Influence of resting period on fruits and secondary tubers of *Harpagophytum procumbens* in Namibia.

Edgar Mowa[1]*, Erika Maas[2]
[1]Sam Nuyoma Marine Research Centre,University of Namibia
P.O Box 462, Henties Bay, Namibia
[2]University of Namibia, Private Bag 13301, Windhoek, Namibia

Received: 24th July, 2013. Accepted: 14th June, 2016. Published: 23rd October, 2016

Abstract

Harpagophytum procumbens, the devil's claw, is a plant with medicinal values in Namibia, leading to high demands, and resulting in unsustainable harvesting techniques by locals. The most commonly practiced harvesting period is 2 years, mostly dictated by the need to make as much money as possible. A study was undertaken to investigate the effect of extending the current 2 year harvesting period to 5 years on secondary tuber and fruit production. Two experimental plots at two sites (Vergenoeg and Tjaka Ben Hur) were explored. The first plot had plants harvested every 2 years and another only after 5 years. Between sites and within sites differences in means were analyzed using a t-test at $\alpha = 0.05$. Results established that there was no difference in fruit production between the 2 groups at Vergenoeg ($p = 0.375$) and Ben-Hur ($p = 0.131$). However, between sites variability in number of secondary tubers was observed ($p = 0.014$). Particularly, at Vergenoeg, the number of secondary tubers produced after 5 years, were abundant ($p = 0.003$). In addition, the harvest at Vergenoeg showed a difference in weight of secondary tubers between the 2 groups ($p = 0.006$). Within Ben-Hur, there was no difference ($p = 0.928$) between the numbers of secondary tubers produced at 2 years and at 5 years. A holistic management approach (rotational harvesting) is recommended for to harvest every 5 years to maximize benefit and sustain the species.

Keywords: *Harpagophytum procumbens*, harvesting period, fruit production, secondary tubers, secondary tuber weight, rotational harvesting

*Corresponding author - E-mail: emowa@unam.na

ISTJN 2016; 8:73-90.

1 Introduction

Harpagophytum procumbens, the devil's claw, is one of the plants with medicinal values in Namibia, leading to high demands of the species and resulting in unsustainable harvesting techniques by locals. *H. procumbens* is a geophyte with a positively gravitropical tuberous main root, from which plagiotropical thick secondary roots develop. The genus Harpagophytum comprises of two species (*H. zeyheri* and *H. procumbens*) which are perennial herbs with creeping stems that sprout every year from the main root. Secondary root tubers, which can reach a length of 5 - 25 cm, grow from the main root, also referred to as the parent tuber. These secondary tubers are harvested for medicinal purposes and contain active ingredients that have analgesic and anti-inflammatory properties (Cole and Strohbach, 2007; Eich et al., 1998; Feistel and Gaedcke, 2000; Inaba et al, 2010; Hachfeld, 2003).

The plant is called devil's claw because of the very sharp and hooked form of the fruit (Cole and Strohbach, 2007). The fruit comprise a flattened woody capsule with spiny appendages on each carpel. This genus Harpagophytum occurs between 15 degrees and 30 degrees latitude in the Southern hemisphere. *Harpagophytum procumbens* in particular, is found in Namibia, Botswana and South Africa (Fig. 1). Currently in Namibia, the plant occurs to a large extent on communal areas (and resettlement farms) where marginalized and poor local people have been harvesting secondary tubers for income augmentation. Consequently, there arose concerns about the sustainability of this economic dependence on harvesting of *H. procumbens*. This led to policies being made to better manage this resource; therefore a permit system for harvesting and transporting *H. procumbens* was introduced in 1977, but failed. In 1999, the Ministry of Environment and Tourism reintroduced a permit system in response to concerns about over-exploitation (Cole and du Plessis, 2001). All harvesters are now required to use the prescribed guidelines provided by NASSP (2004) to sustainably harvest *H. procumbens*. In addition, there is also a new permit system in place to manage the number of harvesters (Nott, 2011). If done properly, the recovery of harvested plants is hastened, for example in South Africa, it has been observed that parent tuber recovery was not affected by harvesting (Stewart, 2009).

Namibia has been the world's largest producer of *H. procumbens* on the international trade market. Of the total 6.3 million tones exported from 1992 to 2006, 95% of exports originate from Namibia, 3% from Botswana, and 2% from South Africa (Cole and Bennett, 2007; Raimondo and Donaldson, 2002).

