2017-03-31

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Journal of Biodiversity and Environmental Sciences (JBES)

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 10, No. 3, p. 204-217, 2017
http://www.innspub.net

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REVIEW PAPER OPEN ACCESS

Invasive plants: ecological effects, status, management challenges in Tanzania and the way forward

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Article published on March 31, 2017

Key words: Competition, Allelopathy, Weeds, IPM, Mowing

Abstract

Over decades invasive plants have been exerting negative pressure on native vascular plant's and hence devastating the stability and productivity of the receiving ecosystem. These effects are usually irreversible if appropriate strategies cannot be taken immediately after invasion, resulting in high cost of managing them both in rangelands and farmlands. With time, these non-edible plant species will result in a decreased grazing or browsing area and can lead to local extinction of native plants and animals due to decreased food availability. Management of invasive weeds has been challenging over years as a result of increasingly failure of chemical control as a method due to evolution of resistant weeds, higher cost of using chemical herbicide and their effects on the environment. While traditional methods such as timely uprooting and cutting presents an alternative for sustainable invasive weeds management they have been associated with promotion of germination of undesired weeds due to soil disturbance. The fact that chemical and traditional methods for invasive weed management are increasing failing nature based invasive plants management approaches such as competitive facilitation of the native plants and the use of other plant species with allelopathic effects can be an alternative management approach. Recently, new weed control mechanisms such as biological control and Integrated Pest Management (IPM) have been recommended to complement both the traditional and chemical control methods for improved performance. Plant-plant competition and allelopathy therefore, as natural plant life phenomenon presents an opportunity for successful invasive weeds management.

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Introduction

Ecological invasions are one of the major threats to most ecosystems (Sheil, 2001). An invasive species both spreads in space and has negative effects on local species (Alpert *et al.*, 2000; Vasquez *et al.*, 2008). Dispersal of invasive plants has been associated with an increased human population and movement patterns (Koutika *et al.,* 2011). Invasive plants have been reported to have impacts on various ecosystem properties such as native plant and animal species diversity and abundance as well as soil nutrients (Weidenhamer *et al.,* 2010). These effects are usually irreversible if appropriate strategies cannot be taken immediately after invasion (Weidenhamer *et al.,* 2010; Biware *et al.,* 2013). While the awareness has increased on the effects of both native and exotic invasive species (Gordon, 1998; Hansen and Muller, 2009), there has also been an increasing response by countries in adopting national legislation relevant to the prevention and/or control of invasive alien species (Mc Geoch *et al.,* 2010). It is through this awareness that this subject was included in the Convention on Biological Diversity (CBD), a multilateral treaty of 196 parties with the main goals of conserving biodiversity, sustainable use of its components and fair and equitable sharing of benefits arising from genetic resources. Under Article 8(h), parties of the Convention agree to "prevent the introduction of, eradicate or control those species which threaten species, habitats or ecosystems" (CBD, 1992).

Management of invasive weeds has been challenging over years as a result of increasingly failure of chemical control as a method (O'rourke *et al.*, 2009), due to evolution of resistant weeds (Holt and Lebaron, 1990), higher cost of using chemical herbicide and their effects on the environment (MG van der Werf, 1996). Moreover the application of chemical herbicides to some areas for instance in protected areas (PRs) is challenging due to their unpredictable effects on native plants and environment (Kimmins, 1975; Poorter, 2007; Kughur, 2012). While traditional methods such as timely uprooting and cutting presents an alternative for sustainable invasive weeds management they have been associated with promotion of germination of undesired weeds (Calado *et al.*, 2013) due to soil disturbance. They are also ineffective due to higher costs involved (Pers. comm.) and thus proving to be unsustainable especially in the face of decline in global economy.

The fact that chemical and traditional methods for invasive weed management are increasing failing (O'rourke *et al.*, 2009; Calado *et al.*, 2013) nature based invasive plants management approaches such as competitive facilitation of the native plants to outcompete the invasives and the use of other plant species with allelopathic effects can be an alternative management approach.

