RESPONSE OF STRAWBERRY GERMPLASM TO ORGANIC FERTILIZERS

MEHRAJ HASAN

DEPARTMENT OF HORTICULTURE
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

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BY

MEHRAJ HASAN

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APPROVED BY:

Dr. Abul Faiz Md. Jamal Uddin
Associate Professor
Department of Horticulture
SAU, Dhaka
Supervisor

Dr. Md. Ismail Hossain
Professor
Department of Horticulture
SAU, Dhaka
Co-Supervisor

Prof. Md. Hasanuzzaman Akand
Chairman
Examination Committee

Sher-e-Bangla Agricultural University
Sher-e -Bangla Nagar, Dhaka-1207

Memo No.: Dated:

CERTIFICATE

This is to certify that thesis entitled **"RESPONSE OF STRAWBERRY GERMPLASM TO ORGANIC FERTILIZERS"** 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 **MEHRAJ HASAN,** Registration No. **06-02098** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:
Dhaka, Bangladesh

Dr. Abul Faiz Md. Jamal Uddin
Associate Professor
Department of Horticulture
Sher-e-Bangla Agricultural University
Dhaka-1207

The greatest gift from Allah I ever had

“I had come to the world through my parents”

Dedicated to

—- Dr. Abul Faiz Md. Jamal Uddin

(My cared for and cherished supervisor)

the person who taught me that
“no one can make you feel inferior without your consent”
and “you know that what you are”

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ABSTRACT

An experiment was accomplished at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from June 2011 to March 2012. Strawberry germplasm viz. V_1 (Germplasm-01), V_2 (Germplasm-02), V_3 (Germplasm-03) and organic matters viz. OMc (Control), OMcd (Cowdung), OMvc (Vermicompost), OMpl (Poultry Litre) were exploited on the experiment; which was outlined in Complete Randomized Design with five replication. Among germplasm, maximum fruits number (16.5/plant), fruit weight (14.1 g), total fruit weight (244.9 g/plant), brix percentage (8.3%) were found from V_1 whereas minimum in V_2 and among organic matters, maximum fruits number (19.2/plant), fruit weight (14.4 g), total fruit weight (282.8 g/plant), brix percentage (10.2%) were found from OMvc whereas minimum in OMc. Maximum fruit weight (400.1 g/plant) were found in V_1OMvc and minimum in V_2OMc. Leaf area showed positive correlation with all of yield and quality parameters significantly. In view of overall performances, this study suggests that vermicompost as a potential source of plant nutrients for suitable strawberry production. So, Germplasm-01 with vermicompost has admirable possibility for organic strawberry production.

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ABBREVIATIONS AND ACRONYMS

SAU	---	Sher-e-Bangla Agricultural University
SAURES	---	Sher-e-Bangla Agricultural University Research System
TSS	---	Total Soluble Solid
SG	---	SAU Germplasm
CD	---	Cowdung
PM	---	Poultry Manure
VC	---	Vermicompost
CF	---	Chemical Fertilizer
FYM	---	Farmyard Manure
FCD	---	Farm Cowdung
FVW	---	Farm Vegetable Waste
FCVW	---	Farm Cow Dung and Vegetable Waste
NAA	---	Naphthalene Acetic acid
IAA	---	Indole Acetic Acid
GA_3	---	Gibbrellic Acid
pH	---	Negative logarithm of hydrogen ions concentration
ppm	---	parts per million
DM	---	Dry matter
CV.	---	Cultivars
EC	---	Electrical Conductivity
AEZ	---	Agro-Ecological Zone
ANOVA	---	Analysis of Variance
df	---	Degrees of freedom
CV%	---	Percentage of Coefficient of Variation
UNDP	---	United Nations Development Programme
FAO	---	Food and Agriculture Organization
r	---	Linear correlation
LER	---	Leaf Extension Rate
LED	---	Duration of Leaf Extension rate
EC	---	Emulsifiable Concentrates
LSD	---	Least Significant Difference
SPSS	---	Statistical Program for Social Science

CHAPTER I

INTRODUCTION

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Strawberry (*Fragaria* × *annanassa*, hybrid species) belongs to Rosaceae family, is cultivated worldwide for its fruit. Strawberry fruit (not a botanical berry; an aggregate accessory fruit) is widely appreciated for its aroma and vitamin contents (Hancock, 1999), bright red color, juicy texture, sweetness also higher percentage of phenolics and flavonoids (Hakkinen and Torronen, 2000). In modern times, it is amazingly popular in the world right through 21st century while improved taste and appearance besides as healthy fruit. It is consumed in large quantities either in fresh or prepared foods. Strawberry is new fruit crop and its commercial production is possible in wide climatic range (Barney, 1999) including sub-tropical areas like Bangladesh. Country's weather is favorable for the production of high quality strawberries though it is normally produced in countries having cold weather particularly in West. Strawberry cultivation technique is fairly new in Bangladesh whereas cultivation area is increasing bit by bit. Strawberry can be grown during month of October to April in Bangladesh. A sustainable variety is needed for the continuous production from year to year. Farmer shows tendency of more chemical fertilization for strawberry production to improve yield. Uses of organic matters have long been recognized as beneficial for plant growth and yield and maintenance of soil fertility. Use of organic amendments in farming have proven to be effective means of improving soil structure, enhancing soil fertility and increasing crop yields. It is excellent source of nutrients and it could maintain high microbial population's activities.

Screening of strawberry variety is needed for suitable variety for continuous production and some varietal screening has also done (Hossan *et al.*, 2013; Nuruzzaman *et al.*, 2011) in Bangladesh. Addition of organic matters increases yield with corresponding improvements of soil quality (Johnston *et al.*, 1995).

Fruit quality is influenced by agro-technical treatments i.e., mulching, irrigation, fertilization, crop rotation, intercropping, proper field preparation, planting time, health status and type of seedlings (LaMondia *et al.*, 2002). Sweetness of strawberry is a major problem. Total Soluble Solid (TSS) of fruit is actively affected by organic matters and has positive effect also may increase sweetness and post harvest life (by thickening fruit peel) of fruit.Organically grown strawberry produce higher quality fruit with sweetest in taste, longer shelf life and better flavor (Reganold *et al.,* 2010). Fruits harvested from plant receiving organic matter were firmer, have superior TSS and ascorbic acid, lower acidity, attractive color and exacerbate marketable fruit yield up to 58.6% with better quality (Singh *et al.*, 2008). Cowdung, vermicompost and poultry litre are excellent organic fertilizers also commonly used to crop production. Vermicompost has high levels of available NPK and micro nutrients, microbial and enzyme activities and growth regulators (Parthasarathi and Ranganathan, 1999; Chaoui *et al.*, 2003). Its continuous use with proper management can increase soil organic carbon, soil water retention, soil water transmission, improvement in other physical properties of soil like bulk density, penetration resistance, aggregation (Zebarth *et al.*, 1999) as well as beneficial effect on growth of a variety of plants (Atiyeh *et al.*, 2002). Vermicompost's products represent a crucial ecofriendly technology capable of recycling organic wastes to be utilized as fertilizers (Daniel and Jader, 2012). Poultry litre improves soil structures, nutrient retention, aeration, soil moisture holding capacity and water infiltration (Deksissa *et al.*, 2008). It contains high NPK and other essential nutrients that more readily supplies P to plants than other organic manure sources (Garg and Bahla, 2008). Hence keeping above points in view, present investigation has been undertaken with following objectives.

- Evaluation of the performance of strawberry germplasm to different organic matters regarding growth, yield and quality

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Strawberry is one of the most popular fruit in the whole world also in Bangladesh. However, it is new fruit crop in Bangladesh but its demand and production area is increasing day by day. Production of strawberry by using organic matters is a strategy to develop a technique of growing organic strawberry. Some of important and informative works have so far been done in home and abroad related to this experimentation have been presented (Year wise) in this chapter.

2.1 Germplasms related

Fruit size is one of most important characteristics of highly productive strawberry cultivars. Large fruits are closely correlated with total yield and depend mainly on the mean fruit weight of all fruits. The size of the fruit is controlled by the dimension of the receptacle, number of achenes position of fruits on the inflorescence. The large-fruited clones have bigger leaves, a larger photosynthetic area, and thicker petioles and flower stalks (Hortynski *et al.*, 1991).

Strawberry is an aggregate fruit and not a true fruit, in that the edible portion is the enlarged receptacle, which has many one-seeded fruit or achenes (a combination of seed and ovary tissue) located on the outer surface. Strawberry fruit is non-climacteric fruit and ripens rapidly. Strawberry fruit develop into fully ripen stage within 30-40 days after anthesis depending on cultivar and environment (Perkins-Veazie, 1995). Perkins-Veazie (1995) also reported that TSS (Total Soluble Solid) content in strawberry varies from 4-11% depending on cultivar and environment.

Strawberry runner plant production is limited to ecological conditions. Therefore, growers have difficulties in obtaining sufficient runner plants of high quality. Moreover, growers often propagate runner plants from their own stocks.

This application has mostly been the main reason of lower fruit yield and quality in strawberries (Turkben *et al*., 1997).

Marketable yield, fruit number and fruit weight was associated with carbohydrate level in roots and its distribution. The increased fruit size, weight and earlier fruit production on plants appears to be related to increased carbohydrate concentration in crown and roots of strawberry plants. An adequate level of carbohydrates in roots seems to be fundamental for stand establishment, early fruiting and high productivity in strawberry. Adequate root starch will help plants to simultaneously generate new feeder roots (Mann, 1930) and to provide carbohydrates for flower bud initiation and early fruit development (Nishizawa and Shishido, 1998). Early fruit growth depends greatly on root starch reserves for up to one month after planting (Nishizawa *et. al*., 1997; Nishizawa and Shishido, 1998). The study concluded that greater levels of soluble carbohydrates and starch in the roots could be responsible for increased early season fruit.

Strawberry can be cultivated in almost all regions e.g. from arctic to tropic regions (Hancock, 1999) and has a wide range of climates from tropics to the near of Arctic Circle (Barney, 1999). Due to the flavor and vitamin contents of strawberry many people in the world use it as a regular diet (Hancock, 1999). It also contains a higher percentage of other components including phenolics and flavonoids (Hakkinen and Torronen, 2000).

LaMondia *et al.*, (2002) have made a report that strawberry plant significantly influenced by agro-technical treatments on their growth and fruit quality. 'Saia' oats (*Avena strigosa*) and 'Triple S' sorgho-sudangrass (*Sorghum bicolor x S. sudanense*) were investigated on the study as rotation crops and as interplanted companion crops the following year for their individual and combined effects on strawberry root pathogens, weed species composition and density, weevil and white grub densities in soil, rhizosphere microbial populations, nutrient content of crowns, and strawberry yield. Weed density was inversely related to rotation crop density. Intercropping was similar to herbicide application, but only when the intercrop was present. Rotation crop did not affect pathogen recovery from roots of 2-year old strawberry crowns. Fruit yield was greatest in plots previously planted to Garry or Saia oats and least after sorgho-sudangrass, possibly due to phytotoxic properties of residues. Production of rotation crops such as sorgho-sudangrass or Saia oats may suppress pathogen densities, weeds, and white grub densities prior to planting strawberries but may also adversely affect strawberry growth and yield.

Strawberry flower produces on a modified stem that is terminated by the primary flowers. Further stems can arise from main stem to produce secondary flowers from which tertiary flowers arise (Morgan, 2006). According to Morgan (2006), the final size and shape of the berry depends on the number of achenes formed, which is determined by pollination and fertilization at the time of blooming. Cell division ceases relatively soon after flower opening, usually within 6 to 9 days and cell enlargement is then responsible for fruit growth. Enlargement normally takes 28 to 30 days but depending on it can vary with many weeks.

Growth, fruit yield and quality attributes of strawberry (*Fragaria X annanasa*), germplasms was screened out from four germplasms viz. SAU Line-1 (Germplasm-03), SAU Line-2 (Germplasm-02), SAU Line-3 (Germplasm-01) and RABI-3 by Nuruzzaman *et al.* (2011). From the study it was found that among germplasms, SAU Line-3 (Germplasm-01) showed to be evidenced for best in terms of growth, fruit yield and quality attributes i.e., maximum number of fruit (42), maximum fruit weight per plant (500.0 g), biggest berry (19.0 g), highest brix percentage (8.2 %) were produced from SAU Line-3 (Germplasm-01), utmost shelf life was also (3.9 days in normal condition) with this germplasm.

Hossan *et al.*, (2013) conducted an experiment at the Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka during the period from October, 2010 to April, 2011. Evaluation of growth and yield performance of three strawberry germplasms (viz. SG-1, RABI-3 and SG-3) was performed and found that SG-1 provided the maximum leaf area (69.8 cm^2), maximum number of fruits (26.0/plant), average fruit weight (14.6 g), maximum yield (379.8 g/plant) and brix (5%), whereas the minimum in RABI-3. Stolon number significantly varied among the strawberry germplasms. It was also recorded that SG-1 and SG-3 produced less number of stolon than the RABI-3. SG-1 had required minimum days for flowering and fruit maturity.

2.2 Organic matters related

A large beneficial microbial population and biologically active metabolites, particularly gibberellins, cytokinins, auxins and B vitamins were observed with application of vermicompost alone or in combination with organic or inorganic fertilizers, so as to get better yield and quality of diverse crops (Tomati *et al.*, 1983; Bano and Kale, 1987 and Bhawalker, 1991).

The reason for increased mean fruit weight and fruit yield by the application of NPK with FYM and vermicompost was attributed to solubilization effect of plant nutrients by the addition of FYM and vermicompost leading to increased uptake of NPK as reported by Subbaiah *et al.* (1985) and similar results were also obtained by Nair and Peter (1990) in chilli.

Bano and Kale (1987) reported that application of vermicompost along with chemical fertilizers provided higher yield of brinjal. Among the various organic manures, the compost produced by earthworms (vermicompost), is a rich source of macro and micronutrients.

Albanell *et al.* (1988) debriefed that vermicompost tended to have pH values near neutrality that may be due to the production of CO_2 and organic acids produced during microbial metabolism. It was found on the study was that moisture content was reduced progressively during vermicomposting giving final moisture contents between 45% and 60%, the ideal moisture contents for land-applied composts (Edwards, 1983).

In crop studies, various crops were grown on organic amended soil by Bryan and Lance (1991). It was found on that study; tomatoes grown in compost-amended soil yielded more.

Curry and Byrne (1992) found that earthworm derived nitrogen could supply 30% of the total crop requirement as it is a potential source of readily available nutrients for plant growth. Vermicompost is the earthworm derived organic fertilizers that not only supplies a good amount of different nutrient elements but also contains beneficial microbes like nitrogen fixing bacteria, mycorrhizae and growth promoting substances (Barik *et al.*, 2006) for betterment of crops.

Poultry manure contains higher N and P compared to other bulky organic manures. Average nutrient content in poultry manure is 3.03% N, 2.63% P_2O_5 and 1.4% K_2O (Malone *et al.*, 1992).

In the vermicompost production, the complex organic residues are biodegraded by symbiotic association between earthworms and microbes. Vermicomposting helps to increase the density of microbes and also provides the vital macro nutrients viz., N, P, K, Ca, Mg and micronutrients such as Fe, Mo, Zn, Cu etc., Apart from this, it also contains plant growth promoting substances like NAA, cytokinins, gibberellins etc. The chemical analysis of vermicompost disclosed the availability of N, P and K content at 0.8, 1.1 and 0.5% respectively (Giraddi, 1993).

Johnston *et al.* (1995) debriefed that crop yields have increased with corresponding improvements in soil quality from addition of organic matter. Significant increases in productivity using animal manures and hay residues. Their important roles in the soil and their potentially positive effect on crop yields have made organic amendments a valuable component of farm fertilization and management programs in alternative agriculture.

Gopalreddy (1997) reported that poultry manure contains 2.00%, 1.97%, 4.29% nitrogen, phosphorus, potassium respectively and 113.2, 71.0, 1400.6, 310.5 mg/kg of total Zn, Cu, Fe and Mn, respectively. Study indicated that incorporation of poultry manure resulted in higher availability of nitrogen. The uric acid readily changes into ammonical form of nitrogen. A large portion of the N in poultry manure is in organic fractions but 20% to 40% of the total N is inorganic (Willrich *et al.*, 1974; Sims, 1987).

Nair *et al.* (1997) compared the microorganisms associated with vermicomposts with those in traditional composts. The vermicomposts had much larger populations of bacteria (5.7 x 107), fungi (22.7 x 104) and actinomycetes (17.7 x 106) compared with those in conventional composts. The outstanding physico-chemical and biological properties of vermicomposts makes them excellent materials as additives to greenhouse container media, organic fertilizers or soil amendments for various field horticultural crops.

Zebarth *et al.* (1999) recounted vermicompost that continuous and adequate use with proper management can increase soil organic carbon, soil water retention, transmission, improvement in other physical properties of soil like bulk density, penetration resistance and aggregation.

Vermicomposting is a bio-oxidation and stabilization process of organic material that involves the joint action of earthworms and microorganisms. The earthworms are the agents of turning, fragmentation and aeration. It also increase N_2 fixation by both nodular and free living N_2 fixing bacteria and thus enhance plant growth. Vermicompost has been proved as cheapest source of nitrogen and other essential elements for better nodulation and yield particularly in legumes. Such plants can meet their N needs through both biological nitrogen fixation (symbiosis) and native nitrogen in the soil (Parthasarthi and Ranganathan, 2002).

In an experiment conducted by Renuka and Ravishankar (2001), application of biogass slurry + FYM, vermicompost alone have provided maximum fruit size, more number of fruits per plant, while inorganic fertilizers (NPK) recorded the minimum fruit size. It is contingent that tomato crop would respond well to the application of organic manures either in combination with FYM or alone. Further, organic manures application helps to maintain good soil health. Vermicompost have a beneficial effect on the growth of a variety of plants (Atiyeh *et al.*, 2002).

Vermicompost is non toxic, utilize low energy input for composting and recycled bioorganic product. Due to absence of toxic enzymes it is also ecofriendly and has beneficial effect on the biochemical activities of the soil (Ali and Jahan, 2001).

Chaoui *et al.* (2003) made a report that vermicompost has been shown to have high levels of total and available nitrogen, phosphorous, potassium (NPK) and micro nutrients, microbial and enzyme activities and growth regulators (Parthasarathi and Ranganathan, 1999).

Vermicompost has been emerging as an important source in supplementing chemical fertilizers in agriculture in view of sustainable development after Rio Conference.

It is a biofertilizer enriched with all beneficial soil microbes and also contains all the essential plant nutrients like N, P and K. Vermicompost that is prepared through conventional method has standard values of total nitrogen: 1.94%, phosphorus: 0.47% and potassium: 0.70% it is also enriched with various micronutrients such as Mg (0.46%), Fe (7563 ppm), Zn (278 ppm), Mn (475 ppm), Cu (27 ppm) (Gupta, 2003).

Compost significantly enhanced strawberry (*Fragaria* × *ananassa* Duch.) plant growth and fruit quality when used as a soil supplement. Compost and fertilizer also significantly enhanced leaf chlorophyll content. Nitrate reductase activity significantly increased in leaves and roots with the greatest increases when using 50% soil plus 50% compost. Strawberry plants grown with compost had significantly higher levels of nitrogen (N) and potassium (K), but lower levels of manganese (Mn), iron (Fe), molybdenum (Mo), and nickel (Ni) in fruit of both “Allstar” and “Honeoye”. Adding compost to the soil mix did not change zinc (Zn) and cadmium (Cd) levels. Use of compost also significantly increased levels of organic acids (malic and citric acid), sugars (fructose, glucose, and total sugars), soluble solids content, and titratable acidity content in both cultivars. The results indicate that the use of compost can reduce the amount of fertilizer required for optimum strawberry plant growth (Shiow and Shin-Shan, 2002).

Commercially processed vermicomposts were applied to 4.5 m^2 field plots, under high plastic hoop tunnels, at rates of 5 or 10 tha^{-1} to evaluate their effects on the growth and yields of strawberries (*Fragaria*×*ananasa*) var. `Chandler'. The vermicomposts were incorporated into the top 10 cm of soil and supplemented, based on chemical analyses, with amounts of inorganic NPK fertilizers calculated to equalize the initial fertilizer rates of 85–155–125 $kgha^{-1}$ NPK applied to the inorganic fertilizer plots.

Vermicompost applications increased strawberry growth and yields significantly; including increases of up to 37% in leaf areas, 37% in plant shoot biomass, 40% in numbers of flowers, 36% in numbers of plant runners and 35% in marketable fruit weights. These responses seemed not to be dose-dependent, since strawberries at one site grew fastest and yielded most in response to the 10 tha^{-1} vermicompost application rate, whereas they responded positively and similarly to both the 5 and 10 tha^{-1} rates of applications at the other site (Arancon *et al.*, 2004a).

Vermicomposts, produced commercially from cattle manure, market food waste and recycled paper waste, were applied to tomatoes *(Lycopersicon esculentum)*, bell peppers *(Capsicum anuum grossum)*, and strawberries (*Fragaria* spp.). The marketable tomato yields in all vermicompost-treated plots were consistently greater than yields from the inorganic fertilizer-treated plots. Leaf areas, numbers of strawberry suckers, numbers of flowers, shoot weights, and total marketable strawberry yields increased significantly in plots treated with vermicompost compared to those that received inorganic fertilizers only besides significant increases in shoot weights, leaf areas and total and marketable fruit yields of pepper plants from plots treated with vermicomposts. The improvements in plant growth and increases in fruit yields could be due partially to large increases in soil microbial biomass after vermicompost applications, leading to production of hormones or humates in the vermicomposts acting as plant-growth regulators independent of nutrient supply (Arancon *et al.*, 2004b).

Vermicompost have fine particulate structure, low C : N ratio, with organic matter oxidized, stabilized and converted into humic materials. It contains nutrients transformed into plant available forms and are extremely microbially-active. Addition of low rate of substitution of vermicomposts on plant growth media to field crops have consistently increases plant germination, growth, flowering, fruiting, independent of nutrient availability.

This can be at least partially attributed to the production, by greatly increased microbial populations, plant growth regulators including plant hormones (Indole acetic acid, Gibberellins, Cytokinins and also humic acid) which stimulate effect of hormones (Edwards *et al.*, 2004). The study confirmed that vermicompost suppress incidence of plant pathogen such as *Pythium*, *Rhizoctonia* and *Verticillium* significantly by general or specific suppression mechanisms. All of these various inputs of vermicomposts into plant growth produce significant and economic increases yields of ornamental, vegetables and fruit crops.

