhaka. Samples of lettuce from different treatment combinations alone with a questionnaire (Appendix XV) were served among the judges in order to evaluate its acceptability.

The results of test were summarized in Table 8. The findings revealed that lettuce grown with V_2P_1 treatment combination had the highest marketable quality with a score 3170. In contrast, the lowest score (2974) was recorded in the treatment combination of V_2P_3.

V_2P_1 secured the top score (684) among the different treatment combination in terms of crispiness. The lowest scoring treatment combination was V_1P_3 (568). In respect of sweetness, produce from V_2P_1 obtained the highest score (660), whereas the lowest score was recorded for V_1P_2 (560). Plants from V_2P_3 and V_2P_1 treatment combination the highest score (632) and lowest score (592), respectively, in case of bitterness. Produce from V_1P_1 (612) obtained the highest sourness acceptance, while produce from V_2P_3 (540) had least acceptability based on sourness. The highest appearance score (632) was obtained by leaves from V_2P_1 treatment combination, whereas the least desirable appearance was found from V_1P_0 (584).

A prediction of the consumers' likings on different marketable qualities of the produced lettuce can be make based on the present results.

Table 8. Quality Attributes of Lettuce

	Crispness	Sweetness	Bitterness	Sourness	Appearance	Total
V_1P_0	604	592	612	600	584	2992
V_1P_1	632	580	604	612	604	3032
V_1P_2	620	560	620	598	602	3000
V_1P_3	568	632	620	604	592	3016
V_2P_0	580	604	624	564	604	2976
V_2P_1	684	660	592	602	632	3170
V_2P_2	656	572	598	578	604	3008
V_2P_3	592	608	632	540	602	2974

Organoleptic test was done by following formula of Villared *et al*. (1979)
Here, $V_1 \Rightarrow$ Green Wave and $V_2 \Rightarrow$ New Red Fire; $P_0 \Rightarrow$ Control, $P_1 \Rightarrow$ SVC, $P_2 \Rightarrow$SV, $P_3 \Rightarrow$ SVS;
Highly Acceptable (HA=7), Slightly Acceptable (SA=5) and Not acceptable (NA=2)

4.9. Safety test

Samples of lettuce leaf from every treatment combination were tested at Molecular and Environmental Microbiology Laboratory, BRAC University. The test was undertaken to detect and enumerate the presence of bacterial population in organically grown lettuce and the results were expressed in terms of Colony Forming Units per Gram (CFU/g). The results of the test are summarized and presented in Table 9.

In general, V_1P_0, V_2P_1 and V_2P_2 had greater amount of bacterial infestation, whereas, V_2P_0 has exhibited the least amount of infestation. *E. coli* was present in all the samples. Highest CFU/g was recorded from V_2P_1 (3810) and the lowest count was found for V_2P_0 (120). The CFU/g for *Klebsiella* spp. ranged from 210(V_2P_0) to 4950 (V_2P_2). The highest and lowest CFU/g for *Enterococci spp.* was found in V_2P_2 (3750) and V_2P_0 (120), respectively. The colony forming unit in each gram of lettuce for *Bacillus ssp*. varied from 1920 (V_1P_2) to 360 (V_2P_0). *Salmonella spp.* were absent from all samples. Heterotopic Plate Count (HPC) was greater than 9000 in all treatment combinations. The range of Total Coliform (TC) was 8250 (V_2P_1) – 450 (V_2P_0).

Fowler and Foster (1976) reported that green salad (fresh lettuce leaf) from an arm-forced medical facility had a Total Plate Count (TPC) range of 3.0 x 10^3 -3 x10^7/g, with a mean of 1.9 x 10^7/g and the salad was safe for consumption. Usually, food that are consumed at fresh condition, such as- fruits and salad crops contain a large number of bacterial population as part of their natural micro-flora. Aerobic colony count (ACC) or HPC or standard plate count provides valuable information on the general quality and remaining shelf life of the food as a quality indicator; however, it cannot be assisted directly as safety assessment of food (*Anon.*, 2014).

