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A short communication on the ethnobotany, phytochemistry, pharmacological evidence and ecosystem restoration potential of South African *Portulacaria afra*

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Abstract
Portulacaria afra is a succulent shrub indigenous to South Africa and is considered as a medicinal plant due to its traditional uses in the treatment of skin disorders, diabetes and hypertension. The plant is also well-known for its ecological uses in ecosystem restoration due to its affinity to absorb high amounts of atmospheric carbon dioxide. Most studies have focused on the aforementioned statement, however in the medicinal aspect, apart from the ethnomedicinal uses of the species, there remains a significant shortage of reports on the phytochemical and pharmacological analyses, to which this communication aims to highlight. The cited literature has been sourced from Google Scholar, Science Direct and the University of the Witwatersrand library guide system for access to journals, to elaborate on the documented research on *P. afra*, including carbon fixation and ecological restoration potential, phytochemical profile, ethnobotanical information as well as the pharmacological evidence.

Keywords: *Portulacaria afra*, ethnobotany, phytochemistry, pharmacology, ecological restoration

Introduction
Plants have been used for many centuries as sources of food for nutritional purposes as well as medicine for the treatment diseases [1]. Medicinal plants are currently used in alternative medicine, which has become an increasing trend due to their accessibility and affordability [1]. It has been stated by the World Health Organization (WHO) that about 80% of the global population, majority of which are from developing countries, rely on these plants for their overall well-being [2, 3]. The reason behind the health-promoting benefits of using medicinal plants is due to the presence of phytochemical compounds or secondary metabolites such as phenolics, flavonoids, tannins, saponins and glycosides. In intact plants, these compounds play a defence mechanism role against the external environment [4], whereas in the perspective of man, the compounds are known to promote health and prevent or treat a myriad of illnesses and diseases such as cancer, diabetes and cardiovascular disorders [3, 5]. One plant species that is commonly used by indigenous people in South Africa and will be the focus of this communication is *Portulacaria afra.*

Portulacaria afra of the Didereaceae family is a succulent shrub that is widely distributed throughout the south to eastern parts of South Africa, ranging from the Western Cape, Eastern Cape, Kwa-Zulu Natal and Limpopo Provinces [6, 7]. This species is characterized by its evergreen, fleshy green leaves, red-purple stems and pink flowers (during the flowering season in spring/summer) [7], and has been known to treat mostly skin-related ailments such as dermatitis as well as high blood pressure, colds, thrush and inflammation [8]. *P. afra* is described as an impressive facultative crassulacean acid metabolism (CAM) plant with the ability to switch to C_3 pathway, enabling it to absorb carbon dioxide day and night, making it a highly potent "CO_2 sponge" [9]. It is because of this feature, that the species has been greatly used in ecological restoration practices throughout the country's near-barren areas with the purpose of increasing fauna and flora biodiversity as well as providing ample grazing material for livestock [10].

Several studies have evaluated *P. afra*'s ability to be utilised in ecosystem engineering as a result of its facultative CAM/C_3 pathway shifts [11, 12]. However, since it is also considered a medicinal plant, there are insufficient studies regarding both phytochemical analysis and pharmacological properties, with only a few papers documenting the above-mentioned gaps

being published in the last decade [13, 14]. Thus the aim of this communication is to discuss the ethnobotanical, phytochemical, pharmacological and ecosystem restoration potential of *P. afra* with the purpose to contribute to knowledge on the species in a broader perspective as well as to highlight the gaps in order to fully expand information on this species.

Methodology

Literature research was conducted using Google Scholar, ScienceDirect, theses and the University of the Witwatersrand library guide system to obtain scientific articles from a wide collection of journals. These sources were used to search for the ethnobotanical, phytochemical, pharmacological and ecological restorative practice studies with keywords "*Portulacaria afra*", "spekboom", "CAM mechanism", "pharmacological", "phytochemical", "traditional uses", "carbon absorption", and "ecological restoration" being used for the literature search. Discussing in detail on the species, covering as much aspects as possible could reveal knowledge gaps, and enable further research in order to contribute more knowledge.