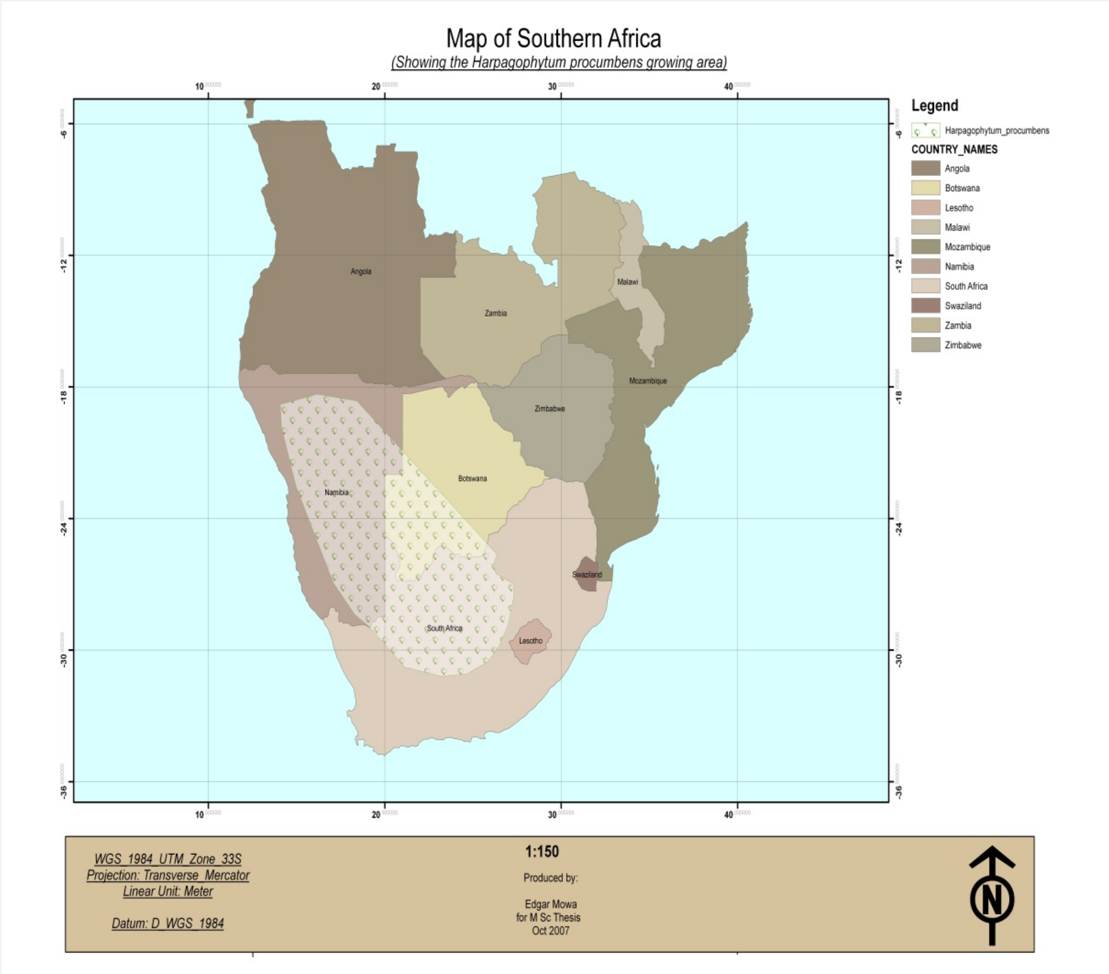

Figure 1: Distribution of *H. procumbens* in Southern Africa. The map adapted from CITES (unpublished).

The most commonly practiced harvesting period has now become every 2 years, mostly dictated by the need to make as much money as possible from the same plants. This study investigates the influence of increasing harvesting intervals to 5 years on secondary tuber and fruit production of the species, given the economic and sustainable management implications. With the realization that the species needs several years before it becomes ready for harvesting (Schneider 1997), a longer interval may benefit maximally. The following are the research hypotheses:

1. *H. procumbens* will produce more fruits when not harvested for five years than when

not harvested for only two years.

2. *H. procumbens* will produce more and larger secondary tubers when not harvested for five years than when not harvested for only two years.

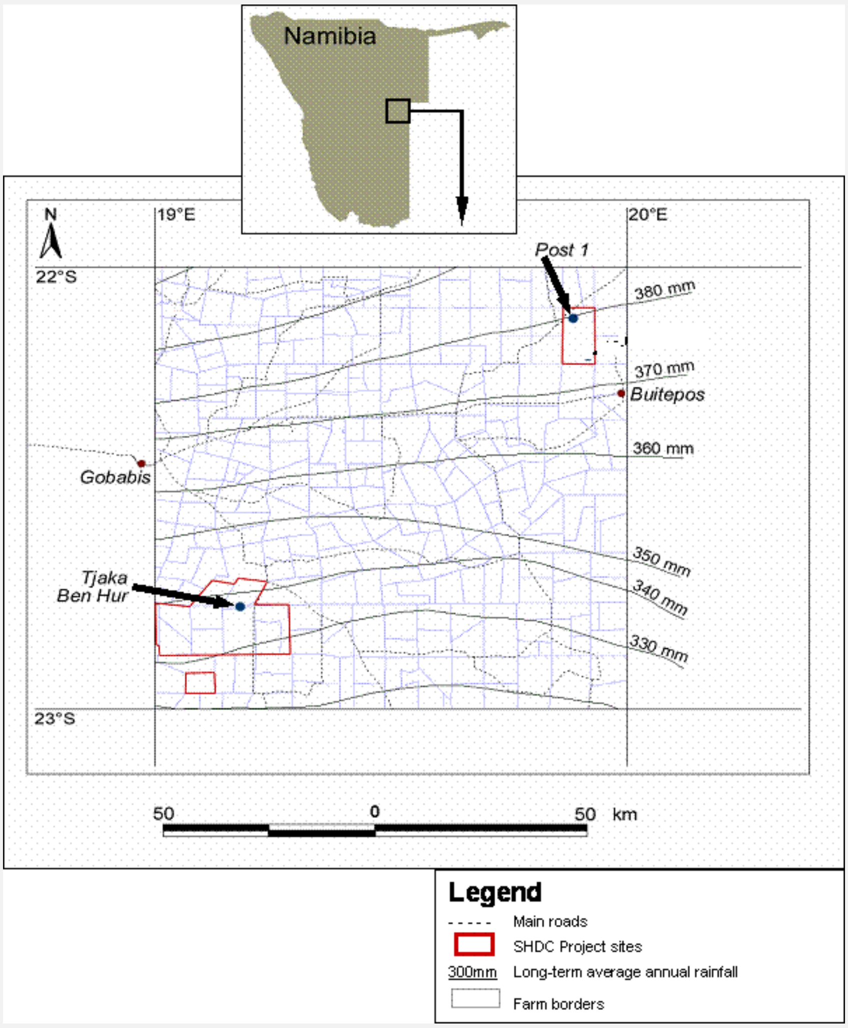

Figure 2: Two sites for harvesting studies: Vergenoeg and Tjaka & Ben Hur Communal Development Center. GIS files adapted from NARIS (AEZ, 2001).