Table 9. Colony Forming Units per gram (CFU/g) of Lettuce Leaf under Different treatment combinations

	E. coli	*Klebsiella spp.*	*Enterococci*	*Bacillus spp.*	*Salmonella spp.*	HPC	TC
V_1P_0	2220	1740	1650	870	Absent	>9000	5100
V_2P_0	120	210	120	360	Absent	>9000	450
V_1P_1	960	630	570	1080	Absent	>9000	4560
V_2P_1	3810	1050	3330	540	Absent	>9000	8250
V_1P_2	360	300	150	1920	Absent	>9000	1110
V_2P_2	3480	4950	3750	810	Absent	>9000	7950
V_1P_3	1080	990	510	1890	Absent	>9000	2400
V_2P_3	390	600	420	1020	Absent	>9000	1350

Here, $V_1 \Rightarrow$ Green Wave and $V_2 \Rightarrow$ New Red Fire; $P_0 \Rightarrow$ Control, $P_1 \Rightarrow$ SVC, $P_2 \Rightarrow$SV, $P_3 \Rightarrow$ SVS;
HPC: Total Heterotopic Count; TC: Total Coliform

4.10 Economic analysis

Input costs included making and installation costs of devices, price of different components of growth media (soil, vermicompost, cocodust and spent mushroom compost), seed, irrigation water and manpower required for all the operations from seed sowing to harvesting of lettuce were recorded as per plot and converted for cost of production on experimental wall (cost/ 24.4 m^2) (Appendix XVI). Price of lettuce produce was determined as per present market rate basis of chain shops of Dhaka city. The economic analysis is presented under the following headings-

4.10.1 Gross return

The gross return calculated from combinations of different lettuce variety and manure under the trial are presented in Table 10. The highest (BDT 17011/24.4 m^2)

and second highest (15314 BDT/ 24.4 m^2) gross return were obtained from the treatment combination of V_1P_1 and V_1P_2. The lowest gross return (BDT 13440 BDT/ 24.4 m^2) was obtained from V_2P_0 treatment combination.

4.10.2 Net return

The net returns was calculated from the difference of gross return and cost of production for different combinations of lettuce variety and manure under the trial and are presented in Table 10. The highest (BDT 4619/24.4 m^2) and second highest (2908 BDT/ 24.4 m^2) net return were obtained from the treatment combination of V_1P_1 and V_2P_1. The lowest net return (BDT 546 BDT/ 24.4 m^2) was obtained from V_1P_3 treatment combination.

4.10.2 Benefit Cost Ratio (BCR)

The benefit cost ratio (BCR) was calculated from the difference of gross return and cost of production for different combinations of lettuce variety and manure under the trial and are presented in Table 10. The highest (1.37) and second highest (1.23) BCR were obtained from the treatment combination of V_1P_1 and V_2P_1. The lowest BCR (1.04) was obtained from V_1P_3 and V_2P_3 treatment combinations.

In general, the gross and net profit earned from the vertical garden was satisfactory as walls have no economic productivity. It can be noted that, the vertical garden set up is a permanent structure. The preparation and installation cost for 32 device on a 24.4 m^2 wall was 8960 BDT. This set up is installed for 10 years. This cost was included in the economic analysis of the first season. However, this amount will be deducted if further cultivation is practiced in the structure. In that case, the both gross and net return will increase by 8960 BDT.

Table 10. Cost and Return of Different Lettuce Varieties in Vertical Gardening As Influenced By Different Growth Media

Treatment combination	Cost of production (BDT)	Yield of lettuce (kg)	Gross return (BDT)	Net return (BDT)	Benefit cost ratio (BCR)
V_1P_0	11989	18.30	13726	1737	1.14
V_1P_1	12392	22.68	17011	4619	1.37
V_1P_2	13328	20.42	15314	1986	1.15
V_1P_3	14065	19.48	14611	546	1.04
V_2P_0	11989	17.92	13440	1451	1.12
V_2P_1	12392	20.40	15300	2908	1.23
V_2P_2	13328	19.40	14551	1223	1.09
V_2P_3	14065	19.52	14640	575	1.04

Here, $V_1 \Rightarrow$ Green Wave and $V_2 \Rightarrow$ New Red Fire; $P_0 \Rightarrow$ Control, $P_1 \Rightarrow$ SVC, $P_2 \Rightarrow$ SV, $P_3 \Rightarrow$ SVS