Mechanism of plant invasion

Invasion process of exotic invasive plants comprises of three stages; introduction from a donor region, establishment in the recipient region and range expansion in the recipient region (Ehrlich, 1986; Simberloff, 2013). However, the invasion of native invasive species has mainly been looked at from an expansion stage following favorable conditions. It has for instance been approximated that across oceans, through vessels alone, more than 3000 species may be introduced in recipient regions per day from a donor region (Carlton, 1996). Although most of invasive species introductions are linked to human activities, some invaders cross barriers and establish in new regions without the help of humans (Ehrlich, 1986). According to Williamson and Fitter (1996), only about 0.1% of all plant species introduced outside their native ranges by humans have actually become invasive. The success of an invasive species can be linked to factors such as low intensities of competition, altered disturbance regimes and low levels of environmental stress, especially high resource availability (Alpert *et al.,* 2000).

Effects of invasive plants on ecosystem

Ecological processes at an ecosystem level normally influence plant and animal productivity that ultimately affects the whole ecosystem functioning.

These processes are always linked to the identity of a plant, and or animal forming the community (Naeem *et al.,* 1999). Several studies have attempted to address the effects of invasive species on ecosystem processes (Levine *et al.,* 2003; Dukes and Mooney, 2004). Invasive plants threaten ecosystems due to their ability to change plant community composition by suppressing the abundance of indigenous species (Vasquez *et al.,* 2008). This suppression often results into local extinction of some native keystone species and a formation of monocultures, which are responsible for further extinction of native plants (Martina and Von Ende, 2008; Cal-IPC, 2016). Local extinction of a particular keystone species normally impacts ecosystem functioning and services (Mills *et al.,* 1993). Invasion of exotic *Prosopis* spp in the Kalahari Desert for instance, has been associated with increased mortality of a keystone tree species, *Acacia erioloba*. This has further affected bird and insect richness and composition (Shackleton *et al.,* 2015), with the net effect of impaired ecosystem functioning i.e. pollination and dispersal reduction. Likewise, costs generated by plant invasions on ecosystem processes and functions relates to impacts on ecosystem services. Ecosystem services are the benefits provided to humans by natural ecosystems (Charles and Dukes, 2008). An exotic invasive, the Neem tree (*Azadirachta indica*) for instance, has been reported to reduce diversity and abundance of small mammals in savannas and riverline vegetations, has been reported in Saadani National Park (Tanzania) and is likely a threat to native species (Silayo and Kiwango, 2010), which eventually reduce income from eco-tourism in Saadani. Moreover, exotic *Eucalyptus* spp plantations have been reported to affect both ground and surface water availability (Bilal *et al.,* 2014), resulting in reduced water availability for both, household and irrigation. Any modification caused by exotic invasive plants to the plant community, therefore, can impair ecosystems in various ways. Unfortunately, losses of ecosystem processes, functions and services caused by invasive species are often overlooked.

Invasive plants and the savanna rangelands

A savanna rangeland is an ecosystem characterized by continuous grass vegetation and scattered trees or shrubs (McPherson, 1997). Savannas are reported to occupy nearly a third of the earth's land surface (McPherson, 1997), therefore representing an important resource for the management and conservation of biodiversity. Savannas provide grazing areas to many grazer species (Mott and Groves, 1994) due to their abundance of palatable grasses and shrubs, thus, representing important niches that support a large number of animals including predators. Due to increased grazing pressure, which contributes to removal of possible native weed competitors, most of the savannas have undergone changes in pasture composition by invasive weeds, which are mostly not palatable to grazers (Winter, 1991). Invasive weeds in the savanna ecosystem have been associated with altering the fire regime, increasing grazing pressure on remaining native grasses, competing with native vegetation and occupying previously vacant ecological niches (Scanlan, 1998). This can significantly alter the structure, composition and functioning of savannas in the long run. The net effect of shifts in native palatable plant composition by unpalatable weeds will, therefore, seriously affect both livestock and wildlife biomass in savanna systems.