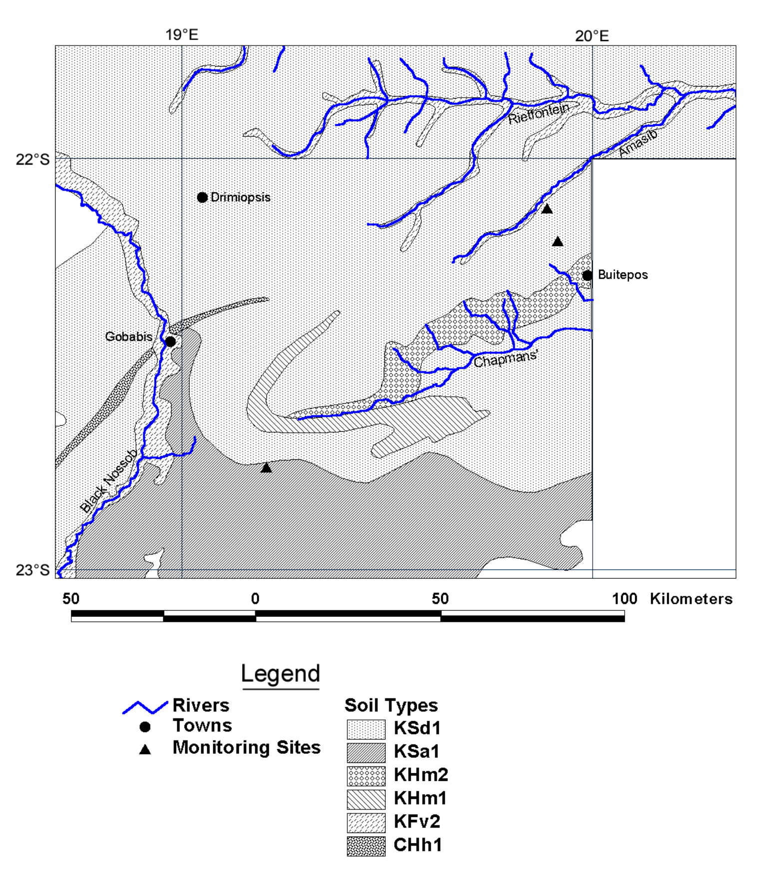

Figure 3: Soil types of the study area: CHh1 = rock outcrops, KFv2 =omuramba and river valleys with arenic Fluvisols and ferralic Arenosols association, KHm1 = relict meanders with ferralic Arenosols, KHm2 = relict meanders with arenic-leptic Regosols, KSa1 = sand deposits and aligned dunes with ferralic Arenosols, KSd1 = sand plains with ferralic Arenosols. Map adapted from the NARIS GIS files (AEZ, 2001).

2 Materials and Methods

2.1 Data collection

2.1.1 Study sites

The study area falls within the Omaheke region of eastern Namibia, which is often referred to as the Sandveld. The study sites were the Tjaka/Ben Hur Communal Development Center and Vergenoeg Post 1 (Fig. 2), which are part of the larger group of communal farms in Eastern Namibia. Tjaka/Ben Hur is about 50 km south of Gobabis whilst Vergenoeg Post 1 is about 140 km North-East of Gobabis. Each study site consisted of a fenced monitoring plot measuring 10 m × 30 m. Plants were selected based on their age and attribute records as tracked by the Sustainably Harvested Devil's Claw (SHDC) project by Strobach and Cole (2007) which further defined age classes of the plants (Table 1). The type and distribution of soil of the study sites are shown in Figure 3.

Table 1: Definitions of age states for *H. procumbens* (from Cole & Strohbach, 2007)

G1	Young reproductive plant	Calendar age estimated to be 2-5 years, main tuber diameter 1.5-2.3 cm. Flowering and fruiting is limited, but shoot growth very strong. Assimilates are still used mainly for main tuber growth, but secondary storage tubers are being formed, the latter mostly smaller than 1 cm in diameter and weighing less than 100 g.
G2	Mature reproductive plant	Calendar age estimated at 3-10 years, but may be much younger under very favorable conditions (e.g. dry land cultivation). Main tuber diameter 2.4 to 3.4 cm.Shoot production, flowering and fruiting rates at their optimal level. Assimilates are first used for the production of large amounts of flowers and the development of fruit. As the fruit ripens, assimilates are replenished and added to the storage tubers. The latter is very variable, but most plants are capable of producing at least 400-500 g under favorable conditions. The increase in main tuber diameter becomes much slower compared to the smaller age states.
G3	Old reproductive plant	Calendar age estimated to be from 5 or 6 years and older. Tuber diameter 3.5 cm and more. Tuber diameters of up to 6.5 cm were observed, but in general plants with a main tuber diameter above 5 cm are very rare. Shoot production, flowering and fruiting levels are optimal. Assimilates are first used for the production of flowers and fruit, then replenished and accumulated in the storage tubers. Plants that are harvested for the first time often have a storage tuber yield above 1kg, while healthy plants are generally able to regenerate at least 400 g of new storage tubers over a period of 4 years after harvesting. Many of these tubers are gnarled and woody to some extent.

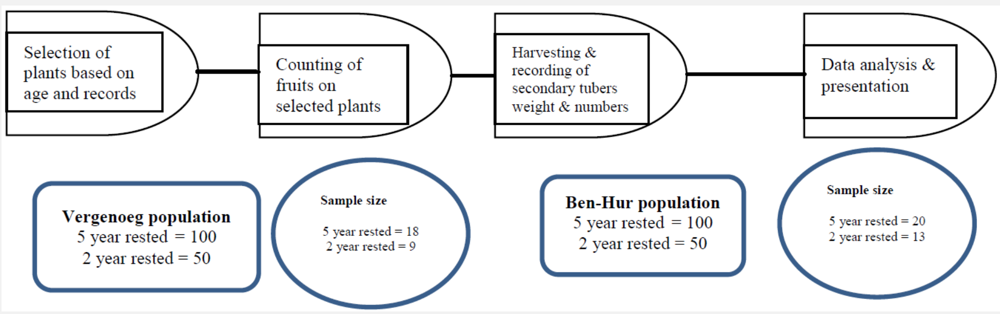

Figure 4: Work flow

2.1.2 Experimental set-up

In order to determine fruit and secondary tuber production in *H. procumbens* over 2 different periods of resting from harvesting, plants in the old reproductive age were observed at Ben Hur and Vergenoeg Post 1. Old reproductive plants were selected because they are known to be the prime age for *H. procumbens* to produce more fruits and secondary tubers (Strohbach and Cole, 2007).

