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*Full Length Research Paper*

# Evaluation of cactus pear fruit quality at Mara ADC, South Africa

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**The present study was conducted to evaluate quality of different Cultivars of cactus pear traits in Mara Research Station. Seven Cultivars (*Nepgen*, *R1251*, *Sharsheret*, *Cross X*, *Berg* x *Mexican*, *Santa Rosa*, *Morado*) of cactus pear were planted in a completely randomized design. Orchard consisted of 10 plants per Cultivar planted in a single row. No irrigation supplementation was given and pruning, pad thinning were performed. Data on fruit quality traits were collected from two different years (2005 and 2006) and subjected to analysis of variance using the general linear model procedure of statistical analyses system (SAS). All Cultivars in the first year had peel thickness of less than 6.00 mm and in the second year more than 6.00 mm. All Cultivars in the year 2005 and 2006 except *Berg* x *Mexican* and *Nepgen* had the fruit mass of more than 120 g, recommended for international market. The mean fruit mass decreased from 143.4 g in the first year to 127.3 g in the second year. The decrease might be due to low rainfall and temperature. Due to a decrease in fruit length in the second year, fruit shape shifted from being elliptic to ovoid shape, however the equatorial diameter remained constant. Total soluble solids (TSS) content increased from 13.17 $^0$Brix during the first year to 13.78 $^0$Brix in the second year. It was then concluded that in each year, the fruit quality change as a function as the type of Cultivar.**

**Key words:** Quality, Cactus pear, Cultivars, South Africa.

## INTRODUCTION

*Opuntias* species are known as cactus pear, which includes numerous species of the *opuntia* genus, all of them from the Americas. Cactus *opuntias* (catus pear) are terrestrial cacti, showing multiple segmented stems with cylindrical, globose or flattened stem segments and spiniferous areoles, which are not restricted to ribs, but regularly arranged on the whole stem surface, partly on low tubercles and which bear spines and glochids (Switzerland, 2001). The family cactaceae are an exciting and challenging group of plants because of their varied morphology and succulence, their showy flowers, their adaptations to the environment, and their reproductive strategies. The subfamily opuntioideae is native to North and South America from Southern Canada to Patagonia. Various species are introduced in many other regions of the world such as Australia, South Africa, and Madagascar. A number of plantations were established in the middle eighties and are increasing in number (Wessels et al., 1997). Commercial plantations of spine-less cactus pear are well established and in South Africa, Limpopo Province contains the largest cactus pear plantations for fruit production. Cactus pear fruits are appreciated for their characteristics taste and aroma as well as their dietetic properties. Fruits of different shapes, colours and flavours can be produced from each Cultivar. The juicy pulp contributes 60 – 70% of the total fruit weight and contains hard coated seeds with the pulp weight of 5 – 10% (Griffiths and Hare (1906); Cantwell, 1991; Barbera, 1995). Fruits require 110 – 120 days to develop and are mainly produced on mature cladodes (Cantwell, 1986). A few international studies have been interested on the characterization of cactus pear varieties for fruit production (Chessa and Nieddu, 1997; Nieddu et al., 2002). Although South Africa hosts one of the largest germplasm collections of cactus pear in the world limited research into emerging crop has been published (Chapman et al., 2002). Few publications have reported on the evaluation of the fruit quality of different varieties that occur in South Africa. Therefore, the aim of this study was to evaluate quality for different Cultivars of cactus

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pear fruit grown at Mara ADC, Limpopo Province for each year.

## MATERIALS AND METHODS

### Trial site and layout

Trial site, Evaluation was carried out at Mara Research Station in the Vhembe district of the Limpopo Province. Mara ADC is located ± 54 km West of Louis Trichard, Limpopo Province at 23°05'S and 29°25'E, at altitude of 961 m above sea level in the Arid Sweet Bushveld. The average annual minimum and maximum temperatures recorded are 12.7 and 25.1°C respectively. The average seasonal rainfall is 441 mm.

Trial layout, Data was gathered from 7 Cultivars (*Nepgen*, *R1251*, *Sharsheret*, *Cross* x, *Berg* x *Mexican*, *Santa Rosa*, Morado) Cultivars. The orchard consisted of 10 plants per variety planted in a single row orientated in an East/West direction. Plants were spaced at 5 m between rows and 2 m in a row. Ten plants were used for data collection. Data were collected over two years (Year 1: 2005 and Year 2: 2006) and used for fruit quality evaluation.

