GENETIC ANALYSIS IN F_5 GENERATION OF TOMATILLO

(*Physalis ixocarpa* Brot.)

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BY

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CERTIFICATE

This is to certify that thesis entitled, "Genetic Analysis in F_5 Generation of Tomatillo (Physalis ixocarpa brot.)" 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 MILON CHANDRO RAY, Registration number 19-10246 under my supervision and guidance. No part of the thesis has 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 been acknowledged.

Dated: December, 2021
Dhaka, Bangladesh

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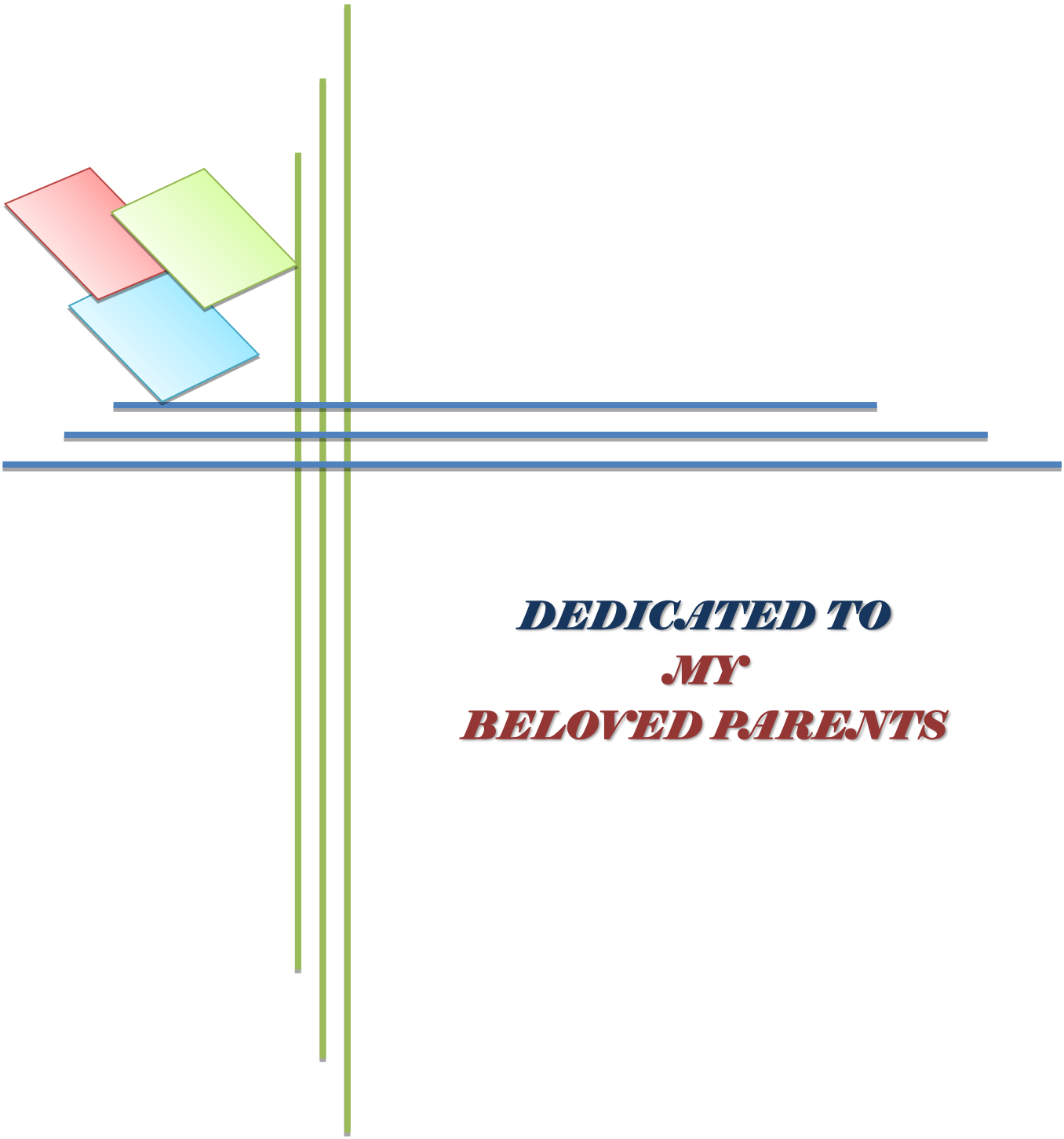
Supervisor



DEDICATED TO

MY

BELOVED PARENTS

Some commonly used abbreviations

Full word	Abbreviation	Full word	Abbreviation
Abstract	*Abstr.*	Information	*Inf.*
Advances/Advanced	*Adv.*	International	*Intl.*
Agriculture	*Agric.*	Journal	*J.*
Agricultural	*Agril.*	Kilogram	Kg
Agronomy	*Agron.*	Limited	*Ltd.*
And others	*et al.*	Ministry	*Min.*
Analysis of Variance	ANOVA	Muriate of Potash	MP
Applied	*Appl.*	Negative logarithm of hydrogen ion concentration (-log $[H^+]$)	pH
Archives	*Arch.*		
Bangladesh Bareau of Statistics	BBS		
Biology	*Biol.*	Non-significant	ns
Botany	*Bot.*	Mid parent	MP
Better parent	BP	Parts per million	ppm
Breeding	*Breed.*	Percentage	%
Centimeter	Cm	Proceedings	*Proc.*
Coefficient of variation	CV	Programme	*Prog.*
Cross between two dissimilar parents	X	Randomized Complete Block Design	RCBD
Degree Celsius	°C	Replication	*Rep.*
Ecology	*Ecol.*	Research	*Res.*
Economic	*Econ.*	Review	*Rev.*
Environment	*Environ.*	Science	*Sci.*
Etcetera	etc.	Serial	Sl.
Experimental	*Expt.*	Society	*Soc.*
Food and Agricultural Organization	FAO	Specific combining ability	SCA
Gazette	*Gaz.*	That is	*i.e.*
General	*Gen.*	The second generation of a cross between two dissimilar parents	F_2
General combining ability (GCA)	GCA		
Genetics	*Genet.*	Triple Super Phosphate	TSP
Gram	G		
Hectare	Ha	University	*Uni.*
Heredity	*Hered.*	Variety	*var.*
Horticulture	*Hort.*	Vegetable	*Veg.*
Horticultural		Videlicet (namely)	*viz.*
Incorporated	*Inc.*	Weight	wt.

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The Author

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GENETIC ANALYSIS IN F_5 GENERATION OF TOMATILLO (*Physalis ixocarpa* Brot.)

By

MILON CHANDRO RAY

ABSTRACT

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the Rabi season of 2021 under field condition to identify the variability, correlation and path coefficient analysis by considering ten yield contributing characters using sixteen populations in F_5 generation of tomatillo (*Physalis ixocarpa* Brot.). The experiment was laid out in RCBD with three replications. The population G14 showed the early flowering plant. The population G2 showed the highest plant height. and the population G15 showed the highest fruit length. The population G12 showed the highest fruit diameter. Population G6 showed the highest brix percentage. G11 have highest pH value than the others. Individual fruit weight (60.39g) was observed in G12 population and highest fruit yield per plant (3.76kg) was observed in G4 population. But the population G7 showed the highest number of fruits per plant. Lower difference between PCV and GCV for days to first flowering, plant height, fruit length, fruit diameter, brix percentage, pH, individual fruit weight, number of fruit per plant, yield per plant, suggested that environmental influence was less on the expression of the genes controlling these traits and selection based upon the phenotypic expression of these characters would be effective for the improvement of tomatillo. High heritability coupled with high genetic advance in percentage of mean for brix percentage, individual fruit weight, number of fruits per plant, fruits yields per plant were obtained, suggesting that the heritability of these traits was due to additive gene effects and selection may be effective in early generations for these traits. Yield per plant showed positively significant association with number of branches per plant and number of fruits per plants for both genotypic and phenotypic level, indicating that a possible increase in these traits tends to increase in fruit yield per plant. A positive direct effect was obtained for plant height, number of branches per plant, fruit length, Brix percentage, pH, individual fruit weight and number of fruits per plant on fruit yield per plant. Therefore, considering the agronomic and genetic performance the population G4 for high yield, G8 population for the fresh consumption, G12 and G15 for larger size fruits might be suggested for further selection in next generation that would be effective in future breeding program.

CHAPTER I

INTRODUCTION

A herbaceous annual with an uncertain growth habit is the tomatillo (*Physalis ixocarpa/Physalis philadelphica)* or husk tomato. It is indigenous to Central America, where it is allegedly impossible to make green sauce or salsa verde without it. Three members of the *Physalis* genus produce edible fruit that is richer in solids, ascorbic acid, and protein than tomato (Yamaguchi, 1983). It is used as a vegetable or in sauces, whereas *Physalis peruviana* L. (cape gooseberry, uchuba) and *P. pruinosa* L. (ground cherry, husk tomato) are used as juice and jam fruit. Tomatillo is a member of the solanaceae family that have spherical or rounded, green or green-purple fruit. Tomatillo has n=12 basic chromosomes and the majority of its species are diploid (Menzel, 1951). An inedible husk that resembles paper and surrounds the tomatillo fruit is made of the calyx (Waterfall, 1967). It looks as the "Foshka Begun" which appears to be a widespread plant in our nation. It can fill the husk and split it open by harvest when it reaches maturity. Gradually, the husk becomes brown. The husk's freshness and greenness are quality indicators. Tomatillo fruits resemble green tomatoes while they are in their husk, but they are compact, firm, and bright green inside. Its inside filled with a delicious flesh and small seeds. The primary culinary features of tomatillo fruit are its vibrant green and purple color and sour flavor. From Mexico, tomatillos were exported to Kenya, South Africa and Australia. The crop in Mexico started to be industrialized around 10 years ago, and in 2019, husk tomato production in Mexico was 834,274 ton, (Alafita-Vásquez *et al*., 2021). In 2013, the Sher-e-Bangla Agricultural University's Department of Genetics and Plant Breeding brought it to Bangladesh as well and after multi-location yield trial two tomatillo varieties were developed as SAU tomatillo 1 and SAU tomatillo 2.

Tomatillo provide 32 Kcal of energy, 5.84 g of carbohydrates, 0.96 g of protein, 1.02 g of total fat, 1.02 g of dietary fiber, and 1.9 g of vitamins (folates, niacin, pyridoxine, thiamin, 114 IU of vitamin A, 11.7 mg of vitamin C,0.38 mg of

vitamin E, and 1.850 mg of thiamin), K 10.1 mg), Sodium 0.1 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 mg, Zinc 0.2mg, Carotene-ß 63 mg, Carotene- 10 mg, and Lutein-zeaxanthin 467 mg (Yamaguchi, 1983).

One of the components in tomatillo proven to be not just antibacterial but also a natural cancer fighter is Ixocarpalactone-A (Choi *et al*. 2006) one of a recently discovered class of naturally occurring phytochemical substances called withanolides. Even if they did not understand how it worked, traditional healers in India have been known to recommend meals that contain these substances as a tonic for arthritis and other musculoskeletal ailments. Tomatillos can be cooked, fried, used in salads, and processed into sauces, pickles, and other foods. Mexican salsa particularly well known in Mexico, the United States, and other nearby nations. Around 22,277,000 kg of table sauces, pickles, and other products are processed in Louisiana, with a value estimated at $58,427,000. About 77% of the volume was made up of table sauces (Broussard and Hinson, 1988). *P. ixocarpa* is becoming more popular as a new crop in California as a result of the rise in popularity of Mexican cuisine in the country (Quiros, 1984).

Development of tomatillo requires information on genetic variability, heritability, and genetic progress across various population. Availability of natural and/or generated genetic variability is a prerequisite for any crop improvement and to develop superior cultivars as it provides a wide scope for the selection. The effectiveness of selection depends on the nature, extent, and magnitude of genetic variability present in the material and the degree of heritability. Selection of genetically varied parental combinations, accurate classification of accessions, and intra- and inter-genus crossing all benefit from analysis of genetic variability, heritability, and genetic advancement of agro-morphogenic features. Genetic variability is the 1st stem for a successful breeding program for any crop species and a successful survey of genetic variability is important before aiming to high yielding variety development.

Heritability in conjunction with genetic advance would give a more reliable index of selection value (Johnson *et al*., 1955). The co-relation co-efficient between yield components usually show a complex chain of interacting relationship. Path co-efficient analysis partitions the components of co-relation co-efficient into direct and indirect effects and visualizes the relationship in more meaningful way. In spite of genetic variability, current study aimed to determine correlation and path coefficients between sixteen population to establish selection criteria which might help to develop population for high yielding.

Considering the above facts, the present study was therefore under taken the following objectives:

- To assess the genetic variability among tomatillo population of F_5 generation;
- To recognize the nature of relationship between yield and its components by estimating genotypic and phenotypic correlation coefficient and
- To identify the direct and indirect effects between yield and yield contributing trait through path coefficient analysis.

CHAPTER II

REVIEW OF LITERATURE

There is a need for greater study due to the high level of genetic variety in tomatillo cultivars. Numerous tomatillo species, both domesticated and wild, exhibit both some similarities and differences. But researchers from across the world are taking notice of the wild tomatillo and speculating about whether it may lead to a significant medical advance. In their preliminary research, they have discovered components from the wild tomatillo that have potent anticancer capabilities against breast cancer, skin cancer, thyroid cancer, and brain cancer (Pearce, 2012).It is clear that maintaining wild species, local variants, and out-of-date population in gene banks is necessary, and doing so has become a crucial aspect of maintaining genes (Gepts, 2006). The accessions in gene banks described and analyzed in order to ascertain the degree of genetic variety. This would enable the selection of population of interest in breeding programs. (Terzopoulos and Bebel, 2008; Balestre *et al*., 2008). The tomatillo is a well-researched agricultural species in terms of plant breeding, genetics, and genomics. There are currently many resources available for its research, which might result in an increase in the assessment of tomatillo biology (Barone *et al*., 2008). Many studies have been done using different genes to examine its genetic diversity (Carelli *et al*., 2006; Martinez *et al*., 2006).

