CELL COMPATIBILITY ANALYSIS IN POMATO (*Solanum tuberosum* L. and *Solanum lycopersicum* L.)

BY

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CERTIFICATE

This is to certify that thesis entitled, " CELL COMPATIBILITY ANALYSIS OF POMATO (Solanum tuberosum L. and Solanum lycopersicum L.) USING LOCAL VARIETIES OF POTATO" 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 MOLLIKA FATIMA NUSRAT, Registration No. 07-02545 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2014
Place: Dhaka, Bangladesh

(Prof. Dr. Naheed Zeba)
Supervisor

DEDICATED TO

MY

BELOVED PARENTS

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CELL COMPATIBILITY ANALYSIS IN POMATO (*Solanum tuberosum* L. and *Solanum lycopersicum* L.)

ABSTRACT

BY

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A field experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka, during November 2013 to April 2014. Four potato (*Solanum tuberosum* L.) and three tomato genotypes (*Solanum lycopersicum L.*) were studied in the present study. The objectives of the study were compatibility analysis of tomato and potato by making pomato plants using cleft grafting and to assess the magnitude of genetic divergence in pomato combinations, association among the characters and their contribution to yield. The analysis of variance indicated significantly higher amount of variability among the combinations for all the characters. Considering genetic parameters high genotypic co-efficient of variation (GCV) was observed for, fruit per cluster, fruit per plant, tuber per plant and fruit yield per plant whereas days to first flowering, days to 50% flowering and tuber yield per plant showed low GCV. High heritability with high genetic advance in percent of mean was observed for number of fruits per cluster, number of fruits per plant, tuber per plant and fruit yield per plant and tuber yield per plant indicating that these traits were under additive gene control and selection for genetic improvement for these traits would be effective. The results obtained, showed that fruit yield per plant had high positive significant relation with plant height, cluster per plant, fruits per cluster, fruits per plant but high negative significant relation with fruit length and fruit diameter. Days to 50% flowering, number of branches per plant and fruit per cluster had high positively direct effect on yield of tomato. Fruit weight and fruit length had high negative direct effect on yield of tomato. So, these were found to be important characters and could be used on improvement for yield. The highest mean total yield per plant was found in P2T1, P4T1, P3T1 and in P1T1 respectively. It means T1 (BARI Tomato-11) showed the best compatibility with all the local potato varieties except P4 (Pakri Alu(Tel). So, BARI Tomato-11 could be recommended to the pomato growers with local potato varieties.

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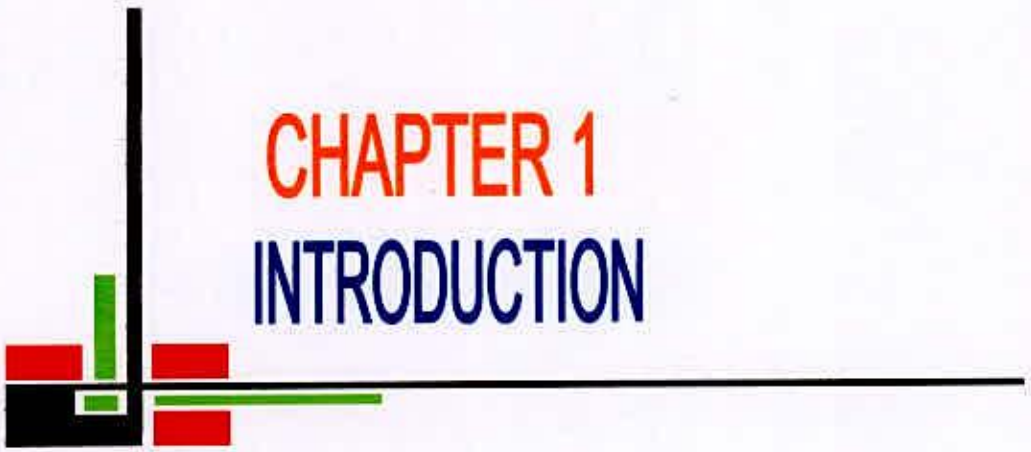
LIST OF ABBREVIATED TERMS

ABBREVIATION	FULL NAME
AEZ	Agro-Ecological Zone
Agril.	Agricultural
et al.	And others
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
cm	Centimeter
CV	Co-efficient of Variation
DAS	Days After Sowing
°C	Degree Celsius
etc.	Etcetera
FAO	Food and Agriculture Organization
GA	Genetic Advance
GCV	Genotypic Co-efficient of Variation
δ^2_g	Genotypic Variance
g	Gram
ha	Hectare
h^2b	Heritability in broad sense
j.	Journal
Kg	Kilogram
m	Meter
MSS	Mean Sum of Square
mm	Millimeter
MP	Muriate of Potash
No.	Number
%	Percent
PCV	Phenotypic Co-efficient of Variation
δ^2_p	Phenotypic variance
RCBD	Randomized Complete Block Design

ABBREVIATION	FULL NAME
Res.	Research
SAU	Sher-e-Bangla Agricultural University
m^2	Square meter
Sci.	Science
TSP	Triple Super Phosphate
Uni.	University



CHAPTER 1
INTRODUCTION

CHAPTER I

INTRODUCTION

The pomato (or tomtato) is a chimera produced by grafting a tomato and a potato plant. Tomatoes grow on the vine, while potatoes grow in the soil from the same plant. The double species works because potato (*Solonaceae tuberosum* L.) and tomato (*Solanum lycopersicum* L.) belong to the same plant family, Solonaceae, and are closely related, sharing a common basic chromosome count of 12. But rather than just the chromosome count, it's the compatibility of the graft union, where the all-important cambium (growth) cells found under the skin of the potato and tomato shoots need to match up for the graft to work.

Grafting is the process of combining two different plants to create a single one. It requires lots of skill and practice, but has been successfully achieved by providing a clean cut on the two plants and taping the ends together until they heal. The purpose is to combine one plant's qualities of flowering or fruiting with the roots of another that offers vigour and resilience. Most plants need to be grafted within their own genus - such as potatoes and tomatoes - but it is sometimes possible to graft those of a differing makeup. The concept of grafting related potatoes and tomatoes so that both are produced on the same plant was originally developed in 1977 at the Max Planck Institute for Developmental Biology in Tübingen, Germany. The Max Planck Institute for Plant Breeding Research in Köln produced a plant with fruit in 1994 (Renneberg, 2008). As with all grafts, this plant will not occur in nature and cannot be grown from seed, because the two parts of the plant remain genetically separate, and only rely on each other for nourishment and growth. Like most standard types of plant grafting, a small incision is made in the stem of both plants and they are strapped together. Once the cuts have healed and the plants are joined, the leafy top of the potato plant can be cut away and the roots of the tomato can be removed, leaving the leaves of the tomato plant to nourish the roots of the potato plant (Mark.com domain, 2013). The rootstock (potato)

acts as a stable and healthy root system and the scions (tomato) are chosen for their fruit, flowers or leaves. The pomatoes should be ready to harvest after about 12 weeks during the summer months; the potatoes should be ready after the tomato leaves begin to die back, normally in early autumn (The Guru, 2013). Pomato plants have been seen as a new technology to make food production more efficient, as they maximize the amount of crops that can be produced on a piece of land or in a small urban environment like a balcony. This has significant impacts on developing countries like Bangladesh, where farmers can save on space, time and labour without affecting the quality of their produce by growing pomato plants. In addition, grafting can improve resistance to bacteria, viruses and fungi attract a more diverse group of pollinators and provide a strong trunk (Jabr, 2013). Grafted pomato plants were launched in the United Kingdom in September 2013 by horticultural mail order company Thompson and Morgan, who sold pre-grafted plants branded as the "TomTato". The Incredible Edible nursery in New Zealand announced a "Double UP Potato Tom" in the same month (Jude, 2013). Thompson and Morgan claim that this is the first time the plant has been produced commercially, and Director Paul Hansord describes originating the tomtato idea himself 15 years ago in the US, when visiting a garden where someone had planted a potato under a tomato (Hall, 2013).

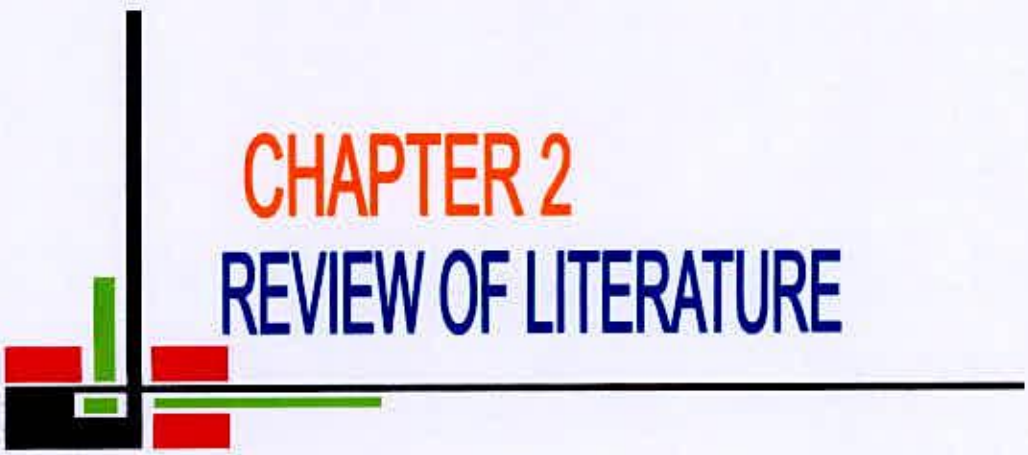
Grafting is a difficult process because the tomato and the potato stems have to be the same thickness and Thompson and Morgan trialled the hybrid for several years before selling it. Production and grafting of tomtatos begins in a specialist laboratory in the Netherlands, before being shipped back to the UK and grown in greenhouses until they are ready to be sold (Wilkes, 2013).

Parameters of genotypic and phenotypic coefficients of variation (GCV and PCV) are useful in detecting the amount of variability present in the available genotypes. Heritability and genetic advance help in determining the influence of environment expression of the characters and the extent to which improvement is possible after selection (Robinson *et al.*, 1949). Evaluation of

germplasm is of immense importance in genetic improvement of the crop. Crop improvement depends upon the magnitude of genetic variability and extent to which the desirable character are heritable (Garcia *et al.*, 2004). Knowledge of genetic variation has important implications for the conservation of genetic resources and breeding programs. High heritability alone is not enough to make efficient selection in segregating generation, unless the information is accompanied for substantial amount of genetic advance (Johnson *et al.*, 1955).

The knowledge of association between yield and its contributing traits is of great values in planning a breeding programme. As yield is the main object of a breeder, so it is important to know the relationship between various characters that have direct and indirect effect on yield. According to Burton (1952), for the improvement of any character, it is essential to know the extent of variability present in that species, nature of association among the characters and the contribution of different characters towards yield. A study was, therefore, conducted on the genetic variability, correlation and path co-efficient analysis between yield and yield contributing characters of tomato. Information about species as well as their identifying characters for most of the germplasms collected was unknown. So, it is an opportunity to categorize the germplasm morphologically under different species for future utilization. With conceiving the above scheme in mind, the present research work has been undertaken in order to fulfill the following objectives:

1. To assess the compatibility of cells of two different species, tomato and potato.
2. To develop a suitable protocol for getting two crops at a time, tomato and potato from a single plant in a small piece of land or homestead area.
3. To assess the magnitude of variability in pomato combinations for identifying the divergent combinations to use them in future pomato
4. To know the nature of association of traits, direct and indirect relation between yield contributing characters through correlation coefficient and path coefficient analysis in pomato plants.



CHAPTER 2
REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Tomato obtained second position after potato in the world ranking. Tomato and potato is a well-studied crop species for research. Pomato plants have been seen as a new technology to make food production more efficient, as they maximize the amount of crops that can be produced on a piece of land or in a small urban environment like a balcony (Fresh Fruit portal newsletter, 2015). This has significant impacts on developing countries like Kenya, where farmers can save on space, time and labour without affecting the quality of their produce by growing pomato plants (Business Daily, 2015). In addition, grafting can improve resistance to bacteria, viruses and fungi, attract a more diverse group of pollinators and provide a sturdy trunk for delicate ornamental plants. Various resources are accessible now for tomato and potato research, which can lead to uprising in evaluation of pomato. Adequate knowledge of genetics of various traits is very essential in vegetable breeding programme for obtaining desired results in the generation. However, the success of vegetable breeding depends on the extent and the magnitude of variability existing in the germplasm. At the same time, improvement is possible on the basis of heritable variation.

Morphological marker is a valuable tool, which can utilize in crop improvement programme. Selection for yield, based on multiple traits is always better than selection based on yield alone. Yield is a quantitative character controlled by many genes (Lungu, 1978). Morphological characters were studied in selected tomato and potato accessions by already set standards for morphological characters by IPGRI (International Plant Genetic Resources Institute) tomato descriptor (Darwin *et al.*, 2003). These Characterizations include the plant growth type and size, leaf shape, size and arrangement, plant height and fruit morphology i.e. number of fruits per plant. Identification of phenotypic marker is essential to sort out the segregating generation and subsequent selection (Weising *et al.*, 1995). The presence of genetic variability

in the breeding material has been emphasized by previous researchers (Naz *et al.*, 2013; Reddy *et al.*, 2013; Singh, 2009; Shuaib *et al.*, 2007). The review of literature concerning to the studies conducted for this dissertation is discussed below:

2.1 World wide news about pomato

According to Lubbock online Fruit or tuber formation (2002) requires a great deal of a plant's energy, so a pomato plant might get confused as to where to direct its energy. A tomato plant is programmed to put energy into large, luscious fruits. A potato plant is programmed to put its energy into fat, fleshy tubers. So a pomato plant probably would not yield many tomatoes or potatoes. Barter (2013), who is a contributor to BBC Gardener's World, said "many of these plants - created by a technique known as grafting - had been created before but taste had previously been a problem. We're looking at it with real interest because Thompson and Morgan is a really reputable firm with a lot to lose, but I wouldn't rule out that it could be a very valuable plant to them. In the past we've never had any faith in the plants - they've not been very good - but grafting has come on leaps and bounds in recent years".

