CELL COMPATIBILITY ANALYSIS OF POMATO

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CELL COMPATIBILITY ANALYSIS OF POMATO

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CERTIFICATE

This is to certify that thesis entitled, "CELL COMPATIBILITY ANALYSIS OF POMATO" 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 JAHANARA PERVIN, Registration No. 08-03064 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, 2015
Place: Dhaka, Bangladesh

(Prof. Dr. Naheed Zeba)
Supervisor


Dedicated to
My
Beloved parents

Some commonly used abbreviations

Full word	Abbreviations	Full word	Abbreviations
Agro-ecological Zone	AEZ	Journal	*J.*
Agricultural	*Agril.*	Kilogram	kg
Agriculture	*Agric*.	Meter	m
And others	*et al.*	Mean sum of square	MSS
Annals	*Ann.*	Methods	Meth.
Applied	*App.*	Meter square	m^2
Application	*Appl.*	Millimeter	mm
Bangladesh Agricultural Research Council	BARC	Muriate of potash	MP
		Number	No.
		Percentage	%
Bangladesh Agricultural Research Institute	BARI	Phenotypic co-efficient of variation	PCV
		Phenotypic variance	δ^2_p
Bangladesh Bureau of Statistics	BBS	Physiology	*Physiol.*
		Plant Genetic Resource Centre	PGRC
Biology	*Biol.*		
Botany	*Bot.*	Proceeding	Proc.
Centimeter	cm.	Progressive	*Progr.*
Cooperative	*Coop.*	Randomized complete block design	RCBD
Days after transplanting	DAT		
		Review	*Rev.*
Edition	*Edn.*	Report	*Rpt.*
Environment	Environ.	Reporter	*Rep.*
Etcetera	etc.	Research / Resource	*Res.*
Evolution	*Ev.*	Sher-e-Bangla Agricultural University	SAU
Food and Agricultural Organization	FAO		
		Serial	*Sl.*
Genetic advance	GA	Science	*Sci.*
Genotypic co-efficient of variation	GCV	Society	*Soc.*
		Soil Resource Development Institute	SRDI
Genotypic variance	δ^2_g		
Gram	g	Standard error	SE
Hectare	ha.	Technology	*Technol.*
Heritability in broad sense	h^2_b	Triple super phosphate	TSP
		That is	i.e.
Horticulture	*Hort.*	Ton	T
International	*Intl*.	University	*Univ.*
Incorporation	*Inc*.	Vegetable	*veg.*

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CELL COMPATIBILITY ANALYSIS OF POMATO

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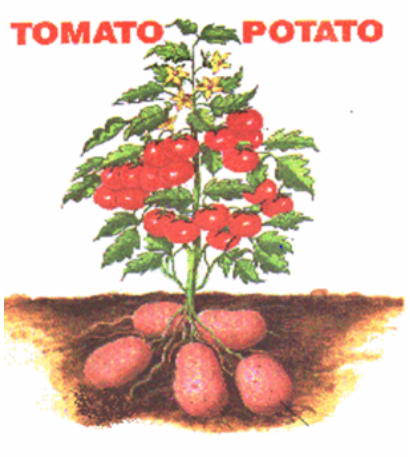
ABSTRACT

An experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh during November 2013 to April 2014 to identify the best cell compatibility of pomato plants which was produced by grafting between tomato and potato plants. The experiment consisted of three genotypes of tomato and four genotypes of potato. BARI Tomato-11, BARI Tomato-2 and BARI Tomato-3 were the tomato varieties and Pakri Alu (Tel), Asterix, Diamant and Cardinal was the potato varieties. The potato and tomato genotypes were grafted in all possible combinations. The experiment was laid out in RCBD with three replications to study the variability, character association and path analysis. Analysis of variance showed the presence of significant variation among the tested genotypes for all the characters studied. The phenotypic coefficients of variation were higher than genotypic coefficients of variation in all the characters studied. Phenotypic coefficients of variation were also close to genotypic coefficients of variation for most of the characters except branches per plant, clusters per plant and fruit yield per plant. The high heritability coupled with high genetic advance in percent of mean observed in plant height, branches per plant, clusters per plant, fruits per cluster, fruits per plant, tubers per plant, fruit length, fruit diameter, fruit yield per plant, tuber yield per plant and total yield per plant. The characters are plant height, branches per plant, clusters per plant, fruits per cluster, fruits per plant, fruit yield per plant and tuber yield per plant showed significant and positive correlation with fruit yield per plant at both genotypic and phenotypic levels. This results suggested that total yield per plant can be increased by improving these characters. The characters fruit yield per plant, days to 50% flowering, branches per plant, fruits per plant, tuber yield per plant, branches per vine, fruit length and fruit diameter showed positive direct effect on total yield per plant. According to the highest total yield per plant, the best combination was found in G4 (Asterix x BARI Tomato 11) followed by G7 (Diamant x BARI Tomato 11), G10 (Cardinal x BARI Tomato 11). BARI Tomato-11 showed the best compatibility with all exotic potato varieties than the local varieties and could be recommended as a scion for grafting to the pomato growers with all potato varieties.



CHAPTER 1
INTRODUCTION

CHAPTER I

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is a self pollinated annual crop and one of the most important solanaceous vegetable in the world in terms of production, harvested area and consumption per capita (FAOSTAT, 2005). Tomato species are diploid (2n=2x=24). It has wider adaptability, high yielding potential and suitability for variety of uses in fresh as well as processed food industries (Meena and Bahadur, 2015). In addition to tomatoes that are eaten directly as raw vegetable or added as ingredient to other food items, a variety of processed products have gained popularity. They contribute significantly to the dietary intake of vitamins A and C as well as essential minerals and nutrients. Tomato ranks the first among all fruits and vegetables as a source of vitamins and minerals (Rick and Chetelat, 1995). Other solanaceous crop, potato (*Solanaum tuberosum* L.) is a staple food next to rice and wheat grown almost all over the world. Not only a staple food, but also popular as vegetables as well as main item of preparing various food and confectionary. The yield potential and food value compared to rice and wheat, potato is considered as a promising food crop against world hunger including Bangladesh where food sortage is a chronic feature (Anonymous, 1997). Now a day, potato has emerged as a major food crop in Bangladesh and is being cultivated throughout the country.

The **“** Pomato” or “Tomtato” is a hybrid or chimera produced by grafting from a tomato plant and a potato plant, both of which are members of the solanaceae (nightshade) family (David, 2013). Tomatoes grow on the vine, while potatoes grow in the soil from the same plant. The grafted plants 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. The purpose is to combine one plant's qualities of flowering or fruiting with the roots

of another that offers increased overall plant vigour, and better quality fruit production. Most plants need to be grafted within the same genus like potatoes and tomatoes. The plants having different makeup are sometimes possible to graft. The idea of producing both potatoes and tomatoes on the same plant by grafting was originally developed in 1977 at the Max Planck Institute for Developmental Biology in Tübingen, Germany, the plant although healthy produced neither potatoes nor tomatoes (Reinhard, 2008). After some years in 2007, Nguyen ThiTrang Nha once wondered as she was working in her family's potato garden because she saw both potato and tomato in her grafted plant. In 2010, a prison farm has made a breakthrough in growing tomatoes and potatoes on the same stem through grafting, potentially helping save on input costs and maximizing use of small land parcels in densely populated areas.

In Bangladesh, pomato or tomtato production is a new technology. Recently Department of Genetics and Plant Breeding of Sher-e-Bangla Agricultural University, Bangladesh produced pomato by grafting BARI released tomato with local potato varieties in 2013(Nusrat, 2014). Later, Bangladesh Agricultural Development Corporation (BADC) also has launched a programme on pomato production in two trial areas Comilla and Pabna by taking one potato and three tomato varieties (Anonymous, 2013a).

Grafting unites the tissues of two or more plants so that they grow and function as a single plant. This gardening innovation lets gardeners grow vertically stacked plants in small space. Each Tomtato/Pomato is grafted by hand to ensure double cropping. Growing potatoes and tomatoes as one plant pomato offers huge benefits. Through them, small farmers can maximize use of their growing plots and thus lower the input costs. By producing pomato plant farmers can get both of tomato and potato plants. One single plant yield a fruit (tomato) and a vegetable (potato) at the same time (John, 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. Another benefit of producing a pomato plant through grafting is that this method of propagation can improve resistance to bacteria, viruses, fungi and certain pests. 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. Most fruit and vegetable plants of the same family, including potato and tomato plants of any variety, can be grafted to create one plant. Grafting is best done with two healthy plants having similar diameter of stems.

Compatibility responses are features common to plant morphogenesis. Compatibility is the adjustment or union between the cells of tissues of different plants and sufficiently closes genetic (taxonomic) relationship between stock and scion for a successful graft union (Nelson, 1968). Through this process, the tissues of two plants are combined so they can grow together and able to produce the unique plant. The determination of the best union among different tomato and potato varieties has been conducted in this study with the following objectives:

- To establish a mechanism for getting two crops tomato and potato at a time from a single pomato plant.
- To evaluate the yield potentiality and efficiency of pomato plants than a single potato or a single tomato plant.
- To identify the best cell compatibility of pomato plants.
- To know the magnitude of variability in pomato combinations for identifying the best combinations in order to use them in future pomato cultivation.
- To identify the nature of association of traits, direct and indirect relation between yield contributing characters through correlation coefficient analysis in pomato plants.

CHAPTER 2
REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

The “Pomato” or “Tomtato” plant exists and is produced by grafting a tomato plant and a potato plant. They yield both potatoes and tomatoes without affecting the quality of the crop. Pomato plant produces tomatoes on the top and potatoes underground. Tomatoes are members of the potato family and are therefore naturally compatible with potatoes. The Tomtato plant is specially grafted by hand for creating this unique double cropping feature. There is no genetic modification in pomato plants, it is a natural, and safe process. Tomato and potato both are well-studied crop species for cytological and genetic analysis. Various resources are accessible for tomato and potato research now, which can lead to uprising in evaluation of tomato and potato biology (Barone *et al*., 2008). Many studies have been done using different genes to examine genetic diversity in these crops (Asamizu and Ezura, 2009, Carelli *et al*., 2006, Martinez *et al*., 2006). The amount and nature of variation of tomato and potato plant characters helps the breeder for improving the selection efficiency. Morphological characters 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 selection (Weising *et al*., 1995). The presence of genetic variability in the breeding material of tomato and potato has been emphasized by previous researchers (Naz *et al*., 2013; Reddy *et al*., 2013). Literature available concerning to the present study has been presented below.

2.1 Potato

The potato is a starchy, tuberous crop from the perennial nightshade *Solanum tuberosum* L. The word "potato" may refer either to the plant itself or to the edible tuber (Anonymous, 2016a). In the Andes, where the species is indigenous, there are some other closely related cultivated potato species. Potatoes were introduced

outside the Andes region approximately four centuries ago, and have since become an integral part of much of the world's food supply. It is the world's fourth-largest food crop, following maize, wheat, and rice (FAO, 2009). Like many other important crops, potato is a polyploid. Potato actually has a number of ploidy levels, based on a haploid number of 12, ranging from diploid (2n=24) to hexaploid (6n=72), and including triploids, tetraploids, and pentaploids. Cultivated potato varieties are tetraploid (4n=48); many wild species are diploid but may range up to hexaploid. The tetraploid cultivated potatoes are not diploidized, so that there are four interchangeable genes at each locus (Anonymous, 2016b).

According to Bell (1948), the failure of early potato cultivar to produce seed was due to tuber formation, indicating that early growth of tubers utilizes materials necessary for floral and fruit development. He concluded that preventing the formation tubers promotes the formation of numerous flowers and berries. Growth and development of different plant parts are affected by total assimilate production and partitioning among sink organs. Shoot and tuber growth are considered competing processes. Since the conventional potato propagation rely on seed tubers. Less attention has been given to the effect of flowering and berry set on the growth of potato. Some researchers have studied the effects of flowering and berry formation on vegetative growth and tuber yield but the result are conflicting.

Ahmad (1980) studied that, stolon formation starts at the most basal nodes and progresses acropetally. Tuberization of potato plants is strongly influenced by day length. Induction to tuberize is promoted by short photoperiod (long dark period) and the signal is perceived in the leaves. Under inductive conditions both the young and old leaves are capable of producing the stimulus (Hammes and Beyers, 1973). Research expended through the 1960 to include fertilizer applications, seed degeneration, mulching, planting techniques and storage (Ahamad, 1995). In 1967-1968 the Bangladesh Agricultural Development Corporation (BADC)

launched a project for the multiplication and distribution of high quality seed potatoes (Ahamad, 1995). He investigated the pattern of stolon formation in three cultivars and found that about half of the stolon was formed at the most basal node, with roughly 10% of the remaining stolons at each of the next four higher nodes.

According to Cutter (1987), potato tubers are shortened and thickened modified stems that bear scale leaves (cataphylls) each with a bud in its axil. The usual site of tuber formation is a stolon tip. Stolons (rhizomes) are diagravitropic stem with long internodes and scale leaves. The potato plant is remarkable for its plasticity in organ development (Clowes and MacDonald, 1987). Potatoes have been grown in Bangladesh since at least the 19th century (Anonymous, 1997). By the 1920s, the first commercial production of the crop was established in the country. Agronomic research on potato dates late 1950s when limited variety trials were started by the Bangladesh Agricultural Research Institute (BARI).

Tuber formation can occur on almost every bud of the plant including axillary buds (Ewing, 1985) and inflorescence (Marinus, 1993). They develop as branch from underground nodes and are terminated by a curved apical portion called a hook. It has been reported that stolons formed first normally grow longer, are more likely to branch, and are preferential sites for tuber formation (Lovell and Booth, 1969). According to Gregory (1956), both air and soil temperature are important cool air temperatures favour induction to tuberize and high soil temperature black the expression of the tuberization stimulus on the underground nodes. There is an interaction between temperature and photoperiod. The higher the temperature the shorter the photoperiod require for a given genotype to tuberize. Generally cool temperatures promote tuberization (Booth, 1963), and the high temperature are inhibition for tuberization under both short and long photoperiod, albeit the degree of inhibition is greater under long days (Wheeler *et al*., 1985). The formation of stolon and tubers takes place preferably underground

although the tuberization stimulus may be present throughout the plant and affects morphological development (Ewing, 1997). The signal for induction to tuberization is omnipresent and can express itself in all buds. Potato tuberization is a complex process involving anatomical, enzymatic, biochemical and hormonal changes leading to the differentiation of the stolon into a vegetative storage organ the tuber (Fernie and Willmitzer, 2001).

2.2 Tomato

The tomato (*Solanum lycopersicum* L.) is an edible, often red berry-type fruit of the nightshade family commonly known as a tomato plant (Anonymous, 2014). The tomato is consumed in diverse ways, including raw, as an ingredient in many dishes, sauces, salads, and drinks. The English word tomato comes from the Spanish word, tomate, derived from the Nahuatl (Aztec language) word *tomatl*. It first appeared in print in 1595. The cultivated tomato originated in the Peru-Ecuador-Bolivia area of the South American (Vavilov, 1951).

According to "International Plant Name Index" and "Slow Food ® Upstate", in 1753, Linnaeus placed the tomato in the genus *Solanum* as *Solanum lycopersicum* and in 1768 Philip Miller moved it to its own genus, naming it *Lycopersicon esculentum*. This name came into wide use, but was in violating of the plant naming rules. Genetic evidence has now shown that Linnaeus was correct to put the tomato in the genus *Solanum*, making *Solanum lycopersicum* the correct name (Peralta *et al*., 2006). Both names, however, will probably be found in the literature for some time.

Tomato is a tropical plant and grown in almost every corner of the world from tropics to within a few degrees of the Arctic Circle. Mexico has been considered the most likely center of domestication of tomato. Italy and Spain are considered secondary centers of diversification (Smith, 1994). Major tomato producing countries are Spain, Brazil, Iran, Mexico, Greece, Russia, China, USA, India,

Turkey, Egypt and Italy. It is believed that the tomato was introduced in subcontinent during the British regime. It is adapted to a wide range of climates. In tomato (*Solanum lycopersicum* L.), one cultivated species and 12 wild relatives have been reported (Peralta *et al*., 2006).

2.3 Background of pomato plant

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.