Table 2: *H. procumbens* plants not harvested for two years and five years at Vergenoeg.

Two years not harvested plants				Five years not harvested plants			
Plant No.	No. of fruits	No. of tubers	Tubers weight	Plant No.	No. of fruits	No. of tubers	Tubers weight
2	0	6	430	9	0	12	588
6	0	4	170	17	12	14	1442
10	14	7	650	18	6	11	812
11	15	18	1650	21	0	11	592
12	1	0	0	23	7	44	1572
227	5	15	1400	24	1	20	1018
30	0	4	420	25	0	13	1290
48	0	5	200	29	22	36	1775
57	1	2	40	31	2	12	1042
				38	13	25	1740
				47	2	8	701
				50	3	24	1090
				53	5	17	1580
				54	3	18	1100
				62	1	8	780
				64	0	14	1174
				65	5	34	3900
				73	8	17	1070

From the Vergenoeg Post 1, 18 plants (not harvested for 5 years) and 9 plants (harvested every second year in the same period) (Table 2) were used. From Ben Hur 20 plants (not harvested for 5 years) and 13 plants (harvested every second year in the same period) were used (Table 3).

For each plant, all fruits were counted and secondary tubers harvested were weighed and recorded. Secondary tubers were harvested at depths between 30 and 120 centimeters. After weighing the secondary tubers at each site, they were all sliced into 7 mm pieces. These pieces were then spread on a net raised 1.5 cm above ground to be sun-dried at each study site.

Table 3: *H. procumbens* plants not harvested for two years and five years at Ben Hur.

Two years not harvested plants				Five years not harvested plants			
Plant No.	No. of fruits	No. of tubers	Tubers weight	Plant No.	No. of fruits	No. of tubers	Tubers weight
8	1	18	1550	7	0	9	1605
10	0	11	1080	14	1	8	1480
17	0	12	2300	16	0	1	110
23	0	12	3600	20	1	12	1960
24	0	25	2765	25	14	15	4785
33	0	8	430	27	0	11	1825
52	3	7	1090	29	1	5	1020
71	0	11	1260	30	4	12	2160
75	0	2	350	31	0	17	2955
77	0	17	830	32	1	12	5050
80	0	7	900	36	6	22	1725
84	0	5	320	37	6	28	4630
88	6	11	550	47	0	10	1280
				48	5	11	2525
				59	0	21	4435
				60	2	10	1656
				69	0	9	1720
				70	0	4	1100
				97	1	7	1530
				100	0	10	1765

2.2 Data analysis

In order to analyze the statistical significance of the difference in the number of fruits, secondary tubers and weight of secondary tuber per plant between the two plant-harvest resting groups, data was tested for normality using the Kolmogorov-Smirnov normality test (Townend, 2002) in Statistical Program for Social Sciences (SPSS). An independent t-test was used where the normality assumption holds. Else, a Mann-Whitney test is used where the normality assumption was violated. The r value was calculated from the t-test results in order to measure the effect of different attributes per site. The following formulae for the r value was employed:

$$r = \sqrt{\frac{t^2}{t^2} + df}$$

where t is the value of t-statistic and df are the degrees of freedom. The r value is constrained to lie between 0 (no effect) and 1(a perfect effect).

3 Results

Secondary tuber weight and the number of fruits at the Vergenoeg site were found to be non-normally distributed and were therefore analyzed using the Mann-Whitney U test (Townend, 2002) in SPSS to test for mean differences. The sample size at Vergenoeg for plants unharvested ($n = 18$) and harvested ($n = 9$) was determined by the limited total populations in the wild. The number of secondary tubers at the Vergenoeg site was found to be normally distributed and hence was analyzed using the independent samples t-test. At the Ben-Hur site, the number of secondary tubers, secondary tuber weight and the number of fruits were all found to be not normally distributed. They were therefore analyzed using the Mann-Whitney U test on the mean differences. Similarly, the sample size was also determined the same way at Ben-Hur for the unharvested ($n = 20$) and harvested ($n = 13$) groups.

3.1 Influence of resting from harvesting for 5 years on the number of fruits per plant

On average there were 4 fruits per plant on *H. procumbens* rested from harvesting for 2 years compared to 5 fruits per plant on *H. procumbens* rested from harvesting for 5 years (Figure 5). The result show that there was no statistically significant difference in the number of fruits between plants rested from harvesting for 2 years and plants rested from harvesting for five years at Vergenoeg ($p = 0.375$). There was also no statistically significant difference in the number of fruits produced per plant between plants that were rested from harvesting for 2 years and those that were rested from harvesting for 5 years at Ben Hur ($p = 0.131$).

3.2 Influence of resting from harvesting for five (5) years on the number of secondary tubers

3.2.1 Vergenoeg site

On average there were more secondary tubers (mean: 18.78, SE=2.40) on H. procumbens rested from harvesting for five years, than (mean: 6.78, SE=1.97) on H. procumbens rested from harvesting for two years only. Figure 6 indicates that there were more secondary tubers on plants rested from harvesting for 5 years than on plants rested from harvesting for 2 years at Vergenoeg. The difference shown in Figure 4 found conclusive evidence when tested statistically ($p = 0.003$). Furthermore, the difference in the number of secondary tubers between the two harvesting years does represent a large sized effect $r = 0.54$.

