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STUDIES ON *SOLANUM TORVUM* SWARTZ ROOTSTOCK ON CULTIVATED EGGPLANT UNDER EXCESS MOISTURE STRESS

SANJEEV KUMAR*, NB PATEL AND SN SARAVAIYA

Department of Vegetable Science, ASPEE College of Horticulture & Forestry, Navsari Agricultural University, Navsari-396 450, Gujarat, India

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Abstract

A field experiment on grafting two cultivars of brinjal, namely Surati Ravaiya Pink and Surati Ravaiya Purple onto the rootstock of *Solanum torvum* Swartz was conducted to elucidate the influence on plant survival and other horticultural parameters under excess moisture stress. The results revealed 24.59 and 17.18% higher plant survival in grafts of Surati Ravaiya Pink and Surati Ravaiya Purple over their respective counter parts. Plant growth indicators like plant height and stem diameter showed significant increase in grafts over normal plants. Grafted plants were quite early in flowering taking 38.60 and 34.53 days in Surati Ravaiya Pink and Surati Ravaiya Purple, respectively which corresponded significantly for earliness in picking by more than 5 days. Grafting also regulated heterostyly polymorphism positively and significantly in both the cultivars resulting in higher fruit set in grafted plants. Higher number of fruits per plant and enhanced cropping period were also important yield contributing traits achieved through grafting. The grafted plants showed tolerance to shoot and fruit borer exhibiting 22.79 and 17.86% infestation in Surati Ravaiya Pink and Surati Ravaiya Purple, respectively. Economic parameters analysis revealed higher net returns in grafted plants compared to non-grafted ones.

Introduction

Brinjal or eggplant (*Solanum melongena* L.) is an important horticultural crop of Solanaceae family and widely cultivated in Asia, Africa, and subtropics (India, Central America), even in some warm temperate regions (Mediterranean area, South of the USA) (Sihachakr *et al.* 1993). Indo-Burma region being centre of origin for brinjal, presents significant variability for fruit shape (oval or egg-shaped to long club-shaped) and colour (white, yellow, green through degrees of purple pigmentation to almost purple black), thus signifies region specific choice among consumers for this crop in India. It is cultivated in an area of 0.67 million ha with annual production of 12.4 million tons in India (Anon. 2017). Brinjal is indicated for the treatment of several diseases like diabetes, arthritis, asthma and bronchitis. In addition, several groups have provided evidence that eggplant extracts have a significant effect in reducing blood and liver cholesterol rates in humans (Khan 1979, Jorge *et al.* 1998). Nasunin, a major component of anthocyanin pigment of eggplant, has been shown to inhibit lipid peroxidation (Igarashi *et al.* 1993). Free radical scavenging and iron chelating activities of nasunin were demonstrated by electron spin resonance (Noda *et al.* 2000).

However, susceptibility of brinjal to several diseases, pests, drought, flooding and others affects plant growth and development which causes serious yield losses. These biotic and abiotic problems have been addressed by hybridizing cultivated brinjal with wild resistant *Solanum* species. However, this approach is limited by sexual incompatibilities with wild relatives (Collonier *et al.* 2001) and difficulties in obtaining fertile progenies (Gleddie *et al.* 1986).

*Author for correspondence: <drsksony@nau.in>.

Nowadays grafting is regarded as a rapid alternative tool to the relatively slow breeding methodology or incompatible crossing and has potential to increase tolerance of vegetables to various stresses (Flores *et al*. 2010). Cultivation of vegetable grafts permits not only pest resistance and high yields but also ameliorates crop losses caused by adverse environmental conditions. It has also been observed that grafting brinjal on wild species affects various physiological processes of a plant which in turn provide better opportunity to survive well and perform better in adverse climatic conditions. Grafting is a widespread technique used especially in cucurbitaceous and solanaceous vegetables (Minuto *et al*. 2007, Davis *et al*. 2008a, Oda 2007).

Though water is important for the plants but excess of water results in oxygen deficiency in the root zone and may cause hindrance in root respiration which lead to rotting and disease attack. These obstacles caused by excess of water availability or flooding can be fixed by grafting onto tolerant/resistant plant. Petran (2013) found that grafting tomato on *Solanum torvum* rootstock improved the flood tolerance and yield significantly.