2.1 Nomenclature, Origin and distribution of tomatillo

The precise borders of *Physalis* are well defined with some names being used twice, and there have been several modifications to the nomenclature over the past 50 years. Tomatillos were cultivated in Mexico before the time of Columbus, claims Plata (1984). For over 400 years, botanists have referred to tomatillo as *P. philadelphica* Lam. In 1651, Francisco Hernandez reported two kinds from a wide range of plant species that the Aztecs termed tomate. According to botanists, the tomatillo is a domesticated plant that is descended from plants that are closely related not identical to the small-fruited miltomate,

which is a wild variety of plant. The vast range of genetic diversity present, which is likely the result of interspecific hybridization (Menzel 1951; Waterfall 1958), as well as the ambiguity of the previous taxonomic classifications, are the key contributors to the species' complexity. Menzel (1951) conducted comprehensive cytologic and taxonomic investigations on the genus *Physalis* in order to clarify its taxonomic categorization. Menzel replaced *P. philadelphica* with the variable *P. ixocarpa* Brot., reducing *P. philadelphica* to synonymy a term that eventually came to be widely used for the domesticated tomatillo. The length of the peduncle, which was shorter in *P. ixocarpa* than in *P. philadelphica*, was the sole obvious distinction between the two species. When researching the species of North Mexico, Waterfall (1958) used this name; however, he changed his mind when researching *Physalis* species from Mexico and Central America (Waterfall 1967). He included the *P. ixocarpa*, which has tiny flowers, inside the more inclusive *P. philadelphica* boundaries. *P. ixocarpa* is a separate species that differs from *P. philadelphica* based on prior cytological data, the unusual sigma, and the tiny blooms of the type, according to Fernandes (1974), who conducted a detailed analysis of this nomenclatural difficulty. Recent research has focused on using chromosome morphology to comprehend the interspecific relation within the genus.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 has not yet clarified especially between *P. ixocarpa* and *P. philadelphica.*

The stems of *Physalis* plants are herbaceous. Some have short to elongated rhizomes, and the leaves are often alternating and widely oval to linear. The flowers occasionally hang in the axillary branches, giving them the appearance of being axillary between the two branches. The blooms are solitary in the axis of the leaves. Many of the blooms dangle barely over the ground, and the dangling blossoms are frequently obscured by the foliage (Sullivan, 1986). The corollas of the flowers are campanulate, rotating, and have reflexed petal

margins. The base of each petal has a dark purple patch that are often seen in yellow petals. The calyx is joined and has lobes that are longer than half of its length. The filaments of the androecium's five stamens are joined to the base of the corolla tube. The ovate-oblong anthers are lateral slit-dehiscent. The fruit is a berry with two carpets and numerous seeds (Waterfall, 1958). A single branch with three to five internodes rises above the cotyledons in the tomatillo seedlings. Flower with one leaf, and two lateral ramifications are present at the end of the final internode. Each ramification contains two branches, one terminal flower, one leaf, and one node that finishes in the same fashion. With the exception that there is no further branching once two leaves are grown, this pattern persists until senescence. The length variation and abundance of adventitious roots in the internodes are two characteristics of the major branches. These roots are separate from the main root system and grow into the soil when they come into touch with it (Pretz and Deanna, 2020; Whitson, 2016; Gollapudi and Motohashi, 2013;).

Since before the Conquest, the tomatillo (*Physalis ixocarpa* Brot.) has been widely cultivated in Mexico, where it is an essential vegetable for making spicy sauces with chili and other foods (Estrada-Trejo *et al*., 1994). It has been growing in Russia since the Vavilov expeditions, in backyard gardens (Medvedev, 1958). This plant is indigenous to Mexico and Central America, where it is currently one of Mexico's most significant crops (Cantwell *et al*., 1992). It is a solanaceous plant native to Mesoamerica grown in Mexico and Guatemala. Its inclusion in the diet of the Mexican populace stretches back to pre-Columbian periods, according to a number of archaeological discoveries. In fact, remains of *Physalis* sp. utilized as food had been discovered during excavations in the Tehuacán valley (900 BC–AD 1540). It was far more popular in pre-Hispanic Mexico than the tomato (*Lycopersicon* sp.). With the exception of rural areas where historical eating traditions still exist and the tomato's higher resistance to rot is appreciated, this preference has not been upheld. The tomato gained more popularity outside of Mesoamerica and *Physalis* sp. was marginalized or its production was

abandoned, as happened in Spain, possibly due to the fruit's colorful look and the fact that there are methods to consume it that are independent of the chile (*Capsicum* sp.). It's important to remember that it is known as "tomate" in other regions of the nation as well as in Central and South America, the fruit of *Lycopersicon* sp. is mostly known as "jitotomate" in central Mexico. (González-Mendoza *et al.*, 2011). *P. philadelphica* was domesticated in Mexico before being transported to Europe and other regions of the world. The story of its arrival in Spain is well known. In fact, it is thought that both wild and domesticated populations of this species may be found in central Mexico, which is where they are said to have first evolved. The name "tomato" originates from the word "tomatl," which is a general term for globose fruits or berries with many seeds and watery flesh that are occasionally covered in a membrane. Very few of the many species in the *Physalis* genus are harvested for their fruit. Peru has grown *P. peruviana* L. since pre-Columbian times. *P. chenopodifolia* fruit are harvested in the Mexican state of Tlaxcala. Because of the colorful calyx of its fruit, *P. alkekengi* are planted throughout Europe as a decorative plant, and their fruits are consumed in central and southern Europe.

Up to the present, the tomatillo has consistently been a staple of the Mexican and Guatemalan cuisine, mostly in the form of sauces made from the fruit and crushed chilies to enhance the flavor of food and increase appetite. In o rder to temper the heat of the green chili, the tomatillo also added to sauces with green chili. The tomatillo fruit is used cooked, or even raw, to make purees or minced meat dishes that serve as the foundation for salsa verde (green sauce), a general term for a variety of chili sauces. They may also use as components in different stews. The husks (calyces) infused to give white rice flavor and to tenderize red meats. They also used to improve the spongy quality of tamale dough and fritter dough.The crop in Mexico started to industrialized around 10 years ago, and 600 tons were thought to be processed annually by agro-industries at that time.Which were exported in an amount of 80% entire tomatillos, without a calyx, and canned, to the United States. The remaining portion was used to make bottled sauces for the domestic market.

P. philadelphica is becoming more significant as a crop that was introduced in California as a result of the rise in popularity of Mexican cuisine in the country. It said to have a variety of medical benefits as well.

2.2 Variability

Assessing the degree and kind of variation of plant traits in breeding populations is essential for achieving genetic improvement of a crop through an effective breeding program. It aids the breeder in increasing the effectiveness of selection. Numerous studies looked on tomatillo and tomato variety because of this. According to Yi *et al.* (2008), domestication and inbreeding significantly decreased genetic variety. Any crop improvement program's capacity to be successful depends on the amount of genetic diversity and how heritable the desired characteristic is. Both morphological and molecular marker used to determine genetic diversity. Previous researchers have stressed that the breeding material contains genetic heterogeneity (Reddy *et al.,* 2013; Singh, 2009; Shuaib *et al*., 2007). A field experiment was conducted to examine the genetic diversity among 25 tomato varieties, which aided in the development of a viable varietal selection procedure for breeding. Two metrics, such as morphological and molecular characteristics were used to examine all tomato accessions. In an another study, there is variation in plant height, fruit size, and color (Naz *et al*., 2013). Again, Reddy *et al.* (2013) investigated 19 exotic tomato collections indicated significant genetic variation for traits related to growth, earliness, yield, and quality. The overall variance was influenced by fruit size, plant height, and fruit production per plant.

In order to investigate the genetic diversity, heritability, and genetic advance for quantitative and qualitative qualities in tomato, a field experiment was carried out at CCSHAU, Hisar throughout the spring and summer of 2013. Featuring three replications and a randomized block design with 27 population, including two checks. All of the examined parameters, with the exception of the quantity of branches, ascorbic acid, and equatorial fruit diameter, showed high levels of significant variation (Nalla *et. al*., 2016). The variation for total soluble solids

(TSS), pericarp thickness, fruit firmness, acidity, lycopene content, and dry matter content were studied in a field experiment conducted by Singh *et al.* (2005) on 15 advance generation breeding lines of tomatoes. Under normal conditions, significant differences were found between population, whereas differences under high temperature conditions were not significant. With the exception of acid content and TSS, all the characters had greater population means during November planting than during February planting. The genetic diversity of 30 tomato population was examined in a field experiment by Shashikanth *et al*. (2010), who found that the range of variance and mean values were high for plant height, days to 50% blooming, and average fruit weight.
Before doing any experiment to enhance tomato population, a multivariate and biochemical examination of their genetic affinity is required (Alam *et. al.,* 2012). Estimation of morphological features can offer a quick method for calculating genetic variance and evaluating genotypic performance in appropriate growth settings (Shuaib *et al.*, 2007).

In an experiment for days to flowering, days to maturity, number of fruits per branch, plant height, etc., Kumari *et al*. (2007) discovered that there were very significant variations between parents for all the traits tested, with the exception of early yield, total yield, and days to flowering. Agong *et al.* (2001) examination of the Kenyan tomato germplasm revealed a considerable diversity in the quantitative features among the accessions. Fruit accessions differed substantially in average fresh and dry weight. Most landraces produced fresh and dry fruit with lower weights than market cultivars. In an experiment between 18 native and non-native tomato cultivars for five economic characteristics (plant height, number of branches per plant, number of fruits per plant, average fruit weight, and yield) in Orissa, India during rabi (1998–99) (Mohanty and Prusti, 2001); discovered significant genetic variability. For successfull enhance a crop's genetics through an effective breeding program, it is essential to understand the scope and kind of population diversity. The evaluation aids of a breeder in increasing the effectiveness of selection. There

have been several studies on tomato variation, but not many on tomatillo variation. As a result, several studies discovered that tomato and tomatillo development habits and characteristics are comparable. Since there aren't any study resources on tomatoes, some of the results are mentioned here.

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. While analyzing combining ability from a 9x9 diallele hybrid, Farzaneh *et al*. (2013) demonstrated an earlyness in days to first flowering; nonetheless, no significant variations were discovered for this trait (Monamodi *et al*., 2013). Days to first flowering among the 26 tomato population varied noticeably, rangin vvg from 49.67 to 68.33 days (Matin and Kuddus, 2001). Total soluble solids, dry matter content, reducing sugars, titratable acidity, ascorbic acid, lycopene, 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 were all measured by Kumari *et al*. (2007). They discovered that all of the characters between parents differed highly, with the exception of acidity, early yield, and total yield Geogieva et al. observed that the pre-flowering times for the different types varied from 56 to 76 days (1969). High degrees of environmental influence may be seen in the phenotypic variation, which was relatively larger than the genotypic variance for days to first flowering (Matin, 2001; Aditya, 1995).

2.2.1 Plant height

Naz *et al*. (2013) compared the height of the plant, the length, shape, and arrangement of the leaves, as well as the size and form of the fruit, to describe morphologically 25-tomato germplasm. This study found that plant height exhibits the most variety. The largest genotypic coefficient of variation for plant height had found by Kumari *et al*. in 2007. To quantify heterosis and character association in 45 single cross hybrids derived from 10 tomato parental lines for yield and yield component characteristics, Hannan *et al*. (2007) conducted an

experiment. Plant height, days until first flowering, number of flowers per cluster, number of fruits per plant, number of fruits per plant weight, and days until first fruit ripening were the traits examined. They discovered positive high significant heterosis over the mid-parent, better parent, and standard parent heterosis, respectively, and acquired substantial genetic differences for each attribute. They came to the conclusion that there was a positive correlation between plant height, fruit number per plant.

To assess the genetic diversity of forty tomato cultivars, Joshi *et al*. (2004) conducted a field experiment. They found that plant height had the highest heritability (78.82%). Significant genotype x environment interaction for plant height had found by Ravindra *et al*. in 2003. Significant variance in plant height had documented by Shravan *et al*. (2004) and Aditya *et al.* (1995). In research involving 23 tomato population, Parthasarathy and Aswath (2002) found that there was a lot of variation among population for eight morphological features. Higher levels of variation had provided by plant height, fruit number, and fruit size.

In order to study genetic variation, Singh *et al.* (2002) conducted a field experiment with 92 tomato population. They reported that the analysis of variance revealed highly significant genetic variation for plant height, number of days until the first fruit set, number of fruit clusters per plant, number of fruits per plant, fruit weight per plant, and fruit yield. The features with sufficient variability may be taken into account in a tomato hybridization program to increase yield. Additionally, Matin *et al*. (2001) noted that for plant height, phenotypic variance was generally larger than genotypic variance. They once more noticed that the genotypic coefficient of variation was lower than the phenotypic coefficient of variation, indicating that the environment may have an impact on how this attribute expressed. While Ahmed *et al.* (1987) noticed a small range of variances, Ghosh *et al.* (1995) and Nandpuri *et al.* (1974) showed a considerable degree of variation for plant height. Additionally, Sonone *et al*.

(1986) and Prasad *et al*. (1977) revealed significant phenotypic and genotypic diversity in tomato plant height.

2.2.2 Number of branches per plant

The number of branches per plant and yield had shown positively correlated by Cuartero *et al.* in 1983. In an experiment, Menzel *et al*. (1951) found that the quantity of fruits, flowers, and fruits increases with the quantity of main branches per plant. In a field experiment with 30 tomato plants, Singh *et al.* (2005) found that five of the population had more main branches than the control. One of the five higher branching population produced the most fruits per plant than the others. Singh *et al*. (2005) noted that given the number of branches per plant, PCV was marginally greater than GCV.

To explore the genetic diversity of 30 tomato population, an experiment was carried out, and it discovered that there were considerable differences in the number of main branches per plant across the population.

2.2.3 Number of Fruits per plant

Moriconi *et al.* (1990) observed abundant blooming and fruit setting in Louisiana; Abak *et al.* (1994) discovered a favorable link between the number of main branches and the number of fruits per plant in Tomatillo. Mulato-Brito *et al*. (1985) discovered that the number of fruits per plant varies across various species of tomatillo, but Cuartero *et al*. (1983) reported that the number of fruits per plant of tomatillo rises in cultivated conditions. In the Rabi session of 2011, Prajapati *et al*. (2015) assessed 39 different tomato population at the Vegetable Research Farm in Rewa, Madhya Pradesh. For each of the qualities that were assessed, analysis of variance revealed a considerable variation among the population. The fruit plant number 1 had the most genotypic and phenotypic variation. To evaluate the kind and degree of variability, correlation, and path coefficient analysis between yield and yield-contributing features, 26 tomato population were examined. Number of fruits per plant and per cluster were considerably and favorably correlated with yield, according to correlation

(Kumar *et al*., 2013). Thakur (2009) investigated 17 different tomato population for their performance and interaction with varying settings using characteristics like fruit production and number of fruits/plant. For all of the analyzed characteristics, the analysis of variance revealed incredibly large variations in population and environments. According to Saeed *et al.* (2007), variables including the number of fruits per plant, number of flowers per plant, and yield per plant had the highest coefficients of variation. According to Joshi *et al*. (2003), the phenotypic and genotypic coefficient of variation for the quantity of fruits per plant is the largest. The output was positively impacted by the quantity of fruits per plant, but the average fruit weight was negatively impacted (Mohanty, 2003).

