Research Article

Local Rootstock of Ber (*Ziziphus mauritiana* L) Grafted with Advanced Scion Cultivars Improved Fruit Yield and Quality under Arid Conditions

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Abstract | Climate change and enormous increase in population are causing food insecurity situation in developing countries like Pakistan. Major food crops are seemed failing to fulfill food requirements hence, it is imperative to search for alternate food sources. Ber could be very handy alternate food crop if its yield and quality is enhanced. Grafting is a widely used technique to improve yield, disease resistance and fruit quality. This work aims to assess the effect of grafting on production, fruit ripening, physical and chemical properties, and nutritional quality of the fruit. Rootstock has a great influence on plant growth and development, including fruit ripening. However, the presence of a cross-interaction between grafting and rootstock is often neglected. To explore cross-interaction between grafting and rootstock on different fruit yield and quality traits, we examined the scion-root interaction of four scion cultivars viz. Delhi White, Suffen, Karela and Mahmud Wali during March-April 2013-14. After the establishment of plant, data were recorded for yield and fruit quality traits during three consecutive years (2016-19). Results showed that Dehli White grafted plants produced maximum yield kg/plant (60.33, 71.43, 78.00) followed by Mehmud Wali, Karela and Suffen scion grafts. Suffen grafted plants produced better quality fruits in terms of total soluble solids (TSS) (14.67, 15.45, 16.56 Brix0), pH and Ascorbate content followed by Karela, Mehmud Wali and Dehli White scion graft. Based on findings of the experiment, it could be recommended that Mahmud Wali and Suffen scions should be used to be propagated on local rootstocks to enhance yield as well as fruit quality that will contribute in ensuring food security.

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Introduction

Climate change is likely to be affected food security at the global, regional and local levels. Climate change can disrupt food availability, reduce food access, and affect food quality. It is estimated that projected increases in temperature, changes in precipitation patterns, changes in extreme weather events, and reduced water availability may all lead to lower agricultural productivity and promote food insecurity. Increases in the frequency and intensity of extreme weather events could disrupt food delivery,

and food prices are expected to increase sharply in the future. Increased temperatures can contribute to spoilage and pollution (USDA, 2015). Most of the semi-arid regions are expected to become deserts due to very low or no rainfall. Under such scenarios of climate change, finding tree species that can survive in very limited water conditions may help limit regional desertification processes. It would be very encouraging to search trees having economic importance also. Ber fruit is an outstanding choice for such areas that can ensure food security, reduce soil erosion and help improve livelihood. However, there are very few species suitable for use in afforestation programs in arid and semi-arid regions. Ber (*Ziziphus mauritiana* L) is an important minor fruit crop that fits in well with the marginal ecosystem of the arid and semi-arid regions of the world. It belongs to the Rahmanaceae family and is known as the poor man's apple due to its nutritional value and is used as food for millions of poor people during the winter. Farmers can obtain additional income by planting ber trees on marginal farmland. Whole fruits are rich in protein, calcium, carotene, phosphorous, and vitamin C (Mukhtar *et al*., 2004).

Ziziphus plants are produced naturally from seeds, although they are easy and cheap, but they are unable to perpetuate the properties of the parent tree due to heterozygosity. Like other open pollinated fruit crops, vegetative propagation is strongly encouraged in Ber. The plant produced through seeds cannot be used directly for horticulture. Fruit plants that are asexually reproduced are true to type, uniform in growth and fruit quality, and take less time to fruiting compared to plants that are sexually reproduced and bear fruit within three to four years (Verma *et al*., 2000). Asexual reproduction is a very successful technique used to preserve germplasm with better yield and quality of fruits. Various grafting techniques are used in vegetative propagation and T-grafting is the most popular method used in Pakistan. This method has some limitations that may reduce the success rate, but this rate can be improved by maintaining proper alignment of cambium tissues with rootstock and graft. Fruit yield and quality are also affected by improper use of the scion and rootstock. In the current scenarios of food insecurity and climate change, current investigations were conducted to authenticate the compatibility of the graft on the rootstock, and its impact on fruit yield and quality under dry conditions.

