STUDIES ON YIELD CONTRIBUTION AMONG GRAFTED AND NON GRAFTED SUMMER TOMATO SEEDLINGS

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STUDIES ON YIELD CONTRIBUTION AMONG GRAFTED AND NON GRAFTED SUMMER TOMATO SEEDLINGS

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CERTIFICATE

This is to certify that the thesis entitled ***"STUDIES ON YIELD CONTRIBUTION AMONG GRAFTED AND NON GRAFTED SUMMER TOMATO SEEDLINGS"*** *submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE in HORTICULTURE****, embodies the result of a piece of authentic research work carried out by* **NAYMUL HASSAN,** *Registration No.* ***18-09111****under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

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ABSTRACT

An experiment was conducted at vegetable research farm of Horticulture Research Centre, Bangladesh Agricultural Research Institute, Gazipur in the year 2019 to assess the resistance level of rootstocks against Bacterial wilt and to evaluate grafting compatibility, seedling survivability, plant stand, growth, development, and yield at field condition for summer tomato production. Six wild rootstocks were taken to study the resistance against Bacterial wilt and most yielding rootstock respectively and BARI hybrid Tomato-8 was grafted on to six rootstocks having practiced with Integrated Pest Management approaches for evaluating field performance. The experiment consisted of following seven treatments, T_1= WSS02 (Tomato grafted onto *S. sisymbriifolium)* T_2= WSM05 (Tomato grafted onto *S. torvum*) T_3= WSM06 (Tomato grafted onto khag-1) T_4= WSM07 (Tomato grafted onto Khag-2) T_5= WSM08 (Tomato grafted onto Khag-3) T_6= WSM04 (Tomato grafted onto EG 203) T_0= BARI Hybrid tomato-8 (Control). Two rootstocks were showed resistant against Bacterial wilt and yield showed better than control as well as any other treatments. T_1 (WSS02-*S. sysimbriifolium) &* T2(WSM05 *S. torvum*) found to be the best where higher yield was obtained from the treatment T2(WSM05 *S. torvum*) (34 ton/h) and T_1(WSS02-*S. sysimbriifolium)* (29 ton/h). Therefore, tomato may be grafted onto *S. torvum* for higher yield & least wilt infestation. Thus, it may be suggested for better yield and safe tomato production in the wilt prone areas of Bangladesh during summer.

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ABBREVIATIONS AND ACORONYMS

AEZ	Agro-ecological Zone
Agric.	Agricultural
ANOVA	Analysis of Variance
BARI	Bangladesh Agricultural Research Institute
Biol.	Biology
CV	Coefficient of variance
DAS	Days After Sowing
et al.	And others
Ex.	Experiment
FAO	Food and Agriculture Organization of the United Nations
g	Gram
Hort.	Horticulture
i.e.	That is
J.	Journal
Kg	Kilogram
LSD	Least Significance difference
mm	Millimeter
RCBD	Randomized Complete Blocked Design
Res.	Research
SAU	Sher-e-Bangla Agricultural University
Sci.	Science
spp.	Species
Technol.	Technology
UNDP	United Nations Development Programme
Viz.	Namely
%	Percent
LAI	Leaf Area Index
RGR	Relative Growth Rate
NAR	Net Assimilation Rate
MSTAT	Michigan State University Statistical Package for Data Analysis
etc.	Etcetera
TSS	Total Soluble Solids
IPM-CRSP	Integrated Pest Management- Collaborative Research Support Program

CHAPTER I
INTRODUCTION

Tomato (*Solanum lycopercicum*) is one of the most popular and widely consumed vegetable crops in the world due to its valuable nutritional components like ascorbic acid, β-carotene, and phenolic compounds to the human diet (Rouphael *et al*., 2010). The consumption of tomato is not only limited to curry or salad, rather it is widely used as ketchup, sauce, soup, and puree. In Bangladesh, it is the third most important vegetable after potato and brinjal in terms of both production and area (BBS, 2015). Taking the suitable number of fresh tomatoes or processed tomato products in a systematic way has been inversely linked to the enhancement of widespread human diseases (Agarwal and Rao, 1998; Erdman *et al*., 2009 and Prakashet *et al*., 2014) and to an increase in the levels of plasma lipid peroxidation (Giovannucci, 1999 and Balestrieriet *et al*., 2004). This protective effect has been predominantly imposed to the carotenoid components of the fruits specially lycopene and β-carotene which act as antioxidants in detoxifying free radicals (Di Mascio *et al*., 1989; Stahl and Sies, 1996; Clinton, 1998 and Erdman *et al*., 2009).

Usually, tomato is grown in winter in Bangladesh for prevailing congenial environment for optimum growth and yield. Its production in summer is limited due to high temperature, heavy rainfall, and prevalence of severe diseases. But the production of summer tomato is highly remunerative and need oriented. Tomato producers are facing critical problems related to soil borne diseases and especially during summer that seriously impacting the yield and quality of fruit (Hasna *et al*., 2009; Cramer *et al*., 2011 and McAvoy *et al*., 2012).

In winter, this crop is mostly cultivated in Bangladesh to prevail adaptable atmospheric circumstance having national average yield 13.69 tons/ha (Anon., 2018, YASB-Published April 2019). But there is scarcity in summer period. BARI has developed four varieties of heat tolerant hybrid tomato so far. The popularity of these varieties is gradually increasing among the tomato cultivators. But comparing with the other tomato growing countries yield is very low in Bangladesh due to lack of good variety, pest, and diseases problem. This poor yield can be increased by adding high yielding new tomato variety and by impeding insect, pest, and diseases infestation problem. The most destroying and threatened pest and diseases for tomato production are: Whitefly (*Beminsia tabaci*) caused virus transmission, Tomato fruit worm/borer (*Helicover armigera*), Common army worm (*Spdoptera litura*), Tomato leaf miner (*Tuta absulata*), Tomato Leaf miner (*Liriomyza bryoniae*), Black leaf mold or Cercospora leaf mold (*Pseudocercospora fuligena*), Tomato bacterial spot (*Xanthomonus* Sp.), Bacterial wilt (*Ralstotia solanacearum*), Late blight (*Phytopthora infestans*), Southern blight (*Sclerotium rolfsi*), and root knot nematode-RKN (*Meloidogyne* sp.) prevail in the both summer and winter season.

During summer growers use toxic pesticide indiscriminately to protect the crop from insects and diseases that resulted poisonous tomato fruit which causes health hazard and diseases and wastes money. To combat this problem only resistant variety is the credible tool though still such variety is not available in the world. Tomato seedlings raising under nylon net, grafted seedlings (grafting of tomato plants onto wild or resistant species), use of yellow sticky trap, apply of tricho compost, spraying of neem extract or oil (Indian lilac- *Azadirachta indica*), using of sex pheromone trap against tomato fruit borer are the integrated worthy approach as an alternative means to lessen previously mentioned problem in production of summer tomato. To minimize this threat in last phase of IPM project ‘Grafting Technology’ was developed and during last couple of years, it has worked very effectively. But recently it was observed that rootstocks are being shown some extent susceptible to BW. Besides, climate change specially, high heat and fluctuation of temperature with humidity are also affecting the grafting success and prevailing many diseases. Consequently, new, or alternate rootstocks are needed and grafting techniques may be adjusted. However, grafting technology may play a vital role to make summer tomato production successful.

In Bangladesh, there is a great demand for summer tomato has a huge demand in Bangladesh, but bacterial wilt greatly affects its production and even complete crop failure may occur at the flowering stage (Rahman and Hogue, 1986). Grafting is an extensive method which combines a desirable shoot cultivar (scion) with a root system (rootstock) that results in a hybrid plant with desirable horticultural or agronomic traits.