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 (Reinhard, 2008). The Max Planck Institute for Plant Breeding Research in Köln produced a plant with fruit in 1994 (Reinhard, 2008). Nguyen Thi Trang Nha in 2007 decided to initiate the cross-breeding produced by the union of different varieties, when she was a sophomore at Nong Lam (Agriculture-Forestry) University, which is based in Thu Duc District, Ho Chi Minh City, Vietnam. She originally wanted to help vegetable growers in her hometown, Da Lat City in the Central Highlands, have bumper tomato and potato crops. According to Nha, tomato and potato seedlings should be cross-breeds when they are 20 days old, insisting there must be equilibrium when nursing the young cross breeds so that they yield the vegetables in balanced volumes. Growers can harvest 60 days after the cross-breeding, which is able to

turn up to 5 kilograms of tomatoes and 0.5 kilo of potatoes on each hybridized plant. She also added, a normal tomato plant chums out almost 7 kilos at the most, while 0.7 kilo is the best a potato stem can generate. Statistics have also shown that the new species yields higher profits but uses less land, time and labor while a higher content of vitamin C is found in the vegetables (Anonymous, 2012).

The Kiambu prison started the trial in 2010, guided by literature from China that showed the tuber and the fruit could actually be grown on the same plant. The prison did not involve the Kenya Agricultural Research Institute or the Kenya Plant Health Inspectorate services until when the experiment was successful.

Fruit or tuber formation needs 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. 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 (Lubbock online news, 2002).

According to Jude (2013), 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. According to Jabr (2013), grafting can improve resistance to bacteria, viruses and fungi attract a more diverse group of pollinators and provide a strong trunk. 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).

Hall (2013), observed that 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. Jabr (2013) suggested that 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*. 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.

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”. Guru (2013) suggested that the pomatoes should be ready to harvest after about 12 weeks during the summer months; the potatoes should be ready after the pomato leaves begin to die back, normally in early autumn. 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. According to Coxworth (2013), 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. 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).

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. According to Hansord (2015) 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. According to 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.

According to "The Orange County Register" (2015) 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. A farm in Kenya has grafted a plant that grows tomatoes and potatoes on the same stem in a bid to maximize 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).

Mail online news (2015), shows that 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. A number of innovations that allow for gardening in small spaces, including a ferris wheel-like contraption, a mat that shows where to plant specially-prepared seeds, and a system that grows vertically-stacked veggies in window. According to Fresh Fruit portal newsletter (2015) 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. This has significant impacts

on developing countries like 13 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.

2.4 Compatibility of cells

Compatibility is one of the four essential criteria for successful grafting. Compatibility is defined as a sufficiently close genetic (taxonomic) relationship between stock and scion for a successful graft union to form, assuming that all other factors (technique, temperature, etc.) are satisfactory. A comprehensive survey of the taxonomic limits of graft compatibility has been published by Nelson (1968). According to Heslop-Harrison (1975), tissue compatibility or incompatibility in plants can be regarded as a physiological tolerance or intolerance, respectively, between the protoplasts of different cells. Although substantial work has been done on reproductive tissue compatibility, such as pollen-stigma interactions little attention has been focused on the mechanisms of vegetative compatibility/incompatibility in plants. Prominent examples involving such vegetative compatibility responses include stem and root grafts, protoplast fusions, mycorrhizal associations, and the interactions of a parasitic vascular plant or of certain epiphytes with a host plant.

A more recent compilation is cited by Andrews and Marquez (1993). Quince (*Cydonia oblonga*) is sometimes used as a dwarfing rootstock for pear, but only certain pear (*Pyrus communis*) cultivars are dirctly compatible with quince. For example the pear cultivars Old Home, Anjou, Comice, Hardy, Gorham, Flemish Beauty and others are all compatible with quince, but the cultivars Bartlett, Bosc, Seckel, Winter Nelis, and others are not (Lombard and Westwood, 1987).

Kumer *et al*. (2013), found that compatibility of stock and scion for grafted plants to unite and grow successfully, the combined plant parts (stock and scion) should be compatible with each other. Closely related plants have a good chance of forming a union, while those remotely related have little or no chance. Plants in the grass family and other monocotyledonous plants cannot be grafted or budded, so they are outside the compatibility pyramid. Conifers and other flowering plants, as well as many herbaceous and woody plants, can be grafted. The highest success in grafting or budding is achieved by grafting plants within or between clones.

2.5 Grafting for crop improvement

According to Hottes (1925), grafting or graftage 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.

Cooper and Chapot (1977) suggested that grafting with detached scions has been practiced for thousands of years. It was in use by the Chinese before 2000 BC, then spread to the rest of Eurasia and was well established in ancient Greece (Garner, 1988). According to Oda (1995), tube grafting has been adopted as the primary method for vegetable grafting on the farm as it can be easily carried out with small healing chambers with typical success rates ranging from 85 to 90 percent. The use of this cultural technique is mainly carried out for intensive cropping systems like greenhouse and tunnel production. This method is especially popular for vegetable production in the orient, and the number of

vegetables in 1998 was estimated to be 540 million transplants in Korea and 750 million in Japan (Lee and Bang, 1998).

The first grafts in the early 20th century were made in order to diminish attacks by infectious organisms, such as *Fusarium oxysporum* on watermelons. Furthermore, many researchers are looking to utilize specific rootstocks as an alternative to methyl bromide-a soil fumigant that has been widely used until recently. Grafting has been highly effective at overcoming (Rivero and Ruiz, 2003) abiotic sources of stress, such as soil salinity, temperature extremes, and excessive soil moisture. Grafting has also been utilized to reduce the effects of flooding in areas where a wet season may occur (Black *et al.*, 2003).

Many of the most economically important vegetable crops like tomato, squash, cucumber, and watermelon are highly sensitive to thermal stress in the roots throughout vegetative development and reproduction. Whether using rootstock tolerant of hot or cold temperatures, the use of temperature tolerant rootstocks often leads to the extension of the growing season in either direction, resulting in better yield and economic stability through the year (Rivero and Ruiz, 2003). Although the vegetable grafting is typically associated with reduction of disease or abiotic stress, yield is often increased without the presence of these identified sources of stress.

Grafting can take place on a number of crops. However, because of the added expense, it is typically associated with melons, cucurbits, and members of the Solanaceae family such as eggplant and tomato. Tomato grafting became popular in the 1960s as a way to reduce certain diseases caused by soil borne plant pathogens such as *Ralostonia solanacearum.* Currently, however, grafting is used to offer not only protection from certain diseases, but also tolerance to abiotic stress like flooding, drought, and salinity (Rivero and Ruiz, 2003).

Core (2005) suggested that grafting is often done for non -woody and vegetable plants tomato, cucumber, eggplant and watermelon. 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.

Grafting of chile peppers (*Capsicum annuum* L.) is a recent practice where *C. annuum* scions are grafted onto *C. annuum* rootstocks that have soil borne disease and nematode resistance (Morra and Biloto, 2006). However, research has shown that this technique can be effective against a variety of fungal, bacterial, viral, and nematode diseases (King *et al*., 2008). 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 genuses. During the past years, the primary objective of horticulture has been to increase yield and productivity. Grafting of woody plants has been common for centuries, but herbaceous grafting has only become popular recently in agricultural systems. The cultivation of grafted vegetable plants began in Korea and Japan at the end of the 1920s when watermelon plants were grafted onto squash rootstock (Kubota *et al*., 2008). Grafting of vegetables is a common practice to control soilborne diseases and nematodes, for both field and greenhouse grown crops (King *et al*., 2008).

Youssef *et al*. (2010) found that 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. 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. Marios and Georgios (2015), suggested that 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).

There are a variety of methods for grafting vegetable crops. Cleft grafting occurs when a V-shape is cut into the rootstock and a complementing wedge-shaped scion is inserted. The graft is then held with a small clip until healing occurs (Oda, 1999). Nutrient uptake for the macronutrients, such as phosphorus and nitrogen, were enhanced by grafting (Ruiz and Romero, 1999). Research has shown that possible mechanisms for increased yield are likely due to increased water and nutrient uptake among vigorous rootstock genotypes. Conductance through the stoma was improved in tomato plants when grafted onto vigorous rootstock (Fernandez-Garcia, 2002).

Approach grafting involves notching opposing sides of the stems of the rootstock and scion, and then using a clip to hold the stems together while they fuse. Once the graft has healed, the original scion is then cut off of the desired rootstock and the unused rootstock is detached from the scion (Lee, 2003). Since this time, this technique has spread throughout Asia and Europe. Currently, 81% of Korean and 54% of Japanese vegetable cultivation uses grafting (Rivero and Ruiz, 2003). In addition, grafted vegetables can produce higher yields and have improved tolerance to environmental stresses, soil salinity, and low soil temperatures

(Edelstein, 2004). This technique has moved to the Mediterranean region as well, where the use of grafting has been proposed as a major component of an integrated management strategy for managing soil borne disease and increasing crop productivity.

Micrografting is a new technique that has been recently integrated into micropropagation production for hybrid tomato. This method uses micropropagated scion shoots that grafted onto 3 week-old rootstock seedlings (Grigoriadis *et al*., 2005). Grafted tomato transplant production has increased in Spain from less than one million plants in 1999-2000 to over 45 million plants in 2003-2004. Grafted tomato is also cultivated in France and Italy, and over 20 million tomato plants were grafted in Morocco in 2004 as a way to reduce soil born disease and increase crop production (Besri, 2005). In tomatoes, increases in fruit yield are typically the results of increased fruit size (Pogonyi *et al*., 2005). The most common commercial technique for grafting tomato is tube grafting. Tube grafting takes place when the scion and rootstock are severed as seedlings and reattached with a small, silicone tube or clip (Rivard and Louws, 2006). This technique has been highly effective as it can be carried out when plants are very small, thereby eliminating the need for large healing chambers while increasing the output. Grafting tomatoes with tolerant rootstocks has been highly effective at producing saline tolerant plants. Research indicates that several rootstocks prevent the translocation of sodium and chloride into the shoot (Leonardi and Giuffrida, 2006).

According to Kubota (2007), more than 40 million grafted tomato seedlings are estimated to be used annually in North American greenhouses. Tomato Grafting has been utilized worldwide in Asia and Europe for greenhouse and high tunnel production and is gaining popularity in the United States (Kubota *et al.*, 2008). Typically, stock or rootstock are selected for their ability to resist infection by

certain soil borne pathogens or their ability to increase vigor and fruit yield. The scion of the grafted tomato represents the upper portion of the plant and is selected for its fruit quality characteristics. There are several methods for grafting tomatoes and they have certain advantages and disadvantages. Once the grafts are made, the plants are moved into a chamber or environment with high relative humidity (>90%) and low light levels to reduce water stress in the scion while the graft union forms.

Lee (2003) suggested that 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).

Based on a report published in www.businessdailyafrica.com, grafted vegetables are created when the top part of one plant (the scion) is attached to the root system of a separate plant (the rootstock). The rootstock contributes vigor and disease resistance while the scion is chosen for fruit flavor and quality. Grafting requires same thickness of the tomato and the potato stems. Fertilization with a water soluble fertilizer in every two weeks is required. New shoots should be trimming away that come from the potato plant on a regular basis. These will grow quickly and rob the tomato plant from valuable nutrients. Successful grafting requires placing the vascular cambia of both the rootstock and scion in close contact and then bind the scion and rootstock with a rubber band, tape, staples, string or wax. Over the next few weeks, the scion and rootstock fuse their internal tissues and grow thickened scar tissue around the graft. First, both plants kill and wall off damaged cells. Meanwhile, callus cells in the vascular cambia proliferate and cement themselves together with sticky proteins, forming a living link between scion and rootstock known as the "callus bridge." Callus cells also provide temporary links between the primary vascular tissues in the scion and rootstock the xylem, which transports water, and the phloem, which carries sugars. Eventually, the vascular cambia builds brand new xylem and phloem that unite scion and rootstock into a single functional organism (Anonymous, 2013b).

2.6 Heritability and genetic advance in tomato

Some statistical analysis used in breeding and genetics to estimate how much variation in a phenotypic trait in a population is due to genetic variation among individuals in that population. Heritability measures the fraction of phenotype variability that can be attributed to genetic variation. Since heritability is concerned with variance, it is necessarily an account of the differences between

individuals in a population (Naomi and Peter, 2008). Several researchers worked on heritability and genetic advance on tomato traits. High heritability was observed for fruit size, plant height, yield per plant, average fruit weight, total fruits, days to first picking, number of fruits per plant and individual fruit weight in tomato (Nessa *et al*., 2000; Singh *et al*., 1988; Abedin and Khan, 1986; Sonone *et al*., 1986; Dudi *et al*., 1983; Singh and Singh, 1980; Nandpuri *et al*., 1973). High genetic advance was observed for plant height, fruit yield, fruit size, individual fruit weight, yield per plant, number of fruits per plant, and individual fruit weight (Mallik, 1985; Nandpuri *et al*., 1973). Kasrawi and Amr (1990) reported that pH gave comparatively higher heritability estimates in a study of seven quality characters using F_2 populations. It is estimated that cultivated tomato genome contains less than 5% of the genetic variation of the wild relatives (Miller and Tanksley, 1990). Reddy and Reddy (1990) observed considerable variations for yield per plant in 139 tomato varieties.

Many varieties of tomato were evaluated for their agromorphogenic and nutritional traits based on the additive and non-additive gene action involved in their performance (Mohanty, 2003; lslam *et al.*,1996; Reddy and Reddy, 1992; Bai and Devi, 1991; Islam and Khan, 1991). Many researchers observed high heritability with high genetic advance for different traits which indicated additive gene action controlling the traits and could be improved through selection (Shravan *et al.*, 2004; Singh, 2002; Matin, 2001; Brar *et al*., 2000; Prasad *et al*., 1999; Vikram and Kohli, 1998; Phookan *et al*., l998; Singh *et al*., 1997; Mittal *et al*., 1996; Pujari *et al*., 1995; Godekar *et al*., 1992)

Moderate heritability and low genetic gain for harvest duration suggests the presence of dominance and epistatic effects. Arun *et al.* (2004); and Joshi *et al.* (2004) observed moderate heritability and moderate genetic gain for plant height, number of fruits per cluster, fruit length, fruit breadth, stem end scar size, number of locules per fruit, whole fruit firmness, ascorbic acid content and plant height

indicating additive gene effects. Low heritability and low genetic gain was observed for pericarp thickness.

Brar *et al*. (1998) reported high degrees of variation for average yield per plant among the 186 genotypes tested. Singh *et al.* (2006) observed considerable range of genetic variability for yield, yield components and biochemical characters in the materials under study and maximum genotypic coefficient of variation was recorded for number of leaves per plant, followed by number of clusters per plant. It has been suggested by Yi *et al*. (2008) that domestication and inbreeding dramatically reduced the genetic variation. Genetic variation in modern cultivars or hybrids is limited (Chen *et al*., 2009). Shashikanth *et al.* (2011) observed the range of variation and mean values were high for plant height, days to 50% flowering and average fruit weight. He also observed high genotypic variance for most of the characters indicating a high contribution of the genetic component for the total variation.

Nardar *et al.* (2007) evaluated 20 tomato genotypes and observed high heritability with high genotypic coefficient of variation and genetic gain for fruit weight and fruit yield, which could be improved by simple selection. Golani *et al.* (2007) evaluated 20 tomato genotypes and observed high heritability with high genotypic coefficient of variation and genetic gain for 10-fruit weight, number of locules per fruit and fruit yield, which could be improved by simple selection. According to Saleem *et al.* (2013) a study of quantitative genetics of yield and some yield related traits. The highest estimates of genotypic and phenotypic coefficients of variability (GCV and PCV) were recorded for number of fruits per plant while fruit width was the most heritable trait.

Some other previous reports also indicated that high heritability with high genetic advance was due to additive gene effects and reflected the effectiveness of selection in the germplasm of tomato improvement for number of fruits per plant,

number of flowers per plant, plant height, total number of fruit bearing branches, weight per fruit and days to maturity (Buckseth *et al*., 2012; Narolia, 2012; Pandit *et al.,* 2010; Ponnusviamy *et al.,* 2010; Kumari *et al.* 2007; Padda *et al*., 2007; Saeed *et al.,* 2007). Pandit *et al*. (2010) recorded that high heritability coupled with low genetic advance as percentage of mean for few characters indicating most of the characters were governed by non-additive genetic components. Ponnusviamy *et al.* (2010) recorded that high heritability coupled with low genetic advance as percentage of mean for the rest of the characters except pericarp thickness, indicating most of the characters were governed by non-additive genetic components.

2.7 Correlation between the characters

Correlation between the characters is an estimate to evaluate the inter-relationships between the characters which will help the breeders to choose selection techniques. In most cases, correlation between yield and yield contributing characters was studied because yield is one of the main targets of most of the breeders. The yield contributing characters are also interrelated among themselves. So, association of characteristics with yield and among its components is important for planning effective selective breeding programme for maximization of yield. If any component of yield has higher heritability than yield itself and there is positive correlation between these, then there may be some possibility to increase in the total yield by selecting that component. But, negative correlation co-efficient among yield components were generally observed indicating selection for any component might not bring improvement for yield. Many authors have studied correlation between yield and yield contributing characters of tomato and potato. Some pertinent recent literatures are reviewed in this section.