According to the Director Dr. Paul Hansord (2015), of the Thompson and Morgan Company the plant has been enormously successful. And it's little wonder. Tomatoes and potatoes, from the same greenery it seems almost like magic. But tomatoes are red and potatoes are brown. Yet here they are, together as one has been successfully produced commercially. Tomatoes are members of the potato family and are therefore naturally compatible with potatoes. Each Tom Tato plant is specially grafted by hand to create this unique double cropping feature. There's no genetic modification - it's an all-natural, and safe (Hansord, 2015). Rather than some freak of nature, or a genetically engineered marvel, it's simply a seedling tomato plant grafted on top of a potato plant, created using a technique similar to that used for years to produce "supertom" tomatoes. Tomato seedlings were used for the top, or scion, part of the plant,

and then grafted on to the emerging shoot from a potato tuber to produce the dual purpose plant (Jude, 2013). The Oregon Seed Company reported in 2014 that the plant was developed in the United Kingdom (CBS Seattle Newsletter (2014). The seed company said since potatoes and tomatoes are fairly closely related, they graft well together. It's not genetic engineering. Gardeners can harvest a double crop of red cherry tomatoes and white potatoes from the plant also called a TomTato. According to Springvale Garden Centre (2014) tomatoes belong to the Potato family and so are naturally compatible with them. The idea of grafting a tomato onto a potato to get two vegetables from the one plant is not a new idea. It simply has never been commercialized before and of course it is a great use of space, especially for people with small gardens or just a patio. As the crop of tomatoes grows and is harvested the Agria potatoes are developing below. Once the tomatoes have finished, simply dig out and harvest the potatoes.

It has been very difficult to achieve a pomato plant because the tomato stem and the potato stem have to be the same thickness for the graft to work. It is a very highly skilled operation. However, on closer inspection the potato is planted in a pot with a tomato planted in the same pot - the plant is one plant and produces no potato foliage. The plants last for one season and by the time the tomatoes are ready for picking, the potatoes can be dug up (BBC News, 2013). If at first it seems like a weird science experiment that just took off, well, it is. Closer inspection, however, shows that the two plants are related. Both are part of the same genus: the tomato is the fruit of the nightshade *Solanum lycopersicum*, while the potato is the crop of the nightshade *Solanum tuberosum*. It was developed in the Netherlands and commercialized in England, yet it's as American as a plant can get. Ketchup 'n' Fries is a plant that's been grafted to bear cherry tomatoes on top and white potatoes beneath the soil, and it's making its way to home gardens in the United States. The plant debuted in the U.S. recently, just in time to catch the attention of Southern California tomato enthusiasts, who typically are scouting now for

new varieties to plant in the coming weeks. But as a chimera-like twofer, Ketchup 'n' Fries are garnering the attention of more than just tomato gardeners (The Orange County Register, 2015). In 1915 Burbank wrote about one of his findings that were with herbaceous plants like the potato and tomato the stem may unite at any portion where the cut surfaces come in contact. To make a neat and thoroughly satisfactory graft, however, it is of course desirable to select stems of exactly the same size. The splice graft, elsewhere described, is the best one to use, and if the incisions are made with care, so that the incised surfaces fit accurately together, it is only necessary to tie a piece of cloth about the united stems for a few days until union has taken place.

A farm in Kenya has grafted a plant that grows tomatoes and potatoes on the same stem in a bid to maximise the use of land parcels. The 'pomato' is a result of trials that began two years ago in Kenya's Kiambu Prison farm, inspired by Chinese literature showing tuber and the fruit could be grown on the same plant (Fresh Fruit Portal newsletter, 2015). According to Greene (2013), there's a new wonder plant on the market. Some are calling it the TomTato. Cherry tomatoes grow above ground on the vine while white potatoes grow in the soil all from the same plant. The double crop plant might sound a little bit like mad science, but tomato and potatoes are members of the same plant family, making them really an ideal couple. A plant which produces both potatoes and tomatoes, described as a "veg plot in a pot", has been launched in the UK. The TomTato can grow more than 500 sweet cherry tomatoes while producing white potatoes (Hall, 2013). Some farmers and gardeners have created pomato plants, which grow potatoes underground and tomatoes above ground. Potatoes and tomatoes might seem very different based on appearances, but they both belong to the genus *Solanum* (Jabr, 2013). After a process of trial and error, and with the help of grafting specialists, Thompson & Morgan hit upon a method using a variety of potato that produces the right size shoot.

Careful variations in the temperature at which the tomato and potato are initially grown are also made to ensure the two plants are a perfect match before being joined together (Mail online news, 2015). We've seen a number of innovations that allow for gardening in small spaces, including a ferris wheel-like contraption, a mat that shows you where to plant specially-prepared seeds, and a system that lets you grow vertically-stacked veggies in your window. The TomTato, however, is in a league of its own – it's a single plant that produces both tomatoes and potatoes at the same time (Coxworth, 2013).

2.2 Grafting

Grafting with detached scions has been practiced for thousands of years. It was in use by the Chinese before 2000 BC, (Cooper and Chapot, 1977) then spread to the rest of Eurasia and was well established in ancient Greece (Garner, 1988). Grafting or graft age is a horticultural technique whereby tissues from one plant are inserted into those of another so that the two sets of vascular tissues may join together. This vascular joining is called inosculation. The technique is most commonly used in asexual propagation of commercially grown plants for the horticultural and agricultural trades. In most cases, one plant is selected for its roots and this is called the stock or rootstock. The other plant is selected for its stems, leaves, flowers, or fruits and is called the scion or cion (Hottes, 1925). The scion contains the desired genes to be duplicated in future production by the stock/scion plant.

In stem grafting, a common grafting method, a shoot of a selected, desired plant cultivar is grafted onto the stock of another type. In another common form called bud grafting, a dormant side bud is grafted onto the stem of another stock plant, and when it has inosculated successfully, it is encouraged to grow by pruning off the stem of the stock plant just above the newly grafted bud. For successful grafting to take place, the vascular cambium tissues of the stock and scion plants must be placed in contact with each other. Both tissues must be kept alive until the graft has "taken", usually a period of a few weeks. Successful grafting only requires that a vascular connection take place between

the grafted tissues. Joints formed by grafting are not as strong as naturally formed joints, so a physical weak point often still occurs at the graft because only the newly formed tissues inosculate with each other. The existing structural tissue or wood of the stock plant does not fuse. Grafting is the process of combining two different plants to create a single one so requires lots of skill and practice, but has been successfully achieved by providing a clean cut on the two plants and taping the ends together until they heal. The purpose is to combine one plant's qualities of flowering or fruiting with the roots of another that offers vigour and resilience. Most plants need to be grafted within their own genus - such as potatoes and tomatoes - but it is sometimes possible to graft those of a differing makeup. The concept of grafting related potatoes and tomatoes so that both are produced on the same plant was originally developed in 1977 at the Max Planck Institute for Developmental Biology in Tübingen, Germany, and although healthy, the plant produced neither potatoes nor tomatoes (Renneberg, 2008).

2.3 Grafting on other vegetable

Grafting is often done for non -woody and vegetable plants (tomato, cucumber, eggplant and watermelon (Core, 2005). Tomato grafting is very popular in Asia and Europe, and is gaining popularity in the United States. The main advantage of grafting is for disease-resistant rootstocks. Plastic tubing can be used to prevent desiccation and support the healing at the graft/scion interface.

Checking the genetic lines of Solonaceous plants, though, it does seem that as eggplants (*Solanum melongena*), are more closely related to potatoes than sweet peppers or chillies (*Capsicum annuum*), they are probably the most likely grafts to work. A graft of peppers on potatoes would require a match between different genera, whereas those with tomatoes, eggplants and potatoes are between the same genus. During the past years, the primary objective of horticulture has been to increase yield and productivity. However, high quality is even more important than total yield for attaining competitiveness in modern

horticulture due to the beneficial role of vegetables in human diet. This report gives an overview of the recent literature on the effects of grafting on fruit vegetable (Solanaceae and Cucurbitaceae) quality including physical properties, flavor and health-related compounds of the product. The review will conclude by identifying several prospects for future researches aiming to improve the product quality of grafted vegetables (Youssef *et al.*, 2010). An experiment was conducted by Xiao *et al.* (2011) on effects of grafting on bitter gourd and they found good controlling effect on *phytophthora* blight. Grafting on disease-resistant rootstocks is a growing practice in watermelon cultivation worldwide. Reports on effects of grafting on watermelon fruit postharvest performance are scarce. The current work examined postharvest performance at 25C of four diploid cultivars grown non-grafted or grafted onto three *Cucurbita maxima*□×□*C.*□*moschata* rootstocks (Marios and Georgios, 2015).

2.4 Vriability, Correlation and Path Analysis

Thirteen potato genotypes were evaluated by Fekadu *et al.* in 2013 for genetic variability and association of agronomic characters among themselves and tuber yield. The study aimed to find out the genetic variability, and interrelationships among different characters in potato.

Tuber/plant was found the minimum 6.1 and the maximum 7.2 and height of potato plants vary from 28.4 to 71.2 cm in an experiment conducted by Khayatnezhad *et al* (2011).

Genotypic and phenotypic variability, heritability, genetic advance, correlation coefficients and path coefficients analysis were done for yield and its contributing characters in 28 genotypes of potato. The experiment was conducted by Sattar *et al.* (2007). Genotypic and phenotypic correlation of the number of tubers per plant was highly significant. Number of tubers per plant, average weight of a tuber and dry matter content of tuber had high degree of positive association with tuber yield per plant. As per path analysis total

number of tubers per plant contributed maximum direct effect to tuber yield indicating their importance as selection index for yield improvement (Sattar *et al.,* 2007). They also found the highest genotypic and phenotypic coefficients of variations were observed for yield of tubers per plant and number of tubers per plant. Estimates of genotypic coefficients of variation alone are not sufficient to assess the heritable variation. For more reliable conclusion, estimates of high heritability and high genetic gain should be considered together (Johnson *et al.*, 1955). Heritability estimates in broad sense were more than 90% for the characters of yield of tubers per plant and number of tubers per plant, and more than 80% were observed in days to maturity, plant height and plant vigour. The heritability estimates were more than 98% for yield of tuber per plant by Sattar *et al.* (2007).

Matin and Kuddus (2001) reported significant differences for yield per plant among the genotypes tested. He also reported that phenotypic variance was little higher than genotypic variance indicating slight environmental influence on this trait. Sachan (2001) performed an experiment with certain tomato genotypes and he also reported significant differences among the genotypes for yield per plant. Kumar and Tiwari (2002) reported higher genotypic co-efficient of variation for average yield per plant among thirty two tomato genotypes. Brar *et al.* (2000) reported high degrees of variation for average yield per plant among the 186 genotypes tested. Reddy and Gulshanlal (1990) observed considerable variations for yield per plant in 139 tomato varieties. Sonone *et al.* (1986) and Dudi *et al.* (1983) reported that genotypic and phenotypic variances were high for average yield per plant.

Singh *et al.* (1997) estimated heritability and genetic advance in 23 genotypes of tomato. High values of heritability and genetic advance indicated that effective selection may be made for fruit weight and number of fruits per plant. Islam *et al.* (1996) studied heritabiltiy and genetic advance in 26 diverse genotypes of tomato. High heritability and genetic advance was observed in number of fruits per plant, plant height, fruit yield and individual fruit weight.

Desai and Jaimini (1997) also reported that tuber yield, number of stem, number of leaves, maturity, shoot fresh weight, number of tubers and average tuber weight had high genotypic coefficients of variation, high heritability and high genetic advance irrespective of environments.

According to Buckseth *et al.* (2012) high GCV obtained for average fruit weight, yield per plant, pericarp thickness, and number of seeds per fruit. Saeed *et al.* (2007) observed the variation among the accessions. The coefficient of variation was greater in traits such as number of fruits per plant followed by number of flowers per plant and yield per plant. Joshi and Singh (2009) conducted a field experiment with forty tomato genotypes to evaluate their genetic variability and observed the number of fruits per plant which provide the highest phenotypic and genotypic coefficient of variation.

According to Thompson- Morgan company especially hand-grafted plants producing potatoes and tomatoes are now available to UK home gardeners for the first time. Above the ground harvest over 500 cherry tomatoes with a Brix level of 10.2 - that's sweeter than supermarket tomatoes and below the ground harvest heavy yields of up to 2kg of delicious white potatoes which are incredibly versatile.

Brar *et al.* (2000) estimated phenotypic and genotypic co-efficient of variation and observed high variability in the characters of number of fruits per plant of 186 genotypes of tomatoes. Das *et al.* (1998) and Islam *et al.* (1996) reported wide range of genotypic variation for number of fruits per plant. Singh *et al.* (1997) studied variability for yield related characters in 23 genotypes of tomato and reported that phenotypic variation was quite large but genotypic variation was low. The phenotypic and genotypic co-efficient of variation indicated that selection may be made for number of fruits per plant. Sidhu and Singh (1989) and Bhutani and Kallo (1989) suggested that the maximum genetic improvement would be possible by genetic variability for number of fruits. Prasad and Prasad (1977), Dudi *et al.* (1983) and Sonone *et al.* (1986) estimated the high genotypic and phenotypic co-efficients of variation for

fruits per plant. Stronger positive correlations were found between tuber yield and plant height (r=0.843) (Khayatnezhad *et al,* 2011).

Correlation and path analyses indicated that tubers/plant was the main components to tuber yield. For this reason, these traits could be used more significantly for potato improvement (Burhan, 2007). Similar research results with this study were published by Galarreta *et al*, 2006, Gunel, *et al*, 1991, Maris, 1988; Er, 1984.

A field experiment was carried out by Monamodi *et al.* (2013) using six determinate tomatoes. Path coefficient analysis results showed that marketable fruit number was directly related to yield. Rani *et al.* (2010) conducted a field experiment to study path coefficient for yield components and quality traits in 23 hybrids of tomato and exhibited that fruit weight had the highest positive direct effect on yield per plant, while, fruit weight was also having high positive indirect effect on yield per plant. Golani *et al.* (2007) performed path analysis and confirmed that the 10-fruit weight had the highest positive direct effect. Compared to the simple correlation analysis, path analysis of tuber yield and potato plant height evolved the highest direct influence (2.19) (Khayatnezhad *et al.*, 2011). Yildirim *et al.* (1997) stated that tubers/plant and plant height had positive and high direct effects on tuber yield/plant.