### Cultural practices

No supplementary irrigation was given and orchard practices followed were as described in Potgieter (1997). Accepted orchard practices such as pruning and pad thinning were performed.

### Experimental procedures

Fruit quality traits characters were evaluated from different types of cactus pear and their descriptive value as describe in Table 1.

### Statistical analyses

The data were subjected to analysis of variance using the general linear model procedure of statistical analyses system (SAS), 1998 for completely randomized design. Each year was run separately. Least square means were used to detect significant differences between means at $p \leq 0.05$.

## RESULTS

Fruit quality traits investigated in this study is given in Table 2, 3 and 4. The fruit quality traits significantly differed between two years. Significant differences in fruit mass were observed between Cultivars at $p < 0.05$ in year 1 and 2 (Table 2 and 3), respectively. *Nepgen* (157.1 g), *R1251* (145.9 g), *Santa rosa* (144.8 g) and *Cross* x (150.6 g) had the highest fruit mass in year 1. Cultivars that had the highest fruit mass were *Sharsheret* (141.3 g) *Santa rosa* (138.8 g) in year 2 (Table 3). Fruit mass decreased from 143.4 g in year 1 to 127.3 g in year 2 (Table 4).

There were significant Cultivar effects on fruit diameter in year 1 and non-significant effects in year 2 (Table 2 and 3). Fruit diameter had a low variability within Cultivars tested in year 1 (Table 2). Cultivars with widest equatorial diameter were *Cross* x (56.7 mm), *Nepgen* (55.9 mm) and *Santa rosa* (56.0 mm). Cultivars with the lowest diameter were *Sharsheret* (50.8 mm) and *Morado* (51.9 mm) in year 1 (Table 2).

There were no significant Cultivar effects on fruit length in year 2 (Table 3) nor significant Cultivar effects on fruit length at $p < 0.05$ in year 1 (Table 2). A Cultivar with the highest fruit length was *Nepgen* (87.6 mm) as compared to Cultivar *Mexican* (74.3 mm).

Fruit shape index used for determining fruit shape did not show large variation between Cultivars in year 1 (Table 2). Cultivars *Mexican* and *Cross* x had a fruit shape index in the range of 0.70 – 0.79 and the majority of other fruits had a fruit shape index in the range 0.60 – 0.69 in year 1 (Table 2). However in year 2, the majority of the Cultivars has fruit shape index range of 0.70 – 0.79 and Cultivar *Mexican* had fruit shape index in the range of 0.80 - 0.89 (Table 3). Fruit shape shifted from being elliptic (shape index 0.56 – 0.69) in year 1 to ovoid (shape index 0.70 – 0.79) in year 2, whilst the equatorial diameter remained constant (53.8 mm in year 1and 53.6 mm in year 2). These changes increases fruit shape index in year 2 (Table 4).

Cultivar *Nepgen* (4.6 mm) and *R1251* (4.1 mm) had the highest peel thickness compared to *Morado* (2.4 mm), *Mexican* (3.2 mm), *Santa rosa* (3.2 mm) and *Sharsheret* (3.3 mm) with low peel thickness in year 1 (Table 2). Peel thickness did not differ among different types of Cultivars in year 2. The overall peel thickness of Cultivars in year 1 (6.8 mm) differed significantly from that recorded for all Cultivars in year 2 (3.5 mm) (Table 4).

Cultivars *Santa rosa* (83.6 g), *Cross* x (79.6 g) and *R1251* (75.9 g) produced fruit with the highest pulp mass whereas Cultivars *Morado* (66.9 g), *Nepgen* (71.3 g) and *Sharsheret* (71.5 g) had the lowest pulp mass in year 1 (Table 2). Cultivars that had the highest pulp mass were *Santa rosa* (83.6 g), *R1251* (75.9 g) and *Cross* x (79.6 g) in year 2 (Table 3). Cultivars with the lowest pulp mass were *Morado* (66.9 g) and *Mexican* (67.8 g) (Table 3). The overall pulp content decreased from 73.8 g in year 1 to 65.9 g in year 2 (Table 4).

Varieties that had the highest TSS content as measured in $^0$Brix were *Morado* (14.4) in year 1 (Table 2) whereas varieties that had the lowest TSS content were *R1251* (11.7), *Santa rosa* (12.7) and *Sharsheret* (12.8). The majority of the varieties had a higher TSS content over year 2 (Table 3), compared to year 1 (Table 2). There was no significant difference for TSS among different types of cactus pear Cultivars in year 2 (Table 3). TSS content known as an indication of the sugar content, increased from 13.17 $^0$Brix during year 1 to 13.78 $^0$Brix in year 2 (Table 4).

