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The phenomenon of fairy circles in Kaokoland (NW Namibia)

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Abstract

Embedded in species-poor grasslands, fairy circles are circular or sub-circular patches devoid of any vegetation. Characteristically, the circumference of each circle shows a band of more densely packed taller tussocks within a shorter, scantier species-poor grassland matrix. The average diameter of the circles is between 5–8 m. Predominantly restricted to sites showing deep sandy deposits, fairy circles occur in a broken belt in the pro-Namib from southern Angola to the Orange River (Republic of South Africa). The distribution of fairy circles is significantly limited to areas with an average of 50-100 mm of annual precipitation. During the last years the phenomenon of fairy circles has increasingly evoked scientific and public interest. Till this day, the origin of fairy circles is not explained satisfactorily. The latest papers are discussed and new evidence is given in support of the hypothesis that harvester ants and harvester termites are the prime causal factor for the forming of fairy circles.

Keywords: harvester ants, harvester termites, plant-insects-interactions

Zusammenfassung

Eingebettet in artenarme Grasländer bilden Feenkreise runde bzw. kreisförmige vegetationslose Flächen. Als typisches Merkmal besitzen diese Flächen einen Rand, der aus dicht stehenden vitalen Grashorsten gebildet wird und sich deutlich von der spärlichen und artenarmen Grasland-Matrix abhebt. Der Durchmesser der Feenkreise liegt häufig zwischen 5 und 8 m. Beschränkt auf Gebiete mit zumeist tiefgründigen, sandigen Substraten, treten Feenkreise in einem unterbrochenen Streifen in der Vornamib vom südlichen Angola bis zum Oranje (Republik Südafrika) auf. Das Areal der Feenkreis ist hier auf Gebiete mit einer durchschnittlichen Jahresniederschlagsmenge von 50-100 mm beschränkt. Während der letzten Jahre hat das Phänomen der Feenkreise zunehmend ein breites öffentliches und wissenschaftliches Interesse hervorgerufen. Bis heute konnte aber die Entstehung von Feenkreisen noch nicht zufriedenstellend geklärt werden. Die neuesten Veröffentlichungen

werden diskutiert und neue Hinweise zur Unterstützung der Hypothese, dass Feenkreise auf die Sammeltätigkeit von Ernteameisen und Erntetermiten zurückzuführen sind, werden dargestellt.

Schlüsselbegriffe: Ernteameisen, Erntetermiten, Pflanze-Insekten-Interaktionen

Introduction

During the past years, the phenomenon of fairy circles has evoked an increasing public and scientific interest. Numerous publications in journals, newspapers, and the Internet contribute to this subject. In collaboration with S. Getzin, the author reported 2000, that the harvesting behavior of the grass-collecting termite species *Hodotermes mossambicus* is the prime causal factor for the forming of fairy circles in the pro-Namib-area in western Kaokoland (Becker & Getzin 2000). Shortly after the paper's publication Albrecht et al. (2001) published a paper about the occurrence of fairy circles in the area of the farm Wolwedans (pro-Namib-area of the Central Namib Desert). In 2002 Grube published an „opinion-paper" as a rejoinder to the paper of Becker & Getzin (2000). A proper "fairy circles-hype" was evoked (and is evoked) by the contribution of van Rooyen et al. (2004), which comprehensively reviews and discusses the theories trying to explain the phenomenon of fairy circles. As a conclusion van Rooyen states: „For the moment, we're left with the fairies" (Coghlan 2004). The author takes the occasion to comment on the current state of international fairy circles-research and to add some new aspects to the discussion.



Photo 1: *Fairy circles in the Marienflussvalley* (Photo: S. Getzin)

Survey of hypotheses and anti-hypothesis – new aspects

The serious research on the phenomena of fairy circles in the western part of Namibia began with a paper published by Theron in 1979. The presented idea that fairy circles are caused by the allelopathic effect of *Euphorbia damarana* has finally been dismissed. For example, in a paper co-authored by Theron (van Rooyen et al. (2004) it is stated that an inhibitory effect of soil found at stands of *Euphorbia damarana* affecting the growth of other plant species is not verifiable. Besides, the argument presented by Becker und Getzin (2000) that the typical characteristics of *Euphorbia damarana*-

habitats (shallow soils with a high portion of coarse material) obviously differ from typical habitats of fairy circles (deep and sandy soils), is confirmed by van Rooyen et al. (2004).