2.2.4 Fruit length

Fruit length and fruit diameter have a direct positive link with yield per plant, according to Mulato-Brito *et al*. (1985). Cantwel *et al*. also noted comparable outcomes (1992). To evaluate the kind and degree of variability, correlation, and path coefficient analysis between yield and yield-contributing features, 26 tomato population were examined. All of the population for the characteristics showed extremely significant differences, according to the analysis of variance (ANOVA). Path analysis at the genotypic level revealed that fruit weight, number of fruits per plant, fruit width, and number of fruits per cluster had the strongest positive direct effects on yield per plant (Kumar *et al*., 2013). In an experiment with data on fruit length, Kumari *et al*. (2007) discovered extremely significant variations between parents. Singh *et al.* (2002) observed a high PCV for fruit length demonstrated a substantial difference (Reddy and Reddy, 1992).

2.2.5 Fruit diameter

Twenty-six tomato population were used in an experiment by Kumar *et al.* (2013) to ascertain the kind and extent of variability, correlation, and path coefficient analysis between yield and yield-contributing features. All of the population for the characteristics showed extremely significant differences, according to the analysis of variance (ANOVA). At the genotypic level, path

analysis revealed that fruit weight, number of fruits per plant, fruit width, and number of fruits per cluster had the most positive direct effects on yield per plant. To research the quantitative genetics of yield and certain yield-related variables, Saleem *et al.* (2013) analyzed 25 F1 hybrids produced from 55 diallel crossings. They discovered that fruit diameter was the most heritable feature.

2.2.6 Fruit weight

In their investigation of genetic variability using several tomatillo population, Cantwell *et al*. (1992) found that both variances were large for individual fruit weight. The number of fruits per plant and production have a direct, positive connection, according to Abak *et al.* (1994). To evaluate the kind and degree of variability, correlation, and path coefficient analysis between yield and yield-contributing features, 26 tomato population were examined. All of the population for the characteristics showed extremely significant differences, according to the analysis of variance (ANOVA). Fruit weight had the greatest favorable direct impact on yield per plant, according to path analysis at the genotypic level (Kumar *et al.,* 2013). In India's Utter Pradesh, Shravan *et al*. (2004) examined genetic variation in 30 tomato population and discovered a striking variation in average fruit weight amongst the population. In a field investigation of 18 tomato varieties, Mohanty *et al.* (2003) discovered that the average fruit weight had direct beneficial impacts on yield and indirect negative effects on the number of fruits per plant. Singh *et al*. (2002) discovered that the average fruit weight had the highest phenotypic (PCV) and genotypic (GCV) coefficients of variation in an experiment using heat-tolerant tomatoes. According to Matin and Kuddus (2001), the average fruit weight of several tomato cultivars varied significantly by varietal. Brar *et al.* (2000) discovered equivalent findings for the typical fruit weight. Ahmed (1987) stated that a large range of variance was seen for individual fruit weight in a field experiment with 4 tomato population.

2.2.7 Yield per plant

In a green house, low tunnel, and open field trial, Abak *et al*. (1994) discovered that *P. ixocarpa* (Brot.) and *P. peruviana* L. species of tomatillo had the greatest

GCV for yield per plant. Procelli and Proto (1991) discovered a direct positive association between yield per plant and the number of flowers, fruits, and fruit weight on the plant. Evaluation of five Mexican tomatillo landraces, totaling 13 accessions, was carried out in Chapingo, central Mexico, and Ontario, Canada, under similar environmental circumstances. Beginning of blooming and harvest, total number of fruits gathered, and yield were the characteristics that were measured. The earliest and highest producing landraces were accession 1 of the Manzano landrace, accession 3 of the Rendidora landrace, and accession 1 of both (Mulato-Brito and Pena-Lomeli, 2007). Singh *et al*. (2006) used Mahalar statistics to analyze 48 tomato population for genetic variation and found that traits like fruit production per plant, average fruit weight, and number of fruits per plant have the greatest influence on genetic variability. Matin and Kuddus (2001) showed significant variations for yield plant-1 across the population examined. In a trial with different tomato population, Sachan (2001) noted notable variations across the population for yield plant-1. By Kumar and Tewari (1999), higher genotypic co-efficients of variance for average yield plant-1 were found across the 32 tomato population. When 8 x 8 half-diallel crosses were performed on tomatoes, the results showed substantial heterosis for yield plant-1, fruits plant-1, fruits cluster-1, and earliness, according to Pujari *et al.* (1994). The hybrid with the highest score, Punjab Chhuhara* Roma, produced 6.4 fruit clusters.

2.3 Heritability and genetic advance

In a study by Pujari *et al*. (1994), the outcomes of an 8 x 8 half-diallel cross in the tomato showed strong heterosis for yield plant-1, fruits plant-1, fruits cluster-1, and earliness. The hybrid that produced the most fruit clusters, Punjab Chhuhara* Roma, came in first place. An investigation on the quantitative genetics of yield and factors that contribute to yield was carried out by Saleem *et al*. (2013). Fruit diameter was the most heritable feature, while the number of fruits per plant exhibits the greatest estimations of GCV and PCV. In a study, Buckseth *et al*. (2012) discovered high heritability and high genetic advance for

the number of fruits plant-1, average fruit weight, yield plant-1, and pericarp thickness. This suggests that selection may be effective and that the heritability is most likely caused by additive gene effects. Saleem *et al*. (2013) investigated the quantitative genetics of yield and the elements that influence yield. The most heritable trait was the fruit diameter, but the GCV and PCV estimates are highest when the quantity of fruits per plant is included. In a study, Buckseth *et al.* (2012) found that the number of fruits plant-1, average fruit weight, yield plant-1, and pericarp thickness had high heritability and high genetic progress. The heritability is most likely produced by additive gene effects, which would support the idea that selection may be beneficial. In an experiment with twelve tomato varieties to test heredity, Pandit *et al*. (2010) found that strong heritability was accompanied by high genetic progress as a percentage of the mean for average fruit weight. In an experiment, Kumari *et al*. (2007) found that all character heritabilities were high and that genetic progress was high for plant height. Twenty tomato population were examined by Golani *et al*. (2007), who found that strong heritability, high GCV, and genetic gain for fruit weight and fruit production were present.

2.4 Correlation co-efficient analysis

Correlation is the best estimate for determining the relationships between the characters. The breeder will find it useful in making selection strategy decisions. Since yield is one of the primary goals for the majority of breeders, correlation studies between yield and features that contribute to yield have been conducted in many situations. Characters that contribute to yield are also connected. Therefore, it is crucial to consider how characteristics relate to yield and to its constituent parts when planning an effective breeding program to get the highest yield.

Agro-climatic differences from year to year and location to place might affect correlation analyses. Higher heritability than yield indicates a positive association between these, therefore by carefully choosing that component, there may be an opportunity to boost total yield. A selection of any component may

not result in an improvement in yield, according to the negative correlation coefficient among yield components. The relationship between yield and features that contribute to yield has been extensively researched. Here is a description of some of the likely scenarios.

Kumar *et al.* (2013). evaluated 49 tomato population (*Solanum lycopersicum* L.) for various quantitative and quality traits, the total number of fruits produced per plant was significantly positively correlated with gross yield, marketable yield, the number of marketable fruits produced per plant, and plant height. According to Mahapatra *et al*. (2013), there is a substantial positive association between fruit output and plant height, primary branch count, flower cluster count, fruit count, fruit length, fruit diameter, and average fruit weight. The quantity of main branches per plant rises in proportion to plant height. The number of branches per plant and the number of fruits per plant have a positive and substantial association, according to Monamodi *et al*. (2013). Buckseth *et al*. (2012) examined forty tomato population to determine the link between several variables and discovered extremely significant differences across the population. In their 2011 study of thirty different tomato population, Kumar and Dudi found that yield/plant was strongly and positively linked with plant height and fruit number/plant, and that genotypic correlation coefficients were greater than phenotypic ones. While the quantity of fruits per plant and fruit weight have a negative link, yield per plant is strongly and positively connected with fruit weight was observed by Rani *et al*. (2010). Golani *et al.* (2007) carried out a field experiment and discovered a strong and positive correlation between fruit length and weight. With 30 tomato population, Kumar *et al*. (2006) conducted a correlation co-efficient analysis and found a substantial and favorable link between the quantity of fruits on plant-1 and the fruit production on plant-1. In an experiment with cherries for correlation coefficient analysis, Manivannan *et al*. (2005) found that fruit output was meaningfully and unmistakably associated with the quantity of leaves and fruit weight. Joshi *et al.* (2004) performed a correlation analysis on 37 tomato population and found that average fruit mass,

fruit size, plant stature, and harvest period were all strongly connected with yield per plant. Arun *et al*. (2003) found that the average fruit mass and plant height were positively connected with tomato output per plant. Thirty-seven tomato population were compared for correlation by Harer *et al.* (2002), who found that the fruit yield per plant was expressively and totally associated with both the number of fruits per bunch and the number of fruits per plant.

CHAPTER III

MATERIALS AND METHODS

This chapter provides clarification on the methods that was employed to carry out the experiment. The following is a brief description of the experimental site, planting materials, soil and climate, seed bed preparation, experiment design, additional operations performed, data gathering techniques, statistical analysis procedure, etc.

3.1 Experimental site

From October 2019 to March 2020, the experiment was carried out in the Sher-e-Bangla Agricultural University's experimental field in Dhaka-1207, Bangladesh. The location was located at 23°75' N latitude, 90°34' E longitude, and 8 meters above sea level under AEZ-28. The map of Bangladesh's AEZ shows the trial site (Appendix I).

3.2 Planting materials

A total of sixteen population of F5 generation tomatillo were used in this experiment. They were obtained from the department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka-1207. Table 1 lists the names and places from which these population were collected.

3.3 Climate and soil

The experimental location was located in a subtropical climate zone where, from October to March (the Rabi season), temperatures was reasonably low and ideal for tomatillo growing in Bangladesh. The soil's pH ranged from 5.45 to 5.61, and its texture was sandy loam. Appendices II and III, which provide information on weather and the physio-chemical characteristics of soil.

Table 1. Name and source of collection of tomatillo population used in the present study

SL No	Population No	Source of collection
1	G1	GEPB, SAU
2	G2	
3	G3	
4	G4	
5	G5	
6	G6	
7	G7	
8	G8	
9	G9	
10	G10	
11	G11	
12	G12	
13	G13	
14	G14	
15	G15	
16	G16	

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

3.4 Seed bed preparation and raising of seedling

On October 23, 2019, seeds were sown in the seedbed. Provax was used to treat the seed before planting. The correct cultural norms were followed for the seed bed. In the main field, seedlings of 24 days old were transplanted. Emergence of the seedlings and tagging in the seedbed is represented in Plate 1A and in Plate 1B.

3.5 Design and layout of the experiment

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The field size was 70 m^2. Spacing was 60 cm x 40 cm. Sixteen population were planted in each replication. Plate 1C shows how the land is laid out.

3.6 Land preparation

The experimental plots were ploughed and brought into a fine tilth. The recommended dose of fertilizers and farmyard manure (FYM) was applied. Weeds and other stubbles were removed carefully from the experimental plot and leveled properly. The final land preparation was done in March 2019. Land preparation is shown in Plate 1C.

3.7 Transplanting of seedlings

On 28 December 2020, the seedlings were transplanted into the main field after being nurtured in the seedbed for 29 days. Plate 1C depicts seedling transplantation.

3.8 Manure and fertilizers application

During the last stage of soil preparation, all fertilizers and cow dung were applied, excluding urea. Three separate applications of urea were made. Table 2 displays the rate of fertilizer application.

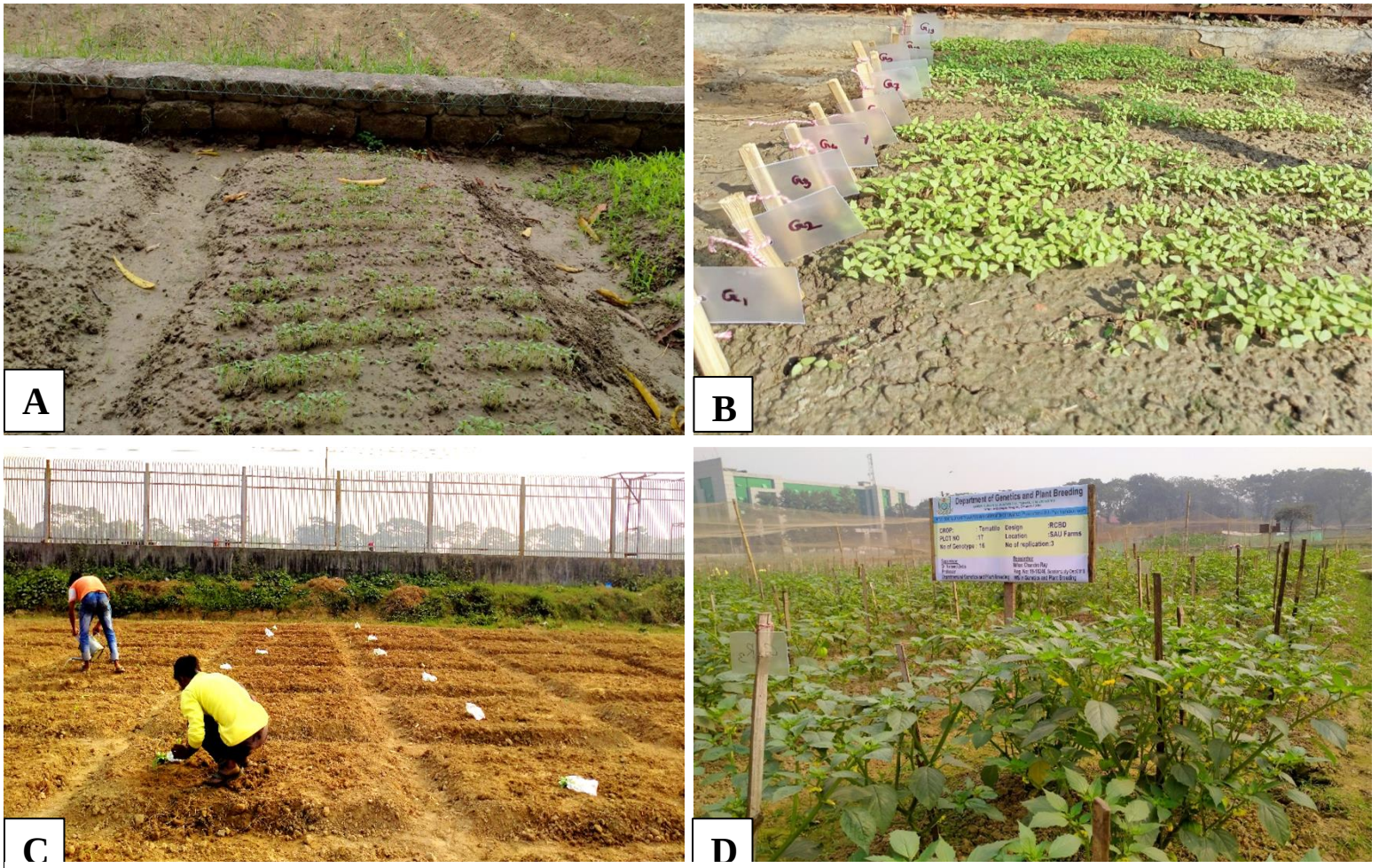

Plate 1. Seed bed and main land A) Seedlings Emergence B) Tagging of the seedling lines C) Layout, field preparation and planting of seedlings D) Tagging and stalking

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

SL. No.	Fertilizer/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

The first step was to evenly weed each plot after the seedlings were well-established. Twenty days following the initial weeding, a second one was carried out. Bamboo sticks were used as mechanical supports to maintain the plants' upright posture as they grew (Plate 1D). In order to provide plants more sunlight, prevent self-shading, pruning was done during the early stages of development by eliminating part of the lateral branches. In accordance with the situation, thinning and gap filling, stalking, watering, and aftercare carried out.