There was significant Cultivar effect on seed mass and total number of seeds in year 2 (Table 3). Cultivars with the highest seed mass were *R1251* (9.4 g), *Nepgen* (8.5 g) *Cross* x (8.8 g) whilst Cultivar *Sharsheret* (6.7 g) had the lowest seed weight. Cultivars with the highest total number of seeds were *Berg* x *Mexican* (291.5), *Morado* 291.5) and *Santa rosa* (282.4) and Cultivar *Nepgen* had the lowest total number of seeds in year 2 (Table 3).

**Table 1.** List of fruit quality traits characters and their descriptive values

| Character name | Fruit quality trait and descriptive value |
|---|---|
| Fruit mass (FM) (g) | Fruit mass of 10 plants per cultivar |
| Peel thickness (PT) (mm) | Measurement was taken at 180 degrees for 10 fruits of the same cultivars using vernier caliper |
| Total soluble solid (TSS) ($^0$Brix) | Total soluble solid content was determined for 10 fruits of the same cultivars using pocket refractometer |
| Pulp mass (PM) (g) | Pulp mass measured for 10 fruits of the same cultivars |
| Fruit diameter (FD) (mm) | Equatorial diameter of 10 fruits per cultivars |
| Fruit length (FL) (mm) | Longitudinal length of 10 fruits per cultivars |
| Pulp colour | Pulp colour, red, yellow and white |
| Fruit shape | Fruit shape index = fwidth / flength<br>0.45 – 0.55 = oblong, 0.56 – 0.69 = elliptic, 0.70 - 0.79 = ovoid, 0.80 - 0.89 = round |

**Table 2**. Evaluation of cactus pear cultivars on fruit quality in year 1

| Cultivar | FM (g) | FW (mm) | FL (mm) | FSHAPE | PEELTH (mm) | PM (g) | TSS $^0$Brix |
|---|---|---|---|---|---|---|---|
| *Berg x mexican* | 128.3$^{b}$ | 52.7$^{bc}$ | 74.3$^{c}$ | 0.71$^{ab}$ | 32.0$^{bc}$ | 67.8$^{c}$ | 13.5$^{ab}$ |
| *Cross x* | 150.6$^{a}$ | 56.7$^{a}$ | 77.1$^{bc}$ | 0.73$^{a}$ | 34.0$^{bc}$ | 79.6$^{ab}$ | 13.4$^{ab}$ |
| *Morado* | 121.5$^{b}$ | 51.9$^{cd}$ | 75.1$^{c}$ | 0.69$^{ab}$ | 24.4$^{d}$ | 66.9$^{c}$ | 14.4$^{a}$ |
| *Nepgen* | 157.1$^{a}$ | 55.9$^{ab}$ | 87.6$^{a}$ | 0.64$^{c}$ | 46.1$^{a}$ | 71.3$^{bc}$ | 13.7$^{ab}$ |
| *R1251* | 145.9$^{a}$ | 55.1$^{abc}$ | 80.6$^{b}$ | 0.68$^{bc}$ | 40.5$^{ab}$ | 75.9$^{abc}$ | 11.6$^{c}$ |
| *Santa – Rosa* | 155.4$^{a}$ | 56.0$^{ab}$ | 82.1$^{b}$ | 0.68$^{bc}$ | 32.3$^{cd}$ | 83.6$^{a}$ | 12.7$^{bc}$ |
| *Sharsheret* | 144.8$^{a}$ | 48.8$^{d}$ | 77.0$^{bc}$ | 0.64$^{c}$ | 33.0$^{bc}$ | 71.5$^{bc}$ | 12.8$^{bc}$ |
| s.e | 5.602 | 1.234 | 1.932 | 0.017 | 2.821 | 3.658 | 0.459 |

$^{a, b, c, d, e, f}$ Column means with common superscripts do not differ (P > 0.05)

FM = Fruit mass, FW = Fruit width, FL = Fruit diameter, FSHAPE = Fruit shape, PEELTH = Peel thickness, PM = Pulp mass and TSS = Total soluble solids