The paper presented by Becker & Getzin (2000) describes the appearance of fairy circles particularly in the Marienflussvalley and the Hartmannsvalley (western Kaokoland). Based on observations in field and the evaluation of literature, the authors conclude, that in the areas surveyed the harvesting activity of the harvester termite *Hodotermes mossamibcus* is responsible for the occurrence of fairy circles. Regarding the literature confirming this thesis the publications of von Coaton (1949, 1953, and 1958) and Coaton & Sheasby (1972, 1975) have to be mentioned. They describe in detail the harvesting activity of *H. mossambicus* and the there from resulting effects on the vegetation. As these publications were originally published in South-Africa (and therefore are easily accessible), it is surprising that these valuable contributions are ignored by other fairy circles-authors (see Albrecht et al. 2001, Grube 2002, van Rooyen et al. 2004). Grube contradicts the termite-thesis presented by Becker & Getzin (2000) by stating that in the Etosha-Park (Namibia), the harvesting activity of *Hodotermes mossambicus* does not result in the occurrence of fairy circles. Regarding this counterargument, it is to be said that Becker & Getzin (2000) emphasize that the occurrence of fairy circles caused by the harvesting activity of *Hodotermes mossambicus* is restricted to regions showing an eminently species poor and therefore homogenous grassland and sites showing deep sandy soils.

To the author, such a combination of site characteristics necessary for the occurrence of fairy circles is unknown for the Etosha-Park area. Becker & Getzin (2000) pointed out, that environmental conditions different from the conditions existing in the distribution area of fairy circles in western Kaokoland may lead to a different harvesting behaviour of *H. mossambicus*. However, even in fairy circles-areas, the harvesting activity of *H. mossambicus* does not necessarily result in the development of fairy circles (see Photo 2). The final answer to the question why in the same area the harvesting activity of *H. mossambicus* results in typically formed fairy circles and simultaneously in unevenly harvested patches should be subject to future research activities.

The vegetation patterns resulting from the harvesting activity of *H. mossambicus* in South-Africa are described in detail by Coaton (1949, 1953, and 1958). Accordingly, in the Heilbron District (in the vicinity of Johannesburg, RSA) the harvester activity of *H. mossambicus* in a relatively species rich *Cymbopogon-Themeda*-Grassland receiving 400 mm to 600 mm of precipitation per year results in „sub-circular denuded patches“. Due to the strong consumption of grass, *H. mossambicus* in southern Africa is a recognized serious threat to the carrying capacity of pastures: „It has been estimated that the species [H. mossambicus] removes 25% of the grass biomass in Namibia in years of average rainfall and twice to three times as much during drought.“ (ARC, o.A.) (See also Ohiagu 1979). Frequently, the author had the opportunity to watch the harvesting activity of *H. mossambicus* in savannah vegetation regions of Namibia not resulting in the development of fairy circles-related denuded patches. Therefore, it has to be emphasized again, that for the development of fairy circles resulting from the harvesting activities of *H. mossambicus*, the presence of a species-poor and homogenous grassland is essential (see photo 3). To maintain fairy circles permanently, the amount of rainfall and the soil's nutrient content must not support a rapid regeneration of the vegetation. Research projects carried out in regions showing different environmental characteristics (*H. mossambicus* appears in the whole of the African continent - excluding the winter rainfall regions - where the annual precipitation ranges between 50 mm and 750 mm) should seriously consider the general conditions linked with the occurrence of fairy circles as described above.



Photo 2: *Area being unevenly harvested by Hodotermes mossambicus(Marienflussvalley)*

Van Rooyen et al. (2004) contradict the termite-hypothesis by presenting the following arguments:



Photo 3: *Well developed fairy circle in the Marienflussvalley (diameter ca. 8 m)*

1. „Moll (1994) suggested that the lack of vegetation in fairy circles was merely the result of termites having eaten all the grass seeds in the immediate vicinity of their nests. However, after good rainfall many small seedlings are noticed in the barren patches indicating that a lack of seeds is not the prime cause of barren patches. Patches remain bare because seedlings do not survive."

Indeed, *H. mossambicus* (like other harvester ants and termites) does not exclusively feed on grass seeds (in Southern Africa, the popular name of *H. mossambicus* is „grass-cutting-termite"). The author had the opportunity to observe *H. mossambicus* feeding on all parts of different *Stipagrostis*-species (*S. uniplumis*, *S. hirtigluma*, *S. giessii*) excluding the partly cellulose-rich parts of the transition from the roots to the shoots. The result is shown on Photo 2. The grass individuals from which the photosynthetic parts had been harvested quickly die off (see. also Photos 4 and 5).