South Gujarat region of the state in India falls under heavy rainfall zone and the people of the region have special preference for Surati Ravaiya type of brinjal cultivars for culinary purposes. However, cultivation of brinjal during rainy season faces various morphological and physiological stress on plant growth and development, thereby affects the plant stand and ultimately yield under such situations. High rainfall coupled with higher humidity limits the production of brinjal and leads to seasonality in its production.

Therefore, present investigation was aimed at getting benefit of grafting brinjal cultivars onto the rootstock of *Solanum torvum* Swartz for plant stand, heterostyly polymorphism, crop span, yield and tolerance of cultivated brinjal to shoot and fruit borer.

Materials and Methods

The investigation on grafting cultivated brinjal onto the rootstock of brinjal was carried out during *Kharif*, 2014, 2015 and 2016 at Regional Horticultural Research Station, Navsari Agricultural University, Navsari, Gujarat, India. The location is situated at a latitude of 20°57'N and longitude of 72°54'E with an altitude of 12 m amsl and falls under high rainfall zone.

Solanum torvum Swartz, a highly vigorous wild species of brinjal and tolerant to various biotic and abiotic stresses, was used as rootstock and Surati Ravaiya Pink and Surati Ravaiya Purple cultivars as scions. Cleft grafting technique was used to prepare grafts in each cultivar, which was performed in the afternoon after 4.00 p.m. onwards for better union and survival. Rootstock and scions were joined firmly with the help of grafting clips. Newly prepared grafts were first put in plug trays and then trays were shifted to water bath under polythene tunnel to initiate and fasten the healing process in grafts (Fig. 1). Relative humidly of more than 85% was maintained for better healing of grafts. After the completion of healing process, removal of grafting clips from grafts was followed by withholding water supply and the grafts were then removed from water bath for hardening. The grafts were ready for translating in 15 - 20 days (Figs 2, 3).

The present experiment was arranged in 4 treatments consisting of grafted plants of both the cultivars and their non-grafted counterparts and laid out in RBD with 5 replicates accommodating 36 plants in each plot (5.4 × 3.6 m) with a spacing of 90 × 60 cm. The experiment in each year was planned systematically in consideration with Agricultural Meteorological Cell, N.M. College of Agriculture, Navsari Agricultural University- Navsari so as to expose the treatments to natural submerged/water logged conditions in each year (Fig. 4.). Therefore, experiment was planted on 16 July, 2014, 25 July, 2015 and 27 July, 2016, which recorded 121 mm, 68 mm and 53 mm rainfall on the day of planting and subsequent days for exposing grafted and non-grafted plants to

such conditions in each year of experimentation (Table 1). The recommended dose of fertilizers at the rate of 100: 50: 50 (NPK kg/ha) was applied to the crop, of which whole dose of P, K and ½ of N was given at time of planting. The remaining N was further split into 2 parts and applied at 30 and 60 days of planting.

Fig. 1. Grafting procedure followed in the experiment.

Figs. 2-3: 2. Healing of grafts in water bath under poly tunnel. 3. Revomal of grafting clip and hardeining of grafts.

The data on various parameters, namely plant survival (%), plant height (cm), stem diameter (cm), days to first flowering, picking, heterostyly polymorphism, fruit set (%), fruit length (cm), fruit diameter (cm), number of fruits per plant, total number of pickings, average fruit weight (g), marketable yield and fruit infestation with shoot and fruit borer were recorded as per the standard procedures and the mean values were subjected to statistical analysis as per procedure laid down by Panse and Sukhatme (1985). The economic analysis of grafted vs. non-grafted brinjal was also carried out as per the methodology suggested by Subba *et al*. (2006).

Fig. 4. Exposure of grafts and non-grafts of brinjal cultivars to submerged conditions during rainy season.

Table 1. Record of rainfall during years of experimentation.