CHAPTER 3

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

This chapter illustrates information concerning methodology that was used in execution of the experiment. It comprises a brief description of locations of experimental site, planting materials, climate and soil, seed bed preparation, layout and design of the experiment, land preparation, manuring and fertilizing, transplanting of seedlings, intercultural operations, harvesting, data collection procedure and statistical analysis procedure which are presented as follows:

3.1 Experimental site

The experiment was accomplished at experimental field, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh during the period from November 2012 to April 2013. Location of the site is 23°74' N latitude and 90°35' E longitude with an elevation of 8 meter from sea level in Agro-ecological zone of "Madhupur Tract" (AEZ-28) (Anon., 1988). The experimental site is shown in the map of AEZ of Bangladesh in (Appendix I).

3.2 Planting materials

A total of three genotypes of tomato and four genotypes of potato were used in this experiment. The local potato varieties were collected with a courtesy of Deputy Director, Horticulture Development Division, Bangladesh Agricultural Development Corporation (BADC), Dhaka and the tomato varieties were collected from Plant Genetic Resource Centre (PGRC) at Bangladesh Agricultural Research Institute (BARI), Gazipur. The name and origin of these genotypes are presented in Table 1, Plate 1 and Plate 2

3.3 Climate and soil

Experimental site was located in the subtropical climatic zone, set aparted by plenty of sunshine and moderately low temperature prevails during October to March (Rabi season). The soil was sandy loam in texture having pH 5.46- 5.62.

Weather information and physicochemical properties of the soil are presented in (Appendix II and Appendix III, respectively).

Table 1. Name and place of collection of three tomato and four potato genotypes used in the present study

Sl. No.	Genotypes No.	Name/Acc. No. (BD)	Place of collection
1	T_1	BARI Tomato-11	PGRC, BARI
2	T_2	BARI Tomato-2	PGRC, BARI
3	T_3	BARI Tomato-3	PGRC, BARI
4	P_1	Shel Bilati	HDD, BADC
5	P_2	Indur Kani	HDD, BADC
6	P_3	Hagrai	HDD, BADC
7	P_4	Pakri Alu (Tel)	HDD, BADC

PGRC = Plant Genetic Resource Centre, BARI = Bangladesh Agricultural Research Institute, HDD= Horticulture Development Division, BADC= Bangladesh Agricultural Development Division

3.4 Land preparation

The experimental plots were ploughed and brought into a fine tilth and raised the nursery bed, applied the recommended dose of fertilizers and farm yard manures (FYM). Weeds and other stubbles were removed carefully from the experimental plot and leveled properly. The final land preparation was done on December 5, 2013.

3.5 Design and layout of the experiment

The experiment was laid out and evaluated under field condition during Rabi 2012- 13 in Randomized Complete Block Design (RCBD).

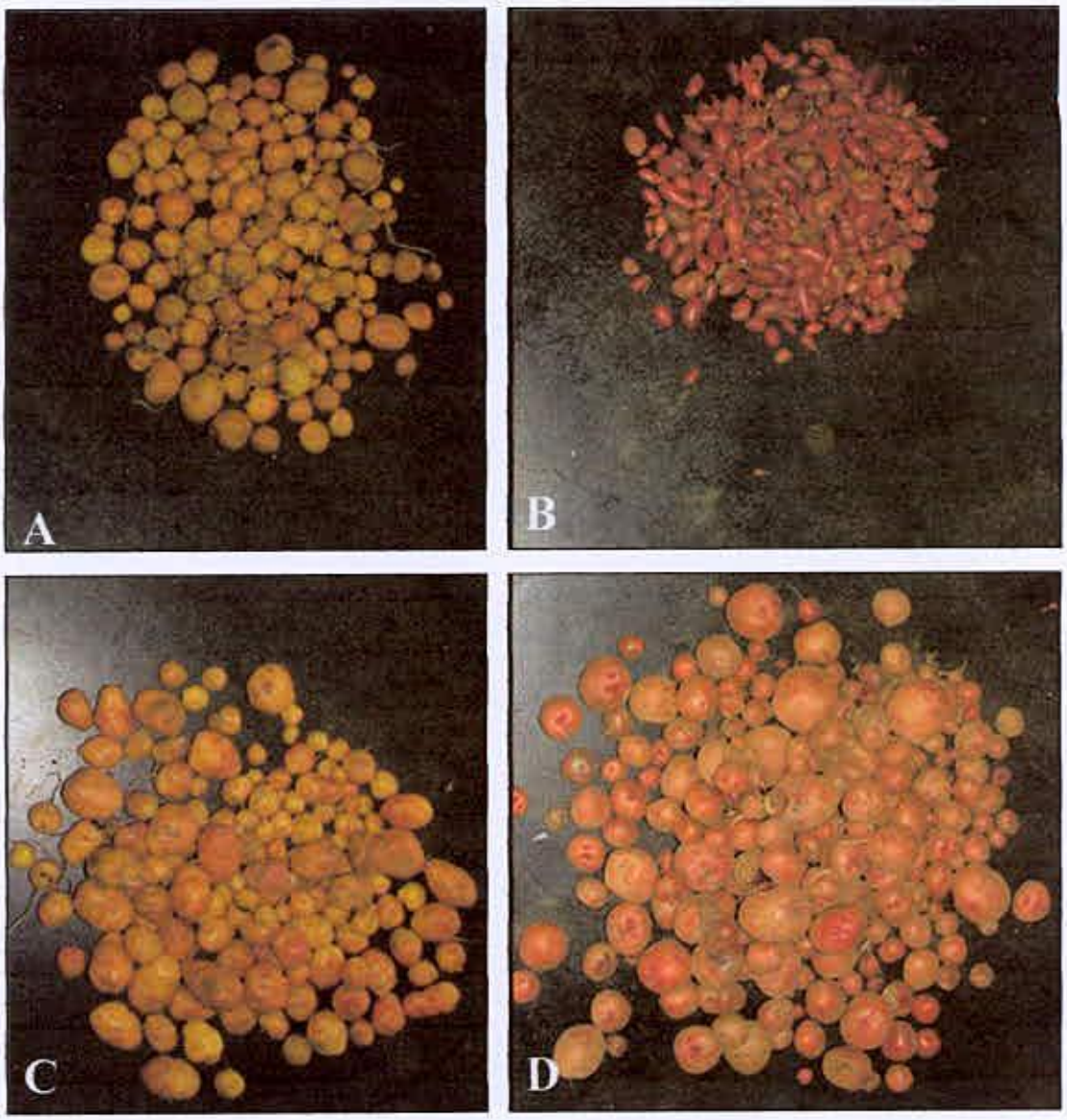


Plate 1. Four genotypes of potato used in the study. **A.** Shel Bilati (P1) **B.** Indurkani (P2) **C.** Hagrai (P3) **D.** Pakri Alu (Tel) (P4)

Plate 2. Three genotypes of tomato used in the study. **A.** BARI Tomato-11 (T1) , **B.** BARI Tomato-2 (P2) **C.** BARI Tomato-3 (T3)

Genotype	:	7
Replications	:	3
Spacing	:	40 cm × 60 cm
Plot size	:	6 × 37 m
Date of grafting	:	26th December 2013

3.6 Seed bed preparation and raising of tomato seedling

Sowing of tomato seed was carried out on December 5, 2013 in the seedbed. Before sowing, seeds were treated with Bavistin for 5 minutes. Seedlings of all genotypes were raised in seedbeds in the Sher-e-Bangla Agricultural University, Dhaka-1207 farm unit. Seeds were sown in rows spaced at 10 cm apart, beds were watered regularly. Seedlings were raised using regular nursery practices. Recommended cultural practices were taken up before and after sowing the seeds. Seven days old seedling were transferred into polybags for hardening. Raising of tomato seedlings, hardening in polybag, growing of potato seedling, intercultural operation is shown in Plate 3.

3.7 Sowing of potato seeds and transfer of tomato seedlings in the main land

The tubers were cut in a half with at least two eyes and sown in plots in the main field. Twenty one days old seedlings of tomato were transplanted to the main land. Necessary intercultural operations were provided as and when required.

3.8 Grafting of seedlings

The 21 days old tomato seedlings, raised in the polybags were grafted on potato plant in the main field on December 26, 2013. Cleft grafting method was used for tomato-potato grafting. Different steps of grafting procedure are shown in plate 4 The grafted seedlings were watered regularly to make a firm relation with scion - root stock and soil to stand along.

Plate 3. Different steps of the experiment. **A.** Raising of tomato seedling in the seedbed **B.** Hardening of tomato seedling in the polybag **C.** Growing of potato seedling in the main land **D.** Intercultural operation in the pomato field.

Plate 4. Cleft Grafting for making pomato plant using potato and tomato seedling . **A.** Cutting of stem of tomato seedling from polybag. **B.** Sharpen the edge of tomato stem from both side. **C.** Cutting the stem of potato plant and tease open the stem. D. Insertion of sharpen edge of tomato seedling into the stem of potato seedling. **E.** Join the two stem with wrapping tape. **F.** Branching of pomato plant.

3.9 Manure and fertilizers application

Total cow dung and Triple Super Phosphate (TSP) were applied in the field during final land preparation. Half Urea and half Muriate of Potash (MOP) were applied in the plot after three weeks of transplanting. Remaining Urea and Muriate of Potash (MOP) were applied after five weeks of transplanting. Doses of manure and fertilizers used in the study are presented in Table 2.

3.10 Intercultural operations

When the seedlings were well established, 1st earthing up was done uniformly after 10 days of grafting. 2nd was done 35 days of grafting.1st weeding was done uniformly in all the plots. Second weeding was done after 20 days of the first one. Mechanical support was provided to the growing plants by bamboo sticks to keep them erect. During early stages of growth, pruning was done by removing some of the lateral branches to allow and plants to get more sunlight and to reduce the self-shading and incidence of increased insect infestation. Staking, pesticide application, irrigation and after-care were also done as per requirement.

3.11 Harvesting and processing

All of the tomato varieties used in this experiment was indeterminate types. So, harvesting continued for about one and half month because fruits of different lines matured progressively at different dates and over long time. The fruits per entry were allowed to ripe and then seeds were collected and stored at 4°C for future use. The potatoes were harvested after several successful harvesting of tomato. Harvesting was started from March 2, 2014 and completed by April 26, 2014.

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

Sl. No.	Fertilizers/ Manures	Dose	
		Applied in the plot	Quantity/ha
1.	Urea	10.5 kg	550 kg
2.	TSP	08 kg	450 kg
3.	MOP	4.5 kg	250 kg
4.	Cow dung	200 kg	10 ton

3.12 Data recording

Three plants in each entry were selected randomly and were tagged. These tagged plants were used for recording observations for the following characters.

3.12.1 Days to first flowering

The number of days was counted from the date of sowing to days to first flowering.

3.12.2 Days to 50% flowering

The number of days was counted from the date of sowing to 50 per cent of plants flowered.

3.12.3 Plant height (cm)

The plant height was measured from ground level to tip of the plant expressed in centimeters (cm) and mean was computed.

3.12.4 Branches per plant

The number of branches arising from the main stem above the ground was recorded at 70 days after transplanting.

3.12.5 Number of clusters per plant

Number of clusters per plant was recorded at the time of harvesting.

3.12.6 Fruits per cluster

Three clusters in each plant were taken at random and the number of fruits in each cluster was counted. Then the average number of fruits per cluster was calculated.

3.12.7 Fruits per plant

The total number of marketable fruits harvested from the five plants was counted and the average number of fruits per plant was calculated.

3.12.8 Fruit length (cm)

It was measured from stalk end to blossom end by using vernier caliper.

3.12.9 Fruit diameter (cm)

It was measured from fruit breadth at highest bulged portion of the fruit by using vernier caliper.

3.12.10 Fruit yield per plant (kg)

The weight of fruits from each picking was recorded from the five labeled plants of each experimental plot. Total yield per plant was worked out by adding yield of all harvests and was expressed in kilogram (kg) per plant.

3.12.11 Tuber per plant

The total number of tuber was collected from pomato plant.

3.12.12 Tuber yield per plant (kg)

The weight of tuber from pomato plant was recorded from the three labeled plants of each experimental plot. Total tuber yield per plant was expressed in kilogram (kg) per plant.

3.13 Statistical analysis

Univariate analysis of the individual character was done for all characters under study using the mean values (Singh and Chaudhury, 1985) and was estimated using MSTAT-C computer programme. Duncan's Multiple Range Test (DMRT) was performed for all the characters to test the differences between the means of the genotypes. Mean, range and co-efficient of variation (CV %) were also estimated using MSTAT-C.

3.13.1 Estimation of genotypic and phenotypic variances

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

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

Where,

GMS = Genotypic mean sum of squares

EMS = Error mean sum of square

r = number of replications

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

Where,

σ^2_g = Genotypic variance

EMS = Error mean sum of square

3.13.2 Estimation of genotypic and phenotypic co-efficient of variation

Genotypic and phenotypic co-efficient of variation were calculated by the formula suggested by Burton (1952)

Genotypic co-efficient of variation, GCV % = $\frac{\sqrt{\sigma^2 g}}{\bar{x}} \times 10$

Where,

σ^2_g = Genotypic variance

$\bar{x}$ = Population mean

Similarly,

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

$$\text{Phenotypic co-efficient variation, PCV} = \frac{\sqrt{\sigma^2 ph}}{\bar{x}} \times 100$$

Where,

σ^2_{ph} = Phenotypic variance

$\bar{x}$ = Population mean

3.13.3 Estimation of heritability

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

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

Where,

h^2_b = Heritability in broad sense

σ^2_g = Genotypic variance

σ^2_{ph} = Phenotypic variance

3.13.4 Estimation of genetic advance

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

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

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

Where,

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

σ_{ph} = Phenotypic standard deviation

h^2_b = Heritability in broad sense

σ^2_g = Genotypic variance

σ^2_{ph} = Phenotypic variance

3.13.5 Estimation of genetic advance mean's percentage

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

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

3.13.6 Estimation of simple correlation co-efficient:

Simple correlation co-efficients (r) was estimated with the following formula (Clarke, 1973; Singh and Chaudhary, 1985).

