



## DEPARTMENT OF AGRICULTURE



### **Comparison of fruit quality characteristics of 24 cactus pear cultivars with different pulp colours at Mara ADC, Limpopo**

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## **SUMMARY**

For many years, cactus pear cultivar recommendations in South Africa have been based on the performance of cultivars at Grootfontein, in the Karoo, Eastern Cape. Both Brutsch (1979) and later Wessels (1988) noted that some cultivars yielded well in the Karoo interior (Grootfontein) but performed poorly in the higher rainfall area of Alice (Eastern Cape), and in Pretoria (Gauteng), indicating clonal differences in environmental adaptation. Mara-ADC also provided a base for further research with its highest germplasm collection in South Africa. For the purpose of the study, twenty four cultivars were evaluated for fruit quality characteristics and these varieties included yellow (*Cross X*, *R 1260*, *Roedtan*, *Sharsheret*, *R 1251*, *Santa Rosa*, *Malta*, *Morado*, *Turpin*, *Gymno Carpo*, *R 1259*, *Robusta X Castillo*, *American Giant*), white (*Tormentosa*, *Van As*, *Zastron*, *Schagen*, *Skinner Court*, *Fusicaulis*, *Negen*) and red (*Meyers*, *Algerian*, *Nudosa*, *Berg X Mexican*) pulp colour types. The following fruit characteristics were evaluated; FM: Fruit mass (g), FW: Fruit width (mm), FL: Fruit length (mm), P: Peelability, PT: Peel thickness (mm), PM: Pulp mass (g), TSS: Total soluble solids (°Brix) and TNS: Total number of seed for each cultivar. Significant differences were observed in all evaluated fruit characteristics as influenced by the different cultivars. It has however been concluded that fruit quality differs among different types of cactus pear cultivars year to year.

## **INTRODUCTION**

Cactus pears (*Opuntia* species) are native to the semi-arid parts of Central America and the southern USA and are extremely versatile. Cactus *opuntias* (cactus 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. Cactus pears, formerly called prickly pears, were first introduced to South Africa more than 300 years ago and were used as fences to protect crops against wild

animals. The spineless "Burbank" varieties cultivated today were introduced into South Africa in 1974, mainly as a drought-tolerant crop for the arid Karoo regions. 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).

The excellent characteristics of their fruit have led to the cultivation of a number of these varieties for fresh fruit production purposes. The cactus pear germplasm orchard was established in 1998 in Mara ADC with only two rows of one cultivar. In 1999 other cultivars were introduced and it now consists of established 42 cultivars, which were replicated into 6 blocks with 12 rows of 10 plants each. The aim of establishing the orchard was to collect, evaluate and characterize cactus pear accessions with economical potential. The orchard is currently used for research, extension and farmer training unit and as a demonstration site. From the research conducted at the establishment, one PhD thesis, one Master of Science dissertation and a few peer reviewed papers were produced.

Mara germplasm is recognized as the largest collection in South Africa and a complete "Burbank" collection in the world. In the last 15-20 years, cactus pear became a commercial fruit crop with good local and export market potential. Of an estimated 73 000 ha under cultivation in South Africa, 1 500 ha is known to be intensively farmed for fruit production purposes. When compared to more common fruits, competitive prices were obtained on the national fresh produce markets as well as the export markets. There are more than 40 varieties, but the following four are the most popular in relation to consumption: Morado (a delicious white fruit with a very delicate taste); Gymno Carpo (has a yellow-orange colour, very sweet and is available in early December); Algerian (an exotic fruit with an attractive pink/red colour. Primarily used for export, but now locally available from the middle of December - not to be confused with the old red cattle "prickly pear) and Skinners Court (a large, sweet green/white fruit, available middle of January)

Some of the uses of cactus pears include, source of food for human and animals; the shallow root system prevents soil erosion, production of by-products; e.g. jams, syrup, soap and mampoer; the young pads can be used as a green vegetable; it provides security (Impermeable fences) etc. The biggest enemy of the plant is the cochineal insect, which is also used in the manufacture of a natural food and textile dye. Composition and nutritional value per 100g gram edible portion is equivalent to - Water: 87.69%, Kilojoules: 172, Vitamin C: 14mg, Protein: 0.7g, Fats: 0.5g, Carbohydrates (Glucose): 7.8g, Fibre: 1.8g, Potassium: 220mg, Magnesium: 85mg, Calcium: 56mg, Phosphorous: 24mg

