GENETIC ANALYSIS OF SEGREGATING GENERATION OF TOMATILLO (*Physalis ixocarpa* Brot.) GENOTYPES BASED ON THEIR YIELD AND YIELD CONTRIBUTING CHARACTERS

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CERTIFICATE

This is to certify that the thesis entitled, " *Genetic Analysis of Segregating Generation of Tomatillo (Physalis ixocarpa brot.) Genotypes Based On Their Yield and Yield Contributing Characters " submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE in GENETICS AND PLANT BREEDING,*** *embodies the result of a piece of bona fide research work carried out by K. M. Diba Farah Toma, Registration No. 18-09274 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: December, 2020
Place: Dhaka, Bangladesh

Prof. Dr. Naheed Zeba
Supervisor

Dedicated to

My Parents and Husband

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SOME COMMONLY USED ABBREVIATIONS

Full word	Abbreviations
Agricultural	*Agril.*
Agriculture	*Agric.*
And others	*et al.*
Canonical Variate Analysis	CVA
Centimeter	cm.
Coefficient of Variation	CV
Days after Transplanting	DAT
Days to First Flowering	DFF
Degree Celsius	^{o}C
Department of Genetics and Plant Breeding	GEPB
Etcetera	etc.
Food and Agricultural Organization	FAO
Fruit Weight	FW
Genotypic Coefficient of Variation	GCV
Genetic Advance	GA
Gram	g
Hectare	ha.
Horticulture	*Hort.*
International	*Intl*.
Journal	*J*.
Kilogram	kg
Least Significant Difference	lsd
Milligram	mg
Muriate of Potash	MOP
Number of Branches per Plant	NOB
Number of Cluster per Plant	CPP
Number of Fruits per Cluster	FPC
Number of Fruits per Plant	FPP
Phenotypic Coefficient of Variation	PCV
Plant Height	PH
Principle Component Analysis	PCA
Randomized Complete Block Design	RCBD
Sher-e-Bangla Agricultural University	SAU
Ton/Hectare	ton/ha
Triple Super Phosphate	TSP
Yield per Hectare	YH
Yield Per Plant	YPP

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GENETIC ANALYSIS OF SEGREGATING GENERATION OF TOMATILLO (*Physalis ixocarpa* Brot.) GENOTYPES BASED ON THEIR YIELD AND YIELD CONTRIBUTING CHARACTERS

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ABSTRACT

An experiment was conducted at experimental field, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2019 to March 2020 to analyze the genetic diversity of tomatillo genotypes. Ten genotypes were used for the study. G_{12} showed the highest yield among all other genotypes. Lowest DFF were found in G_7. G_{10} gave the best result on number of fruits per plant among all other genotypes. Highest fruit weight found in G_7. In case of DFF, number of CPP, FPP, FL, SPF and FW showed higher influence of environment for the expression of these characters. On the other hand, LL, LW, BPP, and FYPP showed least difference in phenotypic and genotypic variance suggesting additive gene action for the expression of the characters. Most of the characters under the present study exhibit the highest value of heritability. In general, most of the characters showed the genotypic correlation coefficient were higher than the corresponding phenotypic correlation coefficient suggesting a strong inherent association between the characters under study. Significant positive correlation with yield was found in DFF, PH, CPP, FPP, FW and FD. Path coefficient analysis showed that single fruit weight had the positive correlation with fruit yield per plant. Coherently, this trait contributes to the yield through direct effect (0.547) indicating selection will be judicious and more effective for these characters in future breeding program. Selection should be applied for desired characters such as lowest days to first flowering in G_7, increased number of

fruits per plant in G10, highest fruit weight in G7 , fruit diameter and fruit length to develop high yielding varieties.

CHAPTER I
INTRODUCTION

Tomatillo or husk tomato is a herbaceous annual with indeterminate growth habit. It is native to Central America where it is claimed that there is no acceptable substitute in making green sauce or salsa verde. Three species of the genus *Physalis* have edible fruit with higher contents of protein, ascorbic acid, nicotinic acid and solids than tomato (Yamaguchi, 1983). *P. peruviana* L. (cape gooseberry, uchuba) and *P. pruinosa* L. (ground cherry, husk tomato) are used as juice and jam fruit; *P. ixocarpa* is used as a vegetable or for sauces. The tomatillo (*P. ixocarpa* Brot.) is a fruit vegetable and belongs to the family Solanaceae bearing round or spherical and green or green-purple fruit.The basic chromosome number of Tomatillo is n=12 and most species are diploid (Menzel, 1951). The tomatillo fruit is surrounded by an inedible, paper-like husk formed from the calyx (Waterfall, 1967). From outside it looks like a common weed of our country "Foshka Begun". At maturity stage, it fills the husk and can split it open by harvest. The husk turns brown gradually. The freshness and greenness of the husk are quality criteria. Inside the husk, tomatillo fruits look same as green tomato but inside the fruit it is compact, firm and bright green. From inside, it has juicy pulp and tiny seeds. Green and Purple color and tart flavor are the main culinary contributions of tomatillo fruit. Tomatillos originated in Mexico and distributed in India, Australia, South Africa and Kenya. About ten years ago the crop began to be industrialized in Mexico and agro-industries are currently estimated to process 600 tonnes per year (FAO, 2015). Recently it was also introduced in Bangladesh by the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University in 2013. In this research tomatillo was evaluated and compared with a similar species tomato (*Solanum lycopersicum* L.). Tomatillo contain Energy 32 Kcal, Carbohydrates 5.84 g, Protein 0.96 g, Total Fat 1.02 g, Dietary Fiber 1.9g, Vitamins (Folate7 µg, Niacin 1.850 mg, Pyridoxine 0.056 mg, Thiamin 0.044 mg, Vitamin A 114 IU, Vitamin C 11.7 mg, Vitamin E 0.38 mg, Vitamin K 10.1 µg), Sodium 1 mg, Potassium 268 mg, Calcium 7 mg, Copper 0.079 mg, Iron 0.62 mg, Magnesium 20 mg, Manganese 0.153 mg, Phosphorus 39 mg, Selenium 0.5 µg, Zinc 0.22 mg, Carotene-ß 63 µg, Carotene-α 10 µg, Luteinzeaxanthin 467 µg (Yamaguchi, 1983). A recently-discovered set of naturally occurring phytochemical compounds called withanolides, such as Ixocarpalactone-A, is one of the compounds in tomatillo found to be not only antibacterial, but also a natural cancer fighter. Traditional healers in India have been known to prescribe foods containing these compounds as a tonic for arthritis and other musculoskeletal conditions, even if they didn't know why it worked .Tomatillo can be used as cooking vegetables, fried vegetables, salad and in processing industries like sauces, pickles etc. Mexican salsa is very popular in Mexico, USA and other adjacent countries. The total volume of table sauces, pickled, and other items processed in Louisiana is around 22,277,000 kg with an estimated value of $58,427,000. Table sauces accounted for approximately 77% of the total volume (Broussard and Hinson, 1988*).* *P. ixocarpa* is gaining ground as a new crop in California due to the increased popularity of Mexican food in the United States (Quiros, 1984). The tomatillo or husk-tomato (*P. philadelphica*) is a Solanaceous plant cultivated in Mexico and Guatemala and originating from Mesoamerica. Various archaeological findings show that its use in the diet of the Mexican population dates back to pre-Columbian times. Indeed, vestiges of *Physalis sp.* used as food have been found in excavations in the valley of Tehuacán (900 BC–AD 1540). In pre-Hispanic times in Mexico, it was preferred far more than the tomato (*Lycopersicon sp.*). However, this preference has not been maintained, except in the rural environment where, in addition to the persistence of old eating habits, the tomato's greater resistance to rot is still valued. Possibly because of the fruit's colourful appearance and because there are ways of eating it which are independent of the chili *(Capsicum sp.),* the tomato achieved greater acceptance outside Mesoamerica and *Physalis sp.* was marginalized, or its cultivation was discontinued, as happened in Spain. It is relevant to note that only in central Mexico is the fruit of *Lycopersicon sp.* known chiefly as "jitotomate", since in other parts of the country and in Central and South America it is called "tomate". *P. philadelphica* was domesticated in Mexico from where it was taken to Europe and other parts of the world; its introduction into Spain has been well documented. Indeed, it is believed that this species originated in central Mexico where, at present, both wild and domesticated populations may be found.The name "tomato" derives from the Nahuatl "tomatl"; this word is a generic one for globose fruits or berries which have many seeds, watery flesh and which are sometimes enclosed in a membrane. Of the great number of species of the genus Physalis, very few are used for their fruit. *P. peruviana* L. has been grown in Peru since pre-Columbian times. The tomatillo is also used in sauces with green chili, mainly to lessen its hot flavour. The fruit of the tomatillo is used cooked, or even raw, to prepare purees or minced meat dishes which are used as a base for chili sauces known generically as salsa verde (green sauce); they can be used to accompany prepared dishes or else be used as ingredients in various stews. Furthermore, numerous medicinal properties are attributed to it. Information regarding genetic variability, heritability and genetic advance among different genotypes of tomatillo is very important for their improvement. Analysis of genetic variability, heritability and genetic advance of agro-morphogenic traits are useful in selecting genetically diverse parental combinations, dependable classification of accessions and for intra and inter-genus crossing. Considering the above facts, the present study was therefore undertaken,

- to evaluate the performance of yield and yield contributing traits of tomatillo
- to recognize the genetic variability among various tomatillo genotypes,
- to study the genetic relationship between yield and yield contributing characters among the various tomatillo genotypes,
- To select parental materials for future breeding package.

CHAPTER II
REVIEW OF LITERATURE

High degree of genetic variability in tomatillo cultivars made demand for more research. There are a number of cultivated and wild species of tomatillo which show some similarities and also some dissimilarity. But scientists from around the world are now noticing the wild tomatillo, and wondering if it might provide a major medicinal breakthrough. They have found compounds from the wild tomatillo that have strong anticancer properties against breast cancer, skin cancer, thyroid cancer and brain cancer in their early studies (Pearce, 2012).The need for the maintenance of wild species, local varieties and outdated genotypes in gene banks is evident, which have become an important form of gene maintenance. However, in order to determine the extent of genetic diversity the accessions in gene banks should be characterized and evaluated, which would allow the selection of genotypes of interest in breeding program. (Balestre *et al* 2008; Terzopoulos and Bebel, 2008).Tomatillo is a well-studied crop species for breeding, genetics and genomics in plants. Various resources are accessible now for its research, which can lead to uprising in evaluation of tomato biology (Barone *et al.,* 2008). Many studies have been done using different genes to examine its genetic diversity (Asamizu and Ezura, 2009; Carelli *et al.,* 2006; Martinez *et al* 2006).

2.1 Nomenclature, Origin and Distribution

The tomatillo (*P. ixocarpa* Brot.) is widely cultivated in Mexico from the pre Columbian time and it is there an indispensable vegetable for preparing hot sauces with chilli and for other dishes (Estrada-Trejo *et al.,* 1994). It is also cultivated in Russia, in home gardens from the time of Vavilov expeditions .This species is native to Mexico and Central America, and it is presently one of the most important crops in Mexico (Cantwell *et al.,* 1992). According to Plata (1984), tomatillos originated in Mexico and were cultivated in the pre Columbian era. Tomatillo has been known to botanists for nearly 400 years as *P. philadelphica* Lam. Two varieties from numerous plant types called tomate by the Aztecs. Botanists have suggested that the small-fruited miltomate is a wild-type plant, whereas, the tomatillo is a domesticated plant that derives from plants similar, if not identical, to miltomate (Hudson, 1986). The specific boundaries in *Physalis* are poorly defined with some duplication of names and many changes in the nomenclature during the last 50 years. The complexity of the genus is caused mainly by the wide range of genetic variability present presumably resulting from interspecific hybridization (Menzel 1951, 1957; Waterfall, 1958) and also by the ambiguity of the earlier taxonomic descriptions (Raja-Rao, 1979). For example, *P. aequata* Jacq. and *P. capscicifolia* Rydb are considered synonymous with *P. ixocarpa*.