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

Where,

$\sum$ = Summation

x and y are the two variables correlated

N = Number of observation

3.13.7 Estimation of genotypic and phenotypic correlation co-efficient

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

The co-variance components were used to compute genotypic and phenotypic correlation between the pairs of characters as follows:

$$\text{Genotypic correlation, } r_{gxy} = \frac{GCOVxy}{\sqrt{GVx.GVy}} = \frac{\sigma_{gxy}}{\sqrt{(\sigma^2_{gx}.\sigma^2_{gy})}}$$

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

$$\text{Phenotypic correlation } (r_{pxy}) = \frac{PCOVxy}{\sqrt{PVxPVy}} = \frac{\sigma_{pxy}}{\sqrt{(\sigma^2_{px}.\sigma^2_{py})}}$$

Where,

σ_{pxy} = Phenotypic covariance between the trait x and y

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

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

3.13.8 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:

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

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

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

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

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

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

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

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

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

$$r_{10.y} = r_{1.10} P_{1.y} + r_{2.10} P_{2.y} + r_{3.10} P_{3.y} + r_{4.10} P_{4.y} + r_{5.10} P_{5.y} + r_{6.10} P_{6.y} + r_{7.10} P_{7.y} + r_{8.10} P_{8.y} + r_{9.10} P_{9.y} + P_{10.y} + r_{10.11} P_{11.y} + r_{10.12} P_{12.y}$$

$$r_{11.y} = r_{1.11} P_{1.y} + r_{2.11} P_{2.y} + r_{3.11} P_{3.y} + r_{4.11} P_{4.y} + r_{5.11} P_{5.y} + r_{6.11} P_{6.y} + r_{7.11} P_{7.y} + r_{8.11} P_{8.y} + r_{9.11} P_{9.y} + r_{10.11} P_{10.y} + P_{11.y} + r_{11.12} P_{12.y} + r_{11.13} P_{13.y}$$

$$r_{12.y} = r_{1.12} P_{1.y} + r_{2.12} P_{2.y} + r_{3.12} P_{3.y} + r_{4.12} P_{4.y} + r_{5.12} P_{5.y} + r_{6.12} P_{6.y} + r_{7.12} P_{7.y} + r_{8.12} P_{8.y} + r_{9.12} P_{9.y} + r_{10.12} P_{10.y} + r_{11.12} P_{11.y} + P_{12.y}$$

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 = Days to 50% flowering

3 = Plant Height (cm)

4 = Number of branches per plant

5 = Number of clusters per plant

6 = Number of fruit per cluster

7 = Number of fruits per plant

8 = Number of tuber per plant

9 = Fruit length (cm)

10 = Fruit diameter (cm)

11 = Fruit yield per plant (kg)

12 = Tuber 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

Where,

$P_{1.y}, P_{2.y}, P_{3.y}. \ldots\ldots\ldots P_{8.y}$ = Path coefficient of the independent variables 1, 2, 3,….,12 on the dependent variable y, respectively.

$r_{1.y}$, $r_{2.y}$, $r_{3.y}$, ..., $r_{12.y}$ = Correlation coefficient of 1, 2, 3,...., 12 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 :

$$P^2_{RY} = 1 - (r_{1.y}P_{1.y} + r_{2.y}P_{2.y} + \ldots\ldots\ldots\ldots\ldots + r_{12.y}P_{12.y})$$

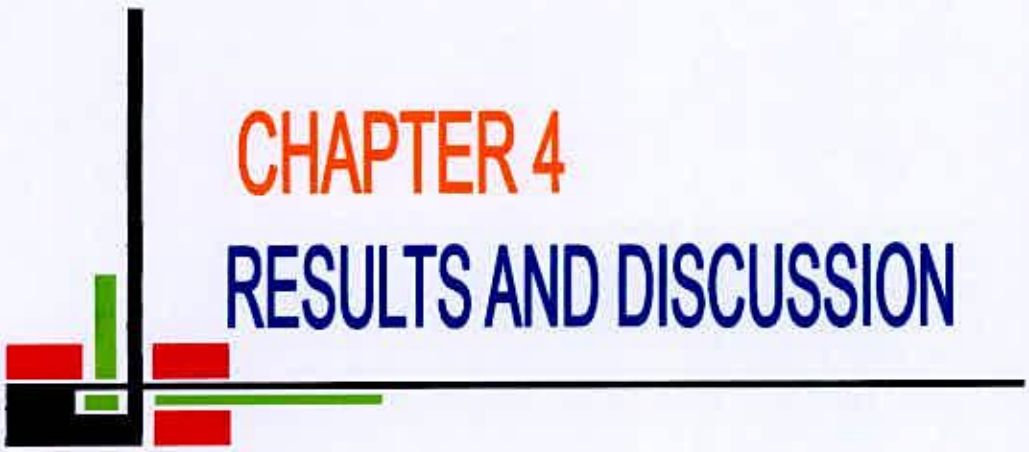
Where,

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

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 4
RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

The present study was conducted with a view to determine the compatibility after grafting among four potato (Plate 1) and three tomato (Plate 2) genotypes and also to study the variability, correlation and path co-efficient for yield and different yield contributing characters of pomato plant. Twenty one days old seedling of tomato and potato were grafted and within 3 to 4 days branching started. Different steps of grafting are illustrated in plate 4. The fruits were harvested in different times and the potatoes were harvested almost at the end of the plant's life cycle. The last stage of pomato plant is shown in Plate 5.The data were recorded from pomato plants on different characters such as plant height (cm), branches per plant, days to 50% flowering, cluster per plant, yield per plant (kg) etc. The data were statistically analyzed and thus obtained results are described below under the following heads:

4.1 Mean Performance

The mean value of all genotypes for each character are shown in Table 3. Performance of the genotypes is described below for each character.

4.1.1 Days to first flowering

Days to first flowering was found the highest in G6 (P2T3) (58.00) which was statistically similar with G3 (P1T3) (56.33), G4 (P2T1) (55.00) and G7 (P3T1) (54.00) (Table 3). Whereas the highest mean data was observed for control tomato in T1R3 (58.00) and the lowest in T2R1 (44.00) (Appendix IV). Lowest days to first flowering was found in G1 (P1T1) (48.67) and G2 (P1T2) (48.00) that is statistically similar with G5 (P2T2) (51.33), G8 (P3T2) (53.00), G9 (P3T3) (53.00), G10 (P4T1) (51.33), G11 (P4T2) (51.67) and G12 (P4T3) (51.00) (Table 3).

4.1.2 Days of 50% flowering

Days of 50% flowering was found the highest in G6 (P2T3) (62.67) which was statistically similar with G3 (P1T3) (61.33), G4 (P2T1) (61.33) and G7 (P3T1) (60.00), G8 (P3T2) (58.67), G9 (P3T3) (58.00), G10 (P4T1) (58.67) and G11

Table 3. Mean performance of various growth parameter and yield components in pomato

Sl No.	Genotypes	DFF	D50%F	PH	BPP	CPP	FPC	FPP	TPP	FL	FD	FYP	TuYP	TYP
1	G1	48.67d	54.00cd	76.15b	6.63de	12.67a	11.11a	202.33a	24.00c-e	2.40d	2.06b	1.47b	1.03ab	2.5b
2	G2	48.00d	53.33d	62.33b-d	5.30e	10.00b	4.33b	91.00b	24.67c-e	3.90bc	4.90a	0.83cd	0.70d	1.53c
3	G3	56.33ab	61.33ab	59.51cd	6.30de	8.67b-d	3.78b	70.00bc	26.33b-e	4.00a-c	4.87a	0.70cd	0.90a-d	1.60c
4	G4	55.00a-c	61.33ab	66.33b-d	9.00a-c	9.33bc	12.25a	186.67a	31.33b-d	2.43d	1.97b	1.93a	1.00a-c	2.93a
5	G5	51.33b-d	56.33b-d	53.04d	9.15ab	8.34b-d	3.67b	77.67bc	32.67bc	4.63a	5.17a	0.97c	0.83b-d	1.80c
6	G6	58.00a	62.67a	57.33d	8.48bc	10.67ab	3.66b	45.33c	35.33b	4.22ab	4.77a	0.77cd	1.00a-c	1.77c
7	G7	54.00a-c	60.00ab	90.86a	9.33ab	10.67ab	12.93a	190.00a	21.67e	2.52d	2.07b	1.93a	0.833b-d	2.77ab
8	G8	53.00b-d	58.67a-c	64.92b-d	10.33a	8.33b-d	3.33b	69.55bc	21.67e	4.50ab	4.79a	0.933cd	0.87a-d	1.80c
9	G9	53.00b-d	58.00a-d	52.85d	6.33de	8.37b-d	4.11b	38.00c	22.67de	3.43c	5.03a	0.63d	1.00a-c	1.63c
10	G10	51.33b-d	58.67a-c	74.51bc	7.33cd	7.30c-e	12.00a	207.00a	46.67a	2.33d	1.97b	1.7ab	1.10a	2.80ab
11	G11	51.67b-d	58.67a-c	52.85d	8.00b-d	6.44de	3.57b	52.67bc	48.67a	4.53ab	4.73a	0.93cd	0.77cd	1.70c
12	G12	51.00cd	57.33b-d	61.61b-d	9.00a-c	5.78e	3.67b	43.33c	46.67a	4.00a-c	4.97a	0.73cd	0.90a-d	1.63c

DFF = Days to first flowering, D50%F = Days to 50% flowering, PH = Plant height (cm), BPP = Branches per plant, CPP = Clusters per plant, FPC = Fruits per cluster, FPP = Fruits per plant, TPP = Tuber per plant, FL = Fruit length (cm), FD = Fruit diameter (cm), FYP = Fruit yield per plant (Kg), TuYP = Tuber yield per plant (Kg), TYP = Total yield per plant (Kg).

G1=P_1T_1, G2=P_1T_2, G3=P_1T_3, G4=P_2T_1, G5=P_2T_2, G6=P_2T_3, G7=P_3T_1, G8=P_3T_2, G9=P_3T_3, G10=P_4T_1, G11=P_4T_2, G12=P_4T_3

(P4T2) (58.67) (Table 3).The lowest days to first flowering was found in G2 (P1T2) (53.33) that are statistically similar with G1 (P1T1) (54.00), G5 (P2T2) (56.33) and G12 (P4T3) (57.33) (Table 3). Whereas the highest mean data was observed for control tomato in T1R3 (62.00) and the lowest in T2R1 (49.00) (Appendix IV).

4.1.3 Plant height (cm)

Plant height was found the highest in G7 (P3T1) (90.86). Whereas the highest mean data was observed for control tomato in T1R1 (103.63) and the lowest in T2R2 (56.00) (Appendix IV).The lowest plant height was found in G5 (P2T2) (53.04), G6 (P2T3) (57.33), G9 (P3T3) (52.85) and G11 (P4T2) (52.85) which was statistically similar with G1 (P1T1) (76.15), G2 (P1T2) (62.33), G3 (P1T3) (59.51), G4 (P2T1) (66.33), G8 (P3T2) (64.92), G10 (P4T1) (74.51) and G12 (P4T3) (61.61) (Table 3).

4.1.4 Branches per plant

Branches per plant were found the highest in G8 (P3T2) (10.33) which were statistically similar with G4 (P2T1) (9.00), G5 (P2T2) (9.15), G6 (P2T3) (8.48), G7 (P3T1) (9.33), G10 (P4T1) (7.33), G11 (P4T2) (8.00) and G12 (P4T3) (9.00) (Table 3). The lowest plant height was found in G9 (P3T3) (6.33) and which was statistically similar with G1 (P1T1) (6.63), G2 (P1T2) (5.30), G3 (P1T3) (6.30) (Table 3). Whereas the highest mean data was observed for control tomato in T1R3 (17.00) and the lowest in T2R2 (4.00) (Appendix IV).

4.1.5 Clusters per plant

Clusters per plant were found the highest in G1 (P1T1) (12.67), which were statistically similar with G2 (P1T2) (10.00), G3 (P1T3) (8.67), G4 (P2T1) (9.33), G5 (P2T2) (8.34), G6 (P2T3) (10.67), G7 (P3T1) (10.67), G8 (P3T2) (8.33), G9 (P3T3) (8.37) (Table 3).The lowest clusters per plant was found in G12 (P4T3) (5.78) which was statistically similar with G10 (P4T1) (7.30), G11 (P4T2) (6.44) (Table 3). Whereas the highest mean data was observed for control tomato in T1R2 (15.00) and the lowest in T3R2 (5.00) (Appendix IV).

Plate 5. Pomato plant

4.1.6 Fruits per cluster

Fruits per cluster were found the highest in G1 (P1T1) (11.11), G4 (P2T1) (12.25), G7 (P3T1) (12.93), and G10 (P4T1) (12.00) (Table 3).The lowest clusters per plant was found in G2 (P1T2) (4.33), G3 (P1T3) (3.78), G5 (P2T2) (3.67), G6 (P2T3) (3.67), G8 (P3T2) (3.33), G9 (P3T3) (4.11), G11 (P4T2) (3.57) and G12 (P4T3) (3.67) (Table 3). Whereas the highest mean data was observed for control tomato in T1R3 (17.00) and the lowest in T3R3 (3.67) (Appendix IV).

4.1.7 Fruits per plant

Fruits per plant were found the highest in G1 (P1T1) (202.33), G4 (P2T1) (186.67), G7 (P3T1) (190.00), and G10 (P4T1) (207.00) (Table 3).The lowest fruits per plant was found in G6 (P2T3) (45.33), G9 (P3T3) (38.00) and G12 (P4T3) (43.67) (Table 3). That are statistically similar with G2 (P1T2) (91.00), G3 (P1T3) (70.00), G5 (P2T2) (77.67), G8 (P3T2) (69.55) and G11 (P4T2) (52.57). Whereas the highest mean data was observed for control tomato in T1R2 (200.00) and the lowest in T3R3 (46.00) (Appendix IV).

4.1.8 Tuber per plant

Tuber per plant were found the highest in G10 (P4T1) (46.67), G11 (P4T2) (48.67) and G12 (P4T3) (46.67).The lowest tuber per plant was found in G7 (P3T1) (21.67) and G8 (P3T2) (21.67) (Table 3). That are statistically similar with G1 (P1T1) (24.00), G2 (P1T2) (24.67), G3 (P1T3) (26.33), G4 (P2T1) (31.33) G5 (P2T2) (32.67), G6 (P2T3) (35.33), and G9 (P3T3) (22.67) (Table 3). Whereas the highest mean data was observed for control potato in P2R1 and P2R3 (43.00) and the lowest in P4R2 (25.00) (Appendix V).

