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Rapid Communication

First records of *Amaranthus palmeri*, a new emerging weed in southern Africa with further notes on other poorly known alien amaranths in the continent

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Abstract

Amaranthus palmeri is native to Mexico and the south-eastern parts of the USA, and is reported as alien in subtropical regions of the Old World. Previous records from Africa were from the northern parts of the continent. This species was first found in South Africa in March 2018 with further records in different regions of the country as well as in northern Botswana in March 2020. We consider it as naturalized weed which invades both ruderal and segetal plant communities. Mechanical control of *A. palmeri* plants may be effective to minimize its spreading, because at the flowering stage these tend to be taller compared to other amaranths. Those species of the genus alien in Africa are discussed in terms of their distribution and possible invasive status, particularly *A. dubius* and *A. standleyanus*.

Key words: Amaranths, naturalized species, tropical Africa, weeds

Introduction

The order Caryophyllales Berchtold & J.Presl encompasses ~ 6% of all flowering plants and includes at least 30 families with the major diversity centers in hot and cold deserts of the World (Brockington et al. 2009; Hernández-Ledesma et al. 2015). Some members from different families of the order became noxious weeds in the tropics and temperate regions as a stable component of diverse disturbed plant communities (see e.g., Esser et al. 2013; Sukhorukov 2014). Only a minor part of them are cultivated plants. Among them, many Cactaceae provide the most negative impact on the landscapes in arid regions of Africa (Novoa et al. 2014; Shackleton 2017; van Wilgen et al. 2020). Other well-known intentionally introduced species and naturalized in the continent are some shrubby Chenopodiaceae s.str., or Amaranthaceae s.l. (e.g., *Atriplex nummularia* Lindl., *A. canescens*

(Pursh) Nutt.) used as forage plants in the deserts (Barnard et al. 1992; Heshmati and Squires 2013). However, the vast majority of naturalized or invasive Caryophyllales are accidentally introduced plants. Recently, *Sesuvium verrucosum* Raf. (Aizoaceae), *Mollugo verticillata* L. (Molluginaceae), *Bassia indica* (Wight) A.J.Scott (Amaranthaceae s.l.), and *Oxygonum sinuatum* (Hochst. & Steud.) Dammer (Polygonaceae) were described as naturalized or invasive xenophytes in different regions of continental Africa and Macaronesia (Sukhorukov et al. 2017, 2018a, 2019).

Many amaranths are widespread aliens that can be competitive weeds in both ruderal and segetal plant communities (Costea et al. 2004). In Europe, *Amaranthus powellii* S.Watson is a recently established neophyte invading ruderal habitats and agricultural areas of Europe (Forman 2003; Sukhorukov 2011) and foothills of East Kazakhstan (Sukhorukov 2009). Another well-established species in southern Europe and eastern Mediterranean is *A. palmeri* S.Watson (Zohary 1966; di Castri et al. 2012; Iamonico 2015; Sukhorukov *pers. obs.* in the Mediterranean part of Israel), a dioecious amaranth originating from Mexico and south-eastern part of the USA (Sauer 1955; Ward et al. 2013). In Africa, this species was recently reported in Egypt (Boulos 1995) and Tunisia (Iamonico and El Mokni 2017). Further records were reported in Ethiopia (APD 2019) and Morocco (EPPO 2020+). In Morocco, it is included in the quarantine pest list (EPPO 2020+). In the present article, we report the first documented records of *A. palmeri* in South Africa and Botswana, with further notes on the most successful amaranths in tropical Africa.

Materials and methods

Study species

Amaranthus palmeri (Palmer amaranth, coded as AMAPA in the EPPO Global Database: EPPO 2020+) is an annual herb with C_4 photosynthetic pathway. The most distinct characteristics of this species are tall stems up to 300 cm high; one type (male or female) of flower in each individual (plants are dioecious); large bracteate synflorescences reaching 60 cm in length; mucronate bracts longer than perianth; 5 spatulate perianth segments with clearly subulate outer segments; flowers with 5 stamens (male individuals) and 2 pistils (female); fruits dehiscent with smooth pericarp (Sauer 1955). A detailed morphological description and taxonomy of *A. palmeri* can be obtained from different references (e.g., Sauer 1955; Wetzel et al. 1999; Ward et al. 2013; Iamonico and El Mokni 2017). The species can thrive under different climatic conditions, but requires full sun and high temperatures (26–35 °C) that enable rapid growth (Ward et al. 2013).