Photo 4: *Hodotermes mossambicus feeding on Stipagrostis giessii (Marienflussvalley); clipped shoots are visible*



Photo 5: *Harvested material (Stipagrostis giessii) is collected by Hodotermes mossambicus at the entrance to the subterranean nest*

The following photos were made available to the author by Stefan Kröpelin (University of Köln) (Photos 6 and 7). They show a weak developed fairy circle in sparse grassland at the eastern border of the Northern Namib Desert (most probably *Stipagrostis uniplumis*). In the central part of the fairy circle (which has a diameter of about 5 m) the material harvested by *Hodotermes mossambicus* is visible (Photo 6). Photo 7 shows the central part of the

same fairy circle with the entrance to the nest in detail. Single individuals of *Hodotermes mossambicus* are visible.

2. „Grube (2002) pointed out that the model by Becker and Getzin (2000) did not adequately take the behaviour of H. mossambicus into account. Observations in the Kaokoveld on actively foraging termites did not reveal that they harvested in circular patches and in areas with a dense grass cover foraging activity left hardly visible irregular bare areas (Grube, 2002, nach Van Rooyen et al., 2004).

The research on *Hodotermes mossambicus* presented by S. Grube in



Photo 6: *Weak developed fairy circle in the eastern Namib Desert (Photo: S Kröpelin)*



Photo 7: *Material harvested by Hodotermes mossambicus – collected at the entrance of the nest system (see arrow in Photo 6; Photo: S. Kröpelin)*

her 2002 BAE-paper were not carried out in Kaokoland, but in the Etosha National Park (see Grube 2000). There, environmental conditions broadly differ from the conditions present in the fairy circles distribution area in Kaokoland (e.g. higher annual precipitation, different vegetation types, different soil characteristics, different biocoenosis). As mentioned before, *H. mossambicus* inhabits large parts of the African continent. It comes as no surprise that *H. mossambicus* – as a ubiquitous species – exhibits a wide range of different behaviors depending on the respective environmental conditions („It is quite within the bounds of probability, that *H. mossambicus* may exhibit a multitude of behavioural adaptations as a response to different habitats“ [Becker & Getzin 2000]). As a result, Grube's dismissal of the termite-hypothesis is not conclusive.

3. "The foraging hypothesis is also unable to explain the inhibition of growth observed in plants grown in soil collected from barren patches."

Becker & Getzin (2000) explained why the inner part of a fairy circle only supports poor growing conditions for plants (low content/poor availability of nutrients due to the missing accumulation of organic material). Please see Eicker et al. (1982), Moll (1994), Albrecht et al. (2001) und van Rooyen et al. (2004; chapter 4.3.: Allelopathy hypothesis) for the results of plant germinating and growing experiments in substrate taken from fairy circles. As emphasised by Becker & Getzin (2000), the typical site where fairy circles occur in Kaokoland shows deep sandy soils. Naturally, sandy soils show a low content of nutrients available for plants. Main sources of nutrients are of biotic origin. In the distribution area of fairy circles in western Kaokoland, the supply of nutrients indirectly results from the accumulation of organic material. In particular, grass individuals facilitate the accumulation of phytogenic material (Becker & Getzin 2000). Therefore, an area devoid of vegetation lacks one important source of the soil's nutrient supply. Additionally, percolating water transports soluble nutrients to deeper soil layers and makes the nutrients unavailable for surface-near roots. Over the years, the nutrient content of the fairy circle's substrate decreases. In this respect, the poor growing conditions in a fairy circle can be explained easily.

4. "Because termites can shift their surface activity from the hot daytime to the cooler night-time to protect workers from unfavourable temperatures, Becker and Getzin's (2000) explanation of how high temperature limits the size of barren patches is questioned by Grube (2002)."

Becker & Getzin (2000) have delineated which influencing factors can limit the size of a fairy circle. The sensitivity of *H. mossambicus* regarding high and low temperatures is indubitable (see Skaife 1955, Coaton 1958). Hence, it is not only due to high temperatures during the day why the radius of action of *H.*

mossambicus is limited on the soil's surface, but also but also a result of low temperatures during the night (Becker & Getzin 2000). Becker & Getzin 2000) have mentioned that the temperatur-sensitivity of *H. mossambicus* and the resulting limitation of the aboveground action radius show an interrelation with numerous animals preying on *Hodotermes mossambicus*. While temperatures above 40° C seriously affect the termite's homeostasis, one of its most important predators – the ant species *Ocymyrmex robustior* – is most active at 52° C. Considering theoretical conditions, the size of a fairy circle is also limited by the fact that in a specific distance from the nest the balance between energy consumed and the energy harvested turns negative.