Ramanjit *et al*. (2001) conducted a field study to determine the degree of correlation of different growth and yield bearing characters to potato germplasm.

In his experiment, tuber yield showed highly significant positive correlations with leaf area index, tuber number, tuber weight, dry matter production of leaves, roots, stolon and tubers. Ozkaynak *et al*. (2003); observed significant positive correlations among tuber yield, plant height, node number, leaf length, leaf width, leaflet length, leaflet width, tuber number and average tuber weight. The result of Roy and Singh (2001) suggested that correlation and path analysis involving eighteen germplasm of potato (*Solanum tuberosum*) under four different environments indicated positive significant association of the quantitative traits with total tuber yield.

Previous researches also showed correlation among different characters in tomato germplasm. Arun *et al.* (2004) observed that in case of tomato, yield per plant was positively and significantly correlated with average fruit weight and plant height. Mohanty (2003) suggested that yield was significantly and positively correlated with number of fruits per plant and number of day to harvest, and significantly but negatively correlated with plant height, number of branches per plant and average fruit weight and the number of fruits per plant was inversely related to average fruit weight. Kumar *et al*. (2004) observed that number of fruits per plant had significant and positive correlation with fruit yield per plant. Joshi *et al*. (2004) showed that yield per plant was positively and significantly correlated with average fruit weight, fruit length, plant height and harvest duration. The average fruit weight was positively correlated with fruit length and fruit breadth.

Kumar *et al*. (2004) observed that correlation coefficients at the genotypic level were generally higher than the corresponding phenotypic ones. He also observed that yield per plant was positively and significantly associated with plant height, fruit number per plant. Highly significant positive correlation was observed between the number of fruits per plant and yield and between plant height and number of fruits per plant while negative correlation was noticed between the number of primary branches per plant and number of fruits per plant (Singh *et al*.,

2005). Manivannan *et al*. (2005) observed that fruit yield was significantly and positively correlated with the number of leaves and fruit weight.

Kumar *et al*. (2006) observed that number of fruits per plant had significant and positive correlation with fruit yield per plant. Megha *et al*. (2006) observed that improvement in yield could be managed by selection for number of flowers per cluster, flower clusters at first picking, number of fruits per cluster and weight per fruit. Correlation analysis performed by Wagh *et al*. (2007) showed that yield improvement can be achieved by selection for 50% flowering, plant height, number of fruits per plant. Wright (2007) observed that yield improvement can be achieved by selection for 50% flowering, plant height, number of fruits per plant. Golani *et al*. (2007) observed that fruit weight had significant and positive correlation with fruit length at both levels.

Rani *et al*. (2010) revealed that fruit weight were positively and significantly associated with yield per plant, while number of fruits per plant was associated negatively. Correlation coefficient analysis was studied for thirty diverse tomato genotypes and noticed that correlation coefficients at the genotypic level were generally higher than the corresponding phenotypic ones and yield per plant was positively and significantly associated with plant height, fruit number per plant, fruit shape index and pericarp thickness (Kumar *et al*., 2011). The experiment carried out by Buckseth *et al*. (2012) consisting of 40 genotypes of tomato to study the correlation among different quantitative and qualitative traits in tomato genotypes. The study revealed highly significant differences among the genotypes for all the characters studied.

Forty nine genotypes of tomato (*Solanum lycopersicum* L.) were evaluated for various quantitative and quality traits by Kumar *et al.* (2013). The character association analysis indicated that total numbers of fruits/plant were significantly and positively correlated with gross yield (g/plant), marketable yield (g/plant),

number of marketable fruits/plant and plant height (cm). Mahapatra *et al.* (2013) found fruit yield had positive and significant correlation with plant height, number of primary branches per plant, number of flower clusters per plant, number of fruits per plant, fruit length, fruit width, and average fruit weight. It was observed that with increase in plant height, there was corresponding increase in number of primary branches per plant, days to 50% flowering and number of flower clusters per plant. According to Monamodi *et al*. (2013), there was a strong positive significant correlation between numbers of branches per plant with fruit number per plant. This was because the more the branch number in a plant, such plant will produce more fruits in a plant.

CHAPTER 3

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the information concerning methodology that was used in carrying out the experiment. It includes a brief description of location of the experiment, planting materials, characteristics of 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 field experiment was conducted at experimental field, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh during the period from November 2013 to April 2014. The location of the experimental site was 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) (Anonymous, 1988). The experimental site is shown in the map of AEZ of Bangladesh in Appendix I.

3.2 Planting materials

A total of seven genotypes including three genotypes of tomato and four genotypes of potato were used in this experiment. The four 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 encoded in Table 1.

3.3 Climate and soil

The experimental area under the sub- tropical climate that is characterized by less rainfall associated with moderately low temperature during rabi season (October-

March). The farm belongs to the general soil type, shallow red brown terrace soils under Tejgaon series. Soil pH ranged from 6.0-6.6 and had organic matter 0.84%. The land was above flood level and sufficient sunshine was available during the experimental period. 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 tomato and potato genotypes used in the 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	Pakri Alu (Tel)	HDD, BADC
5	P_2	Asterix	HDD, BADC
6	P_3	Daimant	HDD, BADC
7	P_4	Cardinal	HDD, BADC

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

3.4 Land preparation

The experimental plots were ploughed, well prepared, brought into a good 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 2013- 14 in Randomized Complete Block Design (RCBD).

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

Tomato seed was sown in the seedbed on December 5, 2013. Seeds were treated with Bavistin for 5 minutes before sowing. 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. Required cultural practices were done before and after sowing the seeds. Seven days old seedlings were transferred into polybags for hardening. Raising of three tomato genotypes seedlings in the seedbed, hardening in polybags and three varieties of tomato seedling are shown in Plate 1.

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

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 transferred to the main land. Necessary intercultural operations were provided as and when required. Growing of potato seedling in the main land are shown in Plate 2.

3.8 Grafting

Tomato seedlings of 21days, raised in the polybags were grafted on potato plant in the main field on December 26, 2013. Cleft grafting was done for producing

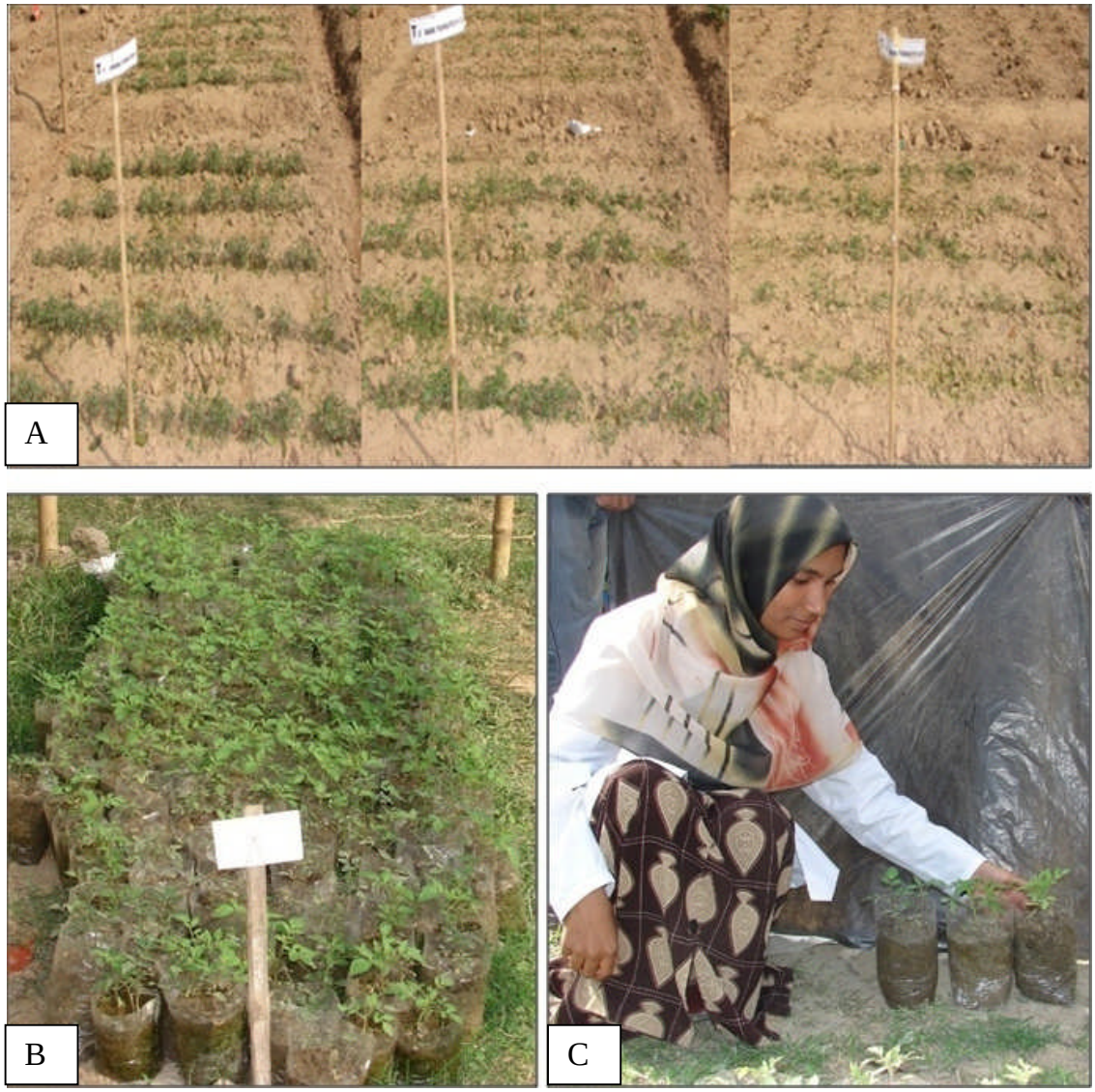


Plate 1. Different steps of raising of seedlings of tomato A. Raising of tomato seedling in the seedbed (BARI Tomato 11, BARI Tomato 2 and BARI Tomato 3, respectively), B. Hardening of tomato seedling in the polybag C. Three seedlings of the experimental tomato varieties, respectively.

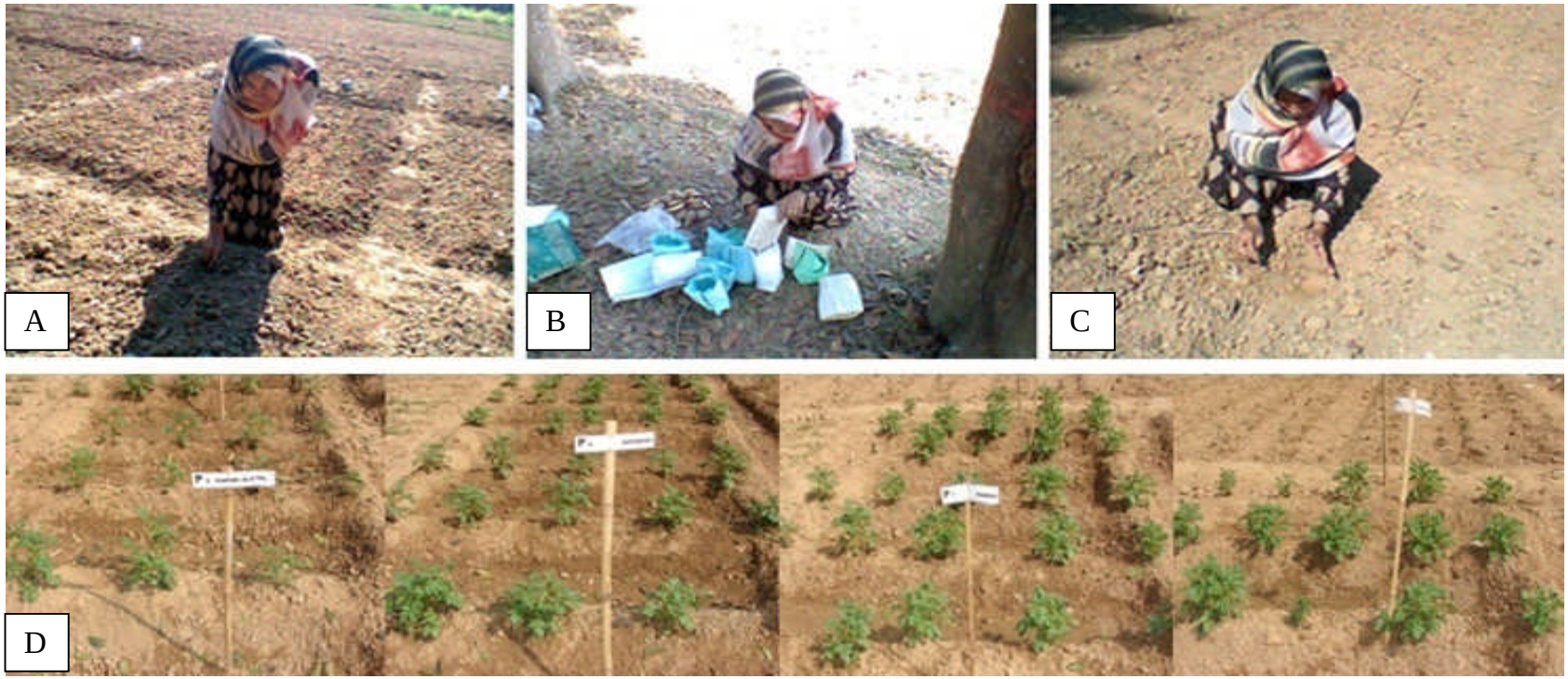


Plate 2. Steps of growing of potato seedling in the field (A) land preparation (B) tuber cutting (C) sowing of potato tuber (D) Growing of potato seedlings of four genotypes (Pakri Alu Tel, Asterix, Daimant and Cardinal, respectively)

pomato plant. The grafted seedlings were watered regularly to make a firm relation with scion - root stock and soil to stand along (Plate 3A).

3.9 Application of manure and fertilizers

Total cow dung and triple super phosphate (TSP) were applied in the field during final land preparation. After three weeks of transplanting, half urea and half muriate of potash (MOP) were applied in the field. 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

After 10 days of grafting first earthing up was done uniformly when the seedlings were well established. After 35 days of grafting second earthing up was done. First weeding was done uniformly in all the plots. Second weeding was done after 20 days of the first one. Mechanical support was provided to the growing plants by bamboo sticks to keep them erect (Plate 3B). 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.

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

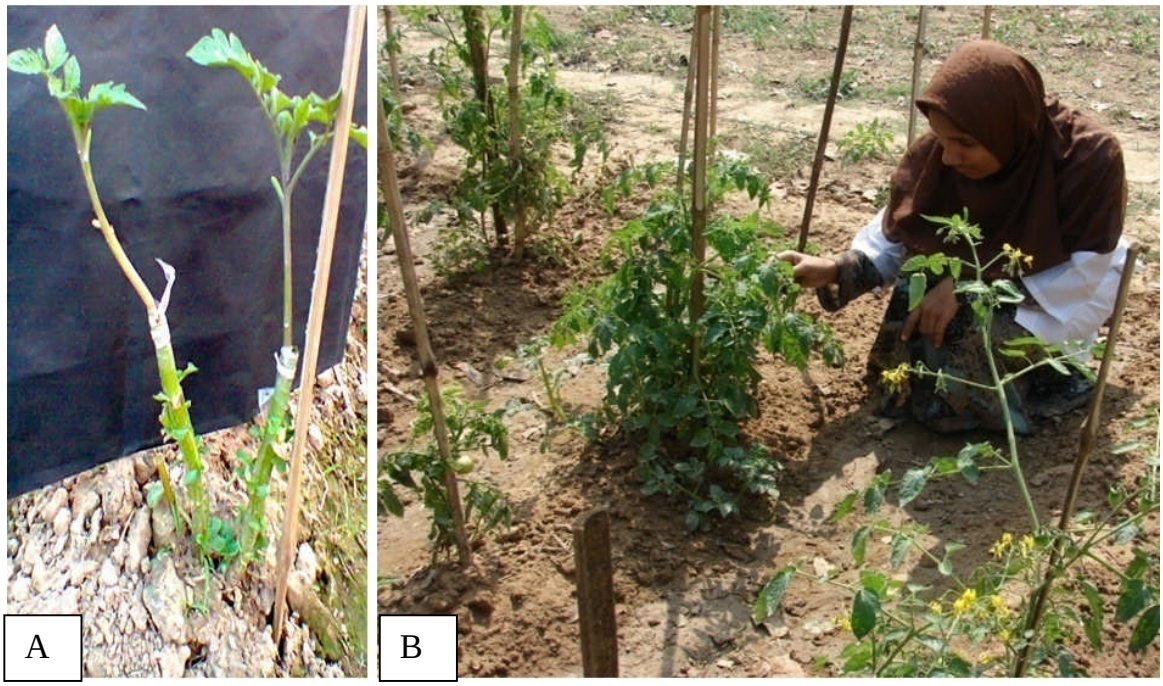


Plate 3. Grafting and intercultural operation A. Grafting of tomato and potato plant. B. Weeding and stalking with bamboo sticks

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 potatoes were harvested after several successful harvesting of tomato. Harvesting was started from March 2, 2014 and completed by April 26, 2014.