Although the huge potential of cactus pear has been recognized and exploited in other parts of the world, the commercial production of the plant as a fruit crop in South Africa is still in its infancy. Initial fruit production efforts were mainly characterized by small orchard size, low fruit quality, less efficient harvest and packaging methods and local marketing arrangements. Current trends dictate larger production units, highly productive varieties, outstanding orchard practices, sophisticated packing equipment and constant adaptation to changing consumer demands. All practices are geared towards improved fruit quality to remain competitive on local- and international markets, while efforts are also made to exploit value-adding and processing opportunities. An overview of modern cultivation, harvest and post-harvest aspects will be presented, with reference to much needed support services will improve the efficiency and sustainability of future cactus pear cultivation.

More than 40 recognized spineless cactus pear varieties are available in South Africa, of which only a few are grown on any commercially significant scale for fruit production. In addition to these varieties, there is a large number of potentially important accessions of which little is known. For farmers to remain competitive on international markets, varieties with improved fruit yield and quality is needed. Germplasm conservation of permanent fruit crops in most developing countries is not seen as a priority. This is mainly due to the long-term nature of permanent crops and the costs involved in the collection, maintenance and horticultural evaluation of these germplasm accessions. The Department of Agriculture in Limpopo has been

conserving 78 accessions (including the Burbank varieties) in the largest spineless cactus pear germplasm bank in Africa at Mara Experimental Farm, Makhado.

Despite recent expansions in the commercial cactus pear industry, limited scientific information is available on the performance of cultivars in the many different agroclimatic regions of South Africa; establishment of cultivar trials is a way in which this situation can be rectified (Brutsch, 1992). Several publications have reported on the evaluation of the fruit quality of different varieties that occur in South Africa (Mashope, 2007 and Potgieter 2001). Therefore, the aim of this study was to collect and evaluate fruit quality characteristics for different cultivars of cactus pear fruit grown at Mara ADC, Limpopo Province.

## **MATERIAL AND METHODS**

The trial is located at Mara Research Station in the Vhembe district of the Limpopo Province. Mara Research Station is situated at 23° 05' S and 29°25' E at altitude of 961 m above sea level. Average annual minimum and maximum temperatures ranges between 12.7°C and 25.1°C, with average annual rainfall of 452mm.

Cactus trees in Mara orchard are planted as 10 trees in a row, with each row representing one cultivar. Twenty four cultivars were evaluated for fruit quality characteristics and these varieties included *Cross X*, *R 1260*, *Roedtan*, *Sharsheret*, *R 1251*, *Santa Rosa*, *Malta*, *Morado*, *Turpin*, *Gymno Carpo*, *R 1259*, *Robusta X Castillo*, *American Giant*, *Tormentosa*, *Van As*, *Zastron*, *Schagen*, *Skinner Court*, *Fusicaulis*, *Negen*, *Meyers*, *Algerian*, *Nudosa* and *Berg X Mexican* regardless of the pulp colour. Ten fruits per tree were collected in January 2008. No irrigation and fertilization were applied and orchard management was followed as described by Potgieter (1997). Fruit traits are described below in Table 1.

The data was subjected to analysis of variance using the general linear model procedure of Number Cruncher Statistical Software in a Complete Randomized Design (CRD). Fisher's LSD Multiple comparison test was used to detect significant differences amongst the means at  $p < 0.05$ .

**Table1.** List of fruit quality traits characters and their descriptive values:

<b>Character name</b>	<b>Fruit quality trait and descriptive value</b>
Fruit mass (FM) g	Fruit mass of ten plants per cultivar
Peel thickness (PT) mm	Measurement was taken at 180 degrees for 10 fruits of the same cultivar using vernier caliper
Total Soluble solids (TSS) °Brix	Total soluble solid content was determined for 10 of the same cultivar using pocket refractometer
Pulp mass (PM) g	Pulp mass measured for 10 fruits of the same cultivars
Fruit length (FL) mm	Longitudinal length of 10 fruits per cultivar
Total number of seeds	Total number of seed per fruit were counted