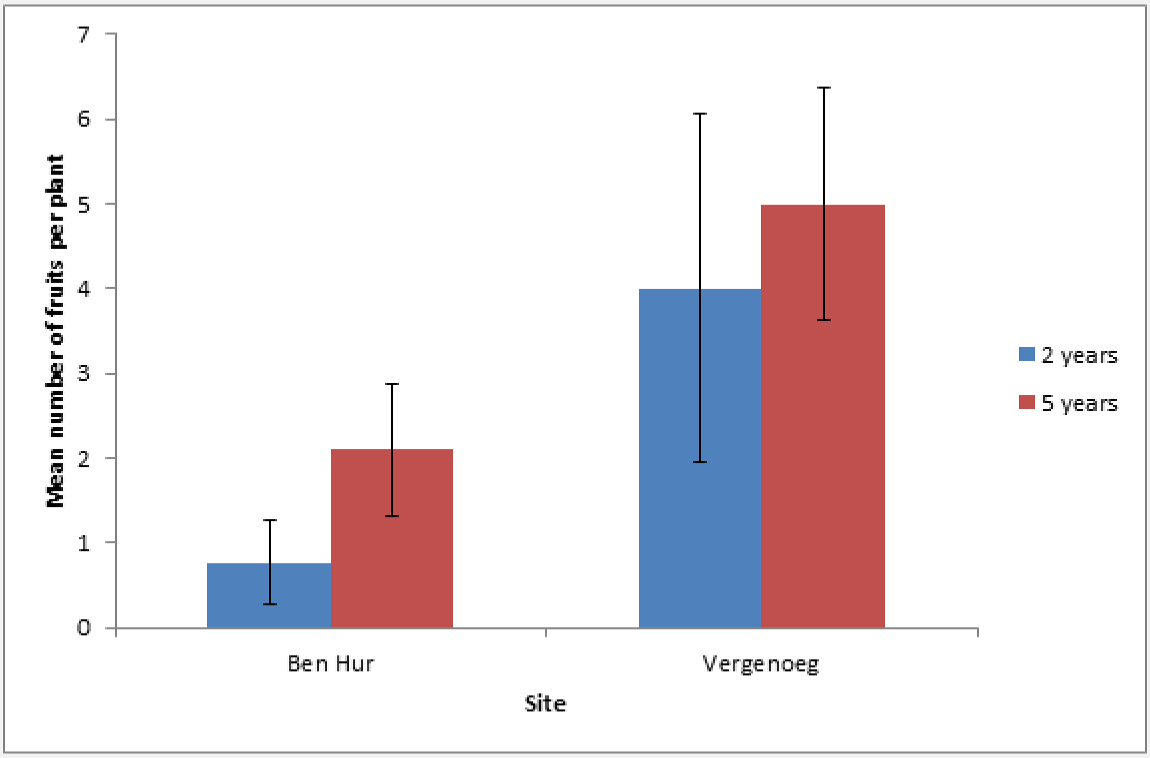

Figure 5: Difference in the number of fruits per plant between plants rested from harvesting for 2 years and plants that not harvested for 5 years at the 2 study sites.

3.2.2 Ben-Hur site

On average, there were more (mean rank: 17.13, sum of ranks: 342.50) secondary tubers on *H. procumbens* rested from harvesting for 5 years than (mean rank: 16.81, sum of ranks: 218.50) on *H. procumbens* rested from harvesting 2 years. There is no significant difference ($p = 0.928$) in the number of secondary tubers on *H. procumbens* rested from harvesting for 5 years compared to *H. procumbens* rested from harvesting for 2 years.

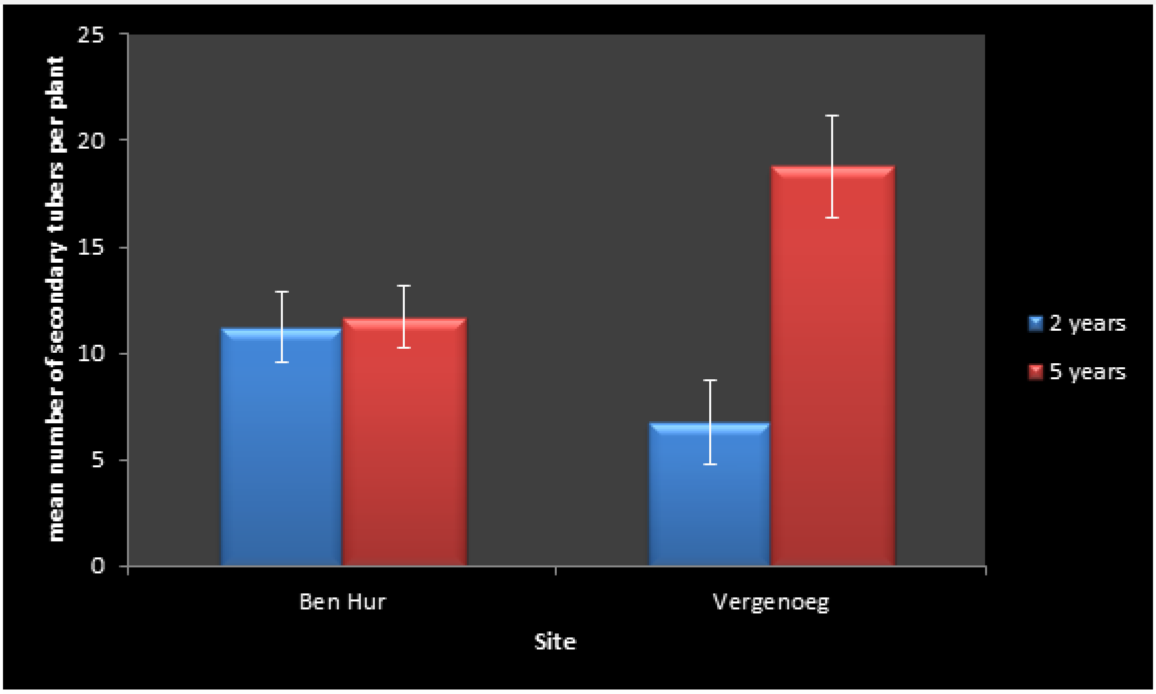

Figure 6: Number of secondary tubers per plant between plants rested from harvesting for two years and plants rested from harvesting for five years at the 2 sites.