Hossain *et al*. (1999) reported that in tomato, incidence of bacterial wilt ranged from 3.33 to 36.76%. The bacterium has wide host range and bacterial wilt causes the extensive crop damage which varies greatly depending upon the bacterial strain, geographical region, host variety, and the population of the bacteria in the soil (Hsu, 1991). Besides, high temperature and soil wetness are also greatly responsible for the development of bacterial wilt. This disease is found very common in high lands which are not overflowed and solanaceous crops are cultivated continuously without crop rotation. Kitchen gardens are normally non flooded areas and generally, this severe problem also occurs in this area. In kitchen gardens of the Bangladesh Agricultural Research Institute (BARI) and Bangladesh Agricultural University (BAU) it has been noticed that in some cases 100% of the tomato plants have died because of wilt problems (Ali, 1993).

Grafting on vigorous rootstocks also develops the growth, quality, yield of plants and even diseases problem which improve tolerance against abiotic stresses (Rivero *et al*., 2003; Louws *et al*., 2010; Schwarz *et al*., 2010; Rivard and Louws, 2011). Grafting inconsistency is a major challenge especially when rootstocks and scions are different in growth vigor. That is why, grafting success among the selected rootstocks (EG190, EG195, EG219 and EG203) and selected F_1 hybrid tomato cultivars (Monica and Assila) have finite information. Plant growth, yield, fruit quality and economic feasibility of the combinations under question are also yet to be explored.

Therefore, this study was designed to evaluate grafting compatibility and success among rootstocks and scion. The study was also undertaken to assess the growth, quality and yield comparison among grafted and non-grafted seedlings of summer tomato. The success of grafting mostly depends on rootstocks selection. For this reason, to lessen soil related problems the main priority should be the selection of suitable rootstocks with desired trait. In view of the role of grafting technique in summer tomato production, the aim of the present study was to find out suitable rootstock by comparing yield among grafted and non-grafted summer tomato as well as to minimize wilt problem during summer tomato production. The objectives of the study were:

1. To avoid Bacterial wilt disease of summer Tomato.
2. To find out suitable grafted seedlings for increasing yield.
3. To popularize grafting technology among Tomato growers.

CHAPTER II
REVIEW OF LITERATURE

Tomato (*Solanum lycopersicum*) is a common and one of the most essential vegetables of Bangladesh as well as all over the world. It is abundant with a lot of natural antioxidants, lycopene, and bioactive compounds. Numerous experiments have been conducted in various parts of the world to find out the grafting success, yield, and suitability of some vegetables like tomato, brinjal, watermelon and different rootstocks to control the prevalence of soil borne diseases, particularly wilt disease. Some of the relevant literatures related to present research are reviewed here.

Hossain *et al*. (2019) reported that grafted and non-grafted plants existed a wide variation for growth, yield, and fruit quality of tomato. Most of the traits of growth (except for plant height), yield and fruit quality were significantly influenced by grafting. The individual fruit weight, total yield per plant and hectare had the significant topmost values (57.88 g, 2.68 kg and 60.87 ton, respectively) of the plants grafted on the Sunchalo than the non-grafted ones and other two rootstocks.

Milenkovic *et al*. (2019) narrated that shading and grafting influenced the total tomato yield in different ways depending on the tomato cultivars. Shading tomatoes, regardless of cultivar and grafting significantly influenced the marketable yield of tomato fruit due to a reduction in physiological disorders. Sugar content, including both fructose and glucose is lower in grafted plants. By providing alternative strategies, like shading with colored nets and grafting provides higher fruit yields and avoiding or reducing a decrease in tomato quality which caused by environmental stresses like excessive radiation and temperature in the summer cropping season.

Hossain *et al*. (2019) the Sunchalo rootstocks showed better performance as to compare to most of the parameters than the brinjal and the wild tomato rootstocks. For growers, postharvest technologist, nutritionists, and consumers Such information might be beneficial.

Ganiyu *et al*. (2018) stated that in integrated pest management program for tomato, the use of resistant rootstocks is an important component to get maximum yield. (Rivard *et al.*, 2012). So, implementation of this technology may be highly beneficial, to reduce crop losses caused by *R. solanacearum* infections to tomato crops.

Rashid *et al.* (2000) conducted a study on bacterial wilt in sick bed to evaluate the reaction of rootstocks of wild *Solanum* spp. and cultivated eggplant variety against bacterial wilt. *Solanum torvum, S. sisymbriifolium, S. melongena* (Var. Khotkhotia long) and *S. melongena* (Var. Sufala) exhibited 0.00, 0.00, 19.44 and 100% wilt incidence, respectively.

Rootstock-scion combination influenced the plant growth rate greatly in grafting. Grafting can be used to promote faster growth rate of less vigorous tomato cultivars, only if an appropriate rootstock x cultivars combination will be identified. (Balliu *et al*., 2007)

Yield is positively affected in tomato plants by grafting due to the increase in fruit index, number of fruits/truss and fruit weight. Therefore, grafted plants offer higher profits by increasing yield consequently (Turan *et al*., 2011).

Gioia *et al*. (2010) vegetative growth can be increased using a vigorous rootstock such as ‘Maxifort F_1’, combined with ‘Cuore di Bue’ as a scion, in terms of LA and LFW. As a result, there is an overall increase promoting in photosynthetic area (LAR and LWF). Even without any soil-borne diseases or abiotic stress conditions, this resulted in marketable yields at a high range. In terms of TSS, TA, TSS/TA ratio, or fruit DM, or in terms of sensory properties, the increased yield gained from grafted plants was not accompanied by any reduction in fruit quality. Time of harvest or year, only vitamin C contents were consistently decreased in the fruits which are from grafted plants, regardless of rootstock combination.

Mayne (1999) mentioned that because of longer harvesting period, grafted tomato on vigorous rootstocks and cultivated tomato under tunnel was economic for high quality and yield.

An experiment was conducted for the selection of tomato rootstock which can resist different soil borne diseases. Accessions of 82 tomato were inoculated artificially with *Fusarium oxysporum*, the causal organism of *Fusarium* wilt and evaluated under field conditions. Through pedigree selection, rootstocks were selected to resist disease those had good grafting affinity and high resistance to tomato southern bacterial wilt (*R. solanacearum*) and *Fusarium* wilt. On that rootstock, different scions were grafted which resulted in disease resistance, developed quality and increased yield from 18.95-50.00% (Huang *et al*., 1999).

Tomato scions were grafted on *Solanum torvum* and eggplant rootstocks and there was a great percentage of successful grafts and huge amount of flowering (Rajendra *et al*., 1975).

Hossain *et al.* (1999) mentioned that *Solanum sisymbriifolium* and *S. torvum* were bacterial wilt resistant. He also stated that for grafting, *S. torvum* was more appropriate than *S. sisymbriifolium* because it contains less spines on leaves and stems.

Since 1930s, Japanese cultivators have used eggplant grafting on rootstocks of resistant wild *solanum*. Nearing 95% commercial eggplant cultivators of Japan indicated to use eggplant grafting in 1990s. During 1950s to eliminate soil borne diseases, scientists of Japan initiated grafting technique to produce tomato. But, due to hollow fruit production with not enough comestible pulp the technique did not become much popular (Ali *et al*., 1994).

In (1890), bacterial wilt of solanaceous plants was first observed by Smith and its causal organism *Pseudomonas solanacearum* E-F Smith was first described by him (1896). The pathogen provides severe yield reduction by creating severe disease in chili, eggplant, potato, tomato as well as other solanaceous vegetables (Rao *et al*., 1976, Gigard *et al.*, 1993).

Islam (1992) stated that five species of root knot nematode (*Melodogyne incognita*) resistant wild *Solanum* were evaluated in Bangladesh. Their susceptibility was graded on the development of nematode and gall in root systems. It was observed that *S. sisymbriifolium* was found as resistant, *S. indicum* and *S. suranthense* as susceptible and *S. integrifolium S. insanum* as highly susceptible. *S. sisymbriifolium*, is a cultivated eggplant variety, was found as a compatible for grafting. To reduce the severity of root knot disease it was found to be an effective rootstock for grafting with susceptible eggplant.

In China, Lu *et al.* (1992) stated that main local tomato cultivars grafted with wild one controlled tomato bacterial wilt 100%. Further, by 120.9; 80.5 and 78.6% when three wild rootstocks (Ch-2-26, Ch-2-25 and Ch- 2-21) were used in tomato grafting.