## RESULTS AND DISCUSSIONS

**Table 2.** Evaluation of cactus pear cultivars on fruit quality characteristics

Cultivar	FM (g)	FW(mm)	FL (mm)	Peelability	PT (mm)	PM (g)	TSS (° Brix)	TNS
Algerian	104 <sup>a</sup>	51.31 <sup>a</sup>	60.64 <sup>a</sup>	2.1 <sup>a</sup>	6.02 <sup>ab</sup>	54.74 <sup>abcd</sup>	13.30 <sup>bcde</sup>	160.2 <sup>a</sup>
Fusicaulis	104.51 <sup>ab</sup>	51.14 <sup>ab</sup>	64.59 <sup>abc</sup>	3.6 <sup>efghijkl</sup>	8.07 <sup>defg</sup>	48.52 <sup>a</sup>	13.06 <sup>bcd</sup>	123.9 <sup>a</sup>
Nudosa	106.69 <sup>abc</sup>	51.93 <sup>abcde</sup>	68.32 <sup>f</sup>	3.5 <sup>efghijkl</sup>	7.31 <sup>bcdef</sup>	51.57 <sup>ab</sup>	9.84 <sup>a</sup>	224.7 <sup>bcd</sup>
American giant	109.32 <sup>abcd</sup>	52.41 <sup>abcde</sup>	61.98 <sup>ab</sup>	3.5 <sup>efghijkl</sup>	6.48 <sup>abcde</sup>	54.74 <sup>abc</sup>	15.96 <sup>efghijklmnop</sup>	300.8 <sup>defghij</sup>
Zastron	110.61 <sup>abcd</sup>	52.66 <sup>abcdef</sup>	73.47 <sup>efghij</sup>	4.1 <sup>efghijkl</sup>	7.35 <sup>bcdef</sup>	51.89 <sup>ab</sup>	12.79 <sup>bc</sup>	206.6 <sup>b</sup>
Turpin	110.97 <sup>abcd</sup>	54.86 <sup>ijk</sup>	68.58 <sup>f</sup>	3.4 <sup>efghijkl</sup>	6.96 <sup>bcdef</sup>	54.72 <sup>abc</sup>	13.33 <sup>bcde</sup>	255.5 <sup>bcdef</sup>
R1260	111.13 <sup>abcd</sup>	53.86 <sup>h</sup>	66.68 <sup>abcde</sup>	2.6 <sup>abcde</sup>	8.50 <sup>efghi</sup>	58.62 <sup>bcdef</sup>	13.54 <sup>cdefgh</sup>	233.6 <sup>bcde</sup>
Skinner court	116.10 <sup>abcde</sup>	52.24 <sup>abcde</sup>	68.88 <sup>f</sup>	3.3 <sup>efghijk</sup>	6.55 <sup>abcde</sup>	62.07 <sup>cdefg</sup>	15.05 <sup>efghijklmno</sup>	258.6 <sup>cdefg</sup>
Nepgen	116.26 <sup>abcde</sup>	51.45 <sup>abcd</sup>	73.71 <sup>efghijk</sup>	3.2 <sup>efghij</sup>	6.45 <sup>abcd</sup>	57.53 <sup>abcde</sup>	13.71 <sup>defghi</sup>	233.5 <sup>bcde</sup>
Roedtan	118.12 <sup>cdef</sup>	50.77 <sup>a</sup>	65.90 <sup>abcd</sup>	3.1 <sup>efghi</sup>	6.31 <sup>abc</sup>	63.55 <sup>cdefg</sup>	13.47 <sup>cdefg</sup>	213.7 <sup>bc</sup>
Van as	118.17 <sup>cdef</sup>	54.37 <sup>i</sup>	70.71 <sup>fgh</sup>	3 <sup>efgh</sup>	8.18 <sup>efgh</sup>	66.78 <sup>efghij</sup>	14.58 <sup>efghijklm</sup>	278.7 <sup>cdefghi</sup>
Malta	118.37 <sup>defg</sup>	53.78 <sup>h</sup>	68.71 <sup>f</sup>	2.8 <sup>abcdef</sup>	6.26 <sup>abc</sup>	64.18 <sup>cdefg</sup>	14.49 <sup>efghijklm</sup>	253.4 <sup>bcdef</sup>