**Table 3.** Evaluation of Cultivar's effect on cactus pear fruit quality in year 2.

| Cultivar | FM (g) | FW (mm) | FL (mm) | FSHAPE | PEELTH (mm) | PM (g) | TSS ($^0$Brix) | Seed weight (g) | TNS |
|---|---|---|---|---|---|---|---|---|---|
| *Berg* x *mexican* | 118.9$^{c}$ | 54.2 | 67.8 | 0.80 | 8.60 | 64.4$^{bc}$ | 13.5 | 7.6$^{bc}$ | 291.5$^{a}$ |
| *Cross x* | 127.1$^{abc}$ | 53.3 | 69.4 | 0.76 | 4.91 | 71.1$^{ab}$ | 14.1 | 8.8$^{ab}$ | 272.6$^{ab}$ |
| *Morado* | 122.1$^{bc}$ | 52.6 | 69.3 | 0.76 | 6.47 | 67.7$^{abc}$ | 13.8 | 7.6$^{bc}$ | 291.5$^{a}$ |
| *Nepgen* | 117.1$^{c}$ | 51.5 | 73.7 | 0.70 | 6.45 | 57.5$^{c}$ | 14.4 | 8.5$^{ab}$ | 233.5$^{b}$ |
| *R1251* | 125.6$^{abc}$ | 50.8 | 65.3 | 0.71 | 6.48 | 64.6$^{bc}$ | 13.5 | 9.4$^{a}$ | 267.8$^{ab}$ |
| *Santa – Rosa* | 138.8$^{ab}$ | 56.4 | 74.1 | 0.76 | 6.57 | 76.2$^{a}$ | 13.8 | 8.1$^{b}$ | 282.4$^{a}$ |
| *Sharsheret* | 141.3$^{a}$ | 56.7 | 75.6 | 0.75 | 8.43 | 60.2$^{c}$ | 13.4 | 6.7$^{c}$ | 252.7$^{ab}$ |
| S.E | 6.019 | 1.803 | 3.379 | 0.025 | 0.1009 | 3.824 | 0.320 | 0.473 | 13.810 |

$^{a, b, c, d, e, f}$ Column means with common superscripts do not differ (P > 0.05).

FM: Fruit mass (g), FW: Fruit diameter (mm), FL: Fruit length (mm), FSHAPE: Fruit shape, PEELTH: Peel thickness (mm), PM: Pulp mass (g), TSS: Total soluble solids ($^0$Brix), TNS: Total number of seeds.

The correlation coefficients were determined among each of the fruit and seed characteristics (Table 5). Fruit mass was significantly and positively correlated to fruit diameter (r = 0.43; p = 0.0002), fruit length (r = 0.71; p =

**Table 4.** Median values of quality characters of fruits during two years.

| Fruit quality trait | Year | Value |
|---|---|---|
| Peel thickness | 1 | 3.45 mm |
| | 2 | 6.86 mm |
| Fruit shape | 1 | 0.68 |
| | 2 | 0.75 |
| Pulp mass | 1 | 73.8g |
| | 2 | 65.9g |
| Fruit diameter | 1 | 53.8 mm |
| | 2 | 53.6 mm |
| Fruit length | 1 | 79.1 mm |
| | 2 | 70.0 mm |
| Fruit mass | 1 | 143.4 g |
| | 2 | 127.3 g |
| Total soluble solid | 1 | 13.17 $^0$Brix |
| | 2 | 13.78 $^0$Brix |

0.0001), pulp mass (r = 0.75; p = 0.0001), seed weight (r = 0.33; p = 0.0050) and total number of seed (r = 0.31; p = 0.0102) and no significant relationship to fruit shape and peel thickness (Table 5). Fruit diameter was significantly and positively correlated to fruit shape (r = 0.68; p = 0.0001), however fruit shape was significantly and negatively correlated to fruit length (r = -0.44; p = 0.0001). Both seed weight and total number of seeds was significantly and positively correlated to pulp mass (r = 0.44 and 0.45, respectively).

## DISCUSSION

Cactus pear mass is affected by the number of seeds (Barbera et al., 1994); cladode load (Wessels, 1988; nglese et al., 1995; rutsch, 1992), water availability (Barbera, 1984) and ripening time (Nerd et al., 1991; Barbera et al., 1994). Results in this study showed that the mean fruit mass of the Cultivars evaluated were 143.4 g in year 1 and 127.3 g in year 2, which is higher than the minimum acceptable mass for cactus pears destined for exportation (120.00 g) (Inglese et al., 2002). The mean fruit mass in year 1 was also higher than that of 140.0 g recommended for commercial fruit production in South Africa (Potgieter and Mkhari, 2002). All cactus pear Cultivars fall within the range 67 to 216 g, which is the range for commercial Cultivars in Mexico (Mondragon and Perez, 1996). The decrease in fruit mass during two years can be attributed to a significant decrease in rainfall in the second year.