4.1.9 Fruit length (cm)

Fruit length were found the highest in G5 (P2T2) (4.63) and statistically similar with G3 (P1T3) (4.00), G6 (P2T3) (4.22), G8 (P3T2) (4.50), G11 (P4T2) (4.53) and G12 (P4T3) (4.00) (Table 3). The lowest fruit length was found in G1

(P1T1) (2.40), G4 (P2T1) (2.43), G7 (P3T1) (2.52) and G10 (P4T1) (2.33) (Table 3). That are statistically similar with G2 (P1T2) (3.90), and G9 (P3T3) (3.43). Whereas the highest mean data was observed for control tomato in T3R2 (4.2) and the lowest in T1R2 (2.00) (Appendix IV).

4.1.10 Fruit diameter (cm)

Fruit diameter were found the highest in G2 (P1T2) (4.90), G3 (P1T3) (4.87), G5 (P2T2) (5.17), G6 (P2T3) (4.77), G8 (P3T2) (4.79), G9 (P3T3) (5.03), G11 (P4T2) (4.73) and G12 (P4T3) (4.97) (Table 3).The lowest fruit diameter was found in G1 (P1T1) (2.06), G4 (P2T1) (1.97), G7 (P3T1) (2.07) and G10 (P4T1) (1.97) (Table 3). Whereas the highest mean data was observed for control tomato in T3R2 (5.00) and the lowest in T1R2 (1.3) (Appendix IV).

4.1.11 Fruit yield per plant (kg)

Fruit yield per plant were found the highest in G4 (P2T1) (1.93) and G7 (P3T1) (1.93) and statistically similar with G10 (P4T1) (1.70) and G1 (P1T1) (1.47). The lowest fruit yield per plant was found in G9 (P3T3) (0.63) (Table 3). That are statistically similar with G2 (P1T2) (0.83), G3 (P1T3) (0.70), G5 (P2T2) (0.97), G6 (P2T3) (0.77), G8 (P3T2) (0.93), G11 (P4T2) (0.93) and G12 (P4T3) (0.73) (Table 3). The highest mean data was observed for control tomato in T1R2 (2.00) and the lowest in T3R2 (0.6) (Appendix IV) and yield performance presented in Fig 1.

4.1.12 Tuber yield per plant (kg)

Tuber yield per plant were found the highest in G10 (P4T1) (1.10) and statistically similar with G1 (P1T1) (1.03), G3 (P1T3) (0.90), G4 (P2T1) (1.00), G6 (P2T3) (1.00), G8 (P3T2) (0.87), G9 (P3T3) (1.00) and G12 (P4T3) (0.90) (Table 3).The lowest fruit yield per plant was found in G2 (P1T2) (0.70). That are statistically similar with G5 (P2T2) (0.83), G7 (P3T1) (0.83) and G11 (P4T2) (0.77) (Table 3).Whereas the highest mean data was observed for control potato in P1R3 (1.00), P4R2 (1.00) and P4R1 (1.00) and the lowest in P2R2 (0.5) (Appendix V) and yield performance presented in Fig 2.

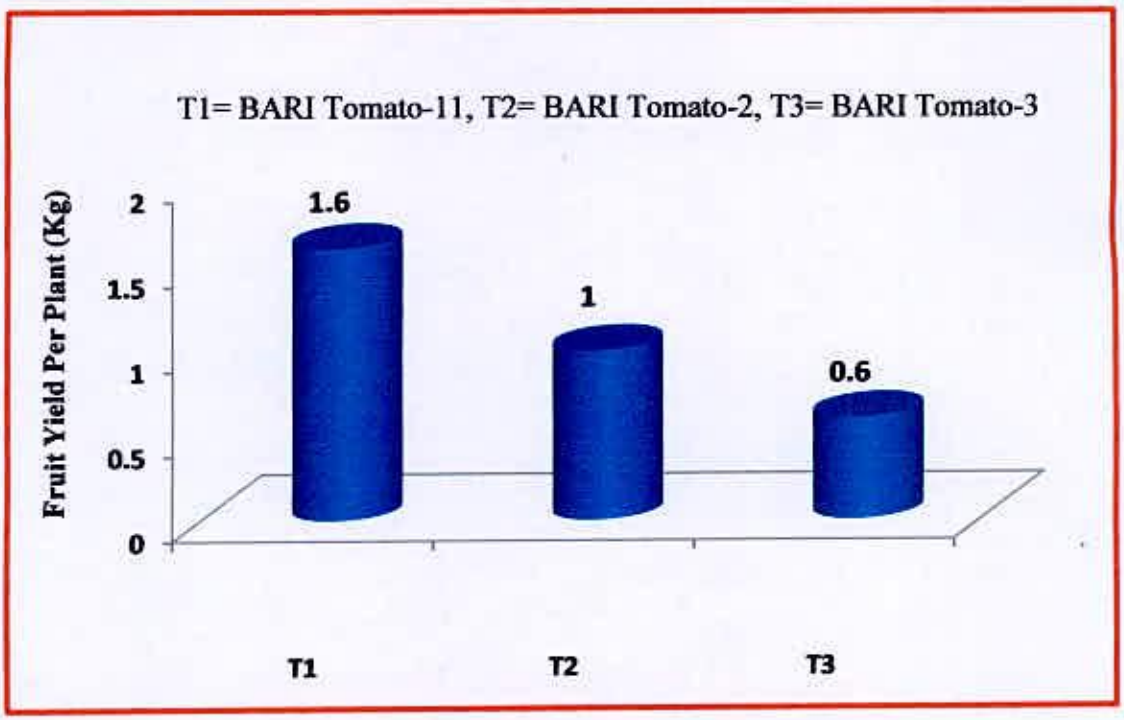


Fig 1. Fruit yield performance in control tomato

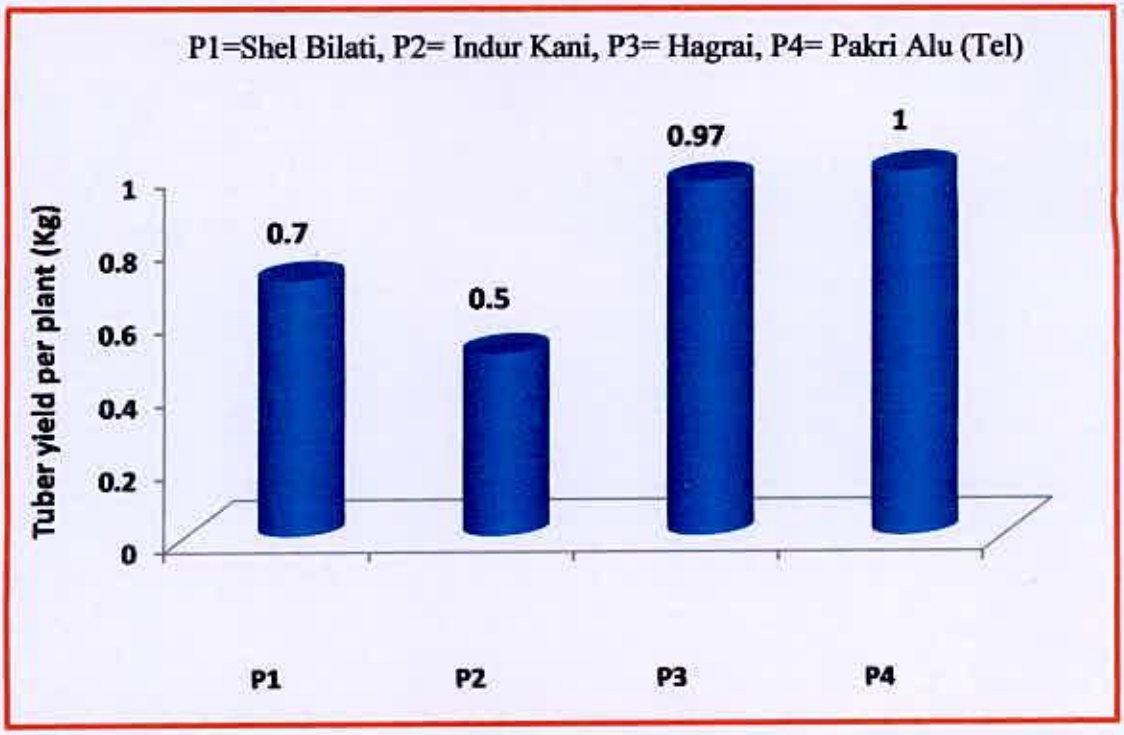


Fig 2. Tuber yield performance in control potato

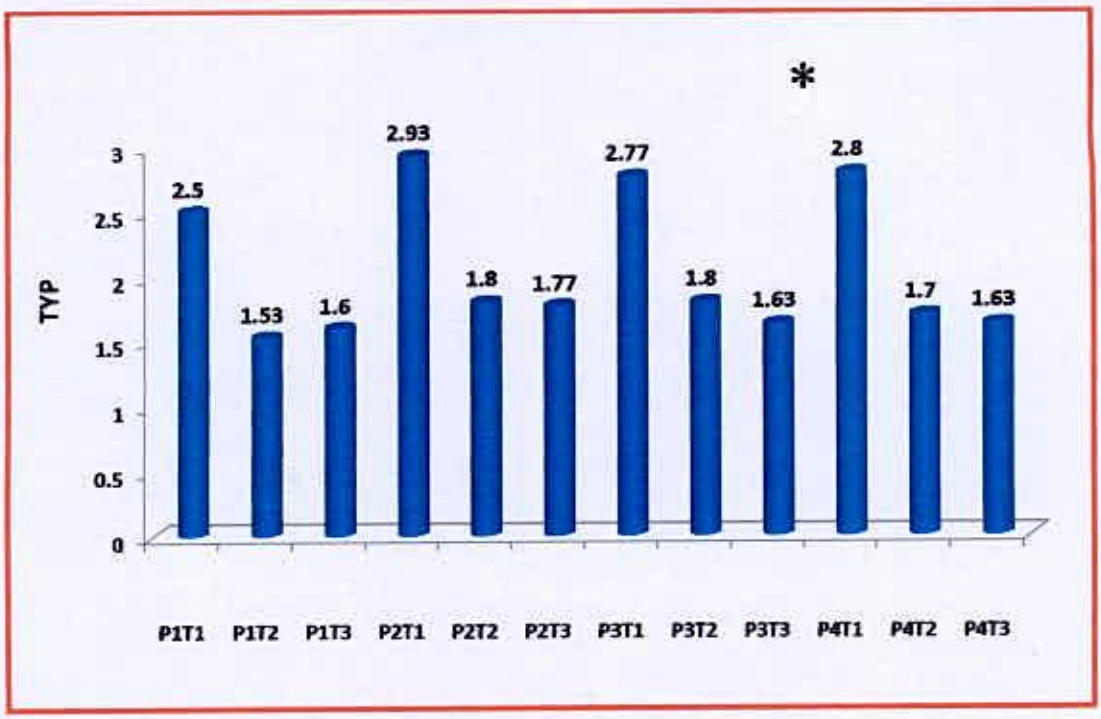


Fig 3. Total yield (fruit & tuber) performance in pomato

* P1T1= Shel Bilati+BARI Tomato-11, P1T2=Shel Bilati+BARI Tomato-2, P1T3=Shel Bilati+BARITomato-3
P2T1= Indur Kani+BARI Tomato-11, P2T2= Indur Kani +BARI Tomato-2, P2T3= Indur Kani +BARITomato-3
P3T1=Hagrai+BARI Tomato-11, P3T2= Hagrai +BARI Tomato-2, P3T3= Hagrai +BARITomato-3
P4T1=Pakri Alu (Tel)+BARI Tomato-11, P4T2= Pakri Alu (Tel) +BARI Tomato-2, P4T3= Pakri Alu (Tel)+ BARITomato-3

4.1.13 Total yield per plant (kg)

Total yield per plant were found the highest in G4 (P2T1) (2.93) and statistically similar with G1 (P1T1) (2.50), G7 (P3T1) (2.77) and G10 (P4T1) (2.80) (Table 3).The lowest total yield per plant was found in G2 (P1T2) (1.53), G3 (P1T3) (1.60), G5 (P2T2) (1.80), G6 (P2T3) (1.77), G8 (P3T2) (1.80), G9 (P3T3) (1.63), G11 (P4T2) (1.70) and G12 (P4T3) (1.63) (Table 3) and yield performance of both tomato and potato are presented in Fig 3.

4.2 Genetic variability, heritability and genetic advance

The extent of variation among the genotypes in respect of twelve characters was studied and mean sum of square, phenotypic variance (σ^2p), genotypic variance (σ^2g), phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (h^2b), genetic advance (GA), genetic advance in percent of mean and coefficient of variation (CV) presented in Table 4 and Fig. 4 and 5. The mean value of all genotypes for each character is shown in Appendix IV and V. Performance of the genotypes is described below for each character.

4.2.1 Days to first flowering

The genotypic variance and phenotypic variance for this trait were 6.28 and 13.20, respectively (Table 4). The phenotypic variance appeared to be high than the genotypic variance suggested considerable influence of environment on the expression of genes controlling this trait. The difference between the genotypic co-efficient of variation (GCV) (4.76) and phenotypic co-efficient of variation (PCV) (6.90) were more, indicated the variability not only for genotype but also influence of environment. Therefore, such selection sometimes is misleading (Table 4). The heritability estimates for days to first flowering was moderate with low genetic advance and genetic advance in percentage of mean. Thus indicating this trait was mostly controlled by non-additive gene.

Table 4. Estimation of genetic parameters in thirteen characters of pomato

Parameters	σ^2 p	σ^2g	σ^2 e	PCV	GCV	ECV	Heritability	Genetic advance (5%)	Genetic advance (% mean)
DFF	13.20	6.28	6.92	6.90	4.76	5.00	47.55	3.56	6.76
D50%F	12.55	5.83	6.72	6.07	4.14	4.44	46.47	3.39	5.81
PH	171.48	108.70	62.78	20.35	16.20	12.31	63.39	17.10	26.57
BPP	2.92	2.09	0.83	21.53	18.22	11.47	71.60	2.52	31.77
CPP	4.83	3.20	1.63	24.74	20.13	14.38	66.22	3.00	33.75
FPC	19.39	15.72	3.66	67.39	60.69	29.30	81.10	7.36	112.66
FPP	5013.06	4553.31	459.74	66.71	63.58	20.20	90.83	132.48	124.83
TPP	122.53	98.32	24.21	34.74	31.12	15.44	80.24	18.30	57.43
FL	0.92	0.79	0.14	26.85	24.80	10.29	85.31	1.69	47.12
FD	2.21	1.95	0.25	37.70	35.47	12.77	88.52	2.71	68.74
FYP	0.26	0.23	0.03	45.03*	42.67	14.38	89.80	0.94	83.19
TuYP	0.03	0.01	0.02	17.67	9.85	14.67	31.09	0.10	10.99
TYP	0.32	0.28	0.04	27.80	25.78	10.39	86.02	1.00	49.07

**, * Correlation is significant at the 0.01 and 0.05 level, respectively.
DFF = Days to first flowering, D50%F = Days to 50% flowering, PH = Plant height (cm), BPP = Branches per plant, CPP = Clusters per plant, FPC = Fruits per cluster, FPP = Fruits per plant, TPP = Tuber per plant, FL = Fruit length (cm), FD = Fruit diameter (cm), FYP = Fruit yield per plant (Kg), TuYP = Tuber yield per plant (Kg), TYP = Total yield per plant (Kg), MS = Mean sum of square, CV (%) = Coefficient of variation and SE = Standard error, σ^2 p = Phenotypic variance, σ^2g = Genotypic variance, σ^2 e = Environmental variance, PCV = Phenotypic Coefficient of Variation, GCV= Genotypic Coefficient of Variation and ECV= Environmental Coefficient of Variation.

