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

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

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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

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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).
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
Resting period on *Harpagophytum procumbens*

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).
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
Resting period on *Harpagophytum procumbens* 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)

<table>
<thead>
<tr>
<th>Age State</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1 Young reproductive plant</td>
<td>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.</td>
</tr>
<tr>
<td>G2 Mature reproductive plant</td>
<td>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.</td>
</tr>
<tr>
<td>G3 Old reproductive plant</td>
<td>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.</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Two years not harvested plants</th>
<th>Five years not harvested plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant No.</td>
<td>No. of fruits</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>227</td>
<td>15</td>
</tr>
<tr>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>48</td>
<td>0</td>
</tr>
<tr>
<td>57</td>
<td>1</td>
</tr>
<tr>
<td>38</td>
<td>13</td>
</tr>
<tr>
<td>47</td>
<td>3</td>
</tr>
<tr>
<td>50</td>
<td>5</td>
</tr>
<tr>
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<tr>
<td>62</td>
<td>6</td>
</tr>
<tr>
<td>64</td>
<td>5</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Plant No.</th>
<th>No. of fruits</th>
<th>No. of tubers</th>
<th>Tubers weight</th>
<th>Plant No.</th>
<th>No. of fruits</th>
<th>No. of tubers</th>
<th>Tubers weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
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<td>11</td>
<td>1080</td>
<td>14</td>
<td>1</td>
<td>8</td>
<td>1480</td>
</tr>
<tr>
<td>17</td>
<td>0</td>
<td>12</td>
<td>2300</td>
<td>16</td>
<td>0</td>
<td>1</td>
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<td>0</td>
<td>12</td>
<td>3600</td>
<td>20</td>
<td>1</td>
<td>12</td>
<td>1960</td>
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<td>7</td>
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<td>1</td>
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<tr>
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<td>0</td>
<td>7</td>
<td>900</td>
<td>36</td>
<td>6</td>
<td>22</td>
<td>1725</td>
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<td>320</td>
<td>37</td>
<td>6</td>
<td>28</td>
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</tr>
<tr>
<td>88</td>
<td>6</td>
<td>11</td>
<td>550</td>
<td>47</td>
<td>0</td>
<td>10</td>
<td>1280</td>
</tr>
</tbody>
</table>

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 (Townsend, 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 $r = 0.54$. 
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.
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 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.
3.3.2 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.
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...
Resting period on *Harpagophytum procumbens* 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.

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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


Resting period on *Harpagophytum procumbens*