Ali (1991) mentioned that use of the *Solanum* sp. directly as rootstock has various problems such as slow growth of seedling, low post grafting affinity, low economic yield of scion and susceptible to high or low temperature etc.

Hinata (1986) stated that bacterial wilt, Fusarium wilt and nematodes are the major limiting factors inhabited tomato production all over the world. Gall information indicates the infection by root-knot nematode in root system which ultimately makes the plant weak. Consequently, it affects the growth and yield. Nematode infection helps the wilt to access easily which results in organisms like bacteria and fungi.

By encouraging wilt incidence, high humidity and rainfall reduced the survival rate of tomato plant reported by Bar-Tsur *et al*. (1985).

In Assam, an experiment was undergone on bacterial wilt of tomato related to some environmental parameters. It was found that there was a significant correlation among the span of bacterial wilt and temperature of soil, air, and total rainfall. small variations in an individual environmental parameter caused variations in wilt incidence. There was no correlation between relative humidity and wilt incidence. A maximum air temperature from 26-30°C was accompanies by soil temperature of 25-30°C. Monthly rainfall ranges from 200-300 mm is favorable for the growth and multiplication of bacteria and causes wilt incidence (Boro *et al*., 1996).

Granges *et al*. (1998) reported that grafted tomato using corky gave 65% increased yield. Higher mineral salt contents with slightly lower dry matter found in tomatoes of grafted plants. No influence on vitamin C content found in yield of grafted plants. It was also reported that soil steaming increased the yield of non-grafted plants by 48%, while plant vigor increased but by using corky root infection rate cannot be reduced.

To compare different rootstock, some studies were undertaken in Germany. Tomato cultivars namely Capita, Ferrai, Riwi and Culina were grafted on wild tomato rootstock, and it was found that comparing with non-grafted plants, yield was increased by 15-35%. It was also mentioned that for ensuring the suitability as rootstock for cv. Capita, two wild tomato crosses (*Lycopersicon esculentum* x *L. hirsutam*), and two cultivars (Corella and Kyndia) were evaluated. Besides, increased yields without changes in quality were the result of grafting on wild tomato (Kell and Jaksch., 1998).

An experiment was undergone in Turkey by Vuruskan and Yanmaz (1991) on the effects of different grafting methods on grafting success and yield of eggplant or tomato graft combination. It was noticed that success in grafting was respectively obtained 83.3, 69.7 and 43.7% for cleft, whip, and tongue. Besides, grafting enhanced yield by 39-67% and increased total number of fruits by 58-28% compared to control.

Alam *el al*. (1995) found that grafted plants provide the lowest borer infested fruits and higher yield significantly compared to normal ones. Researchers used *S. torvum*, *S. sisynibrifollium* and *S. cimphiclipIoid* as rootstock.

It was mentioned that some wild *Solanum* sp. are being used as rootstock of eggplant directly or can be used as breeding materials to exploit resistance (Purseglove, 1974).

Winsted and Kelman (1960) narrated that during mid-summer in North Carolina, bacterial wilt perishes 50% of eggplant.

In many countries, tomato yellow leaf curl virus (TYLCV) acts as a limiting factor for tomato reported by Polizzi and Asero (1994). Moreover, Lal and Singh (1961) reported that TYLCV disease was a severe problem in all over the India and yield loss was so high almost 100%.

From the above review it is found that bacterial wilt and root knot nematode make a great damage to tomato. BARI released some tomato varieties which are especially susceptible to these diseases. However, few wild *Solarium* species were found to be resistant to soil borne disease. Grafting of tomato varieties on resistant *Solanum* spp. has been suggested to have higher yield, to extend the fruiting period avoiding soil borne diseases especially bacterial wilt problem.

CHAPTER III
MATERIALS AND METHODS

The present research work was carried out at the Horticulture Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur during the period from June 2019 to October 2019 to study on yield comparison among grafted and non-grafted summer tomato seedlings. This chapter deals with the materials and methods during conducting the experiment.

3.1 Soil

The land was medium high with good drainage facilities. The soil of the experimental area belongs to the Gray Terrace Soil Tract. The texture of the soil was silt loam having pH 6.4 with an organic matter content of 1.88% (Anon., 1999).

3.2 Climate

The area is characterized by hot and humid climate. The average rainfall of the locality during the experiment was 5.83 mm. The average minimum and maximum temperatures were 30.5°C and 33.3°C respectively. The average relative humidity was 70% during June 2019 to October 2019. The detail meteorological data in respect of monthly temperature, rainfall and relative humidity recorded during the period of the present study are presented in Appendix -I.

3.3 Materials

Control seedlings were raised using the variety namely BARI hybrid tomato-8 & Grafted seedlings were raised using scion namely BARI hybrid tomato-8 and six rootstocks of brinjal namely Kata begun (Sylhet) *(S. sysimbriifolium*) Tita begun

(Turkey berry) (*S. torvum*) Khag-1 *(S. melongena)* Khag-2 *(S. melongena)* Khag-3 *(S. melongena)* EG-203 *(S. melongena)*

3.4 Treatments

The experiment consisted of following seven treatments

T_1= WSS02 (Tomato grafted onto *S. sisymbriifolium)*

T_2= WSM05 (Tomato grafted onto *S. torvum*)

T_3= WSM06 (Tomato grafted onto khag-1)

T_4= WSM07 (Tomato grafted onto Khag-2)

T_5= WSM08 (Tomato grafted onto Khag-3)

T_6= WSM04 (Tomato grafted onto EG 203)

T_0= BARI Hybrid tomato-8 (Control)

3.5 Design and layout

The experiment was laid out in randomized complete block design with three replications. A-block consisted of 7-unit plots each receiving a treatment combination of the experiment. Treatment combinations of the experiment were assigned randomly in each block. Thus, the total number of unit plots was 21. The size of a unit plot was 4 x 1 m. The block-to-block distance was 70 cm.

3.6 Seedling raising

3.6.1 Raising of rootstock seedling

On May 20, 2019, rootstocks seeds were directly sown in the seedbed. At 2-3 true leaf stage, Seedlings were separately transplanted in polyethylene bag (6cm in diameter) which contain a mixture of 3 parts well-decomposed cow-dung and 1 part soil. At 25-30 days, the seedlings of scion were ready for grafting when the plants were 8-10 cm in height and 4-6 fully opened leaves were developed.

3.6.2 Raising of scion seedling

On June 21, 2019, tomato (var. BARI hybrid Tomato-8) were sown directly in the seedbed. Scion has been shown in plate 2. The scion seedlings were ready for grafting when they were 5-8 cm in height with 4-5 leaves at 25-30 days. Adjustment was made with sowing date of scion and stock so that the seedlings were ready for grafting at the same time. Watering, mulching, weeding, and shading were done as and when necessary.

a. BARI hybrid tomato-8 **b. BARI hybrid tomato-8**

Plate 1. Scion seedlings ready for grafting

3.7 Procedure for grafting

3.7.1 Rootstock preparation

- Rootstock was hold tightly between knees in polyethylene bag
- Using a razor blade, the top of the rootstock was removed by a sharp horizontal cut retaining 1-3 leaves with the stock plant.

- To make the rootstock tip into two equal parts, a vertical cut of about 1 cm depth was made.
- To facilitate the insertion of scion, slightly open and wide slit was made.

3.7.2 Scion preparation

- Using a sharp razor blade, 4-5 cm long shoot with growing point was cut from the scion seedling.
- To lessen transpiration, lower leaves were removed from the scion. Tip with the folded or half-opened growing leaf and 1-2 fully opened leaves next to the shoot tip were kept.
- About 1cm long first slanting cut was made on the scion basal end.
- In the opposite side at the basal end, a cut was made similarly to form 'V' or wedge shape at the scion base.
- **Grafting procedure of tomato (scion) on rootstock.**

  (a) Seedling of rootstock (left) was ready for grafting.

  (b) Rootstock seedling was hold in polyethylene bag between knees.

  (c) A vertical cut of about 1cm deep using a razor blade was made at the tip of the detopped stock seedling which made the stock divided into two equal halves.