3.12 Data collection

Five plants were randomly selected from the middle rows of each unit plot for avoiding border effect, except yields of plots, which was recorded plot wise. Data were recorded in respect of the following parameters to assess plant growth yield attributes and yields (Plate 4).

3.12.1 Days to first flowering

First flowering was observed and it was continued when all plots bloomed completely.

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

Plant height at last harvest was measured from sample plants in centimeter from the ground level to the tip of the longest stem of five plants and mean value was calculated.

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.

Plate 4. Data collection and recording A. counting number of clusters per plant and number of fruits per cluster, B. measurement of fruit length and fruit diameter, C. morphological data collection, D. data recording of other parameters

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 number of fruits/plant was counted from the sample plants for the whole growing period and the average number of fruits produced/plant was recorded and expressed in fruits/plant.

3.12.8 Fruit length

The length of fruit was measured with a meter scale from stalk end to blossom end of 10 selected marketable fruits from each plot and there average was taken and expressed in cm.

3.12.9 Fruit diameter

Diameter of fruit was measured at the middle portion of 10 selected marketable fruit from each plot with a digital calipers-515 (DC-515) and average was taken and expressed in cm.

3.12.10 Fruit yield per plant

The weight of individual fruit was measured with a digital weighing machine from 10 selected marketable fruits from each selected plots and there average was taken and expressed in kilogram (kg) per plant.

3.12.11 Tuber per plant

The total number of tuber was counted from the selected pomato plants and their average was taken as the number of tubers per plant.

3.12.12 Tuber yield per plant

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

The collected data were statistically analyzed. 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

According to the formula suggested by Johnson *et al.* (1955) genotypic and phenotypic variances were estimated.

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 given 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.

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 (h^2_b) was calculated by the following formula, suggested by Johnson *et al.* (1955).

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

Where,

h^2_b = Heritability in broad sense

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 Johnson *et al.* (1955).

Genetic advance, GA = K. h^2. σ_p

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

Where,

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

σ_{ph} = Phenotypic standard deviation

h^2_b= Heritability in broad sense

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 estimated by the following formula suggested by Comstock and Robinson (1952):

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

3.13.6 Estimation of simple correlation co-efficient:

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

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

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

Genotypic and phenotypic correlation co-efficient for all possible combinations was estimated by the formula suggested by Miller *et al.* (1958), Johnson *et al.* (1955) and Hanson *et al.* (1956). 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

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

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

According to the procedure quoted by Singh and Chaudhary (1985), using phenotypic correlation coefficient values path co-efficient was done. 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 1 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,

$P_{1.y,}\,P_{2.y,}\,P_{3.y.}$ …… $P_{8.y}$ = 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 :

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

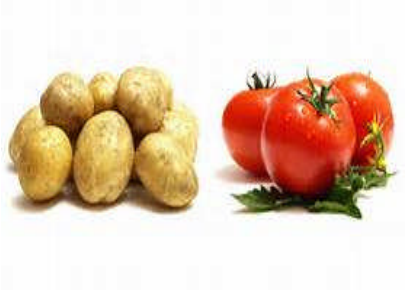
Where,

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

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



CHAPTER 4

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to determine the compatibility of pomato plants which is created by grafting between tomato and potato plants. Four potato (Plate 5) and three tomato (Plate 6) genotypes were used in this study for comparison their yield performance. The present study was conducted 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 new leaves started to appear within 3 to 4 days. Different steps of grafting are illustrated in plate 7. The tomato fruits were harvested in different times and the potatoes were harvested almost at the end of the plant's life cycle. After several harvesting of tomato fruits, almost the last stage of the pomato plant with full bearing of potato is shown in plate 8. The result of the present investigation of mean performance, genetic variability, correlation and path analysis in pomato carried out during Rabi 2013-14 are presented in the following sections.

4.1 Analysis of variance

Analyses of variance showed the presence of significant variation among the tested genotypes for all the characters studied viz. days to first flowering, days to 50% flowering, plant height, branches per plant, clusters per plant, fruits per cluster, fruits per plant, tuber per plant, fruit length, fruit diameter fruit yield per plant (kg), tuber yield per plant and total yield per plant (Table 3). Similar finding were also emphasized by Naz *et al*. (2013) and Reddy *et al*. (2013). The variation due to replication was non-significant for all the characters.

4.2 Mean Performance

The mean value of all genotypes for each character is shown in Table 4. Performance of the genotypes is described below for each character.

Table 3. Analysis of variance for yield and related characters of pomato.

Sources	Df	Mean sum of square (MSS)												
		DFF	**D 50% F**	**PH**	BPP	**CPP**	**FPC**	**FPP**	**TPP**	**FL**	**FD**	**FYP**	**TuYP**	**TYP**
Replication	2	7.69	6.86	230.13	12.32	50.68	0.53	441.75	4.69	0.17	0.01	0.031	0.002	0.017
Genotype	11	28.99**	26.14**	902.84**	10.07**	93.07**	48.93**	17,448.06**	361.59**	2.87**	6.88**	0.554**	0.031**	0.641**
Error	22	4.72	5.61	77.24	2.39	11.47	1.71	341.08	3.24	0.10	0.09	0.052	0.002	0.052

** Significant at 1% level of probability

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 4. Mean performance of various growth parameter and yield related characters of pomato

Genotypes	DFF	D50%F	PH	BPP	CPP	FPC	FPP	TPP	FL	FD	FYP	TuYP	TYP
G1	51.33e	57.67b	99.17a	9.57a	21.03bc	11.42a	193.67b	42.67a	2.53d	2.26d	1.72a	0.32f	2.04ab
G2	47.33f	53.33c	53.08d	8.00ab	15.57c-f	4.56b	85.67de	43.33a	4.20bc	4.83bc	1.20bc	0.37ef	1.57c-e
G3	56.00a-c	61.33ab	65.22b-d	7.87ab	13.93d-f	3.85b	94.00cd	42.33a	3.67c	4.47c	0.83c	0.31f	1.14e
G4	56.33a-c	61.67ab	93.02a	8.96ab	23.33ab	13.10a	223.00ab	20.33bc	2.30d	2.01d	1.92a	0.53bc	2.45a
G5	57.67a	63.67a	64.00b-d	9.20ab	17.30b-e	4.80b	119.00c	20.67bc	4.93a	6.10a	1.12bc	0.49cd	1.61cd
G6	57.67a	63.33a	73.16bc	6.40bc	13.43d-f	3.94b	74.33d-f	21.67b	4.44ab	5.03b	0.80c	0.55a-c	1.35de
G7	56.67ab	61.67ab	99.77a	9.73a	27.40a	12.87a	246.33a	16d	2.70d	2.18d	1.83a	0.60ab	2.44a
G8	54.67a-e	60.33ab	55.27d	7.70a-c	13.13ef	4.22b	58.33e-g	18cd	4.77ab	5.30b	1.00bc	0.49cd	1.49c-e
G9	55.67a-d	62.00ab	64.40b-d	4.80c	10.83f	3.58b	41.00fg	16.33d	4.20bc	4.97bc	0.90bc	0.43de	1.33de
G10	52.33c-e	58.33b	77.70b	6.80a-c	19.67b-d	11.13a	194.67b	19b-d	2.57d	2.00d	1.85a	0.50cd	2.35a
G11	53.33b-e	58.67b	53.07d	4.97c	9.67f	3.39b	42.33fg	19b-d	4.73ab	5.07b	1.27b	0.62a	1.90bc
G12	51.67de	57.67b	59.12cd	4.87c	10.33f	3.91b	39.67g	18cd	4.17bc	4.93bc	0.95bc	0.50cd	1.45de
Min	47.33	53.33	53.07	4.80	9.67	3.39	39.67	16.00	2.30	2.00	0.80	0.31	1.14
Max	57.67	63.67	99.77	9.73	27.40	13.10	246.33	43.33	4.93	6.10	1.92	0.62	2.45
Mean	54.22	59.97	71.41	7.41	16.30	6.73	117.67	24.78	3.77	4.10	1.28	0.48	1.76

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= Pakri Alu Tel + BARI Tomato 11, G2= Pakri Alu Tel + BARI Tomato 2, G3= Pakri Alu Tel + BARI Tomato 3, G4= Asterix + BARI Tomato 11, G5= Asterix + BARI Tomato 2, G6= Asterix + BARI Tomato 3, G7= Diamant + BARI Tomato 11, G8= Diamant + BARI Tomato 2, G9= Diamant + BARI Tomato 3, G10= Cardinal + BARI Tomato 11, G11= Cardinal + BARI Tomato 2, G12= Cardinal + BARI Tomato 3.

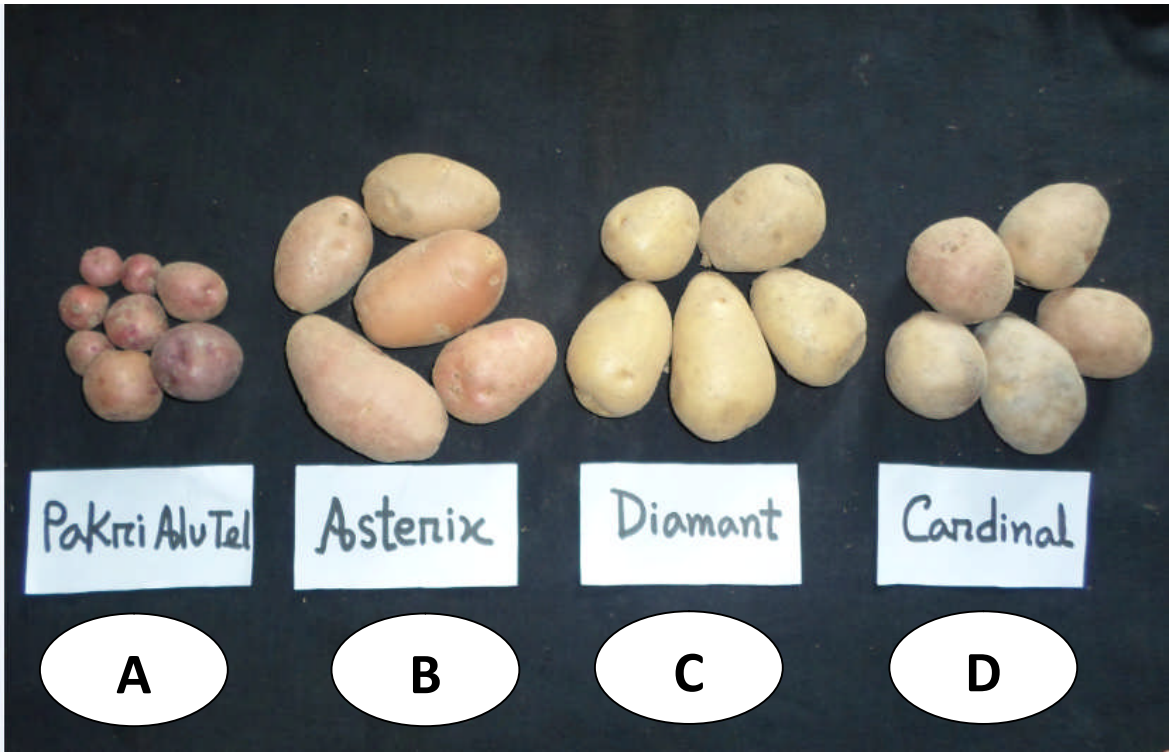


Plate 5. Genotypes of potato from pomato plant A. Pakri Alu (Tel) (P1), B. Asterix (P2), C. Diamant (P3) and D. Cardinal (P4)

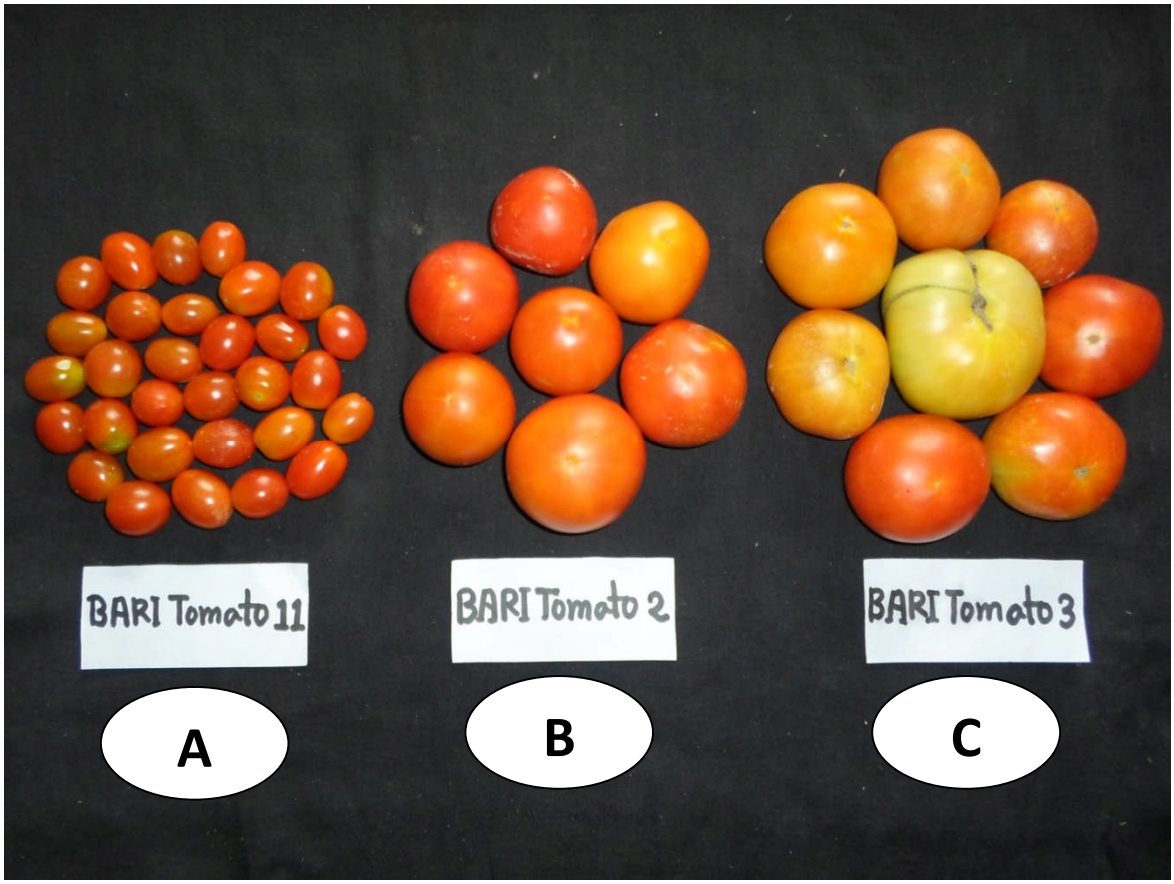


Plate 6. Genotypes of tomato from pomayo plant A. BARI Tomato-11 (T1), B. BARI Tomato-2 (T2) and C. BARI Tomato-3 (T3)