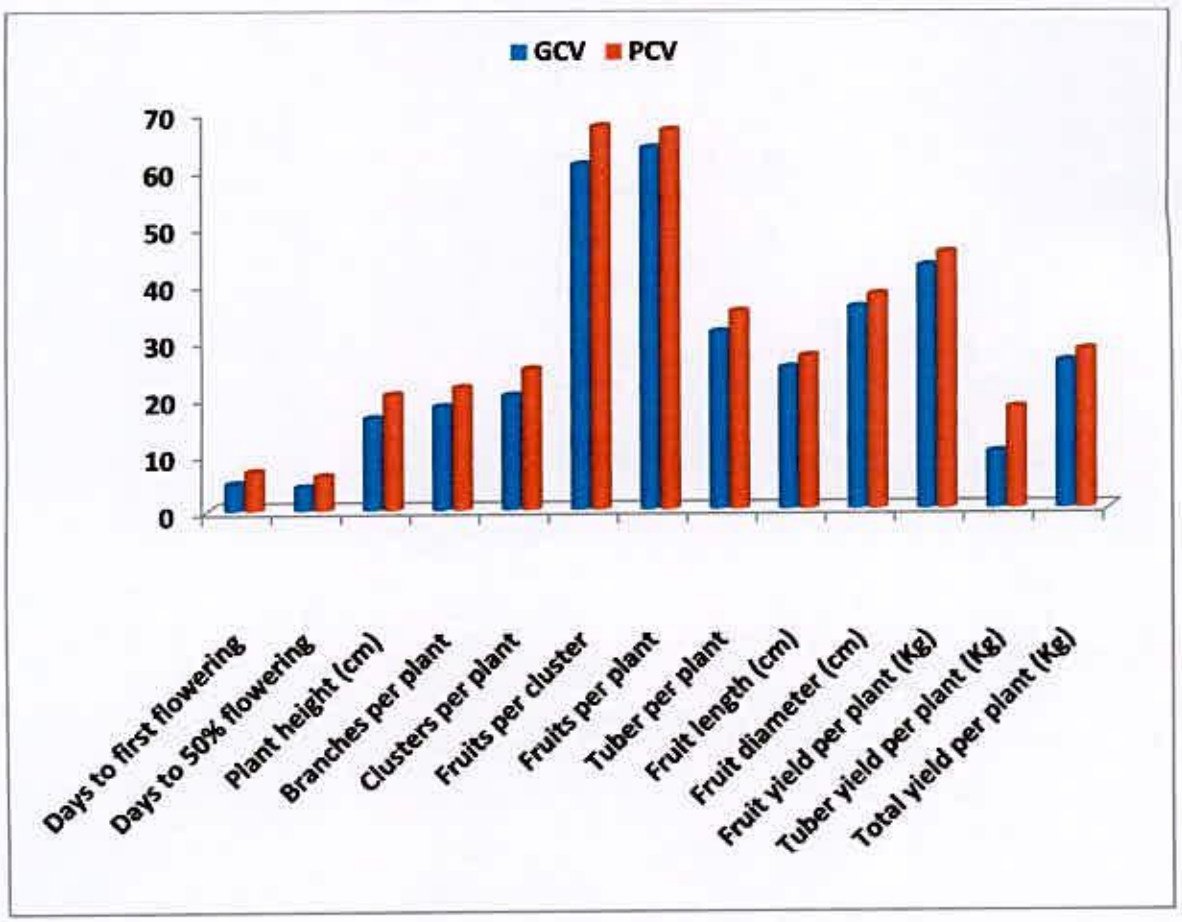


Fig 4. Genotypic and phenotypic variability in pomato

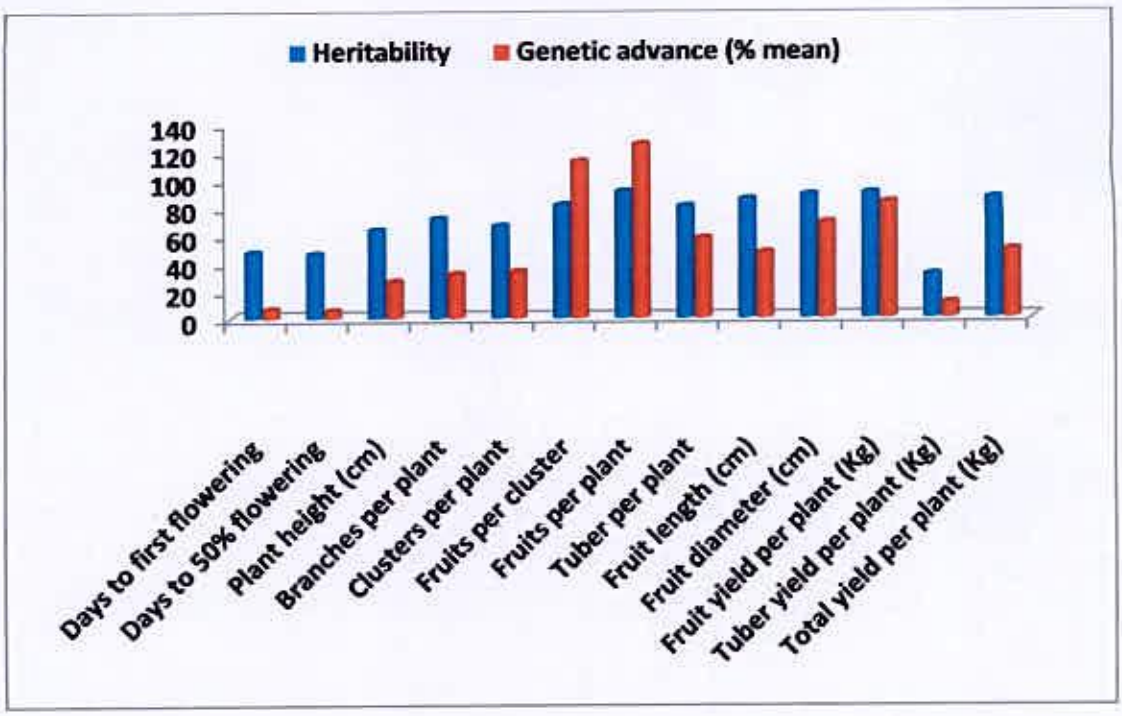


Fig 5. Heritability and genetic advance over mean in pomato

4.2.2 Days to 50% flowering

From the current study we observed that the difference between genotypic variance and phenotypic variance for this trait were 5.83 and 12.55, respectively (Table 4). The phenotypic variance appeared to be high than the genotypic variance suggested considerable influence of environment on the expression of genes controlling this trait. The difference between the genotypic co-efficient of variation (GCV) (4.14) and phenotypic co-efficient of variation (PCV) (6.07) were more, indicated the variability not only for genotype but also influence of environment. Therefore, such selection sometimes is misleading (Table 4). The heritability estimates for days to first flowering was moderate with low genetic advance and genetic advance in percentage of mean. Thus indicating this trait was mostly controlled by non-additive gene.

4.2.3 Plant height (cm)

The genotypic variance and phenotypic variance for this trait were 108.70 and 171.48, respectively (Table 4). The phenotypic variance appeared to be high than the genotypic variance suggested considerable influence of environment on the expression of genes controlling this trait. The difference between the genotypic co-efficient of variation (GCV) (16.20) and phenotypic co-efficient of variation (PCV) (20.35) were more, indicated the variability not only for genotype but also influence of environment. Therefore, such selection sometimes is misleading (Table 4). The heritability estimates for days to first flowering was high with low genetic advance and genetic advance in percentage of mean. Thus indicating this trait was mostly controlled by non-additive gene.

4.2.4 Branches per plant

Number of branches per plant in pomato showed phenotypic variance was higher than the genotypic variance. The genotypic co-efficient of variation and phenotypic co-efficient of variation were 18.22 and 21.53, respectively indicating that the phenotypic expression of this trait are highly governed by

the environment (Table 4). The heritability estimates for this trait was high, genetic advance was low and genetic advance in per cent of mean were found moderate, revealed that this trait was governed by non-additive gene.

4.2.5 Clusters per plant

The genotypic variance and phenotypic variance for clusters per plant were 3.20 and 4.83, respectively (Table 4). The phenotypic variance appeared higher than the genotypic variance which suggested influence of environment on the expression of the genes controlling this character. The genotypic co-efficient of variation was low than phenotypic co-efficient of variation which was not desirable for the improvement of this crop. The heritability estimates for this trait was high with low genetic advance and moderate genetic advance in per cent of mean indicated that this trait was controlled by non -additive gene and selection for this character would take long time.

4.2.6 Fruits per cluster

Significant genotypic variance and phenotypic variance were observed among the genotypes for number of fruits per cluster 15.72 and 19.39, respectively (Table 4). Phenotypic and genotypic coefficients of variation were high but the phenotypic variance appeared higher than the genotypic variance. The genotypic coefficient of variation and phenotypic coefficient of variation for were 60.69 and 67.39, respectively, which indicated presence of high variability among the genotypes. The heritability estimates for this trait was very high (81.10), genetic advance was low and genetic advance in per cent of mean was found high, revealed that this character was governed by additive gene and selection for this character would be effective.

4.2.7 Fruits per plant

From the current study we observed that the difference between genotypic and phenotypic variances indicate high environmental influence (Table 4). The phenotypic coefficient of variation was (66.71) and genotypic coefficient of variation was (63.58), which indicated presence of low variability among the

genotypes. The heritability estimates for this trait was high, genetic advance and genetic advance in per cent of mean were found moderate, revealed that this character was governed by additive gene and selection for this character would be effective.

4.2.8 Tuber per plant

Significant genotypic variance and phenotypic variance were observed among the genotypes for tuber per plant in pomato (Table 4). Phenotypic and genotypic coefficients of variation were high but the phenotypic variance appeared higher than the genotypic variance. The genotypic coefficient of variation and phenotypic coefficient of variation for were 31.12 and 34.74, respectively, which indicated presence of high variability among the genotypes. The heritability estimates for this trait was very high (80.24), genetic advance was low and genetic advance in per cent of mean was found high, revealed that this character was governed by additive gene and selection for this character would be effective.

4.2.9 Fruit Length (cm)

The phenotypic and genotypic variance were very low and genotypic co-efficient of variation (24.80) and phenotypic co-efficient variation (26.85) were close to each other, indicating minor environmental influence on this character that would be effective for the improvement of this crop (Table 4). High heritability estimate with moderate genetic advance over percent of mean indicate that effective selection may be made for fruit length.

4.2.10 Fruit Diameter (cm)

The phenotypic and genotypic variance were very low and genotypic co-efficient of variation (35.47) and phenotypic co-efficient variation were close to each other, indicating minor environmental influence on this character that would be effective for the improvement of tomato (Table 4). High heritability estimate with moderate genetic advance over percent of mean indicate that effective selection may be made for fruit diameter.

4.2.11 Fruit yield per plant (kg)

The phenotypic variance found higher than genotypic variance, suggested considerable influence of environment on the expression of the genes controlling this character (Table 4). The phenotypic coefficient of variation and genotype coefficient of variation were 45.03 and 42.67, respectively for fruit yield per plant, which indicating that significant variation exists among different genotypes which made the trait effective for selection. Estimation of high heritability for fruit yield per plant with high genetic advance revealed that this character was governed by additive gene and provides opportunity for selecting high valued genotypes for breeding programme.

4.2.12 Tuber yield per plant (kg)

The phenotypic variance found higher than genotypic variance, suggested considerable influence of environment on the expression of the genes controlling this character (Table 4). The phenotypic coefficient of variation and genotype coefficient of variation were 9.85 and 17.67, respectively for fruit yield per plant, which indicating that significant variation exists among different genotypes which made the trait effective for selection. Estimation of high heritability for fruit yield per plant with high genetic advance revealed that this character was governed by additive gene and provides opportunity for selecting high valued genotypes for breeding programme.

4.2.13 Total yield per plant (kg)

The phenotypic variance found higher than genotypic variance, suggested considerable influence of environment on the expression of the genes controlling this character (Table 4). The phenotypic coefficient of variation and genotype coefficient of variation were 25.78 and 27.80, respectively for fruit yield per plant, which indicating that significant variation exists among different genotypes which made the trait effective for selection. Estimation of high heritability for fruit yield per plant with high genetic advance revealed that

this character was governed by additive gene and provides opportunity for selecting high valued genotypes for breeding programme.

4.3 Correlation Co-efficient

Yield is a complex product being influenced by several quantitative traits. Some of these traits are highly associated with yield. The analysis of the relationship among those traits and their association with yield is very much essential to establish selection criteria. Higher genotypic correlations than phenotypic ones might be due to modifying or masking effect of environment in the expression of these characters under study as explained by Nandpuri *et al.* (1973). Johnson *et al.* (1955) also reported that higher genotypic correlation than phenotypic correlation indicated an inherent association between various characters. Panse (1957) suggested that effective selection may be done for the characters having high heritability accompanied by high genetic advance which is due to the additive gene effect. He also reported that low heritability accompanied with genetic advance is due to non-additive gene effects for the particular character and would offer less scope for selection because of the influence of environment. Breeders always look for genetic variation among traits to select desirable type. Correlation co-efficient between pairs of trait are shown in Table 5 and 6.

