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Review

Status of parthenium weed (*Parthenium hysterophorus* L.) and its control options in Ethiopia

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Parthenium (*Parthenium hysterophorus* L.) is an invasive herbaceous weed which belongs to the family Compositae. It is believed to have originated in tropical America and now occurs widely in Asia, Australia, Southern and east Africa. Parthenium has been observed to grow on road sides, gardens, waterways, in grasslands and crop fields both during the crop season and after harvest, as long as enough moisture is available. In Ethiopia it is believed to have been introduced in the 1970s and currently covering almost all parts of the country causing up to 97% yield reduction in crop fields and 100% reduction in forage crops. The weed has become a problem for range, forest and crop lands. It grows in any soil type and in a wide range of habitats and is also known to affect animal and human health. It causes loss of bio diversity and presently it was recorded as an invasive alien weed species in Ethiopia. Suggested control measures include hand pulling, mowing and the use of herbicides. Hand pulling and mowing, however, have limited value because of the enormous amount of labor required and the sensitivity of humans to allergens produced by the weed. If herbicides are used, multiple applications are necessary. As well, appropriate herbicides are not available in all areas where the weed is a problem. Small-scale farmers may not be able to invest in management options for parthenium especially for pasture, fallow, wasteland, grazing land and road sides. Biological control using insect pests and plant pathogens in an integrated parthenium management system is one solution but not well reviewed.

Key words: *Parthenium hysterophorus,* epidemiological factors, small scale farmers, pathogens.

INTRODUCTION

Parthenium (*Parthenium hysterophorus* L.) is an invasive herbaceous weed that is believed to have originated in the tropical Americas. It now occurs widely throughout Asia, Australia Southern and east Africa. Parthenium is an annual procumbent leafy herb, 0.5 to 2.5 m tall, bearing alternate, pinnate leaves.

It belongs to the family Compositae. Parthenium has been observed to grow on roadsides, in gardens, along waterways, in grasslands and crop fields, both during the crop season and after harvest, as long as enough moisture is available. Major ecological and morphological characteristics that contribute to its severe invasiveness

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are its adaptability to wide climatic and soil conditions, its production of allelopathic chemicals and its ability to produce large numbers of seeds (10,000 - 25,000 per plant). Seeds are small (1 - 2 mm diameter) and light in weight (50 µg/seed) and can be transported long distance by wind, water and other means (Navie et al., 1996).

There is no solid evidence that indicates how and when it was introduced into Ethiopia. It was first reported in 1988 at Dire Dawa, in Eastern Ethiopia (Seifu, 1990). Possibly, it was introduced into Ethiopia through the wheat seeds donated for relief and/or during the Ethio-Somali war of 1976/1977 (Tamado and Milberg, 2000). At present, it is found profusely distributed in all parts of the country. Thus, its management is of a high concern to the government, researchers and farmers (Taye et al., 2004; Mohammed, 2010).

So far, research attention has focused on its occurrence as a weed on range lands and waste sites (Navie et al., 1996). However, parthenium can cause severe crop losses. In India, a yield reduction of 40% in agricultural crops and a 90% reduction in forage production in grasslands were reported (Khosla and Sobti, 1981). Similarly in eastern Ethiopia, it was reported that sorghum grain yield was reduced between 40 and 97% due to this weed in different seasons (Tamado et al., 2002). Parthenium was reported to replace native grass species and cause dermatitis, bloating and diarrhea on livestock (Dhileepan et al., 1997). These authors also reported that milk, meat and honey obtained from parthenium-infested areas are bitter and not tasteful and they also suggested individuals hand weeding or hoeing in parthenium-infested crops suffer from skin allergy, itching, fever and asthma.

Parthenium is a major new agricultural weed in Ethiopia (Tamado et al., 2002; Taye et al., 2004; Mohammed, 2010). Presently, the major maize, sorghum, tef, coffee, spice and wheat growing regions in Ethiopia, for example, are being infested by parthenium weed. Tadele (2002), Wakjira et al. (2005) and Wakjira (2009) studied the allelopathic effect of parthenium weed in Ethiopia on tef, lettuce and onion, respectively. It was found that this weed has a significant effect on germination capacity and seedling growth of these crops.

This in turn has a significant yield reduction effect on these economically important crops. Thus, the spread of parthenium in Ethiopia would be a bigger risk to the expansion and sustainable production of many crops in the country which can potentially interfere with the food self-sufficiency and food security program envisioned (Wakjira, 2009). Although there are several methods to control parthenium, each has its own limitations. For instance, removing by slashing or mowing results in regeneration of new shoots that entail repeated operation. Manual and mechanical uprooting also prove to be of limited value owing to enormous amounts of labor and time required and the vulnerability of workers to various kinds of allergies.

