Managing the Invasive Alien Plant *Parthenium hysterophorus* in South Africa

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Parthenium hysterophorus is an annual plant of the Asteraceae family, originating from Central and South America. It has invaded southern and eastern Africa, Asia and Australia, causing substantial economic losses in many countries. In South Africa, this invasive alien plant is commonly referred to as parthenium, Demoina weed, Maria-Maria and more recently named 'famine weed' and 'Umbulalazwe', due to the damaging impacts that accompany its rampant spread. Infestations of parthenium can severely impact on agricultural production, by reducing available grazing and crop yields (e.g. yield losses of between 40% and 90% reported in crops such as sorghum), as well as affecting biodiversity conservation in protected areas. Human and animal health is affected as regular exposure to parthenium causes severe respiratory (asthma and hayfever) and skin (contact dermatitis) allergic reactions in many individuals. The meat and milk of animals that ingest parthenium, is tainted.

In South Africa, parthenium has invaded particularly KwaZulu-Natal and Mpumalanga, as well as North-West and Limpopo provinces, and continues to spread. Dense and extensive infestations occur along roadsides and watercourses, and in grazing, cultivated, fallow and conservation land, and protected areas for the conservation of biodiversity. . Some rural homesteads are entirely surrounded by parthenium, with associated health risks through frequent exposure and contact with the plant. Seed dispersal occurs by means of water, vehicles, machinery (agricultural, road construction and maintenance), animals, seed lots, and stock feed.

Up to 25 000 seeds per plant have been recorded, mostly viable, and if buried a few centimetres below the soil surface can survive for at least six years. Local studies revealed considerable annual variability within the parthenium seed bank in the soil, with up to 95 000 parthenium seeds per m^2 recorded on occasion at some sites. Parthenium has also widely invaded Swaziland, as well as parts of Mozambique, Zimbabwe, Tanzania, Kenya, Uganda, Eritrea, Egypt and particularly Ethiopia, where it is a severe problem and impacts on the livelihood of millions of people by reducing grazing and arable land. Predictive modelling has shown that most of sub-Saharan Africa is climatically suitable for the growth of parthenium and at risk of invasion by this plant.

Poor land management practices such as incorrect stocking densities, leading to overgrazing, exacerbate the spread of parthenium, as it readily invades bare, disturbed soil. The production of allelochemicals assist parthenium to outcompete native vegetation, resulting in the formation of monospecific stands. Certain grass species such as *Panicum maximum* can outcompete parthenium when grazers are excluded. Reducing animal stocking densities to improve grass cover can prevent or alleviate parthenium infestations, and such management methods have been effectively used in Australia. However, the modification of stocking densities in systems in Africa where high cultural value is placed on cattle and where unfenced, communal grazing is commonly practiced, is challenging.

Several effective herbicides are registered for the control of parthenium, but chemical control requires repeated follow up treatments which may be beyond the economic means of some landowners or may be impractical in regions where infestations are very extensive. Handweeding, a widely used weed management practice in Africa, carries associated serious health risks through regular exposure and contact with parthenium, and is often not conducted sufficiently early, prior to seed set, to be effective. Biological control, using selected natural enemies (insects, mites and/or pathogens) introduced from the plant's native range, is a cost-effective, long-term, sustainable management option. It aims to reduce (not eradicate) parthenium to levels at which it becomes less problematic in the environment, to the extent where, ideally, either other control measures are not required, or where they are required at lower levels. After selection of the most suitable natural enemies in the native range, and importation of the candidate biological control agents into quarantine facilities in the introduced country, rigorous research assesses their host range to ensure that they are host specific and will only have an impact on the target invasive alien plant, and will not have a detrimental effect on any indigenous and economically important plant species. Biological control of invasive plants has been practiced for more than 100 years in South Africa, with some outstanding successes where no other control options have been required, and other species with significant success but where other control options are still required although to a lesser degree. The track-record throughout this period is clean, with no unpredicted shifts of agents onto any other unintended plant species.

In Australia, the extent and density of parthenium has been considerably decreased since the 1980's, using a combination of natural enemies (seven insect agents and two rust fungi) imported from the native range of parthenium in the Americas. Farmers in Queensland State nowadays consider parthenium far less of a problem than previously. A suite of natural enemies, affecting different parts of the plant, is required to adequately suppress parthenium under the various conditions that it invades. In 2003, a research programme on the biological control of parthenium in South Africa was initiated by the ARC-PPRI, funded by the Working for Water Programme.

