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Performance of Different Grapefruit (*Citrus paradisi* Macf.) Genotypes on Sour Orange (*Citrus aurantium* L.) Rootstock under the Climatic Conditions of Peshawar

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Abstract: Eight grapefruit (*Citrus paradisi* Macf.) genotypes namely Ruby Red, Red Blush, Marsh JBC-430, Reed, Red Mexican, Shamber, White-I local and White-II local on sour orange (*Citrus aurantium* L.) rootstock were planted at Agriculture Research Institute Tarnab, Peshawar, Pakistan during the year 1996. These genotypes were evaluated for fruit maturity, fruit weight, fruit volume, number of seeds per fruit, number of segments per fruit, juice percentage, rind percentage, fruit texture, rind colour, pulp weight, Total Soluble Solids, acidity percentage, reducing sugar, non-reducing sugar, sugar acid ratio, total sugar percentage and vitamin C content during the year 2003-04. The fruit of Ruby Red matured earliest (last week of November). Red Blush, Red Mexican, Shamber and White-I matured in the first week of December while Marsh JBC-430, Reed and White-II matured in the second week of December. Maximum fruit weight was observed in Red Mexican (506 g) and also had maximum fruit volume (600.0 cm³). Ruby Red, Reed, Red Mexican and Shamber had smooth and dotted fruit texture. While fruits of Red Blush and Marsh-JBC-430 had smooth texture and White-I and White-II had rough and dotted texture. Reed, Shamber, Red Blush, Ruby Red and Red Mexican had greenish yellow rind colour while Marsh-JBC.430, White-I and White-II had yellow rind colour. The maximum number of seeds per fruit were found in Ruby Red (54.67) and Red Blush (54.00) while the minimum number of seeds were found in White-I (3.66). Maximum number of segments per fruit were found in Ruby Red (14.67) followed by White-II (14.00) and the minimum number of segments were found in Reed (12.00). Maximum juice percentage was found in Red Blush (57.25) and Ruby Red (52.25) and the minimum juice percentage was observed in White-II (26.78). The maximum rind percentage was found in White-II (43.46%) and the minimum rind percentage was found in Ruby Red (26.97%). Pulp weight were maximum in Red Mexican (85.23 g) followed by Reed (83.10 g) and pulp weight was minimum in Marsh-JBC.430 (51.10 g). Total soluble solids were maximum in Red Mexican (10.30 Brix°) and minimum in Ruby Red (7.66 Brix°). The maximum acidity was found in White-II (2.32%) and the minimum acidity was found in Red Mexican (0.85%). Maximum reducing sugars were found in Red Blush (4.25%) and Shamber (4.24%) and minimum reducing sugar was found in White-II (2.76%). Total sugars were maximum in Ruby Red (6.43%) and Red Blush (6.28%) and minimum in Red Mexican (3.46%). Non-reducing sugar was maximum in Ruby Red (2.81%) and minimum in Red Mexican (0.23%). Maximum sugar-acid ratio was found in Ruby Red (7.34%) and Red Blush (5.34%). Red Blush (58.17) and White-II (55.23) had maximum vitamin C and White-I (42.28) had minimum vitamin C.

Key words: *Citrus paradisi* Macf., *Citrus aurantium* L., genotypes, rootstock, post-harvest quality

INTRODUCTION

Grapefruit (*Citrus paradisi* Macf.) were first reported growing in Barbados about 1750. The grapefruit originated in the West Indies since it was unknown in Europe or the Orient prior to its discovery in the New World. Grapefruit are grown throughout tropical and subtropical regions, particularly in the Western Hemisphere. The top five grapefruit-producing countries in order of importance are the United States, Israel, Cuba,