Chemical control, though effective, is temporary and needs repeated application. Biological control is the best alternative, because it is economically feasible, ecologically sound and socially acceptable. It also minimizes cost of crop production (Evans, 1997a). Use of host specific and indigenous biological control agents including insects and pathogens is recommended but this needs further research. One of the pathogens that cause rust on parthenium in Ethiopia was identified as *Puccinia abrupta* var. *partheniicola* (Taye et al., 2004) which is a macrocyclic and autoecious pathogen. It was found infecting leaves, stems, and floral parts of parthenium in cool and humid areas. Symptoms on the plant were chlorosis, twisting of leaf, necrosis, reduction in vegetative growth and seed production (Taye et al., 2004; Bekeko et al., 2012). So far in Ethiopia there is no compressive information regarding the status and its control options on parthenium weed. Therefore, the objective of this review was to give first hand information for scientists and farmers on this noxious weed for further interventions to be made in managing parthenium weed.

IMPACTS OF PARTHENIUM WEED

The impact of parthenium weed on agriculture is summarized by Gupta and Sharma (1977), Khosla and Sobti (1981), Parsons and Cuthbertson (1992), McFadyen (1992), Evans (1997a), Tamado et al. (2002), Wakjira et al. (2005), Wakjira (2009), Mohammed (2010) and Timsina et al. (2011). These authors described that this weed can affect crop production, animal production, human health, and biodiversity in its area of infestation. Hence, parthenium has a wide range and potentially lethal impact on man's affair.

Effects on crop production

In India, Khosla and Sobti (1981) reported 40% sorghum yield reduction due to parthenium. Channappagoudar et al. (1990) also reported that the presence of parthenium in irrigated sorghum in India reduced grain yields from 6.47 to 4.25 tons/ha (34.3%) and decreased grain weight by 30%. In Ethiopia, Tamado et al. (2002) reported 40 to 97% sorghum yield reduction in eastern Ethiopia owing to this weed at different locations and in different seasons.

Other than direct competition for nutrients, water and sunlight, allelopathic effects of parthenium on other plants is another important biological characteristic for the success and its aggressiveness as a weed. In many studies, water soluble phenolics (caffeic acid, ferulic acid, vanillic acid, anisic acid, and fumaric acid) and sesquiterpene lactones, mainly parthenin, have been reported from the roots, stems, leaves, inflorescence, achens (seeds) and pollen of parthenium (Kanchan and Jayachandra, 1980).

Effect on animal production

Evans (1997a) indicated that the impact of parthenium on livestock production is directly as well as indirectly by affecting grazing land, animal health, milk and meat quality, and marketing of pasture seeds and grain. The occurrence of parthenium weed in grasslands was observed to reduce the forage production besides making the land less fertile. In India, the weed has reduced the pasture carrying capacity by up to 90% (Nath, 1988). McFadyen (1992) reported the loss of AU $ 16 million form the beef industry owing to the impact of this weed on beef cattle in Australia.

Effect on human health

Parthenium is also known to cause human health problems like asthma, bronchitis, dermatitis, and hay fever (Fauzi, 2009). It is reported that continued close contact with parthenium can develop allergic eczematous contact dermatitis (AECD) while inhalation of pollen can cause allergenic rhinitis which can develop into bronchitis or asthma if the pollen enters the respiratory tract during mouth breathing (Evans, 1997a).

Effect on biodiversity

Parthenium is also an environmental weed which can cause irreversible habitat changes in native grasslands, wood lands, river banks and flood plains in India, Australia and Nepal (McFadyen, 1992; Evans, 1997a; Timsina et al., 2011). Huge stand of parthenium is common in almost all open areas. Parthenium, due to its allelopathic potential, replaces dominant flora and suppresses natural vegetation in a wide range of habitats and thus becomes a big threat to biodiversity.

Due to changes in above-ground vegetation cover and below-ground soil nutrient contents, *P. hysterophorus* invasion is likely to have an overall negative effect on the functioning of the entire ecosystem. Therefore, management of noxious *P. hysterophorus* is necessary to prevent future problems (Timsina et al., 2011).

CONTROL OF PARTHENIUM

Biological control

The biological control of weeds involves the use of some suitable living organisms to curb their population to acceptable limits. This approach was first examined in 1902 in Hawaii, USA (Agrios, 2005). The biological weed control method should not be expected to criminate the target weed from an area; in fact success of biological control of weed depends upon continued presence of the weed existing in small numbers and shifting with time (Gupta, 2002).