Larval feeding by *Listronotus setosipennis* inside *Parthenium hysterophorus* stems

The summer rust fungus *Puccinia xanthii var. parthenii-hysterophorae*

The results of the Australian biocontrol programme were relied upon during the selection of potentially suitable biocontrol agents for importation and assessment for their suitability for local conditions. The winter rust fungus *P. abrupta* var. *parthenii-cola* (Pucciniales: Pucciniaceae), was already present in South Africa and was probably introduced with the plant at an earlier stage. To date, the summer rust fungus *Puccinia xanthii* var. *parthenii-hysterophorae* (Pucciniales: Pucciniaceae), the leaf-feeding beetle *Zygogramma bicolorata* (Coleoptera: Chrysomelidae), the seed-feeding weevil (*Smicronyx lutulentus* (Coleoptera: Curculionidae), all originating from Mexico but imported from Australia at various times, and the stem-boring weevil *Listronotus setosipennis* (Coleoptera: Curculionidae) from Argentina, were assessed in the ARC-PPRI quarantine facilities (Cedara and Stellenbosch). Applications for permission to release them in South Africa were approved by the Department of Agriculture, Forestry and Fisheries at various stages since 2010 onwards.

The biocontrol agents target different parts of parthenium: *Z. bicolorata* feed on leaves and under suitable conditions can completely defoliate plants; *L. setosipennis* larvae tunnel inside parthenium stems, structurally damaging the plant; severe infection levels of *P. xanthii* stunt plants; and *S. lutulentus* larvae feed within seeds, reducing the plant's reproductive vigour. Biocontrol agents are mass-reared by ARC-PPRI and released in conjunction with the Department of Environmental Affairs Natural Resrouces Management Programme's biological control implementation in each province, into selected sites within the invaded range in South Africa, particularly in northern KZN and eastern Mpumalanga where parthenium is most extensive. Large numbers of the leaf-feeding beetle, stem-boring weevil and summer rust fungus have been released at about 200 sites and continue to be released, with establishment confirmed at some sites, to varying degrees. Agent performance is variable; they establish and are effective under different conditions. Recent drought conditions in parts of the country appear to be hampering agent establishment.

Additional challenges include the need for secure sites, where mechanical and chemical clearing efforts will not be undertaken for some years, to enable the biocontrol agents to establish, build up population numbers and spread. Efforts are underway to increase the production of agents for release by establishing additional mass-rearing facilities, particularly in the regions that are severely invaded by parthenium. Additional agents are also under consideration; the stem-galling moth *Epiblema strenuana* (Lepidoptera: Tortricidae) has also been investigated, with further research required to elucidate its field host range, and most recently, the sesiid moth *Carmenta Ithaca* (Lepidoptera: Sesiidae) with larvae that tunnel in the root crown of parthenium, from Mexico, was imported from Australia and is currently under assessment in ARC-PPRI quarantine facilities for its suitability for release in South Africa.

Parthenium infestation in the Ndumo Game Reserve

The stem-boring weevil *Listronotus setosipennis* in its mature state

Few invasive plants can boast such broad-reaching detrimental impacts on agriculture, biodiversity conservation, as well as human and animal health, as parthenium, and increased concern due its rapid, recent spread resulted in a call for national, coordinated management interventions. To this end, a national strategy and national implementation plan were compiled for the Department of Environmental Affairs' Natural Resources Management Programme in 2014, for the management of parthenium in South Africa. Using differential zoning of affected and unaffected areas of the country, the strategy and plan outline various goals, recommend structures, and identify stakeholder responsibilities for management efforts including chemical and biological control methods, to increase awareness, facilitate the use of best management practices, and coordinate management activities.

Efforts to facilitate the biological control of parthenium further north in Africa (Ethiopia and Tanzania) have been undertaken in collaboration with international partners (the USAID-funded Integrated Pest Management Innovation Lab and CABI Africa). ARC-PPRI provided advice on quarantine facility establishment and biological control research, and starter cultures of parthenium agents. Wider management efforts on the continent are required to halt the spread of parthenium, which, if left unchecked, will continue to have a devastating impact on the livelihoods of subsistence farmers in particular. Biological control has been demonstrated to play a crucial role in the long-term, cost-effective integrated management of parthenium weed in Australia, and expectations are that it should prove to be equally effective to assist in managing the invasion of this weed in South Africa and, where implemented, further north on the continent.

Financial support, particularly by the Department of Environmental Affairs Natural Resources Management Programme, is gratefully acknowledged. Staff of the ARC-PPRI are thanked for their research and technical inputs.

Defoliation of *Parthenium hysterophorus* by *Zygogramma bicolorata*

The adult leaf-feeding beetle, *Zygogramma bicolorata*