Argentina and South Africa^[1]. Most grapefruit come true-to-type from seed however, growing a citrus tree from seed is undesirable. Seedling trees are juvenile, which means the plants will be vigorous, thorny and have an erect, upright growth habit. Juvenility may last 6 to 15 years, during which time the tree does not flower. Grapefruit can be propagated by budding, grafting and cuttings, although the latter is least desirable. The agro-ecological data of Agriculture Research Institute Tarnab, Peshawar shows that Peshawar has warm,

sub-humid climate having annual rainfall from 450-700 mm, mean temperature 20-22°C, altitude range 300-600 m, fertile plain, loamy soil and 64% irrigated land. There is no regular orchard of grapefruit although the climatic conditions of Peshawar are quite congenial for its cultivation. The most common existing genotypes of grapefruit in Peshawar are Marsh seedless, Duncan, Speen and Sur. The performance of Marsh seedless and Duncan in Peshawar are good but still the growers are looking for better genotypes, which produce healthy and best quality fruits. In other parts of the world the research scientists also studied the performance of different grapefruit genotypes on various rootstocks. Sidahmed and Khalil^[2] studied 13 grapefruit (*Citrus paradisi*) cultivars on a sour orange rootstock in Central Sudan and reported that the newly introduced cultivars (Miami, Brown, Red Blush, Shamber, Little River, Carpenter Marsh, Frost Marsh, Howell, Davis Seedless) showed better performance. Ahmed *et al.*^[3] reported that the different genotypes and dates of harvest had a significant effect on the total soluble solids, acidity, ascorbic acid, sugar acid ratio, total sugar, non-reducing sugar and reducing sugar contents. Human and Kockemoer^[4] studied the performance of pigmented grapefruit cultivars on rough lemon rootstock. They reported that total yields were highest (203 kg/tree) with the pink cultivars Ruby McLean. The red cultivars Star Ruby and Nel ruby also performed well and had the best internal fruit quality despite the trees being 2 years younger than those of the other cultivars. Syvertsen *et al.*^[5] studied the performance of five to six years old Red Blush grapefruit on sour orange rootstock. They reported that there was significant effect on fruit yield. Muller *et al.*^[6] reported that the trees of Marsh seedless grapefruit on 10 year old Gou Tou rootstocks showed good development and cropping. Tuzcu *et al.*^[7] studied the effect of common sour orange rootstocks on the fruit yield of Marsh seedless and Red blush grapefruit and reported that common sour orange performed quite well with both the grapefruit cultivars.

Ye and Ye^[8] studied the grapefruit and its development prospects in China. They reported that most promising genotypes are Marsh, Ruby and Star Ruby. Owing to the high temperature requirements of grapefruit, the most suitable regions for its cultivation in China are Hainan, Guangdong Guangxi, Fujian and some areas in Yunnan and Taiwan. Foguet *et al.*^[9] studied twelve red grapefruit cultivars and clones in Argentina species included Star Ruby, Henderson, Ray Ruby, Flame Rio red, Burgundy, Rouge La Tona, Oran Red and Ruben Pink. Ruben Pink and Rio Red obtained the greatest fruits, while Star Ruby and Henderson obtained the most juicy fruits.

The number of seeds varied from 1.25 to 3.87, with the lowest numbers in Ray Ruby, Star Ruby and Burgundy.

It is locally believed that grapefruit is best for diabetics patient, so it has high value fruit for not only normal healthy person but also among diabetics patients. The price of one dozen grapefruits in the local market is ranged from 36 to 60 Rupees while the same quantity of Kinnow mandarin and sweet oranges price is ranged from 24 to 48 Rupees.

The project was intended to compare the physico-chemical characteristics of different genotypes of grapefruit raised on sour orange (*Citrus aurantium* L.) rootstock under the agro-climatic conditions of Peshawar.

MATERIALS AND METHODS

This study was conducted on different grapefruit genotypes at Agriculture Research Institute Tarnab, Peshawar during the year 2003. Eight different genotypes of grapefruit namely Ruby Red, Red Blush, Marsh JBC-430, Reed, Red Mexican, Shamber, White-I local and White-II local planted in March 1996 on the sour orange rootstock were selected to conduct research studies. The experiment was laid out according to Randomized Complete Block Design, having eight treatments (genotypes). There were three replications of each treatment. Each replication had three trees and the total numbers of trees were 72. Trees were planted at 6 by 6 m plant to plant and row to row space in square planting system. The following parameters were studied; time to fruit maturity, fruit weight (g), fruit volume (cm³), rind texture, rind colour, juice percentage, percent rind, pulp weight (g), number of seeds/fruit, number of segments/fruit, total soluble solids (Brix°), percent acidity, sugar:acid ratio, non-reducing sugar, reducing sugar, percent total sugar and vitamin C (mg/100 mL). The chemical analyses were followed as per methods described by AOAC^[10].