Materials and Methods

Local rootstocks were grafted with scions from four advanced genotypes during 2013-14 in the field area, Department of Horticulture, Ghazi University Dera Ghazi Khan-Pakistan and at maturity of grafts data were collected for fruit yield and quality during 2018-19.

Raising of rootstock

Rootstock nursery was raised in the warehouse Department of Horticulture, Airport campus, Ghazi University, Dera Ghazi Khan by growing healthy stones during March, 2013-14. Stones were washed with tap water and treated with Carbendazim @ 10gram/10 liter of water. Treated seeds were sun dried and preserved in tissue paper bags. A well-mixed soil (sand, silt, clay (1:1:1) was taken in polythene bags and a fair quantity of well-decomposed farmyard manure was mixed thoroughly. Treated seeds were sown in the bags and watered. Stones started germination after 2-3 weeks of sowing and seedlings were established. At 3-4 leaf stage seedlings along with stone were transplanted to the field. Seedlings were watered regularly until reached a graftable-size. All the plant production and protection measures were taken for the establishment of healthy seedlings.

Grafting technique

One year old fully grown ber seedlings were grafted with T-grafting technique during March and April 2015 by using different scion cultivars viz. Dehli white, Karela, Suffen and Mehmud wali. Three to four months old healthy scion sticks were selected and defoliated before grafting operation. Rootstocks were cut just above the active growing point by keeping 3-4 leaves and a T shape was made by deep cut on the side of the rootstock. A 2.5-3 cm long wedge shape cut was made on the bottom of scion, so that it can fit properly in the cut made on the rootstock. Scion stick was inserted into the cut portion of the rootstock and the graft was firmly wrapped with plastic strip. New shoots from the graft union were regularly removed. The experiment was laid out following Randomized Complete Block Design (RCBD) replicated thrice. During 2018-19, data were recorded for.

Fruit setting (%)

To study the fruit set percentage, fruits were first counted a week after the opening of last flowers on randomly tagged branches and counting was

continued at weekly intervals until the fruits matured. Then fruit set percentage was calculated according to the following equation.

$$\text{Fruit set percentage} = \frac{\text{No of developing fruitlets}}{\text{No of flower at full bloom}} \times 100$$

Flesh weight (gm)

Fifty fruits were collected from randomly selected five plants of ber from each cultivar and the flesh from each cultivar was separated from the stone, mixed and average flesh weight was calculated by weighing on electric balance in gm.

Stone weight (gm)

Fifty fruits were collected from randomly selected five plants of ber from each cultivar and the stone from each cultivar was separated from the flesh, mixed and average stone weight was calculated by weighing on electric balance in gm.

Flesh/ stone ratio

Fifty fruits were collected from randomly selected five plants of ber from each cultivar and the stone and flesh from each cultivar were separated. Flesh to stone ratio was calculated by weighing on electric balance.

Fruit weight (gm)

Fifty fruits were collected from randomly selected from five plants of ber from each cultivar and the fruits from each cultivar were mixed and average fruit weight was calculated by weighing on electric balance in gm.

Yield /plant (Kg)

The yield of five tagged plants was measured in gram and converted into kgs.

Total soluble solids (TSS) (°Brix)

Digital Refractometer (RX 5000, Atago, Japan) was used to measure the total soluble solids (TSS) of ber fruit juice. On the clean prism of refractometer, a drop of ber juice was placed carefully, closed the lid and reading (TSS °Brix) was noted directly from the digital scale of refractometer at room temperature.