The status of invasive plants in tanzania

Tanzania lacks a comprehensive documentation on the status of exotic invasive plants currently present. Little work has been done to document the status and effects of invasive plants in Tanzanian protected areas (Elisante *et al.,* 2014; Namkeleja *et al.,* 2014) and most research has focused at woody exotic invasives plants in some selected rangelands (Foxcroft *et al.,* 2006; Obiri, 2011; NCAA, 2011), mainly because of their structural importance. Major invasive plants that have been reported to affect most Tanzanian rangelands include woody plants; *Prosopis juriflora, Acacia mearsiii, Caesalpinia decapetala, Eucalyptus camaldulensis, Lonicera japonica, Psidium guajava, Senna spectabilis, Acacia farnesiana, Acacia polyacantha* (Obiri, 2011) shrubs; *Argemone mexicana, Tagetes minuta, Datura stramonium, Gutenbergia cordifolia, Lantana camara, Bidens schimperi, Opuntia monocantha,* *Opuntia stricta* (Mattay and Lotter, 2005; Foxcroft *et al.,* 2006). Aquatic invasive plants include; *Eichhornia crassipes, Typha latifolia, Ceratophylum dermesum, Rapa natas, Brasenia sp, Cyperus spp, Justicia spp, Pistia spp* (Ndunguru *et al.,* 2001; Guerena *et al.,* 2015). So far, little is known about invasive herbaceous species, and there is no adequate literature on this plant functional group and its effect on the ecosystems of Tanzania.

Invasive species management legislations and policies in tanzania

Although Tanzania has a rich number of legislations that address various issues on biodiversity conservation and management, currently there is no legislation and/or policy that specifically address exotic invasive species. The National Environmental Act 2004 (NEMA), which is the main act pertaining to environmental protection, has to some extent managed to address the issue of management and control of invasive plants, particularly exotic invasives. For instance, sections 1 (a-b) and 2 (a-c) of this act although not directly mentioning invasive species, has strongly recommended an Environmental Impact Assessment (EIA) for projects that are likely to affect ecosystem functioning. Section 12 (f), further insists of the undertaking of EIA for projects in order to protect the productivity, capacity, ecological processes and their maintenance in natural systems. The first schedule (A; page 28) highlights projects that require mandatory EIA, among which are those that require introduction of new/foreign species in agriculture, range management, forestry, fisheries and wildlife. Likewise both the Wildlife Conservation Act 2009 (Section 35 (3) (b)) and Forest Act 2002 (section 18(2) (c)) insists on undertaking of an environmental impact assessment prior to construction of either road or pipelines in protected areas as these might have negative impacts to native plants including introduction and spread of invasive plants. The main weakness of most Tanzania' biodiversity protection acts regarding invasive species control is that they do not directly mention aspects like procedures for import of foreign species and penalties to be undertaken should there be an unlawful import of exotic invasive species.

This shortfall may be responsible for the inadequate attention being given to the management of invasive species and the increasingly introduction and spread of invasive species.

The Status of Invasive Plants in the Ngorongoro Conservation Area (NCA)

The Ngorongoro Conservation Area, together with the Serengeti, Lake Manyara and the Masai Mara National Parks forms an ecologically and economically important area and hosts a vast variety of larger mammalian species. However, invasive plants, both native and exotic, have been identified as among the main known threats to the biological diversity of these areas (NCAA, 2011; Elisante and Ndakidemi, 2014; Namkeleja *et al.,* 2014). In and around NCA alone, for instance, a total of 139 exotic invasive plants have been reported, including *Acacia mearnsii, Datura stramonium, Lantana camara, Leucaena leucocephala, Lonicera japonica, Tagetes minuta* (Plate 1) etc., (NCAA, 2011). Fortunately, the majorities of these species are still at low numbers and have not reached a level where control is necessary, although for some, eradication might already have become impossible (Mattay and Lotter, 2005). Some indigenous invasive plants have also been reported, among them two weedy species *Bidens schimperi* and *Gutenbergia cordifolia* (Plate 1), the latter covering approximately 75% of the crater floor (Mattay and Lotter, 2005). As most of these plant species are not palatable, they pose a risk of reducing native plant biomass and, hence, reducing pasture availability for ungulates, which form a large portion of animals in the crater. This might affect herbivore biomass in the long run.