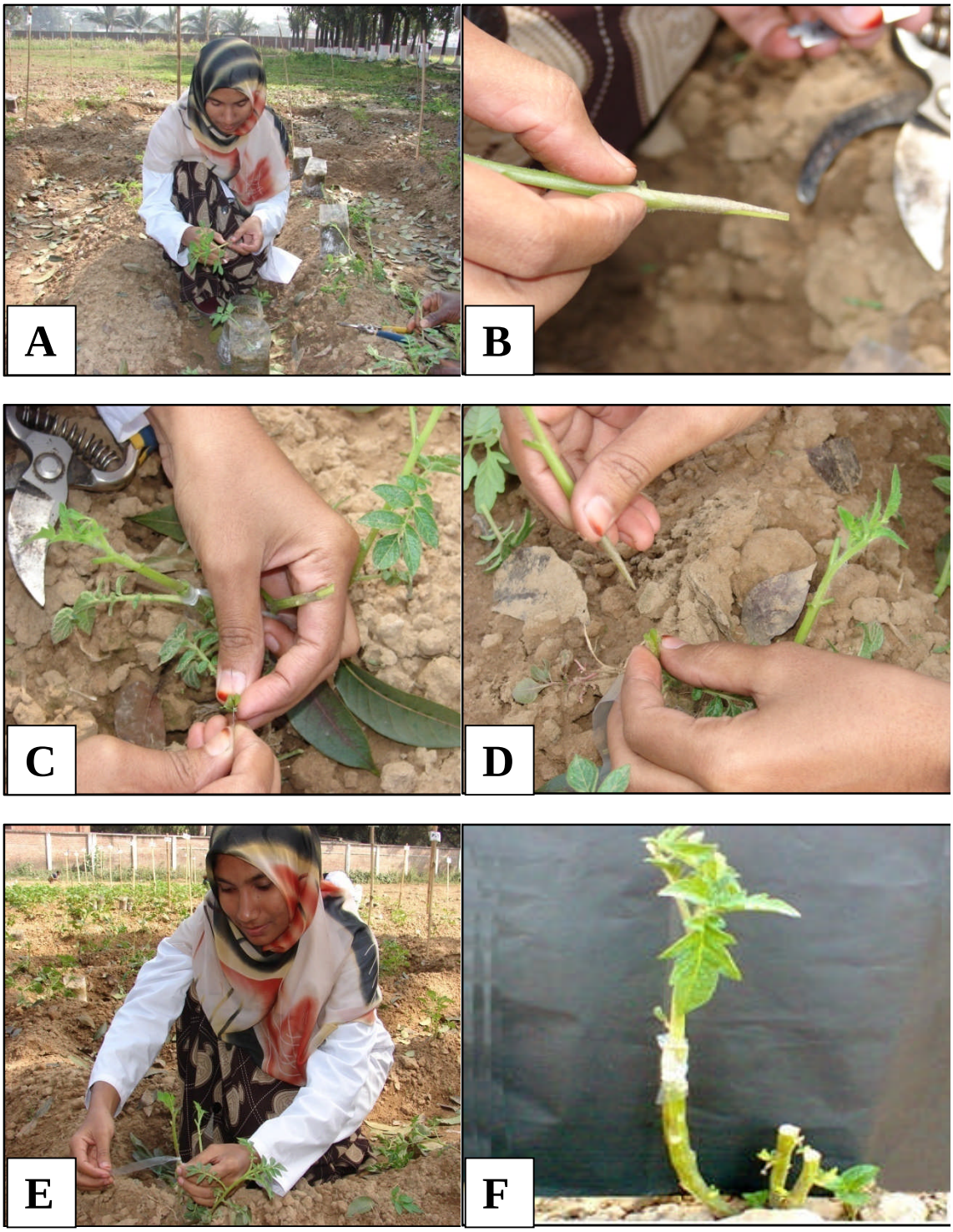


Plate 7. Cleft Grafting for making pomato plant using potato and tomato seedling. A. Cutting of stem of tomato seedling from polybag. B. Sharpen the edge of tomato stem from both side. C. Cutting the stem of potato plant and tease open the stem. D. Insertion of sharpen edge of tomato seedling into the stem of potato seedling. E. Join the two stem with wrapping tape. F. Emerging of new leaves

Plate 8. The last stage of the pomato plant with fruit tomato and tuber potato in pomato plant

4.2.1 Days to first flowering

Days to first flowering was found highest (57.67) in both G5 (Asterix x BARI Tomato 2) and G6 (Asterix x BARI Tomato 3) which were statistically similar with G3 (Pakri Alu Tel x BARI Tomato 3) (56.00), G4 (Asterix x BARI Tomato 11) (56.33) and G7 (Diamant x BARI Tomato 11) (56.67) (Table 4). The mean of days to first flowering was 54.22. It had a range of 47.33 to 57.67days. The accession G2 (Pakri Alu Tel x BARI Tomato 2) was the earliest to flower at 47.33 days while G5 (Asterix x BARI Tomato 2) and G6 (Asterix x BARI Tomato 3) were late to flower, whereas, the highest mean data was observed for control tomato in BARI Tomato-11 (51.33) and the lowest in BARI Tomato-2 (47) (Appendix IV).

4.2.2 Days of 50% flowering

Days of 50% flowering was found the highest in G5 (Asterix x BARI Tomato 2) (63.67) which was statistically similar with G6 (Asterix x BARI Tomato 3) (63.33), G4 (Asterix x BARI Tomato 11) (61.67) and G7 (Diamant x BARI Tomato 11) (61.67), G8 (Diamant x BARI Tomato 2) (60.63), G9 (Diamant x BARI Tomato 3) (62.00) (Table 4). Shashikanth *et al.* (2011) observed the range of mean values were high for this trait that was supported to this findings. The lowest days to 50% flowering was found in G2 (Pakri Alu Tel x BARI Tomato 2) (53.33) (Table 3). The mean of days to 50% flowering was 59.97. The accession G2 (Pakri Alu Tel x BARI Tomato 2) was the earliest to flower at 47.33 days while ‘G5 (Asterix x BARI Tomato 2) and G6 (Asterix x BARI Tomato 3) were late to flower (57.67 days). The highest mean data was observed for control tomato in BARI Tomato-3 (56.33) and the lowest in BARI Tomato-2 (52) (Appendix IV).

4.2.3 Plant height (cm)

Plant height was found the highest in G7 (Diamant x BARI Tomato 11) (99.77) for pomato which was statistically similar with G1 (Pakri Alu Tel x BARI Tomato 11) (99.17) and G4 (Asterix x BARI Tomato 11) (93.02). The grand

mean plant height recorded was 71.41 cm. The maximum plant height was recorded by the genotype G7 and the lowest plant height was recorded by G11 (Cardinal x BARI Tomato 2). High ranges of mean values were also observed by Shashikanth *et al.* (2011). In control tomato, the highest plant height was observed in BARI Tomato-11 and BARI Tomato-3 both (83.1 cm) and the lowest in BARI Tomato-2 (72.7) (Appendix IV). In control potato, the highest plant height was observed in Asterix (80.3) and the lowest was found in Daimant (65.3) (Appendix V).

4.2.4 Branches per plant

Branches per plant were found the highest in G7 (Diamant x BARI Tomato 11) (9.73) which were statistically similar with G1 (Pakri Alu Tel x BARI Tomato 11) (9.57), G2 (Pakri Alu Tel x BARI Tomato 2) (8.00), G3 (Pakri Alu Tel x BARI Tomato 3) (7.87), G4 (Asterix x BARI Tomato 11) (8.96) and G5 (Asterix x BARI Tomato 2) (9.20) (Table 4). Lowest branches per plant were observed in G9 (Diamant x BARI Tomato 3) (4.80) and which was statistically similar with G11 (Cardinal x BARI Tomato 2) (4.97), G12 (Cardinal x BARI Tomato 3) (4.87), G6 (Asterix x BARI Tomato 3) (6.40) (Table 4). In the case of control tomato, the highest branches per plant was observed in BARI Tomato-11 (12.7) and the lowest in BARI Tomato-2 (5.59) (Appendix IV). In case of control potato, the highest and the lowest branches per plant were observed in Asterix (8.22) and Pakri Alu (Tel) (3), respectively.

4.2.5 Clusters per plant

Clusters per plant were found the highest in grafted genotype G7 (Diamant x BARI Tomato 11) (27.40), which were statistically similar with grafted genotype G4 (Asterix x BARI Tomato 11) (23.33) (Table 4). The lowest clusters per plant was found in G11 (Cardinal x BARI Tomato 2) (9.67) which was statistically similar with G12 (Cardinal x BARI Tomato 3) (10.33), G9 (Diamant x BARI Tomato 3) (10.83) (Table 4). The average value of clusters per plant was estimated 16.30. In case of control tomato, the highest clusters

per plant were observed in BARI Tomato-11 (12) and the lowest in BARI Tomato-2 (7.67) (Appendix IV).

4.2.6 Fruits per cluster

Fruits per cluster were found the highest in G4 (Asterix x BARI Tomato 11) (13.10) and statistically similar with G7 (Diamant x BARI Tomato 11) (12.87), G1 (Pakri Alu Tel x BARI Tomato 11) (11.42) and G10 (Cardinal x BARI Tomato 11) (11.13) (Table 4). The mean fruits per plant were 6.73. Lowest fruits per cluster were found in G11 (Cardinal x BARI Tomato 2) (3.39) (Table 4). The highest mean data was observed for control tomato in BARI Tomato-11 (14.6) and the lowest in BARI Tomato-2 (5.33) (Appendix IV).

4.2.7 Fruits per plant

G7 (Diamant x BARI Tomato 11) (246.33) performed the highest fruits per plant which was statistically similar with G4 (Asterix x BARI Tomato 11) (223.00) (Table 4). The lowest fruits per plant were found in G12 (Cardinal x BARI Tomato 3) (39.67). That was statistically similar with G11 (Cardinal x BARI Tomato 2) (42.33) and G9 (Diamant x BARI Tomato 3) (41.00). The average fruits per plant were 117.67. In case of control tomato, the highest fruits per plant were observed in BARI Tomato-11 (166.67) and the lowest in BARI tomato-2 (65) (Appendix IV).

4.2.8 Tuber per plant

Tuber per plant was found the highest in G2 (43.33) which was statistically similar with G1 (42.67) and G3 (42.33). The lowest tuber per plant was found in G7 (16) and it was statistically similar with G9 (16.33) and G8 (18) (Table 4). Whereas the highest tuber per plant was observed for control potato in Pakri Alu (Tel) (55.3) and the lowest in Daimant (22) (Appendix V).

4.2.9 Fruit length (cm)

The highest fruit length was found in G5 (4.93) and it was statistically similar with G8 (4.77) and G6 (4.44) (Table 4). The lowest fruit length was found in

G4 (2.30) which was statistically similar with G1 (2.53) and G7 (2.70) (Table 4). The highest mean data was observed for control tomato in BARI Tomato-3 (4.1) and the lowest in BARI Tomato-11 (2.16) (Appendix IV).

4.2.10 Fruit diameter (cm)

The highest fruit diameter were found in G5 (6.10 cm) and this was followed by G8 (5.30) and G11 (5.07) (Table 4). The average fruit diameter was 4.10. The lowest fruit diameter was found in G10 (2.00) which was statically similar with G4 (2.01d), G7 (2.18) and G1 (2.26) (Table 4). The highest fruit diameter was observed in case of control tomato in BARI Tomato-3 (4.63) and the lowest in BARI Tomato-11 (1.6) (Appendix IV).

4.2.11 Fruit yield per plant (kg)

The yield performance of control tomato was presented in Figure 1. Significant difference for fruit yield per plant among the genotype tested and it was supported the finding of Matin *et al.* (2001) and Ghosh *et al*. (1995). Fruit yield per plant were found the highest in G4 (1.92) which was statistically similar with G10 (1.85), G7 (1.83) and G1 (1.72). The average fruit yield per plant was 1.28. Lowest fruit yield per plant was found in G6 (0.80). That was statistically similar with G3 (0.83) and G12 (0.95) (Table 4). The highest fruit yield per plant was observed for control tomato in BARI Tomato-11 (1.77) and the lowest in BARI Tomato-3 (1.00) (Appendix IV).

4.2.12 Tuber yield per plant (kg)

Tuber yield per plant were found the highest in G11 (0.62) which was statistically similar with G7 (0.60) and G6 (0.55) (Table 4). The lowest fruit yield per plant was found in G3 (0.31) that was statically similar with G1 (0.32) and G2 (0.37) (Table 4). In case of control potato the highest tuber yield per plant was observed in Cardinal (0.85) and the lowest in Pakri Alu (Tel) (0.52) (Appendix V). The tuber yield performance of control potato depicted in Figure 2.

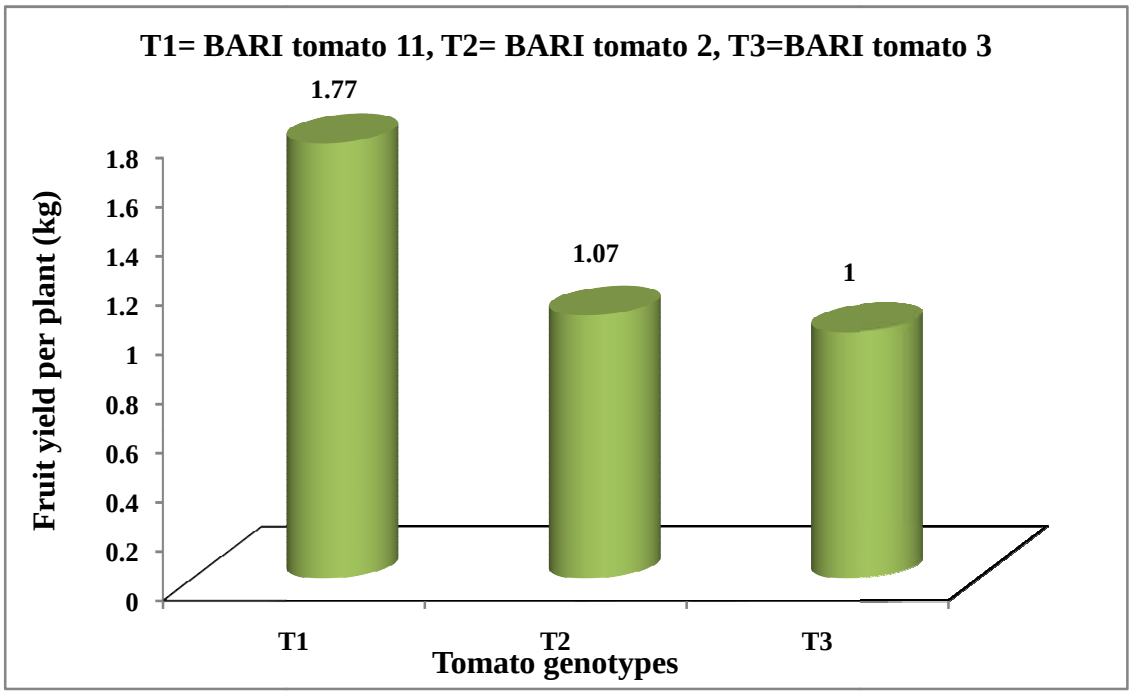


Figure 1. Fruit yield performance in control tomato

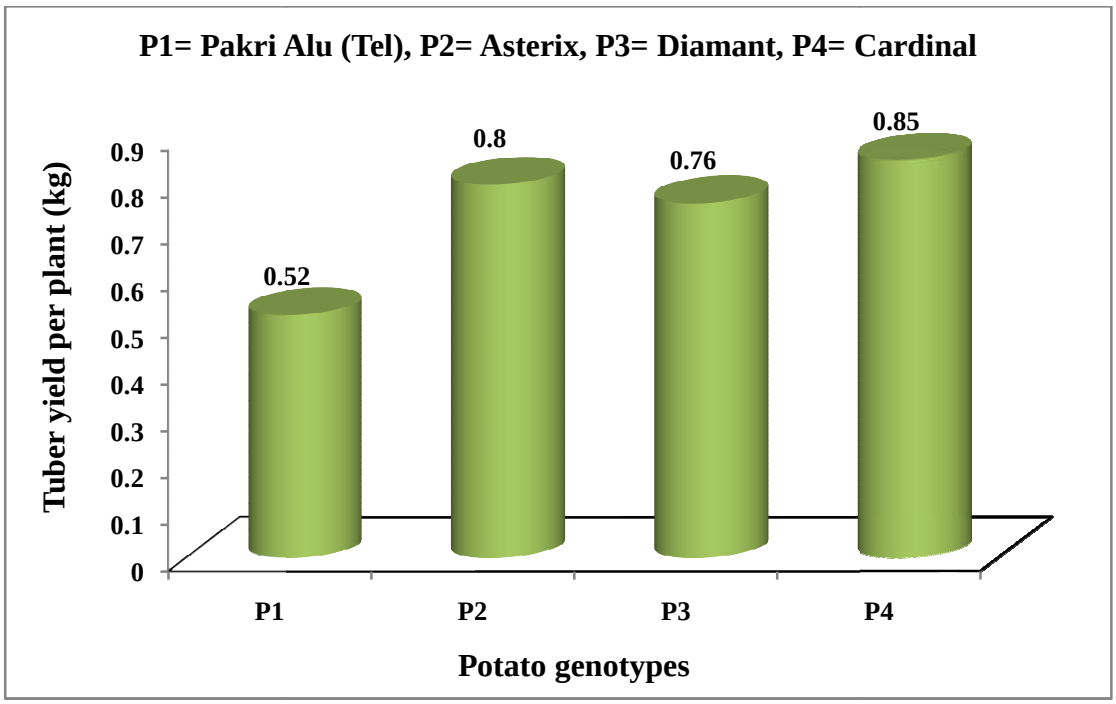


Figure 2. Tuber yield performance in control potato

4.2.13 Total yield per plant (kg)

Total yield per plant were found the highest in G4 (2.45) which was statistically similar with G7 (2.44), G10 (2.35) and G1 (2.04) (Table 3). Lowest total yield per plant was found in G3 (1.14) and that was statistically similar with G9 (1.33) and G6 (1.35) (Table 4) and yield performance of both tomato and potato are presented in Figure 3.