To clarify the taxonomic classification of *Physalis*, Menzel (1951, 1957) and Waterfall (1967) made extensive cytologic and taxonomic studies of the genus. Menzel reduced *P. philadelphica* to synonymy under the variable *P. ixocarpa* Brot. a name that had to come to be widely used for the domesticated tomatillo (Hudson 1986). The only apparent difference between the two species was the length of the peduncle, with the peduncle of *P. ixocarpa* shorter than that of *P. philadelphica*. Waterfall (1958) accepted this nomenclature when studying the species of North Mexico, but he reversed himself when he analyzed *Physalis* spp. from Mexico and Central America (Waterfall 1967). He incorporated the small-flowered *P. ixocarpa* within the broader limits of *P. philadelphica*. Fernandes (1974) made a thorough investigation of this nomenclatural problem and concluded that *P. ixocarpa* is a distinct species, different from *P. philadelphica* based on previous cytological evidence, the distinctive sigma, and the small flowers of the type. Chromosome morphology has recently been used to understand the interspecific relationships in the genus. It was studied the morphology of chromosomes during the pachytene stage with most important *Physalis* spp. and demonstrated cytological differences between the species. Nevertheless, the taxonomic complexity of the genus is not yet clarified, especially between *P. ixocarpa* and *P. philadelphica.* Plants in the genus *Physalis* have herbaceous stems. Some have short to elongated rhizomes, the leaves are usually broadly ovate to linear and generally alternate. The flowers are solitary in the axis of the leaves, sometime pendant in the axillary branches causing them to appear to be axillary between the two branches. The pendant blossoms are often hidden by the foliage and many of the flowers hang just above the ground (Sullivan, 1986). The flowers have corollas campanulate to rotate with the petal borders reflexed. Petals are usually yellow with a dark purple spot near the base of each petal. The calyx is united, with lobes more than one half its length. The androecium has five stamens with the filaments attached to the base of the corolla tube. The anthers are ovate-oblong and dehiscent by lateral slits. The fruit is a two carpet, many seeded-berry (Waterfall, 1958). There are several reports concerned with the development and growth of tomatillo plants (Mulato-Brito *et al.,* 1985; Cartujano-Escobar *et al.,* 1985a, b), and we have 2 years of experience with tomatillo growing in Louisiana.Tomatillo seedlings form a single shoot which has three to five internodes above the cotyledons. The last internode ends with a flower, one leaf and two lateral ramifications. Each ramification has one node which terminates in the same pattern, one end flower, one leaf and two branches. This pattern continues until senescence, "with the exception that when two leaves are formed there is no further branching. One characteristic of the main branches is that the internodes differ in length and have many adventitious roots. When these roots contact soil, they grow into the soil and are independent of the main root system.

2.2 Variability

The fundamental key to achieve the genetic improvement of a crop through a proper breeding programme is to assess the amount and nature of variation of plant characters in breeding population. It helps the breeder for improving the selection efficiency. For this reason, many researchers studied variation in tomatillo and tomato. It has been suggested by Yi *et al.,* (2008) that domestication and inbreeding dramatically reduced the genetic variation.

The success of any crop improvement programme depends on the presence of genetic variability and the extent to which the desirable trait is heritable. Genetic variability can be estimated using both morphological and molecular markers. The presence of genetic variability in the breeding material has been emphasized by previous researchers (Reddy *et al.,* 2013; Singh, 2009; Shuaib *et al.,* 2007). A field experiment was carried out to study the genetic variation among twenty five tomato genotypes that helped in the reliable varietal selection programme for breeding. All tomato accessions were analyzed by two parameters e.g. morphological and molecular parameters. This study showed that plant height, fruit size and color show variability (Naz *et al.,* 2013). Another experiment using nineteen exotic collections of tomato, Reddy *et al.,* (2013) revealed considerable genetic variability for characters which was pertaining to the growth, earliness, yield and quality. Fruit weight, plant height and number of fruits per plant contributed to the total variation. A field experiment was conducted at CCSHAU, Hisar during spring-summer 2013 to study the genetic variability, Heritability and Genetic Advance for quantitative and qualitative traits in tomato. With 27 genotypes including two checks in randomized block design with three replications. A high degree of significant variation was observed for all the characters studied except for number of branches, ascorbic acid and equatorial diameter of fruit (Nalla *et al.,* 2016). Singh *et al.,* (2005) conducted a field experiment on 15 advance generation breeding lines of tomato, to study the variation for total soluble solids (TSS), pericarp thickness, fruit firmness, acidity, lycopene content and dry matter content and observed significant differences among the genotypes under normal conditions, whereas differences were not significant under high temperature conditions. The population mean was higher during November than February planting for all the characters except acid content and TSS.

A field experiment was carried out by Shashikanth *et al.,* (2010) to study the genetic variation among 30 tomato genotypes and observed that the range of variation and mean values were high for plant height, days to 50% flowering and average fruit weight. Multivariate and biochemical analysis of genetic affinity among tomato genotypes are necessary before setting any experiment for their improvement (Alam *et al.,* 2012).

Estimation of Morphological traits can provide a simple technique of quantifying genetic variability and simultaneously assessing genotypic performance under relevant growing environments (Shuaib *et al.,* 2007). An experiment was conducted by Kumari *et al.,* (2007) for days to flowering, days to maturity, number of fruits per branch, plant height etc. and found that there were highly significant differences for all the characters among parents except early yield, total yield and days to flowering. The Kenyan tomato germplasm evaluation by Agong *et al.,* (2001) showed a significant variation in the quantitative traits among the accessions. The average fresh and dry weight of fruit varied significantly among the accessions. Most of the landraces gave lower fresh and dry fruit weight than the market cultivars. Considerable genetic variability was found in an experiment among 18 indigenous and exotic tomato cultivars for five economic characters (plant height, number of branches per plant, number of fruits per plant, average fruit weight and yield) in Orissa, India during rabi 1998-99 conducted by Mohanty and Prusti (2001). The fundamental key to achieve genetic improvement of a crop through a proper breeding program is to find out the amount and nature of variation among the population. The assessment helps breeder for improving the selection efficiency. Many researchers studied variation in tomato but in case of tomatillo it is not widely studied. Therefore some researchers found similar growth habit and characters between tomato and tomatillo. Here, some of the results are discussed on tomato as such research materials on Tomatillo are not available.

2.2.1 Days to first flowering

Abak *et al.,* (1994) found earliness in first flowering in *P. ixocarpa* (Brot.) and *P. peruviana* L. species of tomatillo in green house, low tunnel and open field experiment where Cuartero *et al.,* (1983) found 4 days earliness in first flowering under cultivation condition. Farzaneh *et al.,* (2013) showed earliness in days to first flowering while studying combining abilty from a 9x9 diallele cross, whereas no significant differences were found for this character (Monamodi *et al.,* 2013). Remarkable variation were reported among the 26 tomato genotypes for days to first flowering ranging between 49.67 and 68.33 days (Matin and Kuddus, 2001). Kumari *et al.,* (2007) recorded data for total soluble solids, dry matter content, reducing sugars, titratable acidity, ascorbic acid, lycopene, days to flowering, days to maturity, number of fruits per bunch, weight per fruit, fruit length, fruit width, number of fruit bearing branches, total number of fruits per plant, plant height, early yield and total yield and found that there were highly significant differences for all the characters among parents except acidity, early yield, total yield, and days to flowering. Pre-flowering periods of the varieties ranged from 56 to 76 days were reported by Geogieva *et al.,* (1969). The phenotypic variance was comparatively higher than the genotypic variance indicating high degrees of environmental effect for days to first flowering (Matin, 2001; Aditya, 1995).

2.2.2 Plant height

Naz *et al.,* (2013) used 25-tomato germplasm to characterize morphologically by comparing the height of the plant, leaf length, shape and arrangement, fruit shape and size. This study revealed that height of plant shows the highest variability.Kumari *et al.,* (2007) observed the highest genotypic coefficient of variation for plant height. Hannan *et al.,* (2007) conducted an experiment, to estimate heterosis and character association in 45 single cross hybrids, obtained from 10 parental lines of tomato for yield and yield component traits. The characters studied were plant height, days to first flowering, number of flowers cluster^{-1}, number of fruits plant^{-1}, fruit weight plant^{-1} and days to first fruit ripening. They obtained significant differences among genotypes for all the traits and found positive high significant heterosis over the mid-parent, better parent and standard parent heterosis, respectively. They concluded that five hybrids positively correlated with fruit plant^{-1}, number of fruit cluster^{-1} and plant height. Joshi *et al.*, (2004) conducted a field experiment with forty tomato genotypes to evaluate their genetic variability and noticed that plant height gave the highest heritability (78.82%). Ravindra *et al.,* (2003) observed significant genotype x environment interaction for plant height. Shravan *et al.,* (2004) and Aditya (1995) reported significant variation in plant height. Parthasarathy and Aswath (2002) conducted a study with 23 genotypes of tomato and observed a considerable variability among genotypes for 8 morphological characters. Plant height, fruit number, fruit size were contributed higher variability among them. Singh *et al.,* (2002) carried out a field experiment with 92 tomato genotypes to study genetic variability and reported that the analysis of variance revealed highly significant genetic variation for plant height, number of days to first fruit set, number of fruit clusters per plant, number of fruits per plant, fruit weight per plant and fruit yield. The traits characterized by adequate variability may be considered in a hybridization program for yield improvement in tomato. Matin *et al.*, (2001) also reported that phenotypic variance was relatively higher than genotypic variance for plant height. They again observed that genotypic coefficient of variation was lowering than the phenotypic coefficient of variation indicating the influence of environment for expression of this character. Ghosh *et al.*, (1995) and Nandpuri *et al.,* (1974) reported a high degree of variation for plant height while Ahmed (1987) observed a narrow range of variations. Sonone *et al.,* (1986) and Prasad (1977) also reported high phenotypic and genotypic coefficient of variation for plant height in tomato.

2.2.3 Leaf length and width

Leaf shape, size and thickness are some of the most important morphological features that can directly affect plant yield. These morphological parameters determine cell number, chlorophyll content and ribulose-1,5-bisphosphate carboxylase/oxygenase (RuBisCO) per unit area exposed to sunlight, thus influencing leaf photosynthetic rate (Zhu *et al.,* 2010). Leaf morphology is dependent on an intricate network of multiple processes such as cell division, cell expansion, growth axis establishment, and the differentiation and specification of tissues (Bar and Ori, 2014). This network, in turn, is subject to regulation by phytohormones, transcription factors and changes in the mechanical properties of tissues. A number of recent reviews have discussed the basic genetic mechanisms underlying leaf development and morphogenesis in both monocots and dicots; (Lewis and Hake, 2016; Bar and Ori, 2014)

2.2.4 Number of branches per plant

Cuartero *et al.,* (1983) found positive correlation with yield and no. of branch per plant. Menzel (1951), in an experiment observed that no. of fruits, no. of flowers, no. of fruits increase with no. of primary branches per plant. Singh *et al.,* (2005) conducted a field experiment with 30 tomato and five genotypes among them showed higher number of primary branches than the control. The maximum number of fruits per plant was obtained from one of the five higher branching genotypes. Singh (2005), observed PCV was slightly higher than GCV for number of branches per plant. An experiment was conducted with 30 tomato genotypes to study their genetic variability.