3.10 Harvesting and processing

Fruits from various lines ripened gradually over a lengthy period of time and at different times, harvesting lasted for roughly one and a half months. Fruits for each entry were allowed to ripen before the seeds were harvested and kept for later use at 4°C. On March 1, 2020, harvesting began, and it was finished on March 15, 2020. Intercultural operations, raising of seedlings, experimental fields in plant growth conditions, and the growth stage of a single tomatillo plant with closed eyes were all used there.

3.11 Data recording

Six plants were chosen and tagged from each genotype. The three replications followed this procedure. Information was gathered from those plants. Plate 2 shows the vegetative stage, blooming stage, and fruiting stage for data collection.

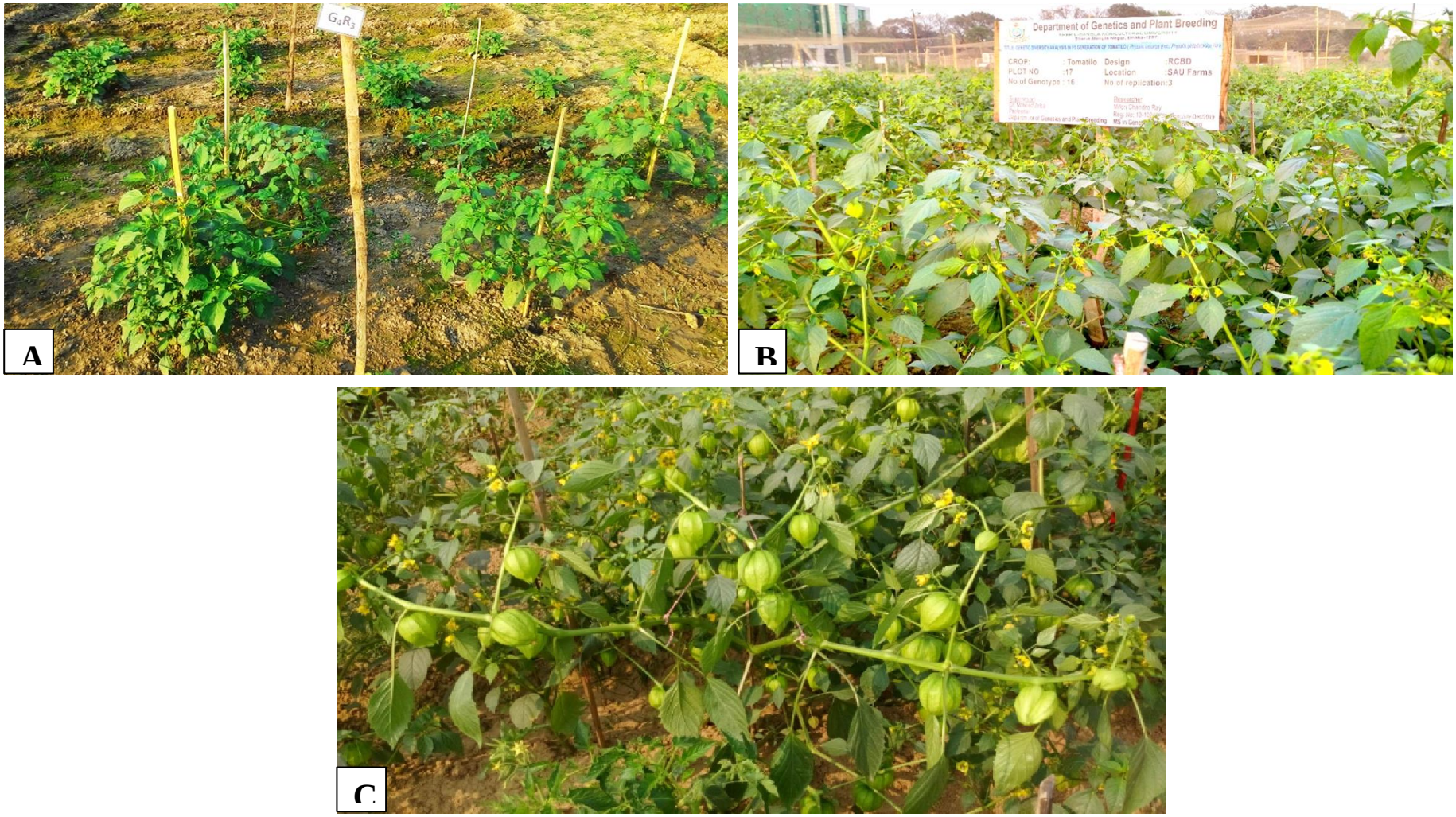

Plate 2. Different stages of plant A) Seedlings at early growth B) Flowering of plants C) Fruit setting in plants

3.11.1 Days to first flowering

Days to first flowering were calculated as the number of days between sowing and the first flower opening.

3.11.2 Plant Height

A single measurement of plant height was made 70 days following transplanting**.**

3.11.3 Number of branches per plant

After 70 days after transplanting, the number of branches per plant was counted.

3.11.4 Number of fruits per plant

From each of the five tagged plants, the total number of marketable fruits that were collected.

3.11.5 Fruit Length (cm)

Fruit length was measured using slide calipers from the stalk end to the bottom end.

3.11.6 Fruit Diameter (cm)

Slide calipers were used to measure fruit length from the stalk end to the bottom end.

3.11.7 Fruit weight (g)

Harvested fruits from the marked plant were weighed individually in grams according to their average weight (g).

3.11.8 Fruit yield per plant (kg)

Each tagged plant's weight from each harvesting was recorded, and the total weight was computed and reported as fruit yield per plant.

3.11.9 Determination of fruit juice P^H

To assess the fruit's pH using a pH meter, fruit juice was extracted from a single fruit of each genotype. To determine the pH value, the electrode was placed within the juice. A reference solution was created for the accuracy of the results before utilizing the pH meter. Extraction of fruit juice and measuring of pH is shown in Plate 3.

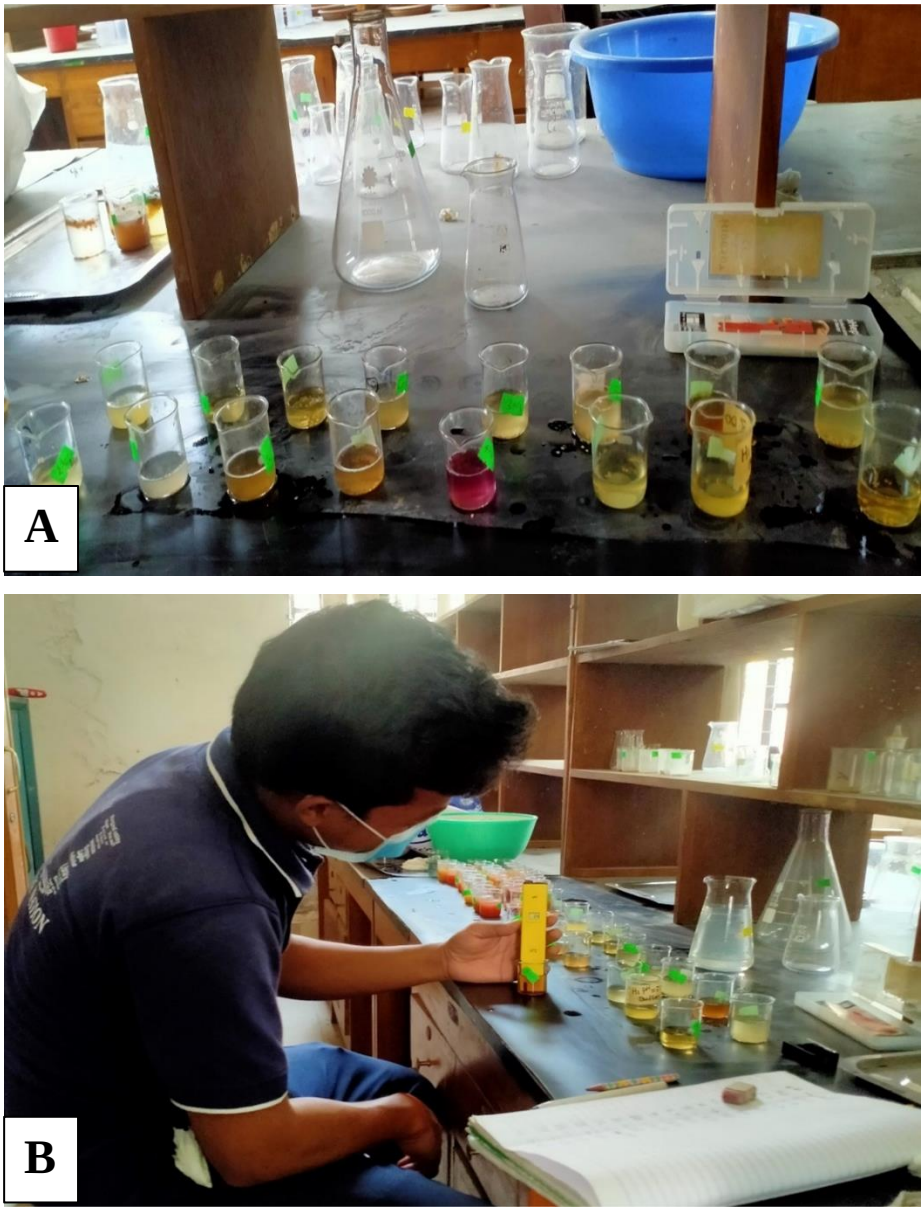

Plate 3. Different steps qualitative measurement of tomatillo fruits A) Extraction of tomatillo juice B) Measuring of pH

3.11.10 Brix percentage

Brix percentages were tested at room temperature using a portable refractive index measuring device (ERMA, Tokyo, Japan). Brix percentage (%) was calculated by extracting fruit juice from a single fruit of each genotype.

3.12 Statistical analysis

The characters' average statistics were subjected to multivariate analysis. The MSTAT-C computer application was used to do a univariate analysis of each character using the mean values for all the characters under examination. The Duncan's Multiple Range Test (DMRT) was run on each character to examine any variances in genotypic means. The mean, range, and coefficient of variation (CV%) were also calculated using MSTAT-C. Multivariate analysis was carried out by using R program (R 4.2.1)

3.12.1Estimation of genotypic and phenotypic variances

The method provided by Johnson *et al.* (1955) was used to estimate the differences in genotypic and phenotypic traits

Genotypic variance, (σ^2_g) = GMS-EMS/r

Where,

GMS = Genotypic mean sum of squares

EMS = Error mean sum of square

r = number of replications

Phenotypic variance, $(\sigma^2_p) = (\sigma^2_g) + EMS$

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

Using Burton's (1952) method, the coefficient of variation for population and phenotypes was estimated.

Genotypic co-efficient of variation, GCV (%) = $\sqrt{\sigma^2_g}/\underline{x} \times 100$

Where,

σ^2_g = Genotypic variance

$\underline{x}$ = Population mean

Similarly,

The phenotypic co-efficient of variation was calculated from the following formula.

Phenotypic co-efficient variation, PCV(%) = $\sqrt{\sigma^2_p}/\underline{x} \times 100$

Where,

σ^2_p = Phenotypic variance

$\underline{x}$ = Population mean

3.12.3 Estimation of heritability

The following formula was proposed by Johnson *et al.* (1955) to assess broad-sense heritability (Lush, 1943).

Heritability, $h^2_b(\%) = \sigma^2_g / \sigma^2_p \times 100$

Where, h^2_b = Heritability in broad sense

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

3.12.4 Estimation of genetic advance

The formula proposed by Lush (1943) and Johnson *et al.* (1955) was used to calculate the projected genetic progress for various traits under selection.