Data sources and analysis

The weed composition in Republic of South Africa has been investigated by Carl F. Reinhardt during the last three decades. The studies of Alexander

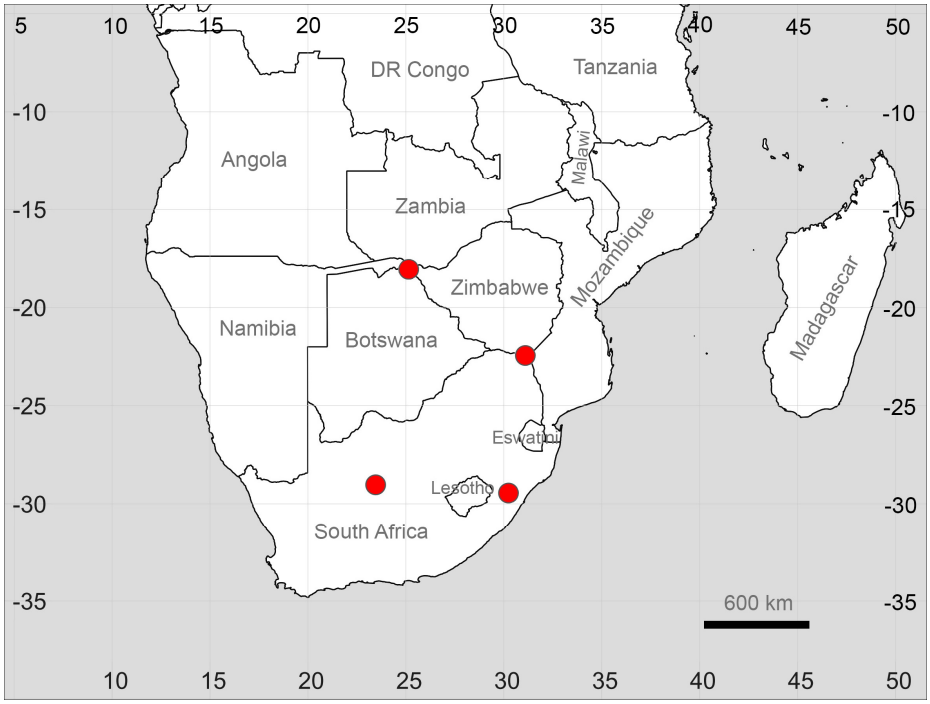

Figure 1. Locations of the new records of *Amaranthus palmeri* in southern Africa.

P. Sukhorukov on invasive Caryophyllales were carried out in 2009+ in different countries including Egypt (2009), Cape Verde (2015+), Namibia (2017, 2018), South Africa (2018), Tanzania (2019), Zimbabwe, Zambia, and Botswana (2020). The material collected during the field studies is kept in the herbaria G, K, MW, PRE, and W. During the last trip by APS in the first half of March 2020, the area under investigation included the surroundings of Victoria Falls (Zimbabwe), Livingstone (Zambia), and Kasane (Botswana) towns. The records of *Amaranthus palmeri* were mapped using simplemappr.net online tool.