2.2.5 Number of cluster per plant

Dufera (2013) conducted an experiment using twenty-one tomato germplasm. Higher genotypic and phenotypic coefficients variation values recorded by the character fruit clusters plant^{-1}, indicating the presence of variability among the genotypes and the scope to improve these characters through selection**.** Singh *et al.*, (2006) observed a considerable range of genetic variability for yield and yield components in the materials under study and maximum genotypic coefficient of variation found for a number of clusters per plant. Prajapati *et al.*, (2015) evaluated 39 diverse genotypes of tomato at Vegetable Research Farm, Rewa (Madhya Pradesh) during the Rabi session of 2011. Analysis of variance showed significant variation among the genotypes for all evaluated traits. Number of fruits plant^{-1} showed the highest genotypic and phenotypic variance. Twenty-six genotypes of tomato were assessed to determine the nature and magnitude of variability, correlation, and path coefficient analysis between yield and yield-contributing characters. Correlation indicated that yield was significantly and positively associated with number of fruit per plant and per cluster (Kumar *et al.,* 2013). Seventeen diverse genotypes of tomato were evaluated by Thakur (2009) for their performance and interaction with changing environments through the characters like fruit yield, number of fruits/plant. The analysis of variance indicated highly significant differences between the genotypes and environments for all the characters studied. Saeed *et al.*, (2007) observed that coefficient of variation was greater in traits such as number of fruits per plant followed by number of flowers per plant and yield per plant. Joshi *et al.,* (2003) observed the number of fruits per plant show the highest phenotypic and genotypic coefficient of variation. The number of fruits per plant had positive effects on the yield and negative effects on average fruit weight (Mohanty, 2003).

2.2.6 Number of fruits per plant

Abak *et al.,* (1994) found positive correlation between no. of primary branches and no. of fruits per plant in Tomatillo, where, Moriconi *et al.,* (1990) found profuse flowering and fruit setting in Louisiana. Cuartero *et al.,* (1983) observed that no. of fruits per plant of Tomatillo increases in cultivated condition where Mulato-Brito *et al.*, (1985); found that no. of fruits per plant varies among different species of Tomatillo.

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2.2.7 Fruit length

Mulato-Brito *et al.,* (1985); found fruit length and fruit diameter has direct positive correlation with yield per plant. Similar results was also observed by Cantwel *et al.,* (1992). Twenty-six genotypes of tomato were assessed to determine the nature and magnitude of variability, correlation, and path coefficient analysis between yield and yield-contributing characters. The analysis of variance (ANOVA) revealed highly significant differences among all genotypes for the characters. Path analysis at the genotypic level indicated that fruit weight had the most positive direct effect on yield per plant followed by number of fruits per plant, fruit diameter, and number of fruits per cluster (Kumar *et al.,* 2013). Kumari *et al.,* (2007); conducted an experiment and recorded data for fruit length and found highly significant differences among parents. High PCV for fruit length was reported by Singh *et al.,*(2002). showed significant variation (Reddy and Reddy, 1992).

2.2.8 Fruit diameter

An experiment was done by Kumar *et al.,* (2013) with twenty-six genotypes of tomato to determine the nature and magnitude of variability, correlation, and path coefficient analysis between yield and yield-contributing characters. The analysis of variance (ANOVA) revealed highly significant differences among all genotypes for the characters. Path analysis at the genotypic level indicated that fruit weight had the most positive direct effect on yield per plant followed by number of fruits per plant, fruit diameter, and number of fruits per cluster.

Saleem *et al.,* (2013) examined twenty-five F_1 hybrids generated from 5×5 diallel crosses to study the quantitative genetics of yield and some yield related traits and found fruit diameter was the most heritable trait.

2.2.9 Seed per fruit

Tomatillo seed develops in a mucilaginous gel which has germination inhibitors. During the process of seed extraction and fermentation this gel is broken down. After the seeds are washed and dried, the seeds are normally tan or light brown in color with a pubescent covering (fuzz). The number of seeds per fruit typically ranges from about 47 to 374 or more seeds per fruit.

2.2.10 Fruit weight

Cantwell *et al.,* (1992) observed that both the variances were high for individual fruit weight in the study of genetic variability with different tomatillo genotypes. Abak *et al.,* (1994) found direct positive relationship with yield and no. of fruits per plant. Twenty-six genotypes of tomato were assessed to determine the nature and magnitude of variability, correlation, and path coefficient analysis between yield and yield-contributing characters. The analysis of variance (ANOVA) revealed highly significant differences among all genotypes for the characters. Path analysis at the genotypic level indicated that fruit weight had the most positive direct effect on yield per plant (Kumar *et al.*, 2013). Shravan *et al.*, (2004) analyzed genetic variability with 30 tomato genotypes in Utter Pradesh of India and reported remarkable difference for average fruit weight among the genotypes. A field experiment was carried out by Mohanty *et al.*, (2003) to study genetic variability of 18 tomato genotypes and observed that the average fruit weight had direct positive effects on the yield and indirect negative effects on number of fruits per plant. Singh *et al.*, (2002) in an experiment with heat tolerant tomato found that average fruit weight has the highest phenotypic (PCV) and genotypic (GCV) coefficients of variation. Matin and Kuddus (2001), reported that varietal differences were significant among different cultivars of tomato for average fruit weight. Similar results for average fruit weight were found by Brar *et al.*, (2000). A field experiment with 4 genotypes of tomato, Ahmed (1987), reported that a wide range of variation was observed for individual fruit weight.

2.2.11 Yield per plant

Abak *et al.*, (1994) found highest GCV for yield per plant in P. ixocarpa (Brot.) and P. peruviana L. species of tomatillo in green house, low tunnel and open field experiment. Procelli and Proto (1991), found direct positive correlation in yield per plant with no. of flower per plant, fruits per plant and fruit weight. Evaluation of five tomatillo Mexican landraces including altogether 13 accessions was performed under environmental conditions of Ontario, Canada and Chapingo in central Mexico. The measured traits were: beginning of flowering and harvest, total number of harvested fruits and the yield. In both localities accessions 1 and 3 of the Rendidora landrace as well as the accession 1 of the Manzano landrace were the earliest and the highest yielding (Mulato-Brito and Pena-Lomeli, 2007). Fourty eight genotypes of tomato were evaluated for their genetic variation using Mahalar statistics by Singh *et al.*, (2006) and observed that characters like number of fruits per plant, av. fruit wt., plant height and fruit yield per plant have highest contribution on genetic variations. Significant differences for yield plant^{-1} was reported by Matin and Kuddus (2001) among the genotypes tested. Sachan (2001), conducted an experiment with several tomato genotypes and observed remarkable differences among the genotypes for yield plant^{-1}. Higher genotypic co-efficient of variation for average yield plant was reported by Kumar and Tewari (1999) among thirty two genotypes of tomato. Pujari *et al.*, (1994) studied the results from an 8 × 8 half-diallel cross in tomato, which indicated high heterosis for yield plant, fruits plant, fruits cluster and earliness.

2.3 Heritability and genetic advance

Plant Selection based on phenotypic characteristics is the most important tools for all breeding practices. Selection efficiency for yield depends on heritability. Character with higher heritability has higher selection efficiency. To judge the potentiality for breeding of a population for further improvement through selection, heritability and genetic advance are the most important parameters. Researchers of the world have studied heritability and genetic advance of yield and yield contributing characters. The literatures very relevant to the present study are reviewed below:

Saleem *et al.*, (2013) conducted an experiment of quantitative genetics of yield and yield contributing traits. Number of fruits per plant shows the highest estimates of GCV and

PCV while fruit diameter was the most heritable trait. In an experiment, Buckseth *et al.*, (2012) found high heritability with high genetic advance for the number of fruits plant^{-1}, av. fruit wt., yield plant^{-1} and pericarp thickness indicate that the heritability is most likely due to the additive gene effects and selection may be effective. Narolia (2012) conducted an experiment with 55 genotypes of tomato and found high heritability and high genetic advance as percent of mean for all the characters except days to 50% flowering. High genotypic variance for most of the characters indicating a larger contribution of the genetic component for total variation (Shashikanth *et al.,*, 2010). Twelve varieties of tomatoes were evaluated by Ponnusviamy *et al.,* (2010) to determine heritability and observed that high heritability with high genetic advance as percentage of mean for average fruit weight. High heritability with high GCV and genetic gain for fruit weight and fruit yield were found in an experiment with 20 tomato genotypes conducted by Nardar *et al.,* (2007). Broad sense heritability was the highest for number of fruits per plant, followed by number of flowers per plant was observed by Padda *et al.,* (2007). Pandit *et al.,* (2010) conducted an experiment with twelve tomato varieties to determine heritability and noticed that high heritability along with high genetic advance as percent of mean for average fruit weight. Heritability were high for all the characters and genetic advance was high for plant height in an experiment was observed by Kumari *et al.,* (2007). Golani *et al.,* (2007) evaluated twenty genotypes of tomato and reported that high heritability with high GCV and genetic gain for fruit weight and fruit yield.

2.4 Correlation coefficient analysis

2.4.1 Correlation between the characters

To evaluate the relationships between the characters, correlation is the best estimate. It will help the breeder to decide about selection methods. Many of the cases, correlation between yield and yield contributing characters was studied as yield is one of the basic target to most of the breeders. Yield contributing characters are also interlinked. So, to plan effective breeding program for obtaining maximum yield, association of characters with yield and with its components is very much important.

Correlation analysis may vary due to agro-climatic variations from year to year and place to place. Higher heritability than yield shows that there is positive correlation between these, then there may be chance to increase in total yield by proper selection of that component. Negative correlation co-efficient among yield components indicate selection for any component might not bring change for yield improvement. Many researchers have studied correlation between yield and yield contributing characters. Some of the likely cases are described here. Kumar *et al.,* (2013) evaluated forty nine genotypes of tomato (Solanum lycopersicum L.) for various quantitative and quality characters and the analysis indicated that total numbers of fruits per plant were positively correlated with gross yield, marketable yield, number of marketable fruits per plant and plant height and was significant. Mahapatra *et al.,* (2013) found Fruit yield has significant positive correlation with plant height, number of primary branches/plant, number of flower clusters/plant, number of fruits/plant, fruit length, fruit diameter and average fruit weight. Number of primary branches per plant increase with the increase in plant height. Monamodi *et al.,* (2013) found positive and significant correlation between no. of branches/ plant with no. of fruits/plant. Fourty genotypes of tomato were studied to find out the correlation among different different traits by Buckseth *et al.,* (2012) and found highly significant dissimilarities among the genotypes. Kumar and Dudi (2011) studied thirty diverse genotypes of tomato and observed that correlation coefficients at the genotypic level were higher than the phenotypic ones and yield/plant was positively and significantly correlated with plant height, fruit number/plant. Fruit weight is positively and significantly correlated with yield per plant, while number of fruits per plant and fruit weight have negative correlation (Rani *et al.,*, 2010). A field experiment was conducted by Golani *et al.,* (2007) and found that fruit weight and fruit length were significantly and positively correlated. Correlation co-efficient study was performed by Kumar *et al.,* (2006) with 30 tomato genotypes and noticed that number of fruits plant^{-1} had significant and positive correlation with fruit yield plant^{-1}. Manivannan *et al.,* (2005) conducted an experiment with cherry for correlation coefficient analysis and perceived that fruit yield was meaningfully and absolutely correlated with the number of leaves and fruit weight.