Ethnobotanical overview

Morphology

Portulacaria afra (Jacq.) is known by many common names such as "spekboom", "spekbosb", "spekboomblareb" (Afrikaans) [8], "igwanitsha" (Xhosa) [15], and elephant bush [6]. It is a perennial small-leaf succulent indigenous to the Mediterranean climates of South Africa [16]. The plant grows up to four metres tall, and is one of the best drought-resistant, CAM photosynthetic garden plants [7]. *P. afra* varies in leaf size and shape, with Van Jaarsveld and Le Roux (2021) [7] reporting that the species that grows in Eastern Cape Province have smaller and more oval-shaped leaves, and those in the Limpopo Province having larger, and more rounded leaves. The red-purple colouration of the stems is due to the presence of anthocyanin pigments which serves as additional protection against environmental stress factors such as drought, cold and strong insolation [7, 17].

Fig 1: Photographic image showing *P. afra* leaves, stems and flowers [7].

Distribution and habitat

Portulacaria afra grows in well-drained slopes ranging from the Western Cape to the Limpopo provinces of South Africa, and also from near-sea levels to elevations of over 1000 metres [7]. The species is commonly found in the semi-arid southern and south-eastern regions of the country. According to Rutherford *et al.* (1986) [18], *P. afra* is mostly abundant in the Albany Thicket region Vegetation biome in the south-eastern parts of the country. It has been reported that *P. afra* occupies approximately 1.7 million hectares in the eastern and south-eastern Cape [9, 19].

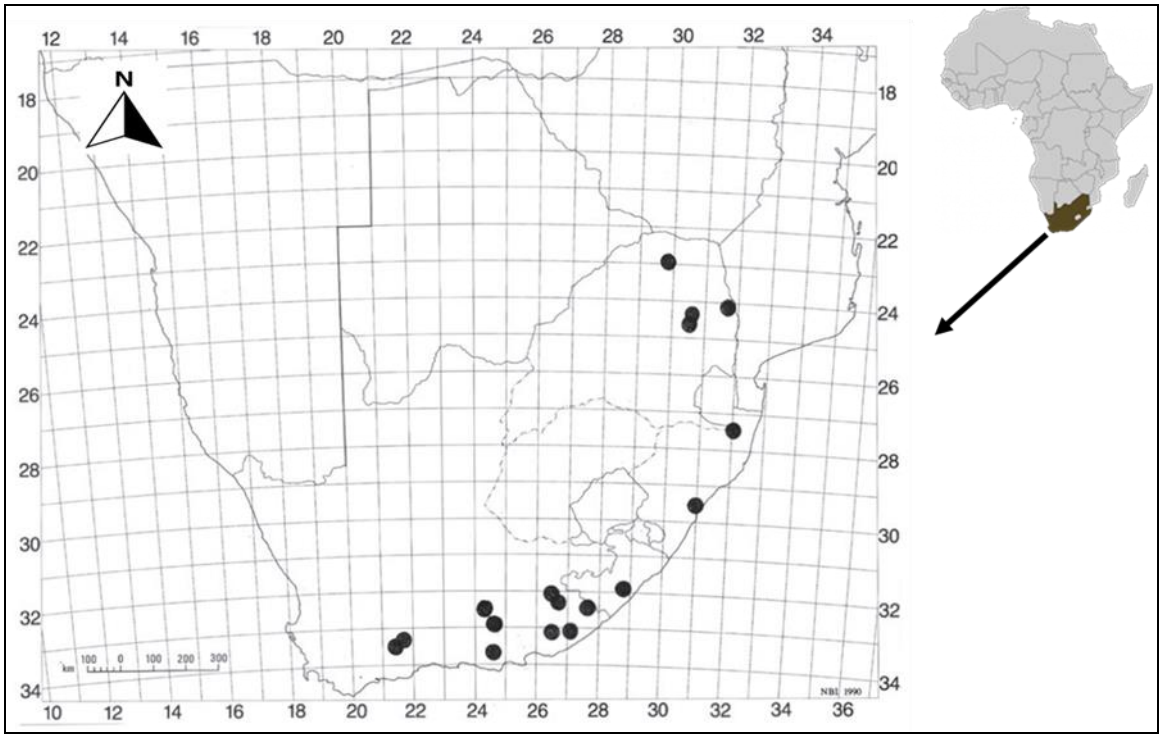

Fig 2: Distribution pattern of *P. afra* in South Africa [7].