RESULTS

By observing the colour of fruit it is evident from Table 1 earliest maturing genotype was Ruby Red that matured in last week of November while the latest Maturity genotypes were Marsh-JBC-430, Reed and White-II matured in second week of December the rest of the genotypes Red Blush, Red Mexican, Shamer and White-I matured in 1st week of December.

The data regarding rind colour showed that genotypes Ruby Red, Red Blush, Reed, Red Mexican and Shamber had greenish yellow colour while genotype Marsh JBC White-I and White-II had yellow colour.

Table 1: Time of fruit maturity, rind colour and rind texture of different genotypes of grapefruit

Genotypes	Time of fruit maturity	Rind colour	Rind texture
Ruby Red	4th week of Nov.	Greenish yellow	Smooth and dotted
Red Blush	1st week of Dec.	Greenish yellow	Smooth
Mash-JBC 430	2nd week of Dec.	Yellow	Smooth
Reed	2nd week of Dec.	Greenish yellow	Smooth and dotted
Red Mexican	1st week of Dec.	Greenish yellow	Smooth and dotted
Shamber	1st week of Dec.	Greenish yellow	Smooth and dotted
White-I local	1st week of Dec.	Yellow	Rough and dotted
White-II local	2nd week of Dec.	Yellow	Rough and dotted

The data regarding rind colour showed that genotypes Ruby Red, Red Blush, Reed, Red Mexican and Shamber had greenish yellow colour while genotype Marsh JBC White-I and White-II had yellow colour.

The data regarding rind texture showed that genotypes Red Blush, Marsh JBC-430 were smooth and Ruby Red, Reed and Red Mexican were smooth and dotted while White-I and White-II were rough and dotted (prominent Oil glands).

Fruit weight of various genotypes was significantly different. Maximum fruit weight was observed in Red Mexican (506.0 g) and the minimum fruit weight was observed in Ruby Red (302.4 g) while the difference in fruit weight among other genotypes Red Blush, Marsh-JBC-430, Reed, Shamber, White-I local and White-II local were not significant (Table 2).

The results regarding the fruit volume were highly significant. Maximum fruit volume (600.0 cm³) was observed in Red Mexican and White-II (483.3 cm³). Minimum fruit volume was observed in Ruby Red and Shamber (343.3 cm³). While the differences in fruit volume among other genotypes Red Blush, Marsh-JBC-430, Reed and White-I were non-significant.

There were significant differences in pulp of different genotypes (Table 2). The pulp weight were maximum in

Red Mexican (85.23 g) followed by Reed (83.10 g) while it was minimum in Marsh-JBC-430 (51.10 g).

Maximum juice percentage was found in Red Blush (57.25%) followed by Ruby Red (52.25%) while the juice percentage was minimum in White-II (26.78%).

It was found that maximum rind percentage was found in White-II (43.46%) and minimum percentage was found in Ruby Red (26.97%). Rind percentage was also more in genotypes Marsh-JBC-430 (33.11%), White-I (29.9%) and Red Mexican (29.8%) (Table 2).

Maximum number of seeds was found in Red Mexican (54.67) and White-II (54.00) and minimum number of seeds were found in White-I (3.66) (Table 2).

Maximum number of segments were observed in Ruby Red (14.67) followed by White-II (14.00) and minimum number of segments were observed in Reed (12.00) (Table 2).

It was found that total soluble solids were maximum in Red Mexican (10.30 Brix°) and minimum total soluble solids were found in Ruby Red (7.66 Brix°).