Genetic advance, $GA = K. h^2. \sigma_p$

or Genetic advance, $GA = K. \sigma^2_g/\sigma^2_p. \sigma_p$

Where,

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

σ_p= Phenotypic standard deviation

h^2_b= Heritability in broad sense

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

3.12.5 Estimation of genetic advance means percentage

Comstock and Robinson (1952) 's approach was used to calculate genetic progress as a percentage of the mean

Genetic advance (% of mean) = Genetic advance/Population mean × 100

3.12.6 Estimation of genotypic and phenotypic correlation coefficient

The formula proposed by Miller *et al.* (1958), Johnson *et al.* (1955), and Hanson *et al.* (1956) was used to calculate the genotypic and phenotypic correlation coefficient for all feasible combinations. In the same manner as for the corresponding variance components, the genotypic co-variance component between two characteristics and the phenotypic co-variance component were generated. The genotypic and phenotypic correlation between the two character pairs was calculated using the covariance components as follows:

Genotypic correlation, $r_{gxy} = GCOV_{XY}/\sqrt{GV_x}.GV_Y = \sigma_{gxy}/\sqrt{(\sigma^2_{gx}.\ \sigma^2_{gy})}$

Where,

σ_{gxy} = Genotypic co-variance between the traits x and y

σ^2_{gx} = Genotypic variance of the trait x

σ^2_{gy} = Genotypic variance of the trait y

Phenotypic correlation, $(r_{pxy}) = PCOV_{XY}/\sqrt{PV_x}.PV_Y = \sigma_{pxy}/\sqrt{(\sigma^2_{px}.\ \sigma^2_{py})}$

Where,

σ_{pxy} = Phenotypic co-variance between the traits x and y

σ^2_{px} = Phenotypic variance of the trait x

σ^2_{py} = Phenotypic variance of the trait y

3.12.7 Estimation of path co-efficient

It was done according to the procedure employed by Dewey and Lu (1959) also quoted in Singh and Chaudhary (1985), using phenotypic correlation coefficient values. In path analysis, correlation coefficients between yield and yield

contributing characters were partitioned into direct and indirect effects on yield per hectare. In order to estimate direct and indirect effects of the correlated characters, i. e. 1, 2, 3….and 12 on yield y, a set of simultaneous equations (twelve equations in this example) is required to be formulated as shown below:

$r_{1.y} = P_{1.y} + r_{1.2} P_{2.y} + r_{1.3} P_{3.y} + r_{1.4} P_{4.y} + r_{1.5} P_{5.y} + r_{1.6} P_{6.y} + r_{1.7} P_{7.y} + r_{1.8} P_{8.y} + r_{1.9} P_{9.y} + r_{1.1} P_{10.y} + r_{1.11} P_{11.y} + r_{1.12} P_{12.y}$

$r_{2.y} = r_{1.2} P_{1.y} + P_{2.y} + r_{2.3} P_{3.y} + r_{2.4} P_{4.y} + r_{2.5} P_{5.y} + r_{2.6} P_{6.y} + r_{2.7} P_{7.y} + r_{2.8} P_{8.y} + r_{2.9} P_{9.y} + r_{2.10} P_{10.y} + r_{2.11} P_{11.y} + r_{2.12} P_{12.y}$

$r_{3.y} = r_{1.3} P_{1.y} + r_{2.3} P_{2.y} + P_{3.y} + r_{3.4} P_{4.y} + r_{3.5} P_{5.y} + r_{3.6} P_{6.y} + r_{3.7} P_{7.y} + r_{3.8} P_{8.y} + r_{3.9} P_{9.y} + r_{3.10} P_{10.y} + r_{3.11} P_{11.y} + r_{3.12} P_{12.y}$

$r_{4.y} = r_{1.4} P_{1.y} + r_{2.4} P_{2.y} + r_{3.4} P_{3.y} + P_{4.y} + r4_{1.5} P_{5.y} + r_{4.6} P_{6.y} + r_{4.7} P_{7.y} + r_{4.8} P_{8.y} + r_{4.9} P_{9.y} + r_{4.10} P_{10.y} + r_{4.11} P_{11.y} + r_{4.12} P_{12.y}$

$r_{5.y} = r_{1.5} P_{1.y} + r_{2.5} P_{2.y} + r_{3.5} P_{3.y} + r_{4.5} P_{4.y} + P_{5.y} + r_{5.6} P_{6.y} + r_{5.7} P_{7.y} + r_{5.8} P_{8.y} + r_{5.9} P_{9.y} + r_{5.10} P_{10.y} + r_{5.11} P_{11.y} + r_{5.12} P_{12.y}$

$r_{6.y} = r_{1.6} P_{1.y} + r_{2.6} P_{2.y} + r_{3.6} P_{3.y} + r_{4.6} P_{4.y} + r_{5.6} P_{5.y} + P_{6.y} + r_{6.7} P_{7.y} + r_{6.8} P_{8.y} + r_{6.9} P_{9.y} + r_{6.10} P_{10.y} + r_{6.11} P_{11.y} + r_{6.12} P_{12.y}$

$r_{7.y} = r_{1.7} P1.y + r_{2.7} P_{2.y} + r_{3.7} P_{3.y} + r_{4.7} P_{4.y} + r_{5.7} P_{5.y} + r_{6.7} P_{6.y} + P_{7.y} + r_{7.8} P_{8.y} + r_{7.9} P_{9.y} + r_{7.10} P_{10.y} + r_{7.11} P_{11.y} + r_{7.12} P_{12.y}$

$r_{8.y} = r_{1.8} P_{1.y} + r_{2.8} P_{2.y} + r_{3.8} P_{3.y} + r_{4.8} P_{4.y} + r_{5.8} P_{5.y} + r_{6.8} P_{6.y} + r_{7.8} P_{7.y} + P_{8.y} + r_{8.9} P_{9.y} + r_{8.10} P_{10.y} + r_{8.11} P_{11.y} + r_{8.12} P_{12.y} +$

$r_{9.y} = r_{1.9} P_{1.y} + r_{2.9} P_{2.y} + r_{3.9} P_{3.y} + r_{4.9} P_{4.y} + r_{5.9} P_{5.y} + r_{6.9} P_{6.y} + r_{7.9} P_{7.y} + r_{8.9} P_{8.y} + P_{9.y} + r_{9.10} P_{10.y} + r_{9.11} P_{11.y} + r_{9.12} P_{12.y} +$

$r_{10.y} = r_{1.10} P_{1.y} + r_{2.10} P_{2.y} + r_{3.10} P_{3.y} + r_{4.10} P_{4.y} + r_{5.10} P_{5.y} + r_{6.10} P_{6.y} + r_{7.10} P_{7.y} + r_{8.10}$

$P_{8.y} + r_{9.10} P_{9.y} + P_{10.y} + r_{10.11} P_{11.y} + r_{10.12} P_{12.y}$

$r_{11.y} = r_{1.11} P_{1.y} + r_{2.11} P_{2.y} + r_{3.11} P_{3.y} + r_{4.11} P_{4.y} + r_{5.11} P_{5.y} + r_{6.11} P_{6.y} + r_{7.11} P_{7.y} + r_{8.11}$

$P_{8.y} + r_{9.11} P_{9.y} + r_{10.11} P_{10.y} + P_{11.y} + r_{11.12} P_{12.y} + r_{11.13} P_{13.y}$

$r_{12.y} = r_{1.12} P_{1.y} + r_{2.12} P_{2.y} + r_{3.12} P_{3.y} + r_{4.12} P_{4.y} + r_{5.12} P_{5.y} + r_{6.12} P_{6.y} + r_{7.12} P_{7.y} + r_{8.12}$

$P_{8.y} + r_{9.12} P_{9.y} + r_{10.12} P_{10.y} + r_{11.12} P_{11.y} + P_{12.y}$

$r_{13.y} = r_{1.12} P_{1.y} + r_{2.12} P_{2.y} + r_{3.12} P_{3.y} + r_{4.12} P_{4.y} + r_{5.12} P_{5.y} + r_{6.12} P_{6.y} + r_{7.12} P_{7.y} + r_{8.12}$

$P_{8.y} + r_{9.12} P_{9.y} + r_{10.12} P_{10.y} + r_{11.12} P_{11.y} + P_{12.y}$

$r_{14.y} = r_{1.12} P_{1.y} + r_{2.12} P_{2.y} + r_{3.12} P_{3.y} + r_{4.12} P_{4.y} + r_{5.12} P_{5.y} + r_{6.12} P_{6.y} + r_{7.12} P_{7.y} + r_{8.12}$

$P_{8.y} + r_{9.12} P_{9.y} + r_{10.12} P_{10.y} + r_{11.12} P_{11.y} + P_{12.y}$

$r_{15.y} = r_{1.12} P_{1.y} + r_{2.12} P_{2.y} + r_{3.12} P_{3.y} + r_{4.12} P_{4.y} + r_{5.12} P_{5.y} + r_{6.12} P_{6.y} + r_{7.12} P_{7.y} + r_{8.12}$

$P_{8.y} + r_{9.12} P_{9.y} + r_{10.12} P_{10.y} + r_{11.12} P_{11.y} + P_{12.y}$

Where,

r_{1y} = Genotypic correlation coefficients between y and I th character (y = Fruit yield)

P_{iy} = Path coefficient due to i th character (i= 1, 2, 3,….12)

1 = Days to first flowering

2 = Plant height

3 = Days to maturity

4 = Number of clusters per plant

5 = Number of flowers per plant

6 = Number of fruits per cluster

7 = Number of fruits per plant

8 = Fruit weight (g)

9= Fruit length (cm)

10 = Fruit diameter (cm)

11 = Fruit yield per plant (kg)

Total correlation, say between 1 and y i. e., r_{1y} is thus partitioned as follows:

$P_{1.y}$ = the direct effect of 1 on y

$r_{1.2}\, P_{2.y}$ = indirect effect of 1 via 2 on y

$r_{1.3}\, P_{3.y}$ = indirect effect of 1 via 3 on y

$r_{1.4}\, P_{4.y}$ = indirect effect of 1 via 4 on y

$r_{1.5}\, P_{5.y}$ = indirect effect of 1 via 5 on y

$r_{1.6}\, P_{6.y}$ = indirect effect of 1 via 6 on y

$r_{1.7}\, P_{7.y}$ = indirect effect of 1 via 7 on y

$r_{1.8}\, P_{8.y}$ = indirect effect of 1 via 8 on y

$r_{1.9}\, P_{9.y}$ = indirect effect of 1 via 9 on y

$r_{1.10}\, P_{10.y}$ = indirect effect of 1 via 10 on y

$r_{1.11}\, P_{11.y}$ = indirect effect of 1 via 11 on y

$r_{1.12}\ P_{12.y}$ = indirect effect of 1 via 12 on y

$r_{1.13}\ P_{12.y}$ = indirect effect of 1 via 13 on y

$r_{1.14}\ P_{12.y}$ = indirect effect of 1 via 14 on y

$r_{1.15}\ P_{12.y}$ = indirect effect of 1 via 15 on y

Where,

$P_{1.y,}\ P_{2.y,}\ P_{3.y.}$ …… $P_{15.y}$ = Path coefficient of the independent variables 1, 2, 3,….15 on the dependent variable y, respectively.

$r_{1.y,}\ r_{2.y,}\ r_{3.y,}$ …., $r_{15.y}$ = Correlation coefficient of 1, 2, 3,…., 15 with y, respectively.

After calculating the direct and indirect effect of the characters, residual effect (R) was calculated by using the formula (Singh and Chaudhary, 1985) given below

$P^2_{RY} = 1- (r_{1.y}P_{1.y} + r_{2.y}P_{2.y} +……..+ r_{15.y}P_{15.y})$

Where,

$P^2_{RY} = R^2$

and hence residual effect, $R = (P^2_{RY})^{1/2}$

$P_{1.y}$ = Direct effect of the i th character on yield y.

$r_{1.y}$ = Correlation of the i th character with yield y.

CHAPTER IV
RESULTS AND DISCUSSION

The experiment was carried out to analyze the variability of tomatillo population utilizing variables that contribute to yield. The presentation and discussion of the experiment's results are included in this chapter. When the fruits started to change color, they were picked. Data on the ten characters that are shared by tomatillo have been provided and statistically examined along with potential interpretations.

4.1 Genetic Variability, heritability and genetic advance

The average values for each character across all population are displayed in Appendix IV. For each character, the population' performance is discussed below. Ten characters were used to determine how much variation there was among the population (Appendix V). The results are shown in Table 3 as mean sum of square, phenotypic variance (σ^2p), genotypic variance (σ^2g), phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (h^2_b), genetic advance (GA) and genetic advance in percent of mean.

The extent of the influence of growing environment on observed traits is explained by the magnitude of the differences between GCV and PCV. According to Deshmukh *et al.* (1986) PCV and GCV can be categorized as low (<10%), moderate (10-20%) and high (>20%). Large difference between PCV and GCV indicate high environmental influence on the expression of particular traits. Heritability is grouped as low (<0.2) moderate (0.2-0.4) and high (>0.4) (Adhikari *et al.,* 2018). Estimated heritability itself alone is not very much useful because it includes the effect of both additive and non-additive genes. The genetic advance is therefore a useful indicator to achieve expected result on the trait of interest of a population after selection. Genetic advance in percentage of mean gives more precise result in comparison to only genetic advance. Genetic advance as percent mean was categorized as low (0-10%), moderate (10-20% and high (≥20%).

4.1.1 Days to first flowering

The variance due to days to first flowering showed that the population differed significantly (Appendix V) and ranged from 16.33 days after transplanting (DAT) in (G14) to 22.83 DAT in (G12) with mean value of 19.95 days after transplanting (DAT) (Appendix IV). The genotypic variance (σ^2g) and phenotypic variance (σ^2p) for this trait were 2.49 and 6.09, respectively (Table 3). The phenotypic variance appeared to be higher than the genotypic variance suggested considerable influence of environment on the expression of genes controlling this trait. The genotypic coefficient of variation (GCV) was 7.91 and phenotypic coefficient of variation (PCV) was 12.37(Table 4). Such wide difference between PCV and GCV for this trait implies their susceptibility to environmental fluctuation. Therefore, selection based upon phenotypic values of this character would not be effective for the improvement of this crop. Similar findings were reported by Farzaneh *et al.* (2013) and Kumari *et al.* (2007). Matin *et al*. (2001) also found similar results in tomato. In contrast, Monamodi *et al.* (2013) and Aditya *et al*. (1995) found in significant difference in days to first flowering. The heritability estimates for days to first flowering was moderate (40.86%) with low genetic advance (2.07%) and genetic advance in percentage of mean (10.41%) (Table 3). This indicates observed character among tested population governed by non-additive gene action and selection would not be effective. Genetic advances in percent of mean were low which was in accordance with the findings of Singh *et al.* (1973). Islam and Khan (1991) reported high heritability for days to first flowering.