Ethnomedicinal uses

Portulacaria afra is said to be used traditionally for the treatment of dermatitis, chronic sores [14, 20], kidney and urinary ailments, oral thrush, toothache, psychological conditions, colds, cough sore throat, pain and inflammation, constipation, diabetes, high blood pressure [8], obesity and cancer [14, 21].

Phytochemical analysis of *P. afra*

As previously mentioned, that medicinal plants possess phytochemical compounds that are deemed useful in the well-being of humans. A few studies have documented the presence of different groups of these bioactive compounds in *P. afra*. De Wet *et al.* (2013) [14] had identified the presence of anthraquinones, flavonoids, tannins and saponins in *P. afra* leaves. A preliminary phytochemical screening of the methanol extracts obtained from the leaves of *P. afra* by Khanyile *et al.* (2021) [6], revealed the presence of alkaloids, saponins, tannins and glycosides. Olaokun *et al.* (2017) [13] performed a quantitative phytochemical analysis on the acetone leaf extracts of *P. afra* along with two other species, *Curtisia dentata* and *Pittosporum viridiflorum*, and discovered that the total phenolic and total flavonoid contents of the *P. afra* extracts exhibited the second highest content of the selected species with concentrations of 63.06 ± 1.67 mg/g and 22.16 ± 6.41 mg/g respectively. These results positively reflect the medicinal potential of *P. afra*, however, more detailed qualitative and quantitative analysis needs to be conducted on other compounds using different and advanced techniques such as high performance liquid chromatography (HPLC), liquid chromatography-mass spectrophotometry (LC-MS) and gas chromatography-mass spectrophotometry (GC-MS) to identify and isolate bioactive compounds. Furthermore, another suggestion would be to perform such analyses using a variety of solvents, and also look into whole plant analysis to achieve a full phytochemical profile of the species.

Pharmacological evidence of *P. afra*

Since *P. afra* is considered a medicinal plant, it is important to explore the pharmacological potential of the plant and to assess whether it has such potential, because people use it to treat a variety of ailments. To our knowledge, the only available evidence on the pharmacological activity of *P. afra* has been reported by Olaokun *et al.* (2017) [13] and Khanyile *et al.* (2021) [6].

Antioxidant activity

In the study by Olaokun *et al.* (2017) [13], three plant species, namely *C. dentata*, *P. viridiflorum* and *P. afra* were assessed for their antioxidant activity against 2, 2-diphenyl-1-picrylhydrazyl (DPPH) radical using acetone leaf extracts. The results showed that, of the three species, *P. afra* exhibited the weakest DPPH scavenging activity with an IC_{50} value of 32.05 ± 3.89 µg/ml compared to *C. dentata* (27.69 ± 4.98 µg/ml) and *P. viridiflorum* (20.31 ± 2.60 µg/ml). Khanyile *et al.* (2021) tested the methanol leaf extracts of *P. afra* against the DPPH and 2, 2'-azino-bis-3-ethylbenzothiazoline-6-sulfonic acid (ABTS) radicals. The results showed that *P. afra* displayed IC_{50} values of 0.26 mg/ml and 0.25 mg/ml respectively.

Antibacterial activity

Khanyile *et al.* (2021) [6] evaluated the potential of methanolic leaf extracts of *P. afra* against gram-positive *Staphylococcus aureus* and gram-negative *Pseudomonas aeruginosa* using the micro-dilution technique. The extracts demonstrated MIC values of 6.25 mg/ml and 12.5 mg/ml respectively. The results show that the methanol leaf extracts of *P. afra* are more effective on the gram-positive *S. aureus* than the gram-negative *P. aeruginosa.*

Anti-quorum sensing activity

Quorum sensing is term used to describe the production and subsequent release of chemical signalling molecules that increase the concentration of bacteria as a function of cell density [22]. The anti-quorum sensing activity of *P. afra* methanolic leaf extract against violacein production, a purple pigment caused by *Chromobacterium violaceum* was evaluated by Khanyile *et al.* (2021) [6]. The leaf extract showed a highly active anti-quorum sensing effect of 93% at a concentration of 12.5 mg/ml and a moderate activity of 65% at a concentration of 0.2 mg/ml, which indicates that *P. afra* methanol leaf extracts have an exceptional anti-quorum sensing activity.