Selection of the bio-control agent will therefore be made based on host specificity, adjustability to the new environmental condition, rapid destroyer of the target weed, ease of multiplication and effectiveness on several taxa of the weed in question. No matter how the initial cost of biological control appears to be high, but in comparison to the cost of developing new herbicide it is quiet reasonable (Gupta, 2002). Therefore, biological control appeared to offer the best, long-term solution for the management of parthenium.

Biological control of parthenium was first proposed in India in 1970 and a brief survey of insects attacking it was made in West Indies. But, no further work was undertaken until the Queensland Department of Lands (QDL), now National Resources Institute (NRI), made preliminary surveys of the weed in South America in 1975 (McFadyen, 1992).

The pathogen *(P. abrupta* var*. partheniicola)*

The pathogen that causes rust on parthenium in Ethiopia was identified as *P. abrupta* Diet*.* and Holw*.* var. *partheniicola* (Jackson) Parmelee 1967 (Taye et al., 2004); it was found infecting leaves, stems and floral parts of parthenium plants in cool and humid areas of Ethiopia. Symptoms revealed on the plant were chlorosis, necrosis, and reduction in vegetative growth, and seed production. Host specificity of *P. abrupta* on related crops and weed species showed that its sporulation was observed only on parthenium.

The rust (*P. abrupta* var. *partheniicola*) is autoecious and macro cyclic (Evans, 1987a). Studies conducted by Parker et al. (1994) and Fauzi (2009) indicated that this pathogen is host specific and completes its life cycle on *P. hysterophorus* and the closely related *Parthenium conferatum* though minor symptoms such as chlorosis and necrosis were observed without sporulation on some sunflower cultivars. In Ethiopia, it was introduced possibly together with parthenium from Kenya and/or Somalia (Taye et al., 2004) for the presence of *P. abrupta* was reported in Kenya in 1977 (Evans, 1997a).

This pathogen has a life cycle of 14 days and its symptom starts to be seen in between 8 and 12 days after inoculation (Evans, 1997a). Evans (1987a) stated that *P. abrupta* reduces both the vegetative growth of young plants and the seed production of older plants in some semi-arid, high-altitude localities (1400 - 1600 m). In these habitats, the rust was found to produce both uredinia and telia in abundance on the leaves, stems and inflorescence. However, in the more humid, low land and coastal situations, infection was generally light and only scattered uredinia occurred on the older rosette leaves (Evans, 1987a).

Parker et al. (1994) made a detail study on *P. abrupta* and worked out its pathogenecity to determine the most virulent isolate, optimum conditions for infection, effect of repeated inoculation on host vigor, and host specificity

against 120 plant species and varieties. They found out that no single isolate was consistently more virulent than others by comparing 1 Kenyan and 5 Mexican isolates although the isolate collected from Saltillo produced the most vigorous infection at high night temperatures (>20°C).

Assessment of inoculation conditions showed that the temperature less than 20°C and dew periods of more than 6 h were required for abundant pustule production. Infection with the rust hastened leaf senescence significantly decreased the life span and dry weight of parthenium plants, and reduced flower production 10-fold.

Different studies conducted by Bekeko et al. (2012), Taye et al. (2004) and Fauzi (2009) showed the rust has a significant effect in suppressing parthenium weed. However, isolates collected form different locations had a significant difference in reducing the morphological parameters of parthenium and its seed producing capacity at different locations and in different seasons.

Pathogenecity of the rust

Because parasites must infect hosts for their survival and parasite infection limits host fitness, pathogenecity in parasites and resistance in hosts are targets of selection. Plants resists disease through a variety of performed and induced barriers to infection (Agrios, 2005) and pathogens use virulence factors to overcome plant defenses and make infection possible.

Much progress has been made in the studies of fungal pathogens at molecular genetics of virulence pathosystem. And this concept is very helpful in the researches of biological control of plant diseases and invasive weed species (McDonald and Linde, 2002). Using the rust (*P. abrupta* var. *partheniicola)*, its pathogenecity was studied on parthenium weed and it was found that the infectivity of this pathogen is highly governed by leaf wetness, age of the plant, inoculum density and types of the isolates (Parker et al., 1994; Fauzi, 2009; Bekeko et al., 2012).