  (d) Two slanting cuts (1 cm long) were made at two opposite sides of the bottom end of the scion thus a "V" shaped structure was made.

  (e) "V" shaped end of the scion was inserted into the vertical cut of the rootstock.

  (f) Grafted tomato seedling on a rootstock were attached with a grafting clip.

  (g) Water was sprayed on grafted seedling.

  (h) Grafted seedlings were kept in a shade house covered with a sheet of polyethylene and a black curtain.

A. Rootstocks

B. Top cut rootstock

C. Vertical cut in rootstock

D. Joining of scion into rootstock

Plate 2. Grafting procedure of tomato (scion) onto rootstock

3.7.3 Making the graft and nursing

1. The wedge of the scion was inserted into the slit portion of the rootstock in such way that cut surface of both scion and rootstock made contact and fitted gently.

2. Plastic clip was used to make the joint tight and strong,

3. By using a hand sprayer water was sprayed on the scion after grafting.

4. Grafted plants were put in a small shade house. These grafted plants were covered with a polyethylene sheet and a black curtain sheet under the polyethylene cover. So high humidity can be maintained, and sunlight can't enter directly into the shade house.

5. The shade house was kept uncovered at night when there was no rain but during the day it again covered. Gently, water was sprayed on the grafted plants 3-4 times a day for a period of 7-10 days.

6. Polyethylene sheet was removed from the top of the house after above mentioned times, but black cover was kept for another few days until the graft union was established.

7. After10-12 days, the scion started to grow. Emerged twig from the rootstock was removed immediately.

8. House was prepared in a shady place and grafting was done in the afternoon to get more grafting success.

A.Grafted onto *S.sisymbriifoliun*

B. Grafted onto *S.torvum*

C. Grafted onto *Khag-1*

D. Grafted onto *Khag-2*

E. Grafted onto *Khag-3*

F. Grafted onto *EG 203*

Plate 3. Grafted seedlings (Grafted onto different rootstock)

3.8 Land preparation

31 July 2019, selected land was opened. Through ploughing and laddering, the land was prepared, and cross ploughing was followed. Land was prepared by adding the basal doses of manures and fertilizers and removing the weeds and stubbles. The plots were 30 cm up from the ground level. Finally, beds were raised 20m long, 1m wide and for providing irrigation and cultural operations, distance between two beds were 30 cm.

3.9 Dose of manure and fertilizers and their methods of application

Manure and fertilizers were applied uniformly in all the experimental plots as per following doses

Manure/Fertilizer	Dose/ha	Dose/plot
Well decomposed cow-dung	10 t	4kg
Urea	550 kg	0.22kg
TSP	450 kg	0.18kg
MP	250 kg	0.10kg
Gypsum	120 kg	0.04kg

At the time of land preparation, the whole amount of cow-dung and triple superphosphate (TSP) was applied as basal dose. After transplanting, urea and muriate of potash were applied as in two equal splits at 21 and 35 days as side dressing (Anonymous, 1999).

3.10 Tunnel setting

Ahmed *et al.* (1996) suggested to set Polytunnels on the plot which was made with bamboo frame and covered with transparent polyethylene sheet. Tunnels saved plants from water logging condition of soil and heavy rainfall.

3.11 Transplanting and establishment of seedlings

On 7 August 2019, three weeks after grafting, Grafted seedlings were transplanted in the main field. On the similar date, same aged non-grafted seedlings (control) were also transplanted in the field.

Before the transplantation in the main field, grafted seedlings were watered 3 to 4 hours. Useless and undesired emerging shoots and twigs of stocks (below grafted point) were removed before the transplantation. For keeping the soil intact with the root system of the rootstock plant, the polyethylene bag was cut and removed carefully during the transplantation. A spacing of 60 x 10 cm was used. After transplanting, the seedlings were irrigated.

3.12 Staking and pruning practices

For keeping the branch upright and hormone application purpose, 'A' shaped bamboo stick supported the plants. After transplanting, the plants were respectively pruned twice at 21 and 35 days.

3.13 Weeding and mulching

To keep the plots free from weeds, mulching and weeding were done when necessary.

3.14 Irrigation

Whenever irrigation was required, the plants were irrigated initially through watering cane and after that, Mood irrigation was provided as they grew older.

3.15 Pest and disease control

Mealy bug & White flies were controlled by spraying Dimecron 50 EC @ 2 ml/l at 15 days interval as suggested by Khurshed & Samiruddin (1987). Pheromone and sticky trap were used to control other insects-pests found in the crop. Bacterial wilt affected plant whenever found was uprooted and destroyed.

3.16 Bacterial wilt infestation (%)

Wilting incidence of plant was recorded at 45, 60, 75 & 90 days after sowing (DAS)

3.17 Harvesting

From 15 October 2019, mature fruits were harvested, and it was continued up to 25 November 2019.

3.18 Nutritional analysis

At Postharvest Technology Division of BARI, Nutritional composition, total acid and soluble solids, vitamin and moisture content were analyzed following standard procedure from the Manual of Analysis of Fruit and Vegetables Products (Ranganna,1979).

3.18.1 Total soluble solid (TSS)

A Refractometer determined the total soluble solid (TSS) content. From every variety of tomato fruit, a drop of juice was squeezed, and the sample was placed on the prism surface of refractometer. From the reading, the percentage of total soluble solid was recorded.

3.18.2 Total acid

From each variety, three tomato fruits were homogenized. 50 g homogenized sample was blended for 5 minutes in warming blender with suitable amount of distilled water. The supernatant was pooled together and transferred to a 250 ml conical flask and mixing with distilled water a constant volume was made and filtered. From the stock solution an aliquot of 10 ml was titrated with 0.1N NaOH solution and 2-3 drops phenolphthalein was used as indicator. The titration was done in triplicate and percent total acid content was calculated using the following formula:

$$\%\text{Total acid} = \frac{T \times N \times V_1 \times E \times 100}{V_2 \times W \times 1000}$$

Where,

T= Titre

N= Normality

V_1= Volume made up

V_2= Aliquot of extract taken for estimation and

W= Weight of sample taken for estimation

E= Equivalent weight of acid

W= Wt. of sample taken for estimation

3.18.3 Vitamin C

Just after harvest from the plant a piece of tomato was cut and weighed. Then the sample was kept in 3% HPO, (metaphosphoric acid) solution in a beaker. Then the sample was homogenized in a blender with the acid solution. The homogenized sample was then centrifuged @ 2000 rpm for 5 minutes. The supernatant was pooled together, transferred to a measuring cylinder, and made a constant volume with the respective solvent. From the stock solution, an aliquot of 5 ml was taken and titrated with standard dyesolution (2,6 - dichlorophenol-indol-phenol). The titration was done triplicate. The dye had been standarized with standard solution of synthetic vitamin C. The vitamin C content of tomato was calculated follows:

$$\text{mg of vitamin C/100g} = \frac{T \times D \times V_1 \times 100}{V_2 \times W}$$

Where,

T = Titer

D = Dye factor

V_1= Volume made up

V_2= Aliquot of extract taken for estimation and

W= Weight of sample taken for estimation

3.18.4 Moisture content

From each fresh and ripened tomato variety, a weighed sample was taken to cut into pieces and was taken in porcelain crucible in triplicate and even dried at 80°C till the weight become constant. Calculation of percent moisture content was done according to the following formula:

$$\% \text{ Moisture} = \frac{I-F}{I} x100$$

Where, I= Initial weight of sample

F= Final weight of sample

3.19 Data collection

Data were recorded on the following parameters from the sample plants to assess the result. The sampling was done randomly. The plants in the outer two rows and at the extreme end of the middle rows were excluded during randomization. Ten plants were randomly selected from each plot. The data on following parameters were recorded.

I. Seedling survival rate (%)
II. Plant height
III. Days to first flowering
IV. Days to 50% flowering

V. Days to first harvest
VI. Duration of harvesting
VII. No. of fruits/plant
VIII. Single fruit weight
IX. Yield/plant
X. Yield/plot
XI. Yield/tunnel
XII. Yield/ha
XIII. Bacterial wilt incidence
XIV. Pest and other diseases
XV. Nutritional analysis

3.20 Statistical analysis

The recorded data were statistically analyzed using MSTAT statistical package program. Test of significance for each character was performed by F-test. The difference between the treatments was judged by Least Significant Difference (LSD) test. Analysis of variance table has been presented in Appendix II-IV.