4.3 Genetic variability, heritability and genetic advance

The success of crop improvement programme depends on the extent of genetic variability existing in the population or germplasm. The magnitude of genetic variability can determine the pace and quantum of genetic improvement through selection or through hybridization followed by selection. Phenotypic variance measures the magnitude of variation arising out of differences in phenotypic values while the genotypic variance measures the magnitude of variation due to difference within the genotypic values. Heritability estimates aim in determining the relative amount of heritable portion of variation. The estimates of heritability alone fail to indicate the response to selection (Johnson *et al.*, 1955). Therefore, the heritability estimates appears to be more meaningful when accompanied by estimates of genetic advance. The genetic advance as percent mean was also estimated.

The estimates of mean sum of square, coefficient of variation, genotypic and phenotypic coefficients of variation, heritability, genetic advance and genetic advance as percent mean in respect of thirteen characters were studied and the results are presented in Table 4 and depicted in Figure 4 and 5. Performance of the genotypes is described below for each character.

4.3.1 Days to first flowering

The genotypic variance and phenotypic variance for this trait were 8.09 and 12.81, respectively (Table 5). The phenotypic variance was appeared higher than the genotypic variance suggested considerable influence of environment effect on the expression of genes controlling of this trait. The phenotypic co-

Table 5. Estimation of genetic parameters of thirteen characters of pomato

Parameters	MS	CV (%)	σ^2 p	σ^2g	σ^2 e	PCV	GCV	ECV	Heritability	Genetic advance (5%)	Genetic advance (% mean)
DFF	28.98**	4.01	12.81	8.09	4.72	6.60	5.25	4.01	63.13	4.65	8.59
D50%F	26.14**	3.95	12.46	6.84	5.62	5.89	4.36	3.95	54.91	3.99	6.66
PH	902.84**	12.31	352.45	275.20	77.25	26.29	23.23	12.31	78.08	30.20	42.29
BPP	10.07**	20.88	4.95	2.56	2.39	30.05	21.61	20.88	51.74	2.37	32.03
CPP	93.07**	20.78	38.67	27.20	11.47	38.15	31.99	20.78	70.33	9.01	55.28
FPC	48.93**	19.46	17.45	15.74	1.71	62.07	58.94	19.46	90.17	7.76	115.31
FPP	17,448.06**	15.70	6043.41	5702.33	341.08	66.07	64.18	15.70	94.36	151.10	128.41
TPP	361.59**	7.26	122.69	119.45	3.24	44.70	44.11	7.26	97.36	22.22	89.65
FL	2.87**	8.68	1.03	0.92	0.11	26.94	25.50	8.68	89.61	1.87	49.70
FD	6.88**	7.31	2.35	2.26	0.09	37.47	36.75	7.31	96.19	3.04	74.15
FYP	0.55**	17.74	0.22	0.17	0.05	36.48	31.88	17.74	76.36	0.74	57.56
TuYP	0.03**	8.98	0.01	0.01	0.00	22.59	20.73	8.98	84.21	0.19	38.82
TYP	0.64**	12.99	0.25	0.20	0.05	28.33	25.18	12.99	79.00	0.81	46.11

** Correlation is significant at the 0.01

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), MSS = 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 co-efficient of variation, GCV= Genotypic co-efficient of variation and ECV= Environmental co-efficient of variation.

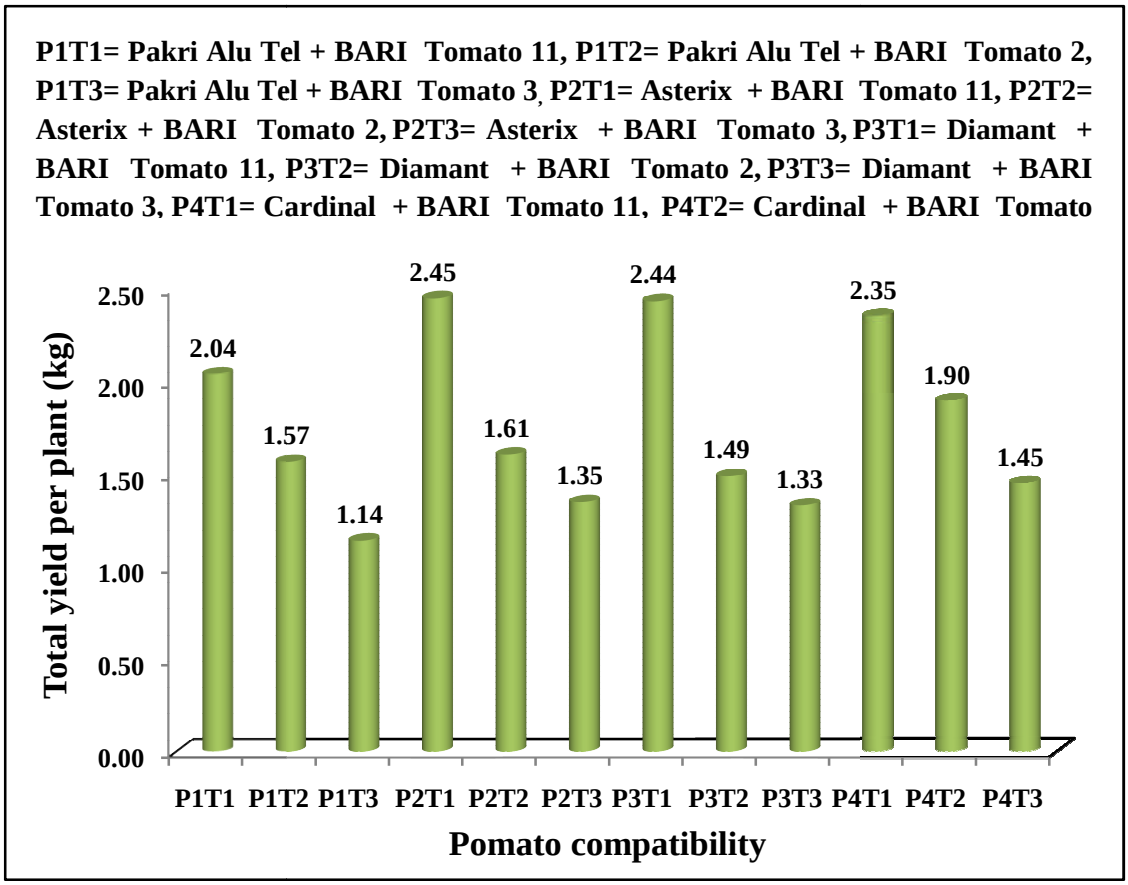


Figure 3. Total yield (fruit and tuber) performance in pomato

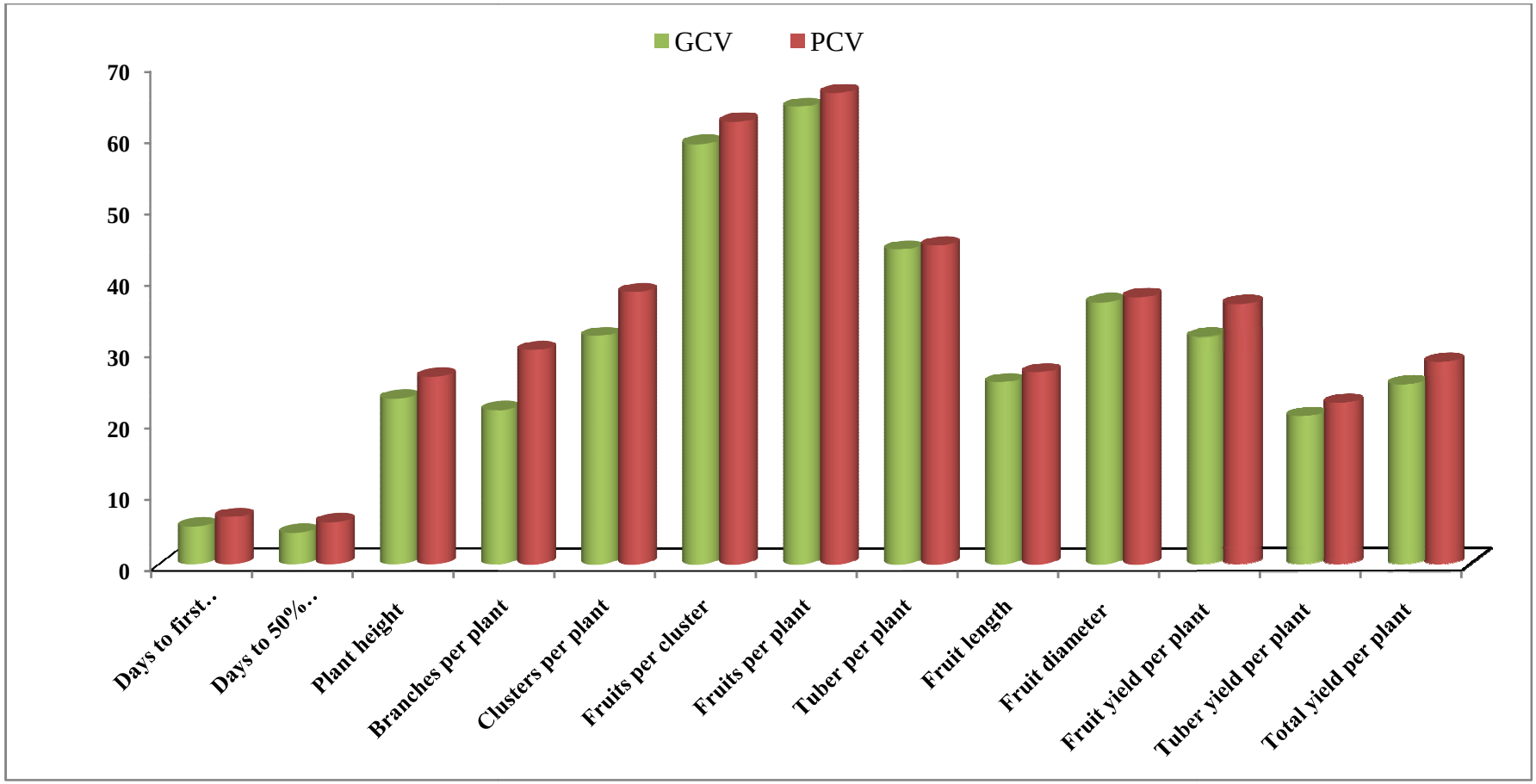


Figure 4. Genotypic and phenotypic variability in pomato

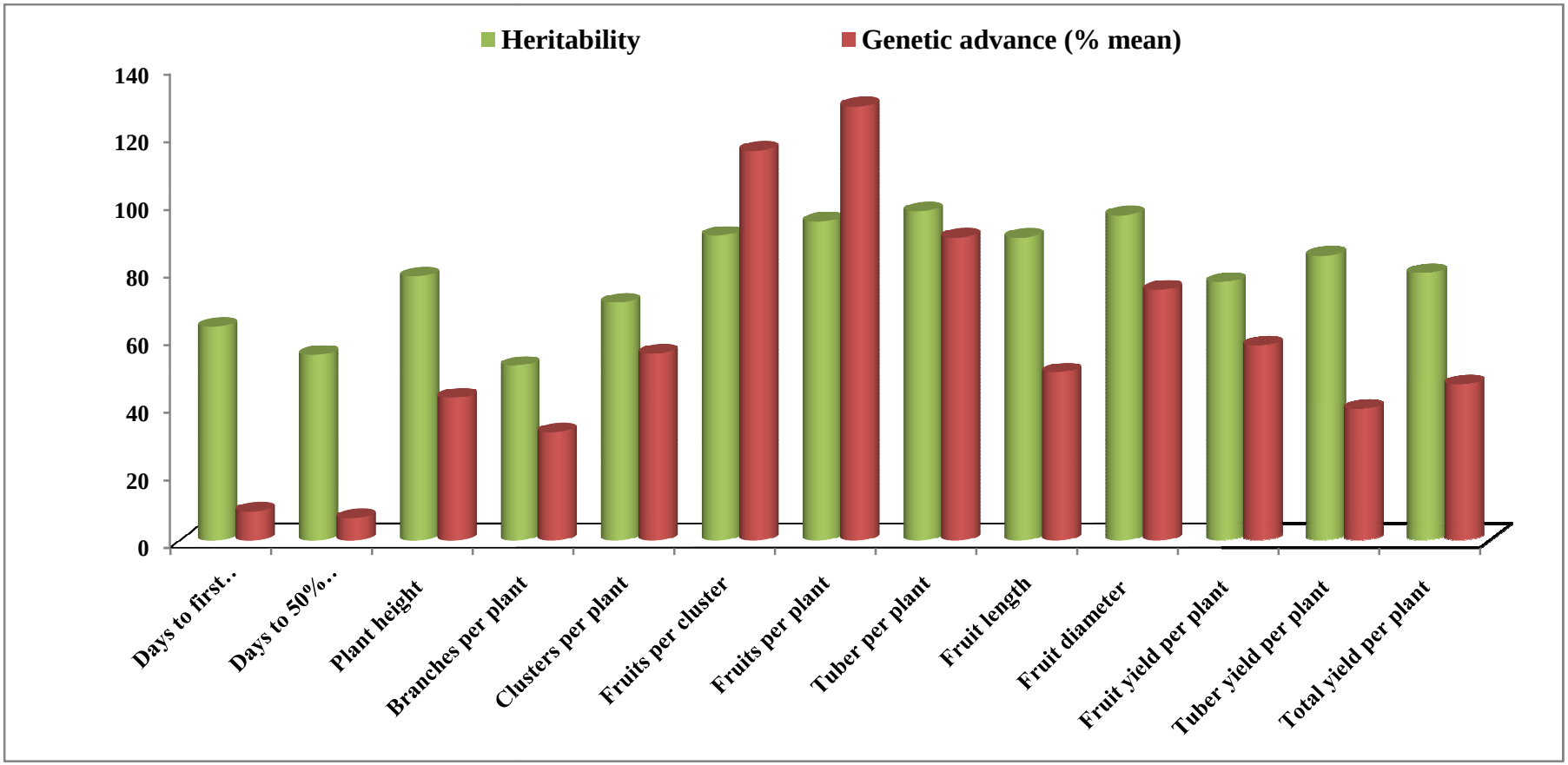


Figure 5. Heritability and genetic advance mean percent (%) of pomato

efficient of variation (PCV) (6.60) was little higher than the genotypic co-efficient of variation (GCV) (5.25) indicating slight environmental influence on this trait (Table 5). This results supported by Matin *et al.* (2001) results. The heritability estimates for days to first flowering was moderate (63.13) with low genetic advance (4.65) and genetic advance in percentage of mean (8.59). Thus indicating this trait was mostly controlled by non-additive gene. Bai and Devi (1991) reported moderate heritability for days to first flowering in tomato.

4.3.2 Days to 50% flowering

From the current study it was observed the genotypic variance and phenotypic variance for this trait were 6.84 and 12.46, respectively (Table 5). 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) (4.36) and phenotypic co-efficient of variation (PCV) (5.89) were more, indicated the variability not only for genotype but also influence of environment. Therefore, such selection sometimes is misleading. Moderate heritability (54.91) coupled with low genetic advance percent mean (6.66) was observed for this character, indicating little scope for the selection upon this character due to the non-additive gene action. Panse (1957) 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.

4.3.3 Plant height (cm)

The genotypic and phenotypic variance for this trait was 275.20 and 352.45, respectively (Table 5). 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) (23.23) and phenotypic co-efficient of variation (PCV) (26.29) were less. The values of high heritability (78.08%) along with

high genetic advance as percent mean (42.29%) were observed for this trait indicating more scope for the selection of high yield pomato variety upon this character. Nessa *et al*. (2000) and Pujari *et al*. (1995) reported that heritability and genetic advance over percent of mean estimates for plant height was high in tomato.