5. "However, even if the nests could not be found, termite tunnels should have been noticed in the trenches if termites were active (Coaton and Sheasby, 1975)". "As for the termites, the team dug trenches up to two meters deep in and around the circles, but found no sign of these insects or their nests, present or past." (The Namibian 2004)

As Becker & Getzin (2000) explained there is no harvesting activity of *H. mossambicus* in the currently existing fairy circles.

According to Coaton (1953, 1958) *H. mossambicus* is able to harvest an area corresponding to a fairy showing a diameter of 5 to 8 m within 5 to 7 days. Hence, the period of time for the developing of a fairy circle is quite short. Since the conditions within a fairy circle hardly support the re-growth of plants, fairy circles are of persisting nature and today visible fairy circles may be older than 10 years. Therefore, it is quiet unlikely to observe harvesting termites within an already existing fairy circle.

However, the author had the opportunity to observe and document actively harvesting ants within a fairy circle (see below).

As *H. mossambicus* neither seals the material deposited outside the nest system when the galleries are built nor the galleries themselves, it is not surprising that in the mostly sandy substrates even after a short time abandoned galleries are no longer visible. Besides, it is imaginable that by digging for galleries they are destroyed (see Coaton 1958). Photos 8 and 9 allow a comparison of a fairy circles area in the Marienflussvalley from 1990 to 2001.

In this period of time in the area covered by the photographs 3 new fairy circles have arisen. None of the fairy circles existing in 1990 has vanished until 2001.

This comparison confirmed the the statement by van Rooyen et al. (2004) about the persistent character of fairy circles. It comes as no surprise that in a more than 10-year old fairy circle no present harvesting activities are signs of former harvesting activities can be observed or found (see also issue 6). According to Coaton (1958) the nest system of *Hodotermes mossambicus* can spread over more than 250 m (see Becker & Getzin 2000).

6. „Damage by *H. mossambicus* usually takes the form of denuded patches fringed by grasses with horizontally cut-off stalks, leaving stubs with finely serrated edges (Coaton and Sheasby, 1975). Plants on the edge of fairy circles, however, grew vigorously and did not show characteristic cut-off stalks."

Please see photographs 2, 4 and 5 for signs of harvesting activities of *Hodotermes mossambicus*. It is not plausible why annual or biennial grasses like *Stipagrostis uniplumis*, *S. giessii* und *S. hirtigluma* (dominant species of the matrix vegetation in the fairy circles-area of western Kaokoland) should currently show signs of harvesting activities of *H. mossambicus* taking into consideration that the concerned fairy circle probably is more than 2 years old. As presented in the photographs shown above, grass individuals subject to current harvesting activities of course show signs of harvesting.

7. „The distribution range of *H. mossambicus* covers most of southern Africa where rainfall is less than 750mm per annum (Coaton and Sheasby, 1975). Fairy circles are limited to a small portion of this range with no similar phenomenon found in the rest of the termite's range."

As presented with issue 2, the development of fairy circles is depending on a set of general conditions. Therefore, only in areas showing these conditions the development of fairy circles is possible. Such conditions are found in the grassland of Idaho. From there Sharp & Barr (1960) report about the effects the harvester ant *Pogonomyrmex occidentalis* has regarding the pastures (see also MacMahon et al. 2000). The photographs 10 and 11 (aerial photographs) oppose the vegetation patterns in the grassland of Idaho caused by the harvesting activity and the fairy circles in the Marienflussvalley (photo 12).

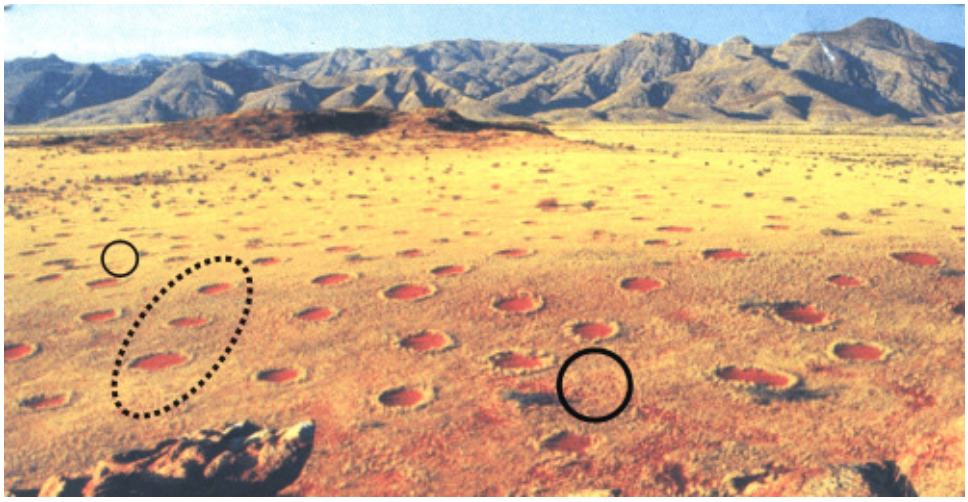


Photo 8: *Reprint of a Namibian postcard of fairy circles in Marienflusstal (Photograph taken in 1990)*