Plate 1. Invasion of *T. minuta* (with yellow flowers) and *G. cordifolia* (brownish and dry) in the Ngorongoro crater (source: Field survey).

Invasive Weed Management Approaches

Since as early as 19th century, weed management in both farmlands and rangelands have been mainly through chemical herbicides (Bell, 2015). Chemical control of weeds has become a normal practice, which has been associated with a consecutive evolution of resistant weeds and, hence, further proliferated the problem of weed control (Holt and Lebaron, 1990). Weed resistance to chemical herbicides is becoming a serious and increasingly challenging issue as fueled by heavy reliance on chemical herbicides. Although chemicals still manage most weeds other management strategies needs to be adopted to reduce the increasingly weed resistance.

Traditional control methods of weeds have been reported to include mechanical uprooting, cultivation and burning (FAO, 1982; Altieri and Liebman, 1988). Prior to late 1800's only mechanical control of weeds was used in agriculture (Bell, 2015) but for over a decade now, new weed control mechanisms such as biological control and Integrated Pest Management (IPM) have been recommended to complement the traditional control methods for improved performance (Altieri, 1994). Among the goals of biological control of weeds are to improve ecosystems by using living organisms and to manage target weedy plants to lesser competitive intensities so that they do not stress native plant communities or cause damage to livestock (Quimby *et al.,* 1991). According to Quimby *et al.* (1991), as a biological control, livestock's differential grazing habits, preferences and selectiveness for instance, allows them to exert selective grazing pressure on palatable problematic weeds which might result into effective control while earning income. In PRs, maintenance of biodiversity through ecological friendly methods is crucial and, hence, this IPM might represent an important sustainable weed control tool. In IPM, re-introduction of ecological processes with which species evolved and elimination of processes detrimental to native species has to be ensured (Esparza and McPherson, 2009).

In the NCA the management of invasive plants has mainly been mechanical removal.

In 2000, the first NCA control programme started through mechanical uprooting and cutting invasive plant species at the base (NCAA, 2011). Later in 2001, mowing followed by burning was introduced as a mechanism to facilitate the removal of the indigenous invasive weeds *Bidens schimperi* and *Gutenbergia cordifolia,* accompanied by some trial plots to monitor its effectiveness. Since then, a programme is in place, in which mowing followed by burning or vice versa has been practiced (NCAA, 2011). However, evidence from trial plots suggested that this approach may not be the most effective control mechanism. Chemical and biological control for invasive plants that pose the biggest threat to NCA have also been suggested, which include the use of 1 % Tordon super (Picloram 120g/l and Triclopyr 240g/l), 100ml Tordon super in 9.9 liters of diesel (NCAA, 2011). Further, biological control suggestions include using seed feeders like *Melanterius maculates* to control *Acacia mearnsii* (NCAA, 2011). Unfortunately, environmentally friendly and nature based approaches for weed control such as plant-plant competition and allelopathy have not yet been tried in NCA.

Invasive weed management challenges

Weed chemical control method has proven to fail both in its final efficiency and economically (O'rourke *et al.,* 2009). Further, chemical herbicides are mostly expensive and can have tremendous negative effects on the environment (HMG van der Welf, 1996), especially when applied to protected rangelands (PRs). Likewise, mechanical control of invasive plants is costly and time intensive (NCAA, 2011). Further, any soil disturbance that arise from mechanical control promotes germination of undesired weed (Calado *et al.,* 2013) while desired indigenous species may be mistakenly destroyed. The most imminent shortfall of mechanical control of weeds is that, most invasive seeds remains in the soil, hence, posing a risk of future invasions (Pers. obs.). One of the major challenge over biological control of weeds have been a rising concern on the potential damage to both threatened and endangered native forage plants closely related to a targeted weedy plant (Turner, 1985 in Quimby *et al.,* 1991).

Although to date there is no known intentional introduction of weed biological control agent that has caused harm to any known endangered plant (Quimby *et al.,* 1991), the potential is imminent (Turner, 1985 in Quimby *et al.,* 1991). Therefore, care must be observed to introduce biological agents that will provide the greatest benefit with the least risk of harming the receiving community.