Chapter V

SUMMARY AND CONCLUSION

Chapter V

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The experiment was carried out on a wall of Horticulture farm, Sher-e-Bangla Agricultural University during the summer season (May to July) of the year 2019 to assess the influence of organic manure on growth and yield performance of two lettuce varieties in vertical garden. It was a two factor experiment and laid out in Randomized Complete Block Design (RCBD) with four replications. The two factors are- Factor A: Lettuce variety (2), such as- $V_1 \Rightarrow$ Green wave and $V_2 \Rightarrow$ New red fire, and Factor B: Growth medias (3) i.e. - $P_0 \Rightarrow$ Control (100% Soil), $P_1 \Rightarrow$ SVC (50% Soil + 30% Vermicompost + 20% Cocodust), $P_2 \Rightarrow$ SV (50% Soil + 50% Vermicompost) and $P_3 \Rightarrow$ SVS (20% Soil + 40% Vermicompost + 40% Spent Mushroom Compost). Different growth and yield parameters were measured and recorded followed by statistical comparison of data.

While the highest plant height was obtained from P_2 (5.50 cm), P_1 (22.04 cm), P_1 (27.35 cm) and P_0 (31.18 cm) at 20, 30, 40 and 50 DAS, the lowest plant height was recorded from P_3 (4.25 cm), P_0 (11.48 cm), P_3 (14.64 cm) and P_3 (17.79 cm), respectively. The leaf number per plant count for $P_{0,}$ $P_{1,}$ P_2 and P_3 were 5.50, 10.88, 16.75 and 19.50; 5.75, 14.00, 19.63 and 21.50; 6.88, 14.88, 18.38 and 20.88; and 5.00, 14.13, 18.13 and 20.25 at 20, 30, 40 and 50 DAS. While P_3 (8.19 cm), P_1 (15.78 cm), P_1 (17.60 cm) and P_1 (19.95 cm) produced the highest length of leaf per plant, least length of leaf was produced on P_0 (6.06, 6.58 and 8.24 cm) and P_3 (16.01cm) at 20, 30, 40 and 50 DAS correspondingly. The leaf breadth measured from $P_{0,}$ $P_{1,}$ P_2 and P_3 at 20, 30, 40 and 50 DAS were 3.63, 4.20, 4.94 and 12.20 cm; 4.50, 8.16, 15.50 and 17.05 cm; 5.69, 9.04, 11.75 and 13.10 cm; and 4.38, 6.50, 13.00 and 14.41cm , respectively. The highest leaf area at 20, 30, 40 and 50 DAS were recorded for 47.00 cm^2 (P_2), 129.51 cm^2 (P_1 and P_2), 274.58 cm^2 (P_1) and 342.11 cm^2 (P_1).In contrast, the lowest leaf area were found from P_0 at all DAS (21.88, 27.55, 40.45 and 216.61cm^2). The widest circumferences were 37.84cm (P_1 and P_2), 48.59cm (P_1), 53.31 cm (P_2) and 56.76cm (P_2) and the least wide circumferences were 27.88 cm, 29.28cm, 37.88cm and 43.76 cm, obtained from P_0 at 20, 30, 40 and 50 DAS, respectively. The greatest and least fresh weight per plant, dry weight of individual plant and yield per growth device was obtained from P_1 (134.63g, 16.71g, and 0.67 kg) and P_0 (113.19g, 11.19g, and 0.57kg), respectively.

V_1 produced the higher plant length (5.16 cm, 17.5 cm, 24.91cm and 28.39 cm) than V_2 (4.8 cm,14.2 cm,19.13 cm and 24.26 cm) at 20, 30, 40 and 50 DAS. The leaf number for individual plant at 20, 30, 40 and 50 DAS was greater in V_1 (5.81, 13.75, 18.44 and 21.06) than V_2 (5.75, 13.19, 18.00 and 20.00). V_2 produced shorter leaves (7.56 cm, 11.65cm, 13.4 cm and 17.2 cm) than V_1 (7.78 cm,12.98 cm, 15.22cm and 18.82 cm) at all DAS. While V_1 was responsible for widest leaves (4.56cm, 6.91cm, 11.66cm and 14.72cm), V_2 was accountable for the least wide leaves (4.53cm, 7.04cm, 10.94cm and 13.66cm) at 20, 30 40 and 50 DAS , respectively. The biggest and smallest leaf leaves were obtained fromV_1 (36.11, 95.26, 192.97 and 280.12cm^2) and V_2 (34.77, 88.35, 157.79 and 234.88 cm^2) at 20, 30, 40 and 50 DAS, respectively. While V1 was responsible for widest circumferences of canopy (35.35 cm, 40.74 cm, 47.57 cm and 51.32 cm), V_2 was accountable for the least wide circumferences (32.91 cm,38.60 cm,45.49 cm and 48.93 cm) at 20, 30 40 and 50 DAS , respectively. The greatest and least fresh weight per plant, dry weight of individual plant and yield per growth device was obtained from V_1 (134.63g, 16.71g and 0.67 kg) and V_2 (113.19g, 11.19g and 0.57kg), respectively.