CHAPTER-IV

RESULT AND DISCUSSION

The present experiment was conducted to investigate the comparison among grafted and non-grafted summer tomato seedlings on grafting success on growth, wilt incidence, quality of fruits and yield of tomato. The results obtained from the study have been presented and discussed in this chapter as below.

4.1 Seedling survival rate (%)

The results of the experiment indicated that grafting success was significantly influenced by different rootstocks (Table 1 and Appendix-II). The maximum success (92.22%) was found in the treatment T_2 (tomato grafted onto *S. torvum*) and the minimum success (66.00%) in T_6 (tomato grafted onto EG 203) (Table 1).

Table 1. Seedling survival rate in grafted and non-grafted plants

Treatment	Survival (%)
T_1	90.81 ab
T_2	92.22 a
T_3	85.33 bc
T_4	80.33 c
T_5	79.66 c
T_6	89.33 ab
T_0	66.00 d
LSD $_{(0.05)}$	5.71
CV (%)	3.85

Different letter indicated significant differences between the treatments after LSD ($p<0.05$). Here, T_0- BARI Hybrid tomato-8 (Control); T_1- grafted seedling (tomato grafted onto *S. sisymbriifolium*-WSS02); T_2- grafted seedling (tomato grafted onto *S. torvum*-WSM05); T_3- grafted seedling (tomato grafted onto Khag-1-WSM06); T_4- grafted seedling (tomato grafted onto Khag-2-WSM07); T_5- grafted seedling (tomato grafted onto Khag-3-WSM08) and T_6- grafted seedling (tomato grafted with EG 203-WSM04).

4.2 Plant height at harvest

In the case of plant height significant variation was found among the treatments (Table 2 and Appendix-II). The tallest plant height (141.33 cm) was recorded in T_2= WSM05 (tomato grafted onto *S. torvum*) whereas the statistically similar result was found from $T_{6=}$ WSM04 (tomato grafted onto EG 203). The shortest plant height was (86.17 cm) observed in WSS02 (tomato grafted onto *S. sisymbriifolium*). So, we easily can determine the suitability of plant height in T_2= WSM05 (tomato grafted onto *S. torvum*).

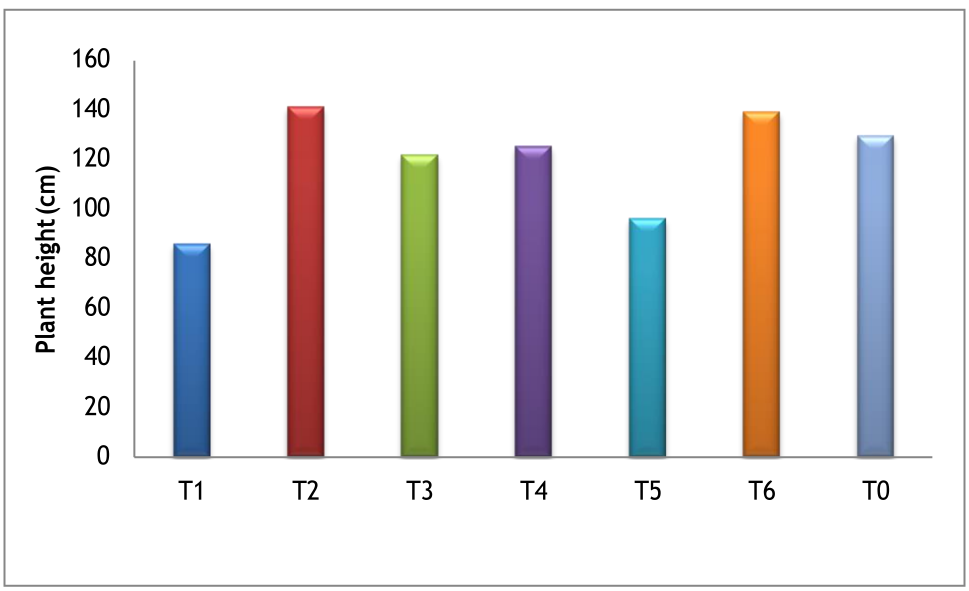

Figure 1. Plant height under grafted and non-grafted condition
Here, T_0- BARI Hybrid tomato-8 (Control); T_1- grafted seedling (tomato grafted onto *S. sisymbriifolium*-WSS02); T_2- grafted seedling (tomato grafted onto *S. torvum*-WSM05); T_3- grafted seedling (tomato grafted onto Khag-1-WSM06); T_4- grafted seedling (tomato

grafted onto Khag-2-WSM07); T_5- grafted seedling (tomato grafted onto Khag-3-WSM08) and T_6- grafted seedling (tomato grafted with EG 203-WSM04).

4.3 Days to first flowering

In the case of first flowering significant variation was found among the treatments. The result represents that the days to 1st flowering was higher in T_2= grafted seedlings (tomato grafted onto *S. torvum*) and it was 55.03 days. On the other hand, 1st flowering was earlier in T_3 = grafted seedlings (tomato grafted onto Khag-1) and it was 49.66 days. So T_2 = grafted seedling (grafting with *S. torvum*) is better technique than control or other methods (Figure 2 and Appendix-II).

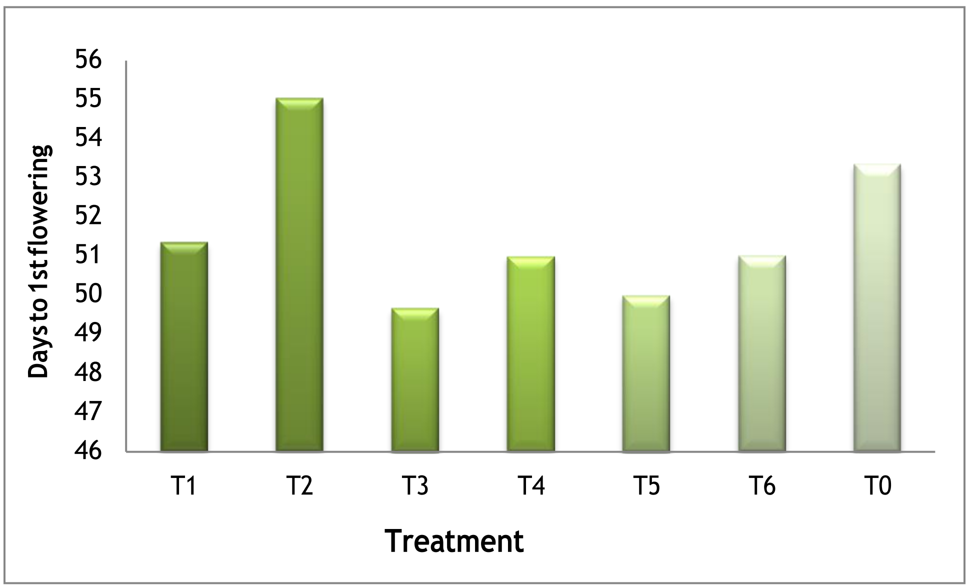

Figure 2. Days to 1st flowering in grafted and non-grafted plants

Here, T_0- BARI Hybrid tomato-8 (Control); T_1- grafted seedling (tomato grafted onto *S. sisymbriifolium*-WSS02); T_2- grafted seedling (tomato grafted onto *S. torvum*-WSM05); T_3- grafted seedling (tomato grafted onto Khag-1-WSM06); T_4- grafted seedling (tomato grafted onto Khag-2-WSM07); T_5- grafted seedling (tomato grafted onto Khag-3-WSM08) and T_6- grafted seedling (tomato grafted with EG 203-WSM04).