4.3.1 Days to first flowering

Days to first flowering had highly significant positive correlation with days to 50% flowering (0.973 and 0.941) at both level (Table 5 and 6) and branches per plant (0.381) at genotypic level. This character also showed positive but non-significant association with fruit length and fruit diameter at genotypic and phenotypic levels (0.149, 0.041 and 0.109, 0.005 respectively). It had non-significant negative correlation with plant height, fruits per cluster, fruit per

Table 5. Genotypic correlation coefficients among different pairs of yield and yield contributing characters for different genotype of pomato

	DFPF	PH	BPP	CPP	FPC	FPP	FL	FD	FYP
DFF	0.973**	-0.042	0.381*	-0.018	-0.072	-0.237	0.149	0.109	-0.049
DFPF		0.088	0.492**	-0.266	0.065	-0.094	0.027	-0.061	0.139
PH			0.169	0.543**	0.920**	0.866**	-0.853**	-0.918**	0.880**
BPP				-0.191	0.064	0.013	0.182	-0.089	0.284
CPP					0.444**	0.478**	-0.481**	-0.446**	0.346*
FPC						0.988**	-0.978**	-0.987**	0.999**
FPP							-0.936**	-0.975**	0.953**
FL								0.972**	-0.863**
FD									-0.982**

** = Significant at 1%.
* = Significant at 5%.

DFF = Days to first flowering, D50%F = Days to 50% flowering, PH = Plant height (cm), BPP = Branches per plant, CPP = Clusters per plant, FPC = Fruits per cluster, FPP = Fruits per plant, TPP = Tuber per plant, FL = Fruit length (cm), FD = Fruit diameter (cm), FYP = Fruit yield per plant (Kg), TuYP = Tuber yield per plant (Kg), TYP = Total yield per plant (Kg).

Table 6. Phenotypic correlation coefficients among different pairs of yield and yield contributing characters for different genotype of pomato

	DFPF	PH	BPP	CPP	FPC	FPP	FL	FD	FYP
DFF	0.941**	-0.177	0.277	0.085	-0.067	-0.160	0.041	0.005	-0.002
DFPF		-0.136	0.311	0.024	0.050	-0.080	-0.029	-0.092	0.103
PH			0.132	0.351*	0.708**	0.758**	-0.612**	-0.671**	0.669**
BPP				-0.263	0.047	-0.023	0.152	-0.047	0.229
CPP					0.373*	0.430**	-0.329	-0.378*	0.307
FPC						0.868**	-0.803**	-0.911**	0.846**
FPP							-0.803**	-0.903**	0.897**
FL								0.848**	-0.743**
FD									-0.892**

** = Significant at 1%.
* = Significant at 5%.

DFF = Days to first flowering, D50%F = Days to 50% flowering, PH = Plant height (cm), BPP = Branches per plant, CPP = Clusters per plant, FPC = Fruits per cluster, FPP = Fruits per plant, TPP = Tuber per plant, FL = Fruit length (cm), FD = Fruit diameter (cm), FYP = Fruit yield per plant (Kg), TuYP = Tuber yield per plant (Kg), TYP = Total yield per plant (Kg).

plant and fruit yield per plant at both level. It showed no correlation for tuber per plant, tuber yield per plant and total yield per plant at both levels.

4.3.2 Days to 50% flowering

Days to 50% flowering showed highly significant positive association with branch per plant (0.492) at genotypic levels (Table 5 and 6). It showed non-significant positive association with plant height, fruit per cluster, fruit length at genotypic and phenotypic level and with branch per plant at genotypic level. Days to 50% flowering exhibited negative relationship with cluster per plant fruit per cluster and fruit diameter at genotypic and phenotypic level. It showed no correlation for tuber per plant, tuber yield per plant and total yield per plant at both levels.

4.3.3 Plant height (cm)

Plant height had highly significant negative correlation with fruit length and fruit diameter at genotypic and phenotypic levels (Table 5 and 6). Plant height had significant positive correlation with cluster per plant, fruit per cluster fruit per plant and fruit yield per plant at both levels. Plant height had non-significant negative relation with days to first flowering at both levels. It showed no correlation for tuber per plant, tuber yield per plant and total yield per plant at both levels.

4.3.4 Branches per plant

The number of branches per plant had non-significant positive correlation with fruits per cluster, fruit length and fruit yield per plant at genotypic and phenotypic levels, respectively and fruits per plant (0.013) in genotypic level (Table 5). It had non-significant negative correlation with clusters per plant and fruit diameter at both levels and fruits per plant in phenotypic level. Branches per plant showed no correlation for tuber per plant, tuber yield per plant and total yield per plant at both levels.

4.3.5 Clusters per plant

The number of clusters per plant had highly significant and positive association with plant height, fruits per cluster (0.444 and 0.373) and fruits per plant (0.478 and 0.430) at the genotypic and phenotypic levels (Table 5 and 6). It also had highly significant negative association with fruit diameter at both level and with fruit length at genotypic level. It had non-significant and negative association with days to first flowering, days to 50% flowering at genotypic level and with branches per plant at both at genotypic and phenotypic levels. It showed no correlation for tuber per plant, tuber yield per plant and total yield per plant at both levels.

4.3.6 Fruits per cluster

The number of fruits per cluster showed highly significant and positive association with plant height, fruits per plant (0.988, 0.868), fruit yield per plant both at genotypic and phenotypic levels (Table 5 and 6). It had highly significant but negative association with fruit length (-0.978 and -0.806) and fruit diameter (-0.987 and -0.911) at both levels It also exhibited non-significant negative association with days to first flowering at the genotypic and phenotypic level, respectively. It showed no correlation for tuber per plant, tuber yield per plant and total yield per plant at both levels.

4.3.7 Fruits per plant

Fruits per plant had highly significant but negative association with fruit length and fruit diameter at genotypic and phenotypic levels (Table 5 and 6). It had significant positive correlation with fruits per cluster, cluster per plant, plant height and fruit yield per plant at both level. It had negative non-significant effect on days to first flowering and days to 50% flowering at genotypic and phenotypic

level, respectively. It showed no correlation for tuber per plant, tuber yield per plant and total yield per plant at both levels.

4.3.8 Fruit length (cm)

Fruit length showed highly significant positive effect on fruit diameter (0.972, 0.848) at both level. It showed highly significant negative effect on plant height (-0.853, -0.612), cluster per plant (-0.481, -0.0.329), fruits per cluster (-0.978, -0.803), fruits per plant and fruit yield per plant at both level (Table 5 and 6).

4.3.9 Fruit diameter (cm)

Fruit diameter showed highly significant positive relation with fruit length at genotypic and phenotypic level (Table 5 and 6). On other hand, fruit diameter was highly negatively associated with plant height, cluster per plant, fruits per cluster and fruit yield per plant at both levels. It was insignificantly positively correlated with days to first flowering.

4.3.10 Fruit yield per plant (kg)

In general, fruit yield is the main target of improvement. Thereby its correlation study is utmost important. From Table 5 and 6 it was observed that, fruit yield per plant was strongly and positively correlated with plant height, cluster per plant, fruits per cluster and fruits per plant at both genotypic and phenotypic level. This study also revealed positive but insignificant correlation between fruit yield per plant and days to 50% flowering and branches per plant at genotypic and phenotypic level. Again, fruit yield per plant showed strong negative association with fruit length and fruit diameter at both genotypic and phenotypic level.

4.4 Path coefficient analysis

The direct and indirect effects of yield contributing characters on yield were worked out by using path analysis. Here yield per plant was considered as effect

Table 7. Path coefficient analysis showing direct and indirect effects of different characters on yield of pomato

	Direct effect	DFF	DFPF	PH	BPP	CPP	FPC	FPP	FL	FD	Correlation with yield
DFF	-0.097	-	0.154	0.004	0.094	0.000	0.024	-0.131	-0.027	-0.069	-0.049
DFPF	0.158	-0.094	-	-0.008	0.122	0.002	-0.022	-0.052	-0.005	0.039	0.139
PH	-0.088	0.004	0.014	-	0.042	-0.003	-0.306	0.479	0.156	0.582	0.880**
BPP	0.248	-0.037	0.078	-0.015	-	0.001	-0.021	0.007	-0.033	0.056	0.284
CPP	-0.006	0.002	-0.042	-0.048	-0.047	-	-0.148	0.264	0.088	0.283	0.346*
FPC	-0.333	0.007	0.010	-0.081	0.016	-0.003	-	0.565	0.188	0.656	.999**
FPP	0.553	0.023	-0.015	-0.076	0.003	-0.003	-0.340	-	0.171	0.636	0.953**
FL	-0.183	-0.014	0.004	0.075	0.045	0.003	0.342	-0.518	-	-0.616	-0.863**
FD	-0.634	-0.011	-0.010	0.081	-0.022	0.003	0.344	-0.555	-0.178	-	-0.982**

Residual effect: **0.016**

* = Significant at 5%. ** = Significant at 1%.

DFF = Days to first flowering, D50%F = Days to 50% flowering, PH = Plant height (cm), BPP = Branches per plant, CPP = Clusters per plant, FPC = Fruits per cluster, FPP = Fruits per plant, FL = Fruit length (cm), FD = Fruit diameter (cm).

(dependent variable) and days of first flowering, days 50% flowering, plant height (cm), branches per plant, clusters per plant, fruits per cluster, fruits per plant, fruit length (cm) and fruit diameter (cm) were treated as independent variables. Path coefficient analysis was showed direct and indirect effects of different characters on yield of pomato in Table 7.

4.4.1 Days to first flowering

From Table 7 days to first flowering had negative direct effect on yield per plant (-0.097) which is contributed to result non-significant negative genotypic correlation with yield per plant (-0.049). It had positive indirect effect on days to 50% flowering (0.154), plant height (0.004), number of branches per plant (0.094), cluster per plant and number of fruits per cluster (0.024).). Negative indirect effect was found via fruit length (-0.131), fruit diameter (-0.069).

4.4.2 Days to 50% flowering

Days to 50% flowering had positive direct effect (0.158) on yield per plant. Days to 50% flowering had positive indirect effect on number of branches per plant (0.122), number of cluster per plant (0.002) and fruit diameter (0.039). But it had negative indirect effect on, days to first flowering (-0.094), plant height (-0.008), fruits per cluster (-0.022), fruits per plant (-0.052) and fruit length (-0.005) (Table 7).

4.4.3 Plant height (cm)

Plant height had negative direct effect on yield per plant (Table 6). It had positive indirect effect through days to first flowering (0.004), days to 50% flowering (0.014), branches per plant (0.042), fruits per plant (0.479), fruit diameter (0.582) and fruit length (0.156) (Table 7). On the other hand, plant height showed negative indirect effect on yield per plant via cluster per plant, number of fruits per cluster (-0.306), which resulted significant positive genotypic correlation with yield per plant (0.880).

4.4.4 Branches per plant

Number of branches per plant had positive direct effect on yield per plant (0.248) and it had also positive correlation with yield per plant (0.284). This trait had positive indirect effect on days to 50% flowering (0.078), number of clusters per plant (0.001) and fruit diameter (0.056) (Table 7). On the other hand negative indirect effect was found on days to first flowering (-0.037), plant height (-0.015), number of number of fruits per cluster (-0.021).

4.4.5 Number of clusters per plant

Number of clusters per plant had negative direct effect (-0.006) on yield per plant and significant positive correlation with yield per plant (0.346). It had positive indirect effect on days to first flowering (0.002), number of fruits per plant (0.264), and fruit diameter (0.283) This trait showed negative indirect effect on days to 50% flowering (-0.042), plant height (-0.048), number of branches per plant (-0.047) and number of fruits per clusters (-0.148) (Table 7).

4.4.6 Fruits per cluster

Number of fruits per cluster showed negative direct effect (-0.333) on yield per plant at genotypic level. It also showed positive indirect effects through days to first flowering (0.007), days to 50% flowering (0.010), number of fruits per plant (0.565) fruit length, fruit diameter (0.656). It had negative indirect effect on plant height (-0.081), number of cluster per plant (-0.003), (Table 7). It had also significant positive correlation with yield per plant (0.999).

4.4.7 Fruits per plant

Number of fruits per plant showed positive direct effect (0.553) on yield per plant. It had also significant positive correlation with yield per plant (0.953) (Table 7). Number of fruits per plant had positive indirect effects on days to first flowering (0.023), number of branches per plant (0.003), fruit length and fruit diameter. It had negative indirect effect on days to 50% flowering (-0.015), plant height (-0.076), number of clusters per plant (-0.003), number of fruits per cluster (-0.346).

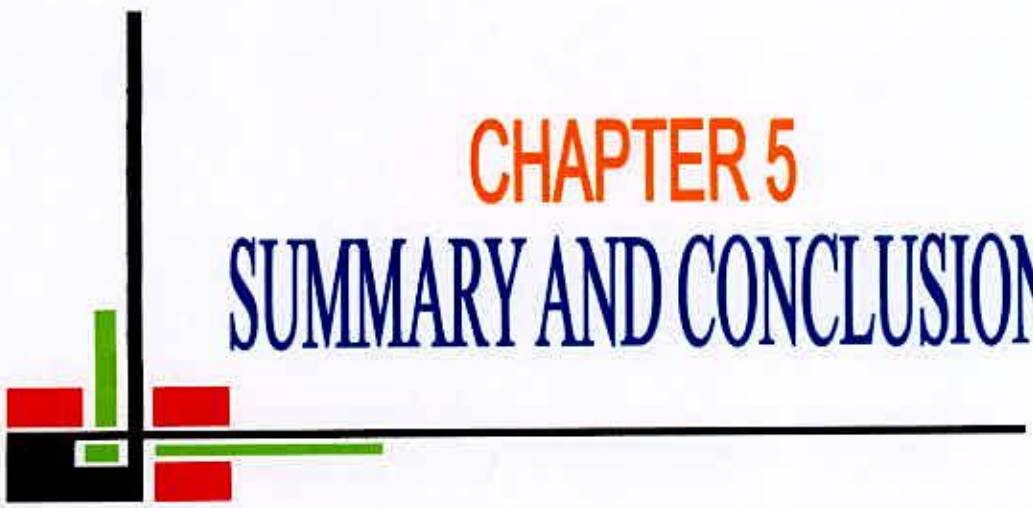
4.4.8 Fruit length (cm)

Fruit length had negative direct effect (-0.183) on yield per plant. It had also significant negative correlation with yield per plant (-0.863). This trait had also indirect positive effect on plant height (0.075), number of branches per plant (0.045) and number of fruits per cluster (0.342). Fruit length showed indirect negative effect on days to first flowering (-0.014), fruits per plant and fruit diameter (Table 7).