Joshi *et al.*, (2004) done correlation analysis with 37 tomato genotypes and revealed that yield per plant was significantly correlated with average fruit mass, fruit size, plant stature and harvest spell. In case of tomato, Arun *et al.,* (2003) detected that, yield per plant was absolutely correlated with average fruit mass and plant tallness. Harer *et al.,* (2002) considered correlation of thirty seven tomato genotypes and disclosed that the number of fruits per bunch and number of fruits per plant were expressively and completely correlated with fruit yield per plant.

2.5 Genetic divergence

Genetic divergence has been considered as an essential parameter in crop improvement program to identify the most diverse parents. Highly heterotic F_1 generation can only be found from genetically diverse parents. Many researchers have studied genetic divergence based on Mahalanobis' D^2-statistics. Among them the most relevant current publications are reviewed below:

Nalla *et al.,* (2014) carried out an experiment and recorded data on fifteen characters and observed high divergence from fruit yield plant^{-1}, TSS and diameter. Reddy (2013) found that fruit weight show maximum diversity followed by plant height and number of fruits plant^{-1}. Xiaorong *et al.,* (2012) in an experiment used 26 phenotypic characters to explore genetic diversity in 67 tomato cultivars. Cluster analysis showed that tomato varieties could be categorized into three clusters at phenotypic levels. A field experiment was carried out by Shashikanth *et al.,* (2010) to perform study on genetic divergence of 30 tomato genotypes and categorized into 10 clusters. He observed no parallelism between genetic diversity and topographical divergence in tomatillo. Zhu *et al.,* (2004) observed large phenotypic variations and significant genetic diversity in wild types. These variations offer great prospective for crop advancement.

CHAPTER III
MATERIALS AND METHODS

This chapter clarifies information regarding methodology, used in implementation of the experiment. It describes a brief statement of experimental site, planting materials, climate and soil, seed bed preparation, design of the experiment, other operations done, data collection methods, statistical analysis procedure etc., which are presented as follows:

3.1 Experimental site

The experiment was conducted at experimental field, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during the period from October 2019 to March 2020. Location of the site is 23°75' N latitude and 90°34' E longitude with an elevation of 8 meter from sea level under AEZ-28. The experimental site is indicated on the map of AEZ of Bangladesh in (Appendix I).

3.2 Planting materials

Ten genotypes were used in the experiment. Among the studied materials, tomatillo seeds of the genotypes were collected from research supervisor. The name and source of collection of these genotypes are presented in Table 1.

3.3 Climate and soil

Experimental site was situated in the subtropical climatic zone, where moderately low temperature prevails during October to March (Rabi season), suitable for tomatillo cultivation in Bangladesh. The soil was sandy loam in texture and pH was 5.45- 5.61. Information regarding Weather and physio-chemical properties of the soil are presented in Appendix II and Appendix III, respectively.

Table 1. Name and origin of tomatillo genotypes used in the present study

Sl. No.	Genotypes No.	Source
1	G7	
2	G8	
3	G9	
4	G10	
5	G11	
6	G12	GEPB, SAU
7	G13	
8	G14	
9	G15	
10	G17	

SAU= Sher-e-Bangla Agricultural University, GEPB= Genetics and Plant Breeding

3.4 Seed bed preparation and raising of seedling

Seed sowing was done on Oct 23, 2019 in the seedbed. Before sowing, seed treatment was done with Provax. All cultural practices necessary for seed bed were done properly. 24 days old seedlings were transplanted in the main field. Seedlings in the seedbed are shown in Plate 1A.

3.5 Design and layout of the experiment

The experiment was designed in Randomized Complete Block Design (RCBD). There were 10 genotypes, 3 replications, spacing was 60 cm × 40 cm and plot size was 70 m^2**.**

3.6 Land preparation

Land was well ploughed at tilth condition. All fertilizers and cow dung except urea were applied during final land preparation.

3.7 Transplanting of seedlings

The seedlings were raised in seedbed and 24 days old seedlings were transplanted in the main field on November 17, 2019.

3.8 Manure and fertilizer application

All fertilizers and cow dung except urea were applied during final land preparation. Urea was applied in three split doses. The rate of application is presented in Table 2.

Table 2. Doses of manures and fertilizers used in the study

Sl. No.	Fertilizers/ Manures	Dose (Quantity/ha)
1.	Urea	550 kg
2.	TSP	450 kg
3.	MOP	250 kg
4.	Cow dung	10 ton

3.9 Intercultural operations

When the seedlings were well established, first weeding was done uniformly in all the plots. Second weeding was done after 20 days of the first one. Mechanical support was provided to the growing plants by bamboo sticks to keep them erect. During early stages of growth, pruning was done by removing some of the lateral branches to allow plants to get more sunlight and to reduce the self-shading and incidence of increased insect infestation. Thinning and gap filling, staking, pesticide application, irrigation and after-care were also done as per requirement.

Plate- 1A: Seedling Stage

Plate- 1B: Flowering Stage

Plate- 2: Stalking of Tomatillo Plants

3.10 Harvesting and processing

All of the tomatillo varieties used in this experiment was indeterminate types. So, harvesting continued for about one and half month because fruits of different lines matured progressively at different dates and over long time. The fruits per entry were allowed to ripe and then seeds were collected and stored at 4^{o}C for future use. Harvesting was started from March 1, 2020 and completed by March 15, 2020. During raising of seedlings, growing condition of plants, intercultural operation, growth stage of a single tomatillo and tomato plant closed eyes were applied there. Fruit harvesting and collection are shown in Plate 3.

3.11 Data recording

Six plants from each genotype were selected and tagged. Thus was done in all the three replication. Data were recorded from those plants.

3.11.1 Days to first flowering

No. of days from sowing to first flower opening was recorded as days to first flowering. Flowering is shown in Plate-1B

3.11.2 Plant height

Plant height was recorded once at 70 days after transplanting.

3.11.3 Leaf length and width

When the plant had showed 50% maturity, I collected leaf length and width of each genotype.

3.11.4 Number of branches per plant

The number of branches per plant was recorded at 70 days after transplanting.

3.11.5 Number of clusters per plant

The number of clusters per plant was recorded at 70 days after transplanting

Plate- 3: Harvesting of fruits of Tomatillo

3.11.6 Number of fruits per plant

Total number of marketable fruits harvested from each of the five tagged plants.

3.11.7 Fruit length (cm)

Fruit length was measured from stalk end to bottom end by slide calipers

3.11.8 Fruit diameter (cm)

Fruit length was measured from stalk end to bottom end by slide calipers

3.11.9 Number of seed per fruit

Number of seed per fruit was calculated just after harvesting mature fruit at the very first week of March, 2020.

3.11.10 Fruit weight (g)

Fruits from the tagged plant harvested and individual fruit weight were calculated as average weight and expressed in gram (g).

3.11.11 Fruit yield per plant (kg)

From each picking, weight data was recorded for each of the tagged plant and total weight was calculated and expressed as fruit yield per plant.

3.12 Statistical analysis

Mean data of the characters were exposed to multivariate analysis. Univariate analysis of the individual character was also done for all characters under study using the mean values and was assessed using MSTAT-C computer program. For all the characters, Duncan's Multiple Range Test (DMRT) was performed to test the differences between the genotypic means. Using MSTAT-C, mean, range and coefficient of variation (CV %) were also estimated. GENSTAT 5.13 and Microsoft Excel 2000 software were used to perform multivariate analysis.

3.12.1 Estimation of genotypic and phenotypic variances

Genotypic and phenotypic variances were estimated according to the formula given by Johnson *et al.*, (1955).

Genotypic variance, $\sigma^2_g = \frac{GMS - EMS}{r}$

Where,

GMS = Genotypic mean sum of squares

EMS = Error mean sum of square

r = number of replications

Phenotypic variance, $\sigma^2_{ph} = \sigma^2_g + EMS$

Where,

σ^2_g = Genotypic variance

EMS = Error mean sum of square

Environmental variance ($\sigma^2 e$) = EMS

Where,

EMS = Mean Square Error

3.12.2 Estimation of genotypic and phenotypic coefficient of variation

Genotypic and phenotypic coefficient of variation was calculated by the formula suggested by Burton (1952)

Genotypic coefficient of variation, GCV % = $\frac{\sqrt{\sigma^2 g}}{\bar{x}} \times 100$

Where,

σ^2_g = Genotypic variance

$\bar{x}$ = Population mean

Similarly,

The phenotypic coefficient of variation was calculated from the following formula.

Phenotypic coefficient variation, PCV = $\frac{\sqrt{\sigma^2 ph}}{\bar{x}} \times 100$

Where,

σ^2_{ph}= Phenotypic variance

$\bar{x}$ = Population mean

3.12.3 Estimation of heritability

Broad-sense heritability was estimated (Lush, 1943) by the following formula, suggested by Johnson *et al.,* (1955).

Heritability, $h^2{}_b\% = \frac{\sigma^2{}_g}{\sigma^2{}_{ph}} \times 100$

Where,

$h^2{}_b$ = Heritability in broad sense

$\sigma^2{}_g$ = Genotypic variance

$\sigma^2{}_{ph}$ = Phenotypic variance

3.12.4 Estimation of genetic advance

The expected genetic advance for different characters under selection was estimated using the formula suggested by Lush (1943) and Johnson *et al.*, (1955).

Genetic advance, GA = K. h^2. σ_p

Or Genetic advance, GA = K. $\frac{\sigma^2{}_g}{\sigma^2{}_{ph}} . \sigma_{ph}$

Where,

K = Selection intensity, the value which is 2.06 at 5% selection intensity

σ_{ph} = Phenotypic standard deviation

$h^2{}_b$= Heritability in broad sense

$\sigma^2{}_g$ = Genotypic variance

$\sigma^2{}_{ph}$ = Phenotypic variance

3.12.5 Estimation of genetic advance mean's percentage

Genetic advance as a percentage of the mean was calculated from the following formula as proposed by Comstock and Robinson (1952):

$$\text{Genetic advance (\% of mean)} = \frac{\text{Genetic Advance}}{\text{Population mean } (\bar{x})} \times 100$$

3.12.6 Estimation of simple correlation coefficient:

Simple correlation coefficients (r) was estimated with the following formula:

$$r = \frac{\sum xy - \frac{\sum x.\sum y}{N}}{\sqrt{[\{\sum x2 - \frac{(\sum x)2}{N}\}\{\sum y2 - \frac{(\sum y)2}{N}\}]}}$$

Where,

$\sum$ = Summation

x and y are the two variables correlated

N = Number of observation

3.12.7 Estimation of genotypic and phenotypic correlation coefficient

For calculating the genotypic and phenotypic correlation coefficient for all possible combinations the formula suggested by Miller *et al.,* (1958), Johnson *et al.,* (1955) and Hanson *et al.,* (1956) were adopted. The genotypic co-variance component between two traits and have the phenotypic co-variance component were derived in the same way as for the corresponding variance components. The covariance components were used to compute the genotypic and phenotypic correlation between the pairs of characters as follows:

$$\frac{\sigma_{gxy}}{\sqrt{(\sigma^2_{gx}.\sigma^2_{gy})}}$$

Genotypic correlation, $r_{gxy} = \frac{GCOVxy}{\sqrt{GVx.GVy}} =$

Where,

$\sigma_{gxy} =$ Genotypic covariance between the traits x and y

$\sigma^2_{gx} =$ Genotypic variance of the trait x

$\sigma^2_{gy} =$ Genotypic variance of the trait y

Phenotypic correlation $(r_{pxy}) = \frac{PCOVxy}{\sqrt{PVx.PVy}} = \frac{\sigma}{\sqrt{\sigma^2_{px}}}$

Where,s

$\sigma_{pxy} =$ Phenotypic covariance between the trait x and y

$\sigma^2_{px} =$ Phenotypic variance of the trait x

$\sigma^2_{py} =$ Phenotypic variance of the trait y

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to perform the variability analysis of different genotypes of tomatillo (*P. ixocarpa* Brot.) using yield contributing traits. This chapter comprises the presentation and discussion of the findings obtained from the experiment. The fruits were harvested when they began the color change. The data pertaining to 12 common characters between tomatillo have been presented and statistically analyzed with the possible interpretations.