Titratable acidity (TA) (%)

Total titratable acidity of ber fruit juice was measured by the method as described by Hortwitz (1960). Ten (10) ml ber juice was taken from each sample, diluted it (1:4) with distilled water, re-titrated with N/10 NaOH solution by adding 2-3 drops of phenolphthalein ($C_{20}H_{14}O_4$) as an indicator. To determine TA, calculations were made as given formula:

$$\text{Titratable acidity (\%)} = \frac{\text{N/10 NaOH used} \times 0.0064 \times 100}{\text{Volume of sample used}}$$

pH

An extract of an aliquot (10 ml) of juice was prepared according to Nunes and Emond (1999), the aliquot of juice was first filtered and then pH value of ber juice was determined by Metrohn-691 pH meter.

Vit-C content (mg/100g)

Fruit juice was extracted, filtered with Whatman® filter paper and stored in 100 ml flask. Ten mL filtered aliquot was taken in 100 ml volumetric flask, then volume was made up to the mark by adding 0.4% oxalic acid. Ascorbic acid contents were determined following the protocol of Pisoschi *et al.* (2011). Ascorbic acid contents were calculated by using given formula:

$$\text{Ascorbic Acid} \left(\frac{\text{mg}}{100}\text{ml}\right) = \frac{\text{R1} \times \text{V} \times 100}{\text{R} \times \text{W} \times \text{V1}}$$

Where;

R1= ml of dye used for aliquot titrati0n; R= ml of dye used to titrate one mL standard ascorbic acid + 1.5 ml 0.4% oxalic acid) of reference solution (Standard reading); V1= ml of juice which was used; V= volume of aliquot made by 0.4% oxalic acid; W= ml of aliquot taken for titration.

Statistical analysis

Analysis of variance technique was used to figure out differences as outlined by Steel *et al.* (1997) and least significant differences (LSD) were found.

Results and Discussion

Yield and its related traits

Scion of ber cv. 'Delhi White' grafted on local rootstock yielded maximum flesh weight (21.19, 23.3, 25.38 gm) during three consecutive years (2016-19) followed by Mehmud Wali (11.4, 12.3, 13.7 gm), Karela (8.3, 10.8, 13.3 gm) and Suffen (7.23, 8.4, 9.8 gm) (Table 1). Scion of ber cv. 'Delhi White' grafted on local rootstock yielded maximum stone weight (1.25, 1.38, 1.43gm) during three successive