Berg x mexican	118.97 <sup>efgh</sup>	53.88 <sup>h</sup>	67.89 <sup>f</sup>	2.9 <sup>efg</sup>	6.04 <sup>ab</sup>	64.40 <sup>defgh</sup>	13.47 <sup>cdefg</sup>	257.1 <sup>cdefg</sup>
Meyers	121.33 <sup>efghi</sup>	55.96 <sup>ijklm</sup>	69.75 <sup>fgh</sup>	2.3 <sup>ab</sup>	9.23 <sup>efghij</sup>	65.75 <sup>defgh</sup>	13.39 <sup>cdef</sup>	258.8 <sup>cdefg</sup>
Morado	122.16 <sup>efghi</sup>	54.65 <sup>ij</sup>	69.33 <sup>fg</sup>	2.3 <sup>ab</sup>	6.47 <sup>abcde</sup>	67.79 <sup>efghijk</sup>	14.43 <sup>efghijkl</sup>	291.5 <sup>cdefghi</sup>
R1259	123.56 <sup>efghij</sup>	54.31 <sup>i</sup>	70.97 <sup>fgh</sup>	3.4 <sup>efghijkl</sup>	8.69 <sup>efghij</sup>	59.13 <sup>bcdef</sup>	13.96 <sup>defghij</sup>	279.4 <sup>cdefghi</sup>
R1251	125.63 <sup>efghij</sup>	50.82 <sup>a</sup>	72.32 <sup>fghi</sup>	3.6 <sup>efghijklm</sup>	6.48 <sup>abcde</sup>	64.58 <sup>defgh</sup>	11.65 <sup>ab</sup>	267.8 <sup>cdefgh</sup>
Cross x	127.11 <sup>ghijk</sup>	53.26 <sup>efg</sup>	69.38 <sup>fgh</sup>	2.6 <sup>abcd</sup>	4.87 <sup>a</sup>	71.08 <sup>efghijklm</sup>	13.38 <sup>cdef</sup>	272.6 <sup>cdefgh</sup>
Gymno carpo	129.47 <sup>ghijk</sup>	55.39 <sup>ijkl</sup>	72.76 <sup>fghi</sup>	3.2 <sup>efghij</sup>	6.87 <sup>abcde</sup>	69.24 <sup>efghijkl</sup>	14.26 <sup>defghijk</sup>	273.6 <sup>cdefghi</sup>
Schagen	129.66 <sup>ghijk</sup>	55.42 <sup>ijkl</sup>	75.59 <sup>efghijklm</sup>	2.7 <sup>abcdef</sup>	6.72 <sup>abcde</sup>	71.48 <sup>efghijklm</sup>	14.34 <sup>efghijkl</sup>	286.5 <sup>cdefghi</sup>
Tormentosa	130.88 <sup>ghijkl</sup>	56.68 <sup>ijklmno</sup>	73.26 <sup>fghi</sup>	3.3 <sup>efghijk</sup>	8.73 <sup>efghij</sup>	71.02 <sup>efghijklm</sup>	13.84 <sup>defghij</sup>	281.4 <sup>cdefghi</sup>
Robusta x castillo	136.44 <sup>ghijklm</sup>	57.15 <sup>ijklmno</sup>	73.56 <sup>efghijk</sup>	3.5 <sup>efghijkl</sup>	9.55 <sup>efghijk</sup>	75.16 <sup>efghijklmn</sup>	14.34 <sup>efghijkl</sup>	256.4 <sup>cdefg</sup>
Santa rosa	138.88 <sup>ghijklmn</sup>	56.42 <sup>ijklmn</sup>	74.14 <sup>efghijkl</sup>	2.4 <sup>abc</sup>	6.57 <sup>abcde</sup>	76.02 <sup>efghijklmno</sup>	12.70 <sup>bc</sup>	282.4 <sup>cdefghi</sup>
Sharsheret	141.35 <sup>ghijklmn</sup>	56.66 <sup>ijklmn</sup>	75.62 <sup>efghijklm</sup>	2.7 <sup>abcdef</sup>	8.43 <sup>efghi</sup>	60.21 <sup>bcdef</sup>	12.84 <sup>bc</sup>	252.7 <sup>bcdef</sup>
<b>Se</b>	<b>267.28</b>	<b>15.21</b>	<b>27.30</b>	<b>0.49</b>	<b>2.04</b>	<b>120.78</b>	<b>1.27</b>	<b>2034.91</b>