Results

Records and population size

In South Africa, *Amaranthus palmeri* (Figure 1) was recorded for the first time in a farm in the Douglas district, Northern Cape Province (NC) [29°02′60.00″S; 23°45′59.99″E, March 2018, *legit* H. Bezuidenhout 871HB, SANBI Pretoria (PRE) & Kimberley South African National Parks Herbarium (KSAN)], where plants infest maize, cotton, and alfalfa fields (Figure 2A). On those crop fields *A. palmeri* was observed growing together with *A. hybridus* L. long since naturalized in South Africa. On that farm, *A. palmeri* only drew attention because it showed resistance against herbicides that usually provide good control of other amaranths. Recently (2019), *A. palmeri* was observed along a main road running past the farm on which it was first recorded in 2018 to the town of Douglas (± 7 km distance), as well as in the Douglas town. Another record originates in the Kruger National Park, Limpopo Province (22°22′26.8″S; 31°12′38.4″E, 12 April 2019,

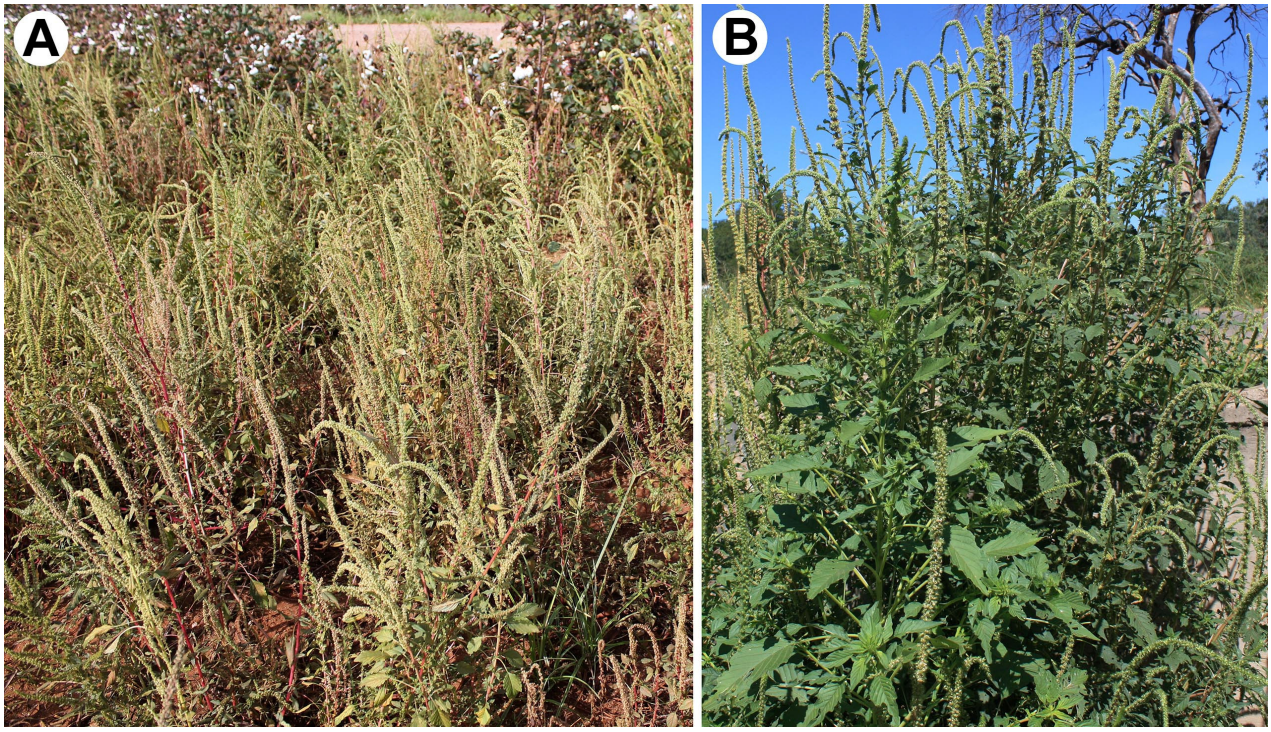

Figure 2. *Amaranthus palmeri*. A: South Africa, Northern Cape Province, Douglas district, cotton field, March 2018, photo by C.F. Reinhardt; B: Botswana, North-West district, Kasane town, March 2020, photo by A. Sukhorukov.

legit G. Zambatis & N. Zambatis GZ1563, KNP0011482/1) as occasional herb up to 2 m high in disturbed habitats on the floodplain and riverbank of the Limpopo River. Subsequently, samples collected from a farm near Howick, Kwa-Zulu Natal (KZN) were identified as *A. palmeri* (29°29′19.0″S; 30°10′52.0″E, March 2020, *legit* S. Friis, PRE).