Maximum acidity was found in White-II (2.32%) and minimum acidity was found in Red Mexican (0.85%).

The maximum Sugar acid ratio were found in Ruby Red (7.34%) followed by Red Blush (5.34%). Minimum sugar acid ratio was found in White-II (1.98%).

It was found that maximum Vitamin C content were found in Red Blush (58.17) and White-II (55.23). Minimum vitamin C content was found in White-I (42.38).

Maximum reducing sugar (4.25%) were found in Red Blush and Shamber (4.24%). Minimum reducing sugar (2.76%) was found in White-II.

The non-reducing sugar among different genotypes were highly significant. It was found that maximum non-reducing sugar was found in Ruby Red (2.81%) and

Table 2: Fruit weight (g), fruit volume (cm³), pulp weight, juice (%), rind (%), seeds/fruit, segments/fruit, total soluble solid (Brix°), acidity (%), sugar acid ratio, vitamin C, reducing sugar (%), non-reducing sugar and total sugar of different genotypes of grapefruit

Genotypes	Fruit weight (g)	Fruit volume (cm ³)	Pulp weight	Juice (%)	Rind (%)	Seeds/fruit	Segments/fruit
Ruby Red	302.4c	343.3d	56.20cd	52.25ab	26.97c	5.33bc	14.67a
Red Blush	375.5bc	460.0bc	55.17d	57.25a	27.71bc	5.00bcd	12.67bc
Marsh-JBC-430	378.0bc	446.7bc	51.10d	45.91b	33.11b	4.33cd	13.3abc
Reed	396.5b	368.3cd	83.10a	47.12b	27.04c	5.33bc	12.00c
Red Mexican	506.0a	600.0a	85.23a	50.40b	29.83bc	54.67a	13.00bc
Shamber	358.8bc	343.3d	70.67b	51.52ab	27.11c	6.00b	13.00bc
White-I	368.1bc	436.7bc	63.73bc	48.82b	29.94bc	3.66d	13.00bc
White-II	321.7bc	483.3b	71.66b	26.78c	43.46a	54.00a	14.00ab
LSD 0.05%	89.09	92.48	8.258	6.654	5.838	1.437	1.406
Genotypes	Brix°	Acidity (%)	Sugar acid ratio	Vitamin C	Reducing sugar (%)	Non-reducing sugar	Total sugar
Ruby Red	7.66c	0.87c	7.34a	53.35b	3.46bc	2.81a	6.43a
Red Blush	9.07abc	1.17bc	5.34b	58.17a	4.25a	1.93ab	6.28ab
Marsh-JBC-430	8.90abc	1.12c	5.12bc	43.89d	3.87ab	1.67bc	5.64bc
Reed	8.80abc	1.28bc	3.15de	45.70cd	3.09cd	0.89cd	4.03e
Red Mexican	10.30a	0.85c	4.96bc	48.60c	3.38c	0.23d	3.64e
Shamber	9.86ab	1.12c	4.71bcd	54.76ab	4.24a	0.93cd	5.23cd
White-I	9.00abc	1.61b	3.49cde	42.38d	3.33c	1.73bc	5.15cd
White-II	8.63bc	2.32a	1.98e	55.23ab	2.76d	2.31ab	4.85d
LSD 0.05%	1.613	0.469	1.786	4.246	0.452	0.973	0.735

minimum non-reducing sugar was found in Red Mexican (0.23%) (Table 2).

It was observed that total sugar were maximum in Ruby Red (6.43%) and Red Blush (6.28%) and minimum in Red Mexican (3.64%) (Table 2).

DISCUSSION

The earliest maturing genotype was Ruby Red that matured in last week of November while the late maturing genotypes were Marsh-JBC-430, Reed and White-II that matured in second week of December. This is due to varietal character. Some genotypes have fast growth so they mature early and some genotypes have slow growth so they mature late.