Vermicompost provides all nutrients in readily available form and also enhances uptake of nutrients by plants. Earthworms consume various organic wastes and reduce the volume by 40–60%. Each earthworm weighs about 0.5 g to 0.6 g, eats waste equivalent to its body weight and produces cast equivalent to about 50% of the waste it consumes in a day. These worm castings have been analyzed for chemical and biological properties. The moisture content of castings ranges between 32% and 66% and the pH is around 7.0. The worm castings contain higher percentage of both macro and micronutrients than the garden compost. Soil available N increased significantly with increasing levels of vermicompost and highest N uptake was obtained at 50% of the recommended fertilizer rate plus 10 tha-1 vermicompost (Nagavallemma *et al.*, 2004). Vermicompost reduces C : N ratio and retains more nitrogen. The prolonged immobilization of soil nitrogen by the vermicomposted organic manures was attributed to the recalcitrant nature of its C and N composition. It increases macro pore space ranging from 50 to 500 μm, resulting in improved air-water relationship in the soil which favorably affects plant growth. The application of vermicompost favorably affects soil pH, microbial population and soil enzyme activities.

For the evaluation of the effects of humic acids extracted from vermicompost and compare them with the action of commercial humic acid in combination with a commercial plant growth hormone, Indole acetic acid (IAA) which is a commonly found in vermicomposts. In the first experiments, humic acids were extracted from cattle, food and paper waste vermicomposts. These were applied to a plant growth medium to marigold, pepper, and strawberry plants in the greenhouse. Substitution of humates ranging from 250 to 1000 $mgkg^{-1}$ MM360 increased the growth of marigold and pepper roots, and increased the growth of roots and numbers of fruits of strawberries significantly. The numbers of pepper flowers and fruits increased significantly in response to treatment with humic acid, IAA and a combination of humic acid and IAA. Peppers treated with humic acids extracted from food waste vermicomposts produced significantly more fruits and flowers than those treated with commercially-produced humic acids (Arancon *et al.*, 2006b).

Application of recommended quantities of vermicompost to different field crops has been reported to reduce the requirement of chemical fertilizers without affecting the crop yield. Application of 100% nitrogen as vermicompost registered the higher plant height and number of branches per plant of tomato and it was significantly superior over supplementation of 100% N through urea and FYM (Kannan *et al.*, 2006). Similar trend was found in plant height of basmati rice at maturity with the application of vermicompost and it was on par with treatment receiving azolla at the rate 1.5 ton/ha. A progressive increase in plant height and leaf area index of soybean was observed with the conjunctive use of 75% N through vermicompost and remaining 25% N through chemical fertilizer and was found at par with 100% N through vermicompost alone. Additive benefit realized from vermicompost application (Govindan and Thirumurugan, 2005) might be ascribed to its higher nutrient contents and their availability to crop.

Federico *et al*. (2007) were investigated the effect of earthworm-processed vermicompost on the growth, productivity and chemical characteristics of tomatoes (*Lycopersicon esculentum*). Vermicompost and soil proportions of 0:1, 1:1, 1:2, 1:3, 1:4 and 1:5 (v/v) were applied on the experiment and the result of the experiment indicated that addition of vermicompost decreased soil pH, titratable acidity and increased soluble and insoluble solids in tomato fruits compared to those harvested from plants cultivated than cultivated in unamended soil. Vermicompost as soil supplement increased tomato yield and soluble, insoluble solids and carbohydrate concentrations.

Vermicompost increases the quality, fertility and mineral content of the soil structure. It enhances soil aeration, texture and jilt thereby reducing soil compaction. It also build up water retention capacity of soil because of its high organic matter content and promotes better root growth and nutrient absorption (Nourbakhsh, 2007).

Organic practices can enhance mycorrhizal populations and functioning (Gosling *et al.*, 2006). Vermicompost applications in strawberries can increase beneficial microbial populations, which enhance production of plant growth hormones (auxin, gibberellins and cytokinins) and humic acids. Several experiments in strawberry have indicated that these hormones and acids may improve plant growth (leaf area, shoot biomass, number of flowers and runners) (Arancon *et al.*, 2004) and yield (Arancon *et al.*, 2004; Singh *et al.*, 2008). Vermicompost applications are known to increase microbial biomass N (Arancon *et al.*, 2006a) and protect fruit marketability through reduction in physiological disorders and fruit disease (*Botrytis* rot) in strawberries (Singh *et al.*, 2008).

The effects of vermicomposts on growth and flowering of petunias have been evaluated by Arancon *et al.* (2008). Vermicomposts have been shown to promote the germination, growth, flowering and yields of plants.

Factors such as improvement of the physical structure of the potting medium, increases in populations of beneficial microorganisms and most probably, the availability of plant growth-influencing-substances such as hormones and humates produced by microorganisms during vermicomposting, probably contributed to the increased petunia germination, growth and flowering.

Grag and Bahla (2008) narrated poultry manure as an excellent organic fertilizer, as it contains high nitrogen, phosphorus, potassium and other essential nutrients. The study also indicated that poultry manure more rapidly supplies P to plants those other organic manures.

Deksissa *et al.* (2008) stated that manure is an excellent organic fertilizer, as it contains high nitrogen, phosphorus, potassium and other essential nutrients. In contrast to chemical fertilizers, adding organic matters to soil improves soil structures, nutrient retention, aeration, soil moisture holding capacity and water infiltration.

The effects of different amounts of vermicompost to soil on growth, yield and chemical characteristics of spinach (*Spinacia oleracea* L.) cultivar "Virofly" were investigated in an unheated greenhouse. The results indicated that an addition of vermicompost to soil can increase number of leaves significantly. Spinach leaves and roots were highest when fertilized with vermicompost and lowest when the vermicompost was not supplied. The plants with 10% vermicompost added to soil gave significantly highest leaf area, potassium, phosphorus, total nitrogen, calcium and magnesium and nitrate-N in petioles and leaves, total soluble solids and microelements such as iron, copper, manganese and zinc (Peyvast *et al.*, 2008).

Manatad and Jaquias (2008) evaluated growth and yield performance of vegetables as influenced by the application of different rates of vermicompost. Data on plant height, number of fruits/plant, length of fruits, diameter of fruits, fruits weight/plant and yield were gathered and analyzed. Findings of their study exposed the following: Chemical analysis of vermicompost used in the experiment has 26.32% organic matter (DM); 2.09% N; 2.57% P; 0.44% K; 1.04% Ca; 0.45% Mg; 73.50 ppm Cu; 118.75 ppm Zn; 1055 ppm Mn; and 3257.5 ppm Fe. It has a pH of 6.9. In watermelon, fruit length, diameter, weight of fruits/plant and yield were significantly influenced by vermicompost application except for the length of vines and number of fruits. In eggplant, all parameters were markedly influenced by the application of the different rates of vermicompost except for the fruit length and diameter. In tomatoes, different rates of vermicompost generated significant variation on the fruit length and diameter, weight of fruits and fruit yield. In sweet pepper, all parameters significantly increased, regardless of the amount of vermicompost applied. The application of vermicompost significantly lowered the severity of bacterial wilt incidence in sweet pepper while in eggplant and tomatoes infestation was slightly reduced by statistically comparable in all treatments.

Chamani *et al.* (2008) carried out an experiment to find out the effects of vermicompost on the growth and flowering of *Petunia hybrida* ‘Dream Neon Rose’. From the study it was disclosed that vermicompost had significant ($P<0.05$) positive effects on flower numbers, leaf growth and shoot fresh and dry weights compared to both control and peat amended media. Plant performance was best in the 20% vermicompost medium. Further increasing the vermicompost content in base media decreased flower numbers, leaf growth rates and shoot fresh and dry weights. Plants in media with 20, 40 and 60% vermicompost incorporated produced flowers significantly ($P<0.05$) sooner than other treatments. Plant performance was poorest in 60% sphagnum peat medium.

After analyzing plant tissue it was found that total extractable N, P and K were highest in petunia plants grown in 60% vermicompost medium and were lowest in plants grown in 60% peat medium. Use of vermicompost tended to increase tissue Ca and Mg concentrations compared to control but generally not significant at $P<0.05$. Fe and Zn were also highest in plants grown in 60% vermicompost medium. Cu and Mn concentrations in petunia plants grown in vermicompost media were significantly ($P<0.05$) lower than for those grown in control medium. Besides, beneficial effects of vermicompost were associated with elevated tissue concentrations of macronutrients.

Vermicompost is a very important biofertilizer produced through the artificial cultivation of worms i.e., vermiculture. Vermicompost is enriched with all beneficial soil bacteria and also contain many of the essential plant nutrients like N, P, K and micronutrients. It increases soil aeration, texture and jilt. Plant grown in vermicompost pretreated soil exhibited maximum increase in all morphological parameters such as root length, shoot length, number of root branches, number of stem branches, number of leaves, number of flowers, number of pods and number of root nodules in four months sampling in comparison to untreated, FYM treated and DAP treated soils in *Pisum sp.* and *Cicer sp.* (Sinha *et al.*, 2010). Furthermore, in vermicompost pretreated soil, number of N_2 fixing bacterial colony was maximum and showed highest diversity indices (1.6 and 0.99 and 2.0 and 0.99 for *Cicer sp.* and *Pisum sp.* respectively) than FYM, DAP and untreated control. Vermicompost not only stimulate plant growth but also it increases the N_2 fixing bacterial population in soil and also its diversity.

Various growth, yield and quality parameters like mean stem diameter, plant height, yield/plant, marketable yield/plant, leaf number, total plant biomass, ascorbic acid, titrable acidity, soluble solids, insoluble solids and pH were increased significantly when treated with vermicompost (Joshi and Vig, 2010).

Organic farms had strawberries with longer shelf life, greater dry matter and higher antioxidant activity and concentrations of ascorbic acid and phenolic compounds but lower concentrations of phosphorus and potassium. In one variety, sensory panels judged organic strawberries to be sweeter and have better flavor, overall acceptance and appearance than their conventional counterparts. It was reported that organically farmed soils to have more total carbon and nitrogen, greater microbial biomass and activity, and higher concentrations of micronutrients. The organic strawberry farms produced higher quality fruit and that their higher quality soils may have greater microbial functional capability and resilience to stress (Reganold *et al.*, 2010).

Theunissen *et al.* (2010) stated that vermicompost contains plant nutrients including N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and B; chlorophyll content of the leaves and improves the nutrient content of the different plant components (roots, shoots and fruits). The high percentage of humic acids in vermicompost contributes to plant health, as it promotes the synthesis of phenolic compounds such as anthocyanins and flavonoids which may improve the plant quality and act as a deterrent to pest and diseases.

Three leachates collected from vermicomposting of cow dung (FCD), vegetable waste (FVW) and mixture of cow dung and vegetable waste in 1:2 ratio (FCVW) were used at 2 mll^{-1} at monthly interval (total five sprays) in strawberry to determine growth, yield and quality of strawberry (CV. Chandler). The results pointed out that foliar application of vermicompost leachates improved leaf area (10.1–18.9%), dry matter of plant (13.9–27.2%) and fruit yield (9.8–13.9%) significantly over control (water spray only). Foliar application of FCVW reduced albinism (from 12.1 to 5.7%), fruit malformation (11.2–8.5%) and grey mould (5.1–2.6%) thus improving marketable fruit yield (26.5% higher) with firmer fruits of better quality.

The foliar application of FCD and FVW also improved these parameters and resulted in to higher marketable fruit yield (12.6 and 17.8% higher, respectively) compared to control. The study confirmed that leachates derived from composting processes have potential use as foliar fertilization for strawberry (Singha *et al.*, 2010).

Earth-worms restore & improve soil fertility and significantly boost crop productivity. Earthworms excreta (vermicast) is a nutritive 'organic fertilizer' rich in humus, NKP, micronutrients, beneficial soil microbes 'nitrogen-fixing & phosphate solubilizing bacteria' & 'actinomycetes' and growth hormones 'auxins', 'gibberellins' & 'cytokinins'. Both earthworms and its vermicast & body liquid (vermiwash) are scientifically proving as both 'growth promoters & protectors' for crop plants. There is also less incidences of 'pest & disease attack' and 'reduced demand of water' for irrigation in plants grown on vermicompost. Presence of live earthworms in soil also makes significant difference in flower and fruit formation in vegetable crops. Composts work as a 'slow-release fertilizer' whereas chemical fertilizers release their nutrients rather quickly in soil and soon get depleted. Significant amount of 'chemical nitrogen' is lost from soil due to oxidation in sunlight. With application of vermicompost the 'organic nitrogen' tends to be released much faster from the excreted 'humus' by worms and those mineralized by them and the net overall efficiency of nitrogen (N) is considerably greater than that of chemical fertilizers. Availability of phosphorus (P) is sometimes much greater. Study showed that earthworms and vermicompost can promote growth from 50-100% over conventional compost & 30-40% over chemical fertilizers besides producing 'nutritive and tasty food' at a much economical cost (at least 50-75% less) as compared to the costly chemical fertilizers (Rajiv *et al.,* 2010).

Singh *et al.* (2010) conducted an experiment to look at the effects of vermicompost and NPK fertilizer on morpho-physiological traits, yield and quality of tomato (*Solanum lycopersicum* L.) in mild-tropical agro-climate. Application of vermicompost together with NPK fertilizer increased plant height, leaf area, leaf weight, fruit weight, fruit yield, fruit density, post-harvest life and TSS of tomato. Application of vermicompost alone increased the shelf-life by 250% and TSS beyond 4.5%. The study reveled that application of vermicompost in the amount of 7.5 t/ha in combination with 50% dose of NPK fertilizer (60:30:30 kg/ha) was optimum for obtaining better quality and productivity of tomatoes. Results revealed that increase in plant growth, i.e. plant height, leaf area and leaf weight due to improvement in the physio-chemical properties of soil; increase in enzymatic activity, microbial population, plant growth hormones, diversity and activity; easy availability of macro and micronutrients by the application of vermicompost. Zinc is a part of several enzymes such as carboxypeptidase, alcohol dehydrogenase, carbonic anhydrase, etc. and mediates leaf formation and auxin synthesis which might have played an important role in plant height, leaf area and leaf weight. The finding clearly showed that vermicompost plays an indirect role in partitioning of photo-assimilates from source to sink. Application of vermicompost and NPK fertilizer simultaneously promotes the plant growth, and fruit yield and quality which might be due to increase in budget of essential nutrients; improved soil texture and structure and enhanced microbial population, activity and diversity by vermicompost.

Effects of vermicompost on growth and productivity of cymbidium (*Cymbidium* sp.) plants were evaluated. Cymbidium was grown in a container medium including 50% pumice, 30% charcoal, 10% vermiculite and 10% peat moss, which was basic plant growth medium substituted with 10%, 20%, 30% and 40% (by volume) vermicompost besides control consisted of container medium alone without vermicompost.

Greatest vegetative growth resulted from substitution of container medium with 30% and 40% vermicompost and lowest growth was in potting mixtures containing 0% vermicompost. Most flower buds and inflorescences occurred in potting mixture containing 30% and 40% vermicompost also causes most and greatest number of flower, greatest length of inflorescences was observed in 30% vermicompost. Some of cymbidium growth and productivity enhancement, resulting from substitution of container medium with vermicompost, may be explained by nutritional factors; however, other factors, such as plant-growth-regulators and humates might have also been involved since all plants were supplied regularly with all required nutrients (Hatamzadeh and Masouleh, 2011).

Amir and Ishaq (2011) has found that the importance of composts as a source of humus and nutrients to increase the fertility of soil and growth of plant. Different composts (Vermicompost and Pitcompost) and garden soil (Control) were taken for the chemical analysis firstly and then to find the effect of these composts on the growth of a vegetative crop '*Pisum sativum*'. From the chemical analysis it was found that vermicompost was rich in nutrients like potassium, nitrate, Sodium, calcium, magnesium and chloride and have the potential for improving plant growth than pit compost and garden soil (control). The study also showed distinct differences between vermicompost, pitcompost and garden soil (control) in terms of their nutrient content and their effect on plant growth.

Vermicompost can be described as a complex mixture of earthworm faeces, humified organic matter and microorganisms that when added to the soil or plant growing media, increases germination, growth, flowering, fruit production and accelerates the development of a wide range of plant species. The enhanced plant growth may be attributed to biologically mediated mechanisms such as the supply of plant-growth regulating substances and improvements in soil biological functions.

Stimulation of plant growth may depend mainly on biological characteristics of vermicompost, plant species used and cultivation conditions. Extensive research on inorganic fertilization and plant breeding was carried out within the framework of conventional agriculture that had allowed agricultural producers to fine-tune nutrient inputs and plant needs in order to maximize yields. However, such detailed knowledge has not yet been attained as regards the interactions between plants and organic fertilizers in sustainable agriculture. The complex and variable composition of vermicompost in comparison with inorganic fertilizers and the myriad of effects that it can have on soil functioning, a clear and objective concept of vermicompost is required. The complex interactions between vermicompost-s oil-plant must be unraveled in order to maintain consumer confidence in this type of organic fertilizer (Cristina and Jorge, 2011).

Tharmaraj *et al.* (2011) narrated that the physical properties such as pH, electrical conductivity (EC), porosity moisture content, water holding capacity and chemical properties (N, P, K, Ca and Mg) were found distinctly enhanced in vermicompost treated soil with addition to the reduction of soil pH. The physical properties such as water holding capacity, moisture content and porosity in soil amended with vermicompost were improved. Vermiproduct treated plants exhibit faster and higher growth rate with maximum number of leaves, height, leaf length and productivity.

Daniel and Jader (2012) reported that use of vermicompost and its product represents a crucial ecofriendly technology that capable of recycling organic wastes to be used as fertilizers. Through its hormone-like substances vermicompost, liquid humus or worm bed leachate stimulates plant growth. Additionally, manipulation of microbial population present in vermicompost and its products may increase both nutrient content and availability.

Vermicompost of cowdung garden waste and kitchen waste in combination were applied by Mamta *et al.* (2012) for the investigation of the effect of vermicompost on growth and productivity of brinjal and found significant variation on seed germination, plant height, number of leaves and fruit weight. The findings of the experiment suggested that vermicompost amendments affected brinjal crop differently and recommend that while raising brinjal crop farmers should use vermicompost instead of synthetic fertilizers due to observe their findings. The findings of the study were addition of vermicompost to soil maximize the seed germination, plant height, number of leaves and fruit weight also minimize the incidence of disease in brinjal fruits.

Jayakumar and Natarajan (2012) conducted an experiment and find out that vermicomposting is a non-thermophilic, boioxidative process that involves earthworms and associated microbes. Vermicompost is a finely divided, peat like material with high porosity, good aeration, drainage, water holding capacity, microbial activity and excellent nutrient status and buffering capacity thereby resulting the required physiochemical characters congenial for soil fertility and plant growth. Vermicompost enhances soil biodiversity by promoting beneficial microbes which in turn enhance plant growth directly by production of plant growth-regulating hormones and enzymes and indirectly by controlling plant pathogens, nematodes and other pests thereby enhancing plant health and minimizing the yield loss. Due to its innate biological, biochemical and physiochemical properties, vermicompost may be used to promote sustainable agriculture and also for the safe management of agricultural, industrial, domestic and hospital wastes which may otherwise pose serious threat to life and environment.

Okra fruit production can be alternatively supported with application of organic manures, to reduce the use of chemical fertilizers. Experiments were conducted to assess the growth and yield of okra (Variety: NH47-4) with cowdung (CD) and poultry manure (PM). Plants were generally taller at 6 and 8 weeks after planting (WAP) with PM and CD. Application of the treatments provided the tallest plants of 34 cm with CD and 83 cm with PM at 8 WAP. Okra pod yields were lower with PM relative to CD. 10 tha^{-1} PM gave the highest yield of 640 $kgha^{-1}$ while the highest of 1297 $kgha^{-1}$, with 15 tha^{-1} was got with CD. Poultry manure supports more of vegetative growth of okra while cowdung gives higher fruit yields have been traced by Makinde and Ayoola (2012).

Nath and Singh (2012) used of vermiwash extracted from vermicomposts as liquid biofertilizer for growth and productivity of paddy (*Oryza sativa*), maize (*Zea mays*) and millet (*Penisetum typhoides*) crops and noticed significant effect on growth and productivity. Their outcome of the experiment denoted that 10 mg/m^2 of vermiwash buffalo dung with straw shows significant growth (89.2±2.7 cm) and 30 mg/m^2 concentration of similar combination shows highly significant growth in paddy crops (102.6±2.3 cm) after 75 days as well as 10 mg/m^2 concentration of combination horse dung with gram bran caused significant growth (85.2±4.3 cm) 50 days while at the same time 30 mg/m^2 concentration of combination of straw with buffalo dung and horse dung caused highly significant growth in maize crops. Combinations of buffalo dung with gram bran and with straw; and combination of horse dung with gram bran and with straw have significant growth in millet crops. All concentrations of different combinations of animal agro and kitchen wastes have significant early start in flowering and enhance the productivity of crops.

An experiment was carried out by Lamo *et al.* (2012) to find the effect of different organic nutrient sources on seed quality and yield characters of radish. Thirteen treatments comprising of organic manures, bio-fertilizers, inorganic and control (no treatment) were used. The observations were recorded on pod length (cm), number of seeds per pod, seed yield per plant and per plot (g), 1000-seed weight (g), seed germination (%) and vigor index. Analysis of variance showed highly significant differences among treatments. Among organic manures vermicompost was found comparatively better.

Vermicompost produced lower in pH, total organic carbon and C/N ratio, but higher in humic acid content (Khye *et al.*, 2012) also contributed to the enrichment in some important plant nutrients, such as total and available N, P, K and Ca.

Attarde *et al.* (2012) conducted an experiment to investigate the effect of organic and inorganic fertilizers on growth and nutrient status of *Abelmoschus esculentus* (okra plant). For the experiment, various combinations of fertilizers such as Vermicompost (VC), Chemical Fertilizer (CF) and Farmyard Manure (FYM) were applied by followings, T_1: Control, T_2: (FYM 100%), T_3: (VC 100%), T_4: (CF 100%), T_5: (VC 75% + CF 25%), T_6: (VC 75% + FYM 25%), T_7: (VC 50% + FYM 50%) and T_8: (VC 50% + CF 50%). The study indicated that that with the use of inorganic fertilizers plants physical characteristics were enhanced compared to other treatments whereas nutrient status of okra fruit was recorded maximum in treatment T_3 (VC 100%) and followed by T_6 (VC 75% + FYM 25%). Although, treatment T_4 has shown high potential for rapid growth of plant comparatively similar results in the growth of plant were observed in treatment T_5 (VC 75% + CF 25%). Thus combination of organic fertilizer along with inorganic fertilizer is beneficial for the physical growth of okra plant while nutrient content of okra fruit are dependent only on organic fertilizer dose.