Selected focal invasive plant species of the Ngorongoro Crater

Tagetes minuta (Mexican marigold)

The genus *Tagetes* of the family Asteraceae comprises of 56 species that include popular annual plants known as marigolds (Soule, 1993a). Of the 56 species, 29 and 27 are perennials and annuals respectively (Soule, 1993a). While 6 of the 27 annual *Tagetes* are currently cultivated, only 3 of the 29 perennial *Tagetes* are currently cultivated as horticultural crops (Soule, 1993a). Most of *Tagetes* are native to Mexico (Soule, 1993b; Hulina, 2008) and are cultivated throughout the world as ornamentals, medicinal and as ritual plants (Nutall, 1920). While *Tagetes erecta* L., *Tagetes patula* L., *Tagetes lunulata* Ort. and *Tagetes tenuifolia* Cav are four annual *Tagetes* that are commonly cultivated throughout the world as ornamentals (Soule, 1996), *Tagetes filifolia* Lag. and *Tagetes minuta* L. are annuals currently used for essential oil extraction (Lawrence, 1985). These plants are to be used with care as most of them contain strong scented secondary compounds that might have unpredicted effects to ecosystems. Unfortunately, the abundant yet to be utilized as horticultural crops (21 and 26 annual and perennial *Tagetes* respectively) if not well managed could escape and become problematic weeds.

Tagetes minuta has escaped cultivation in most nations and is considered a noxious weed in parts of southern Africa (Wells *et al.,* 1986) and recently reported as among problematic weeds that have invaded the Ngorongoro Conservation Area (NCAA, 2011). Its seeds produce some chemicals which are used for defense against herbivores and possess hooks that ensure its dispersal (Martinez-Ghersa *et al.,* 2000).

This species has been introduced into various areas to the extent that it became a weed in most rangelands and farmlands of Tanzania (USAID, 2012). According to Meissner *et al.* (1986), *T. minuta* roots exudates contain a polyacetylene derivative (thiophene) which delays germination and reduces the yield of crops grown in soil previously infested with the species. Thiophene compounds (Fig. 1) have extensive use in both pharmaceuticals and agro-chemicals (Swanston, 2006). They have been proven to kill root knot nematodes (Winoto-Suatmadji, 1969) and hence can possibly affect the growth and development of leguminous pastures that are crucial for improving soil nitrogen. This not only pose a risk of reduced pasture to Ngorongoro crater's herbivores as the weed suppress native pastures but also affect soil available Nitrogen (Ngondya *et al.,* 2016 under review).

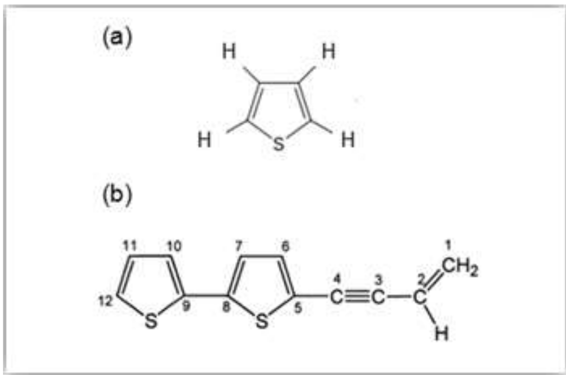

Fig. 1. (a) Chemical structure of thiophene ring (b) Chemical structure of 5-(3-buten-1-ynuyl)-2, 20-bithiophene (BBT, 1) common in *Tagetes* species (Margl *et al.*, 2001).

Gutenbergia cordifolia

Gutenbergia cordifolia is an annual plant of the family Asteraceae native to Africa. Its leaves and flowers are allergenic and toxic to animals as they contain a chemical sesquiterpene lactone (Zdero and Bohlmann, 1990; Bussmann *et al.,* 2006) (Fig. 2). According to Amorim *et al.* (2013), the sesquiterpene lactone alters the microbial composition of the rumen and thereby affects its overall metabolic functioning. *Gutenbergia cordifolia* has been used extensively for medicinal purposes (Koch *et al.,* 2005; Ngezahayo *et al.,* 2015), which has led to introduction to various areas to the extent that it might become a weed in most rangelands. In East Africa for instance, particularly in Kenya, the plant has already been reported as an invasive weed in most farmlands (Anderson and Morales, 2005; Gharabadiyan *et al.,* 2012). In Tanzania, the plant is invading and dominating large areas in Ngorongoro Conservation Area (NCA). Recently, the species seems to have invaded and dominated more than half of the entire crater floor (250 km^2) (UNESCO, 2001).