4.3.4 Branches per plant

Number of branches per plant in pomato showed phenotypic variance was higher than the genotypic variance. The coefficient of variability at genotypic and phenotypic level was 21.61 and 30.05 percent respectively (Table 5) indicating that the phenotypic expression of this trait is highly governed by the environment. The heritability estimates for this trait was moderate (51.74), genetic advance was low (2.37) and genetic advance in per cent of mean were found high (32.03), revealed that this trait was governed by non-additive gene. This results supported by the results of Shravan *et al*. (2004) in tomato.

4.3.5 Clusters per plant

The genotypic variance and phenotypic variance for clusters per plant were 27.20 and 38.67, respectively (Table 5). 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 smaller (31.99) than phenotypic co-efficient of variation (38.15) which has limited scope for the improvement of this crop. The heritability estimates for this trait was high (70.33) with high genetic advance in per cent of mean indicated that selection for this character would be suitable.

4.3.6 Fruits per cluster

Significant genotypic variance and phenotypic variance were observed among the genotypes for number of fruits per cluster 15.74 and 17.45, respectively (Table 5). The phenotypic variance appeared higher than the genotypic variance. The genotypic coefficient of variation and phenotypic coefficient of variation were 58.94 and 62.07, respectively. The heritability estimates for this

trait was very high (90.17) and genetic advance in percent of mean was high, revealed that this character was governed by additive gene and selection for this character would be effective.

4.3.7 Fruits per plant

From the current study it was observed that the difference between genotypic and phenotypic variances indicate high environmental influence (Table 5). The highest estimates of phenotypic coefficient of variation was (66.07) and genotypic coefficient of variation was (64.18), which indicated less environmental influences among the genotypes. The heritability estimates for this trait was high (94.36) and genetic advance in percent of mean was also high and it was revealed that this character was governed by additive gene and selection for this character would be effective. Buckseth *et al*. (2012) and Padda *et al*. (2007) reported the similar results for this trait.

4.3.8 Tuber per plant

Significant genotypic variance and phenotypic variance were observed among the genotypes for tuber per plant in pomato (Table 5). Phenotypic and genotypic coefficients of variation were high 44.70 and 44.11 and the difference between phenotypic and genotypic coefficient of variation was low. The heritability estimates for this trait was very high (97.36), genetic advance and genetic advance in percent of mean were found high, revealed that this character was governed by additive gene and selection for this character would be effective.

4.3.9 Fruit length (cm)

The phenotypic and genotypic variance were very low and genotypic co-efficient of variation (25.50) and phenotypic co-efficient variation (26.94) were close to each other, indicating minor environmental influence on this character that would be effective for the improvement of this crop (Table 5). High heritability (89.61) estimate with high genetic advance over percent of mean (49.70) indicate that effective selection may be made for fruit length.

4.3.10 Fruit diameter (cm)

The phenotypic and genotypic variance were very low and genotypic co-efficient of variation (36.75) and phenotypic co-efficient variation (37.47) were close to each other, indicating minor environmental influence on this character that would be effective for the improvement of tomato (Table 5). High heritability (96.19) estimate with moderate genetic advance over percent of mean (74.15) indicated that effective selection may be made for fruit diameter.

4.3.11 Fruit yield per plant (kg)

The phenotypic and genotypic variance found very low (Table 5). The phenotypic coefficient of variation and genotype coefficient of variation were 36.48 and 31.88, respectively for fruit yield per plant, which indicating that significant variation exists among different genotypes which made the trait effective for selection. Similar findings were reported by Brar *et al*. (1998) and Reddy and Reddy (1992) in tomato. Estimation of high heritability (76.36) for fruit yield per plant with high genetic advance percent of mean (57.56) revealed that this character was governed by additive gene and provides opportunity for selecting high valued genotypes for breeding programme and this findings supported by Buckseth *et al*. (2012) and Nardar *et al.* (2007) results.

4.3.12 Tuber yield per plant (kg)

The phenotypic variance found similar with genotypic variance, suggested no influence of environment on the expression of the genes controlling this character (Table 5). The phenotypic coefficient of variation and genotype coefficient of variation were 22.59 and 20.73, respectively for tuber yield per plant, which indicating that close variation exists among different genotypes which made the trait effective for selection. Estimation of high heritability (84.21) for fruit yield per plant with high genetic advance in percent of mean (38.82) revealed that this character was governed by additive gene and provides opportunity for selecting high valued genotypes for breeding programme.

4.3.13 Total yield per plant (kg)

The phenotypic and genotypic variances were low (Table 5). The phenotypic coefficient of variation and genotype coefficient of variation were 28.33 and 25.18, respectively for fruit yield per plant, which indicating that close variation exists among different genotypes which made the trait effective for selection. Estimation of high heritability (79) for fruit yield per plant with high genetic advance in percent of mean (46.11) revealed that this character was governed by additive gene and provides opportunity for selecting high valued genotypes for breeding programme. 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.

4.4 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. Correlation co-efficient between pairs of trait are shown in Table 6 and 7.

4.4.1 Days to first flowering

Days to first flowering had highly significant positive correlation with days to 50% flowering (0.999** and 0.981**) at both genotypic and phenotypic level (Table 6 and 7) and with tuber yield per plant (0.422* and 0.332*) at both level. This character also showed positive but non-significant association with plant height, branches per plant, cluster per plant, fruits per plant and fruit diameter at genotypic and phenotypic levels (0.299, 0.243, 0.207, 0.161, 0.102

Table 6. Genotypic correlation coefficients among different pairs of yield and yield contributing characters for different genotypes of pomato

	D50%F	PH	BPP	CPP	FPC	FPP	TPP	FL	FD	FYP	TuYP	TYP
DFF	0.999**	0.299	0.243	0.207	0.028	0.161	-0.549**	0.065	0.102	-0.153	0.422*	-0.048
D50%F		0.295	0.189	0.162	-0.012	0.126	-0.565**	0.088	0.143	-0.193	0.378*	-0.094
PH			0.738**	0.973**	0.957**	0.935**	0.017	-0.895**	-0.890**	0.820**	0.064	0.771**
BPP				0.908**	0.718**	0.853**	0.432**	-0.557**	-0.498**	0.648**	-0.252	0.542**
CPP					0.982**	1.00**	0.047	-0.853**	-0.862**	0.982**	0.094	0.928**
FPC						0.988**	-0.030	-0.944**	-0.968**	1.00**	0.127	0.963**
FPP							0.052	-0.900**	-0.891**	0.959**	0.087	0.905**
TPP								-0.153	-0.065	-0.065	-0.856**	-0.251
FL									0.999**	-0.869**	0.112	-0.777**
FD										-0.928**	-0.020	-0.861**
FYP											0.236	0.976**
TuYP												0.441**

** = 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 7. Phenotypic correlation coefficients among different pairs of yield and yield contributing characters for different genotypes of pomato

	D50%F	PH	BPP	CPP	FPC	FPP	TPP	FL	FD	FYP	TuYP	TYP
DFF	0.981**	0.185	0.007	0.069	0.044	0.080	-0.418*	0.090	0.074	-0.102	0.332*	-0.024
D50%F		0.166	0.020	0.049	0.030	0.052	-0.399*	0.115	0.097	-0.134	0.267	-0.068
PH			0.475**	0.706**	0.811**	0.824**	0.035	-0.798**	-0.791**	0.634**	0.008	0.597**
BPP				0.732**	0.519**	0.638**	0.284	-0.362*	-0.380*	0.384*	-0.188	0.320
CPP					0.835**	0.880**	0.052	-0.685**	-0.692**	0.617**	0.065	0.594**
FPC						0.926**	-0.038	-0.873**	-0.895**	0.831**	0.112	0.805**
FPP							0.043	-0.811**	-0.852**	0.782**	0.050	0.746**
TPP								-0.164	-0.073	-0.046	-0.788**	-0.213
FL									0.934**	-0.767**	0.119	-0.695**
FD										-0.821**	-0.021	-0.776**
FYP											0.175	0.977**
TuYP												0.380*

** = 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).

and 0.185, 0.0.007, 0.069, 0.080, 0.074, respectively). It had significant negative correlation (-0.549** and -0.418*) with tuber per plant. It showed non-significant negative correlation with total yield per plant (-0.048 and -0.024) at both levels.

4.4.2 Days to 50% flowering

Days to 50% flowering showed significant positive association with days to 50% flowering (0.999** and 0.981**) at both level and with tuber yield per plant (0.422*) at genotypic level (Table 6 and 7). It showed non-significant positive association with plant height (0.295 and 0.166), branches per plant (0.189 and 0.020), clusters per plant (0.162 and 0.049) at both level. Days to 50% flowering exhibited significant negative relationship with tuber per plant (-0.565** and -0.399*) at genotypic and phenotypic level which indicating early flowering reduce tuber yield but late flowering increase tuber yield.

4.4.3 Plant height (cm)

Plant height had highly significant positive correlation with branches per plant (0.738** and 0.475**), clusters per plant (0.973** and 0.706**), fruits per cluster (0.957** and 0.811**), fruits per plant (0.935** and 0.824**), fruit yield per plant (0.820** and 0.634**) and total yield per plant (0.771** and 0.597**) at genotypic and phenotypic levels (Table 6 and 7). It had significant negative relation with fruit length (-0.895** and -0.798**) and fruit diameter (-0.890** and -0.791**) at both levels.

4.4.4 Branches per plant

The number of branches per plant had significant positive correlation with cluster per plant (0.908** and 0.732**), fruits per cluster (0.718** and 0.519**), fruits per plant (0.853** and 0.638**), tuber per plant (0.432**), fruit yield per plant (0.648** and 0.384*) at both levels, respectively and with total yield per plant (0.542**) at genotypic level (Table 6 and 7). It had significant negative correlation with fruit length (-0.557** and -0.362*) and fruit diameter (-0.498** and -0.380*) at both genotypic and phenotypic levels.

4.4.5 Clusters per plant

The number of clusters per plant had highly significant and positive association with fruits per cluster (0.982** and 0.835**), fruits per plant (1.00** and 0.880**), fruit yield per plant (0.982** and 0.617**), plant height (0.973** and 0.706**), branches per plant (0.908** and 0.732**) and total yield per plant (0.928** and 0.594**) at genotypic and phenotypic levels (Table 6 and 7). It also had highly significant negative association with fruit length (-0.853** and -0.685**) and fruit diameter (-0.862** and -0.692**) at both level. It had non-significant and positive association with days to first flowering, days to 50% flowering, tuber per plant and tuber yield per plant at both genotypic and phenotypic levels.

4.4.6 Fruits per cluster

The fruits per cluster showed highly significant and positive association with plant height (0.957** and 0.811**), branches per plant (0.718** and 0.519**), clusters per plant (0.982** and 0.835**), fruits per plant (0.988** and 0.926**), fruit yield per plant (1.00** and 0.831**) and total yield per plant (0.963** and 0.805**) both at genotypic and phenotypic levels (Table 6 and 7). It had highly significant but negative association with fruit length (-0.944** and -0.873**) and fruit diameter (-0.968** and -0.895**) at both levels. It also exhibited non-significant negative association with tuber per plant (-0.030 and -0.038) the genotypic and phenotypic level, respectively. It showed positive correlation with days to first flowering and tuber yield per plant at both levels.

4.4.7 Fruits per plant

Fruits per plant had significant positive correlation with fruits per cluster (0.988** and 0.926**), cluster per plant (1.00** and 0.880**), plant height (0.935** and 0.824**), branches per plant (0.853** and 0.638**), cluster per plant (1.00** and 0.880**), and fruit yield per plant (0.959** and 0.782**) and total yield per plant (0.905** and 0.746**) at both level. It had highly significant but negative association with fruit length (-0.900** and -0.811**) and fruit diameter (-0.891** and -0.852**) at genotypic and phenotypic levels

(Table 6 and 7). It showed positive correlation with days to first flowering, days to 50% flowering.

4.4.8 Fruit length (cm)

Fruit length showed highly significant positive effect on fruit diameter (1.00** and 0.934**) at both level. It showed highly significant negative effect with plant height (-0.895** and -0.798**), branches per plant (-0.557** and -0.362*), clusters per plant (-0.853** and -0.685**), fruits per cluster (-0.944** and -0.873**), fruits per plant (-0.900** and -0.811**), fruit yield per plant (-0.869** and -0.767**) and total yield per plant (-0.777** and -0.695**) at both level (Table 6 and 7).

4.4.9 Fruit diameter (cm)

Fruit diameter showed highly significant positive relation with fruit length (1.00** and 0.934**) at genotypic and phenotypic level (Table 6 and 7). On other hand, fruit diameter was highly significantly negatively associated with plant height (-0.890** and -0.791**), branches per plant (-0.498** and -0.380*), clusters per plant (-0.862** and -0.692**), fruits per cluster (-0.968** and -0.895**), fruits per plant (-0.891** and -0.852**) and fruit yield per plant (-0.928** and -0.821**) and total yield per plant (-0.861** and -0.776**) at both levels. It was insignificantly positively correlated with days to first flowering.

4.4.10 Fruit yield per plant (kg)

In general, fruit yield is the main target of improvement. Thereby its correlation study is utmost important. From Table 6 and 7 it was observed that fruit yield per plant was strongly and positively correlated with plant height (0.820** and 0.634**), branches per plant (0.648** and 0.384*), cluster per plant (0.982** and 0.617**), fruits per cluster (1.00** and 0.831**), fruits per plant (0.959** and 0.782**) and total yield per plant (0.976** and 0.977**) at both genotypic and phenotypic level. Fruit yield per plant showed strong negative association

with fruit length (-0.869** and -0.767**) and fruit diameter (-0.928** and -0.821**) at both genotypic and phenotypic level.

4.4.11. Tuber yield per plant (kg)

Significant positive correlation was observed of tuber yield per plant with days to first flowering (0.422* and 0.332*) at genotypic and phenotypic level and total yield per plant (0.441** and 0.380*) at both levels.

4.4.12 Total yield per plant (kg)

Total yield per plant had significant and positive association with plant height (0.771** and 0.597**), branches per plant (0.542** and 0.320), clusters per plant (0.928** and 0.594**), fruits per cluster (0.963** and 0.805**), fruits per plant (0.905** and 0.746**), fruit yield per plant (0.976** and 0.977**) and tuber yield per plant (0.441** and 0.380*) at both levels.

4.5 Path coefficient analysis

The direct and indirect effects of yield contributing characters on yield were worked out by using path analysis. Here total yield per plant was considered as effect (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 8.

4.5.1 Days to first flowering

From Table 8, days to first flowering had negative direct effect on total yield per plant (-0.067) which is contributed to result insignificant negative genotypic correlation with yield per plant (-0.048). It had positive indirect effect on total yield per plant via days to 50% flowering (0.154), tuber per plant (0.045) and tuber yield per plant (0.09).

Table 8. Path coefficient analysis showing direct and indirect effects of different characters on yield of pomato

	DFF	D50%F	PH	BPP	CPP	FPC	FPP	TPP	FL	FD	FYP	TuYP	Genotypic correlation with yield
DFF	**-0.067**	0.154	0.004	0.094	0.000	0.024	-0.131	0.045	-0.027	-0.069	-0.14	0.09	-0.048
D50%F	-0.094	**0.144**	-0.008	0.122	0.002	-0.022	-0.052	0.074	-0.005	0.039	-0.18	0.08	-0.094
PH	0.004	0.014	**-0.075**	0.042	-0.003	-0.306	0.479	-0.344	0.156	0.582	0.76	0.01	0.771**
BPP	-0.037	0.078	-0.015	**0.323**	0.001	-0.021	0.007	0.032	-0.033	0.056	0.60	-0.06	0.542**
CPP	0.002	-0.042	-0.048	-0.047	**-0.007**	-0.148	0.264	-0.043	0.088	0.283	0.91	0.02	0.928**
FPC	0.007	0.010	-0.081	0.016	-0.003	**-0.324**	0.565	-0.087	0.188	0.656	0.94	0.03	0.963**
FPP	0.023	-0.015	-0.076	0.003	-0.003	-0.340	**0.543**	0.021	0.171	0.636	0.89	0.02	0.905**
TPP	-0.014	0.004	0.075	0.045	0.003	0.342	-0.518	**-0.197**	0.433	-0.616	-0.06	-0.19	-0.251
FL	-0.011	-0.010	0.081	-0.022	0.003	0.344	-0.555	-0.043	**-0.178**	0.043	-0.80	0.02	-0.777**
FD	0.005	0.015	-0.078	0.032	-0.002	-0.206	0.579	-0.074	-0.534	**-0.122**	-0.86	0.00	-0.861**
FYP	-0.014	-0.030	0.091	-0.042	0.008	0.754	-0.825	-0.073	-0.178	-0.023	**0.92**	0.05	0.976**
TuYP	0.07	0.030	-0.091	0.036	-0.006	-0.224	-0.234	-0.097	0.288	0.556	0.32	**0.22**	0.441**

Residual effect: 0.311

* = 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, TPP=Tuber per plant, FL = Fruit length (cm), FD = Fruit diameter (cm), FYP = Fruit yield per plant (kg), TuYP = Tuber yield per plant (kg).