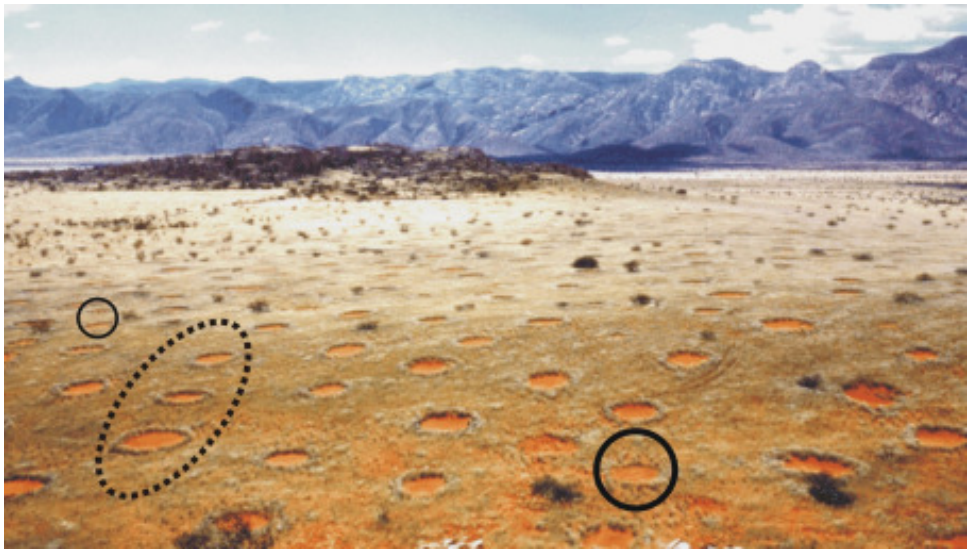
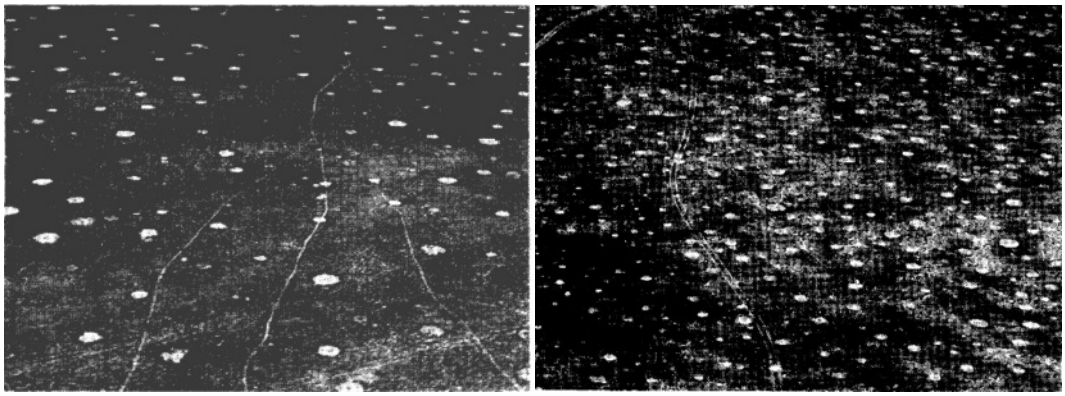


Photo 9: *The same area photographed in 2001 (Photo: B. Hachfeld)*
(In both photographs the following structures were marked: solid circles – new emerged fairy circles (time frame 1990-2001); dotted circle: orientation aid)

Sharp und Barr (1960) describe the effects of the harvesting activity of *P. occidentalis* as follows:

„In Kansas, Fritz and Vickers […] found the clearings relatively small with the largest measuring 150 to 200 square feet [45 bis 59 m²]. Knowlton and Nye (1946) stated that individual clearings may occupy 500 [149 m²] square feet or more in Utah. […] Weber (1959), observing ant clearings in Utah from air, calculated that 30976 clearings per square miles […] could be present in certain areas." (Sharp & Barr, 1960: page 131)

It is the author's opinion that the circle-like shapes found in southern Idaho have to be regarded as an obvious analogy to the fairy circles of Kaokoland. This opinion is supported by the fairy circles