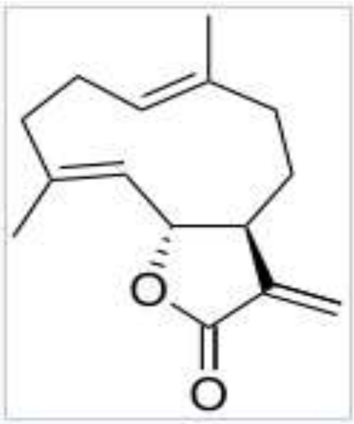

Fig. 2. Chemical structure of costunolide a prototypical sesquiterpene lactone (germacranolides) (Fraga, 1988).

The way forward-allelopathy and plant-plant competition for weed control

The use of plant species, particularly those with allelopathic effects, has recently been emphasized as an effective method to suppress invasive weeds (Makoi and Ndakidemi, 2012). Interestingly, plant species like *Desmodium uncinatum* and *Desmodium intortum* have been used to successfully control most weeds in farmlands due to their allelopathic nature and, hence, were able to increase crop yield (Khan *et al*., 2006; Khanh *et al*., 2007; Khan *et al*., 2008; Makoi and Ndakidemi, 2012). Moreover, plant-plant competition, being among the factors that shape the plant community, allows for the use of strong competitors that are also palatable to animals as an approach for weeds management (Tilman *et al*., 1999; Rey Benayas *et al*., 2007; Makoi and Ndakidemi, 2012; Goss and Wheeler, 2017).

Allelopathic effects of crop plants on weeds

Weed-crops interactions have been observed over a long time in agroecosystems. It was observed by Peters (1968), that fields of Kentucky-31 fescue (*Festuca arundinaceae* Schreb.) were oftenly free of weeds *Brassica nigra* (L.) Koch and *Lotus corniculatus*. With extracts and culture experiments it was later demonstrated that fescue produced toxic materials that inhibited the growth of the two weeds. In 1971, Dzubenko and Petrenko reported that root excretions of *Lupinus albus* L. and of Maize (*Zea mays*) inhibited growth of weeds; *Chenopodium album* and *Amaranthus retroflexus*. It was further reported by Prutenskaya (1974) that wheat (*Triticum durum* Desf.), rye and barley strongly inhibits the growth of weedy *Sinapis arvensi* L. Recently, *Desmodium* species as intercrops in maize and sorghum have been reported to successfully inhibit the growth of a noxious weed *Striga hermonthica* (Khan *et al.,* 2008).

Possible use of allelopathy as biological control for weeds

The possible use of allelopathy as a natural phenomenon for the control of noxious weeds is increasingly promising (Ndakidemi and Dakora, 2003; Makoi and Patrick, 2011). Putnam and Duke (1974), after screening 526 and 12 accessions of cucumber (*Cumis sativus*) and eight related *Cucumis* species respectively concluded that inducing an allelopathic character into a crop cultivar can improve its competitive advantage over certain noxiuos weeds. Similarly, Fay and Duke (1977) concluded after screening some accessions of *Avena* species that weedy Wild mustard (Brassica kaber (DC) L.C. Wheeler var. Pinnatifida (Stokes) L.C. Wheeler) grown in close association with the toxic accession exhibited severe chlosis, were stunted and twisting as a result of allelopathy reather than competition. Robson (1977) further suggested that allelopathy could be used as an excellent means of biological control of water weeds. Unfortunately, to-date little have been done on the application of extracts from allelopathic plants to control such problematic weeds as *T. minuta* and *G. cordifolia* despite of few available promising studies on genetic study of allelopathic agents (Panchuk and Prutenskaya, 1973; Grodzinsky and Panchuk, 1974).