Cytotoxicity

Khanyile *et al.* (2021) [6] also assessed the cytotoxicity of *P. afra* methanol leaf extracts against human hepatocellular carcinoma (HepG2) cells at various concentrations. Results showed the highest viability (120%) at 500 µg/ml, which then returned to 100% at 2500 µg/ml. Overall, the extracts exhibited an IC_{50} value of 4010 µg/ml. These results showed that the *P. afra* leaf extract is only safe to use up to 2500 µg/ml, but it also indicates high toxicity at high concentrations.

It is clear that the previously discussed studies indicate the medicinal potential of *P. afra*, however, there is still much to be done since the pharmacological evidence of the species has, to date, been demonstrated on the leaves. There needs to be an extensive evaluation of the whole plant parts of this species and further expand other pharmacological properties such as inflammation and diabetes in order to fully document the medicinal properties of the species for its potential applications in the pharmaceutical industry.

Carbon fixation and ecosystem restoration potential of *P. afra*

Portulacaria afra has been identified as a facultative CAM species [9], which is described as an environmentally triggered optional CAM that is able to undergo daytime CO_2 uptake, traditional C_3 photosynthesis but utilizes the CAM pathway during water stress [9, 23]. *P. afra* was shown to have nocturnal CO_2 uptake and a large acid fluctuation when water stressed (Guralnick and Gladsky 2017) [9]. Guralnick *et al.* (1984 a, b) [24, 25] later discovered that CAM response is seasonal and is relative to long day photoperiods, showing more CAM activity during summer.

Mills *et al.* (2005) [19] reported that using *P. afra* at the Krompoort and Andries Vosloo Kudu Nature Reserves for the restoration of the two thickets in the Eastern Cape Province could be beneficial because *P. afra* propagates vegetatively in nature [11, 19]. The authors further stated that restoration using *P. afra* is most likely to reduce soil erosion, increase biodiversity, enhance tourism, increase wildlife carrying capacity and provides substantial browsing for livestock [10]. Van der Vyver *et al.* (2013) [13] reported that *P. afra* is an "ecosystem engineer" due to its ability to create, maintain or modify habitats resulting in physical changes in abiotic and biotic materials within an ecosystem [13, 26]. They also explained that because of the species' rapid growth under semi-arid conditions, its use to rehabilitate ecosystems produces carbon-rich microclimates [13, 27-29].

Conclusions and recommendations

Portulacaria afra is an evergreen succulent plant known for its uses in the treatment of dermatitis, inflammation, colds and obesity. This plant species has been thoroughly investigated for its ability to absorb carbon dioxide and its uses in ecosystem rehabilitation, however, to date, there is insufficient literature on the phytochemical profile and the pharmacological properties of the whole plant plants. Although there have been documented reports on the phytochemistry and pharmacological properties of *P. afra*, the extent of the research on the aforementioned sections is limited, since only leaves have been analyzed and even the research on the leaves is not sufficient enough. Therefore, it is recommended that an extensive phytochemical analysis that include qualitative and quantitative research be conducted on the whole plant parts such as leaves, stems, flowers and roots, in order to fully understand the phytochemical profile of the plant. To date, only antioxidant, antibacterial, anti-quorum and cytotoxic assays have been performed on the leaf extracts of *P. afra*. More pharmacological research needs to be conducted by expanding the antioxidant assays (hydrogen peroxide, metal chelating, beta carotene, ferric reducing antioxidant power etc.), antimicrobial analysis (increasing bacterial assays and introducing fungal and viral assays), as well as introducing anti-diabetic, anti-inflammatory and anti-platelet aggregation assays. Studies on the stems and roots are highly encouraged as well as evaluating multiple solvents to provide a much broader view on the phytochemical profile of the species.

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