***Photos 10** und **11:** Fairy circles resulting from the harvest activity of Pogonomyrmex occidentalis in an Idaho pasture (from Sharp & Barr 1960, note the tracks for scale comparison)*

in *Schmidtia kalahariensis*-grassland caused by the harvesting activity of a harvester ant in the Orupembe-area (western Kaokoland, pro-Namib) (see photos 13, 14 and 15). In this area fairy circles show a lower density than in the Marienflussvalley and the Giribisvlakte. In contrast to areas where fairy circles are caused by the *Hodotermes mossambicus* in the Orupembe-area the soil is not deep and sandy. Here, the shallow soil is characterized by coarse weathered and packed material of the Etendeka-Basalt and quartzite.

The examined fairy circles showed a

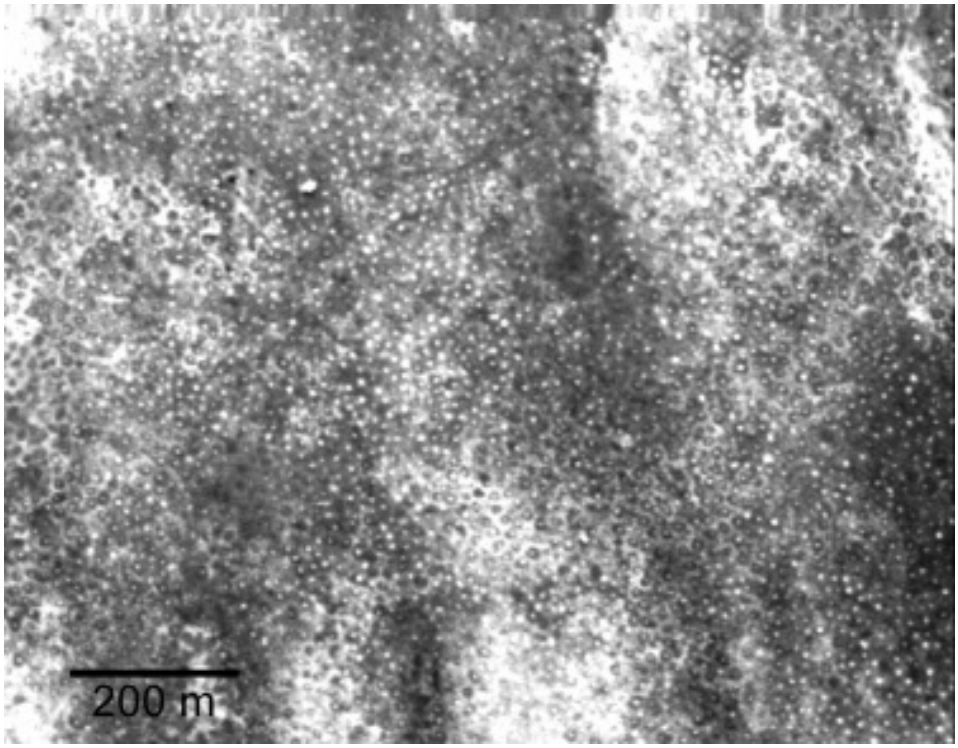


***Photo 12**: Fairy circles in Marienflusstal, aerial photo (1996)*



Photo 13: *Fairy circle resulting from the harvest activity of a harvester ant in the Orupembe area (Schmidtia kalahariensis-Grassland, note spade as scale)*

diameter of 3 to 5 m. After an above-average rainy season the the seeds of Schmidtia kalahariensis were ripe when the field study was carried out (2001). Therefore, it is allegeable that the harvester ant focused its harvesting activity on the energy-rich seeds while otherwise the green parts of the grasses are harvested.

In contrast to *H. mossambicus* the nestsystem of the harvester ant seems to have a smaller spatial extent. This



Photo 14*: Fringe of the fairy circle shown in photo 14. In front of the folding rule, husks of Schmidtia kalahariesis left by the harvester ant are visible.*