4.1 Genetic variability, heritability and genetic advance

The mean values for each character of all the genotypes are shown in Table 3. Performance of the genotypes is described below for each character. The extent of variation among the genotypes in respect of twelve characters was studied and mean sum of square, phenotypic variance (σ2p), genotypic variance (σ2g), phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (h2b), genetic advance (GA), genetic advance in percent of mean and coefficient of variation (CV) presented in Table 4.

4.1.1 Days to first flowering

The variance due to days to first flowering showed that the genotypes differed significantly and ranged from 23.33 days after transplanting (DAT) in (G17) to 28.66 DAT in (G7) with mean value 25.77 days after transplanting **(**Table 3**)** . The σ^2g and σ^2p for this trait were 3.28 and 3.66, respectively (Table 6). The σ^2p appeared to be high than the genotypic variance suggested considerable influence of environment on the expression of genes controlling this trait. The GCV (7.03) and PCV (7.43) were more or less similar to each other, indicated presence of low variability in this trait (Table 7).

Table 4. Range, mean CV (%) and standard deviation of ten tomatillo genotypes

Parameters	Range		Mean	CV (%)	SD	SE
	Min	Max				
Days to first flowering	23.33	28.67	25.77	2.40	1.888	0.36
Plant Height (cm)	71.07	133.67	93.22	14.91	21.842	8.03
Leaf Length (cm)	5.40	8.93	7.34	13.89	1.4009	0.59
Leaf Width (cm)	3.53	5.40	4.46	13.37	0.7176	0.34
Branch/ Plant	4.33	8.00	5.73	20.02	1.5298	0.70
Cluster/ Plant	17.00	44.33	29.93	14.08	10.455	2.43
Fruit/ plant	19.00	36.00	27.73	15.80	6.1248	2.53
Fruit Length (mm)	24.76	40.23	32.36	13.61	5.8637	2.54
Fruit Diameter (mm)	33.38	44.76	38.62	10.71	5.0148	2.39
Seed/Fruit	47.67	374.00	161.90	12.54	110.34	11.73
Fruit Weight (g)	23.13	41.03	30.53	19.53	8.0646	3.44
Yield per plant (kg)	0.44	1.11	0.85	19.53	0.2456	0.10

Table 4. Mean performance of ten genotypes of tomatillo in respect of twelve important characters

Genotypes	Days to first flowering	Plant Height (cm)	Leaf Length (cm)	Leaf Width (cm)	Branch/ Plant	Cluster/ Plant	Fruit/plant	Fruit Length (mm)	Fruit Diameter (mm)	Seed/Fruit	Fruit Weight (g)	Yield per plant (kg)
G7	28.66 a	98.80 bc	8.30 ab	4.96 ab	4.33 c	24.66 de	22.33 de	39.95 a	42.63ab	374.00 a	41.03 a	0.94 abc
G8	28.00 ab	98.00 bc	7.43 abc	3.76 cd	4.33 c	30.33 cd	26.33 cde	34.09 ab	34.01 c	71.67 fg	37.60 ab	1.03 ab
G9	27.00 bc	133.67 a	8.93 a	4.13 bcd	8.00 a	44.33a	30.66 abc	24.76 c	36.02 bc	319.00 b	29.33 bc	0.88 abcd
G10	24.66 ef	92.73 bcd	8.16 ab	3.53 d	5.33 bc	42.00 ab	36.00 a	32.80 ab	38.47 abc	118.67 de	27.30 c	0.97 abc
G11	26.00 cd	97.73 bc	8.13 abc	4.70 abc	5.66 bc	36.00 bc	35.000 ab	29.22 bc	43.48 a	76.00 fg	28.56 bc	0.99 abc
G12	24.33 efg	87.40 bcd	6.70 bcd	4.36 bcd	6.00 abc	31.66 cd	27.667 bcd	40.22 a	44.75 a	251.67 c	40.13 a	1.10 a
G13	27.00 bc	75.17 cd	7.13 bcd	5.40 a	6.33 abc	35.00 bc	25.333 cde	30.76 bc	39.08 abc	121.33 de	28.60 bc	0.72 cd
G14	23.66 fg	71.07 d	6.40 cd	4.46 abcd	5.00 c	17.00 f	26.667 cd	28.81 bc	36.08 bc	137.00 d	23.76 c	0.61 de
G15	25.00 de	75.70 cd	6.80 bcd	4.80 ab	7.33 ab	19.66 ef	19.000 e	31.95 bc	38.23 abc	102.00 ef	23.13 c	0.43 e
G17	23.33 g	101.97 b	5.40 d	4.4667 abcd	5.00 c	18.66 ef	28.333 bcd	30.97 bc	33.37 c	47.67 g	25.80 c	0.76 bcd
LSD	1.060	23.848	1.749	1.023	2.067	7.230	7.519	7.555	7.098	34.839	10.225	0.285

Values with same letter(s) are statistically identical at 5% level of probability

Table 5. Analysis of variance for different characters

Character	Mean sum of square		
	Replication (r-1)=2	**Genotype (g-1)=9**	**Error (r-1)(g-1)=18**
Days to first flowering	2.233	10.226**	0.382
Plant height (cm)	761.490	981.515**	193.280
Leaf length (cm)	3.844	3.391*	1.039
Leaf width (cm)	0.112	0.923*	0.356
Branch/ plant	0.933	4.430*	1.452
Cluster/ plant	156.133	281.985**	17.763
Fruit/ plant	4.433	81.467**	19.211
Fruit length (mm)	12.605	69.192*	19.398
Fruit diameter (mm)	1.034	46.562*	17.121
Seed/fruit	1795.300	38005.900**	412.500
Fruit weight (g)	31.084	131.600**	35.528
Yield per plant (kg)	0.036	0.131**	0.028

** Denote Significant at 1% level of probability ** Denote Significant at 5% level of probability

Table 6. Estimation of genetic, phenotypic and environmental variance in twelve traits

Parameters	**$\sigma 2_p$**	**$\sigma 2_g$**	**$\sigma 2_e$**
Days to first flowering	3.66	3.28	0.38
Plant height (cm)	456.03	262.75	193.28
Leaf length (cm)	1.82	0.78	1.04
Leaf width (cm)	0.54	0.19	0.36
Branch/ plant	2.44	0.99	1.45
Cluster/ plant	105.84	88.07	17.76
Fruit/ plant	39.96	20.75	19.21
Fruit length (mm)	36.00	16.60	19.40
Fruit diameter (mm)	26.93	9.81	17.12
Seed/fruit	12943.63	12531.13	412.50
Fruit weight (g)	67.55	32.02	35.53
Yield per plant (kg)	0.06	0.03	0.03

σ 2p = Phenotypic variance, σ 2g = Genotypic variance and σ 2 e = Environmental variance, PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation, ECV = Environmental coefficient of variation.

Table 7. Estimation of phenotypic and genotypic coefficient variation

Parameters	**PCV (%)**	**GCV (%)**	**PCV:GCV**
Days to first flowering	7.43	7.03	94.64
Plant height (cm)	22.91	17.39	75.91
Leaf length (cm)	18.40	12.06	65.58
Leaf width (cm)	16.55	9.75	58.91
Branch/ plant	27.27	17.38	63.72
Cluster/ plant	34.37	31.35	91.22
Fruit/ plant	22.80	16.43	72.06
Fruit length (mm)	18.54	12.59	67.91
Fruit diameter (mm)	13.44	8.11	60.36
Seed/fruit	70.27	69.14	98.39
Fruit weight (g)	26.92	18.54	68.85
Yield per plant (kg)	29.34	21.90	74.63

σ 2p = Phenotypic variance, σ 2g = Genotypic variance and σ 2 e = Environmental variance, PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation, ECV = Environmental coefficient of variation.

4.1.2 Plant height (cm)

Significant differences were observed among the genotypes for plant height which ranged from 133.67 cm (G_9) to 71.07 cm ($G1_4$) with mean value 93.22 cm. (Table 3) Naz *et al.,* (2013), Ravindra *et al.,* (2003), Shravan *et al.,* (2004) and Prasad and Mathura (1999) were also found similar significant variation for plant height. The phenotypic and genotypic variance was observed 456.03 and 262.75, respectively (Table 6) with large environmental influence. The phenotypic co-efficient of variation (22.91) and genotypic co-efficient of variation (17.39) were revealed higher influence of environment for plant height (Table 7). Kumari *et al.,* (2007) obtained highest genotypic coefficient of variation which disagree with this result. Singh *et al.,* (2002) showed that the phenotypic coefficient of variation was greatest for this character. Similar observations were made by Matin and Kuddus (2001). The heritability estimates for this trait was moderate (57.62%) with high genetic advance (25.35%) and genetic advance in percent of mean (27.19%) (Table 8) indicated that most likely the heritability was due to additive gene effects and selection for this character might be effective. Bai and Devi (1991), Mahesh *et al.,* (2006), Singh *et al.,*

4.1.3 Leaf length

Leaf length showed significant difference among the genotypes which was ranged from 5.40 cm in G17 to 8.93 in G9 and their mean was 7.34 (Table 4). Genotypic variance and phenotypic variance were 0.78 and 1.82 (Table 6), respectively with high environmental influence. GCV (12.06) and PCV (18.40) values revealed that the influence of environment was high. The observations found by Singh *et al.,* (2002) were similar to us. Moderate PCV and GCV were found by Aradhana and Singh (2003) also. Heritability (43%) for this trait was moderate with low genetic advance (1.20%) and lower percent mean of genetic advance (16.29%) which indicated non-additive gene action. Moderate heritability due to good environment and selection for this character might not be rewarding.

Table 8 Estimation of heritability and genetic advance

Parameters	Heritability	Genetic advance (5%)	Genetic advance (% of mean)
Days to first flowering	89.585	3.532	13.707
Plant height (cm)	57.616	25.346	27.188
Leaf length (cm)	42.999	1.196	16.294
Leaf width (cm)	34.702	0.528	11.830
Branch/ plant	40.606	1.308	22.811
Cluster/ plant	83.217	17.636	58.918
Fruit/ plant	51.928	6.762	24.384
Fruit length (mm)	46.111	5.699	17.613
Fruit diameter (mm)	36.436	3.895	10.087
Seed/fruit	96.813	226.897	140.147
Fruit weight (g)	47.406	8.026	26.293
Yield per plant (kg)	55.695	0.286	33.665

4.1.4 Leaf width

Leaf width showed significant difference among the genotypes which was ranged from 3.53cm in G10 to 5.40cm in G13 and their mean was 4.46 (Table 3). Genotypic variance and phenotypic variance were 0.19 and 0.54 (Table 6), respectively with high environmental influence. GCV (9.75) and PCV (16.55) values revealed that the influence of environment was high. The observations found by Singh *et al.,* (2002) were similar to us. Moderate PCV and GCV were found by Aradhana and Singh (2003) also. Heritability (34%) for this trait was moderate with low genetic advance (0.53%) and mean of genetic advance (11.83%) which indicated non-additive gene action. High heritability due to good environment and selection for this character might not be rewarding. Moderate heritability and moderate genetic gain for this character were also observed by Joshi *et al.,* (2004).