Date	Year 2014	Year 2015	Year 2016
	Rainfall (mm)	Rainfall (mm)	Rainfall (mm)
01 July	0.0	0.0	25.0
02 "	14.0	0.0	34.0
03 "	0.0	0.0	108.0
04 "	1.0	0.0	26.0
05 "	0.0	0.0	6.0
06 "	0.0	1.0	1.0
07 "	0.0	1.0	1.0
08 "	6.0	0.0	0.3
09 "	24.0	0.0	9.0
10 "	2.0	5.0	1.0
11 "	2.0	1.0	5.0
12 "	0.4	0.5	2.0
13 "	10.6	0.0	0.2
14 "	1.0	0.0	3.0
15 "	0.5	0.0	3.5
16 "	**121.0**	0.5	5.0
17 "	5.5	3.0	4.0
18 "	19.0	0.0	19.0
19 "	74.0	5.0	14.0
20 "	1.0	21.0	22.0
21 "	0.0	1.5	18.0
22 "	1.0	39.0	1.0
23 "	1.0	25.5	3.0
24 "	79.0	19.0	1.0
25 "	11.0	**68.0**	0.0
26 "	2.0	22.0	2.0
27 "	3.0	36.0	**53.0**
28 "	5.0	37.0	26.0
29 "	181.0	31.0	29
30 "	110.0	2.0	13
31 "	44.0	2.0	87
Total	719.0	321.0	497.0
Mean	23.2	10.4	16.6

Source: Agricultural Meteorological Cell, N.M. College of Agriculture, Navsari Agricultural University, Navsari.

Results and Discussion

The results of the present study indicated significantly higher survival percentage of grafts of Surati Ravaiya Pink as well as Surati Ravaiya Purple under submerged field conditions to the level of 96.67 and 97.78, respectively exhibiting 24.59 and 17.18% higher plant stand compared to their non-grafted counterparts (Table 2). The better plant survival of grafted plants in both the cultivars in high intense rains during monsoon at Navsari expresses the suitability of *Solanum torvum* as rootstock to perform well under such conditions. A high moisture situation in the soil causes oxygen starvation and is often associated with so many soil borne problems like wilts, root knot nematodes etc. The vigorous root system of *Solanum torvum* and resistance to soil-borne diseases or pests, tolerance to abiotic stress, selective absorption of available soil nutrients confer a high degree of vigour to the scion (Lee and Oda 2003, Rivero *et al*. 2003, Davis *et al*. 2008b). Hu *et al*. (2006) have also suggested that improved nutrient uptake in grafted seedlings increases photosynthesis under week sunlight conditions and such conditions generally prevails during rainy season under South Gujarat conditions at Navsari.

The mean plant height among different treatments was also found to be significantly higher in grafted plants of both the cultivars. The grafts of Surati Ravaiya Pink showed a gain of 8.11% and Surati Ravaiya Purple 5.64% compared to normal plants of respective cultivars. The comparative performance of grafted vs. non-grafted plants also showed significant differences for stem diameter exhibiting an increase of 2.81 and 5.64% in Surati Ravaiya Pink and Surati Ravaiya Purple, respectively (Table 2). Grafting had positive impact on plant vigour indicators like plant height and stem diameter thereby conferring the importance of rootstock in brinjal (Bletsos 2006, Khah 2011). Young (1989) has also suggested that vigorous root system of rootstock is often capable of absorbing nutrients more efficiently than scion roots. Leonardi and Giuffrida (2006) and Passam *et al*. (2005) have also indicated the different effect of grafting on plant height in respect of the combination of rootstock/brinjal varieties used.

Grafted plants showed significantly earliest in flowering taking 38.60 and 34.53 days in Surati Ravaiya Pink and Surati Ravaiya Purple, respectively compared to their counter parts (43.07 and 39.67 days). Thus earliness in flowering corresponded proportionally and significantly for days to first picking in both the cultivars. The grafted plants showed an earliness of more than 5 days in comparison to their analogues (Table 2). Though, grafts of each cultivar responded significantly but expressed variable response. Thus, such a variable response of these cultivars for earliness suggests the specificity of rootstock to cultivars influencing various physiological processes to enhance the reproductive ability of the crop (Bletsos 2003).

Grafting cultivated brinjal onto *Solanum torvum* regulated heterostyly polymorphism positively and significantly in both the cultivars. The overall percentage of long styled flowers was observed to be higher in grafted Surati Ravaiya Pink (38.22%), while much higher percentage of such flowers (43.89) was noticed in grafted Surati Ravaiya Purple (Table 2). Consequently, the presence of significantly higher percentage of medium styled flowers in non-grafts was observed compared to grafts. Likewise, normal plants of both the cultivars showed higher percentage of pseudo short and true short styled compared to grafts (Table 2). Therefore, positive effect of grafting on heterostyly polymorphism was corresponded to fruit set percentage in both the cultivars under study. Grafted plants of Surati Ravaiya Pink and Surati Ravaiya Purple showed an overall fruit set of 69.69 and 72.37%, respectively compared to their respective non-grafts (60.95 and 63.23 %) (Table 2). It has been well established that heterostyly polymorphism is an important phenomenon deciding extent of fruit set in brinjal (Handique and Sarma 1995, Passam and Bolmatis 1997, Kowalska 2006). Among various stylar levels in brinjal, long styled flowers shows high pollination as well as fruit set efficiency followed by medium styled flowers and so on (Chen