The length of the tallest plants at 20, 30, 40 and 50 DAS due to combined effect of variety and organic manure were noted for V_1P_2 (5.88 cm) and V_1P_1 (25.88 cm, 32.45 cm and 34.88 cm) , respectively. While V_1P_3 and V_1P_0 was responsible for the shortest plants at 20 DAS (3.75 cm) and 30 DAS (11.25 cm) correspondingly, V_2P_3 accounted for the lowest plant lengths at 40 DAS (12.53 cm) and 50 DAS (16.95 cm). The highest leaf numbers were 7.25(V_1P_2), 15.75 (V_1P_3), 19.75 (V_2P_1) and 21.5 (V_1P_1 and V_2P_1) at 20, 30, 40 and 50 DAS, respectively. 4.75(V_1P_3), 10.25(V_1P_0), 16(V_1P_0) and 18.75 (V_2P_0) was the lowest number of leaf per plant from 20, 30, 40 and 50 DAS. The tallest leaves at 20, 30, 40 and 50 DAS were noted for V_1P3 (8.50 cm) and V_1P_1 (16.35 cm, 18.50 cm and 21.05 cm), respectively. The shortest leaves were detected under V_2P_0 at 20 DAS (5.63 cm), 30 DAS (6.33cm) and 40 DAS (7.15 cm) as well as V_2P_3 at and 50 DAS (14.08 cm). While V_2P_2 and V_1P_2 was responsible for the widest leaves at 20 DAS (5.75 cm) and 30 DAS (11.25 cm) correspondingly, V_1P_1 accounted for the highest leaf width at 40 DAS (17.75 cm) and 50 DAS (18.88 cm). The least breadth of leaf (3.50 cm, 3.93 cm and 4.75cm) was recorded for V_1P_0 in all DAS except 50DAS, in which it was credited to V_2P_0 (12.15 cm). At 20, 30, 40 and 50 DAS the highest leaf area was recorded from V_2P_2 (47.50 cm^2), V_1P_1 (137.96 cm^2, 328.13 cm^2 and (397.38 cm^2). V_2P_0 (21.06 cm^2), V_1P_0 (26.78 cm^2), V_2P_0 (36.66 cm^2) and V_2P_3 (198.84 cm^2) was noted to had the least leaf area at 20, 30, 40 and 50 DAS, respectively. While longest circumference at 20 DAS and 30 DAS was found for V_1P_1 (38.07 cm and 49.46 cm, respectively), it was obtained from V_1P_2 at 40 DAS (56.76 cm) and 50 DAS (59.97 cm). The shortest circumference was recorded for V_2P_0 at 20, 30, 40 and 50 DAS (25.04 cm, 26.61cm, 37.84cm and 42.78 cm, respectively). The weight of the healthiest plants at harvest was noted for V_1P_1 (141.75 g). The least heavy plant at fresh condition was detected at V_2P_0 (112.00g). The greatest dry mass per plant was noted for V_1P_1 (17.65 g). The plant with least dry mass was detected under V_2P_0 (10.19g). While V_1P_1 produced the highest yield (0.71 g), V_2P_0 was the least yield (0.56 g) producing combination.

V_2P_1 treatment combination had the highest quality attributes with a score 3170. In contrast, the lowest score (2974) was recorded in the treatment combination of V_2P_3. V_2P_1 secured the top score (684) among the different treatment combination in terms of crispiness. The lowest scoring treatment combination was V_1P_3 (568). In respect of sweetness, produce from V_2P_1 obtained the highest score (660), whereas the lowest score was recorded for V_1P_2 (560). Plants from V_2P_3 and V_2P_1 treatment combination the highest score (632) and lowest score (592), respectively, in case of bitterness. Produce from V_1P_1 (612) obtained the highest sourness acceptance, while produce from V_2P_3 (540) had least acceptability based on sourness. The highest appearance score (632) was obtained by leaves from V_2P_1 treatment combination, whereas the least desirable appearance was found from V_1P_0 (584).