4.1.5. Number of branches per plant

Number of branches per plant in tomatillo showed significant difference where the highest number of branches was found 8 in G9 and the lowest was recorded 4.33 in G7 and mean value 5.73 (Table 3). The phenotypic variance (2.44) was much higher than the genotypic variance (0.99) (Table 6). The genotypic co-efficient of variation and phenotypic co-efficient of variation were 17.38 and 27.27 respectively (Table 7) indicating that the phenotypic expression of this trait is highly governed by the environment. Singh *et al.,* (2002) also showed that the PCV was higher than GCV for number of primary branches per plant. The heritability estimates for this trait was moderate (40.61), genetic advance was low (1.31%) and genetic advance in per cent of mean (22.81) (Table 8) were found moderate, revealed that this trait was governed by non-additive gene action. Moderate heritability and low genetic advance for this character was also observed by Kumar *et al.,* (2004).

4.1.6 Number of clusters per plant

Cluster per plant showed significant difference among the genotypes which was ranged from 17 in G14 to 44.33 in G9 their mean was 29.93 (Table 3). Genotypic variance and phenotypic variance were 88.07 and 105.84 (Table 6), respectively. GCV (31.35) and PCV (34.37) (Table 7) values revealed that the influence of environment was high. Similar PCV and GCV results were also observed by Singh *et al.*, (2002). Heritability (83.22%) for this trait was high with moderate genetic advance (17.64%) and moderate percent mean of genetic advance (58.92%) (Table 8) which indicated additive gene action. High heritability due to good environment and selection for this character might be effective. In contrast, high heritability coupled with high genetic advance was obtained by Singh *et al.,* (2002).

4.1.7 Number of fruits per plant

From the current study we observed that the maximum range for number of fruits per plant was found 36 in G10 and the minimum was recorded 19 in G15 and mean was 27.73 (Table 3). The difference between genotypic (20.75) and phenotypic (39.96) variances indicated a very high environmental influence (Table 6). The difference between phenotypic coefficient of variation (22.80) and genotypic coefficient of variation (16.43) was low, which indicated presence of variability among the genotypes (Table 7). Singh *et al.,* (2002), Saeed *et al.,* (2007) and Joshi and Singh (2003) found same result in case of number of fruits per plant. The heritability estimated for this trait was moderate (51.93%) accompanied with low genetic advance (6.76%) and genetic advance in percent of mean (24.38%), revealed that this character was governed by non-additive gene and selection for this character would be ineffective. This character showed moderate heritability coupled with low genetic gain which is not supported by Ara *et al.,* (2009) and Saeed *et al.,* (2007).

4.1.8 Fruit length

The mean fruit length was noticed as 32.36 mm with a range of 24.76 mm to 40.23 mm. The Genotype G9 showed the minimum fruit length and the maximum fruit length was recorded in the accession G12 (Table 3). The σ^2g and σ2p were high (36 and 16.60 respectively) and GCV (12.59) and PCV (18.54) were not close to each other **(**Table 6), indicating higher environmental influence on this character that would be ineffective for the improvement of this crop. Singh *et al.*, (2002) showed that the phenotypic coefficient of variation was greatest for this character, which support the present study. Moderate heritability estimates (46.11) with low genetic advance (5.70%) and high genetic advance over percent of mean (17.61%) **(Table 8)** indicative of non-additive gene action. The moderate heritability is being exhibited due to influence of environmental rather than genotypes effective selection may not be rewarding for this trait. Joshi *et al.*, (2004). observed moderate heritability and moderate genetic gain for this character.

4.1.9 Fruit diameter

The mean fruit diameter was 38.62 mm with a minimum range of 33.38 mm (G17) to 44.76 mm (G12) (Table 3**)**. The σ^2p and σ^2g were low (26.93 and 9.81 respectively) and GCV (8.11) and PCV (13.44) (Table 7) were not close to each other, indicating higher environmental influence on this character that would be ineffective for the improvement of tomatillo. Singh *et al.*, (2002) showed that the PCV was greatest for this character, which supports the present study. Low heritability estimate (36.44%) with low genetic advance (3.90%) over high genetic advance percent of mean (10.09%) **(**Table 8**)** indicate that selection may not be made for fruit diameter. Pandit *et al (2010).*observed high heritability coupled with low genetic gain for this character.

4.1.10 Number of seeds per fruit

From the current study we observed that the maximum range for number of seeds per fruit was found 374.00 in G7 and the minimum was recorded 47.67 in G17 and mean was 161.90 (Table 3). The difference between genotypic (12531.13) and phenotypic (12943.63) variances indicated lower environmental influence (Table 6). The difference between phenotypic coefficient of variation (70.27) and genotypic coefficient of variation (69.14) was low, which indicated presence of variability among the genotypes (Table 7). Singh *et al.,* (2002), Saeed *et al.,* (2007) and Joshi and Singh (2003) found same result in case of number of seeds per fruit. The heritability estimated for this trait was higher (96.81%) accompanied with higher genetic advance (226.90%) and genetic advance in percent of mean (140.15%), revealed that this character was governed by additive gene and selection for this character would be effective. This character showed moderate heritability coupled with low genetic gain which is not supported by Ara *et al.,* (2009) and Saeed *et al.,* (2007).

4.1.11 Fruit weight (g)

A significant difference were found within ten genotypes of tomatillo for the character of single fruit weight where the maximum single fruit weight was recorded 41.03 g in G7 and the minimum was recorded 23.13 g in G15 with mean value 30.53 g (Table 3). The genotypic variance (32.02) and phenotypic variance (67.56) for fruit weight was very high (Table 6). The difference between genotypic co-efficient of variation (18.54) and phenotypic coefficient of variation (26.93) was not close to each other, proved that environment has higher influence for the expression of this character. Therefore selection based upon phenotypic expression of this character would be ineffective for the improvement of this crop. High GCV and PCV for average fruit weight were also noticed by Singh *et al.,* (2002) and Manivannan *et al.,* (2005).

4.1.12 Yield per plant (g)

Highest fruit yield per plant was found 1.10 kg in G12 and the lowest was recorded 0.44 kg in G15 with mean value 0.85 kg (Table 3). The phenotypic variance (0.06) found lower than genotypic variance (0.03) (Table 4). The phenotypic coefficient of variation and genotype coefficient of variation were 29.34 and 21.90, respectively for fruit yield per plant, which indicating that significant variation exists among different genotypes which made the trait effective for selection. Similar findings supported by Singh *et al.*, (2006) and Manivannan *et al.*, (2005). Estimation of moderate heritability (55.70%) for fruit yield per plant with lower genetic advance (0.29 %) and high genetic advance of % mean (33.67 %) (Table 8) revealed that this character was governed by additive gene and provides opportunity for selecting high valued genotypes for breeding program. High heritability and high genetic advance was also observed by Anupam *et al.*, (2002).

4.2 Correlation Coefficient

Correlation studies along with path analysis provide a better understanding of the association of different characters with fruit yield. Simple correlation was partitioned into phenotypic (that can be directly observed), genotypic (inherent association between characters) components as suggested by Singh and Chaudhary (1985). As we know yield is a complex product being influence by several inter-dependable quantitative characters. So, selection may not be effective unless understanding the other contributing components influence the yield directly or indirectly. When selection pressure is applied for improvement of any character highly associated with yield, it simultaneously affects a number of other correlated characters. Hence knowledge regarding association of character with yield and among themselves provides guideline to the plant breeders for making improvement through selection with a clear understanding about the contribution in respect of establishing the association by genetic and non-genetic factors (Dewey and Lu 1959). Phenotypic and genotypic correlation coefficients among different pairs of yield and yield contributing characters for different genotype of tomatillo are given in Table 9 and Table 10

4.2.1 Days to first flowering

Days to first flowering had significant positive correlation with leaf length at phenotypic level (0.504**) (Table 9). Patil and Bojappa (1993), Mayavel *et al.*, (2005) and Samadia *et al.*, (2006) observed positive correlation which support the present findings. Days to first flowering had significant positive correlation with fruit weight (0.493**) and seed per fruit (0.431*) at phenotypic level (Table 9). It had negatively non-significant correlation at genotypic level with fruit per plant (-0.244) and branch per plant(-0.088) (Table 10).Days to first flowering had positive but non-significant correlation with number of leaf width, fruit length and fruit diameter, yield per plant at both level. This trait had non-significant negative correlation at both levels for branch per plant, number of fruits per plant.

4.2.2 Plant height (m)

Plant height had a significant positive correlation with fruit/plant at genotypic level (0.556**) but at phenotypic level the character had a non-significant positive correlation (0.221) (Table 10 and Table 9). Again plant height had non-significant negative correlation with fruit diameter (-0.256) at genotypic level and at phenotypic level found the same result for the character which is supported by Mohanty (2003). Plant height had also non-significant positive correlation with number of branches per plant, fruit weight.

4.2.3 Leaf length:

Leaf length was significantly positively correlated with cluster per plant (0.588**), and seed per fruit (0.385*) at phenotypic level) and significant positive correlation with cluster per plant (0.915**), branch per plant (0.364*), fruit per plant (0.445*), fruit diameter (0.369*), seed per fruit (0.660*), fruit weight (0.437*) and yield per plant (0.611**) (Table 9 and 10) at genotypic level. Leaf length showed significant negative correlation with leaf width (-0.375*) at genotypic level.

4.2.4 Leaf width

Leaf width was significantly positively correlated with fruit diameter (0.518**) at genotypic level. Leaf width showed significant negative correlation with cluster per plant (-0.510**), Fruit per plant (-0.831**) and yield per plant (-0.705**) at genotypic level.

4.2.5 Number of branches per plant

The number of branches per plant had highly significant positive correlation with clusters per plant (0.500**) at genotypic level (Table 10). At phenotypic level no characters were found in a significant positive correlation with no. of branch (Table 9). Monamodi *et al.*, (2013) found more branch number in a plant will produce more fruits.

But a negative correlation between the number of branches per plant and number of fruits per plant was noticed by Singh *et al.,* (2005). Branch per plant showed negatively significant correlation with fruit length (-0.378*) at phenotypic level. The number of branches per plant had highly significant negative correlation with fruit length, fruit weight and yield per palnt (-0.637**, -0.707**, -0.537**) at genotypic level (Table 10).

4.2.6 Number of clusters per plant

The number of Clusters per plant had highly significant positive correlation with fruit per plant (0.746**) and yield per plant (0.669**) at genotypic level (Table 10). At phenotypic level fruit per plant (0.549**) & yield per plant (0.452*) showed significant positive correlation with no. of clusters per plant (Table 9). Clusters per plant showed negatively significant correlation with fruit length (-0.213*) at phenotypic level. The number of clusters per plant had non-significant negative correlation with fruit length at genotypic level and phenotypic level (Table 10). A positive correlation between number of clusters per plant and fruit yield per plant was also observed by Prasanth (2003). Nesgea *et al.,* (2002) also found similar results for this trait in tomatillo.