4.4 Days to 50% flowering

When grafting was made among the rootstocks significant variation was found (Table 2 and Appendix-II). 50% of total flowering was completed earlier in T_2 =

grafted seedlings (tomato grafted onto *S. torvum*) and it was 57.33 days. So T_2 = grafted seedling (tomato grafted onto *S. torvum*) is better than control or other methods for quickly flowering.

Table 2. Days to 50% flowering in grafted and non-grafted plants

Treatments	Days to 50% flowering
T_1	56.00 ab
T_2	57.33 a
T_3	54.00 c
T_4	55.33 bc
T_5	56.33 ab
T_6	56.00 ab
T_0	56.00 ab
LSD $_{(0.05)}$	1.779
CV (%)	1.79

Here, T_0- BARI Hybrid tomato-8 (Control); T_1- grafted seedling (tomato grafted onto *S. sisymbriifolium*-WSS02); T_2- grafted seedling (tomato grafted onto *S. torvum*-WSM05); T_3- grafted seedling (tomato grafted onto Khag-1-WSM06); T_4- grafted seedling (tomato grafted onto Khag-2-WSM07); T_5- grafted seedling (tomato grafted onto Khag-3-WSM08) and T_6- grafted seedling (tomato grafted with EG 203-WSM04).

4.5 Days to first harvest

The effect of treatments on days to harvest was found significant (Table 3 and Appendix-II). The results indicated that 99.05 days were needed to harvest T_2= grafted seedling (tomato grafted onto *S. torvum*) whereas the fruits were harvested from T_5= grafted seedling (grafting with Khag-3) and T_6 = grafted seedling (tomato grafted onto EG 203) in 98 and 97 days after planting of seedling (Table 5). Among the treatments T_6 = grafted seedling (tomato grafted onto EG 203) had the inheritance trait to early flowering and delay fruiting. It was revealed from the result that the duration of fruit harvest was grafted plants than those of non-grafted plants. Generally grafted plants had a tendency of delay in flowering, fruit set and harvesting compared to non-grafted plants. This might be due to the transplanting shocks during grafting. Matasuzoe *et al.* (1990) and Ali (1994) also reported the same observation.

Table 3. Days to first harvest and harvesting duration in grafted and non-grafted plant

Treatment	Days to first harvest (days)
T_1	95.33 bc
T_2	99.05 a
T_3	94.00 cd
T_4	96.33 abc
T_5	98.00 ab
T_6	97.00 abc
T_0	90.66 d
$LSD_{(0.05)}$	3.55
CV (%)	2.08

Here, T_0- BARI Hybrid tomato-8 (Control); T_1- grafted seedling (tomato grafted onto *S. sisymbriifolium*-WSS02); T_2- grafted seedling (tomato grafted onto *S. torvum*-WSM05); T_3- grafted seedling (tomato grafted onto Khag-1-WSM06); T_4- grafted seedling (tomato grafted onto Khag-2-WSM07); T_5- grafted seedling (tomato grafted onto Khag-3-WSM08) and T_6- grafted seedling (tomato grafted with EG 203-WSM04).

4.6 Number of fruits per plant

The number of fruits per plant of different varieties exhibited significant variation (Table 6 and Appendix-III). The maximum number of fruit (31.33) was obtained from the treatment T_2 = WSM05 (tomato grafted onto *S. torvum*). The lowest number of fruits per plant (24.00) was recorded from T_4 = WSM07 (tomato grafted onto Khag-2). Similar results were also obtained by Kader et al. (1967) who reported that grafting increased the total number of fruits by 28 to 58%.

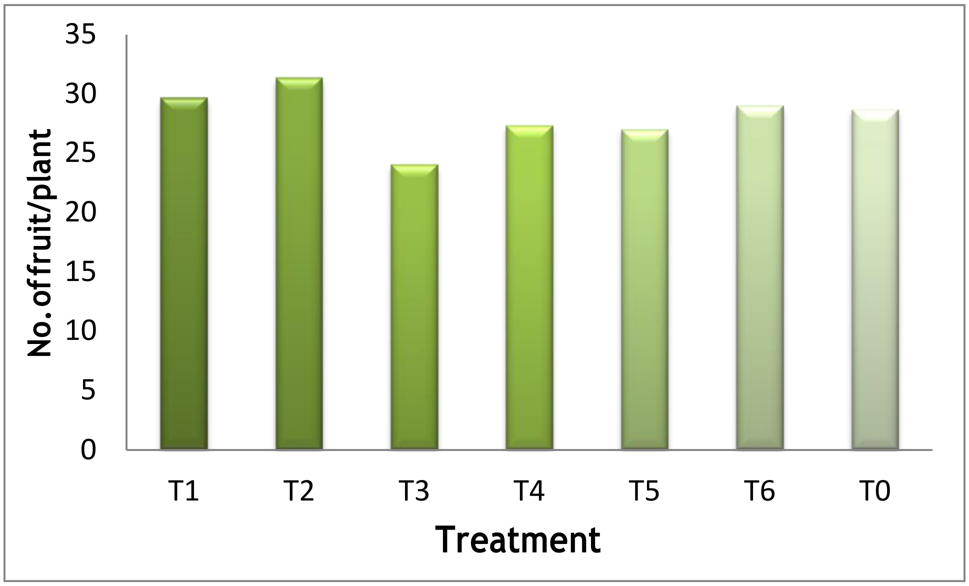

Figure 3. Number of fruits per plant in grafted and non-grafted tomato plants

Here, T_0- BARI Hybrid tomato-8 (Control); T_1- grafted seedling (tomato grafted onto *S. sisymbriifolium*-WSS02); T_2- grafted seedling (tomato grafted onto *S. torvum*-WSM05); T_3- grafted seedling (tomato grafted onto Khag-1-WSM06); T_4- grafted seedling (tomato grafted onto Khag-2-WSM07); T_5- grafted seedling (tomato grafted onto Khag-3-WSM08) and T_6- grafted seedling (tomato grafted with EG 203-WSM04).

4.7 Individual fruit weight (kg)

The variation in individual fruit weight was found significant in different treatments. The maximum fruit weight (53.66.84gm) was recorded in WSM05 (tomato grafted onto *S. torvum*). The lowest fruit weight (40.56 gm) was obtained from WSM07 (tomato grafted onto Khag-2). (Table 4 and Appendix-III). This difference was probably due to genetic potentialities of the varieties.

Table 4. Individual fruit weight in grafted and non-grafted tomato plants

Treatment	Individual fruit wt. (g)
T_1	46.00 b
T_2	53.66 a
T_3	42.66 bc
T_4	40.56 c
T_5	43.09 bc
T_6	40.91 c
T_0	45.50 b
LSD $_{(0.05)}$	4.06
CV (%)	5.12

Here, T_0- BARI Hybrid tomato-8 (Control); T_1- grafted seedling (tomato grafted onto *S. sisymbriifolium*-WSS02); T_2- grafted seedling (tomato grafted onto *S. torvum*-WSM05); T_3- grafted seedling (tomato grafted onto Khag-1-WSM06); T_4- grafted seedling (tomato grafted onto Khag-2-WSM07); T_5- grafted seedling (tomato grafted onto Khag-3-WSM08) and T_6- grafted seedling (tomato grafted with EG 203-WSM04).

4.8 Yield per plant (kg)

Yield per plant was significantly influenced by the effect of rootstocks that were used (Table 5 and Appendix-III). The highest yield per plant in T_2 and it was 1.15 kg and lowest yield per plant was in T_4 and it was 0.73 kg. In controlled condition the yield per plant was 1.07 kg. So suitable grafting style is T_2 = grafted seedling (tomato grafted onto *S. torvum*).

Table 5. Yield per plant in grafted and non-grafted tomato plants

Treatment	Yield/ plant(kg)
T_1	1.02 abc
T_2	1.15 a
T_3	0.76 d
T_4	0.73 d
T_5	0.91 bcd
T_6	0.85 cd
T_0	1.07 ab
LSD $_{(0.05)}$	0.18
CV (%)	11.16

Here, T_0- BARI Hybrid tomato-8 (Control); T_1- grafted seedling (tomato grafted onto *S. sisymbriifolium*-WSS02); T_2- grafted seedling (tomato grafted onto *S. torvum*-WSM05); T_3- grafted seedling (tomato grafted onto Khag-1-WSM06); T_4- grafted seedling (tomato grafted onto Khag-2-WSM07); T_5- grafted seedling (tomato grafted onto Khag-3-WSM08) and T_6- grafted seedling (tomato grafted with EG 203-WSM04).