In addition to herbarium vouchers, various living amaranths were collected from the locations in NC and KZN and additional verification was done by sequencing the ITS region using the method developed by Murphy and Tranel (2018). ITS sequencing identified *A. palmeri* in NC (NCBI: MT811920) and KZN (MT811923), *A. hybridus* in NC (MT811921) and KZN (MT811924), and *A. standleyanus* (MT811922) from the NC region. Subsequent sequence characterization of herbicide resistance genes has shown the two *A. palmeri* populations to be distinct from each other.

Another record for *Amaranthus palmeri* in southern Africa is from Botswana (Figure 1) where it was found in enormous quantity along the roads in Kasane town, North-West district of Botswana (17°47′31.96″S; 25°10′49.93″E, March 2020, *legit* A. Sukhorukov 482, G, K, MW, W). Both male and female individuals were present in flowering and fruiting [female individuals] stages (Figure 2B). A survey of the local people showed that the plant has been present in the town for at least 10 years. *A. palmeri* has invaded ruderal places distributed across an area of 10 km^2 westwards from the border with Zimbabwe. Along the main road in Kasane, the number of plants ranges from 40–50 per 100 m. Further observations are needed to determine whether *A. palmeri* is an invasive plant, since this status requires

that the offspring are found "at considerable distances from the parent plants" (Pyšek et al. 2004). The species was not observed in the investigated areas in Zimbabwe and Zambia, including the road Kasane – Victoria Falls.

Habitat preferences

Amaranthus palmeri is a plant adapted to both ruderal and segetal communities. It was not found in the natural plant communities but in a degraded area on the floodplain of the Limpopo River. It is plausible that the KNP population originated from propagules carried downstream in the Limpopo River from farmland adjacent to this river. Our observations are in agreement with other data showing the same habitat preferences (Zohary 1966; Smith et al. 2000). In Kasane town (Botswana), most individuals were highly branched and remarkably tall compared with other weedy plants, reaching 250 cm in height. The co-occurring species found there were typical alien weeds (e.g., *Amaranthus spinosus* L., *Boerhavia repens* L., *B. diffusa* L., *Tridax procumbens* L.). On the Douglas farm (South Africa), in cotton crop that reaches height of ± 100 cm, *A. palmeri* grows to about as tall as the crop, and in this setting the weed tends to be multi-stemmed or bushy. In alfalfa crop on the same farm, *A. palmeri* is regularly cut together with the crop during harvest, but the weed survives and produces fruits and seeds below the cut line, or by growing horizontally under the alfalfa canopy. In contrast, on said farm in the taller growing maize crop, *A. palmeri* tends to grow as tall and even taller than the crop, i.e. attains 200 cm height and taller. When growing in maize crop this weed tends to have a single stem. The aforementioned growth characteristics of *A. palmeri* are in agreement with the data from USA and Argentina (e.g., Berger at al. 2016, with references therein).

Discussion

Possible impact of Amaranthus palmeri

Like many other amaranths that are prolific seed producers (Weaver 1984; Mohler and Callaway 1995), a single individual of *Amaranthus palmeri* is able to produce up to 600,000 seeds in favorable conditions (Keeley et al. 1987). The seeds are both non-dormant and dormant and can successfully germinate after 3 years (Korres et al. 2018). This indicates that *A. palmeri* establishes a long lasting seed bank. Rapid growth and high density of *A. palmeri* induce competition for water, nutrients, and light and reduce the harvesting efficiency of agricultural crops (Smith et al. 2000, with references therein). The spread can be further accelerated if the plant is cultivated for its edible leaves (Shurtleff and Aoyagi 2010; Grubben and Denton 2004) and may have negative impacts on both ruderal and segetal plant communities.