3.3 Influence of resting from harvesting for five (5) years on the weight of secondary tubers

3.3.1 Vergenoeg site

On average, there were larger (mean rank: 16.89, sum of ranks: 304.0) secondary tubers on *H. procumbens* rested from harvesting for 5 years than (mean rank: 8.22, sum of ranks: 74.0) on *H. procumbens* rested from harvesting for 2 years. Figure 7 displays that there were larger secondary tubers on *H. procumbens* rested from harvesting for 5 years than on *H. procumbens* rested from harvesting for 2 years. This difference was found to be highly-significant ($p = 0.006$).

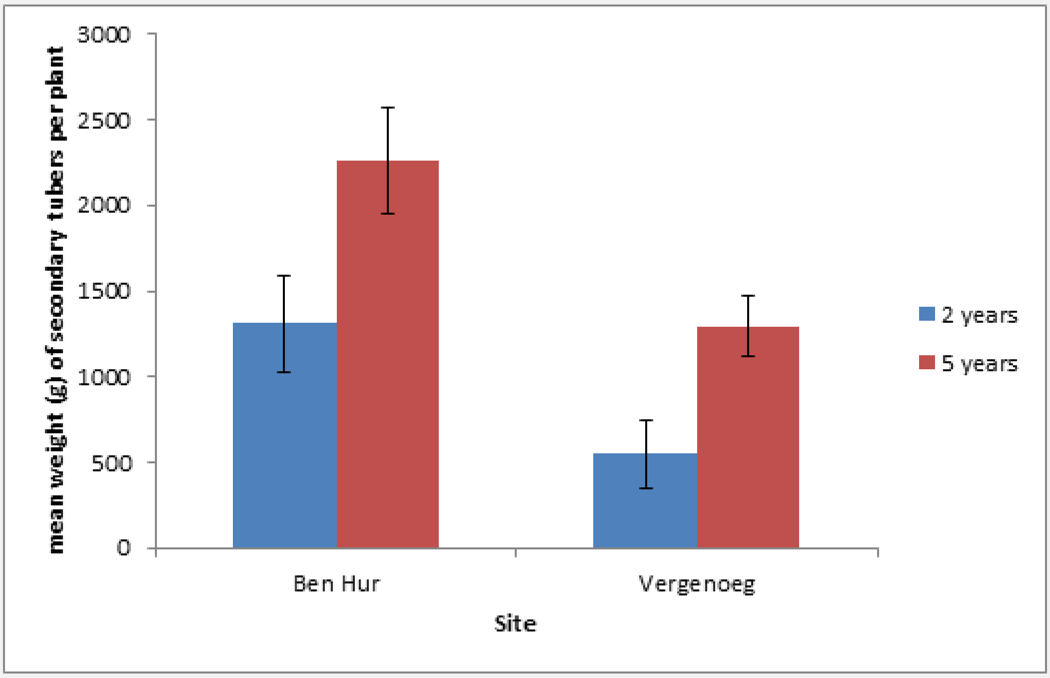

Figure 7: Secondary tuber weight for plants rested from harvesting for 2 years and plants rested from harvesting for 5 years at Vergenoeg.

3.3.2 Ben-Hur site

On average, there were larger (mean rank: 20.30, Sum of ranks: 406.0) secondary tubers on *H. procumbens* rested from harvesting for 5 years than (mean rank: 11.92, sum of ranks: 155.0) on *H. procumbens* rested from harvesting for 2 years. As shown in Fig. 7, plants rested from harvesting for 5 years produced larger secondary tubers compared to plants rested from harvesting for 2 years, statistical analysis of these differences show that there was a significant difference ($p = 0.014$). Figure 8 shows that secondary tubers lose 90% of their initial fresh weight when they get sliced and dry-up. This gives an idea of how much local community members around the study sites will have to collect to get profit from their labour costs.

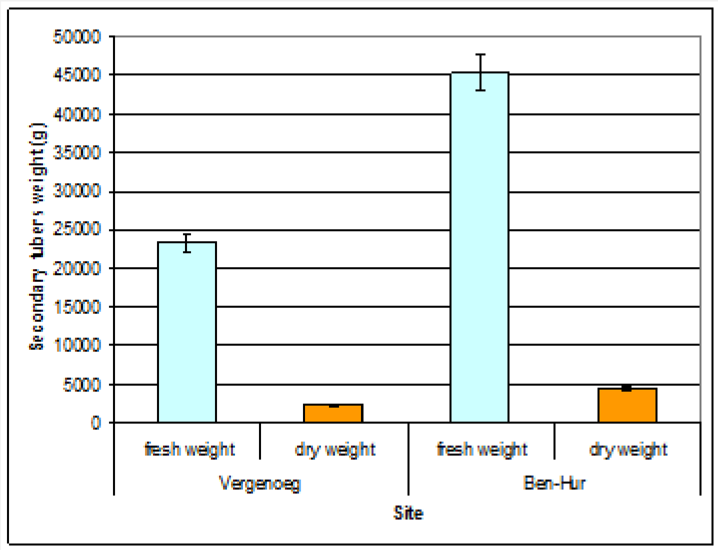

Figure 8: Difference in secondary tuber weight between fresh tubers and dry slices of the same tubers at the two study sites.

3.4 Differences in weight between fresh secondary tubers and sliced, dried secondary tubers

4 Discussion

4.1 Fruit production

The results from Ben-Hur and Vergenoeg provide basis to accept the study's null hypothesis that *H. procumbens* rested from harvesting for 5 years produce the same number of fruits as when rested from harvesting for two years only. These results show an unexpected result considering the hypothesis that there was going to be more fruits on *H. procumbens* plants that were rested from harvesting for 5 years compared to plants harvested twice within the same period.