In general, V_1P_0, V_2P_1 and V_2P_2 had greater amount of bacterial infestation, whereas, V_2P_0 has exhibited the least amount of infestation.

The highest and the lowest gross return (17011 and 13440 BDT), net return (4619 and 546 BDT) and benefit cost ration (1.31, 1.04) were obtained from the V_1P_1 and V_1P_3 treatment combinations, respectively. V_2P_0 treatment had the lowest benefit cost ratio.

All in all, Green Wave lettuce variety alone with SVC pot mix (40% Soil + 40% Vermicompost + 20% Cocodust) was the most an excellent choice for summer vertical gardening.

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APPENDICES

APPENDICES

Appendix I. Monthly Weather Report during the experimental period, May to July, 2019

Month	RH (%)	Air Temperature (℃)			Rainfall (mm)
		Highest	Lowest	Average	
May	72.30	36	33	34.5	162.2
June	65.30	37	28	34	170.0
July	81.60	36	29	32.5	195.0

Source: Anon., 2019. Monthly weather report. AccuWeather

Appendix II. Physiochemical properties of soil, vermicompost and spent mushroom compost of horticulture farm of Sher-e-Bangla Agricultural University were analyzed by Soil Resources Development Institute (SRDI)

Property	Soil	Vermicompost	Spent Mushroom Compost
Organic Carbon (%)	0.47	3.97	24.5
Total Nitrogen (%)	0.03	1.5	1.54
C:N	15.7:1	12:1	15.9:l
Available Phosphorus (%)	0.02	1.45%	0.49
Exchangeable Potassium (%)	0.1	0.75	1.09
Available Sulphur (%)	0.0045	0.54	0.56
pH:	5.6	7.5	7.4

Source: *Anon.*, 2019

Appendix III. Growth device used in the experiment (1 × 0.1016 m^2 PVC pipe)

Appendix IV. A part of the experimental set up

Appendix V. Different growth media (Control media and SVC media)

Control Mixture

SVC Mixture

Appendix VI. Different growth media (SV media and SVS media)

SV Mixture

SVS Mixture

Appendix VII. Analysis of variance of plant height of two lettuce varieties at different Days After Sowing (DAS) as influenced by growth media

Source	DF	Mean Square			
		20	30	40	50
Replication	3	0.08	4.67	3.74	6.26
Variety (A)	1	1.02	87.12*	267.38	136.54
Growth media (B)	3	2.58	171.49*	226.78	307.04
Interaction (A×B)	3	2.02	27.02*	17.58	1.610
Error	21	0.41	1.342	5.86	1.585
CV		12.79	7.31	11	4.78

*⇒ Significant at 0.05 level of significance

Appendix VIII. Analysis of variance of leaf number per plant of two lettuce varieties at different Days After Sowing (DAS) as influenced by growth media

Source	DF	Mean Square			
		20	30	40	50
Replication	3	0.95	0.86	0.78	0.45
Variety (A)	1	0.03*	2.53*	1.53*	9.03*
Growth media (B)	3	5.03*	25.11*	11.11*	5.86*
Interaction (A×B)	3	0.53*	7.78*	5.45*	1.53*
Error	21	0.57	1.82	1.81	1.78
CV		13.02	10.01	7.37	6.50

*⇒ Significant at 0.05 level of significance

Appendix IX. Analysis of variance of leaf length of two lettuce varieties at different Days After Sowing (DAS) as influenced by growth media

Source	DF	Mean Square			
		20	30	40	50
Replication	3	0.42	0.78	0.18	0.45
Variety (A)	1	0.38*	1.53*	26.46*	20.96*
Growth medias (B)	3	9.26*	11.11*	144.40*	21.12
Interaction (A×B)	3	0.82*	5.45*	13.14*	6.96*
Error	21	0.64	1.81	1.459	0.96
CV		10.42	7.37	8.44	5.45

*⇒ Significant at 0.05 level of significance

Appendix X. Analysis of variance of leaf breadth of two lettuce varieties at different Days After Sowing (DAS) as influenced by growth media