4.1.2 Plant height

Significant differences were observed among the population for plant height which ranged from 92.47 cm (G16) to 123.53 cm (G2) with mean value 107.82 cm. (Appendix IV and appendix V). Highly significant variation was observed among all the population. Naz *et al.* (2013), Shravan *et al*. (2004), Ravindra *et al.* (2003),

Table 3. Estimation of genetic parameters in ten characters of sixteen population in tomatillo

Parameters	Mean	σ^2p	σ^2g	$\sigma^2 e$	PCV	GCV	ECV	Heritability	Genetic Advance (5%)	Genetic Advance (% of mean)
Days to first flowering	19.952	6.09	2.49	3.60	12.37	7.91	9.51	40.86	2.07	10.41
Plant height	107.82	61.68	40.76	20.91	7.28	5.92	4.24	66.09	10.69	9.91
Number of branches	5.77	0.41	0.0216	0.39	11.15	2.54	10.86	5.2	0.069	1.1945
Fruit length	36.13	14.23	8.67	5.56	10.44	8.14	6.52	60.91	4.73	13.10
Fruit diameter	44.01	15.88	8.89	6.99	9.05	6.77	6.00	55.96	4.59	10.43
Brix %	2.17	0.71	0.66	0.04	38.88	37.64	9.75	93.71	1.62	75.06
pH	3.56	0.15	0.10	0.045	10.89	9.11	5.97	69.98	0.56	15.71
Individual fruit weight	32.07	131.81	129.33	2.47	35.79	35.45	4.90	98.12	23.20	72.35
No. of fruits per plant	85.12	960.70	944.27	16.42	36.40	36.09	4.76	98.29	62.75	73.72
Yield per plant	2.53	0.35	0.34	0.01	23.67	23.22	4.57	96.26	1.18	46.94

σ^2p: Phenotypic variance
σ^2g: Genotypic variance
σ^2e: Environmental variance
PCV: Phenotypic coefficient of variation
GCV: Genotypic coefficient of variation
ECV: Environmental coefficient of variation
GAM: Genetic advance (% of mean)
GA (5%): Genetic advance

and Prasad and Mathura (1999) were also found similar significant variation for plant height. The phenotypic and genotypic variance was observed 61.68 and 40.76 respectively (Table 3) indicating environmental influence on the expression of genes controlling this trait. Wide differences between the phenotypic co-efficient of variation (7.28) and genotypic co-efficient of variation (5.92) revealed higher influence of environment on the expression of plant height (Table 3). 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 were high (66.09) with moderate genetic advance (10.69%) and genetic advance in percent of mean (9.91) (Table 3) indicated that most likely the heritability was due to additive gene effects and selection for this character might be effective.

4.1.3 Number of branches per plant

Number of branches per plant in tomatillo showed significant difference (Appendix V) where the highest number of branches was found 6.66 in G4 and the lowest was recorded 5.06 in G14 and mean value 5.77 (Appendix IV; Figure 1.). The phenotypic variance (0.41) was much higher than the genotypic variance (0.21) (Table 3) indicating environmental influence on the expression of genes controlling this trait. The genotypic co-efficient of variation and phenotypic coefficient of variation were 2.54 and 11.15 respectively (Table 3) indicating that the phenotypic expression of this trait was highly governed by the environment. Large differences between PCV and GCV for this trait implies their susceptibility to environmental fluctuation. 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 high (5.2) with low genetic advance (0.069) and genetic advance in percent of mean (1.19) (Table 3) revealed that this trait was governed by non-additive gene action

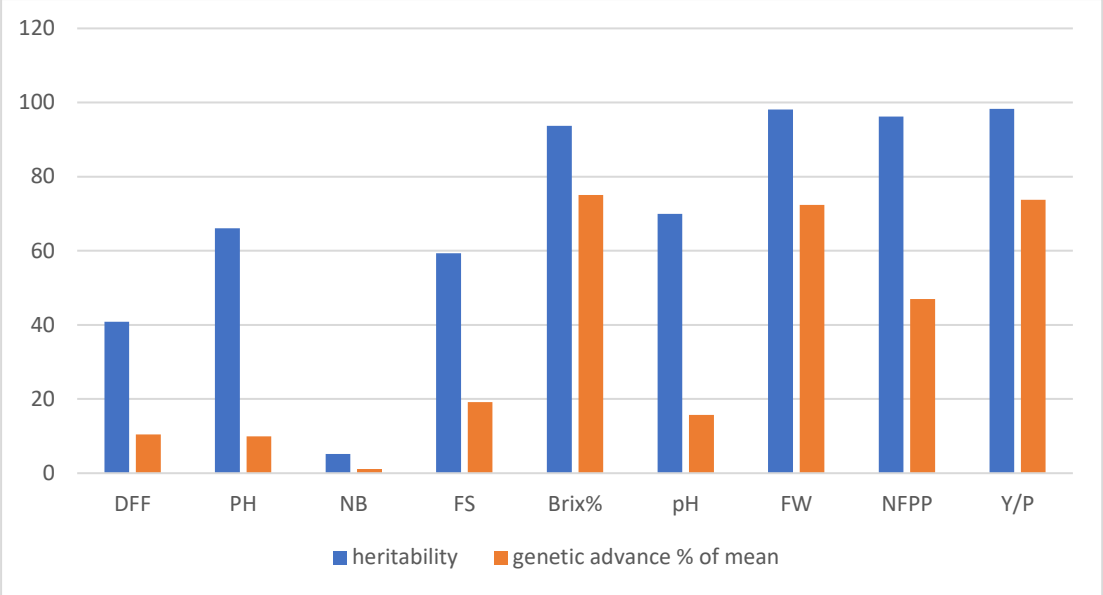

Figure 1. Bar-graph illustrate heritability in relation with genetic advance % of mean among different traits .

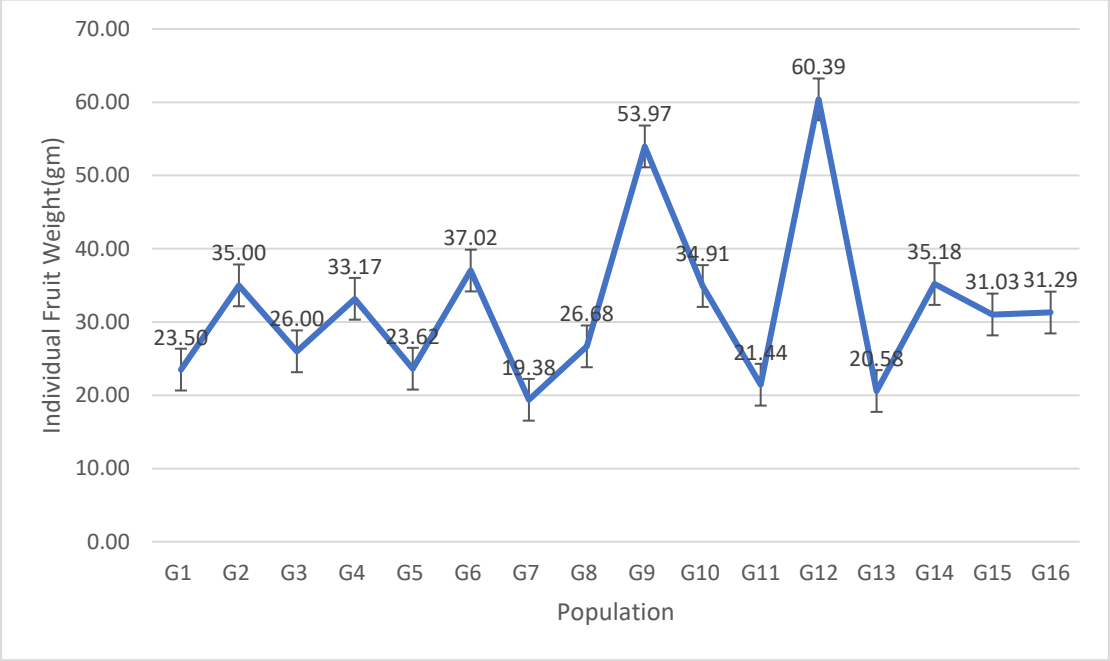

Figure 2. Line graph illustrate individual fruit weight among different population

and selection would not be effective for the improvement of this crop. High heritability and low genetic advance for this character was also observed by Kumar *et al*. (2004).

4.1.4 Fruit length

The mean fruit length was noticed as 36.13 mm with a range of 31.60 mm to 42.27 mm. The Genotype G11 showed the minimum fruit length and the maximum fruit length was recorded in the accession G15 (Appendix IV). Significant genotypic variation was observed as revealed by ANOVA (Appendix V). A pictorial view of Fruit length of tomatillo is presented in Plate 4. The σ^2p (14.23) was higher than the σ^2g (8.67) and GCV (8.14) and PCV (10.44) were not close to each other (Table 3), indicating higher environmental influence on the genes controlling this character and 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 to high heritability estimates (60.91) with low genetic advance (4.73) and high genetic advance over percent of mean (13.10) (Table 3) indicated of non-additive gene action. The moderate heritability was being exhibited due to influence of environmental rather than population and effective selection may not be rewarding for this trait. Joshi *et al*. observed moderate heritability and moderate genetic gain for this character. (2004).

4.1.5 Fruit diameter

The mean fruit diameter was 44.01 mm with a minimum range of 39.38 mm (G2) to 52.18 mm (G12) (Appendix IV). ANOVA revealed significant variation among the population (Appendix V). A pictorial view of tomatillo fruit diameter is illustrated in Plate 4. The σ^2p was higher than the σ^2g (15.88 and 8.89, respectively) and GCV (6.77) and PCV (9.05) (Table 3) were not close to each other, indicating higher environmental influence on the genes controlling this character that selection based on this trait would be ineffective for the improvement of tomatillo.

Plate 4. Morphology of fruit size (length and diameter)

Singh *et al.* (2002) showed that the PCV was greatest for this character, which supported the present study. High heritability estimate (55.96%) with high genetic advance at percent of mean (10.43%) (Table 3) indicated predominance of additive gene action for this character. High genetic advance at percent of mean which coincide with high heritability was very useful than heritability alone in predicting the resultant effect during selection of best individual genotype, which was revealed in present study. The experiment of Pandit *et al.* (2010) contradict with the result of the present study as he observed high heritability coupled with low genetic gain for this character.

4.1.6 Brix Percentage

Significant genotypic variation was observed for brix percentage (Appendix V). The higher amount of brix% was found in G6 (3.66) and minimum in G2 (1.16) with an average of 2.17 (Appendix IV). Higher amount of brix % (7 %-10) was found by Ostrzycka *et al*. (2014). The phenotypic co-efficient of variation was 38.88 and the genotypic co-efficient of variation was 37.64 (Table 3). This narrow gap of PCV and GCV indicated that there was very little environmental influence on this trait and cannot be improved by providing favorable environment. High heritability 93.71 coupled with high genetic advance at percent of mean 75.06 (Table 3) were indicating predominance of additive gene action and selection will be effective for the improvement of this crop.

4.1.7 pH Content

The pH of different population from tomatillo juice samples showed higher 4.43 (G11) and lower 3.23(G5) with average 3.56 (Appendix IV). ANOVA revealed significant variation among the population (Appendix V). Phenotypic co-efficient of variation (10.89) and genotypic co-efficient of variation (9.11) was close to each other indicated less influence of environment on the genes controlling this character and that would be ineffective for the improvement of tomatillo. Higher heritability 69.98 with moderate genetic advance at percent of mean 15.71 offered scope of the traits for improvement through selection, so this character could be improved more easily than the other characters (Singh *et al*.,

2016). The pH of purple tomatillo (range from 4.0 to 4.5) was measured by González-Mendoza *et al*., 2011.

4.1.8 Fruit weight (g)

A significant difference was found within sixteen population of tomatillo for the character of single fruit weight (Appendix IV) where the maximum single fruit weight was recorded 60.393 g in G7 and the minimum was recorded 19.38 g in G15 with mean value of 32.0727 g (Appendix V; Figure 2). The genotypic variance (129.33) and phenotypic variance (131.81) for fruit weight was very high (Table 3). The difference between genotypic co-efficient of variation (35.45) and phenotypic co-efficient of variation (35.79) was close to each other (Table 3), proved that environment had not higher influence for the expression of this character. Therefore, selection based upon phenotypic expression of this character would be effective 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). Higher heritability (98.12%) associated with high genetic advance in percent of mean (72.35) (Table 3) was observed in this study indicating fruit weight governed by additive gene and selection would be effective.

4.1.9 Number of fruits per plant

Significant variation was observed among the population for number of fruits per plant (Appendix V). From the current study we observed that the maximum range for number of fruits per plant was found 152.31 in G7 and the minimum was recorded 42 in G9 and mean was 85.128 (Appendix IV; Figure 3). The high genotypic (944.27) and phenotypic (960.70) variances indicated a very high variability among the population for this trait (Table 3). The difference between phenotypic coefficient of variation (36.40) and genotypic coefficient of variation

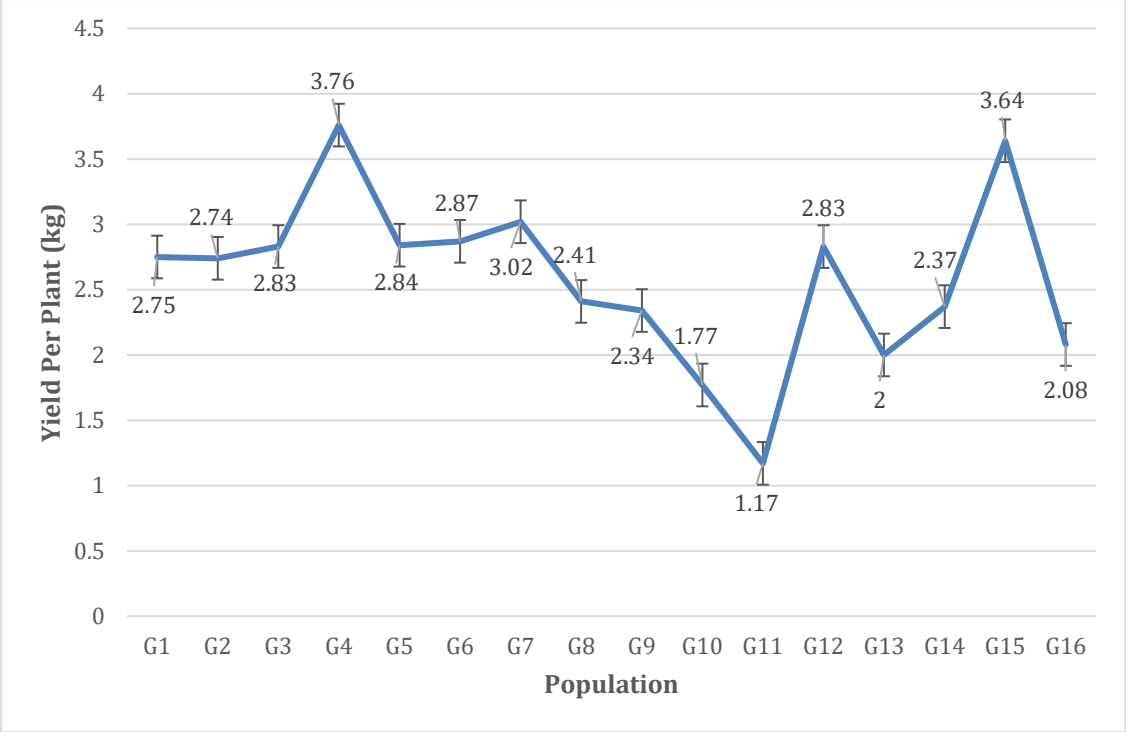

Figure 3. Line graph illustrate yield per plant among different population

(36.09) was low (Table 3) which indicated very low environmental influence on this character. Saeed *et al*. (2007), Singh *et al.* (2002) and Joshi and Singh (2003) found same result in case of number of fruits per plant. The heritability estimated for this trait was high (98.29%) accompanied with high genetic advance (62.75%) and genetic advance in percent of mean (73.72%), revealed that this character was governed by additive gene and selection for this character would be effective. This character showed high heritability coupled with high genetic gain which was supported by Ara *et al*., (2009) and Saeed *et al*., (2007).