Means with the same letter are not significantly different ( $p>0.05$ ). FM: Fruit mass (g), FW: Fruit width (mm), FL: Fruit length (mm), P: Peelability, PT: Peel thickness (mm), PM: Pulp mass (g), TSS: Total soluble solids (°Brix) and TNS: Total number of seed.

Fruit quality characteristics evaluated for this particular year are shown in Table 1 and 2. All the fruit quality parameters in question differed significantly as a result of different cultivars in during the year of review. The average mean fruit mass ranged from 104g to 141.35g. The lowest fruit mass was obtained with *Algerian* followed by *Fiscaulis* at 104g and 104.51g, respectively. The highest fruit mass was obtained with *Sharsheret*, *Santa Rosa* and *Robusta x Castillo* at 141.35, 138.88 and 136.44 respectively. Of all the recorded fruit mass from various cultivars on eleven were found to be well within the required mass of 120g for market purposes in relation to destined exportation (Inglese *et al.*, 2002) despite the 140g recommended by Potgieter and Mkhari (2002) for commercial purpose. There were instances where fruit mass from different cultivars did not differ significantly from each other.

Fruit width from various cultivars was found to be significantly different among cultivars. The fruit width ranged from 50.77mm to 57.15 and this was obtained with *Roedtan* and *Robusta X Castillo*, respectively. On the other hand fruit length was also found to be significantly different as influence by the cultivars. The lower performers were obtained with *Algerian*, *American Giant* and *Fiscaulis* at 60.64mm, 61.98mm and 64.59mm respectively. The highest fruit length was obtained with *Shasheret*, *Schagen* and *Santa Rosa* at 75.62mm, 75.59 and 74.14mm, correspondingly. Peelability was found to be significantly different as per cultivar and this was very clear well within the range of 2.1 to 4.1 obtained with *Algerian* and *Zastron*, respectively. Peel thickness did not follow the trend displayed by peelability at all. 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 meet the requirements for fruit production in South Africa except with *Cross X* which was found to be 4.87mm. In general, consumers prefer a thin peel of less than 5 mm, despite the fact that thin peel is convenient for handling. The highest peel thickness was obtained with *Robusta X Castillo* at 9.55mm.

The pulp mass ranged from 48.52g to 76.02g, thus indicating a much wider significant variation amongst cultivars. *Santa Rosa* and *Robusta X Castillo* exhibited a much higher pulp mass at 76.02g and 75.16g, correspondingly, while the lowest was recorded with *Fiscaulis* at 48.52g.



The TSS content recommended for cactus pear fruits ranges from 13 to 15 °Brix. All cultivars evaluated were well within the range, except *Nudosa*, *R1251*, *Santa Rosa*, *Zastron*, and *Sharheret* which ranged from 9.84 to 12.84 °Brix. The highest was obtained with *American Giant* and *Skinner Court* at 15.96 and 15.05, respectively. Significant differences were found on total seed number for the study which ranged from 123.9 to 300.08. *American Giant* and *Morado* had the highest seed number amounting to 300.08a and 291.5 correspondingly while the lowest was obtained with *Fusicaulis* at 123.9. All cactus pear Cultivars have a large number of seeds to attain good size with a high ratio of aborted to normal seeds.

**Table 3.** Pairwise correlation coefficient between fruit quality characters.

	FM	FW	FL	P	PT	PM	TSS	TNS
<b>FM</b>	-							
<b>FW</b>	<b>0.64</b>	-						
<b>FL</b>	<b>0.74</b>	<b>0.42</b>	-					
<b>P</b>	0.22	-0.04	<b>0.16</b>	-				
<b>PT</b>	0.10	<b>0.20</b>	<b>0.14</b>	0.11	-			
<b>PM</b>	<b>0.82</b>	<b>0.57</b>	<b>0.57</b>	-0.09	-0.08	-		
<b>TSS</b>	<b>0.29</b>	<b>0.27</b>	0.08	-0.25	0.03	<b>0.29</b>	-	
<b>TNS</b>	<b>0.45</b>	<b>0.35</b>	<b>0.30</b>	0.02	-0.05	<b>0.47</b>	<b>0.25</b>	-

FM: Fruit mass (g), FW: Fruit width (mm), FL: Fruit length (mm), P: Peelability, PT: Peel thickness (mm), PM: Pulp mass (g), TSS: Total soluble solids (°Brix) and SC: Seed count. Bold correlation coefficients are significant at p0.05 level.

The correlation coefficients were determined amongst each of the measured fruit quality characteristics (Table 3). In the year of review 24 cultivars were characterized without taking the pulp color in to consideration. In 2008, the relationships among fruit characteristics exhibited very high correlation coefficients. Amongst the relationships only eleven pairs were found not to be significantly correlated while the rest were found to be highly positively correlated and significant. The highest correlation coefficient was obtained with fruit mass and pulp mass at 0.82, followed by fruit mass and fruit length at 0.74 and at 0.64 between fruit mass and fruit length. There were also negative correlations pairs obtained in five of the relationships. For example, fruit width was negatively correlated to peelability at -0.04, peelability and pulp mass at -0.09, peelability and total soluble solids at -0.25. In addition to

that, other fruit quality characteristics were positively correlated to a lesser degree. For example peelability was positively correlated to peel thickness at 0.11, but this relationship was not significant at all. Similarly, fruit length and total soluble solids was at 0.08 while peelability and seed content was at 0.02 and peel thickness and total soluble solids was at 0.03 to an almost no relationship. It is very clear from this data that the fruit quality characteristics differs year to year and thus this is more related to the prevailing environmental conditions.