Table 2. Comparative performance of grafted and non-grafted brinjal during rainy season for plant survival, vigour and reproductive parameters (Pooled mean of 3 seasons).

Treatments	Plant survival (%)	Plant height (cm)	Stem diameter (cm)	Days to first flowering	Days to first picking	Long styled (%)	Med. styled (%)	Pseudo-short styled (%)	True short styled (%)
T_1: Surati Ravaiya Pink : Non-graft	77.59 (61.90)	76.08	1.78	43.07	65.07	27.24	53.86	10.39	8.51
T_2: Surati Ravaiya Pink: Graft	96.67 (80.73)	82.25	1.83	38.60	60.80	38.22	50.97	4.86	5.96
T_3 : Surati Ravaiya Purple: Non-graft	83.15 (66.14)	81.93	1.64	39.67	60.00	29.24	53.31	10.18	7.27
T4: Surati Ravaiya Purple: Graft	97.78 (83.21)	86.55	1.82	34.53	54.80	43.89	46.28	6.42	3.38
S. Em. ±	1.34	1.45	0.03	0.82	1.09	077	0.79	0.20	0.35
C. D. $_{0.05}$	(3.82)	4.15	0.09	2.33	3.10	2.18	2.25	0.58	1.00
C. V.%	7.00	7.40	7.57	8.76	7.53	9.22	6.46	10.66	23.08
	Y × T	Y × T	Y × T	Y × T	Y × T	Y × T	Y × T	Y × T	Y × T
S. Em.±	2.29	2.71	0.06	1.53	2.03	1.43	1.48	0.38	0.65
C. D. $_{0.05}$	NS	NS	NS	NS	NS	NS	NS	NS	NS

Values in parenthesis are arc sign transformed.

Table 3. Comparative performance of grafted and non-grafted brinjal during rainy season for fruit set, yield components and shoot and fruit borer infestation (Pooled mean of 3 seasons).

Treatments	Fruit set (%)	Fruit length (cm)	Fruit diameter (cm)	Number of fruits /plant	Av. fruit weight (g)	No. of pickings	Marketable yield per plant (g)	Marketable yield per hectare (ton)	Shoot and fruit borer infestation (%)
T_1: Surati Ravaiya Pink : Non-graft	60.95 (7.81)	8.14	7.63	13.40	73.03	23.20	984.27	18.13	32.72 (5.72)
T_2: Surati Ravaiya Pink: Graft	69.69 (8.35)	8.23	7.69	18.91	73.27	31.27	1392.58	25.30	22.79 (4.77)
T_3 : Surati Ravaiya Purple: Non-graft	63.23 (7.95)	6.71	6.05	25.57	68.51	26.67	1752.01	32.04	30.47 (5.52)
T4: Surati Ravaiya Purple: Graft	72.37 (8.51)	6.75	6.06	35.25	69.64	36.33	2471.27	45.24	17.86 (4.23)
S. Em.±	0.08	0.13	0.13	0.90	0.99	0.77	60.80	1.02	0.10
C. D. $_{0.05}$	(0.24)	0.38	0.36	2.58	2.81	2.19	173.60	2.91	(0.33)
C. V.%	4.24	7.52	7.75	16.23	5.75	10.57	15.40	14.11	4.35
	Y × T	Y × T	Y × T	Y × T	Y × T	Y × T	Y ×T	Y × T	Y × T
S. Em.±	0.15	0.25	0.24	1.69	1.83	1.39	113.68	1.90	0.09
C. D. $_{0.05}$	NS	NS	NS	NS	NS	NS	NS	NS	NS

Values in parenthesis are square root transformed.