Source	**DF**	**Mean Square**			
		20	30	40	50
Replication	3	0.09	0.23	0.26	1.43
Variety (A)	1	0.01*	0.15*	4.13*	8.93*
Organic Manure (B)	3	5.82*	36.24*	163.24*	35.67*
Interaction (A×B)	3	0.22*	0.77*	12.76*	6.10*
Error	21	0.68	0.8023	0.93	0.93
CV		18.14	12.84	8.56	6.81

*⇒ Significant at 0.05 level of significance

Appendix XI. Analysis of variance of leaf area of two lettuce varieties at different Days After Sowing (DAS) as influenced by growth media

Source	DF	Mean Square			
		20	30	40	50
Replication	3	30.98	301.1	91.3	989.2
Variety (A)	1	14.45*	381.8*	9896.5	16377.3
Growth media (B)	3	853.69	18923.4	76609.5	26209.3
Interaction (A×B)	3	5.22*	729.4*	6935.3	5602.9*
Error	21	63.60	279.4	381.4	496.9
CV		22.50	18.21	11.14	8.66

*⇒ Significant at 0.05 level of significance

Appendix XII. Analysis of variance of circumference of two lettuce varieties at different Days After Sowing (DAS) as influenced by growth media

Source	DF	Mean Square			
		20	30	40	50
Replication	3	5.91	7.13	3.32	0.89
Variety (A)	1	47.65*	36.61*	34.90*	45.47*
Growth media (B)	3	180.99	589.32	487.04	335.28
Interaction (A×B)	3	16.11*	9.69*	20.81*	15.97*
Error	21	9.18	9.094	6.38	6.533
CV		8.88	7.60	5.43	5.10

*⇒ Significant at 0.05 level of significance

Appendix XIII. Analysis of variance of fresh weight and dry weight per plant of two lettuce varieties as influenced by growth media

Source	DF	Mean Square	
		Fresh Weight per Plant	Dry Weight per Plant
Replication	3	5.84	0.99
Variety (A)	1	258.78	16.68*
Growth media (B)	3	623.01	42.37
Interaction (A×B)	3	80.01	4.95*
Error	21	4.81	0.87
CV		1.78	6.76

*⇒ Significant at 0.05 level of significance

Appendix XIV. Analysis of variance of yield per growth device of two lettuce varieties as influenced by growth media

Source	DF	Mean Square
Replication	3	0.0002
Variety (A)	1	0.0065
Growth media (B)	3	0.0156
Interaction (A×B)	3	0.0020
Error	21	0.0001
CV		1.78

*⇒ Significant at 0.05 level of significance

Appendix XV. Questionnaire for quality attributes assessment of lettuce

Please give a (√) mark desired on level of acceptance of treatments.

Treatment	Crispness			Sweetness			Sourness			Bitterness			Appearance		
	HA	SA	NA	HA	SA	NA	HA	SA	NA	HA	SA	NA	HA	SA	NA
V_1P_0															
V_1P_1															
V_1P_2															
V_1P_3															
V_2P_0															
V_2P_1															
V_2P_2															
V_2P_3															

Here, HA ⇒ Highly Acceptable (7), SA ⇒ Slightly acceptable (5) and NA⇒ Not Acceptable

Name of the Judge:

Address:

Age: Profession:

Signature: Date:

Appendix XVI. Cost of production of lettuce varieties in vertical gardening as influenced by growth media

Input Cost

Treatment combination	Installation cost	Labour cost	Seed cost	Manures cost	Irrigation Water cost	Input cost
V_1P_0	8960	2100	50	360	96	10966
V_1P_1	8960	2100	50	728	96	11334
V_1P_2	8960	2100	50	1584	96	12190
V_1P_3	8960	2100	50	2258	96	12864
V_2P_0	8960	2100	50	360	96	10966
V_2P_1	8960	2100	50	728	96	11334
V_2P_2	8960	2100	50	1584	96	12190
V_2P_3	8960	2100	50	2258	96	12864

A. Overhead Cost

Treatment combination	Cost of lease of land (13% 0n price of land yearly)	Interest on running capital for 4 month (13% per year)	Miscellaneous (5% of input cost)	Total overhead cost	Total cost of Production
V_1P_0	0	475	548	1023	11989
V_1P_1	0	491	567	1058	12392
V_1P_2	0	528	610	1138	13328
V_1P_3	0	557	643	1201	14065
V_2P_0	0	475	548	1023	11989
V_2P_1	0	491	567	1058	12392
V_2P_2	0	528	610	1138	13328
V_2P_3	0	557	643	1201	14065