Table 9. Phenotypic correlation coefficients among different pairs of yield and yield contributing characters for different genotype

Characters	**Days to first flowering**	**Plant Height (cm)**	**Leaf Length (cm)**	**Leaf Width(cm)**	**Branch/ Plant**	**Cluster/ Plant**	**Fruit/plant**	**Fruit Length (mm)**	**Fruit Diameter (mm)**	**Seed/Fruit**	**Fruit Weight (g)**	**Yield per plant (kg)**
Days to first flowering	1											
Plant Height (cm)	0.266^{NS}	1										
Leaf Length (cm)	0.504**	0.421*	1									
Leaf Width (cm)	0.116^{NS}	-0.320^{NS}	-0.049^{NS}	1								
Branch/ Plant	-0.062^{NS}	0.177^{NS}	0.123^{NS}	0.104^{NS}	1							
Cluster/ Plant	0.346^{NS}	0.376*	0.588**	-0.173^{NS}	0.228^{NS}	1						
Fruit/ plant	-0.162^{NS}	0.221^{NS}	0.245^{NS}	-0.285^{NS}	-0.125^{NS}	0.549**	1					
Fruit Length (mm)	0.095^{NS}	-0.021^{NS}	0.002^{NS}	-0.063^{NS}	-0.378*	-0.213^{NS}	-0.171^{NS}	1				
Fruit Diameter (mm)	0.077^{NS}	-0.095^{NS}	0.267^{NS}	0.246^{NS}	0.004^{NS}	0.159^{NS}	0.108^{NS}	0.475**	1			
Seed/ Fruit	0.431*	0.378*	0.385*	0.089^{NS}	0.151^{NS}	0.215^{NS}	-0.149^{NS}	0.264^{NS}	0.319^{NS}	1		
Fruit Weight (g)	0.493**	0.257^{NS}	0.158^{NS}	0.076^{NS}	-0.103^{NS}	0.099^{NS}	-0.149^{NS}	0.607**	0.353^{NS}	0.478**	1	
Yield per plant	0.290^{NS}	0.386*	0.246^{NS}	-0.192^{NS}	-0.171^{NS}	0.452*	0.528**	0.422*	0.395*	0.268^{NS}	0.740**	1

** = Significant at 1%. * = Significant at 5%. NS= Non-significant

Table 10 . Genotypic correlation coefficients among different pairs of yield and yield contributing characters for different genotype

Characters	Days to first flowering	Plant Height (cm)	Leaf Length (cm)	Leaf Width(cm)	Branch/ Plant	Cluster/ Plant	Fruit/plant	Fruit Length (mm)	Fruit Diameter (mm)	Seed/Fruit	Fruit Weight (g)	Yield per plant (kg)
Days to first flowering	1											
Plant Height (cm)	0.400*	1										
Leaf Length (cm)	0.842**	0.671**	1									
Leaf Width (cm)	0.234^{NS}	-0.461*	-0.375*	1								
Branch/Plant	-0.088^{NS}	0.296^{NS}	0.364*	0.227^{NS}	1							
Cluster/ Plant	0.366*	0.652**	0.915**	-0.510**	0.500**	1						
Fruit/plant	-0.244^{NS}	0.556**	0.445*	-0.831**	0.037^{NS}	0.746**	1					
Fruit Length (mm)	0.224^{NS}	-0.521**	-0.244^{NS}	0.225^{NS}	-0.637**	-0.226^{NS}	-0.499**	1				
Fruit Diameter (mm)	0.215^{NS}	-0.256^{NS}	0.369*	0.518**	0.083^{NS}	0.287^{NS}	0.024^{NS}	0.608**	1			
Seed/Fruit	0.452*	0.441*	0.660**	0.164^{NS}	0.199^{NS}	0.236^{NS}	-0.211^{NS}	0.370*	0.522**	1		
Fruit Weight (g)	0.648**	0.215^{NS}	0.437*	-0.227^{NS}	-0.707**	0.244^{NS}	-0.097^{NS}	0.927**	0.577**	0.647**	1	
Yield per plant	0.352^{NS}	0.541**	0.611**	-0.705**	-0.537**	0.669**	0.585**	0.401*	0.382*	0.305^{NS}	0.759**	1

** = Significant at 1%. * = Significant at 5%. NS= Non-significant

4.2.7 Number of fruits per plant

The number of fruits per plant had highly significant and positive association with yield per plant (0.585** and 0.528**) at genotypic and phenotypic levels respectively (Table 9 & 10). Rani *et al.*, (2010) reported that the number of fruits per plant was negatively associated with yield per plant. It had also highly significant negative correlation with fruit length (-0.499**) at genotypic levels. Joshi *et al.,* (2004) showed that number of fruits per plant was negatively correlated with fruit weight.

4.2.8 Fruit length (mm)

Fruit length was significantly positively correlated with fruit diameter (0.475**), fruit weight (0.607**) and yield per plant (0.422*) at phenotypic level and significant positive correlation with fruit diameter (0.608**), seed per fruit (0.370*), fruit weight (0.927**) and yield per plant (0.401*) (Table 9 and 10) at phenotypic level.

4.2.9 Fruit diameter (mm)

Fruit diameter showed significant positive relation with seed per fruit (0.522**), fruit weight (0.577**) and yield per plant (0.382*) at genotypic level and it showed significant positive correlation with yield per plant (0.395*) at phenotypic level (Table 9&10). It indicated that if the diameter of fruit is high, seed per fruit will be higher. As well as fruit weight and yield per plant will also be superior if the fruit diameter gains a higher value.

4.2.10 Seed per fruit

The number of seeds per fruit had highly significant and positive association with fruit weight (0.478** and 0.647**) both at genotypic and phenotypic levels respectively (Table 9 & 10). Rani *et al.,* (2010) reported that the number of seeds per fruit was negatively associated with yield per plant.

4.2.11 Fruit weight

Single fruit weight showed positively significant (0.759** and 0.740**) on yield per plant both at phenotypic and genotypic level (Table 9&10). Rani *et al.,* (2010), Singh *et al.,* (2006) and Manivannan *et al.,* (2005) also reported positive direct effects on fruit yield.

4.2.12 Yield per plant (kg)

Fruit yield is the ultimate target of any plant breeding program. So its correlation study is very important. Type of association of this trait with other characters has already discussed.

4.3 Path coefficient analysis

Though correlation analysis indicates the association pattern of components traits with yield, they simply represent the overall influence of a particular trait on yield rather than providing cause and effect relationship. The path coefficient analysis technique was developed and demonstrated by Deway and Lu (1959) facilitates the portioning of correlation coefficients into direct and indirect contribution of various characters on yield. It is standardized partial regression coefficient analysis. As such, it measures the direct influence of one variable upon other. Such information would be of great value in enabling the breeder to specifically identify the important component traits of yield and utilize the genetic stock for improvement in a planned way. The direct and indirect effects of yield contributing characters on yield were worked out by using path analysis. Here yield per plant was considered as effect (dependent variable) and days of first flowering, plant height (m), number of clusters per plant, fruits per plant, fruit weight (g), fruit length (mm), fruit diameter (mm) were treated as independent variables. Path coefficient analysis was showed direct and indirect effects of different characters on yield of tomatillo in (Table 11).

4.3.1 Days to first flowering

Days to first flowering had positive direct effect (0.076) on yield per plant (Table 11) which is contributed to result non-significant positive genotypic correlation with yield per plant (0.352). Matin *et al.*, (2001) reported similar result with the present study and they stated that days to first flowering had positive direct effect on yield per plant. It had positive indirect effect on plant height (0.066), branch per plant (0.003), fruit length (0.020), fruit diameter (0.004), fruit weight (0.458).

It had negative indirect effect on leaf length, leaf width, fruit per plant and seed per fruit.

4.3.2 Plant height

Plant height had positive direct effect (0.164) on yield per plant (Table 11), which is contributed to result significant positive genotypic correlation with yield per plant (0.541**). It had positive indirect effect through DFF (0.030), LW (0.012) CPP (0.101), FPP (0.304), FW (0.152) .

4.3.3 Leaf length

Leaf length had negative direct effect (-0.174) on yield per plant. It had also significant positive correlation with yield per plant (0.611**) at genotypic level (Table 11**)**. This trait had also indirect positive effect on DFF (0.064), PH (0.110), LW (0.010), CPP (0.141), FPP (0.243), FD (0.007) & FW (0.309). Leaf length showed indirect negative effect on BPP (-0.011), FL (-0.022), LW (-0.006) and SPF (-0.065) (Table 11). Padda *et al.*, (2007), Singh *et al.*, (2004) revealed that leaf length exhibited positive effect on yield per plant at the genotypic and phenotypic levels.

4.3.4 Leaf width

Leaf width had negative direct effect (-0.025) on yield per plant. It had also significant negative correlation with yield per plant (-0.705**) at genotypic level

(Table 11). This trait had also indirect positive effect on DFF (0.018), LL (0.065), indirect effect on yield per plant through LL (-0.117), BPP (-0.009) and FL (-0.047), FD (-0.005), SPF (-0.043). Matin *et al.,* (2001) reported that plant height had negative direct effect on yield per plant.

Table 11. Partitioning of genotypic correlations into direct (bold) and indirect effects of twelve important characters by path analysis

Characters	Days to first flowering	Plant Height (cm)	Leaf Length (cm)	Leaf Width (cm)	Branch/ Plant	Cluster/ Plant	Fruit/plant	Fruit Length (mm)	Fruit Diameter (mm)	Seed/Fruit	Fruit Weight (g)	Genotypic correlation with Yield per plant (kg)
Days to first flowering	**0.076**	0.066	-0.147	-0.006	0.003	0.057	-0.133	0.020	0.004	-0.044	0.458	0.352^{NS}
Plant Height (cm)	0.030	**0.164**	-0.117	0.012	-0.009	0.101	0.304	-0.047	-0.005	-0.043	0.152	0.541**
Leaf Length (cm)	0.064	0.110	**-0.174**	0.010	-0.011	0.141	0.243	-0.022	0.007	-0.065	0.309	0.611**
Leaf Width (cm)	0.018	-0.076	0.065	**-0.025**	-0.007	-0.079	-0.454	0.020	0.010	-0.016	-0.161	-0.705**
Branch/ Plant	-0.007	0.049	-0.064	-0.006	**-0.031**	0.077	0.020	-0.058	0.002	-0.020	-0.500	-0.537**
Cluster/ Plant	0.028	0.107	-0.160	0.013	-0.016	**0.155**	0.408	-0.021	0.005	-0.023	0.173	0.669**
Fruit/ plant	-0.019	0.091	-0.078	0.021	-0.001	0.115	**0.547**	-0.045	0.000	0.021	-0.068	0.585**
Fruit Length (mm)	0.017	-0.086	0.043	-0.006	0.020	-0.035	-0.273	**0.091**	0.011	-0.036	0.655	0.401*
Fruit Diameter (mm)	0.016	-0.042	-0.064	-0.013	-0.003	0.044	0.013	0.055	**0.018**	-0.051	0.408	0.382*
Seed/ Fruit	0.034	0.072	-0.115	-0.004	-0.006	0.036	-0.115	0.034	0.010	**-0.098**	0.458	0.305^{NS}
Fruit Weight (g)	0.049	0.035	-0.076	0.006	0.022	0.038	-0.053	0.084	0.011	-0.064	**0.707**	0.759**
Residual effect 0.016												

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

4.3.5 Number of branches per plant

Number of branches per plant had a negative direct effect on yield per plant (-0.031). It had also negative but indirect effect on DFF (-0.007), LL (-0.064), LW (-0.006), SPF (-0.020) and FW(-0.500). It had a significant negative correlation with yield per plant (-0.537**) (Table 11). It had positive indirect effect via PH (0.049), CPP (0.077), FPP (0.020) and FD (0.002).

4.3.6 Number of clusters per plant

Number of clusters per plant showed positive direct effect (0.155) on yield per plant and significant positive correlation (0.669**) at genotypic level. It also showed positive indirect effects through DFF (0.028), PH (0.107), LW (0.013), FPP (0.0.408), FD (0.005) and FW (0.173) **(**Table 11). It also showed negative indirect effects on LL (-0.160), BPP (-0.016), FL (-0.021) and SPF (-0.023). Mayavel *et al.,* (2005) also reported that number of clusters per plant had negative direct effects on fruit yield.