In year 1 the *Morado* Cultivar had low fruit diameter and fruit length which was also reported by Mashope (2007).

In year 1, Cultivar *Mexican* and *Cross x* with oval or barrel – shaped fruits were easier to harvest than the elongated fruits and therefore suffered less harvest damage at the stem – end (Cantwell, 1991). Higher resistance of the peel to handling, especially on the fruit base has been shown to reduce damage (Wessels, 1988). This is extremely important because cactus pear is harvested by hand and minor twisting of the fruit results in tears of the peel. Therefore, in terms of shape, the majority of the Cultivars (with ovoid shaped fruits) would qualify for commercialization. During two years, fruit shape shifted from being elliptic in the first year to ovoid in the second year and this can be attributed to a decrease in length of the fruit.

Potgieter and Mkhari (2002) recommended a peel thickness of less than 6 mm for cactus pear fruits. With regards to peel thickness, all Cultivars evaluated in year 1 and *Cross x* in year 2, except *Berg* x *Mexican*, *Morado*, *Nepgen*, *R1251*, *Santa rosa* and *Sharsheret* in year 2, meet the requirements for fruit production in Vhembe district, South Africa. Mexican consumers prefer a thin peel of less than 5 mm, despite the fact that thin peel is convenient for handling.

Pulp colour is a determinant character of the market to be supplied. Local consumers prefer a white pulp whilst overseas consumers prefer a red/orange or purple coloured pulp (Inglese et al., 2002). Varieties with a white pulp colour that suited the preference of the local market were *Morado* and *Nepgen*. The majority of other Cultivars (*Cross x*, *R1251*, *Santa rosa* and *Sharsheret*) would thus be suitable for the international market.

The mean TSS content for the Cultivars tested was 13.17 °Brix in year 1 and 13.78 $^0$Brix in year 2. This TSS level compares well with that recommended for cactus pear fruits (13 – 15 $^0$Brix) (Kuti, 1992). TSS level increased during two years in this study and similar findings of year to year variation in the mean TSS of cactus pear clones have been reported (Wang et al., 1997).

Seed mass for the study ranged from 6.7 to 9.4 g in year 2 for all Cultivars, which is more than the range (2.2 to 6.4 g) reported by Parish and Felker (1997) from Chilean and Mexican clones grown at Kingsville, Texas. Total number of seeds ranged from 233.5 to 291.5, which was higher than the one reported by other authors (Barbera et al., 1991; Pimienta 1990; Parish and Felker, 1997). All cactus pear Cultivars have a large number of seeds to attain good size with a high ratio of aborted to normal seeds.

It has been concluded that fruit quality differs among different types of cactus pear Cultivars in each year. A study to investigate the seed content of Cultivars will be recommended in order to determine the extent to which they affect fruit size. Rainfall and temperature should also be recorded in order to determine their effects on fruit quality.

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**Table 5.** Pairwise correlation coefficient between fruit quality characters.

| | FM | FW | FL | FSHAPE | PEELTH | PM | SWT | TNS |
|---|---|---|---|---|---|---|---|---|
| **FM** | - | | | | | | | |
| **FW** | **0.43** | - | | | | | | |
| **FL** | **0.71** | **0.35** | - | | | | | |
| **FSHAPE** | -0.14 | **0.68** | **-0.44** | - | | | | |
| **PEELTH** | 0.11 | 0.11 | 0.07 | 0.06 | - | | | |
| **PM** | **0.75** | **0.41** | **0.49** | -0.00 | 0.04 | - | | |
| **SWT** | **0.33** | 0.05 | 0.23 | -0.13 | -0.17 | **0.44** | - | |
| **TNS** | **0.31** | **0.25** | 0.02 | 0.22 | -0.08 | **0.45** | **0.43** | - |

FM: Fruit mass (g), FW: Fruit diameter (mm), FL: Fruit length (mm), FSHAPE: Fruit shape, PEELTH: Peel thickness (mm), PM: Pulp mass (g), SWT: Seed weight (g) and TNS: Total number of seeds

NB: Bold-type indicates that correlation coefficients are significant at the 0.05 level.

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