years (2016-19) followed by Mehmud Wali (1.11, 1.14, 1.31 gm), Karela (0.8, 0.9, 1.01gm) and Suffen (0.7, 0.88, 0.97gm) (Table 1). Sivakov *et al.* (1988) reported average stone weight in the range of 0.28 and 0.65 g in 6 ber varieties and Ghosh and Mathew (2002) reported stone weight range between 0.6 and 1.9 g in 9 cultivars of ber. Present findings are in line with previous studies and the minor differences may be due to environmental variations. Lal (2001), and Ouédraogo *et al.* (2006) found differences in fruit yield very high after grafting. Results of present study have shown positive trend in yield after grafting but much lower than the values stated in the literature for the fruit production on adult trees ranging from 80 to 200 kg per tree achieved at the age of 10 years normal conditions (Pareek, 2001). Scion of ber cv. 'Delhi White' grafted on local rootstock shown high F/S ratio (16.95, 16.88, 17.74) during all years (2016-19) followed by Mehmud Wali (10.27, 10.79, 10.46), Karela (13.83, 12.00, 12.64) and Suffen (10.33, 9.55, 10.10) (Table 1). Kundi *et al.* (1989b) reported highest ratio of pulp/seed (16.22) like the results of the present investigations. Hence, the results are justified by previously conducted studies. Fruit volume of ber cv. 'Delhi White' grafted on local rootstock was higher (25.5, 25.8, 27.74 cm^3) during all years (2016-19) followed by Mehmud Wali (13.56, 14.66, 16.5 cm^3), Karela (11.34, 13.56, 14.30 cm^3) and Suffen (9.65, 9.88, 10.86 cm^3) (Table 2). Higher volume of the fruit is indication of the change in ploidy level of genotypes and it is expected that larger volume cultivars may be triploid. It was interesting fact that cultivars having smaller fruits were rich in quality compared with larger fruit hence, it may be concluded that fruit volume had negative correlation with fruit quality (Chen *et al.*, 2006; Sivakov *et al.*, 1988; Kundi *et al.*, 1989b; Gao *et al.*, 2003) these cultivars were more suitable for drying (Gao *et al.*, 2003). Fruit yield of ber cv. 'Delhi White' grafted on local rootstock was higher (60.33, 71.43, 78.00 kg) during all years (2016-19) followed by Mehmud Wali (54.33, 61.56, 65.33 kg), Karela (58.09, 61.03, 68.89 kg) and Suffen (49.35, 52.46, 56.39 kg) (Table 2). Yield, its contributory traits and quality parameters of fruit are some of the principal objectives of plant breeders in fruit improvement breeding programs. Fruit yield in the utmost important characteristic and the newly bred cultivars showed better yield especially 'Delhi White'. Findings of present research work is in line with Prasad (2005) who reported fruit with of adapted cultivars in the range of 50.51 and 54.45 kg per tree Kundi *et al.* (1989a) reported highest as 111.8 kg per tree and 88.33 kg per tree, respectively. The variability in yield might be attributed to different environmental conditions and age of the tree. Fruit weight of ber cv. 'Delhi White' grafted on local rootstock was higher (22.44, 24.68, 26.81 gm) during all years (2016-19) followed by Mehmud Wali (12.51, 13.44, 15.01 gm), (9.1, 11.7, 14.31 gm) and (7.93, 9.28, 10.77 gm) (Table 2). Results of present study are in line with (Sivakov *et al.*, 1988; Kundi *et al.*, 1989b; Gao *et al.*, 2003; Liu *et al.*, 2004; Prasad, 2005; Jiang *et al.*, 2006). Physical appearance of Dehli White fruits was very good along with size of the fruit. These results are in line with Taain *et al.* (2015) who reported that ber flesh weight is a yield contributing trait which has positive association to overall yield of the plant. Bigger size of the fruit is also a consumer attractive trait. Type of rootstock affects fruit setting, size and fruit yield (Sanou *et al.*, 2014). Findings of the present study are trending like the findings of Prasad and Bankar (2006) who reported that fruit related traits could be improved by grafting. It has been reported that favorable conditions (soil moisture) promote trees growth, better rooting system, higher water potential and better yield. The size or age of rootstocks has been reported to promote better growth and yield of the plant (Copes,1987).

Table 1: *Flesh, Stone weight and F/S ratio of different ber cultivars in three years (2016-19).*

Varieties	2016-17			2017-18			2018-19		
	Flesh weight (gm)	Stone weight (gm)	Flesh/ Stone ratio	Flesh weight (gm)	Stone weight (gm)	Flesh/ Stone ratio	Flesh weight (gm)	Stone weight (gm)	Flesh/Stone ratio (gm)
Dehli White	21.19ab	1.25abcd	16.95abc	23.30bc	1.38a	16.88def	25.38abc	1.43a	17.74bcde
Mehmud Wali	11.4cd	1.11ae	10.27cd	12.3cd	1.14abcd	10.79bc	13.7abc	1.31abc	10.46def
Karela	8.3abcd	0.8e	13.83bcd	10.8bc	0.9cd	12.00ef	13.3ab	1.01abcd	12.64a
Suffen	7.23abc	0.7d	10.33def	8.4bc	0.88cde	9.55bcd	9.8ab	0.97bcd	10.10ef

Table 2: *Fruit volume and yield per plant of different ber cultivars in three years (2016-19).*