For strawberry, tallest plant (31.4 cm), the maximum number of leaves (11.1), leaf area (64.5 cm^2), number of flower bud (30.0), number of flowers (28.7), number of fruits (25.9), fruit weight (13.2 g) and yield (336.6 g) per plant were found with 75 ppm GA_3 application (Jamal Uddin *et al.*, 2012).

The potential of vermicompost was investigated as one of the substrate constituents on yield indexes of three strawberry cultivars. For this, were used from four substrates consisted of (0%, 5%, 15% and 25% vermicompost indicated by S_1, S_2, S_3 and S_4 respectively) and three cultivars (Camarosa, Mrak and Selva). It was found that diameter of crown, number of inflorescences, fruit length, number of fruit, mean of fruit weight and yield varied among the cultivars. The results of the experiment indicated that application of vermicompost in substrate improved indexes of yield like number of inflorescences, fruit length, number of fruit, mean of fruit weight and yield. The highest of diameter of crown, fruit length and yield were obtained in interaction of Mrak and S_2 (19.45 mm, 4.47 cm and 264.143 g respectively). The interaction of Selva and S_3 had more fruit number (26.63) than other treatments. Selva cultivar in S_4 had the highest of mean of fruit weight (12.33 g) also Mrak in S_4 had 44 more number of inflorescence (7) than other treatments. Camarosa in S_1 had lower fruit length (2.66 cm) and mean of fruit weight (8.27 g) than other treatments also Selva in this substrate had the lowest of yield (140.79 g). The lowest of inflorescence number was observed in interaction of Camarosa and S_3. Selva in S_4 had the lowest of new diameter crown (13.47 mm) and fruit number (13.34 g) (Atefe *et al.*, 2012).

Hibiscus esculentus is allowed to grow in the medium of vermicompost and urea to evaluate the effect of vermicompost and urea on the growth and yield. There were 3 treatments viz., control, vermicompost (T1) and urea (T2). The germination percentage, shoot length and yield of the plant were recorded on 20^{th}, 40^{th} and 60^{th} days.

From the study, maximum plant height (19.8 ± 2.9 cm), number of flower (21.3±0.36), number of fruit (15.0), fruit weight (10.3 g), total fruit weight (185.0 g) and fruit length (12.3 cm) was found from the application of vermicompost on *Hibiscus esculentus*. The present study revealed that vermicompost seems to be maintained the soil which is ideal for growth of the plant. The highest yield of *Hibiscus esculentus* was found in vermicompost treatment (T1) followed by urea (T2) and lowest in control. Application of vermicompost increased the vegetative growth and yield of *Hibiscus esculentus* (Vanmathi and Selvakumari, 2012).

2.3 Methodology related

Dhaka, Gazipur, Narsingdi, Narayangonj, Tangail, Jamalpur, Mymensingh, Kishoregonj districts covering 4244 km^2 area belongs to Agro-Ecological Zone of Madhupur Tract (AEZ No. 28) among 30 AEZ in Bangladesh having upland area with well drained red brown soil, mean annual rainfall is about 2000 mm in south and 2300 mm in north, annual temperature is about 25.3^0C (UNDP – FAO, 1988).

Shape ridges or raised beds 8 to 10 inches high. Make ridges wide enough to grow a single row of plants; raised beds should be wide 3 to 4 feet (91.4 to 121.9 cm) between rows. Allow runners that form from these “mother” plants to develop and they will form a matted row 18 inches (45.7 cm) wide. Set plants 12 to 15 inches (30.5 to 38.1 cm) apart in double- or triple-wide rows on raised bed (Strik, 1993).

Strawberries responded positively and similarly to both 5 tha^{-1} and 10 tha^{-1} rates of application (Guerena and Holly, 2007). These responses could not have been mediated by the availability of macronutrients. Based on other research in laboratory, however, responses could have been due to production of plant growth regulators by microorganisms during vermicomposting.

Singh *et al.* (2008) were determined the effect of vermicompost on growth, physiological disorders, fruit yield and quality of ‘Chandler’ strawberry by using 4 levels of vermicompost (2.5, 5.0, 7.5 and 10.0 tha^{-1}) that was incorporated into top 10 cm layer of soil on the basis of chemical analysis, with amount of inorganic NPK fertilizer calculated to equalize recommended dose of nutrients. It was found that vermicompost application increased plant spread (10.7%), leaf area (23.1%) and dry matter (20.7%) and increased total fruit yield (32.7%) also increasing marketable fruit yield up to 58.6% with better quality by reducing incidence of physiological disorders like albinism (16.1–4.5%); fruit malformation (11.5–4.0%) and occurrence of grey mould (10.4–2.1%) in strawberry which have a significant role in reducing nutrient-related disorders and disease like Botrytis rot. Fruit harvested from plant receiving vermicompost were firmer, have higher TSS, ascorbic acid content and lower acidity, and attractive color. Among the doses, best results were achieved by the application @ 7.5 tha^{-1} vermicomposts in terms of all of these parameters.

2.4 Correlation related

Days to flowering had negative correlation with yield per plant (Kumar and Muthukrishnan, 1979). Further, there had positive correlations between locule numbers, fruit weight with number of fruits per plant in all populations.

The correlation and path coefficient analysis of 90 F2 population of brinjal showed that fruit yield was positively correlated with plant height, number of fruits/branch, number of fruits/plant and fruit diameter, both phenotypically and genotypically. Fruit yield was negatively correlated with days to flowering phenotypically but positively correlated genotypically. Fruit diameter and the number of fruits per branch were the main factors contributing to fruit yield (Singh and Singh, 1980).

A total of 180 aubergine plants of F2 generation of the cross *Pattabiram x Annamalai* were evaluated for correlation factors. The study revealed a significant positive correlation between fruit yield and number of fruits/plant, fruit length, number of branches and plant height (Vadivel and Bapu, 1990).

Hortynski *et al.* (1991) conducted an experiment to establish the factors responsible for the expression of fruit size. The total yield of large fruits correlates closely with the total yield of all fruits and depends mainly on the mean fruit weight of all fruits. The position of fruits on the inflorescence influences the decline of fruit size to a larger extent in small-fruited clones than in the large-fruited ones. The size of the fruit is controlled by the dimension of the receptacle and number of achenes. The stimulating effects of achenes are quite different in various genotypes and the fruit weight per achene declines with the inferior blossom position. The large-fruited clones have bigger leaves, a larger photosynthetic area, and thicker petioles and flower stalks. The results suggest that there exists a possibility for indirect selection of fruit size on the basis of some additional parameters, which can be useful particularily in the years of unsuitable weather conditions.

The observations from 48 advanced generation (F8) lines of okra were worked out for correlation and path coefficient analysis. Yield was significantly and negatively correlated with days to flowering and picking. Fruit weight had positive and strong association with fruit length and number of fruits/plant. High positive indirect effect was found in case of marketable yield/plant via number of fruits/plant, fruit weight, fruit length (Dhall *et al*., 2000).

With minimum care, no land preparation and transplanting, ratooning of rice can yield at least half of the main rice crop. Oad *et al.* (2002) was made the attempt to exploit the relationship of yield contributing characters and physiological parameters with each other to understand the mode of relationship with yield attributes. The study envisaged that the locklodged rice grain yield was associated with all the agronomic and physiological traits including plant height, leaf dry matter total dry matter, leaf area index, relative growth rate, crop growth rates, biomass duration, 1000 grain weight, seed length, panicle length, number of panicles per plant, tiller number at harvest, and ratoon rating. The study denoted that the grain yield had a non-significant relationship with net assimilation rate. These all the growth, yield and physiological parameters were also associated with each other except net assimilation rate of the crop.

Rana and Chauhan (2003) investigated the relationship between different growth and yield parameters in maize. Experiment enclosed different levels of phosphorus viz., 0, 50, 75, 100 and 125 kg P_2O_5 ha^{-1} with a recommended constant dose of nitrogen @ 150 $kgha^{-1}$ on the leaf growth of two maize varieties in RCBD with four replications. The maize cultivars included were Composite-17 against a standard variety Akbar. By using data for full leaf length (FLL) and the calculated leaf extension rate (LER), duration of leaf extension rate (LED) they were adopted standard procedures to record yield component parameters. The values of linear correlation (r) were worked out to get a relationship between FLL, LER with other growth and yield parameters influencing grain yield in maize. FLL and LER were positively correlated with phosphorus applications. Similarly number of grains/cob, grain weight/cob, 1000-grain weight and grain yield were also significantly correlated with FLL and LER. Therefore, the later two parameters were directly responsible for increasing the various yield components in maize.

Correlation coefficients among 11 quantitative traits were estimated in F2 and F3 populations derived from 11 vegetable cowpea (1998-99) crosses by Subbaiah *et al.* (2003). All the traits except days to flowering, plant height and crude fiber content of pods showed positive association with green pod yield. Number of branches per plant showed a positive direct effect on crop yield.

Pod length was significantly and positively associated with green pod yield. The number of branches and test weight were significant and positively correlated with green pod yield in all the crosses.

Burio *et al.* (2004) was conducted a field experiment at Student`s Experimental Farm, Sindh Agriculture University, Tandojam to find out the correlation of growth and yield attributes of wheat (Kiran-95 variety) under different nitrogen levels and placements. Three nitrogen levels (80, 120 and 150 $kgha^{-1}$) were incorporated through broadcast, band application, pop-up and foliar application and observed that a unit increase in wheat grain yield was positively associated with plant height (r = 0.431), productive tillers (r = 0.419), spike length (r = 0.757), grains/spike (r = 0.860), seed index (r = 0.878) and harvesting index (r = 0.949). It was also found that the grain yield had non-significant and negative association with flowering days (r = -0.146) and maturity days (r = -0.054). The study concluded that correlation coefficient values should be determined for observing the degree of relationship of plant traits with yield to ensure that these parameters significantly contribute or not and positive contributing traits must be treated under intensive care to achieve yield targets.

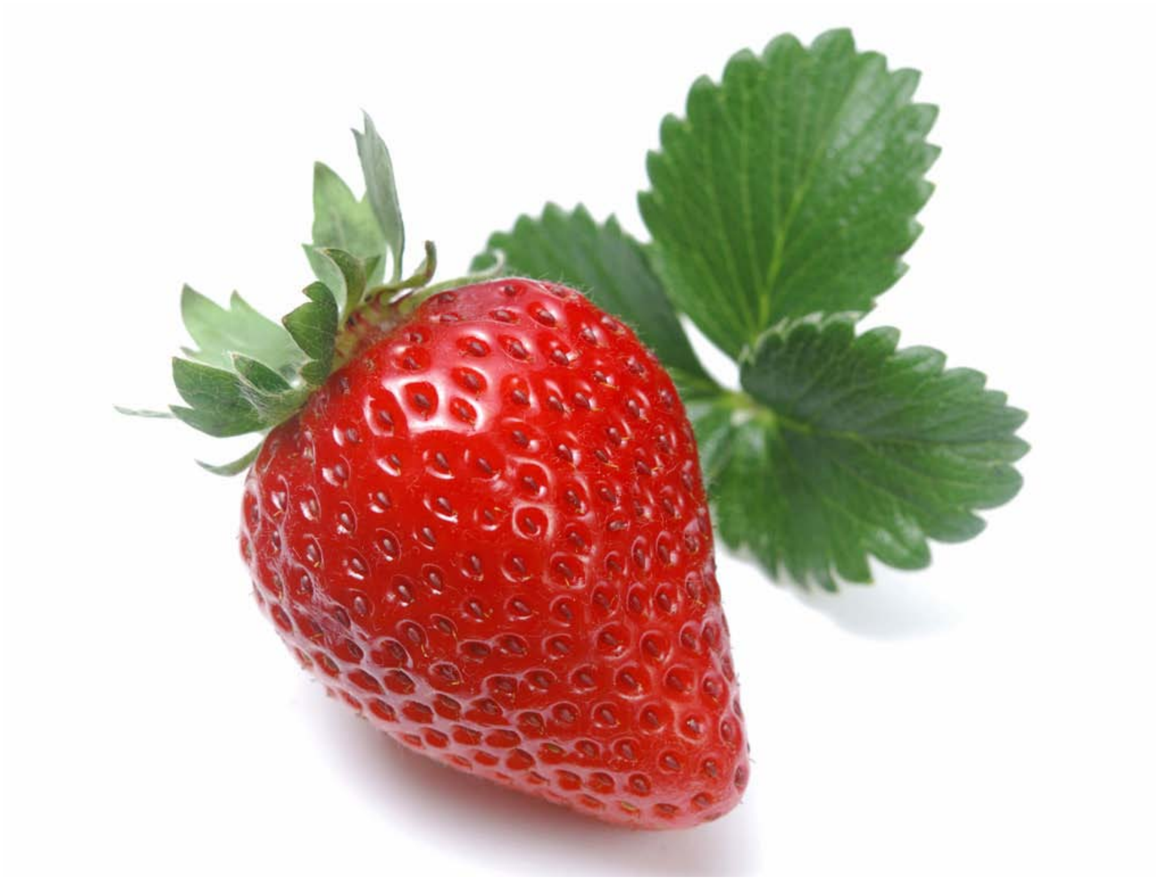
Phenotypic correlation coefficients, indicating an inherent association among the characters i.e. days to flowering, plant height, number of branches/plant, length of first fruiting node, fruit length and width, number of fruits/plant and yield/plant. Similarly, the genotypic correlation coefficients were higher in F1 generation than in the parental or F2 generation (Shekhavat *et al*., 2005).

The correlation studies in thirty-six brinjal genotypes of brinjal comprising 8 parents and 28 F1 hybrids during summer season in 2006 indicated strong correlation of number of branches per plant, fruit weight and flowers per inflorescence with fruit yield.

However, it exhibited weak association with days to flowering and fruits per cluster. Path analysis revealed high direct contribution of fruits per plant (0.290), fruit weight (0.275) and flowers per inflorescence (0.250) on fruit yield, while fruits per cluster (-0.355), days to flowering (-0.112) exhibited negative direct effect. However, indirect positive contributions of branches per plant and fruits per cluster were appreciable (Nalini *et al.*, 2009).

CHAPTER III

MATERIALS AND METHODS



CHAPTER III

MATERIALS AND METHODS

This chapter illustrates information concerning methodology that was used in execution of the experiment. It comprises a short portrayal of location of experimental site, climatic condition, materials used for the experiment, treatments of the experiment, data collection procedure and statistical analysis etc.

3.1 Experimental sites

The experiment was accomplished at Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka, during the period from June 2011 to March 2012. Location of the site is $23^0$74' N latitude and $90^0$35' E longitudes with an elevation of 8 meter from sea level (UNDP - FAO, 1988) in Agro-Ecological Zone of Madhupur Tract (AEZ No. 28).

3.2 Climatic conditions

Experimental site was located in the subtropical monsoon climatic zone, set aparted by heavy rainfall during the months from April to September (Kharif season) and scantly of rainfall during the rest of the year (Rabi season). Plenty of sunshine and moderately low temperature prevails during October to March (Rabi season), which is suitable for strawberry growing in Bangladesh.

3.3 Planting materials

Growing strawberry plants from a runner is, for most, the easiest and quickest way to propagate strawberries. Three plants of each germplasms were collected from the project of *"Varietals Trial and Sustainable Technology Development for The Commercial Production of Strawberry in Bangladesh"* financed by The Sher-e-Bangla Agricultural University Research System (SAURES) on April 2010 and then multiplied at SAU Horticultural farm and new plantlet obtained from runner.

3.4 Treatments of the experiment

The experiment was conducted to detect the performance of mentioned strawberry germplasms to different organic matter on growth, yield and quality attributes. There were two factors in this experiment. They were as follows:

Factor A: Germplasms

In experiment, three different germplasms were used. These were -

i. Germplasm – 01, V_1
ii. Germplasm – 02, V_2
iii. Germplasm – 03, V_3

Factor B: Different organic matter

Organic matters employed on experiment are given below-

i. OMc, Control (No Organic Matter)
ii. OMcd, Cowdung
iii. OMvc, Vermicompost
iv. OMpl, Poultry Litre

All organic fertilizers were collected from Krishibid Upokoron Nursery, Agargaon, Dhaka.

3.5 Application of organic matters

Soil was well prepared for pot and then cowdung, vermicompost and poultry litter were exerted to pots @ 1.0 $kgpot^{-1}$. following the application rate 7.5 tha^{-1} (Singh *et al.*, 2008; Guerena and Holly, 2007). Chemical fertilizers were not used on experiment.

3.6 Design and layout of the experiment

Experiment was provoked in Completely Randomized Design (CRD) with five replications thus comprised 60 pots (Plate 1). The size of each pot was 25 cm (10 inches) in diameter and 20 cm (8 inches) in height.

3.7 Production methodology

3.7.1 Pot preparation

Pots were filled up 7 days before transplanting on 12th October 2011. Weeds and stubbles were completely removed from soil and soil was treated with a little amount of lime to keep soil free from pathogen.

3.7.2 Transplanting of plantlets

60 runners were settled up for transplanting. Runners were transplanted in such a way that crown does not go much under soil or does not remain in shallow (Plate 2a). Runners were planted in pot on 19th October 2011. Total numbers of pots were used in 60 and 20 from each germplasm. Each pot contains single plant.

3.7.3 Tagging of plants

Plants were tagged on 23rd October 2011 using card.

3.7.4 Intercultural operations

Weeding: Weeding was performed in all pots as and when required to keep plant free from weeds.

Watering: Frequency of watering depended upon soil moisture status by observing visually. However, avoided water logging as it is detrimental to plants.

Disease and pest management: Diseases and pests is a major limiting factor to strawberry production. Experimental strawberry plants were treated with Malathion 250 EC and Cupravit 50 WP to prevent unwanted disease problems @ 0.5 ml/L and 2 g/L. On the other hand, leaf feeder is one of the important pests during growing stage. Leaf feeder was controlled by Pyrithrum @ 1.5 ml/L. Those fungicides and pesticide were sprayed two times, first at vegetative growing stage and next to early flowering stage to manage pests and diseases

Fruit management: Throughout fruit ripening time all strawberry pots were covered with net to defend fruits from birds.

Harvesting of fruits: Harvesting of fruits was done after fruits reached at maturity stage. Mature fruits were harvested when fruits turned to red in color with waxy layer on surface of fruits. Fruits were harvested from first week of January 2012 to last week of February 2012.

3.7.5 Parameters

Data were collected from each pot. Data were collected in respect of following parameters:

i. Growth related parameters

a) Number of runner
b) Number of stolon
c) Plant height (cm)
d) Leaves number
e) Leaf area (cm^2)
f) Days to first flower bud initiation from plantlets transplanting (*visual observation*)
g) Days to first flowering from plantlets transplanting

h) Days to first fruit set from plantlets transplanting
i) Days to first fruit harvest from plantlets transplanting

ii. Yield related parameters

j) No of flowers / plant
k) No of fruits / plant
l) Fruit weight (g)
m) Total fruit weight (g / plant)
n) Fruit length (mm)
o) Fruit Diameter (mm)

iii. Quality related parameters

p) Brix (%)

3.8 Data Collection

3.8.1 Measurement of plant height

Plant height of each plant was measured in cm by using meter scale and mean was calculated (Plate 2b).

3.8.2 Number of runners, stolons and leaves

Number of runners, stolons and leaves per plant were recorded by counting all runners, stolons and leaves from each plant and mean was calculated. After 60 days of transplanting number of runners was not counted and all of runners including newly emerged were removed for better yield and quality fruits.

3.8.3 Leaf area measurement

Leaf area was measured by non-destructive method using CL-202 Leaf Area Meter (USA) (Plate 2c). Mature leaf (from 4^{th} node) were measured at different days after transplanting and expressed in cm^2. Five mature leaves from each plant were measured and then average it after that mean was calculated.

3.8.4 Days to flower bud initiation, flowering, fruit setting and harvesting

Days to flower bus initiation (*visual observation*), flowering, fruiting and harvesting were counted the days from the date of strawberry plantlets transplanting.

3.8.5 Measurement of fruit weights

Fruit weight was measured by Electronic Precision Balance in gram (Plate 2d). Total fruit weight of each pot was obtained by addition of weight of the total fruit number and average fruit weight was obtained from division of the total fruit weight by total number of fruit.

3.8.6 Fruit length and diameter measurement

Fruit length and diameter were measured using Digital Caliper -515 (DC-515) in millimeter (mm). Mean was calculated each treatment (Plate 2e).

3.8.7 Measurement of brix percentage

Brix percentages were measured by Portable Refractometer (ERMA, Tokyo, Japan) (Plate 2f). Every single fruit was blend and juice was collected to measure brix percentage. Mean was calculated for each treatment. Brix percentage of fruits was measured at room temperature.

3.8.8 Statistical analysis

Collected data were statistically analyzed using MSTAT-C computer package programme. Mean for every treatments were calculated and analysis of variance for each one of characters was performed by F–test (Variance Ratio). Difference between treatments was assessed by Least Significant Difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984). Correlations between different parameters were investigated at 1% and 5% level of significance by using SPSS computer program (SPSS 19.0.1). For correlation analysis, data were selected at mature stage i.e., 60DAT in terms of number of runners and numbers of stolons whereas 70DAT in terms of number of leaves, plant height and leaf area.