The effective methods of population control and local eradication of *Amaranthus palmeri* have not yet been established in the new territory, but control programs that rely heavily on various herbicides are utilized in the USA, and herbicide type vary from crop to crop (Lindsay et al. 2017). *Amaranthus palmeri* is well adapted to withstand certain common active principles (a.p.) through the rapid evolution of resistance to at least eight very important a.p. sites of action (Ward et al. 2013; Berger et al. 2016, with references therein). However, we believe that selective mechanical removal of younger plants may be effective, because these are much taller than other similar looking amaranths. Unfortunately, selective mechanical removal will require weeding by hand which is time-consuming and relatively expensive. Mechanical control by means of soil tillage operations can be considered either as substitute or supplement for chemical control. Failure to control this weed effectively and timely in crops will likely result in catastrophic crop yield losses.

Based on the presence and persistence of *A. palmeri* populations for long periods, its invasive status in southern Africa can be considered as "naturalized". However, this status may be changed to "invasive" if further observations will allow to conclude and quantify its negative impacts and its rate of spread and consequent distribution in adjacent regions.

Notes on distribution of some alien Amaranthus *species in Africa*

The taxonomic composition of *Amaranthus* in the temperate and tropical regions is different. For instance, *A. retroflexus* L., widely distributed in the temperate regions of Eurasia, has not been found in the lowlands of African tropics. In addition, many records of the "tropical" amaranths in temperate European Russia are clearly erroneous (Sukhorukov and Kushunina 2012). According to the observations of the first author, the most common naturalized amaranths in Africa are the American *A. spinosus* L. and, especially, *A. viridis* L. Other frequently encountered species are *A. blitum* L. and *A. hybridus* L. [sub *A. patulus* Bertol. in the treatment of Amaranthaceae by Baker and Clarke (1909)]. *Amaranthus blitum* prefers arable lands, while *A. hybridus* is a typical ruderal species which can also grow on volcanic soil at elevation up to 1500 m a.s.l. (caldera of Fogo volcano, Fogo Island, Cape Verde; *legit* A. Sukhorukov, G, MW).

Amaranthus dubius Mart. was not listed in the earlier African floras (e.g., Baker and Clarke 1909; Hutchinson and Dalziel 1927; Maire 1962), but is reported from different African countries in many recent floristic accounts (e.g., Germishuizen and Meyer 2003; Grubben and Denton 2004; Mapaura and Timberlake 2004; Arechavaleta et al. 2005; Phiri 2005). Despite the fact that *A. dubius* is now widely cultivated in many tropical countries in Africa as a pot herb along with other species of the same genus (Grubben and Denton 2004), its intentional introduction in Africa is

doubtful. Surprisingly, this species is considered to be a "protected weed" (Grubben and Denton 2004), although it does not need any protection, and cultivation as a food crop clearly increases its spread. The current scattered distribution of *A. dubius* in Africa shown in APD (2019) is clearly underestimated. In fact, *A. dubius* is frequently found in waste and grassy places in different African countries (Sukhorukov, field observations and revision of the herbarium material at BR and K). In the countries with arid tropical climate, it thrives in any irrigated areas and sewage (e.g., on Sal Island, Cape Verde), and is abundant in disturbed habitats in the inlands of Santo Antão Island (*pers. obs.* of AS in 2018). We consider *A. dubius* a naturalized species according to Pyšek et al. (2004) in the tropics with humid climate.

Another South American amaranth, *Amaranthus standleyanus* Parodi, is mostly known from the arid subtropical parts of Africa (Germishuizen and Meyer 2003; Klaassen and Kwembeya 2013; APD 2019, with references herein) as well as from Macaronesia (Cape Verde) with a pending invasive status (Arechavaleta et al. 2005; Sukhorukov et al. 2018b). It is still rare in Namibia and Cape Verde, and in these countries *A. standleyanus* can be considered an alien introduced species in human-made habitats.

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