Varieties	2016-17			2017-18			2018-19		
	Fruit volume	Fruit weight (gm)	Yield/plant (Kg)	Fruit volume	Fruit weight (gm)	Yield/plant (Kg)	Fruit volume	Fruit weight (gm)	Yield/plant (Kg)
Dehli White	25.5b	22.44ab	60.33f	25.87b	24.68a	71.43bc	27.74a	26.81a	78.00a
Mehmud Wali	13.56d	12.51bc	54.33h	14.66d	13.44b	61.56ef	16.5c	15.01b	65.33d
Karela	11.34e	9.1bc	58.09g	13.56d	11.7bc	61.03f	14.30c	14.31ab	68.89c
Suffen	9.65f	7.93cd	49.35j	9.88ef	9.28a	52.46i	10.86ef	10.77abc	56.39g

Table 3: *TSS and TA content of different ber cultivars in three years (2016-19).*

Varieties	2016-17		2017-18		2018-19	
	TSS (˚Brix)	TA (%)	TSS (˚Brix)	TA (%)	TSS (˚Brix)	TA (%)
Dehli White	8.36b	0.58a	9.38c	0.575a	9.87c	0.59a
Mehmud Wali	8.31b	0.56a	9.59bc	0.55a	9.34c	0.58a
Karela	11.78a	0.42b	12.32b	0.46b	12.45c	0.48b
Suffen	14.67a	0.28c	15.45a	0.27c	16.56b	0.28c

Table 4: *pH and Ascorbic acid content of different ber cultivars in three years (2016-19).*

Varieties	2016-17		2017-18		2018-19	
	pH	Vit. C (mg/100g fruit)	pH	Vit. C (mg/100g fruit)	pH	Vit. C (mg/100g fruit)
Dehli White	4.3d	27.89a	4.3c	27.17a	4.3c	26.59a
Mehmud Wali	5.3c	24.87bc	5.2b	25.11ab	5.2b	26.1ab
Karela	5.5b	22.85c	5.3b	23.06b	5.3b	24.43b
Suffen	6.3a	24.54a	6.2a	23.39a	5.6a	25.49b

Quality and its related traits

Total soluble solids (TSS) content of ber cv. 'Suffen' grafted on local rootstock was higher (14.67, 15.45, 16.56 ˚Brix) during all years (2016-19) followed by Karela (11.78, 12.32, 12.45˚Brix), Dehli White (8.36, 9.38, 9.87 ˚Brix) and Mehmud Wali (8.31, 9.59, 9.34 ˚Brix) (Table 3). Fruit quality is an important criterion to shortlist varieties for better economic benefits because it attracts consumers. Their liking and disliking affects market value of any commodity, hence, it is imperative to bio fortify food producing plants to get benefits. TSS content of the fruit is low during the initial stages of growth but increases throughout the growth period and reaches a peak in the physiologically mature fruit (Jawanda and Bal, 1980; Bal, 1981b; Abbas *et al.*, 1988, 1994). A gradual increase in starch content was observed up to full maturation and then it decreases during ripening in 'Sanaur 2' (Bal, 1981a), and in 'Gola', 'Kaithli', and 'Umran' fruit (Bhatia and Gupta, 1985), which may contribute to the changes in TSS. Titratable acidity value of ber cv. 'Delhi White' grafted on local rootstock was higher (0.58, 0.575, 0.59%) during all years (2016-19) followed by Mehmud Wali (0.56, 0.55, 0.58%), Karela (0.42, 0.46, 0.48%) and Suffen (0.28, 0.27, 0.28%) (Table 3). pH of ber cv. 'Suffen' grafted on local rootstock was higher (6.3, 6.2, 5.5) during all years (2016-19) followed by Karela (5.5, 5.4, 5.3), Mehmud Wali (5.3, 5.2, 5.2) and Dehli White (4.3, 4.3, 4.3) (Table 4). Ascorbic acid content of ber cv. 'Delhi White' grafted on local rootstock was higher (27.89, 27.17, 26.59 mg/100 g fruit) during all years (2016-19) followed by Mehmud Wali (24.87, 25.11, 26.1 mg/100 g fruit), Suffen (24.54, 23.39, 25.49 mg/100 g fruit) and Karela (22.85, 23.06, 24.43 mg/100 g fruit) (Table 4). Ascorbic acid content of ber fruit is initially low and continues to increase until the fruit reaches physiological maturity (Abbas and Fandi, 2002). The increase in ascorbic acid with the advancement of ripening reached peak value (559 mg per 100 g) on the 15th day of storage at 20C (Kader *et al.*, 1984). Bal *et al.* (1995) also noted the increase in vitamin C content as the maturity advanced in 'Umran' fruit. Rootstocks generally affect tree water relations. The interaction of grafting with rootstock affects the physiology and quality of the fruit (Olien