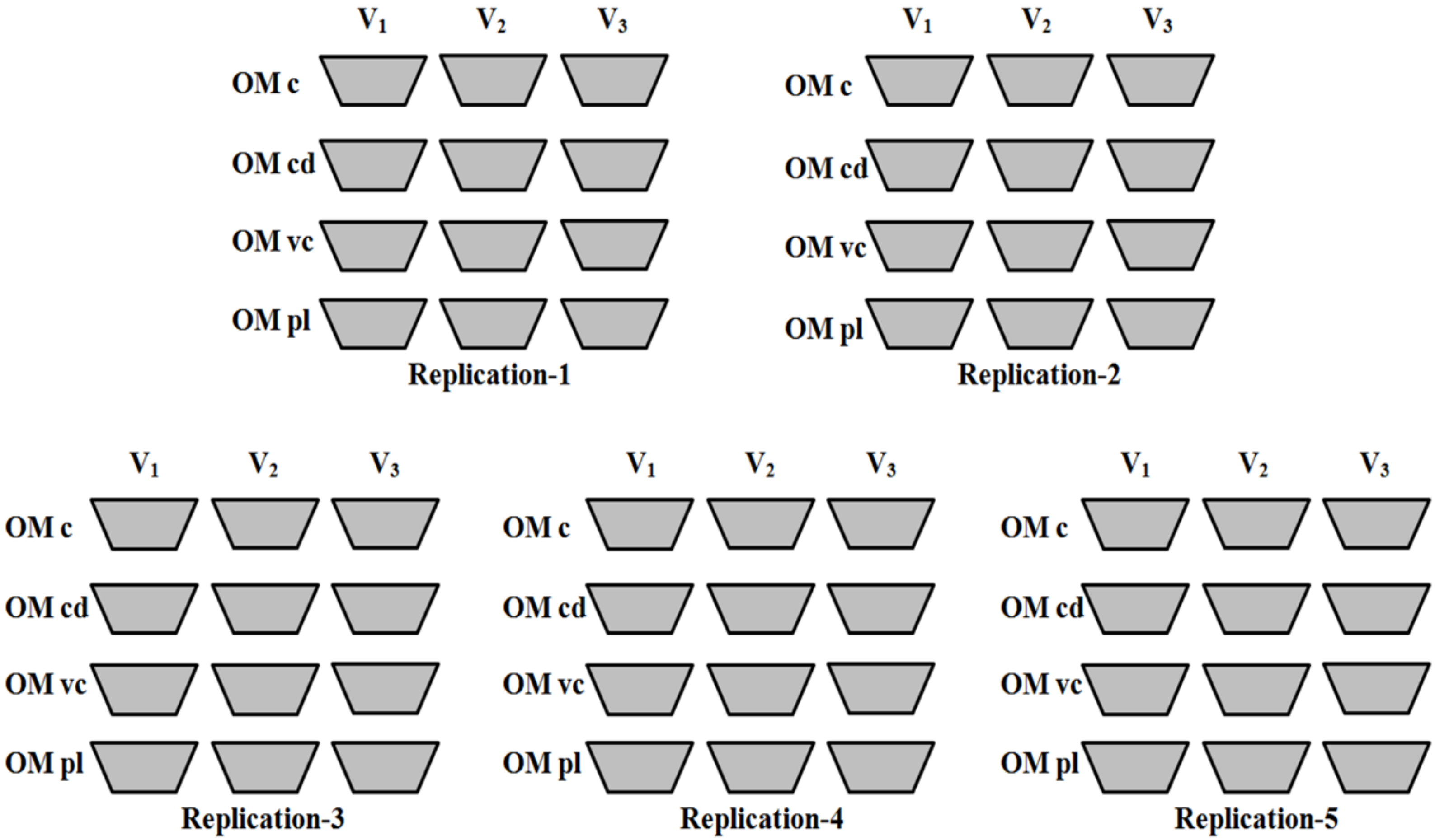
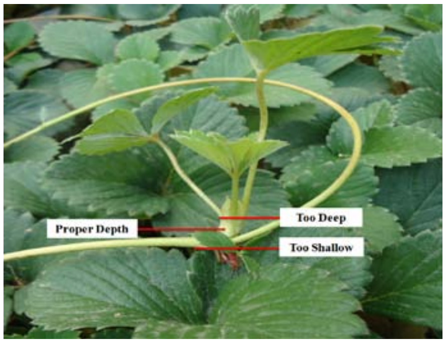


Plate 1: Sketch of experiment



a.

b.

c.

d.

e.

f.

Plate 2: a. Planting depth of strawberry plantlet; **b.** Measurement of plant height using meter scale in cm; **c.** Leaf area measurement using CL-202 Leaf Area Meter (USA) in cm^2; **d.** Fruit weight measurement by using Electronic Precision Balance in gram (g); **e.** Fruit length and diameter measurement using Digital Caliper -515 (DC- 515) in millimeter (mm); **f.** Measurement of percentage of brix using Portable Refractometer (ERMA, Tokyo, Japan)

CHAPTER IV

RESULTS AND DISCUSSION

CHAPTER IV
RESULTS AND DISCUSSION

The research work was accomplished for the evaluation of the performance of strawberry germplasm and their performance against different organic matters. Crops characteristics differed among the cultivars due to their genetic variation. Three strawberry germplasm were evaluated on the experiment that was differentiated in terms of different characters (Plate 4a, 4b, 4c, 4d and 4e).

4.1 Discrepancy between strawberry germplasm exploited on experiment (Plate 3a-e)

	Characteristics	Germplasm		
		V_1	**V_2**	**V_3**
1.	Plant vigority	Vigorous plant	Highly vigorous plant	Moderately vigorous plant
2.	Runner and stolon production	Produce least runners and stolons	Produce plentiful runners and stolons	Produce moderate runners and stolons
3.	Leaf	Trifoliate and curly with rough surface	Trifoliate, spreaded and flattened with smooth surface	Trifoliate, flattened with smooth surface
4.	Peduncle	Longest	Smallest	Medium length
5.	Petal area	Maximum	Minimum	Moderate
6.	Time for fruiting	Early fruiting variety	Late fruiting variety	Late than V_1 but earlier than V_2
7.	Fruit formation	Not formed in cluster	Formed in cluster	Not formed in cluster
8.	Fruit size	Large	Small	Medium
9.	Fruit shape	Long conical	Oblate	Short Wedge
10.	Fruit flavor	Excellent	Good	Very good
11.	Fruit ripening	Start ripening from middle portion	Start ripening from lower portion	Start ripening from upper portion
12.	Fruit color	Bright red	Light red	Medium red
13.	Yield	High yielding	Low yielding	Relatively low yielding than V_1
14.	Sweetness	More sweet	Less sweet	Moderate sweet
15.	Dessert quality	Excellent	Not good quality	Good quality

V_1, Germplasm-01; V_2, Germplasm-02; V_3, Germpasm-03

$\mathbf{V_2}$ $\mathbf{V_2}$ $\mathbf{V_3}$

Plate 3a. Leaf variation of strawberry germplasm

$\mathbf{V_2}$ $\mathbf{V_2}$ $\mathbf{V_3}$

Plate 3b. Peduncle length distinction of strawberry germplasm

V_1, Germplasm-01; V_2, Germplasm-02; V_3, Germpasm-03

V_2 **V_2** **V_3**

Plate 3c. Flower petal area differentiation of strawberry germplasm

V_2 **V_2** **V_3**

Plate 3d. Ripening system unusually of strawberry germplasm

V_2 **V_2** **V_3**

Plate 3e. Fruit shape inequality of strawberry germplasm

V_1, Germplasm-01; V_2, Germplasm-02; V_3, Germpasm-03

In this chapter, findings of executed research work have been put forwarded and discussed. Some of the data have been presented in table (s) and others in figure (s) for ease of discussion, comprehension and understanding. A summary of the analysis of variances in respect of all parameters have been shown in appendices.

Results have been presented, discussed and possible interpretations are given under the following heads.

4.2 Number of runner

Significant variation was found among the germplasm performance in terms of runner number (Appendix I). Runner number of strawberry exposed statistically significant inequality among V_1, V_2 and V_3 germplasm at 40, 50 and 60 DAT (Figure 1). In case of number of runners, it was observed that profuse runner was produced on V_2 (Germplasm-02). Maximum number of runner was scored from Germplasm-02 (V_2; 5.5) whereas minimum from Germplasm-01 (V_1; 2.5) at 60 days after transplanting (i.e., 60 DAT) of strawberry plantlets (Table 1). This result indicates that the runner numbers of different strawberry germplasm are not same and this character was genetically controlled. Lower number of runner production increases fruit production and quality of strawberry (Turkben *et al*., 1997).

Organic matters significantly affected on runner number production of strawberry germplasm (Appendix I). Runner number of strawberry germplasm exposed statistically significant inequality among control, cowdung, vermicompost and poultry litre at 40, 50 and 60 DAT (Figure 2). Maximum number of runner was observed in vermicompost (OMvc; 5.5) treated plants whereas minimum in control (OMc; 2.4) at 60 DAT of strawberry plantlets (Table 2). Study referred that vermicompost produce more number of runner and judgment represents the similar findings to Arancon *et al.* (2004a and 2004b). They were come into view that vermicompost application on strawberry plant increased 36% runners. The number of runner can be increased due the presence of plant-growth regulating substances in vermicompost and soil biological function improvement (Cristina and Jorge, 2011) through the application of vermicompost in soil.

Combined effect of different strawberry germplasm and different organic matters also showed a significant variation in terms of runner number production

(Appendix I). Runner number of strawberry germplasm showed statistically significant inequality among treatments combinations at 40, 50 and 60 DAT (Figure 3). Maximum number of runner (7.8) was counted under V_2OMvc treatment whereas minimum from V_1OMc (1.8) treatment which was statistically identical with V_1OMcd (Table 3).

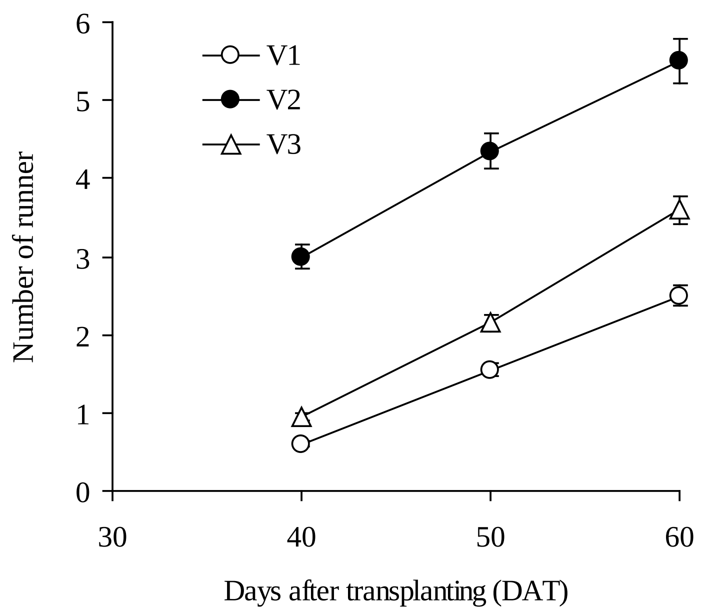


Figure 1. Performance of strawberry germplasm on runner number at different days after transplanting

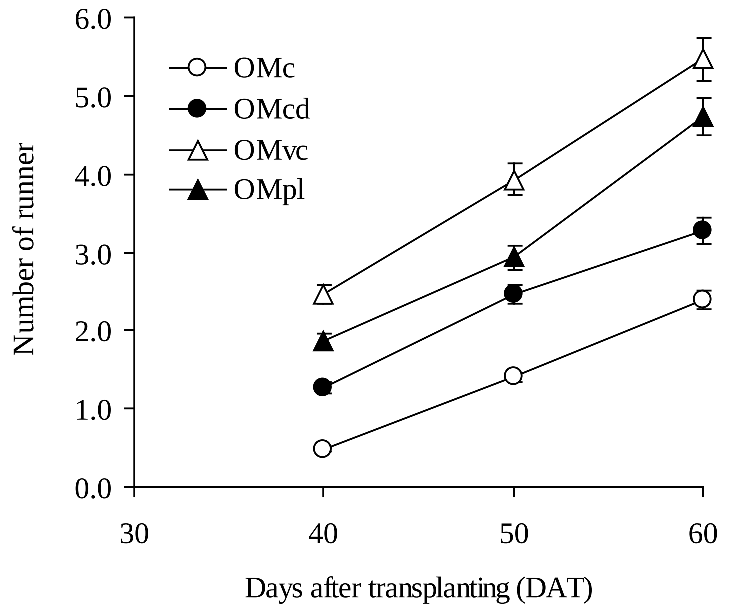


Figure 2. Effect of organic matters on number of runner at different days after transplanting

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V_1, Germplasm-01; V_2, Germplasm-02 and V_3, Germplasm-03; OMc, Control; OMcd, Cowdung; OMvc, Vermicompost and OMpl, Poultry litre

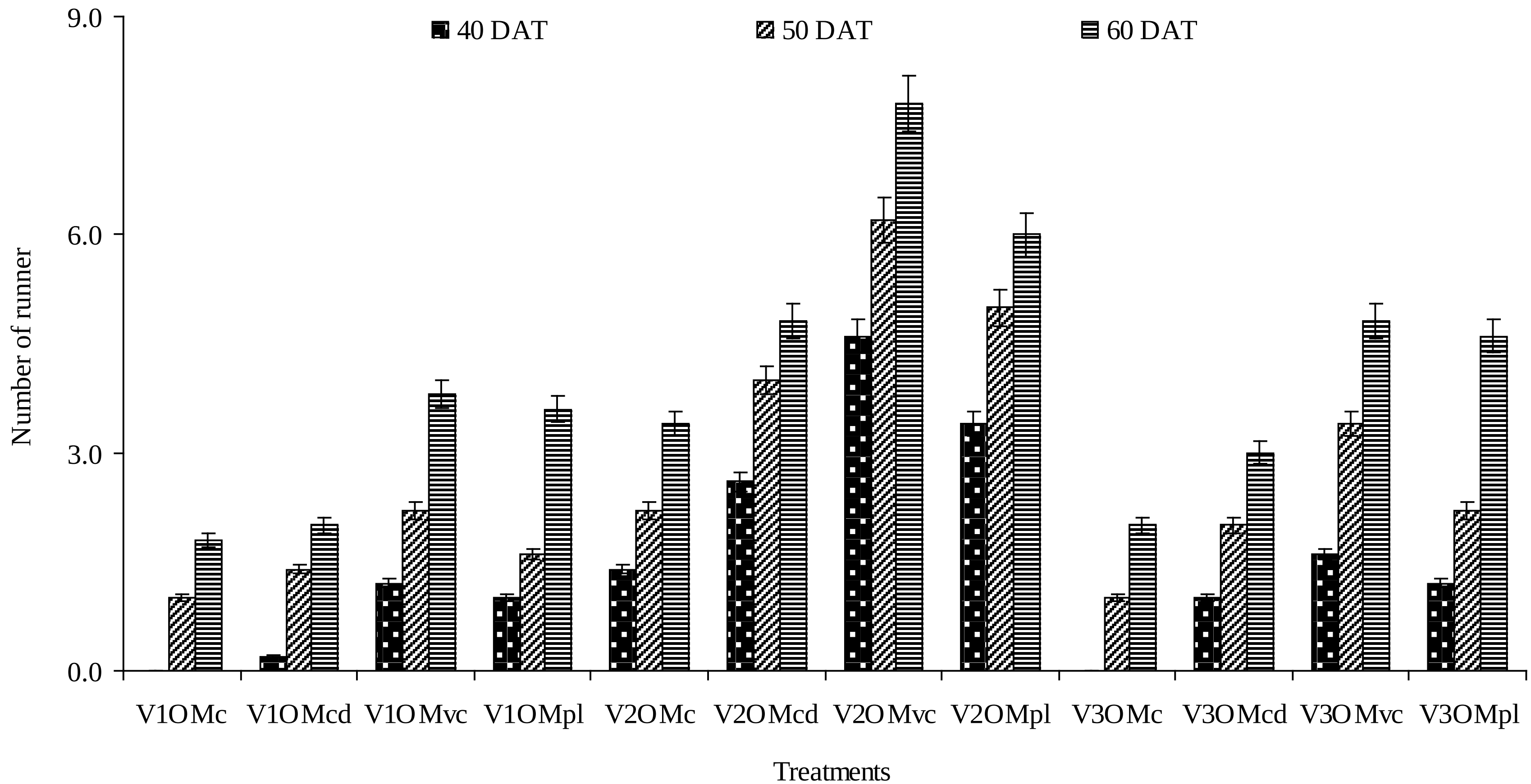

Figure 3. Combined effect of strawberry germplasm and organic matters on number of runner at different days after transplanting

V_1, Germplasm-01; V_2, Germplasm-02 and V_3, Germplasm-03; OMc, Control; OMcd, Cowdung; OMvc, Vermicompost and OMpl, Poultry litre

4.3 Number of stolon

Significant variation was found among the germplasm for the production of stolon number (Appendix II). Stolon number exposed statistically significant inequality among V_1, V_2 and V_3 germplasm at 40, 50 and 60 DAT (Figure 4). Maximum number of stolon was obtained from Germplasm-02 (V_2; 8.9) and minimum from Germplasm-01 (V_1; 3.1) at 60 DAT of strawberry plantlets (Table 1). This result indicates that stolon numbers of strawberry germplasm are not same and this character was genetically controlled. Hossan *et al.*, (2013) also found that Germplasm-01 produced 3.1 stolon/plant.

Stolon number was significantly affected by organic matter treatments (Appendix II). Stolon number of strawberry germplasm exposed statistically significant inequality among control, cowdung, vermicompost and poultry litre at 40, 50 and 60 DAT of strawberry plantlets (Figure 5). Maximum number of stolon was observed in vermicompost (OMvc; 7.6) treated plants while minimum from control (OMc; 3.2) at 60 DAT (Table 2). Study referred that vermicompost produce maximum number of stolons. Vermicompost may provide sufficient requirements for proper growth of crop plant (Mamta *et al.*, 2012) and enhance the uptake of nutrients, increase the assimilation capacity and stimulate hormonal activity (Rajiv *et al.,* 2010) for that reasons vermicompost produce maximum number of stolon.

Combined effect of different strawberry germplasm and different organic matters in terms of stolon number also exposed significant variation (Appendix II). Stolon number of strawberry germplasm showed statistically significant inequality among treatments at 40, 50 and 60 DAT (Figure 6). Maximum number of stolon was observed under the V_2OMvc (12.2) treatment whereas minimum from V_1OMc (1.6) treatment which was statistically identical with V_1OMcd (1.8) (Table 3).

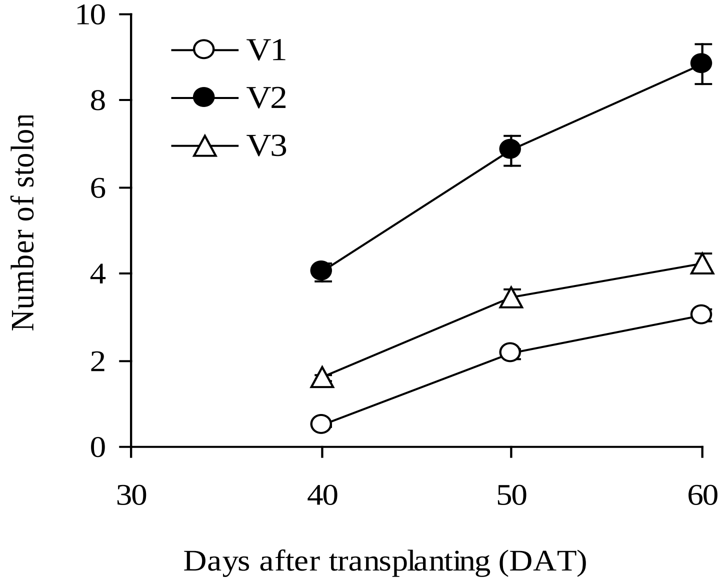

Figure 4. Performance of strawberry germplasm on number of stolon at different days after transplanting

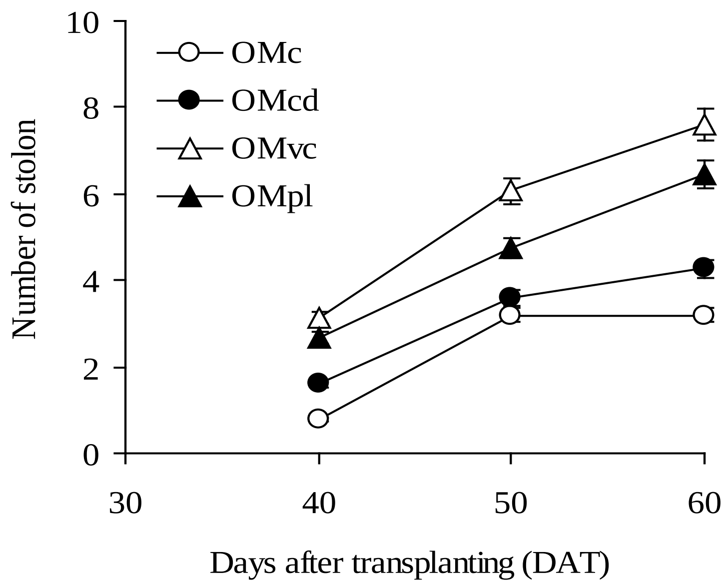

Figure 5. Effect of organic matters on number of stolon at different days after transplanting

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V_1, Germplasm-01; V_2, Germplasm-02 and V_3, Germplasm-03; OMc, Control; OMcd, Cowdung; OMvc, Vermicompost and OMpl, Poultry litre

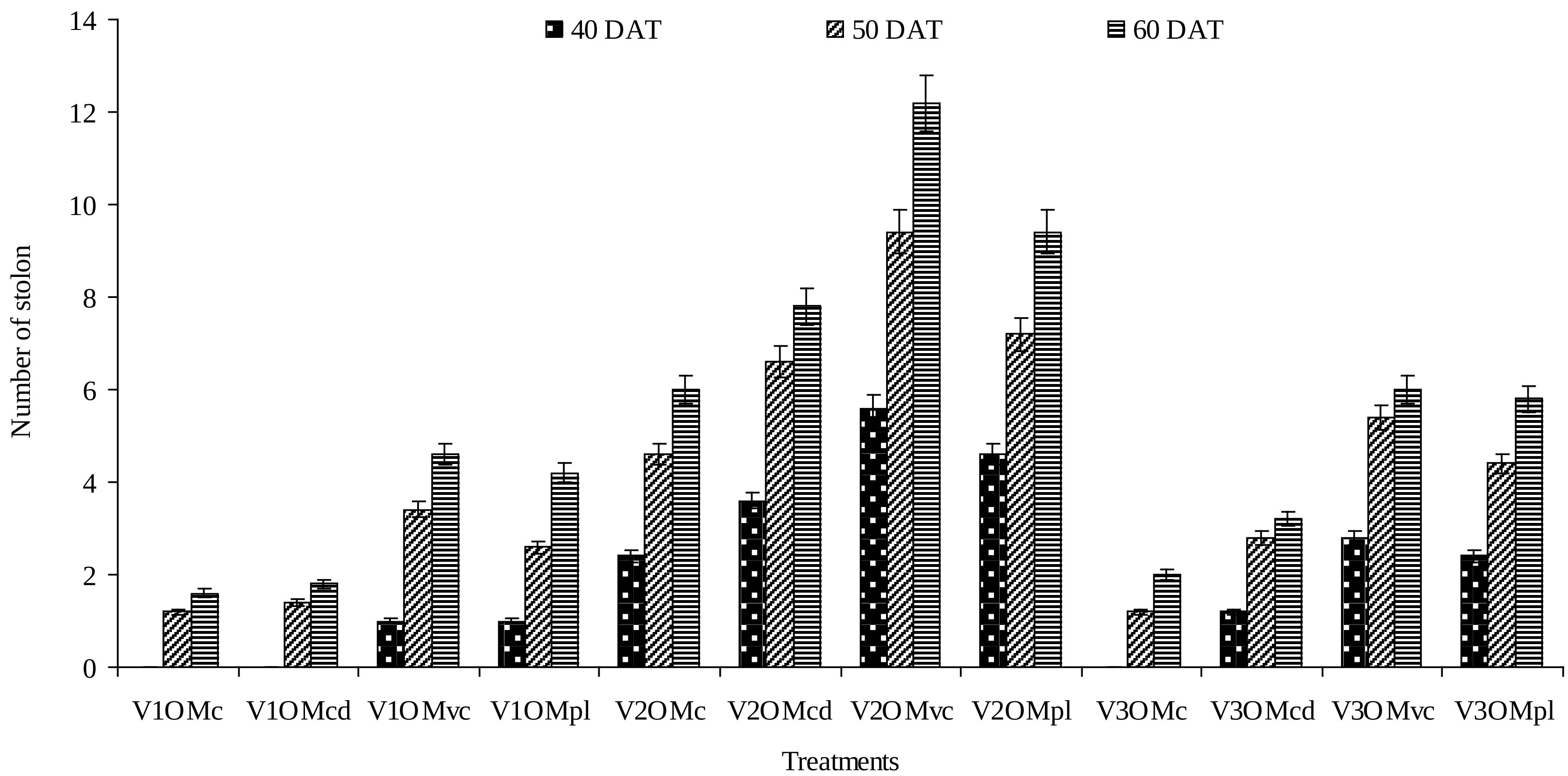

Figure 6. Combined effect of strawberry germplasm and organic matters on stolon number at different days after transplanting

V_1, Germplasm-01; V_2, Germplasm-02 and V_3, Germplasm-03; OMc, Control; OMcd, Cowdung; OMvc, Vermicompost and OMpl, Poultry litre

4.4 Number of leaves

Leaves number was significantly affected by strawberry germplasm (Appendix III). Leaf number of strawberry exposed statistically significant inequality among V_1, V_2 and V_3 germplasm at 30, 40, 50, 60 and 70 DAT (Figure 7). Maximum number of leaves was scored from V_2 (42.9) and minimum from V_1 (20.6) at 70 DAT (Table 1) i.e., Germplasm-02 produced maximum number of leaves.