The implications of the results of the current study at Ben-Hur and Vergenoeg are that the ability of producing fruits by *H. procumbens* does not depend on how long it is left without harvesting. According to Hachfeld (2003), fruit-set depends on climatic conditions i.e. fruits tend to grow slower under dry conditions with many aborting before ripening. This and possibly other factors like rainfall could influence fruiting over a period of time and not the resting period since it is evident from these results that plants are able to produce the same number of fruits regardless of the resting period. Rainfall, for example, has been found in particular to positively influence production of flowers and shoots in *H. procumbens* (Stewart, 2009).

4.2 Secondary tuber production

The result that there was no difference in the number of secondary tubers between plants not harvested for 2 years and those not harvested for 5 years at Ben-Hur could be attributed to the soil type. In this area, the brown coarse ferralic Arenosols (Fig. 2) can retain water long enough to allow *H. procumbens*, to develop superficial roots to absorb water each year which will be used in development of secondary tubers. For this reason, the resting period may be less important.

The average annual long-term rainfall has been observed to be 340mm (Strohbach and Cole, 2007), though it was exceptionally high in 2005/2006 rainfall season. Rainfall has been found by Strohbach & Cole (2007) to trigger growth in *H. procumbens.* Stewart (2009) also established that environmental factors such as rainfall determine a plant's ability to grow and regenerate whether harvested or not. The current study's results at Ben Hur would therefore concur with previous studies, given the abundant rainfall received in 2005/6 season.

At Vergenoeg, a different result was found where plants that were rested from harvesting for 5 years produced significantly more secondary tubers than plants that were rested from harvesting for two years. At Vergenoeg there are sandy plains with ferralic Arenosols (Fig. 3) that allows quick water drainage. Plants that have not been harvested for 5 years have enough time to develop superficial roots to absorb enough water even within a short period that it is present before draining downwards. The plants rested from harvesting for 5 years were observed to have also developed deeper roots (personal observation) compared to plants at Ben-Hur. According to Strohbach and Cole (2007), these deeper roots take years to reach beyond 1m to absorb water when superficial roots have no more water around to absorb. In contrast, *H. procumbens* not harvested for two years would have less time to develop superficial roots to absorb water which drains quickly when it rains. Because of fewer superficial roots that may be developed on plants not harvested for two years, water absorption in these plants may be limited to amounts enough to enable the plant to produce few secondary tubers.

Considering that the final product (sliced-dried tubers) lose 90% of the initial fresh weight (Fig. 6), the results from the current study implicates that a harvester would need to harvest 19 plants to get 1 kg of dried tubers if such plants were rested from harvesting for the past two years, whereas a harvester would only need to harvest 8 plants to get 1 kg of dried secondary tubers if such plants were rested from harvesting for 5 years.

According to Cole and Bennett (2007), one 1 kg of secondary tubers is currently costing N$20.00 and considering that the final product (sliced-dried tubers) for harvesters loses 90% of the initial fresh weight, more plants need to be harvested for each harvester if they are to be harvesting every after two years from the same plants compared to when they would harvest after five years.

Therefore, harvesters from Vergenoeg would benefit more when they do not harvest such plants for five years whilst managing their own resource sustainably.

Even though rainfall at Vergenoeg has been 40 mm higher than Ben-Hur for the period under study, the fact that Ben-Hur's soil type retains water for longer periods giving time for absorption by all plants, explains why the two-year rested from harvesting plants can produce as many secondary tubers as the five-year rested from harvesting plants at Ben-Hur.

The reason why there was no significant difference in the number of secondary tubers and yet there was a significance difference in weight at Ben-Hur is because secondary tubers produced by the two-year rested from harvesting plants were smaller in size compared to those produced by the five-year rested from harvesting plants. An average tuber from plants rested from harvesting for five years weighed 193.65 g, compared to 116.92 g from plants rested from harvesting for two years only within that same period of time. This means that secondary tubers from the five-year rested from harvesting plants would be increasing in size in each of the five years they have not harvested, whereas for the two-year rested from harvesting plants, the increase would only be from the two years they are not harvested. The difference of more than 76.8 g in weight per secondary tuber is the profit harvesters would benefit at Ben-Hur for not harvesting a plant twice in a space of five years. This translates into 2265.8 g of secondary tubers fresh weight per plant in contrast to 1309.615 g from plants not harvested for two years only.

Therefore, in order for a harvester at Ben-Hur to get 1 kg of dried tubers, they only need to harvest 5 plants if such plants were not harvested for the past 5 years, compared to 8 plants they would harvest if such plants were not harvested for the past 2 years only.

The same reasons given for the difference in the number of secondary tubers above are attributed to why the same pattern still exists in secondary tuber weight for Vergenoeg.

Considering the economic situation of local harvesters, conservation of *H. procumbens* and the benefits of not harvesting for five years, sustainable harvesting quotas equally divided between the numbers of harvesters per area would help in this regard. Harvesters would divide their *H. procumbens* production area into five parts allowing themselves to harvest from one of the parts per year allowing them to harvest from each part only after five years. A similar approach has been done by some harvesters who divided their production area into two parts which allowed them to harvest from each part after 2 years (Cole, 2005). It was evidently beneficial to the harvesters involved and if done on a large scale of involving all harvesters, it would benefit all involved.

This holistic approach would link conservation with economic satisfaction for local harvesters who would become managers of their own resource. It has been established that such management systems workout successfully by Jones (2003). These systems have been found successful because they encourage community members to seek economic benefit from the managed exploitation of their resource (Jones, 2003).

5 Conclusion

The ability of producing fruits by *H. procumbens* does not depend on how long it is left without harvesting, but possibly on other conditions like soil type, age of a plant and rainfall conditions found by previous studies. This therefore, implies that *H. procumbens* in the wild can regenerate well with its fruits even when it is being harvested. Local harvesters can therefore, still have *H. procumbens* continuing to recruit future plants for them to harvest in their production areas with sustainable harvesting techniques that leave the main tuber undisturbed after harvesting.