4.9 Yield per plot (kg)

The effect on yield per plot was significantly influenced by the effect of rootstocks that were used (Table 6 and Appendix-III). The highest yield per plant in T_2 and it was 27.07 kg and lowest yield per plot was in T_3 and it was 13.11 kg. So suitable grafting style is T_2 = grafted seedling (tomato grafted onto *S. torvum*).

Table 6. Yield per plot in grafted and non-grafted tomato plant

Treatment	Yield/plot (kg)
T_1	23.00 b
T_2	27.07 a
T_3	17.74 c
T_4	17.89 c
T_5	19.780 c
T_6	19.00 c
T_0	13.11 d
LSD $_{(0.05)}$	2.44
CV (%)	6.99

Here, T_0- BARI Hybrid tomato-8 (Control); T_1- grafted seedling (tomato grafted onto *S. sisymbriifolium*-WSS02); T_2- grafted seedling (tomato grafted onto *S. torvum*-WSM05); T_3- grafted seedling (tomato grafted onto Khag-1-WSM06); T_4- grafted seedling (tomato grafted onto Khag-2-WSM07); T_5- grafted seedling (tomato grafted onto Khag-3-WSM08) and T_6- grafted seedling (tomato grafted with EG 203-WSM04).

4.10 Yield per tunnel

There was significant variation in yield per tunnel due to different rootstock's influence (Table 7 and Appendix-III). The maximum yield per tunnel (209.32 kg) was recorded from tomato grafted onto *S. torvum* which was statistically similar with tomato grafted onto *S. sisymbriifolium* (186.45 kg). The lowest yield per tunnel (117.75 kg) was obtained from tomato grafted onto Khag-2.

Table 7. Yield per tunnel in grafted and non-grafted tomato

Treatment	Yield/tunnel(kg)
T_1	186.45 ab
T_2	209.32 a
T_3	130.75 c
T_4	117.75 c
T_5	134.59 c
T_6	153.02 bc
T_0	141.63 c
LSD $_{(0.05)}$	40.72
CV (%)	14.93

Here, T_0- BARI Hybrid tomato-8 (Control); T_1- grafted seedling (tomato grafted onto *S. sisymbriifolium*-WSS02); T_2- grafted seedling (tomato grafted onto *S. torvum*-WSM05); T_3- grafted seedling (tomato grafted onto Khag-1-WSM06); T_4- grafted seedling (tomato grafted onto Khag-2-WSM07); T_5- grafted seedling (tomato grafted onto Khag-3-WSM08) and T_6- grafted seedling (tomato grafted with EG 203-WSM04).

4.11 Yield per hectare

The yield of tomato per hectare was significantly influenced by the effect of different rootstocks that were used. When the yield of tomato per plot was converted into yield per hectare, WSM05 (tomato grafted onto *S. torvum*) produced the highest yield 34.00 ton/ha which was statistically similar to WSS02 (tomato grafted onto *S. sisymbriifolium*). The lowest yield was obtained from WSM07 (tomato grafted onto Khag-2) (Figure 4 and Appendix-III). It might be due to genetic potentialities of the varieties studied. Kill and Jaksch (1998) showed that yield increases 15-35% in grafted plant compared to the yield of tomato plants without grafting.

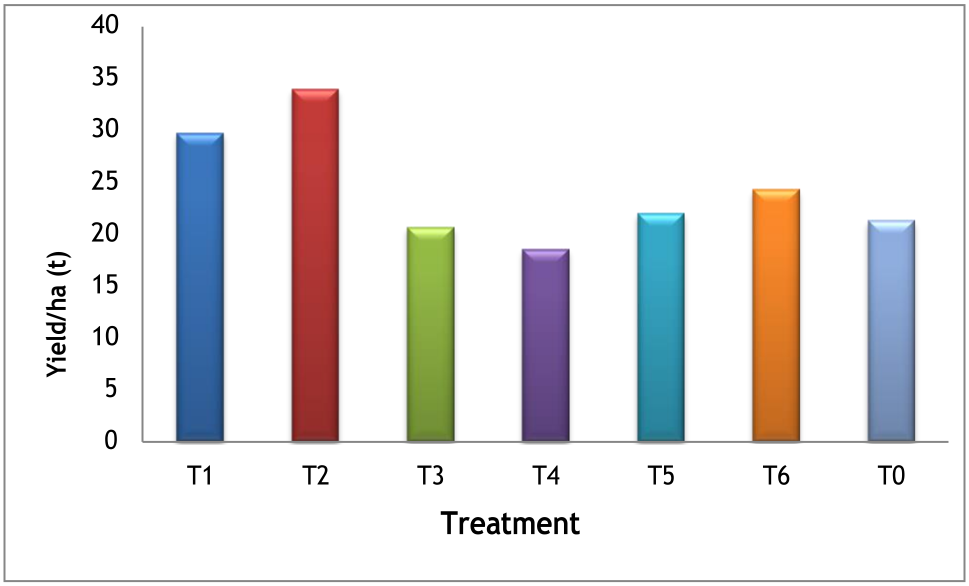

Figure 4. Yield per hectare in grafted and non-grafted tomato

Here, T_0- BARI Hybrid tomato-8 (Control); T_1- grafted seedling (tomato grafted onto *S. sisymbriifolium*-WSS02); T_2- grafted seedling (tomato grafted onto *S. torvum*-WSM05); T_3- grafted seedling (tomato grafted onto Khag-1-WSM06); T_4- grafted seedling (tomato grafted onto Khag-2-WSM07); T_5- grafted seedling (tomato grafted onto Khag-3-WSM08) and T_6- grafted seedling (tomato grafted with EG 203-WSM04).

4.12 Effects of grafting technique on bacterial wilt infestation

Table-8 shows that T_1 (tomato grafted onto *S. sisymbriifolium-WSS02)* and T_2 (tomato grafted onto *S. torvum*) was totally bacterial wilt free in whole life cycle, at 60 days and 90 days' age 8% and 12% T_3= grafted seedling (tomato grafted onto Khag-1-WSM06) infested with bacterial wilt respectively, 8%, 12% and 12% of T_5 (tomato grafted onto Khag-3-WSM08) infested with bacterial wilt during 60, 75 and 90 days respectively, 6% T_6 (tomato grafted onto Khag-3) was infested with bacterial wilt 75 days, controlled plantation (T_0) is also highly infests with bacterial wilt highly. If we compare the bacterial wilt infestation, then T_1 and T_2 are the best for bacterial infestation free plant.

Table 8. Bacterial wilt infestation in grafted and non-grafted tomato plants (%)

Treatment	Bacterial wilt infestation (%)			
	45 Days	**60 Days**	**75 Days**	**90 Days**
T_1	0.0	0.0	0.0	0.0
T_2	0.0	0.0	0.0	0.0
T_3	0.0	8.0	0.0	12.0
T_4	0.4	0.0	12.0	8.0
T_5	0.0	8.0	12.0	12.0
T_6	0.0	0.0	6.0	0.0
T_0	0.0	12.0	28.0	12.0

Here, T_0- BARI Hybrid tomato-8 (Control); T_1- grafted seedling (tomato grafted onto *S. sisymbriifolium*-WSS02); T_2- grafted seedling (tomato grafted onto *S. torvum*-WSM05); T_3- grafted seedling (tomato grafted onto Khag-1-WSM06); T_4- grafted seedling (tomato grafted onto Khag-2-WSM07); T_5- grafted seedling (tomato grafted onto Khag-3-WSM08) and T_6- grafted seedling (tomato grafted with EG 203-WSM04).

4.13 TSS (Total soluble solid)

The results of effect of rootstocks were found significant (Table 9 and Appendix-IV). The highest TSS (4.77%) was recorded from WSM05 (tomato grafted onto *S. torvum*) which was statistically similar to WSM08 (tomato grafted onto Khag-3) and the lowest tomato soluble solid was found in BARI Hybrid tomato-8 (3.83).