2001, Sekara and Bieniasz 2008). The presence of higher percentage of long styled flowers followed by medium styled flowers in grafted plants of both the cultivars reflects the ability of rootstock to bring changes in heterostyly. It is also supported by the findings of earlier workers (Zeevaart 1976, Mohamed *et al.* 2013) who stated that initiation of morphogenic changes in scions by grafting induce changes on leaves, flowers and fruits due to genetic changes highlighting its potential in genetic improvement.

It is evident from *per se* performance of all the treatments that grafted plants recorded higher average values for fruit length and diameter in both the cultivars. However, variations between grafted and non-grafted plants were observed to be non-significant. Grafted plants of Surati Ravaiya Pink produced significantly higher number of fruits with average value of 18.91 in comparison to non-grafts (13.40). The grafted plants of Surati Ravaiya Purple also showed similar trend producing 35.25 fruits compared to 25.57 in non-grafts. Grafting also exerted significant effect on crop duration resulting into higher number of pickings. Grafted plants of Surati Ravaiya Pink had an overall 31.27 pickings compared to non-grafted ones (23.20), while grafts of Surati Ravaiya Purple showed even more number of pickings (36.33) in comparison to 26.67 pickings in normal plants of this cultivar. However, performance of grafts vs. normal plants in both the cultivars did not show any significant difference for average fruit weight. Marketable yield per plant and hectare differed significantly over the years between grafted and non-grafted plants of both the cultivars. Marketable yield was 1392.58 g per plant and 21.81 tonnes per ha in grafted plants of Surati Ravaiya Pink compared to 984.27 g and 15.62 in non-grafted plants. Whereas, grafted plants of Surati Ravaiya Purple produced 2471.27 g yield per plant and 38.99 tonnes per ha in comparison to 1752.01 g and 27.61 tonnes in non-grafts (Table 3). The major yield contributing traits observed in grafted plants of both the cultivars were production of higher number of fruits per plant and enhancement of cropping span to take more number of harvests from these plants compared to non-grafted plants. This was also corroborated with the findings of Sabatino *et al.* (2013), Miceli *et al*. (2014) and. Hormonal signaling in rootstock-scion interactions might have a greater impact on flowering and fruit setting (Aloni *et al.* 2010). This increase in yield can also be related to higher vigorous growth of grafted plants and such response has also been observed by Leonardi and Giuffrida (2006) while studying the grafting effect of inter-specific tomato rootstock on tomato.

Table 4. Comparative economic analysis of grafted vs. non-grafted brinjal.

Treatments	Fruit yield (t/ha)	Gross realization (Rs/ha)	Cost A (Variable cost + Interest on working capital)	Cost B (Cost A + Rental value of land)	Cost C [Total cost of cultivation (Rs/ha)]	Net return (Rs/ha)
T_1: Surati Ravaiya Pink : Non-graft	18.12	453000.00	133740.00	163940.00	163940.00	289060.00
T_2: Surati Ravaiya Pink: Graft	25.30	632500.00	242312.00	284478.00	284478.00	348022.00
T_3 : Surati Ravaiya Purple: Non-graft	32.36	809000.00	135501.00	189434.00	189434.00	619566.00
T4: Surati Ravaiya Purple: Graft	45.23	1130750.00	245968.00	321352.00	321352.00	809398.00

The tolerance of grafted plants to shoot and fruit borer was indicated by significantly less infestation. The overall infestation of 22.79% was observed in grafted plants of Surati Ravaiya Pink compared to 32.72%, while grafted Surati Ravaiya Purple recorded 17.86% infestation in contrast to 30.47 in normal plants of the cultivar (Table 3). Less infestation in grafted plants of

brinjal by brinjal shoot and fruit borer also confer to contribute towards yielding ability of grafted plants. Similar kind of response was also observed in eggplant cv. Epic upon grafting onto the rootstocks of *Solanum lycopersicum* × *S. habrochaites* and *S. aethiopicum* by Johnson *et al*. (2014).

Economic analysis of grafted vs. non-grafted revealed that cost of planting material in grafted crop though was higher but net returns to the tune of Rs. 348022.00 and Rs. 809398.00 could be realized in grafted Surat Ravaiya Pink and Surat Ravaiya Purple, respectively in comparison to Rs. 289060.00 and Rs. 619566.00 in their non-grafted analogues (Table 4).

It can be concluded that grafting brinjal onto the rootstock of *Solanum torvum* Swartz provides better plant survival during rainy season, fruit set, comparatively less shoot and fruit borer infestation, extended crop period, higher yield and net returns.

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