and Lakso, 1986). Trees grafted on physiological active rootstocks have reliably higher water potential than trees grafted onto stunted rootstocks. Rootstock is the biological source for improving yield and quality of different fruits, it not only improves plant physiology but also improves quality and shelf-life of fruit (Ezzahouani and Williams, 1995). Autio and Southwick (1993) concluded that grafting of apple showed variable results for all type of grafting showing very small differences in fruit color and volume while Ferree (1992) reported minimal differences in quality parameters especially in total soluble solids, vitamin-C contents and mass of apples grafted on to diverse rootstock.

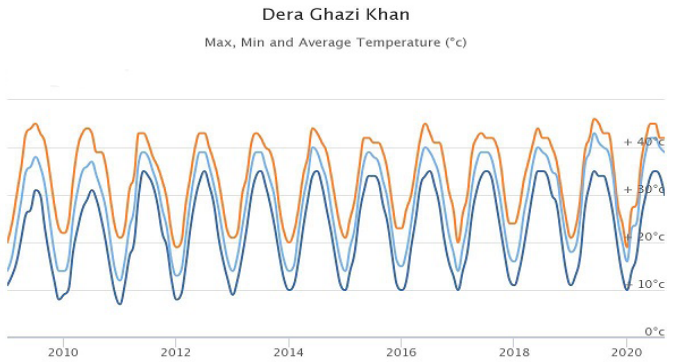

Figure 1: *Average minimum and maximum temperature of DG Khan during 2010-2020*

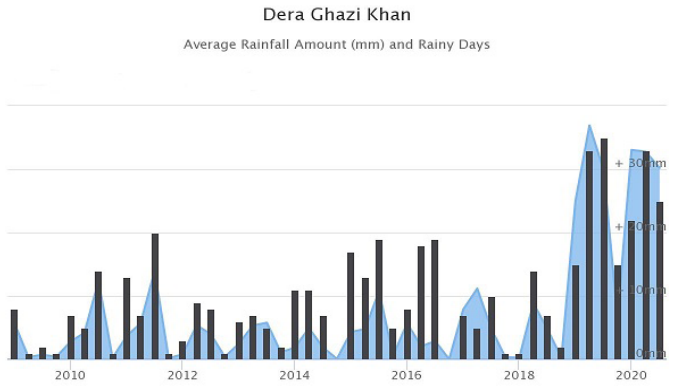

Figure 2: *Average rainfall data of DG Khan during 2010-2020.*

Conclusions and Recommendations

It is concluded from the findings of the present investigations that "Dehli White and Suffen" grafts should be used for scion grafting. Dehli White is an excellent cultivar to achieve high fruit yield. Suffen is better yielding and highly biofortified cultivar that can appeal consumers. So, it would be recommended that general cultivation of Dehli White and Suffen can ensure food security and can also impart in afforestation.

Novelty Statement

Local rootstock of ber was a sexually propagated by using t-grafting technique that enhanced fruit yield and quality in arid climate of DG Khan.

Author's Contribution

Javaria Sherani conducted research, collected data and prepared manuscript. Muhammad Saleem Jilani and Tanveer Ahmad supervised the study. Sohail Kamaran, Tehseen Ali Jilani, Abdul Manan and Mateen Sajid performed data analysis, reviewed manuscript and made changes.

Conflict of interest

The authors have declared no conflict of interest.

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