## CONCLUSION

Experience over the last two decades has shown that scientifically sound evaluations can be made with simplified descriptors, more suitable for less developed countries. Evaluation data collected from this genebank has been supplied to various researchers involved in cactus pear around South Africa and abroad. In addition, plant material of described cultivars from these germplasm blocks has been used to establish other germplasm blocks in other provinces to monitor the performance of various cultivars in the different agro-ecological regions of South Africa. There can be little doubt that *Opuntia* species are highly successful in their distribution, multiplication and establishment. It is therefore easy to see why they have become so successful in spreading to diverse environments around the world. Significant differences were observed in all measured fruit quality characteristics. Data obtained from twenty four cultivars has exhibited that there is no superior cultivar amongst all the measured cultivars and this was in totality ascribed to the fact that comparisons were made without considering the pulp color which seems to be a market determinant. It is therefore recommended that the cultivars be evaluated on a yearly basis in order to have a long term data that will assist in future decision making. More research still needs to be done in order to assess factor affecting the fruit quality characteristics.

## REFERENCES

- Barbera G (1995). History, economic, and agro-ecological importance. In: Barbera G., P. Inglese and B.E. Pimienta (Eds.), *Agroecology, cultivation and uses of cactus pear*. FAO Plant production and protection paper 132. Rome, Italy. pp 19-35
- Brutsch, M.O. 1979. The prickly pear (*Opuntia ficus-indica*) as a potential fruit crop for the drier regions of the Ciskei. *Crop Production* 8: 131-137.
- Brutsch MO (1992). Crop manipulation in spine-less prickly pear (*Opuntia ficusindica*) in South Africa. In: *Proceedings of the Second International Conference on Cactus Pear and Cochineal*. Santiago, Chile. pp 40-47.
- Cantwell M (1991). Quality and post-harvest physiology of 'nopalitos' and 'tunas'. In: *Proceedings of the Second Annual Texas Prickly pear Conference*, McAllen, Texas, pp. 50-66.
- Cantwell M (1986). Post-harvest aspects of prickly pear fruits and vegetable cladodes. In: *Perishables handling, post-harvest technology of fresh horticultural crops*. Cooperative extension, University of California. 59: 6-9.
- Griffiths D, Hare RF (1906). Prickly pear and other cacti as food for stock. 2. New Mexico College of Agriculture and Mechanic Arts. *Agriculture Experiment Station Bulletin*. 60, 125.
- Mashope BK (2007). Characterization of cactus pear germplasm in South Africa. Phd dissertation. University of Free State. South Africa.
- Mokoboki K, Kgama T and Mmbi N (2009). Evaluation of cactus pear fruit quality at Mara ADC South Africa, *African Journal of Agricultural Research* Vol. 4 (1), pp. 028-032, January, 2009.
- Potgieter JP (2007) The influence of environmental factors on spineless cactus pear (*Opuntia* spp.) fruit yield in Limpopo Province, South Africa. MSc dissertation. University of Free State. South Africa.
- Potgieter JP (1997). *Guidelines for the cultivation of spine-less cactus pears for fruit production*. Second Edition. Group 7 Trust Publishers, Sinoville, SA.
- Potgieter JP and Mkhari JJ (2002). Evaluation of cactus pear (*Opuntia* spp.) germplasm for fruit production purposes. Combined Congress, 15-17 January 2002, Pietermaritzburg, Kwazulu/Natal.

- Inglese P, Basile F and Schirra M (2002). Cactus pear fruit production. In: *Nobel, P.S. (Ed.), Cacti: Biology and Uses*, University of California Press, California, USA. pp. 163-183.
- Switzerland (2001). Convention on international trade in endangered species of wild fauna and flora. Eleventh meeting of the plants committee. Langkawi (Malaysia), 3-7 September 2001.
- Wessels AB (1988). Spine-less prickly pear. Perskor Publishers, Johannesburg, pp. 21-24