Leaves number of strawberry germplasm exposed statistically significant inequality among control, cowdung, vermicompost and poultry litre at 30, 40, 50, 60 and 70 DAT (Figure 8). Maximum leaf number was counted in vermicompost (OMvc; 38.3) treated plants whereas minimum in control (OMc; 22.3) at mature stage (Table 2). Study referred that vermicompost produce maximum number of leaf. Vermicompost provided all essential plant nutrients in readily available form (Nagavallemma *et al.*, 2004) like nitrogen from vermicompost could supply 30% of the entire crop requirement as it is a potential source of readily available nutrients for plant growth (Curry and Byrne, 1992). The earthworms in vermicomposts are the agents of turning, fragmentation and aeration which increase N_2 fixing bacteria thus enhance plant growth (Parthasarthi and Ranganathan, 2002) and stimulation of plant growth mainly depends on biological characteristics of vermicompost (Cristina and Jorge, 2011). So, addition of vermicompost to soil significantly increases leaves number of plants (Mamta *et al.*, 2012; Joshi and Vig, 2010; Peyvast *et al.*, 2008) in *Pisum sp*. and *Cicer sp.* (Tharmaraj *et al.*, 2011; Sinha *et al.*, 2010).

Combined effect of different strawberry germplasm and different organic matter in terms of leaf number also exposed significant variation (Appendix III). Leaf number of strawberry germplasm observed statistically significant inequality among treatments at 30, 40, 50, 60 and 70 DAT (Figure 9). Maximum number of leaf (54.2) was achieved from V_2OMvc treatment whereas minimum from V_1OMc treatment (13.4) (Table 3).

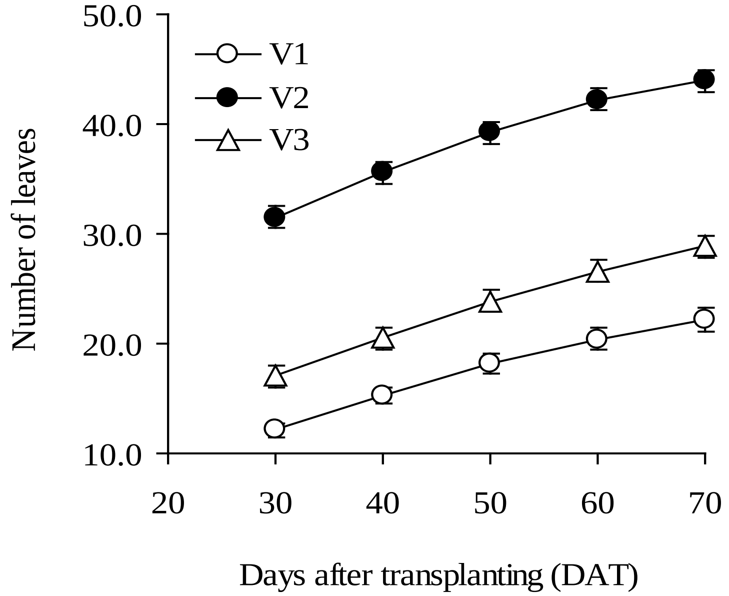

Figure 7. Performance of strawberry germplasm on number of leaves at different days after transplanting

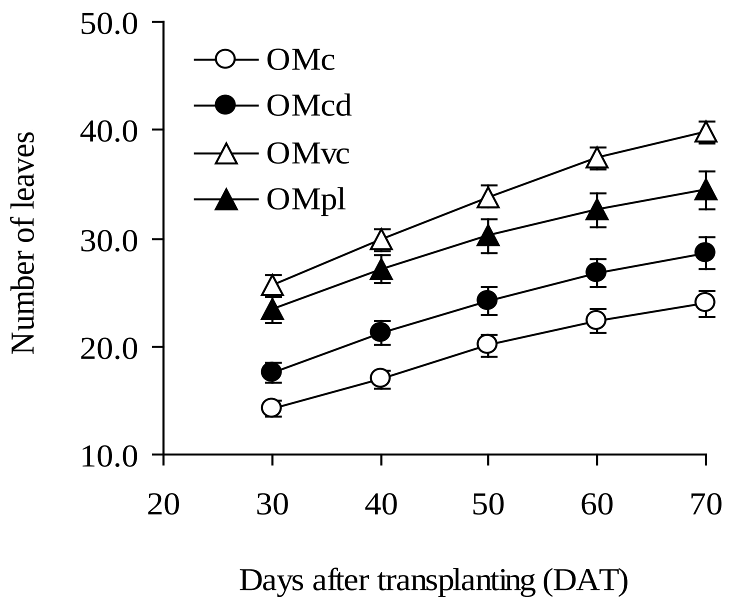

Figure 8. Effect of organic matters on number of leaves at different days after transplanting

V_1, Germplasm-01; V_2, Germplasm-02 and V_3, Germplasm-03; OMc, Control; OMcd, Cowdung; OMvc, Vermicompost and OMpl, Poultry litre

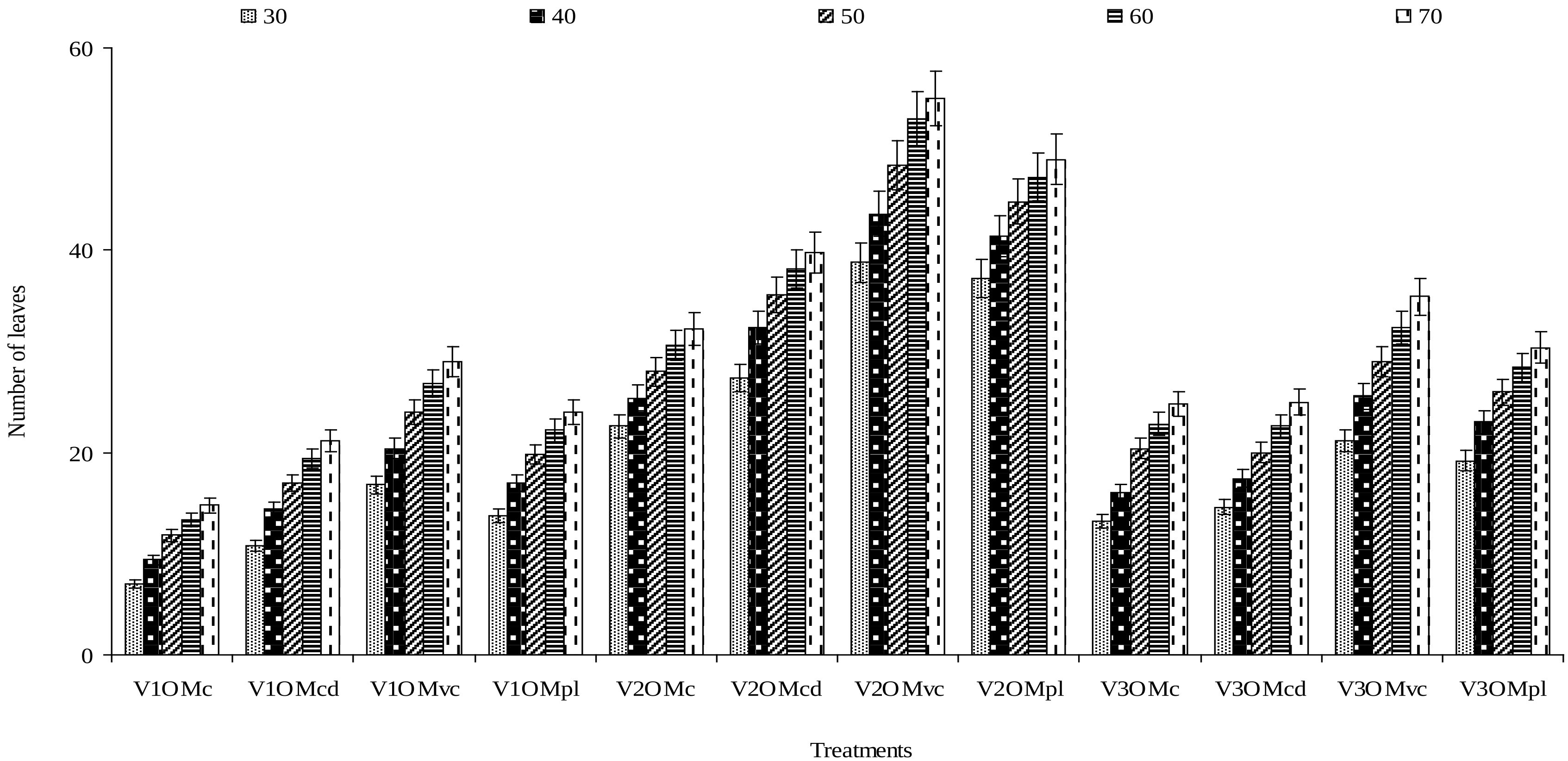

Figure 9. Combined effect of strawberry germplasm and organic matters on number of leaves at different days after transplanting

V_1, Germplasm-01; V_2, Germplasm-02 and V_3, Germplasm-03; OMc, Control; OMcd, Cowdung; OMvc, Vermicompost and OMpl, Poultry litre

4.5 Leaf area

Significant variation was detected among germplasm performance in terms of leaf area (Appendix IV). Leaf area of strawberry exposed statistically significant inequality among V_1, V_2 and V_3 germplasm at 30, 40, 50, 60 and 70 DAT (Figure 10). V_1 (Germplasm-01; 67.3 cm^2) was accorded topmost result in terms of leaf area whereas V_2 (Germplasm-02; 44.5 cm^2) was scored as inferior at mature stage (Table 1). Study referred that Germplasm-01 exposed best result in terms of leaf area. Hossan *et al.* (2013) denoted that SG-1 (Germplasm-01) provided maximum leaf area (69.8 cm^2) which notified resemblance of present study.

Leaf area was significantly affected by organic matter treatments (Appendix IV). Leaf area of strawberry germplasm exposed statistically significant inequality among control, cowdung, vermicompost and poultry litre at 30, 40, 50, 60 and 70 DAT (Figure 11). Maximum leaf area was marked in vermicompost (OMvc; 68.3 cm^2) treated plants whereas minimum was scored in control (OMc; 41.1 cm^2) at mature stage (Table 2). Strawberry plant produces maximum 64.5 cm^2 leaf area (Jamal Uddin *et al.*, 2013) and leaf area increases using vermicompost as fertilizer (Aracon *et al.*, 2004a and 2004b), which are resemblance of the current study. Leaf area improves due to the application of vermicompost in *Solanum lycopersicum* (Singh *et al.*, 2010), in soybean (Kannan *et al.,* 2006) as well as the foliar application of vermicompost leachates improves (10.1-18.9%) leaf area (Singha *et al.*, 2010). Leaf area increases due to improvement in the physio-chemical properties of soil; increase in enzymatic activity, boost up the microbial population diversity and activity also amplify in plant growth hormones by the application of vermicompost (Singh *et al.,* 2010). Vermicompost enhances soil biodiversity by promoting beneficial microbes thus increases plant growth directly through the production of plant growth regulating hormones and enzymes also indirectly by controlling plant pathogens, nematodes and other pests (Jayakumar and Natarajan, 2012). Vermicompost increases macro pore space ranging from 50 to 500μm, resulting in improved air-water relationship in the soil which favorably affect plant growth (Nagavallemma *et al.*, 2004), is useful as it increases soil porosity, aeration and water holding capacity. Soil amended with vermicompost had significantly greater soil bulk density and the soil does not become compacted, increases the surface area as well as provides strong absorbability and retention of nutrients for a longer period of time. Additive benefit realized from vermicompost application (Govindan and Thirumurugan, 2005) might be ascribed to its higher nutrient contents and their availability to crop. Possibly as a result of high soluble salt concentrations in the vermicompost increase of plant growth also leaf area of plant. Besides, it also contains plant growth promoting substances like NAA, cytokinins, gibberellins (Giraddi, 1993) can increase the leaf area of strawberry.

Combinations of strawberry germplasm and organic matters also exposed significant variation in terms of leaf area (Appendix IV). Leaf area of strawberry germplasm observed statistically significant inequality among treatments at 30, 40, 50, 60 and 70 DAT (Figure 12). Maximum leaf area was scored under V_1OMvc (81.7 cm^2) whereas minimum from V_2OMc (32.1 cm^2) (Table 3). The study disclosed that SAU Germplasm-03 treated with vermicompost performed best in terms of leaf area.

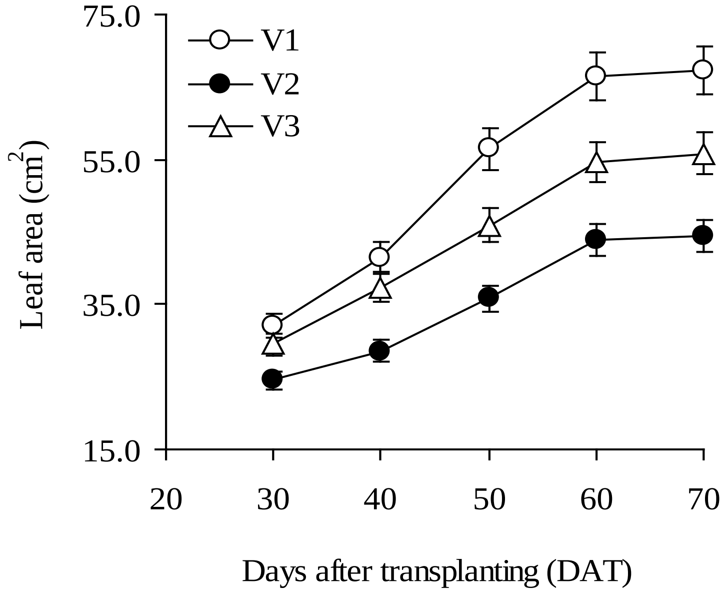

Figure 10. Performance of strawberry germplasm on leaf area at different days after transplanting

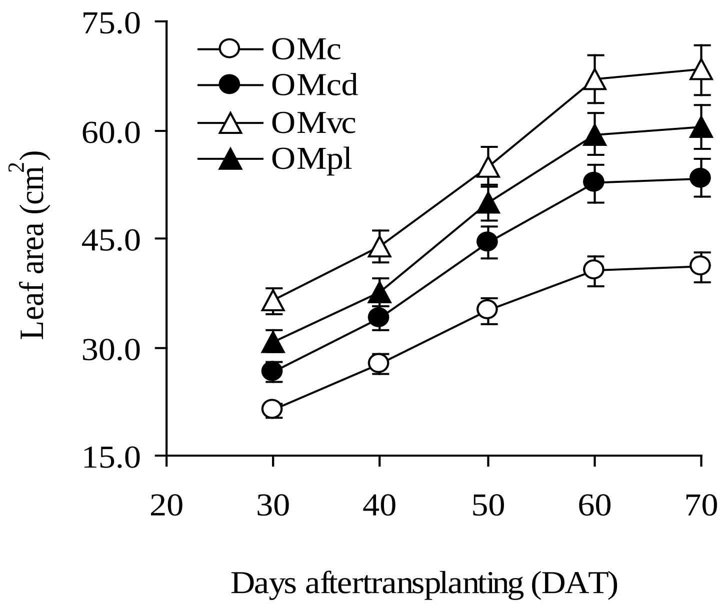

Figure 11. Effect of organic matters on leaf area at different days after transplanting

V_1, Germplasm-01; V_2, Germplasm-02 and V_3, Germplasm-03; OMc, Control; OMcd, Cowdung; OMvc, Vermicompost and OMpl, Poultry litre

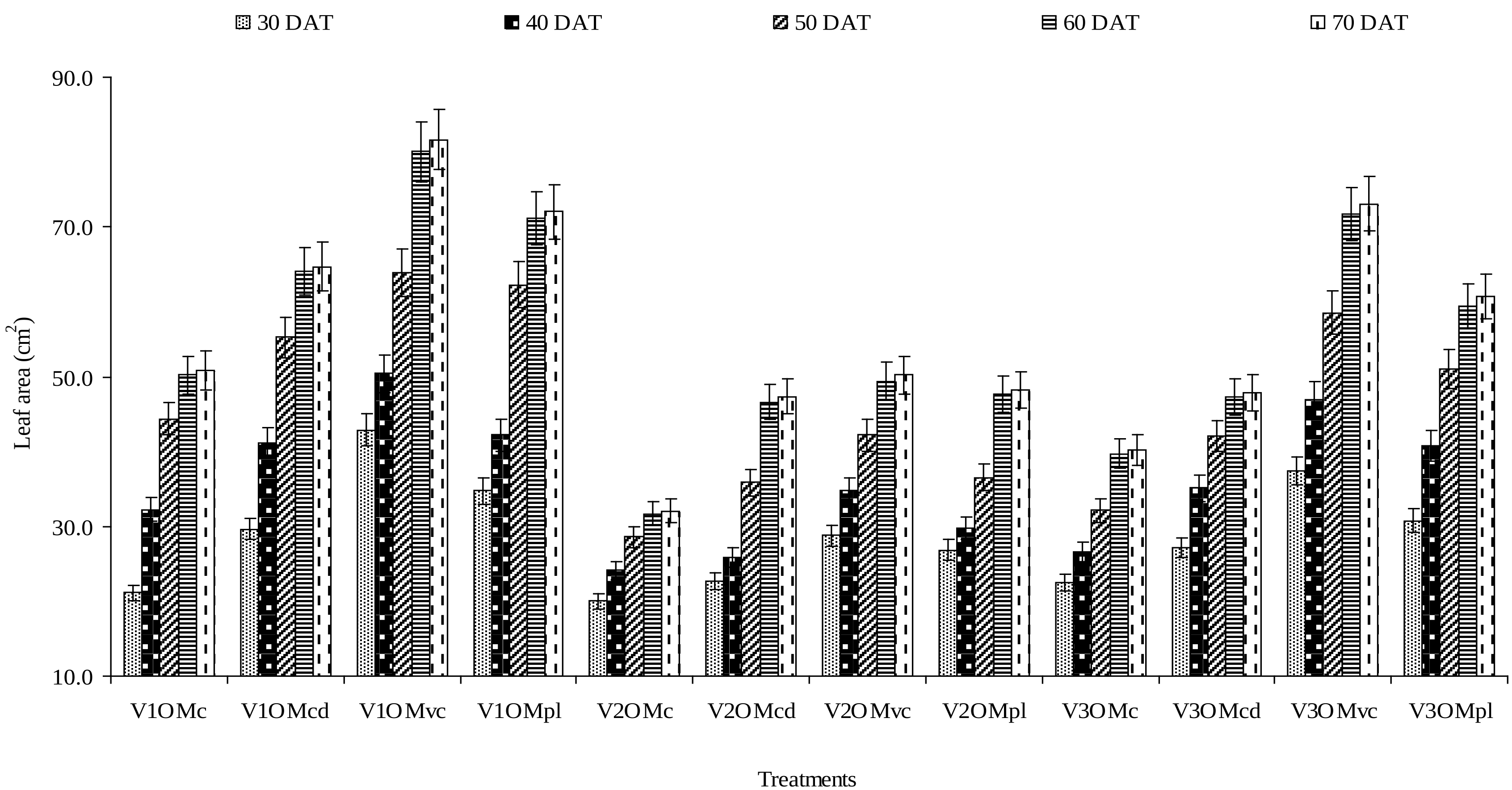

Figure 12. Combined effect of strawberry germplasm and organic matters on leaf area at different days after transplanting

V_1, Germplasm-01; V_2, Germplasm-02 and V_3, Germplasm-03; OMc, Control; OMcd, Cowdung; OMvc, Vermicompost and OMpl, Poultry litre

4.6 Plant height

Significant variation was found among the germplasm performance in terms of plant height (Appendix V). Plant height of strawberry exposed statistically significant inequality among V_1, V_2 and V_3 germplasm at 30, 40, 50, 60 and70 DAT (Figure 13). V_2 (Germplasm-02; 21.2 cm) was accorded topmost result in terms of plant height whereas inferior from V_1 (Germplasm-01; 17.33 cm) at mature stage (Table 1). Present investigation referred that Germplasm-02 exposed tallest plant.

Plant height was significantly affected by organic matters (Appendix V). Plant height of strawberry germplasm exposed statistically significant inequality among control, cowdung, vermicompost and poultry litre at 30, 40, 50, 60 and 70 DAT (Figure 14). Tallest plant (OMpl; 22.9 cm) was marked in poultry litre treated plants whereas smallest from control (OMc; 15.7 cm) at mature stage (Table 2). Makinde and Ayoola (2012) debriefed that poultry litre supports more of vegetative growth of a plant and for this strawberry germplasm respond well to poultry litre in terms of plant height. Presence of higher nitrogen (Gopalreddy, 1997; Willrich *et al.*, 1974; Sims, 1987), phosphorous compared to other organic manures (Malone *et al*., 1992) and more water retention capacity may lead to the more plant vegetative growth especially on plant height.