Because of the ability to retain water by the Ben Hur soils, *H. procumbens* can produce the same number of secondary tubers regardless of whether there is no harvesting for 2 years or for 5 years. Though the number of secondary tubers may not be significantly different between the 2 periods, their size will be significantly different, resulting in higher benefits from those not harvested for 5 years. The bigger the size of secondary tubers, the more dried slices will be sold and hence the more money for the harvesters who spend much effort and time to dig-up tubers. Therefore, since the number of secondary tubers was not significantly different but their weight had significant difference, it is recommendable to rest these plants for 5 years at a site such as Ben Hur.

At Vergenoeg, the sandy plains with ferralic Arenosols allow quick water drainage. In order to absorb much of this quick-draining water when it rains, *H. procumbens* must develop superficial roots to absorb enough water. It is evident from the results of this study that, two-year resting from harvesting plants would not have as many of these superficial roots to absorb enough water helping the plant to produce more secondary tubers. Five years of resting on the other hand was evident to have enough deeper superficial roots, which helped absorb water enough to produce more secondary tubers that were bigger in size.

Considering the economic needs of harvesters, conservation concerns for *H. procumbens* and a higher profit for harvesters resulting from 5 years of not harvesting these plants, a holistic management approach or rotational harvesting is required to benefit stakeholders involved over a sustained period of time. This management approach would give local harvesters control over their own resource linking conservation with economic satisfaction, where many locals would in the end be benefiting from this resource, as opposed to when few individuals get to harvest many plants after every two years.

Acknowlegements

We would like to acknowledge and thank Centre for Research Information Action in Africa Southern African Development & Consulting (CRIAA SA-DC) for partialy funding and supervising this research in the field. We also acknowledge and thank the The German Academic Exchange Service (DAAD) for funding this research through-out. We would like to also thank Mrs M. Thomas and Mr. Uzabakiriho. We would also like to thank Dr. M. Strobach for her field and other practical guidance. We further thank all the Ben-Hur and Vergenoeg community members for their input and help during data collection. We thank the Komeho staff at Ben-Hur for their help in resources and guidance. Lastly but not least,we thank God for all the protection given unto us from the start to the end of this project.

Abbreviations

CITES - Convention on International Trade in Endangered Species of Wild Fauna and Flora

CRIAA SA-DC - Centre for Research Information Action in Africa Southern African Development & Consulting

DAAD - German Academic Exchange Service.

References

[1] AEZ-AGRO-ECOLOGICAL ZONING PROGRAM: Namibia Agricultural Information System (NARIS), Windhoek, Namibia, Directorate of Agricultural Research and Training, Ministry of Agriculture, Water and Rural Development. GIS Digital Files. (2001)

[2] CITES. Proposal Inclusion of H. procumbens in Appendix II in accordance with Article II 2(a). Retrieved/accessed September 14, 2005, from: http://www.cites.org/eng/cop/11/prop/60.pdf. (Unpublished).

[3] Cole D, Bennett B. Trade, poverty and natural products: lessons learned from Namibian organic devil's claw. Namibian Trade and Poverty Programme, a project of the UK Department for International Development (DfID). CRIAA âĂŞ SADC, Windhoek, Namibia. 32 pp. (2007)

[4] Cole D, du Plessis P. 2001. Namibian Devil's Claw (Harpagophytum spp.): A Case Study on Benefit-Sharing Arrangements: Prepared for the MET. CRIAA SA-DC. Windhoek (unpublished report) (2001).

[5] Cole D, Strohbach M. Population Dynamics and sustainable Harvesting of the Medicinal Plant H. procumbens DC (Devil's Claw) in Namibia. (2007).

[6] Eich J, Schmidt M, Betti G. HPLC Analysis of Iridoid Compounds of Harpagophytum taxa: quality control of pharmaceutical drug material. Pharm Pharmacol Lett 8:75-78. (1998)

[7] Feistel B, Gaedcke F. Analytische Identifizierung von Radix Harpagophyti procumbentis und zeyheri Zeitschrift für Phytotherapie 21: 246-251. (2000)

[8] Hachfeld B. Ecology and utilization of Harpagophytum procumbens (devil's claw) in southern Africa. In: Plant species conservation monographs 2. Bundesamt fur Naturschutz (BFN). 25 pp. (2003).

[9] Jones B. Enhancing equity in the relationship between protected areas and indigenous and local communities in the context of global change: Lessons learned from the philosophy and practice of CBNRM in Southern Africa. In Whande, W., Kepe, T. and Murphree, M., Local Communities, Equity and Conservation in Southern Africa: A synthesis of lessons learnt and recommendations from a Southern African Technical workshop. Cape Town: Programme for Land and Agrarian Studies (2003).

[10] Inaba K, Murata K, Naruta S, Matsuda H. Inhibitory effects of devil's claw (secondary root of Harpagophytum procumbens) extract and harpagoside on cytokine production in mouse macrophages. The Japanese Society of Pharmacognosy and Springer: J Nat Med (2010) 64:219-222. (2010.)

[11] Nott K. Training of Devil's Claw Traders and Exporters and MET Officials. Final report: commissioned by the Millennium Challenge Account Namibia with funding from the Millennium Challenge Corporation. (2011).

[12] Sandison MR, Munuz MC, Koning J, Sajeva M. CITES and plants - a user's guide. Royal Botanical Gardens, Kew, UK. 40 pp. (1999).

[13] Schneider E. Sustainable use in semi-wild populations of Harpagophytum procumbens in Namibia. Medicinal Plant Conservation, 4, 7-9. (1997).

[14] Stewart K. Effects of secondary tuber harvest on populations of devil's claw (Harpagophytum procumbens) in the Kalahari savannas of South Africa. Blackwell Publishing Ltd, Afr. J. Ecol., 48, 146-154. (2009).

[15] Townend J. Practical statistics for environmental and biological scientists. John Wiley & Sons Inc, UK. (2002).