4.1.10 Yield per plant (kg)

The highest fruit yield per plant was found 3.76 kg in G4 and the lowest was recorded 1.17 kg in G11 with mean value of 2.53 kg (Appendix IV). The population were significantly varied with each other (Appendix V). The phenotypic variance (0.35) found higher than genotypic variance (0.34) (Table 4), suggested very less influence of environment on the expression of the genes controlling this character. The phenotypic coefficient of variation and genotype

coefficient of variation were 23.67 and 23.22, respectively for fruit yield per plant. Narrow gap between PCV and GCV indicating their relative resistance to environmental variation and significant variation exists among different population which made the trait effective for selection. Similar findings supported by Singh *et al.* (2006) and Manivannan *et al*., (2005). Estimation of high heritability (96.26%) for fruit yield per plant with high genetic advance of % mean (46.94 %) (Table 3) revealed that this character was governed by additive gene and provides opportunity for selecting high valued population for breeding program. High heritability and high genetic advance was observed by Anupam *et al*., (2002).

4.2 Correlation Co-efficient

Correlation studies along with path analysis provide a better understanding of the association of different characters with fruit yield. Singh and Chaudhary, (1985) suggested that simple correlation was partitioned into phenotypic (that can be directly observed), genotypic (inherent association between characters) components. As is common, yield is a sophisticated product that is influenced by a number of interdependent quantitative traits. Therefore, selection may not be successful until other relevant factors are understood. Either directly or indirectly affect the yield. when there is a demand for selection enhancement of any trait closely related to yield concurrently influences a handful of additional characters that are connected. Therefore, knowledge of the relationship between character and yield and among themselves offers guidance to plant breeders for improving via selection with a comprehensive understanding of the role that genetic and non-genetic variables played in forming the relationship (Dewey and Lu, 1959). Table 5 provided phenotypic and genotypic correlation coefficients between various pairs of yield and yield-contributing features for several tomatillo population.

4.2.1. Days to first flowering

Days to first flowering had significant positive correlation with number of branch (0.3429*) at phenotypic level and (0.82**) at genotypic level (Table 4).

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 individual fruit weight (0.3078*) at phenotypic level. Fruit diameter, pH Content, Yield/plant have non-significant positive correlation at both phenotypic and genotypic level. Individual fruit weight, plant height, fruit length has non-significant positive correlation at genotypic level. No of fruit have non-significant negative correlation at both levels.

Table 4. Genotypic and phenotypic correlation coefficients among different pairs of yield and yield contributing characters for 16 population of tomatillo

Characters		DFF	PH	NB	FL	FD	Brix%	pH	IFW	NFPP	
PH	r_g	0.1295ns									
	r_p	-0.0408 ns									
NB	r_g	0.82**	0.3653ns								
	r_p	0.3429*	0.1986 ns								
FL	r_g	0.0462ns	-0.1623ns	0.74**							
	r_p	-0.018 ns	-0.192 ns	0.2283							
FD	r_g	0.4849ns	-0.3654	-0.3726 ns	0.5796*						
	r_p	0.1934 ns	-0.3439*	0.0213 ns	0.5132**						
Brix%	r_g	-0.0073 ns	-0.272 ns	-0.5311**	0.4498 ns	0.2661 ns					
	r_p	-0.0615 ns	-0.169 ns	-0.0895 ns	0.3453*	0.1937 ns					
pH	r_g	-0.0952 ns	-0.1679 ns	0.5518**	-0.3051 ns	-0.1219 ns	-0.0405 ns				
	r_p	0.0281 ns	-0.0465 ns	0.1139 ns	-0.2314 ns	-0.1832 ns	-0.0713 ns				
IFW	r_g	0.4869 ns	0.0478 ns	0.1819 ns	-0.0304 ns	0.378 ns	-0.4859 ns	-0.2561 ns			
	r_p	0.3078*	0.0064 ns	0.0353 ns	-0.0068 ns	0.2891*	-0.4569**	-0.2179 ns			
NFPP	r_g	-0.0272 ns	0.2028	0.74**	0.2172 ns	-0.2595 ns	0.3265 ns	0.0433 ns	-0.6751**		
	r_p	-0.0172 ns	0.155 ns	0.2452 ns	0.1629 ns	-0.1672 ns	0.3147*	0.0248 ns	-0.6692**		
YPP	r_g	0.3965 ns	0.3324	0.95**	0.3274 ns	-0.0168 ns	-0.0587 ns	-0.1249 ns	0.1418 ns	0.5805*	
	r_p	0.2706 ns	0.227 ns	0.3869**	0.219 ns	0.0199 ns	-0.053 ns	-0.1195 ns	0.1404 ns	0.5785**	

Note: DFF= Days to first flowering, PH= Plant height (cm), NB= No. of branches per plant, FL= Fruit length, FD=Fruit Diameter, IFW=Individual Fruit weight

4.2.2 Plant height (cm)

Plant height had significant negative correlation with fruit diameter at both phenotypic (-0.3439*) and genotypic (-0.3654) level. Individual fruit weight (0.0064), no of branch (0.1985), yield/ plant (0.227) all had positive non-significant correlation at phenotypic level. Again, no of branches (0.3653), Individual fruit weight (0.0478), yield/plant (0.332) had non-significant positive correlation. Fruit length (-0.192), Brix % (-0.169), pH (-0.0465) has non-significant negative correlation at phenotypic level. Fruit length (-0.3514), Brix% (-00272), pH (-0.1679) had non- significant negative correlation at genetic level (Table 10 and Table 9) same result for the character which was supported by Mohanty (2003).

4.2.3 Number of branches per plant

The number of branches per plant had highly significant positive correlation with yield per plant 0.3869** at phenotypic level and 0.95* at genotypic level (Table 4). Akhter (2021), Padda *et al.* (2007) and Verma *et al.* (2000) also observed that number of branches per plant exhibited positive correlation with yield per plant. It also showed a significant negative correlation with brix% (-0.5311**). Number of branches per plant was significant positive correlation with yield (0.95**), no of fruits per plant (0.74**), pH value (0.5518**), fruit length (0.74**) at genotypic level (Table 4). Monamodi *et al*. (2013) found more branch number in a plant will produce more fruits. Non-significant positive correlation was found with fruit length (0.2283), pH (0.1139) and no of fruits (0.2425) at phenotypic level. Individual fruit weight (0.1819) had non-significant positive correlation where fruit diameter (-0.3726) showed non-significant negative correlation at genetic level. Number of branches per plant showed negative non-significant correlation with brix%(-0.0895) at phenotypic level (Table 4). But a negative correlation between the number of branches per plant and number of fruits per plant was noticed by Singh *et al*. (2005).

4.2.4 Fruit length

Fruit length had significantly positively correlated with fruit diameter at both genotypic (0.5796*) and phenotypic level (0.5132). Fruit length had positive significant correlation with brix% (0.3453) at phenotypic level. Brix% (0.4498), no of fruits per plant (0.2172), yield per plant (0.3274) had non-significant positive correlation at genotypic level. Number of fruits per plant (0.1629), yield (0.219) had non-significant correlation with fruit length. Individual fruit weight and pH had non-significant negative correlation at both phenotypic and genotypic level.

4.2.5 Fruit diameter

Fruit diameter showed significant positive relation with individual fruit weight (0.2891*). Brix% (0.2661), individual fruit weight (0.378) had non-significant positive correlation at genotypic level with fruit diameter. Yield (0.0199), brix% (0.2661) hand non-significant positive correlation at phenotypic level. Number of fruits per plant, pH had non-significant negative correlation at both phenotypic and genotypic level.

4.2.6 Brix %

Total dry matter content showed non-significant positive correlation with no of fruits per plant (0.3265) at genetic level. pH value (-0.0405), individual fruit weight (-0.4859), Yield/plant(-0.0587) showed negative non-significant correlation at genetic level. Brix% with individual fruit weight (-0.3462*) shows negative significant correlation at genotypic level. pH Content(0.04067), yield/plant(0.053), no. of fruits per plant(0.237) showed non-significant positive correlation at phenotypic level.

4.2.7 P^H Content

No of fruits per plant (0.0248) showed non-significant positive correlation with pH value. Individual fruit weight (-0.2179), yield/plant (-0.1198) showed non-significant negative correlation at phenotypic level. pH Content showed non-

significant positive correlation with (0.0433) at genotypic level. Individual fruit weight (-0.2561), yield/plant (-0.1249) shows non-significant negative correlation with p^H value at genotypic level.

4.2.8 Individual Fruit Weight

Individual fruit weight showed negative significant correlation with no of fruits per plant (-0.6751**) at genotypic level. Yield/plant (0.1404) showed non-significant positive correlation with individual fruit weight ar phenotypic level. No of fruits per plant (-0.6751**) showed negative significant correlation at genotypic level. Yield/plant (0.1418) showed positive non-significant correlation with individual fruit weight at genotypic level. Rani *et al.* (2010), Singh *et al.* (2006) and Manivannan *et al.* (2005) reported positive direct effects on fruit yield.

4.2.9 Yield per/plant

Yield/plants showed significant positive correlation with number of fruits per plant (0.5785**) at phenotypic level and (0.5805*) at genotypic level.

4.3 Path coefficient analysis

Although correlation analysis shows the pattern of associations between component qualities and yield, these associations do not always show a cause-effect relationship; rather, they merely show the overall influence of a given feature on yield. The Wright (1921) and Deway and Lu (1959) method of route coefficient analysis makes it easier to divide correlation coefficients into the direct and indirect contributions of different features on yield. It is examination of the standardized partial regression coefficients. It assesses the direct impact of one variable on another. Such knowledge would be very helpful in helping the breeder to explicitly identify the essential yield component qualities and make strategic use of the genetic stock for improvement

Table 5. Partitioning of genotypic correlations into direct (bold) and indirect effects of 10 important characters by path analysis

Characters	DFF	PH (cm)	NB	FL	FD	Brix %	pH	FW	NFPP	Genetic correlation with YPP
DFF	**-0.00944**	0.00547	0.03842	0.01192	-0.1244	-0.0006	-0.01334	0.51851	-0.02996	0.3965 NS
PH(cm)	-0.00122	**0.04222**	0.01146	-0.04192	0.09378	-0.0230	-0.0235	0.05091	0.22366	0.3324 NS
NB	-0.01157	0.01543	**0.03136**	0.1871	0.09564	-0.0446	0.07726	0.19374	1.1083	1.6525**
FL	-0.01157	0.0154	0.03136	**0.18713**	0.09564	-0.0449	0.07726	0.19374	0.23954	0.3274 ns
FD	-0.0045	-0.0154	-0.0116	0.14969	**-0.2566**	0.02252	-0.01706	0.40260	-0.28615	-0.0168 ns
Brix %	0.00007	-0.01148	-0.0166	0.11615	-0.0683	**0.08464**	-0.0056	-0.5175	0.3600	-0.0587 ns
pH	0.0009	-0.00709	0.01730	-0.07878	0.03128	-0.0034	**0.14001**	-0.27286	0.04778	-0.1249 ns
FW	-0.0046	0.00202	0.00570	-0.00785	-0.0970	-0.0411	-0.0358	**1.06497**	-0.74438	0.1418 ns
NFPP	0.00026	0.00856	0.03152	0.05610	0.06661	0.02764	0.00607	-0.71893	**1.10267**	0.5805*
	Residual effect 0.0803									

Note: DFF= Days to first flowering, PH= Plant height (cm), NB= No. of branches per plant, FL= Fruit length, FD=Fruit Diameter, FW=Individual Fruit weight.

4.3.1 Days to first flowering

Days to first flowering had negative direct effect (-0.00944) on yield per plant (Table 5) which was contributed to result non-significant positive genotypic correlation with yield per plant (0.3965). 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 (0.00547), number of branch (0.03842), fruit length (0.01192), fruit weight (0.51851).
It had negative indirect effect on fruit diameter (-0.12446), brix% (-0.0006), Number of fruits per plant (-0.02996).

4.3.2 Plant Height

Plant height had positive direct effect (0.04222) on yield per plant, which was contributed to result non-significant positive genotypic correlation with yield per plant (0.3324) (Table 5). Matin *et al.* (2001) reported that plant height showed negative direct effect on yield per plant. Days to first flowering (-0.00122), fruit length (-0.04192), Brix% (-0.02302), pH Content (-0.0235) had negative indirect effects on it. Number of branches (0.01146), fruit weight (0.0.05091), number of fruits per plant (0.22366) had indirect positive effects on it.

4.3.3 Number of Branch per plant

Number of branches per plant had a positive direct effect on yield per plant (0.03136), which was contributed to result significant positive genotypic correlation with yield per plant (1.6525**) (Table 5). Akhter (2021), Padda *et al.* (2007) and Verma *et al.* (2000) also observed that number of branches per plant exhibited positive direct effect on yield per plant. It had also negative but indirect effect on DFF (-0.01157) and brix% (-0.0446). It had positive indirect effect via fruit length (0.1871), fruit diameter (0.09564), pH (0.07726) and Fruit weight (0.19374), number of fruits per plant (1.1083).

4.3.4 Fruit length

Fruit size had positive direct effect on yield per plant (0.18713). It had a non-significant positive genotypic correlation with yield/plant (0.3274) (Table 5). Padda *et al.* (2007) and Singh *et al.* (2006) also revealed that fruit length exhibited positive effect on yield per plant at the genotypic level. It had negative indirect effect with days to first flowering (-0.01157) and Brix % (-0.0449). It had positive indirect through plant height (0.0154 0), fruit diameter (0.09564), pH (0.07726), number of fruits per plant (0.23954) and fruit weight (0.19374).

4.3.5 Fruit Diameter

Fruit diameter had negative direct effects on yield per plant (-0.2566). It had a non-significant negative genotypic correlation with yield per plant (-0.0168) (Table 5). Padma *et al.* (2002) found that fruit diameter had high positive direct effect on fruit yield at the genotypic level. It had negative indirect effect on days to first flowering (-0.0045), plant height (-0.0154), pH (-0.0056), number of fruits per plant (-0.28615). It had positive indirect effects on fruit length (0.14969), fruit weight (0.40260).