Combination of strawberry germplasm and organic matter to plant height also exposed significant variation (Appendix V). Plant height observed statistically significant inequality among treatment combinations at 30, 40, 50, 60 and 70 DAT (Figure 15). Tallest plant (24.8 cm) was observed under the V_2OMpl treatment and smallest from V_1OMc (14.5 cm) (Table 3). The study disclosed that Germplasm-02 treated with poultry litre performed as best in terms of plant height.

From the experiment it was observed that plant growth had started to stop which may be due to cease of cell division after flowering (Morgan, 2006).

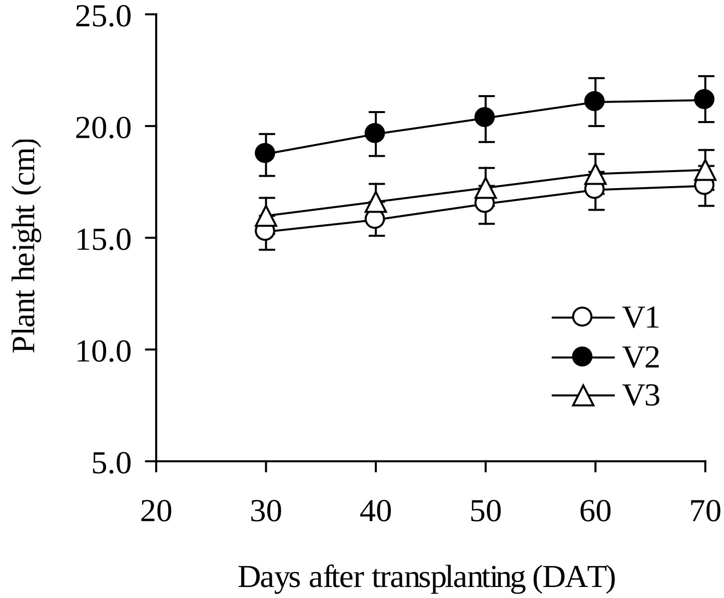

Figure 13. Performance of strawberry germplasm on plant height at different days after transplanting

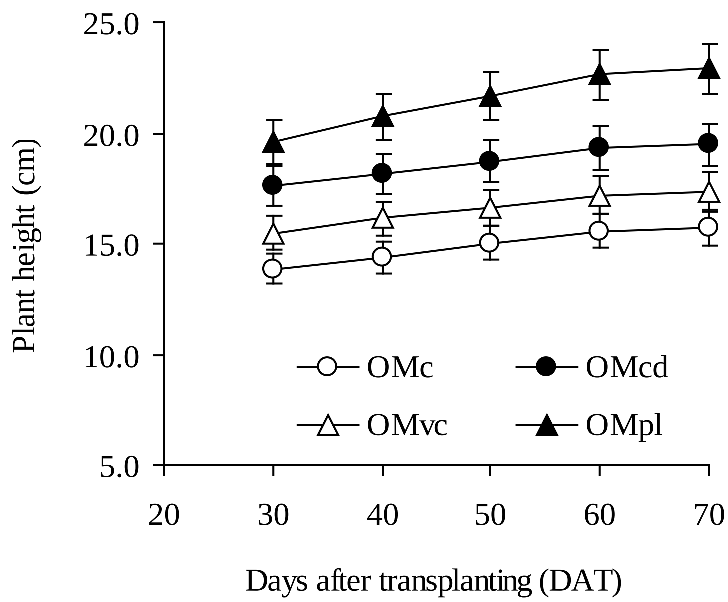

Figure 14. Effect of organic matters on plant height at different days after transplanting

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V_1, Germplasm-01; V_2, Germplasm-02 and V_3, Germplasm-03; OMc, Control; OMcd, Cowdung; OMvc, Vermicompost and OMpl, Poultry litre

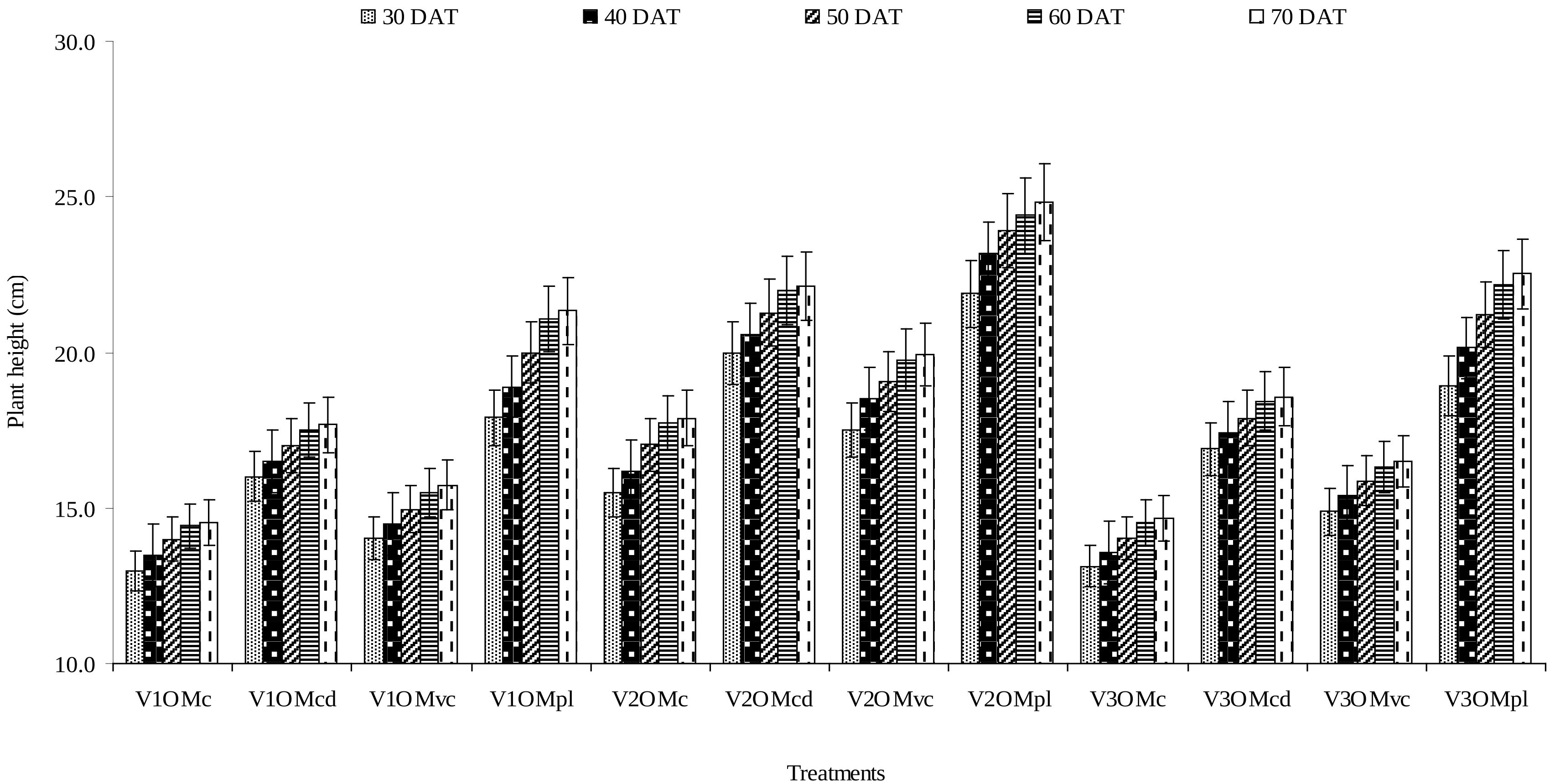

Figure 15. Combined effect of strawberry germplasm and organic matters on plant height at different days after transplanting

V_1, Germplasm-01; V_2, Germplasm-02 and V_3, Germplasm-03; OMc, Control; OMcd, Cowdung; OMvc, Vermicompost and OMpl, Poultry litre

Table 1. Growth related attributes of different strawberry germplasm[Y]

Treatments[X]	Number of runner	Number of stolon	Number of leaves	Leaf area (cm^2)	Plant height (cm)
V_1	2.8 c	3.1 c	20.6 c	67.3 a	17.3 c
V_2	5.5 a	8.9 a	42.9 a	44.5 c	21.2 a
V_3	3.6 b	4.3 b	27.6 b	55.5 b	18.07 b
CV (%)	15.3	21.5	11.3	1.7	1.0
LSD 0.05	0.4	0.7	2.2	0.6	0.1

[X] V_1, Germplasm-01; V_2, Germplasm-02 and V_3, Germplasm-03

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

Table 2. Effect of organic matters on the growth related attributes of strawberry[Y]

Treatments[X]	Number of runner	Number of stolon	Number of leaves	Leaf area (cm^2)	Plant height (cm)
OMc	2.4 d	3.2 d	22.3 d	41.1 d	15.7 d
OMcd	3.3 c	4.3 c	27.6 c	53.3 c	19.5 b
OMvc	5.5 a	7.6 a	38.3 a	68.3 a	17.4 c
OMpl	4.7 b	6.5 b	33.2 b	60.3 b	22.9 a
CV (%)	15.3	21.5	11.3	1.7	1.0
LSD 0.05	0.4	0.9	2.5	0.7	0.1

[X] OMc, Control; OMcd, Cowdung; OMvc, Vermicompost and OMpl, Poultry litre

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

Table 3. Combined effect of germplasm and organic matters on growth related attributes of strawberry[Y]

Treatments[X]	Number of runner	Number of stolon	Number of leaves	Leaf area (cm^2)	Plant height (cm)
V_1OMc	1.8 f	1.6 g	13.4 i	50.8 e	14.5 j
V_1OMcd	2.0 f	1.8 fg	19.4 h	64.8 c	17.7 g
V_1OMvc	3.8 d	4.6 de	27.2 ef	81.7 a	15.7 i
V_1OMpl	3.6 de	4.2 ef	22.2 gh	72.0 b	21.3 d
V_2OMc	3.4 de	6.0 d	30.6 de	32.1 h	17.9 g
V_2OMcd	4.8 c	7.8 c	38.6 c	47.4 f	22.1 c
V_2OMvc	7.8 a	12.2 a	54.2 a	50.2 e	19.9 e
V_2OMpl	6.0 b	9.4 b	48.2 b	48.2 f	24.8 a
V_3OMc	2.0 f	2.0 fg	22.8 gh	40.2 g	14.6 j
V_3OMcd	3.0 e	3.2 ef	24.8 fg	47.9 f	18.6 f
V_3OMvc	4.8 c	6.0 d	33.4 d	73.1 b	16.5 h
V_3OMpl	4.6 c	5.8 d	29.2 de	60.8 d	22.5 b
CV (%)	15.3	21.5	11.3	1.7	1.0
LSD 0.05	0.8	1.5	4.4	1.23	0.2

[X] V_1, Germplasm-01; V_2, Germplasm-02 and V_3, Germplasm-03; OMc, Control; OMcd, Cowdung; OMvc, Vermicompost and OMpl, Poultry litre

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

4.7 Days to first flower bud initiation (*visual observation*)

Significant variation in respect of days (from days after transplantation of strawberry plantlets) taken for flower bud appearance (visual observation) was received among the germplasm (Appendix VI). Longest period was required for flower bud initiation in Germplasm-02 (V_2; 78.2 days) whereas shortest period from Germplasm-01 (V_1; 57.7 days) (Table 4). This result shows that V_1 was early flower bud initiating germplasm whereas V_2 was late one.

Days to flower bud initiation was significantly affected by organic matters (Appendix VI). Flower bud initiation was earliest in vermicompost (OMvc; 59.4 days) treated germplasm and delayed in control (OMc; 72.9 days) (Table 5). Early flower bud initiation is vital to minimize cropping period that will increase cropping intensity.

Combination of strawberry germplasm and organic matters affected significantly on days taken to flower bud initiation from transplantation of strawberry plantlets (Appendix VI). V_1OMvc (51.0 days) required minimum days for flower bud initiation whereas maximum days from V_2OMc (84.2 days) treatment (Table 6).

4.8 Days to first flowering

Significant variation was received among the germplasm in respect of days to flowering from days after transplantation of strawberry plantlets (Appendix VI). Longest period was required for flowering in Germplasm-02 (V_2; 83.2 days) while shortest period in Germplasm-01 (V_1; 62.6 days) (Table 4). The result showed that V_1 was early flowering germplasm whereas V_2 was the late one. Early flowering is required to increase cropping intensity.

Days to flowering were significantly affected by organic matters (Appendix VI). There was significant variation among organic matters treated strawberry germplasm. Early flowering was recorded in vermicompost (OMvc; 64.3 days) treated germplasm and delayed in control (OMc; 77.9 days) (Table 5). Plant produce early flowering due to incorporation of vermicompost (Chamani *et al.*, 2008). Nath and Singh (2012) notified that all concentrations of different combinations of animal agro and kitchen wastes have significant early start in flowering and enhance the productivity of crops.

Combination of strawberry germplasm and organic matters affects on days taken to flowering (Appendix VI). V_1OMvc (55.8 days) treatment required minimum period for flower bud initiation whereas maximum from V_2OMc (89.4 days) (Table 6).

4.9 Days to first fruit setting

Significant variation was received for days to first fruit setting with different germplasm (Appendix VI). Longest period was required for fruiting in Germplasm-02 (V_2; 88.8 days) whereas shortest period from Germplasm-01 (V_1; 68.3 days) (Table 4). The result indicated that V_1 was early fruiting germplasm whereas V_2 was the late one. Early fruiting is required to increase cropping intensity.

Days to fruiting were significantly affected by organic matters (Appendix VI). Early fruiting was recorded in vermicompost (OMvc; 69.2 days) treated germplasm and delayed in control (OMc; 83.8 days) (Table 5).

Strawberry germplasm and organic matters combinedly affected on days taken to fruiting (Appendix VI). V_1OMvc treatment was exhibited as superior combination (60.8 days required) for days to fruiting whereas V_2OMc was performed as inferior combination (95.0 days required) showed in Table 6.

4.10 Days to first fruit harvesting

Significant variation was received on days to first fruit harvesting with germplasm (Appendix VI). Longest period was required for harvesting in Germplasm-02 (V_2; 117.7 days) whereas shortest period from Germplasm-01 (V_1; 92.5 days) (Table 4). The result showed that V_1 was the early harvesting germplasm whereas V_2 was the late one. Early fruit harvesting is essential to minimize the cropping period that will increase cropping intensity. Hossan *et al.* (2013) reported that maximum 129.3 days required for fruit maturity of strawberry plant and Germplasm-01 was early maturating germplasm.

Days to harvesting were significantly affected by organic matters (Appendix VI). Early harvesting was performed in vermicompost (OMvc; 93.7 days) treated germplasm and delayed in control (OMc; 111.6 days) (Table 5).

Strawberry germplasm in combination with organic matters affected significantly on days taken to harvest fruit (Appendix VI). In this case, V_1OMvc imparted the best result by taking earlier harvesting period (82.4 days) whereas V_2OMc represented as a inferior combination (126.8 days of harvesting period) (Table 6).

Early flower bud initiation, flowering, fruiting and harvesting is very important for better strawberry production with better quality in Bangladesh. As it grows well under temperate climate i.e., low temperature is required for quality production. Production and quality decrease dramatically with the increase of temperature. In Bangladesh, from month of February temperature increases rapidly and strawberry plants face a major problem on fruit development and ripening. Early flower bud initiation, flowering, fruiting and harvesting can overcome this problem. Regarding this fact, it can be announced that V_1 (Germplasm-01) is suitable among germplasm and vermicompost was the best among organic matters exploited on current experiment for Bangladesh condition respecting early flower bud initiation, flowering, fruiting and harvesting.

Table 4. Crop duration related attributes of different strawberry germplasm[Y]

Treatments[X]	Days to flower bud initiation	Days to flowering	Days to fruit setting	Days to fruit harvesting
V_1	57.7 c	62.6 c	68.3 c	92.5 c
V_2	78.2 a	83.2 a	88.8 a	117.7 a
V_3	61.7 b	66.7 b	72.4 b	98.5 b
CV (%)	2.4	2.3	2.2	1.4
LSD 0.05	1.0	1.0	1.0	0.9

[X] V_1, Germplasm-01; V_2, Germplasm-02 and V_3, Germplasm-03
[Y] In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

Table 5. Effect of organic matter on crop duration related attributes of strawberry[Y]

Treatments[X]	Days to flower bud initiation	Days to flowering	Days to fruit setting	Days to fruit harvesting
OMc	72.9 a	77.9 a	83.8 a	111.6 a
OMcd	68.5 b	73.5 b	79.5 b	105.9 b
OMvc	59.4 d	64.3 d	69.2 d	93.7 d
OMpl	62.5 c	67.5 c	73.5 c	100.3 c
CV (%)	2.4	2.3	2.2	1.4
LSD 0.05	1.2	1.2	1.2	1.1

[X] OMc, Control; OMcd, Cowdung; OMvc, Vermicompost and OMpl, Poultry litre
[Y] In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

Table 6. Combined effect of strawberry germplasm and organic matters on crop duration related attributes[Y]

Treatments[X]	Days to flower bud initiation	Days to flowering	Days to fruit setting	Days to fruit harvesting
V_1OMc	64.8 f	69.8 f	75.8 e	101.2 f
V_1OMcd	60.2 g	65.2 g	71.2 f	96.0 g
V_1OMvc	51.0 j	55.8 j	60.8 i	82.4 i
V_1OMpl	54.6 i	59.4 i	65.4 h	90.2 h
V_2OMc	84.2 a	89.4 a	95.0 a	126.8 a
V_2OMcd	80.4 b	85.4 b	91.4 b	119.8 b
V_2OMvc	72.6 d	77.6 d	82.2 d	108.8 d
V_2OMpl	75.4 c	80.4 c	86.4 c	115.2 c
V_3OMc	69.6 e	74.6 e	80.6 d	106.8 e
V_3OMcd	64.8 f	69.8 f	75.8 e	101.8 f
V_3OMvc	54.6 i	59.6 i	64.6 h	89.8 g
V_3OMpl	57.6 h	62.6 h	68.6 g	95.6 h
CV (%)	2.4	2.3	2.2	1.4
LSD 0.05	2.0	2.1	2.1	1.8

[X] V_1, Germplasm-01; V_2, Germplasm-02 and V_3, Germplasm-03; OMc, Control; OMcd, Cowdung; OMvc, Vermicompost and OMpl, Poultry litre

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

4.11 Number of flower per plant

Number of flowers per plant was significantly varied with strawberry germplasm (Appendix VII). Number of flower was highest in Germplasm-01 (V_1; 20.0/plant) whereas lowest in Germplasm-02 (V_2; 13.2/plant) (Table 7). Atefe *et al.* (2012) also found that number of flower/plant varied significantly among the strawberry germplasm.

Different organic matters were significantly subjective on production of flowers per plant (Appendix VII). Vermicompost (OMvc) treated plants produced maximum number of flowers (22.7/plant) while minimum in control (OMc; 10.2/plant) (Table 8). Present study notified that exceedingly flower generated by vermicompost treated plants than other organic matter and which is alike to conception of Atefe *et al.* (2012) and Aracon *et al.* (2006a and 2006b). Vermicompost pretreated soil increases flower number in *Pisum sp.* and *Cicer sp*. (Sinha *et al.*, 2010) also in *Hibiscus esculentus* (Vanmathi and Selvakumari, 2012). Availability of plant growth influencing substances such as hormones and humates produced by microorganisms during vermicomposting, probably contributed to increased flowering (Arancon *et al.*, 2008). Humic acid from vermicompost substitution increased flower number of pepper, marigold and strawberry stated by Aracon *et al.* (2006a and 2006b). Strawberry plants from vermicompost treated soil had most and greatest number of flowers; reason may be explained as the nutritional factors. However, other factors, such as plant-growth-regulators and humates might have also been involved since all plants were supplied regularly with all required nutrients narrated by Hatamzadeh and Masouleh (2011). They found supreme number of flowers from vermicompost in Cymbidium.

Combined effect of different strawberry germplasm and organic matters showed statistically significant variation in number of flowers per plant (Appendix VII).

Maximum number of flowers was recorded from V1OMvc (28.6/plant) while minimum from V2OMc (8.4/plant) (Table 9).

4.12 Number of fruit per plant

Number of fruit per plant was exposed significant inequality with strawberry germplasm (Appendix VII). Maximum number of fruit was observed in Germplasm-01 (V_1; 16.5/plant) whereas minimum from Germplasm-02 (V_2; 10.3/plant) (Table 7). Strawberry plant produced significantly varied number of fruits/plant (Atefe *et al.*, 2012). Hossan *et al.* (2013) were also found that SG-1 (SAU Germplasm-01) produce maximum fruits/plant (26.0). Maximum number of fruits was offered from Line-3 (SAU Germplasm-01) (Nuruzzaman *et al.*, 2011).

Different organic matters significantly influenced on the production of fruit per plant (Appendix VII). Vermicompost treated plants produced maximum number of fruit (OMc; 19.2/plant) while minimum was obtained from control (OMc; 7.5/plant) (Table 8). Vermicompost treated strawberry plants bear more fruits (Atefe *et al.*, 2012) due to the greater supply of humic acid from vermicompost (Aracon *et al.*, 2006a and 2006b). Humic acid from vermicompost substitution increased fruit number in pepper, marigold and strawberry (Aracon *et al.*, 2006b), *Hibiscus esculentus* (Vanmathi and Selvakumari, 2012) also number of pod in *Pisum sp*. and *Cicer sp*. (Sinha *et al.*, 2010). Vermicompost has larger populations of bacteria, fungi and actinomycetes compared with conventional composts also outstanding physico-chemical and biological properties (Nair *et al.*, 1997) can increase number of fruit.

Combined effect of strawberry germplasm and organic matters showed statistically significant variation in number of fruit per plant (Appendix VII). Maximum number of fruit was recorded from V_1OMvc (24.4/plant) as minimum from was recorded from V_2OMc (6.2/plant) treatment (Table 9).

4.13 Fruit weight

Fruit weight was significantly influenced by strawberry germplasm (Appendix VII). V_1 (Germplasm-01) gave maximum fruit weight (14.1 g) while minimum fruit weight was obtained from Germplasm-02 (V_2; 10.7g) (Table 7). According to the present study, Germplasm-01 afforded the utmost result as similarly came across by Nuruzzaman *et al.* (2011) and Hossan *et al.* (2013). Hossan *et al.* (2013) found that fruit weight of Germplasm-01 was 14.6 g. Mean fruit weight of strawberry fruit varied among the cultivars (Atefe *et al.,* 2012) According to Morgan (2006), final size of berry dependent on number of achene's formed, which was determined by pollination and fertilization at the time of blooming.