Table 9. TSS content, total acid, vitamin C, and moisture content of grafted and non-grafted tomato fruits

Treatment	TSS (%)	Total acid (%)	Vitamin- (mg/100g)	Moisture content (%)
T_1	4.10 bc	0.42 c	5.52 b	89.00 bc
T_2	4.47 a	0.66 a	6.67 a	94.33 a
T_3	4.12 bc	0.57 ab	5.30 b	87.37 cd
T_4	4.10 bc	0.46 c	4.45 c	88.07 bc
T_5	4.19 b	0.43 c	4.30 cd	86.37 cd
T_6	4.04 bc	0.52 bc	3.89 d	85.08 d
T_0	3.83 c	0.51 bc	6.18 a	90.26 b
LSD $_{0.05\%}$	**0.37**	**0.10**	**0.54**	**2.77**
CV (%)	**6.49**	**11.51**	**5.96**	**11.76**

T_0= BARI Hybrid tomato-8 (Control); T_1= grafted seedling (tomato grafted onto *S. sisymbriifolium*-WSS02); T_2= grafted seedling (tomato grafted onto *S. torvum*-WSM05); T_3= grafted seedling (tomato grafted onto Khag-1-WSM06); T_4= grafted seedling (tomato grafted onto Khag-2-WSM07); T_5= grafted seedling (tomato grafted onto Khag-3-WSM08) and T_6 = grafted seedling (tomato grafted with EG 203-WSM04).

4.14 Total acid (%)

Total acid (%) registered the significant variation among the treatments (Table 9 and Appendix-IV). The maximum total acid (0.66%) was estimated in WSM05 (tomato grafted onto *S. torvum*) followed by Grafting with khag-1 (0.57%) and the lowest (0.42%) quantity was recorded in (tomato grafted onto *S. sisymbriifolium*). This may might be due to varietal characteristics of the rootstocks.

4.15 Vitamin-C

Vitamin-C content (mg/100 g edible portion) varied widely among the varieties (Table 9 and Appendix-IV). It ranged from 3.89 to 6.67, being the highest in tomato grafted onto *S. torvum* and the lowest in (tomato grafted onto EG 203) while the intermediate vitamin-C content was recorded in tomato grafted onto Khag-3 (4.30 mg). Kobayasi *et al.* (1996) stated that the vitamin-C content in tomatoes was positively correlated with the cumulative duration of sunshine for a month before harvest and this comment satisfies the results of the present research.

4.16 Moisture content

There was significant variation in tomato fruit for moisture content due to different rootstocks (Table 9 and Appendix-IV). It appeared from the Table 9 that the maximum moisture content (94.44%) was found from tomato grafted onto *S. torvum* while the lowest in tomato grafted onto *S. sisymbriifolium* (Table 9).

CHAPTER-V
SUMMARY AND CONCLUSION

The present study was conducted at the Horticulture Research Centre, BARI, Gazipur during the period from October 2018 to April 2019 to study the performance of six tomato varieties grafted on *Solanum sisymbriifolium* rootstock. The treatment of the experiment consisted of all possible combinations of 7 tomato rootstocks viz. WSS02 (grafting with *S. sisymbriifolium*), WSM05 (grafting with *S. torvum*), WSM06 (grafting with khag-1), WSM07 (grafting with Khag-2), WSM08 (grafting with Khag-3), WSM04 (grafting with EG 203) and BARI Hybrid tomato-8 control where no grafting was done. The experiment was laid out in RCBD factorial with three replications. In this study seedlings of rootstock and scion were raised and grafting was done at the rootstock. Grafted seedlings were transplanted in October 2018 and harvesting was done up to April 2019. Data on different parameters were recorded and statistically analyzed.

The effect of different varieties on grafting success was found significant. The highest percentage of grafting success was obtained using grafting with *S. torvum* (92.22%) and grafting with *S. sisymbriifolium* (90.81%). The poorest success was observed in BARI Hybrid tomato-8.

In case of days to 50% flowering it was found that grafting with *S. torvum* plants bloomed earlier than grafted ones. The days to first harvest was started earlier in the variety grafting with *S. torvum* (68.67 days). In the grafted plants harvest was delayed by 8-10 days compared to non-grafted plants. This might be due to the transplanting shocks during grafting.

The maximum number of fruits per plant was obtained from grafting with *S. torvum* (31.33) and the minimum number of fruits per plant was obtained from grafting with khag-1 (24.00). The maximum individual fruit weight was recorded in grafting with *S. torvum* (53.66 gin), and minimum fruit weight was 40.56 gm. The fruit yield and yield contributing characters were evaluated. The highest number of fruits per plant and yield per hectare was obtained from grafting with S. torvum and the lowest were received from BARI Hybrid Tomato-8. Among the tomato varieties grafting with *S. torvum* and (Grafting with *S. sisymbriifolium*), produced maximum yield when same variety was grafted on grafting with EG 203 which differed significantly from the plants of control treatment. The reaction of grafted plants against bacterial wilt was tested in field condition. The tomato plants grafted on *S. sisymbriifolium* showed complete resistance against bacterial wilt irrespective of tomato varieties. Higher percentage of wilt incidence was recorded in grafting with S. torvum (17.93%) followed by BARI Tomato-3 (16.58%) and the lowest in BARI Tomato 4 (12.78%). In case of combined effect, non- grafted plants suffered more from wilt incidence. Nutritional composition was studied in respect of TSS. The higher percentage of total acid was obtained from grafted plants compared to non-grafted plants resulting in higher yield.

Conclusion

In the case of grafting, the grafted plant showed higher fruit length, fruit diameter, days to harvest, fruit per plant and yield per plant compared to non-grafted planted. The grafted plants showed resistance to bacterial wilt in field conditions. The grafted plants had prolonged harvesting period and gave higher yield grafting with *S. torvum* harvested 9th days earlier than BARI Hybrid tomato-8and other characters such as grafting success, individual fruit weight was the best compared to other cultivates Among the (grafting with *S. torvum*) can be treated as the best cultivar that can be grown through grafting technique.

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Appendices

Appendix I. Monthly record of air temperature, relative humidity, rainfall, and sunshine (average) of the experimental site during the period from April to September 2019

Month (2017)	Air temperature (^0c)		Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
April	37.5	24.7	84.2	352	5.5
May	35.7	25.3	84.4	385	6.2
June	32.4	25.5	83.8	228	
July	38.8	24.9	83.5	573	6.8
August	35.2	23.3	85	303	6.5
September	33.7	22.6	83.8	234	6.7

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka–1207

Appendix II: Analysis of variance on the grafting success, first flowering, plant height, days to 50% flowering and days to harvest

Source of variation	Degree of freedom	Grafting success (%)	First flowering	Plant height (cm)	Days to 50% flowering	Days to harvest
Replication	2	272.54	187.45	204.08	532.32	559.95
Grafting	6	248.95*	10.94*	1329.79*	4.25	23.46*
Error	12	10.31	1.98	7.69	2.39	3.98

Appendix III: Analysis of variance on no. of fruit, single fruit weight, yield per plant, yield per plot, and yield per tunnel of tomato plant

Source	Degree of freedom	Fruit per plant	Individual fruit weight (gm)	Yield per plant (Kg)	Yield/plot	Yield per ha (ton)	Yield/tunnel
Replication	2	73.00	53.89	0.20	0.20	69.03	1081.95
Grafting	6	16.31*	60.40*	0.07*	0.07*	91.89*	3247.94
Error	12	2.88	5.21	0.01	0.01	12.14	524.09

Appendix IV: Analysis of variance on TSS, total acid, vitamin-C and moisture content of tomato plant

Source of variation	Degree of freedom	TSS	Total acid (%)	Vitam-C (gm/100g)	Moisture content (%)
Replication	2	9.30	0.03	10.57	130.74
Grafting	6	0.11	0.02*	3.15*	27.47*
Error	12	0.07	0.003	0.09	2.43