4.3.6 Brix%

Brix% had negative direct effects on yield per plant (0.08464) (Table 5). It had a non-significant negative correlation with yield per plant (-0.0587). It had negative indirect effects with plant height (-0.01148), number of branches (-0.01148), fruit diameter (-0.0683), fruit weight (-0.5175). It had positive indirect effects through days to first flowering (0.00007), fruit length (0.11615), number of fruits per plant (0.3600) had positive indirect effects on it.

4.3.7 pH Content

Brix had negative direct effect on yield per plant (0.14001). It had a negative non- significant genotypic correlation with yield per plant (-0.1249). It had positive indirect effects on days of first flowering (0.0009), number of branches (0.0130), fruit diameter (0.03128) and number of fruits per plants (0.04778).

Plant height (-0.00709), fruit length (-0.07878), Brix% (-0.0034) and fruit weight (-0.27286) had negative indirect effects through it.

4.3.8 Individual fruit weight

Individual fruit weight had direct positive effects on yield per plant (1.06497). It had a positive non-significant genotypic correlation with yield per plant (0.1418). It had positive indirect effects on plant height (0.00202), number of branch (0.00570). Again, it had negative indirect effects on days to first flowering (-0.0046), fruit length (0.00785), pH value (-0.0358) and number of fruits per plant (-0.74438). Rani *et al.* (2010), Singh *et al.* (2006) and Manivannan *et al.* (2005) also reported positive direct effects on fruit yield.

4.3.9 No of fruits per plant

Number of fruits per plant had direct positive effects on yield per plant (1.10267). It had a positive significant genotypic correlation with yield per plant (0.5805*). It had positive indirect effects on days of first flowering (0.00026), plant height (0.00856), number of branches (0.03152), fruit length (0.05610), fruit diameter (0.06661), brix% (0.02764) and pH (0.00607). It had negative indirect effects on fruit weight (-0.71893). 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

Sixteen population of tomatillo (*Physalis ixocarpa* Brot.) were used in the current study, which was conducted at the Sher-e-Bangla Agricultural University Farm in Dhaka-1207, Bangladesh, from October 2020 to March 2021. In a Randomized Complete Block Design (RCBD) with three replications. Seeds were first sown in the seed bed and then moved to the main field. Data were gathered on a variety of yield-related characteristics, including days to first flowering, plant height, number of branches per plant, number of fruits per plant, fruit weight (g), fruit length (mm), fruit diameter (mm), and fruit and yield per plant (g). Significant differences between all of the population for all of the investigated characteristics were identified by analysis of variance.

Since pesticide treatment is not required to control insects and other pests, tomatillos are an environmentally benign crop. It was discovered that Bangladesh has a nearly five-fold higher tomatillo production than Mexico, where it originated. Tomatillo plants are extremely self-incompatible and need cross-pollination to develop fruit, thus we must grow at least two plants in order for the flowers to be pollinated. When the fruit is still green but the husk has expanded, the tomatillo is ready to be plucked from the plant. The fruit will commonly split the husk and turn yellow if allowed to mature any more.

The biggest range of variance was seen in the amount of fruits produced per plant (1.2 to 3.8 Kg), indicating that this attribute is subject to a broad range of variation.

Days to first flowering, plant height, fruit length, fruit diameter, number of fruites per plant all shown greater environmental effect on these traits' manifestation. The least variation in phenotypic and genotypic variance was found for number of branches per plant, brix%, pH content, and fruit yield per

plant, indicating additive gene action for the expression of the features. All of the characteristics included in this study had the greatest heritability values.

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 co-efficient suggesting a strong inherent association between the characters under study. Significant positive correlation with yield had found in number of branches and number of fruits per plant at both phenotypic and genotypic level. Non-significant positive correlation had found in days to first flowering, fruit length and individual fruit weight at both phenotypic and genotypic level. Non-significant negative correlation with yield had found with pH content and brix% at both phenotypic and genotypic level.

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 (1.06497) indicating selection will be judicious and more effective for these characters in future breeding program. It was also showed that number of fruit per plant had the highest positive direct effect (1.10267) with fruit yield per plant and this trait contributes to the yield through significant positive genotypic correlation (0.5805**) indicating selection will be judicious and more effective for these characters in future breeding program. Plant height, number of branches, fruit length, brix% and pH had positive direct effect with fruit yield per plant. Days to first flowering and fruit diameter had negative direct effect on yield per plant.

The following inferences might be made based on the study's findings:

- G4 followed by G7 could be selected for higher yield,
- G6 followed by G8 could be selected for fresh consumption and G12 and G15 for larger fruit size. These traits might be suggested for further selection in corresponding population in next generation.
- Selection should be used for desired traits such the shortest days to first flowering, an increase in the number of fruits produced per plant, number of branches, individual fruit weight, number of fruits per plant and fruit length.

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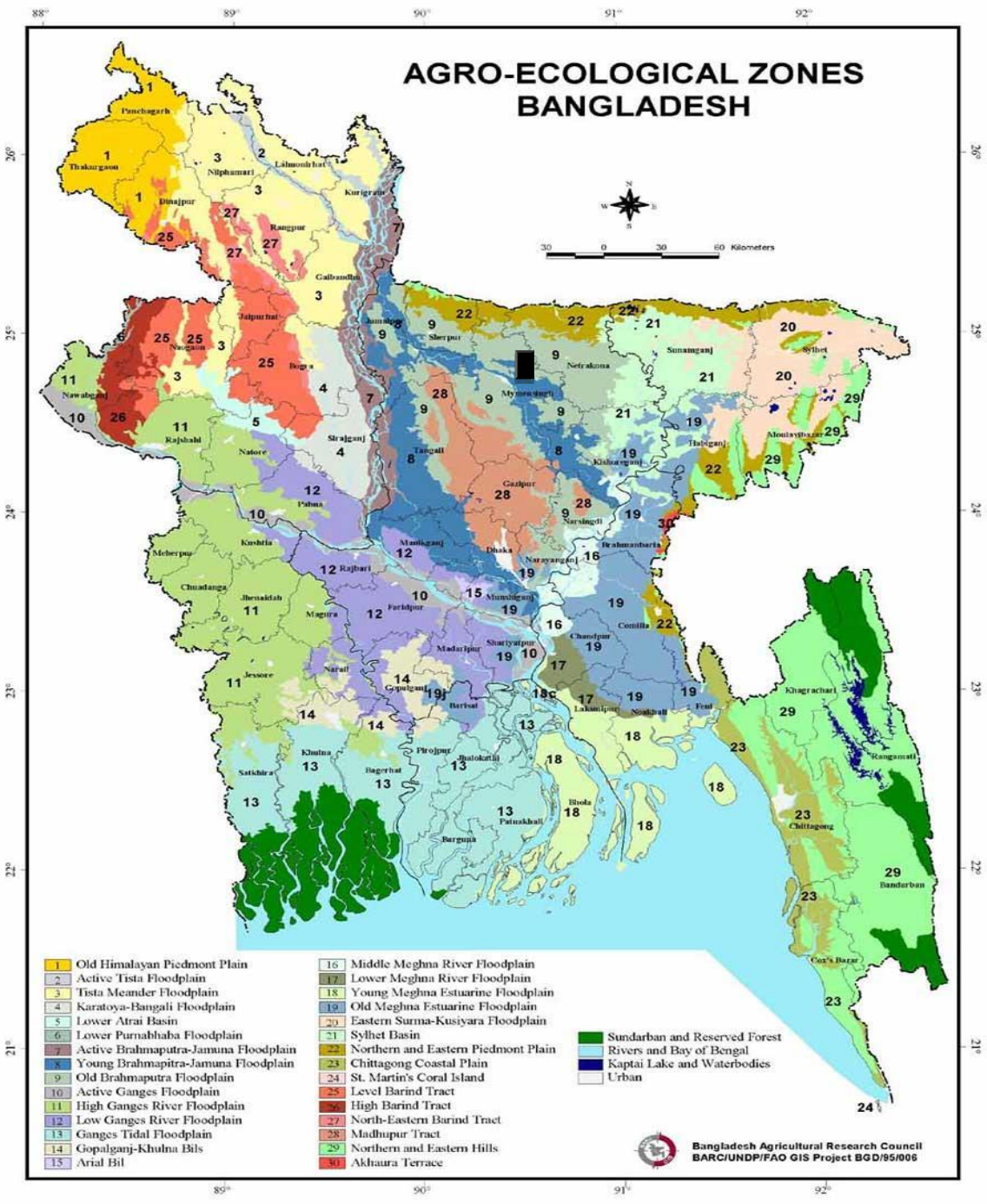
APPENDICES

Appendix I. Map showing the experimental site under the study



■ Experimental area under study

Appendix II. Themorphological, mechanical and chemical characteristics of soil of the experimental site as observed prior to experimentation (0-15 cm depth)

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Research Farm, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Deep Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical composition of the soil

Soil separates	%	Methods employed
Sand	36.90	Hydrometer method (Day, 1915)
Silt	26.40	Do
Clay	36.66	Do
Texture class	Clay loam	Do

C. Chemical composition of the soil

Sl. No.	Soil characteristics	Analytical data	Methods employed
1	Organic carbon (%)	0.45	Walkley and Black, 1947
2	Total N (%)	0.03	Bremner and Mulvaney, 1965
3	Total S (ppm)	225.00	Bardsley and Lanester, 1965
4	Total P (ppm)	840.00	Olsen and Sommers, 1982
5	Available N (kg/ha)	54.00	Bremner, 1965
6	Available P (ppm)	20.54	Olsen and Dean, 1965
7	Exchangeable K (me/100 g soil)	0.10	Pratt, 1965
8	Available S (ppm)	16.00	Hunter, 1984
9	pH (1:2.5 soil to water)	5.6	Jackson, 1958
10	CEC	11.23	Chapman, 1965

Source: Soil Resource and Development Institute (SRDI), Farmgate, Dhaka.

Month	Year	Monthly average air temperature (°C)			Average relative humidity (%)	Total rainfall (mm)	Total sunshine (hours)
		Maximum	Minimum	Mean			
Oct.	2019	36	21	28	69	Trace	219
Nov.	2019	31	18	24	63	Trace	216
Dec.	2019	28	16	22	61	Trace	212
Jan.	2020	27	13	20	57	Trace	198
Feb.	2020	29	18	23	70	3	225
Mar.	2020	32	22	25	73	4	231

Appendix III. Monthly records of air temperature, relative humidity, rainfall and sunshine hours during the period from October 2019 to March 2020

Source: Bangladesh Meteorological Department (Climate division), Agargaon Dhaka- 1212.

Appendix IV. Mean performance of various growth parameters and yield components of 16 population of tomatillo

Population	DFF	PH	NBP	FL	FD	Brix%	pH	IFW (g)	NFPP	YPP
G1	17.777de	112.83bc	5.8667abc	35.41 cde	40.21 f	2.3333c	4.00b	23.500gh	114.35bc	2.7533cd
G2	19.667abcd	123.53a	5.5833bc	32.407 ef	39.38f	1.1667g	3.3333c	35.000cd	78.42f	2.7433cd
G3	18.00de	144.00b	5.8778abc	36.197 bcde	42.973 def	2.2.3333c	3.2667c	26.000fg	109.27c	2.833 cd
G4	22.289a	105.00de	6.667a	33.99 ef	41.74ef	1.40000efg	4.2333ab	33.167de	118.51b	3.76 a
G5	21.611ab	107.00bcd	5.5bc	34.193 def	42.15 def	3.2.8333b	3.2333c	23.623gh	115.24bc	2.843 bc
G6	21.889a	109.16bcd	5.875abc	39.860 ab	48.46 ab	3.6667a	3.5333c	37.023c	75.22fg	2.8733bc
G7	20.889a	114.19b	6.0857abc	38.47 abc	44.81bcde	2.8333b	3.4333c	19.380i	152.31a	3.026 b
G8	20.389abcd	103.22de	5.8444abc	42.17 a	47.7 bc	3.63333a	3.4333c	26.677f	88.77e	2.41e
G9	21.222abc	109.67bcd	5.8444abc	33.01 ef	41.89 ef	1.3333fg	3.3333c	53.970b	42.49j	2.3467e
G10	21.389ab	110.17bcd	5.95abc	33.58 ef	41.94 ef	1.6667def	3.4667c	34.910cd	50.87hi	1.7667 g
G11	18.667bcde	106.33cde	5.2667bc	31.60 f	43.55 cdef	2.4333c	4.4333a	21.437hi	54.47h	1.17 h
G12	22.832a	105.97cde	5.8167abc	38.10 bcd	52.18 a	1.1667g	3.4667c	60.393a	45.29ij	2.83 bcd
G13	20.110abcd	99.00ef	5.7333abc	35.970 bcde	46.44 bcd	1.7000de	3.5333c	20.580i	95.92d	2.006 f
G14	16.333e	105.60cde	5.0667c	35.72 cde	45.71 bcde	1.8000d	3.3667	35.183cd	68.49g	2.3767e
G15	17.997de	107.00bcd	6.20ab	42.27 a	42.42def	1.5333def	3.5333	31.027e	81.10f	2.6467d
G16	18.167cde	92.47f	5.25bc	35.197cdef	42.70 def	2.9000b	3.4333c	31.293e	71.33g	2.083 f
Min.	16.33	92.47	5.06	31.60	39.38	1.16	3.23	19.38	42.49	1.17
Max.	22.83	123.53	6.66	42.27	52.18	3.66	4.43	60.039	152.31	3.76
Mean	19.952	107.82	5.77	36.13	44.01	2.17	3.56	32.07	85.12	2.53
LSD	3.116	7.6267	1.0464	3.93	4.41	1.5436	0.3550	2.6257	6.7584	0.193

Note: DFF= Days to first flowering, PH= Plant height (cm), NBP= No. of branches per plant, , NFPP= No. of fruits per plant, YPP=Yield per plant

Appendix V. Analysis of variance of 10 character of 16 population of tomatillo

Character	Mean sum of square		
	Replication (r-1)=2	Genotype (g-1)=9	Error (r-1)(g-1)=18
Days to first flowering	10.8378	11.0828**	3.6069
Plant Height (cm)	52.010	143.210**	20.919
Number of Branch	0.61265	0.45860	0.39375
Fruit Length	1.0099	31.58**	24130
Fruit Diameter	9.19	33.667**	6.99
Brix percentage	0.05771	2.04794**	0.04482
pH Content	0.05021	0.36199**	0.04532
Fruit weight (g)	2.321	390.488**	2.479
No of fruits	5.30	2849.26**	16.43
Yield / plant	0.04698	1.0492**	0.0134

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

Appendix VI. Pictorial view of the experimental site