Fruit weight varied significantly with application of different organic matters (Appendix VII). Maximum fruit weight of strawberry was found in vermicompost (OMvc; 14.4g) treatment followed by poultry litre (OMpl; 13.4 g) treatment whereas lowest in control (OMc; 10.4 g) (Table 8). In Bangladesh, fruit weight of strawberry was 13.2 g (Jamal Uddin *et al.*, 2012); 14.6 g (Hossan *et al.*, 2013) that was a precedent of the present study. Application of vermicompost increases fruit weight (Atefe *et al.*, 2012) in *Hibiscus esculentus* (Vanmathi and Selvakumari, 2012) and in *Solanum lycopersicum* (Singh *et al.*, 2010). Vermicompost has rich nutrient content and leading to increase uptake of NPK (Subbaiah *et al.*, 1985; Nair and Peter, 1990; Mamta *et al.* 2012) which help the plant to get adequate food and nutrients thus may help to enhance the fruit weight. Fruit weight of okra was increased due to the amplification of nutrient content through the application of vermicompost (Attarde *et al.*, 2012). Besides vermicompost reduces C:N ratio (Nagavallemma *et al.*, 2004) that can responsible for the maximum fruit weight.

Combination of germplasm and organic matters was significantly influenced the fruit weight of strawberry (Appendix VII). Maximum fruit weight was gained from V_1OMvc (16.3 g) that was statistically similar with V_1OMpl (15.5 g) whereas minimum was offered by V_2OMc (8.8 g) (Table 9).

4.14 Total fruit weight

It was observed from the results of the present experiment that strawberry germplasm significantly differed by means of the total fruit weight per plant (Appendix VII). Maximum total fruit weight of strawberry per plant was observed in Germplasm-01 (V_1; 244.9 g/plant) while minimum was found in Germplasm-02 (V_2; 115.0 g/plant) (Table 7). Germplasm-01 reacted as the best results in terms yield per plant i.e., total fruit weight per plant (Nuruzzaman *et al.*, 2011, Hossan *et al.*, 2013). Atefe *et al.*, (2012) also found a significant variation among the strawberry germplasm in case of yield.

Total fruit weight varied significantly with the application of different organic matters (Appendix VII). The total fruit weight of strawberry per plant was observed maximum in vermicompost (OMvc; 282.8 g/plant) while minimum was found in control (OMc; 78.4 g/plant) (Table 8). Application of vermicompost in substrate improved indexes of yield (Atefe *et al.*, 2012) in *Hibiscus esculentus* (Vanmathi and Selvakumari, 2012) and in *Solanum lycopersicum* (Singh *et al.*, 2010). Vermicompost has the rich nutrient content (Amir and Ishaq, 2011) and better supply of required nutrients to the soil for plants which have the potential for improving plant growth. Vermicompost increases mineral content, improves structure and texture, enhances aeration thereby reducing compaction also build up water retention capacity of soil thus promotes better root growth and nutrient absorption (Nourbakhsh, 2007) which help to better production. Vermicompost is a great source of macro and micronutrients (Bano and Kale, 1987). Besides it not only supplies a good amount of different nutrient elements but also contains beneficial microbes like nitrogen fixing bacteria, mycorrhizae and growth promoting substances (Barik *et al.*, 2006; Jayakumar and Natarajan, 2012 and Gosling *et al.*, 2006) for betterment of crops; protect fruit through reduction in plant pathogen nematode and other diseases of plant (Jayakumar and Natarajan, 2012), physiological disorders and fruit disease in strawberries (Singh *et al.*, 2008); these are minimizes the yield loss. Vermicompost furnishes maximum fruit size, more numbers of fruits/plant are the major reason for the maximum yield (Renuka and Ravishankar, 2001). Vermicompost is used to get better yield of diverse crops (Tomati *et al.*, 1983; Bano and Kale, 1987; Bhawalker, 1991) and in tomato (Bryan and Lance, 1991 and Federico *et al.*, 2007). Strawberry plant yielded 336.6 g/plant (Jamal Uddin *et al.*, 2012) and 379.8 g/plant (Hossan *et al.*, 2013). Addition of the vermicompost to soil significantly increases the yield (increased 32.7% total fruit yield and 58.6% marketable fruit yield with better quality per plant (Singh *et al.*, 2008; Joshi and Vig, 2010).

Treatment combinations of strawberry germplasm and organic matters significantly influenced the total fruit weight per plant (Appendix VII). The total fruit weight per plant was observed maximum in V_1OMvc (400.g g/plant) while minimum was found under V_2OMc (54.3 g/plant) (Table 9).

In case commercial cultivation on field, if strawberry plantlet are planted by maintaining 15 inches (38.1 cm) plant to plant and 36 inches (91.44 cm) row to row distance on raised bed (Strik, 1993) which could provide approximately 28735.0 plants/ha. From the present study, V_1 (Germplasm-01) would yield 7037.2 kg/ha while V_2 (Germplasm-02) would yield 3304.5 kg/ha. Vermicompost treatment would provided 8126.3 kg/ha whereas control would yield 2264.3 kg/ha. Strawberry germplasm in combination with organic maters, from the present study V_1OMvc would provide maximum yield (11496.9 kg/ha) while V_2OMc would offer least yield (1560.3 kg/ha). Therefore, Germplasm-01 (V_1) was the best among the germplasm whereas vermicompost was the best organic matter among the organic matters exploited on experiment for the commercial cultivation. Germplasm-01 (V_1) in combination with vermicompost (OMvc) represented as a most excellent combination in respect of yield in organically.

Table 7. Performance of strawberry germplasm related to yield [Y]

Treatments[X]	Number of flower	Number of fruit	Fruit weight (g)	Total fruit weight (g)
V_1	20.0 a	16.5 a	14.1 a	244.9 a
V_2	13.2 c	10.3 c	10.7 c	115.3 c
V_3	15.7 b	13.7 b	12.3 b	173.4 b
CV (%)	8.1	6.2	4.9	6.6
LSD 0.05	0.8	0.5	0.4	7.5

[X] V_1, Germplasm-01; V_2, Germplasm-02 and V_3, Germplasm-03
[Y] In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

Table 8. Effect of organic matter on strawberry germplasm related to yield [Y]

Treatments[X]	Number of flower	Number of fruit	Fruit weight (g)	Total fruit weight (g)
OMc	10.2 d	7.5 d	10.4 d	78.4 d
OMcd	13.4 c	11.0 c	11.3 c	126.6 c
OMvc	22.7 a	19.2 a	14.4 a	282.8 a
OMpl	18.8 b	16.3 b	13.4 b	223.7 b
CV (%)	8.1	6.2	4.9	6.6
LSD 0.05	1.0	0.6	0.4	8.6

[X] OMc, Control; OMcd, Cowdung; OMvc, Vermicompost and OMpl, Poultry litre
[Y] In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

Table 9. Combined effect of strawberry germplasm and organic matter related to yield [Y]

Treatments[X]	Number of flower	Number of fruit	Fruit weight (g)	Total fruit weight (g)
V_1OMc	11.8 gh	8.2 h	11.7 e	95.8 h
V_1OMcd	16.2 ef	13.4 f	12.9 c	173.4 e
V_1OMvc	28.6 a	24.4 a	16.3 a	400.1 a
V_1OMpl	23.4 b	20.0 b	15.5 a	310.6 b
V_2OMc	8.4 i	6.2 i	8.8 h	54.3 j
V_2OMcd	11.0 h	8.0 h	9.6 g	76.9 i
V_2OMvc	18.0 d	14.6 e	12.5 cd	182.9 e
V_2OMpl	15.2 f	12.4 fg	11.9 de	147.2 f
V_3OMc	10.4 h	8.0 h	10.7 f	85.2 hi
V_3OMcd	13.0 g	11.6 g	11.2 ef	129.6 g
V_3OMvc	21.0 c	18.6 c	14.3 b	265.5 c
V_3OMpl	17.0 de	16.6 d	12.9 c	213.4 d
CV (%)	8.1	6.2	4.9	6.6
LSD 0.05	1.7	1.1	0.8	14.9

[X] V_1, Germplasm-01; V_2, Germplasm-02 and V_3, Germplasm-03; OMc, Control; OMcd, Cowdung; OMvc, Vermicompost and OMpl, Poultry litre

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

4.15 Fruit length

Significant variation was recorded for fruit length among strawberry germplasm (Appendix VII). Results indicated that longest fruit length (35.5 mm) was recorded from V_1 (Germplasm-01) while V_2 (Germplasm-02) was the shortest (21.4 mm) one (Table 10). Hossan *et al.* (2013) also found that SG-1 (Germplasm-01) the best in terms of fruit length. They found that SG-1 provided 31.6 mm fruit length. Fruit length of strawberry cultivars varied from one cultivar to another (Atefe *et al.*, 2012). From present study, V1 gives the maximum fruit length and it may be due to the earlier flower bud initiation, flowering and fruiting also the maximum leaf area at the mature stage that enables V_1 enhanced carbohydrates concentration in crown and root at the of fruiting. Large size fruit intimately correlates with fruit weight and total fruit weight (Hortynski *et al.*, 1991).

Fruit length showed significant variation with different organic matters (Appendix VII). Longest fruit was found in vermicompost (OMvc; 32.4 mm) followed by poultry litre (OMpl; 30.6 mm) treatments and shortest in control (OMc; 24.2 mm) (Table 11). Vermicompost application increases the length in strawberry fruit (Atefe *et al.*, 2012) like *Hibiscus esculentus* (Vanmathi and Selvakumari, 2012). According to Edwards *et al.* (2004) vermicompost can have dramatic effects upon germination, growth, flowering, fruiting and yields of most of the crops, particularly fruits and vegetables. Current investigation posed that vermicompost accorded the best result in terms of fruit length of strawberry. Analogous outcome was traced incase of radish pod length (Lamo *et al.*, 2012); in watermelon, tomatoes, sweet pepper (Manatad and Jaquias, 2008) from vermicompost treatment. According to Morgan, (2006) the final size and shape of the berry dependent on the number of achene's formed, which is determined by pollination and fertilization at the time of blooming. Marketable yield, fruit number and fruit weight were associated with carbohydrate level in roots and its distribution. The increased fruit size, weight and earlier fruit production on plants appears to be related to increase carbohydrate concentration in crown and roots of strawberry plants. Adequate root starch help plants to simultaneously generate new feeder roots and to provide carbohydrates for flower bud initiation and fruit development. Early fruit growth depends greatly on root starch reserves for up to one month after planting (Mann, 1930; Nishizawa *et al.*, 1997; Nishizawa and Shishido, 1998). Vermicompost contains plant growth promoting substances like NAA, cytokinins, gibberlins (Giraddi, 1993) which can increase the leaf area of strawberry. Maximum leaf area enables to enhance CHO concentration in crown and roots at the time of fruiting, these increased CHO concentration was helped to produce larger fruit.

Combined effect of strawberry germplasm and organic matters in terms of fruit length of strawberry exposed significant variation (Appendix VII). It was remarked that longest fruit was found in V_1OMvc (41.1 mm) treatment whereas shortest was in V_2OMc (18.0 mm) treatment (Table 12).

4.16 Fruit diameter

Significant variation was recorded for fruit diameter among germplasm of strawberry (Appendix VII). Results indicated that maximum fruit diameter was recorded from Germplasm-01 (V_1; 26.5 mm) while minimum from Germplasm-02) (V_2; 18.8 mm) (Table 10). The final size and shape of the berry dependent on the number of achene’s formed which is determined by pollination and fertilization at the time of blooming (Morgan, 2006). Large size fruit closely correlates with the fruit weight and total fruit weight which is controlled by dimension of receptacle, number of achenes position of fruits on the inflorescence (Hortynski *et al.*, 1991).

Fruit diameter showed significant variation among organic matters (Appendix VII). Fruit diameter was highest in vermicompost (OMvc; 26.9 mm) followed by poultry litre (OMpl; 25.3 mm) treatments and lowest was observed in control (OM; 19.1 mm) (Table 11). Vermicompost treated strawberry plants furnished maximum diameter of fruit. Vermicompost boosted up the diameter of fruit in various crops like watermelon, tomatoes, sweet pepper (Manatad and Jaquias, 2008). It may be due to the beneficial effect on biochemical activities of the soil (Ali and Jahan, 2001).

Combined effect of strawberry germplasm and organic matters in terms of fruit diameter of strawberry exposed significant variation (Appendix VII). It was remarked that widest fruit was found in V_1OMvc (30.9 mm) whereas lowest in V_2OMc (15.1 mm) treatment (Table 12).

4.17 Percentage of brix

This research work exhibited distinct variations in percentage of brix of strawberry germplasm (Appendix VII). Maximum percentage of brix in fruits (8.3%) were found in V_1 (Germplasm-01) whereas minimum from Germplasm-02 (V_2; 6.3%) (Table 10). This finding is an agreement with Perkins-Veazie (1995). TSS content of strawberry fruits varies from 4-11% depending on cultivars and environment. Germplasm-01 gave an idea about ceiling percentage of brix among germplasm brought to bear in current study. Premier percentage of brix was acquired in Germplasm-01 (Nuruzzaman *et al.*, 2011; Hossan *et al.*, 2013).

Percentage of brix in strawberry fruits varied significantly with different organic matters (Appendix VII). Maximum percentage of brix was found in vermicompost (OMvc; 10.2%) treated strawberry plants while minimum was found in control (OMc; 4.1%) (Table 11). Strawberries grown in well-drained, fertile soil that is slightly acidic will yield more and be sweeter. Humic acid isolated from vermicompost enhance root elongation and formation of lateral roots that enhance the nutrient uptake by the plants by increasing the permeability of root cell membrane, stimulating root growth and increasing proliferation of root hairs. High content of humic acid in vermicompost (Theunissen *et al.*, 2010; Khye *et al.*, 2012) and vermicompost tended to have pH values near neutrality (Albanell *et al.*, 1988) i.e., vermicompost treatment decreases the soil pH, titratable acidity

(Federico *et al.*, 2007) and makes soil slightly acidic thus help to increases the sweetness of strawberry. Besides, use of compost also significantly increased levels of organic acids (malic and citric acid), sugars (fructose, glucose and total sugars) (Shiow and Shin-Shan, 2002) soluble solids and insoluble solids (Federico *et al.*, 2007). Macronutrients is also responsible for the sweetness of strawberry. Vermicomposts provided easy availability of macro and micronutrients (Singh *et al.*, 2010). Addition of vermicompost into soil helps to increase the density of microbes and also provides the vital macro nutrients viz., N, P, K, Ca, Mg (Amir and Ishaq, 2011; Giraddi, 1993) and micronutrients viz. Fe, Mo, Zn, Cu etc (Giraddi, 1993). Vermicompost was enriched with micronutrients such as Mg (0.46%), Fe (7563 ppm), Zn (278 ppm), Mn (475 ppm), Bo (34 ppm), Cu (27 ppm) (Gupta, 2003). Due to the availability of micronutrient, sweetness of strawberry was increased. Vermicompost is used as to get better quality of diverse crops. (Tomati *et al.*, 1983; Bano and Kale, 1987 and Bhawalker, 1991).

Combined effect of strawberry germplasm and organic matters significantly influenced the percentage of brix in strawberry fruit (Appendix VII). It was observed that maximum percentage of brix was provided by V_1OMvc (11.7%) followed by V_3OMvc (10.3%) whereas minimum from V_2OMc (3.3%) (Table 12).

Table 10. Performance of strawberry germplasm related to quality attributes[Y]

Treatments[X]	Fruit length (mm)	Fruit diameter (mm)	Brix %
V_1	35.5 a	26.5 a	8.3 a
V_2	21.4 c	18.8 c	6.3 C
V_3	28.1 b	23.9 b	7.5 b
CV (%)	3.2	2.1	3.62
LSD 0.05	0.6	0.3	0.2

[X] V_1, Germplasm-01; V_2, Germplasm-02 and V_3, Germplasm-03
[Y] In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

Table 11. Effect of organic matter on strawberry germplasm related to quality attributes[Y]

Treatments[X]	Fruit length (cm)	Fruit diameter (mm)	Brix %
OMc	24.2 d	19.1 d	4.1 d
OMcd	26.2 c	21.0 c	6.4 c
OMvc	32.4 a	26.9 a	10.2 a
OMpl	30.6 b	25.3 b	8.7 b
CV (%)	3.2	2.1	3.6
LSD 0.05	0.7	0.4	0.2

[X] OMc, Control; OMcd, Cowdung; OMvc, Vermicompost and OMpl, Poultry litre
[Y] In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

Table 12. Combined effect of strawberry germplasm and organic matters related to quality attributes[Y]

Treatments[X]	Fruit length (cm)	Fruit diameter (mm)	Brix (%)
V_1OMc	30.4 d	22.0 f	4.8 h
V_1OMcd	32.2 c	24.0 e	7.7 e
V_1OMvc	41.0 a	30.9 a	11.7 a
V_1OMpl	38.5 b	29.1 b	9.0 cd
V_2OMc	18.0 h	15.1 j	3.3 j
V_2OMcd	20.1 g	17.0 i	5.2 g
V_2OMvc	24.1 f	22.0 f	8.7 d
V_2OMpl	23.6 f	21.1 g	7.8 e
V_3OMc	24.2 f	20.0 h	4.3 i
V_3OMcd	26.3 e	21.9 f	6.2 f
V_3OMvc	32.0 c	27.7 c	10.3 b
V_3OMpl	29.7 d	25.8 d	9.2 c
CV (%)	3.2	2.1	3.6
LSD 0.05	1.1	0.6	0.3

[X] V_1, Germplasm-01; V_2, Germplasm-02 and V_3, Germplasm-03; OMc, Control; OMcd, Cowdung; OMvc, Vermicompost and OMpl, Poultry litre

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

4.18 Interpretation of correlation analysis and regression

From correlation analysis by using different growth, yield and quality attributes it was found that number of runner, number of stolon, number of leaves, plant height, days to flower bud initiation, days to flower bloom, days to fruit set and days to fruit harvest significantly correlated with each other at 1% level of significance. On the other hand, significant relationship was found among leaf area, number of flower, number of fruit, fruit weight, total fruit weight, fruit length, fruit diameter and percentage of brix (Appendix VIII). Leaf area had a significant positive relationship with yield and quality related parameters like number of flower (0.914**), number of fruit (0.912**), fruit weight (0.912**), total fruit weight (0.922**), fruit length (0.914**), fruit diameter (0.940**) and percentage of brix (0.888**) but significant negative correlation with days to flower bud initiation (-0.855**), days to flower bloom (-0.886**), days to fruit set (-0.893**), days to fruit harvest (-0.899**) at 1% level of significance (Appendix VIII). Leaf number had significant correlation with plant height (0.562**), days to flower bud initiation (0.431**) days to flower bloom (0.431**), days to fruit set (0.406**), days to fruit harvest (0.410**) at 1% level of significance. On the contrary, plant height had significant correlation with days to flower bud initiation (0.268*) days to flower bloom (0.266*), days to fruit set (0.274*), days to fruit harvest (0.298*) at 5% level of significance (Appendix VIII). Besides, days to flower bud initiation had negatively significant relationship with leaf area (-0.885**), number of flower (-0.783**), number of fruit (-0.820**), fruit weight (-0.856**), total fruit weight (-0.822**), fruit length (-0.925**), fruit diameter (-0.941**) and percentage of brix (-0.749**); days to flower blooming had negatively significant relationship with leaf area (-0.886**), number of flower (-0.784**), number of fruit (-0.821**), fruit weight (-0.858**), total fruit weight (-0.823**), fruit length (-0.927**), fruit diameter (-0.943**), and percentage of brix (-0.751**); days to first fruit set had significantly negatively correlated with leaf area (-0.893**), number of flower (-0.801**), number of fruit (-0.836**), fruit weight (-0.869**), total fruit weight (-0.838**), fruit length (-0.927**), fruit diameter (-0.949**) and percentage of brix (-0.769**); days to fruit harvesting was significantly negatively correlated with leaf area (-0.899**), number of flower (-0.807**), number of fruit (-

0.831**), fruit weight (-0.866**), total fruit weight (-0.835**), fruit length (-0.935**), fruit diameter (-0.951**) and percentage of brix (-0.764**) at 1% level of significance (Appendix VIII).

In the scatter plot, it was observed that leaf area had a close relation with fruit weight and leaf area and percentage of brix represented in a straight line (Figure 16 and Figure 17). The gradient of this line for leaf area with fruit weight was 0.1455 which expressed that 0.1455 g fruit weight will be increased with the increase of 1 cm^2 in leaf area. The predicted fruit weight from the linear regression for 40 cm^2 leaf area will be (0.1455 × 40 + 4.24 = 10.06) 10.06 g whereas 10.7 g the fruit weight was found for the 40.2 cm^2 leaf area from the experiment (Figure 16). Similarly, the gradient line for leaf area with percentage of brix was 0.1609 which expressed that 0.1609% brix will be increased with the increase of 1 cm^2 in leaf area. The predicted percentage of brix for 40 cm^2 leaf areas will be (0.1609 × 40 – 1.6117 = 4.8243) 4.8243% whereas 4.3% brix was found for the 40.2 cm^2 leaf areas (Figure 17).

Correlation analysis involves a method to find out the direct, indirect and no relationship among the characters. Correlation coefficients indicated an association among the characters (Shekhavat *et al*., 2005). Thus, these characters are important yield attributes to be reckoned in the selection criteria for improvement. Similarly, several experiments were also conducted for the correlation analysis (Oad *et al*., 2002; Rana and Chauhan, 2003).

The correlation study suggested that characters like runner number, stolon number, plant height and leaves number showed no relation with fruit weight i.e. increase of runner number, stolon number, plant height and leaves number does not reflects yield. But runner number, stolon number, plant height and leaves number is significantly related with days to flower bud initiation, days to flower bloom, days to fruit set and days to fruit harvesting i.e., increases runner number, stolon number, plant height and leaves number reflects on days to flower bud initiation, days to flower bloom, days to fruit set and days to fruit harvesting. On the other hand, days to flower bud initiation, days to flower bloom, days to fruit set and days to fruit harvest were negatively correlated with number of flower, number of fruit, fruit weight, total fruit weight, fruit length, fruit diameter and percentage of brix that means late production gives the lowest yield with less quality. From the experiment V_2 provided maximum number of runner, number of stolon, number of leaves and plant height on the contrary V_2 provided maximum days to flower bud initiation, days to flower bloom, days to fruit set and days to fruit harvest with lowest yield and awful quality. Similarly it was also found from organic matters treated strawberry plants. Kumar and Muthukrishnan (1979) reported that days to flowering and harvesting (Dhall *et al*., 2000) had negative relationship with the yield per plant.