4.3.7 Number of fruits per plant

Path analysis revealed that fruits per plant had direct positive effect (**0.547**) on yield per plant and highly significant positive correlation with yield per plant (0.585) at genotypic level (Table 11**)**. Further, number of fruits per plant showed indirect positive effect on PH (0.091), LW (0.021), CPP (0.115) and SPF (0.021). This trait had also indirect negative effect on DFF (-0.019), LL (-0.078), BPP (-0.001), FL (-0.045) and FW (-0.068). Significant genotypic correlation between fruit weight and yield further strengthened their reliability in the process of selection for higher yield. Rani *et al.,* (2010), Singh *et al.,* (2006) and Manivannan *et al.,* (2005) also reported positive direct effects on fruit yield.

4.3.8 Fruit length

Fruit length had positive direct effect (0.091) on yield per plant. It had also significant positive correlation with yield per plant (0.401*) at genotypic level **(**Table 11). This trait had also indirect positive effect on DFF (0.017), LL (0.043), BPP (0.020), FD (0.011) AND FW (0.655). Fruit length showed indirect negative effect on DFF (-0.0006), PH (-0.086), LW (-0.006), CPP (-0.035), FPP (-0.273) and SPF (-0.036) (Table 11). Padda *et al.*, (2007), Singh *et al.*, (2004) revealed that fruit length exhibited positive effect on yield per plant at the genotypic and phenotypic levels.

4.3.9 Fruit diameter

Fruit diameter showed negative direct effect (0.018) on yield per plant. It had also non-significant positive correlation with yield per plant (0.382*) at genotypic level (Table 11). It had positive indirect effect on DFF (0.016), CPP (0.044), FPP (0.013), FL (0.055), FD (0.018) AND FW (0.408). Fruit diameter had negative indirect effects on PH (-0.042), LL (-0.064), LW (-0.013), BPP (0.003) and SPF (-0.051) (Table 11). Padma *et al.*, (2002) found that fruit diameter had high positive direct effect on fruit yield at the genotypic and phenotypic levels. This is supported by present findings.

4.3.10 Number of seeds per fruit

Path analysis revealed that number of seeds per fruit had direct negative effect (-0.098) on yield per plant and non-significant positive correlation with yield per plant (0.305) at genotypic level (Table 11). Further, it showed indirect positive effect on DFF (0.034), PH (0.072), CPP (0.036), FL (0.034) FD (0.010) and FW(0.458). This trait had also indirect negative effect LL (-0.076), LW (-0.004), BPP (-0.006) and FPP (-0.115). Rani *et al.*, (2010), Singh *et al.*, (2006) and Manivannan *et al.*, (2005) also reported positive direct effects on fruit yield.

4.3.11 Fruit weight

Path analysis revealed that single fruit weight had direct positive effect (0.707) on yield per plant and significant positive correlation with yield per plant (0.759**) at genotypic level (Table 11). This trait had also indirect positive effect on DFF (0.049), PH (0.035), LW (0.006), BPP (0.022), CPP (0.038), FD (0.011 and FL (0.084). Further, fruit weight showed indirect negative effect on LL (-0.076), FPP (-0.053), SPF (-0.064). Significant genotypic correlation between fruit weight and yield further strengthened their reliability in the process of selection for higher yield. Rani *et al.*, (2010), Singh *et al.*, (2006) and Manivannan *et al.*, (2005) also reported positive direct effects on fruit yield.

CHAPTER V
SUMMARY AND CONCLUSION

The present study was undertaken at the Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh, with ten genotypes of tomatillo (*P. ixocarpa* Brot.) during October 2019 to march 2020. Seeds were sown in seed bed and then transferred to the main field in Randomized Complete Block Design with three replications. Data on various yield attributing characters such as, days to first flowering, Plant height, number of branches per plant, number of clusters per plant, number of fruits per plant, leaf length, leaf width, fruit weight, fruit length , fruit diameter , seed per fruit and yield per plant were recorded. Analysis of variance revealed significant differences among all the genotypes for all the characters under study.. The number of fruit yield per plant showed highest range of variation (0.44 to 1.10 kg) that means wide range of variation present for this character. In case of days to first flowering, number of clusters per plant, fruit per plant, fruit length, seed per fruit and fruit weight, showed higher influence of environment for the expression of these characters. On the other hand, Leaf length, leaf width, branch per plant, and fruit yield per plant showed least difference in phenotypic and genotypic variance suggesting additive gene action for the expression of the characters. All the characters under the present study exhibit the highest value of heritability.

Correlation coefficients among the characters were studied to define the association between yield and yield components. In general, most of the characters showed the genotypic correlation co-efficient were higher than the corresponding phenotypic correlation coefficient suggesting a strong inherent association between the characters under study. Significant positive correlation with yield was found in DFF, PH, CPP, FPP, FW and FD. Significant negative correlation with yield was found in LL, LW AND BPP. Non-significant negative correlation with yield per plant was found in days to SPP at genotypic and phenotypic level, respectively.

The significant positive correlation with yield per plant was found in plant height, single fruit weight, number of fruits per plant content at genotypic and phenotypic level. In addition, there were non-significant positive correlation with fruit yield per plant was also found in number of clusters per plant at genotypic and phenotypic level, respectively. On the other hand, the non-significant negative correlation with yield per plant was also found in days to first flowering and plant height while the high significant negative correlation was found to first flowering in genotypic and phenotypic level, respectively.

Path coefficient analysis showed that single fruit weight had the positive correlation with fruit yield per plant. Coherently, this trait contributes to the yield through direct effect (0.547) indicating selection will be judicious and more effective for these characters in future breeding program. It was also showed that fruit weight had the highest positive correlation (0.707) with fruit yield per plant and this trait contributes to the yield through direct effect (0.759**) indicating selection will be judicious and more effective for these characters in future breeding program. LL, LW, BPP and seed per fruit had negative direct effect with fruit yield per plant.

From the findings of the present study, the following conclusions could be drawn:

i. Tomatillo could be a promising crop in Bangladesh as they are high yielding

ii. Selection should be applied for desired characters such as lowest days to first flowering, increased number of fruits per plant, fruit weight, fruit diameter and fruit length to develop high yielding varieties.

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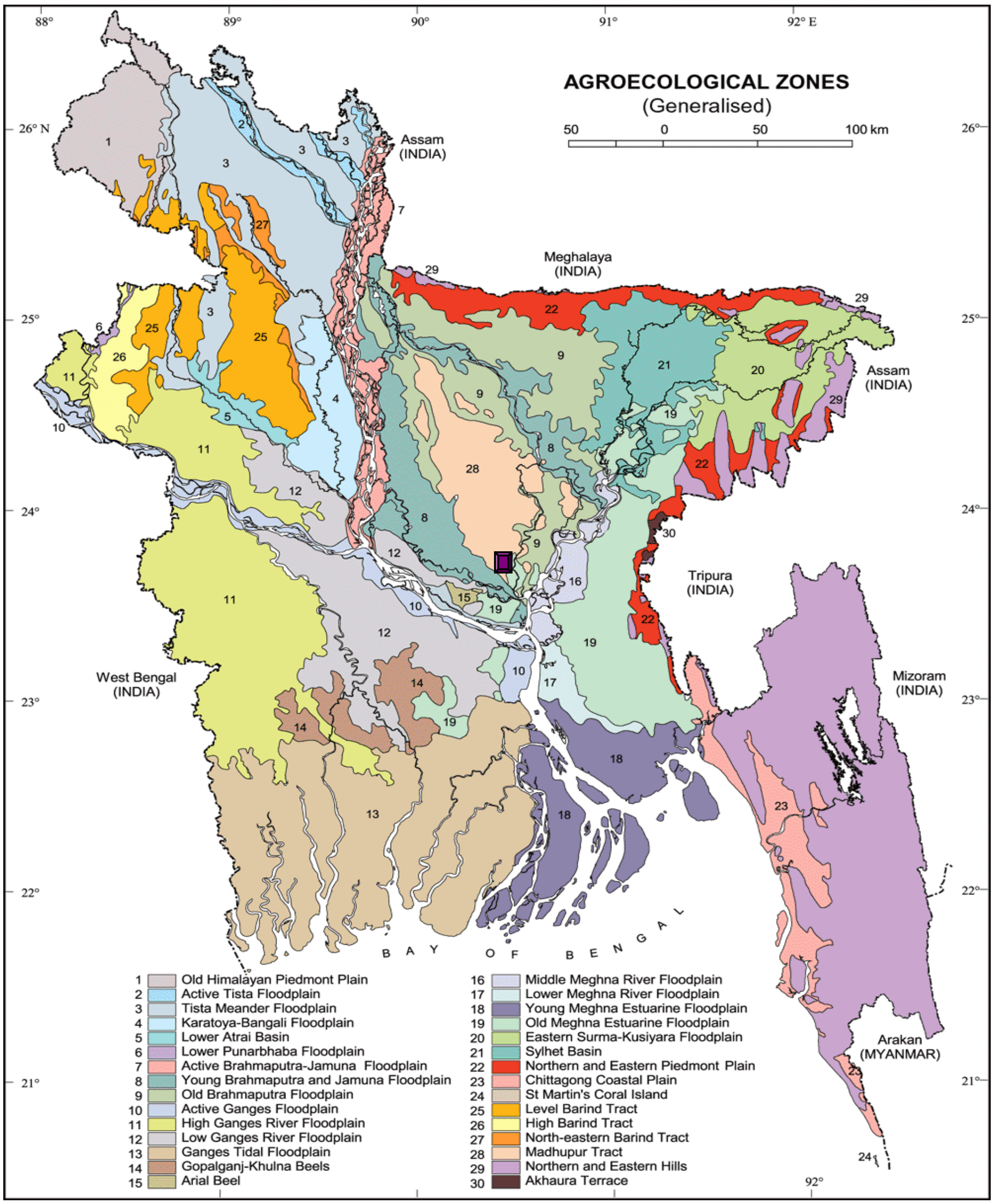
APPENDICES

Appendix I. Map showing the experimental site under the study



The experimental site under study

Appendix II. Monthly average temperature, relative humidity and total rainfall and sunshine of the experimental site during the period from 10 November, 2019 to 26 February, 2020

Month	Air temperature (ºC)		Relative humidity (%)	Rainfall (mm) (total)	Sunshine (h)
	Maximum	Minimum			
November 2019	34.8	18.0	77	227	5.8
December 2019	32.3	16.3	69	0	7.9
January 2020	29.0	13.0	79	0	3.9
February 2020	28.1	11.1	72	1	5.7

Source: Bangladesh Meteorological Department (Climate and Weather Division), Agargoan, Dhaka - 1212

Appendix III: Mechanical, physical and chemical characteristics of initial soil (0-15 cm depth) of the experimental site

A. Physical composition of the soil

Soil separates	%
Sand	36.90
Silt	26.40
Clay	36.66
Texture class	Clay loam

B. Chemical composition of the soil

Sl. No.	Soil characteristics	Analytical data
1	Organic carbon (%)	0.82
2	Total N (kg/ha)	1790.00
3	Total S (ppm)	225.00
4	Total P (ppm)	840.00
5	Available N (kg/ha)	54.00
6	Available P (kg/ha)	69.00
7	Exchangeable K (kg/ha)	89.50
8	Available S (ppm)	16.00
9	pH (1:2.5 soil to water)	5.55
10	CEC	11.23

Source: SAU library, Sher-e-Bangla Agricultural University, Dhaka.

Appendix IV. Showing a part of experimental field of the present study with research supervisor

Appendix V. Showing tallest (133.67cm) Tomatillo plant of the research