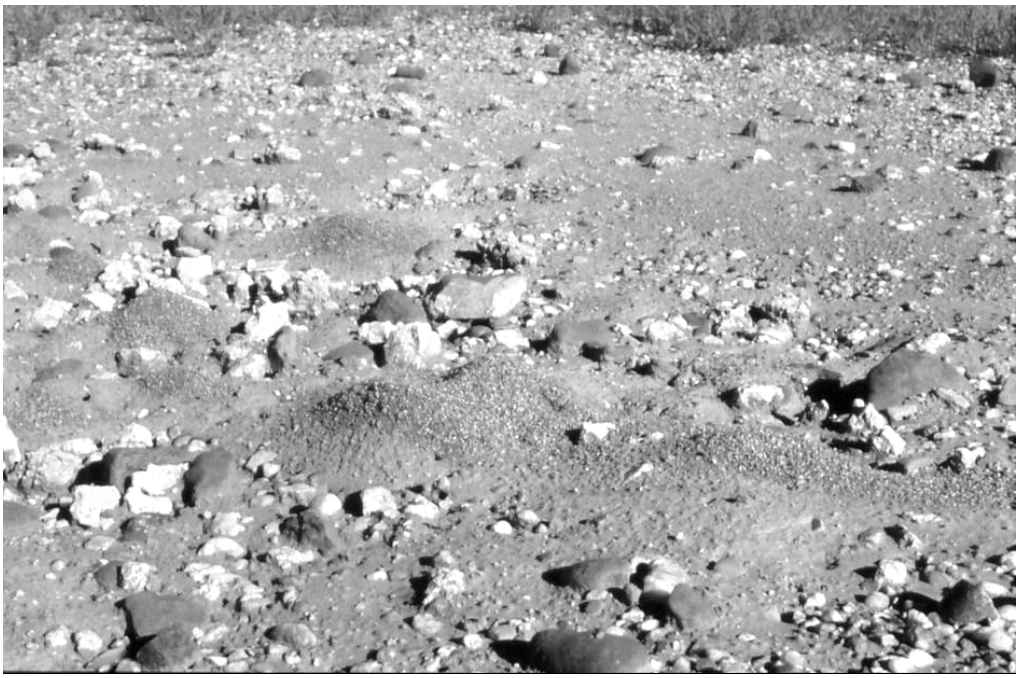


Photo 15: *Entrance to the nest system in the central part of the fairy circle shown in photos 13, 14.*

opinion is supported by the huge amount of waste material (pred. bracts and glumes) deposited in the centre of the fairy circle right next to the entrance of the sub-surface nest system. We watched the workers carrying spikelets inside the underground nest system while other workers deposited the waste material outside.

Final remarks

In the author's opinion the harvesting activity of ants and termites has to be regarded as the primal factor fort he development of fairy circles. Die arguments opposing the (ant-)termite-hypothesis are discussed and new evidence supporting the (ant-)termite-hypothesis are presented. As a new argument supporting the (ant-)termite-hypothesis the fairy circles-like structures caused by the harvester ant *Pogonmyrmex occidentalis* in the grassland of Idaho come into play. Besides, the importance of harvester ants regarding the development of fairy circles is described exemplary introducing an actively harvested fairy circle.

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author's ideas about the origin of fairy circles in Kaokoland. The author thanks two anonymous reviewers for their valuable comments on the original manuscript..

Literatur

Albrecht, C.F., Joubert, J.J., de Rycke, P.H., 2001. Origin of the enigmatic, circular, barren patches ('Fairy Rings') of the pro-Namib. - South African Journal of Science 97, pp. 23-27.
(on-line: http://www.drcarlalbrecht.com/documents/Fairy_Circle.pdf)

ARC – Plant Protection Research Institute (o.A.): Termites in Rangeland. – on-line: http://www.arc.agric.za/home.asp?pid=971&toolid=63&itemid=2102. South Africa.

Becker, T., 2001. Die Feenkreise des Kaokolandes. - Naturwissenschaftliche Rundschau 8, S. 430-431.

Becker, T., Getzin, S., 2000: The fairy circles of Kaokoland – origin, distribution, and characteristics. - Journal of Basic and Applied Ecology 1, pp. 546-559.
(on-line: http://www.uni-jena.de/img/unijena_/faculties/bio_pharm/inst_oeko/SpatialEcology/PDFs/Becker+ and+Getzin+2000.pdf)

Britton, K.E, Ncube, C., Wenzel, K. 2004. Fairy Circles, A Unifying and Testable Hypothesis. - World Journal of Nuclear Medicine, 3, pp. 300-302.
(http://www.wolwedans.com/FairyCircles/Article%202.html)

Coaton, W.G.H. 1949. The harvester termite problem in South Africa. Union of South Africa. - Dept. Agric and Forest., Ent. Ser. No 25, Bull. 292, 38 pp.

Coaton, W.G.H., 1953. Termites and their control in cultivated areas in South Africa. - Union of South Africa, Department of Agriculture, Division of Entomology, Bulletin No. 305, Pretoria.

Coaton, W.G.H., 1958. The HODOTERMID harvester termites of South Africa. - Union of South Africa, Department of Agriculture, Division of Entomology, Science Bulletin No. 375, Entomology Series No. 43.