Leaf area had significant positive relationship with number of flowers, number of fruits, fruit weight, total fruit weight, fruit length, fruit diameter and percentage of brix i.e., increases of leaf area positively reflects on the yield and quality contributing characters of strawberry. That denotes, increases the leaf area would increase the number of flowers, number of fruits, fruit weight, total fruit weight, fruit length, fruit diameter and percentage of brix. It was found from the experiment that V_1 and vermicompost treated plants provided the maximum leaf area. Maximum number of flowers, number of fruits, fruit weight, total fruit weight, fruit length, fruit diameter and percentage of brix were also found from V_1 and vermicompost treated plants. So it can be stated that leaf area had a significant positive relationship with the yield and quality contributing characters. Path analysis of the present study revealed that number of fruits per plant, individual fruit weight, fruit length, fruit diameter significantly related with yield per plant i.e., direct effect in increasing or decreasing fruit yield (Vadivel and Bapu, 1990). The results were in agreement with the general statement that plants those producing maximum number of fruits per plant and higher individual fruit weight are generally observed to be high yielder (Burio *et al.*, 2004; Singh and Singh, 1980). Subbaiah *et al.* (2003) reported that all the traits except days to flowering, plant height were positively related with yield. Similar correlation study was also conducted on brinjal by Nalini *et al.* (2009). The increased weight of berries with nutrient application might had first improved the internal nutritive condition of plant leading to increased growth and vigor associated with photosynthesis and translocation of assimilates in the fruits. Despite fewer leaves, the total photosynthetic area of leaf blades was much larger in the large leaved plants. The thickness of their petioles and flower stalks was greater, yet insignificantly higher. The obtained results confirm the previous statement that large-fruited clones show the effects of gigantism which are expressed in larger cells, thicker and higher petioles and flower stalks, bigger leaves, larger photosynthetic area and finally, greater fruit weight. All these traits can be used as indices in the selection work of large-fruited cultivars (Hortynski, 1991).

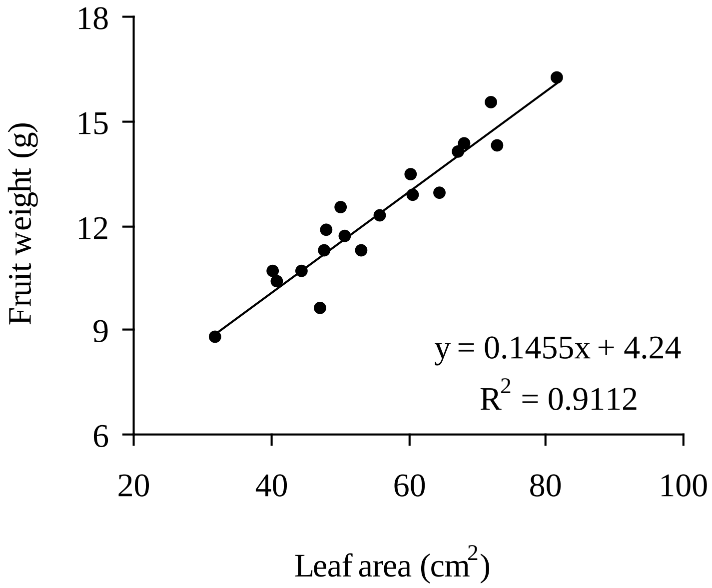

Figure 16. Regression line between the variables of leaf area and fruit weight

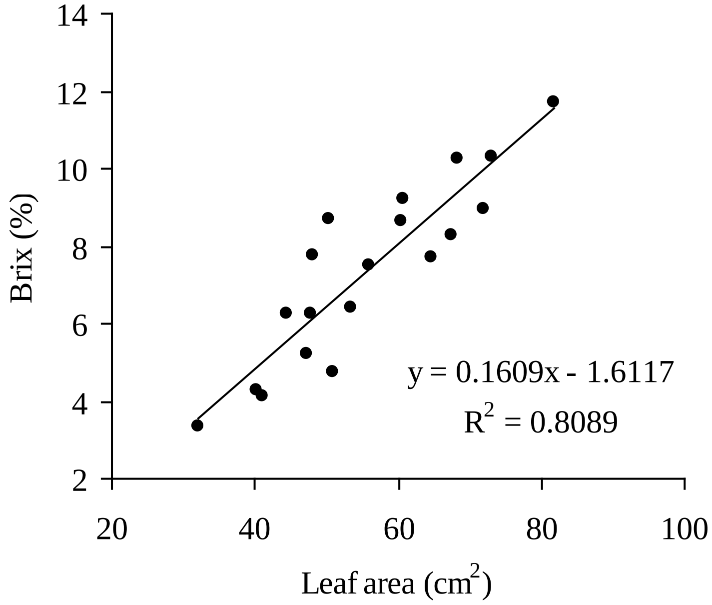

Figure 17. Regression line between the variables of leaf area and percentage of brix

CHAPTER V

SUMMARY AND CONCLUSION

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5.1 Summary

Strawberry is a sweet, fleshy and extremely delicious berry, which fills our body with vitamins, micro and macro elements lost during winter because it is a major source of minerals for human body besides this it contains full vitamin complex: vitamin C, B5, magnesium, potassium, calcium, zinc, manganese, phosphorus, copper and folic acid. Strawberry cultivation is gaining popularity in Bangladesh and its farmers are making good profit by producing it. Its cultivation begun on a small scale in Bangladesh but now cultivation area is increasing rapidly whereas Bangladesh has lack (or very little) of information and technology thus can provide as a guideline for the profitable production.

In order to produce strawberry under organic condition with low cost for Bangladeshi farmers, a research was conducted to inspect the growth and yield of strawberry germplasm to organic matters at Horticultural farm, Sher-e-Bangla Agricultural University, Dhaka during period from June 2011 to March 2012. Two factorial experiment included strawberry germplasm viz. V_1 (Germplasm-01), V_2 (Germplasm-02), V_3 (Germplasm-03) and organic matters viz. OMc (Control), OMcd (Cowdung), OMvc (Vermicompost), OMpl (Poultry Litre) was outlined in Complete Randomized Design (CRD) with five replications.

Collected data were statistically analyzed for the evaluation of treatments for the detection of the best strawberry germplasm, the best organic matter and the best amalgamation. Summery of the results and conclusion have been described in this chapter.

Looking upon the germplasm characteristics, utmost number of runners (5.5), stolons (8.9) and leaves (42.9) was generated by V_2 (Germplasm-02) whereas minimum number of runners (2.5), stolons (3.1) and leaves (20.6) was produced by V_1 (Germplasm-01) at mature stage.

On the other hand, observing the organic matters treated plants, OMvc (vermicompost treated plants) generated maximum number of runners (5.5), stolons (7.6) and leaves (38.3) while OMc (control) produced minimum number of runners (2.4), stolons (3.2) and leaves (22.3) at mature stage. In amalgamation of strawberry germplasm and organic matters, V_2OMvc treatment generated utmost number of runners (7.8), stolons (12.2) and leaves (54.2); V_1OMc treatment produced lowest number of runners (1.8), stolons (1.6) and leaves (13.4) mature stage.

Monitoring leaf area among germplasm, maximum leaf area (67.3 cm^2) was found in V_1 (Germplasm-01) whereas minimum from V_2 (Germplasm-02) (44.5 cm^2) at mature stage. In case of organic matters, vermicompost provided maximum leaf area (68.3 cm^2) whereas minimum from control (41.1 cm^2) at mature stage. In amalgamation, V_1OMvc provided maximum leaf area (81.7 cm^2) while minimum from V_2OMc (32.1 cm^2) at mature stage.

In case of plant height, V_2 (Germplasm-02) was the tallest plant (21.2 cm) and V_1 (Germplasm-01) was the smallest plant (17.3 cm) at mature stage. Conversely, poultry litre and control were marked as tallest (22.9 cm) and smallest (15.7 cm) plant respectively at mature stage. Alternatively, V_2OMpl treatment combination offered tallest plant and V_1OMc treatment combination presented smallest plant at mature stage.

In strawberry germplasm, V_1 (Germplasm-01) had taken shortest period for first flower bud initiation (57.7 days), flowering (62.6 days), fruit set (68.3 days) and fruit harvesting (92.5 days) whereas V_2 (Germplasm-02) had taken longest period for first flower bud initiation (78.2 days), flowering (83.2 days), fruit set (88.8 days) and fruit harvesting (117.7 days). Regarding on organic matters, vermicompost treated strawberry germplasm had taken less time for first flower bud initiation (59.4 days), flowering (64.3 days), fruit set (69.2 days) and fruit harvesting (93.7 days) whereas longest period from control for first flower bud initiation (72.9 days), flowering (77.9 days), fruit set (83.8 days) and fruit harvesting (111.6 days). In amalgamation, V_1OMvc was taken earliest period for first flower bud initiation (51.0 days), flowering (55.8 days), fruit set (60.8 days) and fruit harvesting (82.4 days) whilst V_2OMc had taken delayed period for first flower bud initiation (84.2 days), flowering (89.4 days fruit set (95.0 days) and fruit harvesting (126.8 days).

Considering the germplasm, V_1 (Germplasm-01) produced utmost number of flowers (20.0/plant) and fruits (16.5/plant) while least number of flowers (13.2/plant) and fruit (10.3/plant) were produced by V_2 (Germplasm-02). Concerning organic matters, vermicompost provided highest number of flowers (22.7/plant) and fruits (19.2/plant) even as minimum flowers (10.2/plant) and fruits (7.2/plant) from control. Conversely, best combination was V_1OMvc (as it brought into being 28.6 flowers/plant and 24.4 fruits/plant) and worst combination was V_2OMc (as it generated 8.4 flowers/plant and 6.2 fruits/plant).

Among the strawberry germplasm, premier fruit weight (14.1 g of a single fruit) and total fruit weight (244.9 g/plant) were achieved from V_1 (Germplasm-01) as lesser amount of fruit weight (10.7 g of a single fruit) and total fruit weight (115.0 g/plant) were got from V_2 (Germplasm-02). Vermicompost stood for highest fruit weight (14.4 g of a single fruit) and total fruit weight (282.8 g/plant) conversely control represented for least fruit weight (9.9 g of a single fruit) and total fruit weight (78.4 g/plant). In case of combination, V_1OMvc corresponded to topmost results in terms of fruit weight (16.3 g of a single fruit) and total fruit weight (400.1 g/plant) whereas lowest results were acquired from V_2OMc (8.8 g of a single fruit and total fruit weight 54.3 g/plant).

Regarding strawberry germplasm, V_1 (Germplasm-01) provided longest (35.5 mm) and widest (26.5 mm) fruit whereas V_2 (Germplasm-02) provided shortest fruit (21.4 mm) with minimum diameter (18.8 mm). Organic matters concerning, vermicompost put forwarded longest (32.4 mm) and widest (26.9 mm) fruit while control proposed shortest fruit (24.2 mm) with minimum diameter (19.1 mm). In amalgamation of strawberry germplasm with organic matters, V_1OMvc produced longest (41.1 mm) and widest (30.9 mm) fruit and V_2OMc brought into being shortest fruit (18.0 mm) with least diameter (15.1 mm).

Strawberry germplasm, was maximum brix was in V_1 (Germplasm-01) (8.3%) and minimum in V_2 (Germplasm-02) (6.3%). Regarding organic matters, maximum brix was in vermicompost (10.2%) and minimum in control (4.1%). Conversely, in combination of germplasm with organic matters, maximum brix was put forwarded by V_1OMvc (11.7%) while minimum from V_2OMc (3.3%).

In correlation study, it was found that number of runner, number of stolon, number of leaf, plant height and percentage of brix has significant positive correlation with each other also leaf area, number of flower, number of fruit, fruit weight, total fruit weight, fruit length, fruit diameter and percentage of brix significantly positively correlated with each other. On the other hand, leaf area, days to flower bud initiation, flowering, fruiting and harvesting were negatively correlated with each other whereas days to flower bud initiation, flowering, fruiting, harvesting, number of flower, number of fruit, fruit weight, total fruit weight, fruit length, fruit diameter and percentage of brix were negatively correlated with each other.

5.2 Conclusion

Regard as the above results it can be concluded that V_1 (Germplasm-01) stood for early bud initiation, flowering, fruiting and harvesting also greatest leaf area, utmost number of flowers and fruits. Weight of fruit, total fruit weight per plant, fruit length, fruit diameter and percentage of brix were premier in V_1. V_2 (Germplasm-02) stands for the best germplasm for new plantlet production. On the other hand, vermicompost performs as excellent among the organic matters used in terms of all parameters (except plant height). Besides the combination, Germplasm-01 treated with vermicompost performed as the best combination. Regarding correlation studies, it can be easily stated that growth parameter leaf area was significantly positively correlated with all of yield and quality parameters. Thus, help to make the decision that increasing leaf area of strawberry plant increases the yield and quality of strawberry. Looking upon the above circumstances it can easily articulated that Germplasm-01 was the most outstanding germplasm and vermicompost was the most excellent organic matters for growth, yield and quality attributes of strawberry. Vermicompost was produced the sweetest strawberry.

5.3 Recommendation

Based on the findings of the research, recommendations are:

- ® Grmplasms-01 could be recommended for production in farmer's field
- ® To use of to vermicompost as organic matter to improve the sweetness of strawberry

5.4 Suggestions

Further research in the subsequent areas may be suggested:

- ® Scope to improve seedling production (through tissue culture) and management
- ® Solve short low temperature period and rapid high temperature during fruit ripening
- ® Improvement of the post harvest quality

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APPENDICES

APPENDICES

Appendix I. Analysis of variance of the data on number of runner at different DAT of strawberry

Source of Variation	Degrees of freedom (df)	Mean Square for Number of Runner		
		40 DAT	50 DAT	60 DAT
Factor A	2	33.6*	43.5*	38.5*
Factor B	3	11.0*	16.6*	28.9*
Interaction (A x B)	6	1.1*	1.9*	1.4*
Error	48	0.3	0.3	0.4

*: Significant at 0.05 level of probability;

Appendix II. Analysis of variance of the data on number of stolon at different DAT of strawberry

Source of Variation	Degrees of freedom (df)	Mean Square for Number of Stolon		
		40 DAT	50 DAT	60 DAT
Factor A	2	66.1*	117.8*	187.5*
Factor B	3	16.6*	40.6*	60.5*
Interaction (A x B)	6	1.2*	2.3*	2.9*
Error	48	0.2	0.8	1.3

*: Significant at 0.05 level of probability;

Appendix III. Analysis of variance of the data on number of leaf at different DAT of strawberry

Source of Variation	Degrees of freedom (df)	Mean Square for Number of Leaf				
		40 DAT	50 DAT	60 DAT	70 DAT	80 DAT
Factor A	2	2032.2*	2223.8*	2370.7*	2529.8*	2613.8*
Factor B	3	406.8*	507.4*	561.9*	658.7*	718.5*
Interaction (A x B)	6	27.6*	30.7*	44.9*	48.7*	50.8*
Error	48	5.8	5.8	7.3	11.0	11.3

*: Significant at 0.05 level of probability

Appendix IV. Analysis of variance of the data on leaf area at different DAT of strawberry

Source of Variation	Degrees of freedom (df)	Mean Square for Leaf Area				
		30 DAT	40 DAT	50 DAT	60 DAT	70 DAT
Factor A	2	291.4*	866.8*	2132.5*	2539.5*	2616.7*
Factor B	3	620.3*	700.6*	1089.1*	1905.3*	2005.8*
Interaction (A x B)	6	36.3*	29.8*	57.0*	108.0*	126.1*
Error	48	2.1	2.5	1.0	1.5	0.9

*: Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data on plant height at different DAT of strawberry

Source of Variation	Degrees of freedom (df)	Mean Square for Plant Height				
		30 DAT	40 DAT	50 DAT	60 DAT	70 DAT
Factor A	2	67.8*	79.3*	82.2*	87.1*	88.6*
Factor B	3	93.0*	111.4*	125.0*	140.*	144.2*
Interaction (A x B)	6	0.6*	0.7*	0.6*	0.6*	0.6*
Error	48	0.2	0.2	0.2	0.2	0.1

*: Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data on performance of different strawberry germplasms related to yield

Source of Variation	Degrees of freedom (df)	Mean Square rof			
		Days to flower bud initiation	Days to flower blooming	Days to fruit setting	Days to fruit harvesting
Factor A	2	2361.7*	2390.5*	2441.1*	3461.2*
Factor B	3	543.4*	554.6*	622.9*	881.6*
Interaction (A x B)	6	3.6*	3.3*	3.5*	2.3*
Error	48	2.6	2.6	2.7	2.1

*: Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data on performance of different strawberry germplasms related to yield

Source of Variation	Degrees of freedom (df)	Mean Square for						
		Number of flower	Number of fruit	Fruit weight	Total fruit weight	Fruit length	Fruit diameter	Percentage of brix
Factor A	2	239.7*	192.8*	58.1*	84317.3*	991.0*	306.0*	21.3*
Factor B	3	466.3*	415.8*	51.4*	128156.6*	216.7*	198.9*	106.8*
Interaction (A x B)	6	14.2*	15.0*	0.6*	7843.7*	7.2*	1.3*	1.3*
Error	48	1.7	0.7	0.4	137.8	0.8	0.2	0.071

*: Significant at 0.05 level of probability

Appendix VIII. Correlations among growth, yield and quality attributes of strawberry germplasms

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Pearson Correlation	1	.852**	.850**	0.036	.588**	0.221	0.219	0.191	0.192	0.24	0.232	0.091	0.165	-0.22	0.004	.400**
	Sig. (2-tailed)		0	0	0.787	0	0.09	0.093	0.143	0.143	0.065	0.075	0.491	0.208	0.091	0.978	0.002
	N		60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
2	Pearson Correlation		1	.855**	-0.13	.576**	.395**	.392**	.366**	.382**	0.059	0.059	-0.062	0.011	-.355**	-0.171	0.22
	Sig. (2-tailed)			0	0.307	0	0.002	0.002	0.004	0.003	0.654	0.654	0.638	0.931	0.005	0.19	0.092
	N			60	60	60	60	60	60	60	60	60	60	60	60	60	60
3	Pearson Correlation			1	-0.18	.562**	.431**	.431**	.406**	.410**	0.046	0.036	-0.099	-0.026	-.424**	-0.214	0.197
	Sig. (2-tailed)				0.168	0	0.001	0.001	0.001	0.001	0.727	0.783	0.454	0.841	0.001	0.101	0.132
	N				60	60	60	60	60	60	60	60	60	60	60	60	60
4	Pearson Correlation				1	-0.08	-.885**	-.886**	-.893**	-.899**	.914**	.912**	.912**	.922**	.914**	.940**	.888**
	Sig. (2-tailed)					0.569	0	0	0	0	0	0	0	0	0	0	0
	N					60	60	60	60	60	60	60	60	60	60	60	60
5	Pearson Correlation					1	.268*	.266*	.274*	.298*	0.014	0.055	-0.066	-0.019	-0.243	-0.11	0.157
	Sig. (2-tailed)						0.038	0.04	0.034	0.021	0.918	0.675	0.615	0.887	0.061	0.403	0.231
	N						60	60	60	60	60	60	60	60	60	60	60
6	Pearson Correlation						1	1.000**	.998**	.986**	-.783**	-.820**	-.856**	-.822**	-.925**	-.941**	-.749**
	Sig. (2-tailed)							0	0	0	0	0	0	0	0	0	0
	N							60	60	60	60	60	60	60	60	60	60
7	Pearson Correlation							1	.998**	.986**	-.784**	-.821**	-.858**	-.823**	-.927**	-.943**	-.751**
	Sig. (2-tailed)								0	0	0	0	0	0	0	0	0
	N								60	60	60	60	60	60	60	60	60
8	Pearson Correlation								1	.988**	-.801**	-.836**	-.869**	-.838**	-.927**	-.949**	-.769**
	Sig. (2-tailed)									0	0	0	0	0	0	0	0
	N									60	60	60	60	60	60	60	60

**. Correlation is significant at the 0.01 level (2-tailed); *. Correlation is significant at the 0.05 level (2-tailed)

1: Number of Runner; 2: Number of Stolon; 3: Number of Leaf; 4: Leaf Area; 5: Plant Height; 6: Days to Flower Bud Initiation; 7: Days to Flower Bloom; 8: Days to Fruit Set; 9: Days to Fruit Harvesting; 10; Number of Flower; 11: Number of Fruit; 12: Fruit Weight; 13: Total Fruit Weight; 14: Fruit Length; 15: Fruit Diameter; 16: Percentage of Brix

Continued

Appendix VIII. Correlations among growth, yield and quality attributes of strawberry germplasms (Continued)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
9	Pearson Correlation									1	-.807**	-.831**	-.866**	-.835**	-.935**	-.951**	-.764**
	Sig. (2-tailed)										0	0	0	0	0	0	0
	N										60	60	60	60	60	60	60
10	Pearson Correlation										1	.972**	.906**	.968**	.833**	.905**	.930**
	Sig. (2-tailed)											0	0	0	0	0	0
	N											60	60	60	60	60	60
11	Pearson Correlation											1	.910**	.985**	.831**	.926**	.947**
	Sig. (2-tailed)												0	0	0	0	0
	N												60	60	60	60	60
12	Pearson Correlation												1	.944**	.918**	.947**	.872**
	Sig. (2-tailed)													0	0	0	0
	N													60	60	60	60
13	Pearson Correlation													1	.874**	.933**	.917**
	Sig. (2-tailed)														0	0	0
	N														60	60	60
14	Pearson Correlation														1	.941**	.735**
	Sig. (2-tailed)															0	0
	N															60	60
15	Pearson Correlation															1	.876**
	Sig. (2-tailed)																0
	N																60
16	Pearson																1

Correlation
Sig. (2-tailed)
N

**. Correlation is significant at the 0.01 level (2-tailed); *. Correlation is significant at the 0.05 level (2-tailed)

1: Number of Runner; 2: Number of Stolon; 3: Number of Leaf; 4: Leaf Area; 5: Plant Height; 6: Days to Flower Bud Initiation; 7: Days to Flower Bloom; 8: Days to Fruit Set; 9: Days to Fruit Harvesting; 10; Number of Flower; 11: Number of Fruit; 12: Fruit Weight; 13: Total Fruit Weight; 14: Fruit Length; 15: Fruit Diameter; 16: Percentage of Brix