4.5.2 Days to 50% flowering

Days to 50% flowering had positive direct effect (0.144) on total yield per plant. Days to 50% flowering had positive indirect effect on total yield through branches per plant (0.122), tuber per plant (0.074), fruit diameter (0.039) and tuber yield per plant (0.08). But it had negative indirect effect on total yield through days to first flowering (-0.094), fruits per cluster (-0.022), fruits per plant (-0.052) and fruit yield per plant (-0.18) (Table 8).

4.5.3 Plant height (cm)

Plant height had insignificant negative direct effect (-0.075) on total yield per plant (Table 8). It had positive indirect effect on total yield via branches per plant (0.042), fruits per plant (0.479), fruit length (0.156), fruit diameter (0.582) and fruit yield per plant (0.76) which resulted significant positive genotypic correlation with total yield per plant (0.771**). As plant height indirectly increase tuber yield per plant therefore, genotype can be select based on plant height to develop new variety. On the other hand, plant height showed negative indirect effect on total yield per plant via fruits per cluster (-0.306), tuber per plant (-0.344).

4.5.4 Branches per plant

Branches per plant had positive direct effect on total yield per plant (0.323) and it had also positive correlation with yield per plant (0.542**). This trait had positive indirect effect on total yield through days to 50% flowering (0.078), tuber per plant (0.032), fruit diameter (0.056), fruit yield per plant (0.60) (Table 8). On the other hand negative indirect effect was found through days to first flowering (-0.037), plant height (-0.015), fruits per cluster (-0.021), fruit length (-0.033) and tuber yield per plant (-0.06).

4.5.5 Clusters per plant

Clusters per plant had negative direct effect (-0.007) on total yield per plant and significant positive correlation with yield per plant (0.928**). It had positive

indirect effect on total yield per plant through days to first flowering (0.002), number of fruits per plant (0.264), fruit length (0.088), fruit diameter (0.283), fruit yield per plant (0.91) and tuber yield per plant (0.02). This trait showed negative indirect effect on total yield via days to 50% flowering (-0.042), plant height (-0.048), number of branches per plant (-0.047), number of fruits per clusters (-0.148) and tuber per plant (-0.043) (Table 8).

4.5.6 Fruits per cluster

Fruits per cluster showed negative direct effect (-0.324) on total yield per plant. It showed positive indirect effects through days to first flowering (0.007), days to 50% flowering (0.010), branches per plant (0.016), number of fruits per plant (0.565), fruit length (0.188), fruit diameter (0.656) and fruit yield per plant (0.94) and the results significant positive genotypic correlation with total yield (0.963**). It had negative indirect effect on plant height (-0.081), number of cluster per plant (-0.003), (Table 8).

4.5.7 Fruits per plant

Number of fruits per plant showed positive direct effect (0.543) on total yield per plant. It had also significant positive correlation with yield per plant (0.905**) (Table 8). Number of fruits per plant had positive indirect effects on total yield through days to first flowering (0.023), number of branches per plant (0.003), tuber per plant (0.021), fruit length (0.171), fruit diameter (0.636), fruit yield per plant (0.89) and tuber yield per plant (0.02). It had negative indirect effect on total yield per plant via days to 50% flowering (-0.015), plant height (-0.076), number of clusters per plant (-0.003), number of fruits per cluster (-0.340).

4.5.8 Fruit length (cm)

Fruit length had negative direct effect (-0.178) on total yield per plant. It had also significant negative correlation with yield per plant (-0.777**). This trait had

indirect positive effect on total yield per plant via plant height (0.081), fruits per cluster (0.344), fruit diameter (0.043) and tuber yield per plant (0.02). Fruit length showed indirect negative effect on total yield per plant though days to first flowering (-0.011), days to 50% flowering (-0.010), branches per plant (-0.022), fruits per plant (-0.555), tuber per plant (-0.043), fruit yield per plant (-0.80) (Table 8).

4.5.9 Fruit diameter (cm)

Fruit diameter showed negative direct effect (-0.122) on total yield per plant. It had highly significant negative correlation with yield per plant (-0.861**). It had positive indirect effect on total yield per plant through, branches per plant (0.032), fruits per plant (0.579).

The genotypic residual effect was 0.311, which indicated that there were other responsible traits for contribution to yield per plant but not taken into consideration in the present study.

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

The present experiment 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 in RCBD design with three replication to study the variability, character association and path analysis of developed pomato genotypes based on thirteen characters. The salient findings of the present study have been summarized on the basis of the characters studied.

Analyses of variance showed the presence of significant variation among the tested genotypes for all the characters studied. Days to first flowering was found highest (57.67) in both G5 and G6. The accession G2 was the earliest to flower at 47.33 days. Days of 50% flowering was found the highest in G5 and the accession G2 was the earliest to flower at 47.33 days. The maximum plant height was recorded for the genotype G7 (99.77 cm) and the lowest plant height was recorded for G11 (53.07 cm). Branches per plant were found the highest in G7 (9.73) and lowest in G9 (4.80) pomato genotypes. Clusters per plant were found highest in grafted genotype G7 (27.40) and the lowest in G11 (9.67). A lowest fruit per cluster was found in G11 (3.39) and the highest in G4 (13.10). Pomato genotype G7 (246.33) beared the highest number of fruits per plant and G12 (39.67) performed the lowest value. Tuber per plant were found the highest in G2 (43.33) and lowest in G7 (16.00). The highest fruit length was found in G5 (4.93 cm) and the lowest fruit length was found in G4 (2.3 cm). The highest fruit diameter was found in G5 (6.1 cm) and the lowest in G10 (2.00 cm). Fruit yield per plant were found the highest in G4 (1.92 kg) and the lowest fruit yield per plant was found in G6 (0.80 kg). Tuber yield per plant were found the highest in G11 (0.62 kg) and the lowest tuber yield per plant was found in G3 (0.31 kg). In pomato genotype total yield per plant were found the highest in G4 (2.45 kg) and the lowest total

yield per plant was found in G3 (1.14 kg). Fruit yield per plant were found the highest in BARI tomato-11 (1.77 kg) and the lowest fruit yield per plant was found in BARI tomato-3 (1 kg) in control tomato. Tuber yield per plant were found the highest in cardinal (0.85 kg) the lowest tuber yield per plant was found in pakri alu tel (0.52 kg) in control potato.

The phenotypic variance was higher than genotypic variance in all the characters studied. The phenotypic coefficients of variation were also higher than genotypic coefficients of variation in all the characters studied. Phenotypic coefficients of variation were also close to genotypic coefficients of variation for most of the characters except branches per plant, clusters per plant fruit yield per plant. High heritability (>60%) was observed for the characters like days to first flowering, plant height, clusters per plant, fruits per cluster, fruits per plant, tuber per plant, fruit length, fruit diameter, fruit yield per plant, tuber yield per plant and total yield per plant. The high heritability coupled with high genetic advance in percent of mean observed in plant height, branches per plant, clusters per plant, fruits per cluster, fruits per plant, tubers per plant, fruit length, fruit diameter, fruit yield per plant, tuber yield per plant and total yield per plant which indicating that additive gene involved in the inheritance of these character and suggested that effective selection may be done for these characters. Moderate heritability coupled with low genetic advance in percent of mean was observed in days to 50% flowering.

Plant height, branches per plant, clusters per plant, fruits per cluster, fruits per plant, fruit yield per plant and tuber yield per plant showed significant and positive correlation with total yield per plant at both genotypic and phenotypic levels. Significant and positive genotypic and phenotypic correlation was observed between days to first flowering with days to 50% flowering, tuber yield per plant. Significant and positive correlation was observed between plant height and branches per plant, clusters per plant, fruits per cluster, fruits per plant and fruit

yield per plant. Branches per plant was significantly and positively correlated with cluster per plant, fruits per cluster, fruits per plant, tuber per plant and fruit yield per plant. Significant positive genotypic and phenotypic correlation was observed by fruits per cluster with fruits per plant and fruit yield per plant. Fruit per plant was positively and significantly correlated with fruit yield per plant. Fruit length showed highly significant and positive association with fruit diameter. Fruit yield per plant positively and significantly associated with plant height, branches per plant, clusters per plant, fruit per cluster and fruits per plant.

Total yield per plant showed the highest positive direct effect (0.92) with fruit yield per plant. Days to 50% flowering, branches per plant, fruits per plant, tuber yield per plant also showed positive direct effect on total yield per plant. On the other hand negative direct effect on total yield per plant showed by days to first flowering, plant height, clusters per plant, fruits per cluster, tuber per plant, fruit length and fruit diameter. The highest indirect effect of fruit per cluster observed with total yield per plant via fruit yield per plant. Fruit yield per plant showed high direct effect on total yield indicated that direct selection for this trait might be effective and there is a possibility of improving total yield per plant through selection based on those characters.

From the findings of the present study, it could be concluded, firstly, yield improvement in grafted pomato plant would be achieved through selection of the characters like, plant height, branches per plant, clusters per plant, fruits per cluster, fruits per plant, tubers per plant, fruit length, fruit diameter, fruit yield per plant, tuber yield per plant and total yield per plant as they have high heritability coupled with high genetic advance in percent of mean. Secondly, the characters, plant height, branches per plant, clusters per plant, fruits per cluster, fruits per plant, fruit yield per plant and tuber yield per plant showed significant and positive correlation with fruit yield per plant at both genotypic and phenotypic levels. This

results suggested that total yield per plant can be increased by improving these characters. Thirdly, the total yield improvement was associated with the characters fruit yield per plant, days to 50% flowering, branches per plant, fruits per plant, tuber yield per plant, branches per vine, fruit length and fruit diameter, as they showed positive direct effect on total yield per plant. Lastly, 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.

According to the highest total yield per plant, the best combination was found in G4 (Asterix x BARI Tomato 11) followed by G7 (Diamant x BARI Tomato 11), G10 (Cardinal x BARI Tomato 11). It means BARI Tomato-11 showed the best compatibility with all exotic potato varieties than the local varieties and could be recommended as a scion for grafting to the pomato growers with all potato varieties.

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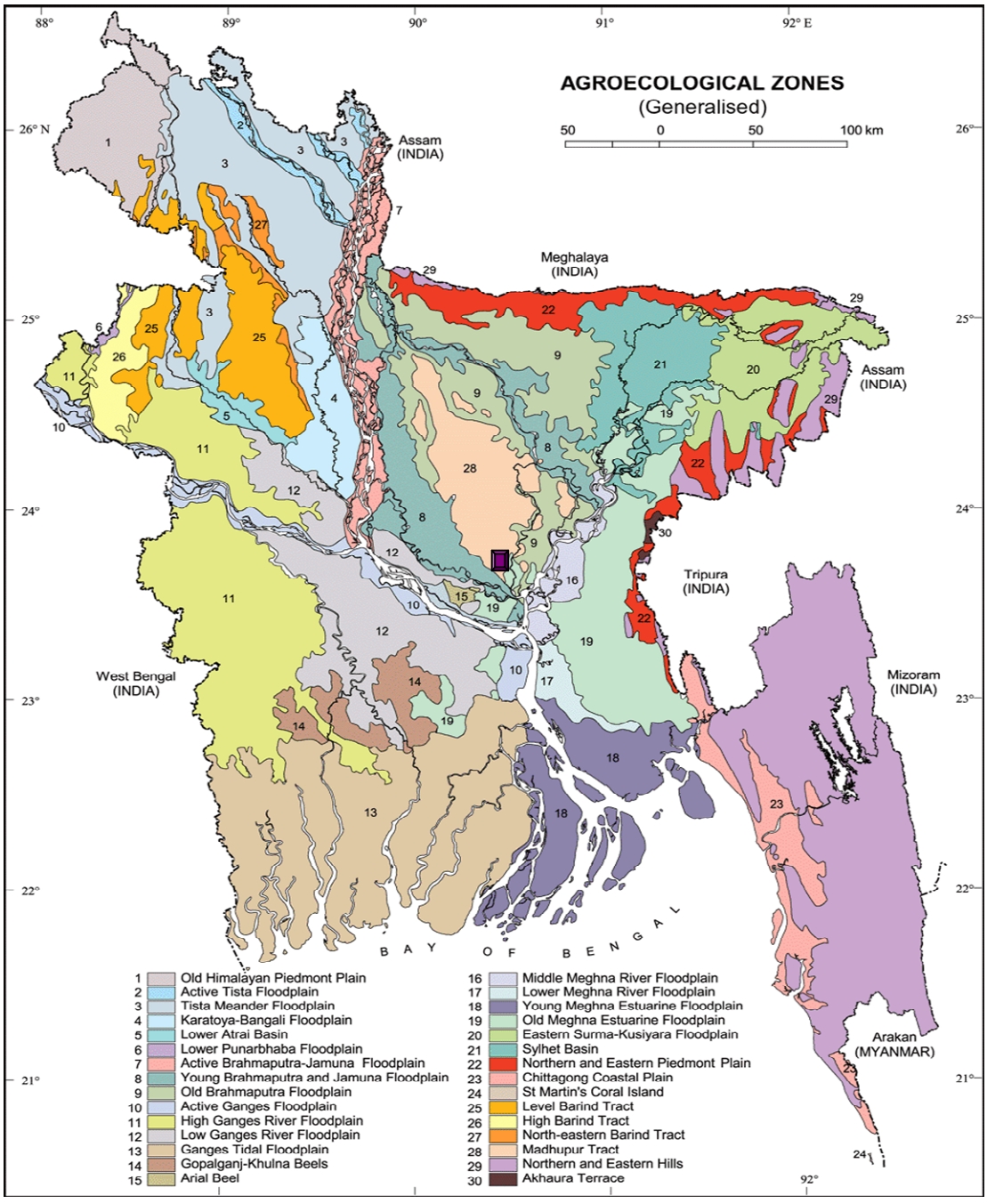
APPENDICES

APPENDICES

Appendix I. Map showing the experimental site under the study



The experimental site under study

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

Month	Year	Monthly average air temperature (^{o}C)			Average relative humidity (%)	Total rainfall (mm)	Total sunshine (hours)
		Maximum	Minimum	Mean			
Nov.	2013	34.36	18.4	26.38	77	Trace	218.50
Dec.	2013	32.52	16.30	24.41	69.92	Trace	216.50
Jan.	2014	29.1	13	21.05	79.0	Trace	212.50
Feb.	2014	28.00	11.2	19.60	72	4.0	195.00
Mar.	2014	33.9	12.2	23.05	55	3.0	225.50
Apr.	2014	34.22	16.5	25.36	67	4.0	235.50

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

Appendix III. Characteristics of field soil

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University, Dhaka-1207
AEZ	Madhupur tract (28)
General soil type	Shallow red brown terrace soil
Land type	High land
Soil series	Ceata
Topography	Fairy leveled
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of the initial soil

Characteristics	Critical value
% Sand	27
% Silt	43
% Clay	30
Textural class	Silty-clay
p^H	6.00-6.63
Organic carbon (%)	0.45
Organic matter (%)	0.84
Total N (%)	0.46
Available P (ppm)	21.00
Exchangeable K (mg/100 g soil)	0.41
Available S (ppm)	45

Source: Soil Resources Development Institute (SRDI)

Appendix IV. Mean performance of control tomato for yield and related characters

Genotype	DFF	D50%F	PH	BPP	CPP	FPC	FPP	FL	FD	FYP
BARI Tomato-11	51.33	56	83.1	12.7	12	14.6	166.67	2.16	1.6	1.77
BARI Tomato-2	47	52	72.7	5.59	7.667	5.33	65	3.3	4.33	1.07
BARI Tomato-3	51	56.33	83.1	10	8.667	4.56	68.667	4.1	4.63	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), FYP = Fruit yield per plant (Kg).
T1= BARI Tomato 11, T2=BARI Tomato 2, T3=BARI Tomato 3

Appendix V. Mean performnce of control potato for yield aand related charcaters.

Genotype	PH	BPP	LPP	SPP	TPP	TuYP
Pakri Alu (Tel)	77.2	3	130	14.1	55.3	0.52
Asterix	80.3	8.22	160	9.5	23.3	0.8
Daimant	65.3	4.87	132	10	22	0.76
Cardinal	71.7	6.83	130	10.8	25.3	0.85

PH = plant height, BPP = branches per plant, LPP = leaves per plassnt, SPP = shoot per plant, TPP= tuber per plant, TuYP = tuber yield per plant
P1=Pakri Alu Tel, P2=Asterix, P3=Diamant, P3=Cardinal