Coaton, W.G.H., Sheasby, J.L., 1972. Preliminary report on a survey of the termites (Isoptera) of South West Africa. Cimbebasia Memoirs 2, pp. 1-129.

Coaton, W.G.H., Sheasby, J.L., 1975. National Survey of the Isoptera of southern Africa, 10. The genus Hodotermes (Hagen) HODOTERMITIDAE. Cimbebasia (A) 3, pp. 105-138.

Coghlan, A., 2004: Mysterious 'fairy circles' defy explanations. – New Scientist, April 3rd 2004 (on-line: http://www.newscientist.com/article.ns?id=dn4833).

Eicker, A., Theron, G.K, Grobbelaar, N. 1982. `n Mikrobiologiese studie van “kaal kolle” in die Giribesvlakte van Kaokoland, S.W.A.-Namibia. South African Journal of Botany1, pp. 69-74.

Grube, S., 2000. Soil dumps - indicators of foraging activity by Hodotermes mossambicus (Hagen) (Isoptera, Hodotermitidae) in northern Namibia. Cimbebasia 16, pp. 269-270.

Grube, S., 2002. The fairy circles of Kaokoland (Northwest Namibia) - is the harvester termite Hodotermes mossambicus the casual factor in circle formation? - Basic and Applied Ecology 3, pp. 367-370.

Günster, A., 1993. Fairy Circles - Bare vegetationless patches in the desert. Flamingo Magazine, Air Namibia.

Helmström, A.M. 1990: En Krönika om Asbro. Asbro.

Lovegrove, B., 1993. The living deserts of southern Africa. Fernwood Press, Vlaeberg.

MacMahon, J.A., Mull, J.F., Crist, T.O., 2000: Harvester ants (Pogonomyrmex spp.): Their Community and Ecosystem Influences. - Annual Review of Ecology and Systematics 31, pp. 265-291.

Moll, E., 1994. Fairy rings in Kaokoland. - In: Seynai, J.H. & Chikuni, A.C. (Eds.) Proceedings of the 13th Plenary Meeting AETFAT, Zomba, Malawi, pp 1203-1210.

Ohiagu, C.E., 1979. A quantitative study of seasonal foraging by the grass harvesting termite, *Trinervitermes geminatus* (Wasmann), (Isoptera, Nasutitermitinae) in Southern Guinea savanna, Mokwa, Nigeria. – Oecologia 40, pp. 179-188.

Owen-Smith, G., 1996. The Kaokoveld - southern Africa´s last wilderness. In: Tarr, P. (Ed.): Namibia Environment Vol. 1, pp. 62-65.

Sharp, L.A., Barr, W.F., 1960. Preliminary investigations of harvester ants on Southern Idaho rangelands. – Journal of Range Managements 13, pp. 131-134. (on-line: http://jrm.library.arizona.edu/jrm/GetFileServlet?file=file:///data1/pdf/TheJournalOfRangeManagement/Volume13/Number3/azu_jrm_v13_n3_131_134_m.pdf&type=application/pdf)

Skaife, S.H., 1955. Dwellers in Darkness. An introduction to the study of termites. Longmans Green and Co, London.

Sunday Times, 2005. Circles in the desert - Henk Rossouw meets a Namib sage and tries to solve a desert mystery. Sunday Times, March 13th 2005.
(on-line: http://www.wolwedans.com/FairyCircles/Article%201.html)

Naidoo, S., 2004. Fairy circles in desert leave scientists baffled - Four-year study into strange rings fails to find any new clues. Sunday Times, 25. 4. 2004 (on-line: http://www.suntimes.co.za/2004/04/25/ news /news19.asp)

The Namibian, 2004: 'Fairy circles' leave scientists perplexed. – The Namibian, online-Ausgabe vom 2.4.2004 (on-line: http://www.namibian.com.na/2004/april/national/04345FD6F5.html)

Theron, G.K, 1979. Die verskynsel van kaal kolle in Kaokoland, Suidwes-Afrika. Journal of the South African Biological Society 20, pp. 43-53.

Tinley, K.L., 1974. Synopsis of outstanding problems in Etosha-Damarana-Kaokoveld region of S.W.A. unpl. paper, University of Pretoria.

van Rooyen, M.W., Theron, G.K., van Rooyen, N., Jankowitz, W.J., Matthews, W.S., 2004. Mysterious circles in the Namib Desert: review of hypotheses on their origin. - Journal of Arid Environments 57, pp. 467–485
(on-line: http://www.boker.org.il/meida/negev/desert_biking/Jordan_summits/fairy_circles_of_namibia.pdf)