4.4.9 Fruit diameter (cm)

Fruit diameter showed highly negative direct effect (-0.634) on yield per plant. It had also highly significant negative correlation with yield per plant (-0.982). It had positive indirect effect on plant height (0.081) and number of fruits per cluster (0.344). Fruit diameter had negative indirect effects on days to first flowering (-0.011), days to 50% flowering (-0.010), number of branches per plant (-0.022), fruits per plant (-0.555) and fruit length (-0.178) (Table 7).

The genotypic residual effect was 0.016, which indicated that there were other responsible traits for contribution to yield per plant but not taken into consideration in the present study.



CHAPTER 5
SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

The present study was undertaken at the Sher-e-Bangla Agricultural University Farm, Dhaka-1207, Bangladesh with three genotypes of tomato *(Solanum lycopersicum* L.) and four genotypes of potato (*Solanum tuberosum* L.) during November 2013 to April 2014. Seeds were sown in seed bed then transferred to the main field in Randomized Complete Block Design (RCBD) with three replications. Data on various yield attributing characters such as, days to first flowering, days to 50% flowering, plant height (cm), number of branches per plant, number of clusters per plant, number of fruits per cluster, number of fruits per plant, fruit length (cm), fruit diameter (cm) and yield per plant (kg) were recorded. Analysis of variance revealed significant differences among all the genotypes for all the characters under study.

The phenotypic variance and phenotype coefficient of variation were higher than the corresponding genotypic variance and genotypic coefficient variation for all the characters under study. In case of plant height, number of cluster per plant, number of fruits per cluster, number of fruits per plant, tuber per plant and fruit yield per plant tuber yield per plant showed higher influence of environment for the expression of these characters. On the other hand, branch per plant, fruit per cluster, fruit length and fruit diameter showed least difference in phenotypic and genotypic variance suggesting additive gene action for the expression of the characters. All the characters under study exhibit the highest value of heritability.

Correlation coefficients among the characters were studied to define the association between yield and yield components. In general, most of the characters showed the genotypic correlation co-efficient were higher than the corresponding phenotypic correlation co-efficient suggesting a strong inherent association between the characters under study and suppressive effect of the environment modified the phenotypic expression of these characters by

reducing phenotypic correlation values. In few cases, phenotypic correlation co-efficient were higher than their corresponding genotypic correlation co-efficient suggesting that both environmental and genotypic correlation in these cases act in the same direction and finally maximize their expression at phenotypic level. The significant positive correlation with seed yield per plant was found in fruits per cluster and fruits per plant. In addition, there were non-significant positive correlation with fruit yield per plant was also found in days to 50% flowering at genotypic and phenotypic level, respectively. On the other hand, the non-significant negative correlation was also found in days to first flowering while the highest significant negative correlation was found in fruit length and fruit diameter at genotypic and phenotypic level, respectively.

Path coefficient analysis showed that average fruit weight had the highest positive correlation with fruit yield per plant. Coherently, this trait contributes to the yield through high direct effect (0.553) indicating selection will be judicious and more effective for these characters in future breeding program. Fruit length and fruit diameter had negative indirect effect on fruit yield and finally make significant negative correlation with fruit yield though it had some positive indirect effect. Number of fruit per cluster and cluster per plant had a high positive correlation to fruit yield per plant though their direct effect was negative. Fruits per plant had positive direct effect on yield and it had a high positive correlation to fruit yield per plant. It had positive indirect effect on days to 50% flowering and branches per plant. From the findings of the present study, the following conclusions could be drawn:

i. Selection procedure would be applied for desired characters such as lowest days to first flowering and increase number of clusters per plant, number of fruits per cluster, number of fruits per plant, tuber per plant, and fruit diameter to develop high yielding varieties.

ii. Wide range of genetic diversity existed among the tomato and potato genotypes. That variability could be used for future breeding programme of tomato in Bangladesh.

iii. Relatively higher value and lower differences between genotypic co-efficient of variation and phenotypic coefficient of variation of different yield contributing characters like number of fruits per plant, tuber per plant, fruit yield per plant and tuber yield per plant were observed which indicates high potentiality to select these traits in future which were less affected by environmental influence.

iv. The highest mean total yield per plant was found in P2T1, P4T1, P3T1 and in P1T1, respectively. It mean T1 (BARI Tomato-11) showed the best compatibility with all the local potato varieties except P4 (Pakri Alu (Tel).)

v. BARI Tomato-11 could be recommended to the pomato growers with local potato varieties.

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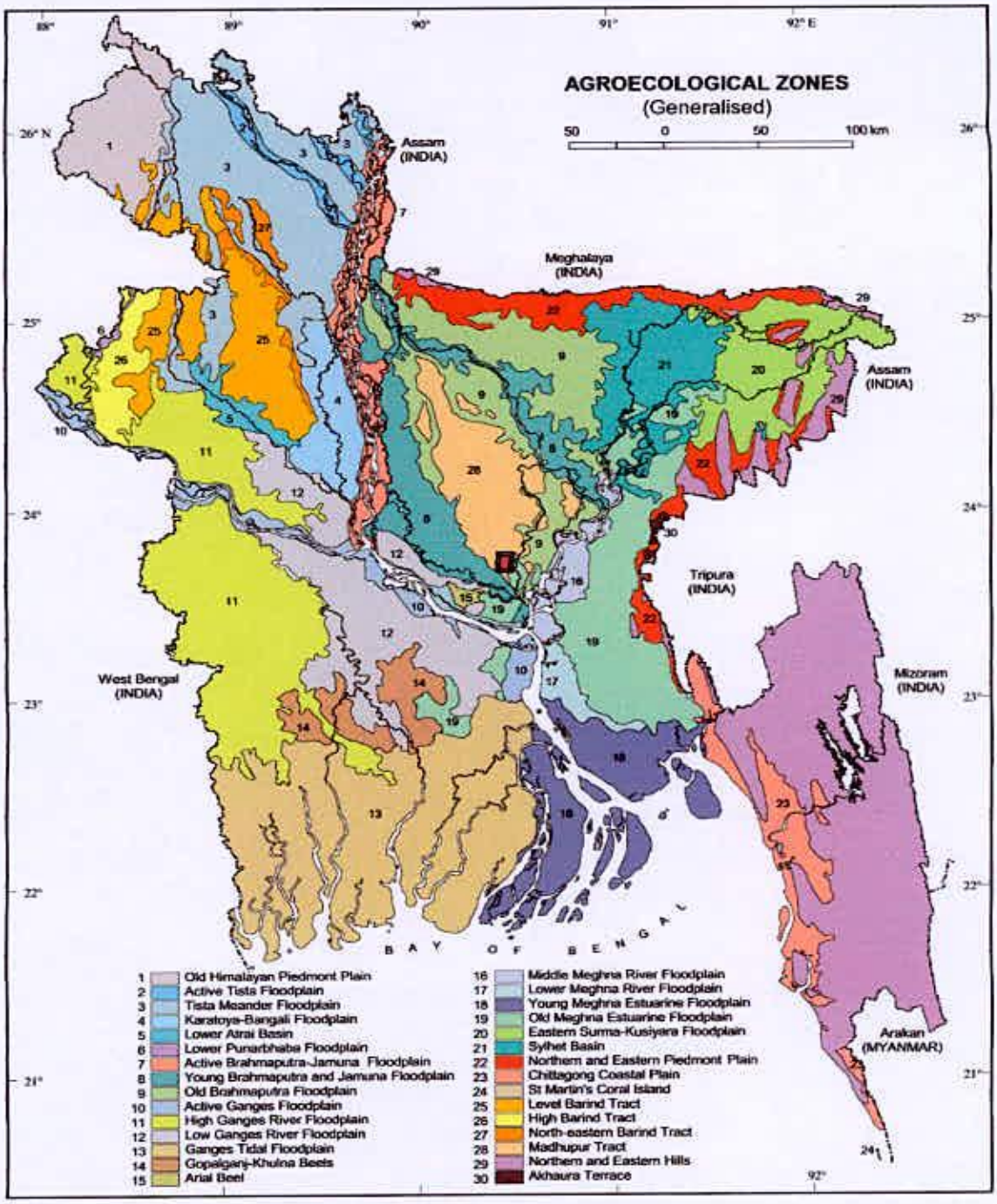
Appendix I. Map showing the experimental site under the study



The experimental site under study

Appendix II. Monthly average temperature, relative humidity, total rainfall and sunshine of the experimental site during the period of December, 2013 to April, 2014

Month	Air temperature (°C)		Relative humidity (%)	Rainfall (mm) (total)	Sunshine (h)
	Maximum	Minimum			
November, 2012	34.8	18.0	77	227	5.8
December, 2012	32.3	16.3	69	0	7.9
January, 2013	29.0	13.0	79	0	3.9
February, 2013	28.1	11.1	72	1	5.7
March, 2013	33.9	12.2	55	1	8.7
April, 2013	34.6	16.5	67	45	7.3

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

Appendix III. Physical characteristics and chemical composition of soil of the experimental plot

Soil characteristics	**Analytical results**
Agrological Zone	Madhupur Tract
P^H	6.00 – 6.63
Organic matter	0.84
Total N (%)	0.46
Available phosphorous	21 ppm
Exchangeable K	0.41 meq / 100 g soil

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

Appendix IV. Mean performance of various growth parameter and yield components for control tomato

Sl No.	Genotypes	DFF	D50%F	PH	BPP	CPP	FPC	FPP	FL	FD	FYP
1	R1T1	46	51	103.66	10	9	11.66	180	2.4	1.8	1.6
2	R2T1	50	55	56.44	11	15	15	200	2	1.3	2
3	R3 T1	58	62	89.33	17	12	17	120	2.1	1.7	1.7
4	R1T2	44	49	84	5.76	8	4	67	3.4	4.5	1
5	R2T2	46	50	56	4	8	6	74	3	4.5	1.3
6	R3T2	51	57	78	7	7	6	54	3.5	4	0.9
7	R1T3	51	57	75	8	8	4.33	74	4.1	4	0.6
8	R2T3	46	50	89	9	5	5.67	86	4.2	4.9	0.9
9	R3T3	56	62	85.4	13	13	3.67	46	4	5	1.1

DFF = Days to first flowering, D50%F = Days to 50% flowering, PH = Plant height (cm), BPP = Branches per plant, CPP = Clusters per plant, FPC = Fruits per cluster, FPP = Fruits per plant, TPP = Tuber per plant, FL = Fruit length (cm), FD = Fruit diameter (cm), FYP = Fruit yield per plant (Kg), TuYP = Tuber yield per plant (Kg), TYP = Total yield per plant (Kg).

R1= Replication 1, R2= Replication 2, R3= Replication 3, T1= BARI Tomato-11, T2= BARI Tomato-2, T3=BARI Tomato-3

Appendix V. Mean performance of various growth parameter and yield components for control potato

Sl No.	Genotypes	PH	BPP	LPP	SPP	TPP	TuYP
1	R1P1	98	10	166	6.3	34	0.7
2	R2P1	57	6	197	8	40	0.9
3	R3P1	78	17	179	12	42	1
4	R1P2	67	16	312	6	43	0.7
5	R2P2	66.33	22.66	269	3.7	34.4	0.5
6	R3P2	89	18	250	9	43	0.9
7	R1P3	76	17	298	7.67	32	0.67
8	R2P3	80	20	234	5.43	29	0.57
9	R3P3	99.67	24.33	251	4	27	0.97
10	R1P4	53.33	12.67	88.3	2.3	28.33	1
11	R2P4	67	9	100.67	3.44	25	1
12	R3P4	89.34	16	150.76	8.67	30.54	0.97

PH = Plant height (cm), BPP = Branches per plant, LPP = Leaves per plant, SPP = Shoot per plant, TPP = Tuber per plant, FL = Fruit length (cm), FD = Fruit diameter (cm), FYP = Fruit yield per plant (Kg), TuYP = Tuber yield per plant (Kg), TYP = Total yield per plant (Kg).
R1=Replication 1, R2= Replication 2, R3= Replication 3, P1= Shel Bilati, P2= Indur Kani, P3= Hagrai, P4= Pakri Alu (Tel)

Appendix VI. Estimation of genetic parameters in thirteen characters in pomato

Parameters	Range	Mean	MS	CV (%)	SE
DFF	48-58	52.61	25.74**	5.00	2.14
D50%F	53.33-62.67	58.36	24.20**	4.44	2.11
PH	52.85-90.86	64.36	388.87**	12.31	6.47
BPP	5.3-10.33	7.93	7.09**	11.47	0.74
CPP	5.78-12.67	8.88	11.21**	14.38	1.04
FPC	3.33-12.93	6.53	50.83**	29.30	1.56
FPP	38-207	106.13	14,119.67**	20.20	17.50
TPP	21.67-48.67	31.86	319.17**	15.44	4.01
FL	2.33-4.63	3.58	2.49**	10.29	0.30
FD	1.97-5.17	3.94	6.11**	12.77	0.41
FYP	0.63-1.93	1.13	0.72**	14.38	0.13
TuYP	0.70-1.10	0.91	0.04*	14.67	0.10
TYP	1.53-2.93	2.038	0.87**	10.39	0.17

**, * Correlation is significant at the 0.01 and 0.05 level, respectively.

DFF = Days to first flowering, D50%F = Days to 50% flowering, PH = Plant height (cm), BPP = Branches per plant, CPP = Clusters per plant, FPC = Fruits per cluster, FPP = Fruits per plant, TPP = Tuber per plant, FL = Fruit length (cm), FD = Fruit diameter (cm), FYP = Fruit yield per plant (Kg), TuYP = Tuber yield per plant (Kg), TYP = Total yield per plant (Kg), MS = Mean sum of square, CV (%) = Coefficient of variation, SE= Standard Error.

AppendixVII. ANOVA Table

Source	Df	MS										
		DFF	D50%F	PH	BPP	CPP	FPC	FPP	TPP	FL	FD	YPP
REP	2	40.52	36.11	97.70	0.16	0.45	7.48	298.41	28.36	0.05	0.06	244.53
G	11	25.74**	24.20**	388.87**	7.09**	11.21**	50.83**	14,119.67**	319.17**	2.49**	6.11**	63.19**
Error	22	6.92	6.71	62.78	0.82	1.63	3.66	459.74	24.20	0.13	0.25	2.74