As showed in data Ruby Red, Reed, Red. Mexican and Shamber had smooth and dotted fruit texture. While fruit of Red Blush and Marsh-JBC-430 had smooth texture and White-I and White-II had rough and dotted texture. It is due to varietal character. These results are in agreement with the findings of Anwar^[11]. It was found that Ruby Red, Reed, Shamber and Red. Mexican had greenish yellow rind colour while Marsh-JBC.430, White-I and White-II had yellow colour. It is due to genetic makeup or a genotype character.

As showed in data the maximum number of seeds were found in Ruby Red (54.67) and Red Blush (54.00) and the minimum number of seeds were found in White-I (3.66). The maximum number of segments were found in Ruby Red (14.67) and White-II (14.00). While the minimum number of segments were found in Reed (12.00). It is due to genotype character.

The maximum juice percentage was found in Red Blush (57.25) and Ruby Red (52.25) while the minimum juice percentage was found in White-II (26.78). The difference in percentage of juice is a genotype character. Some genotypes produce fruit, which are juicier while some genotypes produce fruit, which are less juicy. These results are in agreement with the findings of Foguet *et al.*^[9]

The maximum rind percentage was found in White-II (43.46%) and the minimum rind percentage was observed in Ruby Red (26.97%). The genotypes with thick rind have maximum rind percentage and the genotypes with thin rind have minimum rind percentage.

The pulp weight was maximum in Red. Mexican (85.23 g) followed by Reed (83.10 g) and pulp weight as minimum in Marsh-JBC-430 (51.10 g). These differences in pulp weight are due to genotype character. These results are in agreement with the findings of Sidahmed and Khalil^[12].

Total soluble solids were maximum in Red Mexican (10.30) and minimum in Ruby Red (7.66). The difference in total soluble solids is due to difference in genotypes.

Major portion of the soluble solids of the fruit juices are the sugars. Bravorman^[13] found that orange juices contained about 11 to 20% soluble solids most of which were sugars. Von Leosecke *et al.*^[14] reported that in Florida seedling, pineapple and Valencia oranges are commonly used for juice production the Parson Brown considered less suitable because of somewhat lower soluble solids and flavour.

Acidity of citrus juice is due to content of citric acid, malic acid small amount of benzoic acid, oxalic acid, tartaric acid, succinic acid as well as formic acid. The maximum acidity was found in White-II (2.32%) and the minimum acidity was found in Red Mexican (0.85%). The difference in acidity of different genotypes is due to rootstock, mineral nutrition and climatologically factors. The data regarding the amount of reducing, non-reducing, total sugar and sugar-acid ratio showed that maximum reducing sugar were found in Red Blush (4.25%) and Shamber (4.24%) while the minimum reducing sugar was found in White-II (2.76%). Non-reducing sugar was maximum in Ruby Red (2.81%) and minimum in Red. Mexican (0.23%). Total sugar were maximum in Ruby Red (6.43%) and Red Blush (6.28%) and minimum in Red. Mexican (3.46%). Maximum sugar-acid ratio were found in Ruby Red (7.34%) and Red Blush (5.34%) while minimum sugar-acid ratio was found in White-II (1.98%). The difference in reducing, non-reducing, total sugar and sugar-acid ratio is due to environmental factors or genetic make up of the genotypes. Similar trends were reported by Harding^[15] for Duncan grapefruit grown in Florida Vitamin C was maximum in Red Blush (58.17 mg/100 mL) and white-II (55.23 mg/100 mL) and minimum in White-I (42.28 mg/100 mL). Haag *et al.*^[16] studied the mandarin cultivars orange cultivars and tangerine cultivar and found that ascorbic acid concentration ranged from 30 to 95 mg/100 mL, juice. Kefford^[17] found that juice of citrus contains about 40 to 70 mg of ascorbic acid per 100 mL.

Ruby Red was the early maturing variety with maximum total sugar, non-reducing sugar and sugar-acid ratio while minimum fruit weight and rind percentage. Red Blush had maximum juice percentage, reducing sugar and vitamin C. Red Mexican had maximum fruit weight, yield and total soluble solids. White-II was late maturing variety with minimum reducing sugar, sugar-acid ratio, juice percentage and had maximum acidity.

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