Allelopathic effects of Desmodium species on noxious weeds

Plants of the genus *Desmodium* (Leguminosae) have long been used in traditional Chinese medicine due to their rich possession of phytochemicals (Ma *et al.,* 2011). According to Ma *et al.* (2011), a total of 212 compounds have been isolated from fifteen *Desmodium* species (including *Desmodium uncinatum*), which were characterized mainly as flavonoids (81) and alkaloids (40). The main flavonoids contained in *Desmodium* plants are: flavones, 7, 8 prenyl-lactone flavonoids, flavonols, flavan-3-ols and flavanonols whereas isoflavonoids include isoflavones, isoflavanones, pterocacarpans and coumaronochromone (Ma *et al.,* 2011).

Root exudates of *D. uncinatum* have been reported to contain flavonoids, some of which promotes *Striga hermonthica* (African witch-weed) germination while others inhibit seedling development including radical growth (Khan *et al.,* 2008). *Desmodium* species have also been used to control *S. hermonthica* successfully as intercrops in both maize and sorghum. According to Khan *et al.,* (2008), *Desmodium* based intercropping represents a practical example of allelopathy at work as more than 10,000 small-scale farmers in Eastern Africa have adopted its use. This, therefore, opens a door for further studies on the use of *Desmodium* species, particularly *D. uncinatum* and *D. intortum*, as potential bio-herbicides in controlling other problematic weeds such as *T. minuta* and *G. cordifolia*.

Plant-Plant competition for weed control

Competition has received a lot of attention in ecological research (Connell and Slatyer, 1977; Keddy, 1989; Goldberg and Barton, 1992) and was found to directly affect the local distribution of plants in a community (Stoll and Prati, 2001). Plant-Plant competition has well been demonstrated in a range of ecosystems; most vividly in ecosystems where native plants have been exposed to several stresses, for instance water shortage, soil nutrient deprivation and ecological invasion (Daehler, 2003). The most competitive plant always dominates the ecosystem and hence, poses a risk for local extinction of some associated flora and fauna.

As a low-cost, low impact management technique, plant-plant competition has been reported to be effective in restoration projects, for instance in restoration of *Quercus coccifera* oak forests where competition had a strong impact on oak recruitment (Rey Benayas *et al.,* 2007). Similarly Goss and Wheeler (2017) recommended on the use of most competitive varieties of barley and wheat as an integral part of the integrated weed management strategies and should be considered when planning for weed management. Tilman *et al.* (1999) further insisted that adjustments in resource supply rates is likely to determine the outcome of interspecific competition thereby allowing desired species to competitively manage weedy species. Therefore, identification and facilitation of the most competitive native plants that can out compete invasive weeds might present an opportunity for the development of management strategies for some problematic weeds such as *Tagetes minuta* and *Gutenbergia cordifolia*.

Conclusion

An invasive plant both exotic and native jeopardizes the sustainability of both farmlands and rangelands. Although in farmlands the use of chemical herbicides has advanced, in most rangelands it is still not recommended as a first option but rather an alternative. This highlights for the need of developing management strategies that are environmentally friendly. Allelopathy and plant-plant competition presents an opportunity to achieve this. Meanwhile as the spread of invasive plants has been associated with an increased human population and movement patterns, efforts to achieve invasive weeds free farmlands and rangelands for sustainable farmland/rangelands management has to be prioritized. To achieve this, new areas of research can be pioneered which may include but not limited to:

i. Researching on and developing pro-active measures to ensure no new introduction of invasive weeds to farmlands/protected rangelands.
ii. Modelling of possible future spread of the invasive weeds including *T. minuta and G. cordifolia* to new areas to prepare for future management actions.
iii. Detailed field assessment and monitoring to identify the most likely invasion hotspots so that weed reduction activities can be concentrated on these areas.
iv. Adoption of legislations and policies that address issues pertaining to export, import and handling of invasive plants, particularly exotic invasive plants, to prevent future introductions and spread.

Competing interests

The Authors declare that they have no competing of interests

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