Epidemiology of the rust

Knowledge of epidemiological features of plant diseases provides useful information for understanding the biology of their causal agents, and is the basis for the establishment, planning and monitoring of effective disease management strategies (Jeger, 2004). The first and more common approach to the epidemiological study of an epidemic is the analysis of its temporal dynamics through the description and interpretation of the disease progress curve (DPC).

DPC measures the change with time in the amount of diseases in the population of host plants, and may be considered as the epidemic "Signature" in the sense that it integrates all host, pathogen and environmental factors occurring during the epidemic (Campbell and Madden, 1990), which determine the final amount of disease.

In the biological control research, the pattern of the pathogen movement, sources of inoculum, direction of inoculum movement, the amount of initial inoculum and its rate of movement dictates the efficacy of the bio-agent (Savary, 2006) and pathogens which have fast generation cycle and which are poly cyclic have a profound effect on the target pest.

MATHEMATICAL TOOLS USED IN RUST DISEASE EPIDEMIOLOGY

Plant disease epidemics are investigated according to variables of interest which are formulated as a function of external factors, for instance temperature and rain. The natures of the problem and epidemiologists specific questions determine the mathematical tool to be used for modeling plant disease epidemics (Kranz and Royle, 1978). In the study of polycyclic disease epidemics, disease progress curve, logistic regression, logistic and Gompertz models are used as a mathematical tools (McDonald and McDermott, 1993; Xu et al., 2006). In addition, geostatistical analysis can also be used in polycyclic diseases like rust to determine spatial dependence of epidemics between neighboring plots or fields and in dictating patterns of epidemic dynamics at different distances and directions from foci (Fernando and Zhang, 2004).

Disease progress curve

Disease progress curve shows the epidemic dynamics over time (Agrios, 2005). This mathematical tool can be used to obtain information about the appearance and amount of inoculum, changes in host susceptibility, during growing period, weather events of cultural and control measures (Xu et al., 2006).

Logistic model

It was proposed firstly by Veshult in 1838 to represent human population growth. A second type of logistic model was proposed by Van der Plank (1963), being more appropriate for most polycyclic diseases, meaning that there is secondary spread within a growing season (Forrest, 2007). This growth model is most widely used for describing epidemics of plant diseases.

Gompertz model

This growth model is appropriate for polycyclic diseases

as an alternative to logistic models. Gompertz model has an absolute rate curve that reaches a maximum more quickly and declines more gradually than the logistic models (Forrest, 2007). On general, growth models that incorporate few variables to describe disease dynamics have a good performance, however, this kinds of models sometimes do not satisfy the acquiring characteristics because they frequently ignore relevant variables that affect the epidemic development (Xu et al., 2006) e.g. host growth, fluctuating environmental conditions, length of latent, infection period, etc.

Logistic regression model

The logistic regression model is proved to be more sensitive than classical growth function models to detect significant differences in parameters such as the rate of incidence increase in fields or the initial amount of disease and to detect differences associated to explanatory variables such as the ecological area (Bergua et al., 2008).

Hau and Mersha (2008) used logistic regression, logistic and Gompertz models to study the effect of bean rust on host dynamics of common bean in controlled greenhouse experiments. In addition, Fininsa (2001) has studied the epidemiology of maize rust (*Puccinia sorghi*) and common bean rust (*Uromyces appendiculatus*) using logistic regression, logistic and Gompertz models and in Savary (2006), it was shown that polycyclic diseases are more studied by using logistic and Gompertz models.

Similarly in studying the association of barley leaf rust (*Puccinia hordei*) with different production systems in Ethiopia, Woldeab et al. (2007) also used logistic regression model to determine the prevalence, incidence and severity of leaf rust on barley. In the same manner, Tamire et al. (2007) used logistic regression model to study the association of White rot (*Sclerotium cepivorm*) of garlic with environmental factors and cultural practices in the North Shewa, highlands of Ethiopia. But so far, the association of the rust (*P. abrupta var. partheniicola*) epidemics with land use systems, cropping practices and various environmental conditions was not studied using logistic regression model in Ethiopia and elsewhere in the world.

MOLECULAR APPROACHES IN WINTER RUST PATHOGEN CHARACTERIZATION

Molecular markers have been replacing or complimenting traditional morphological and agronomic characterization since they are virtually unlimited, cover the whole genome not influenced by the environment, and less time consuming. Each molecular marker has its advantages and drawbacks. Therefore, application of molecular marker techniques to diversity of questions must take into account weather or not the data derived from technique provide the right information for answering the question being addressed (McDonald and McDermott, 1993). In the last two decades, DNA marker technologies have revolutionized the plant pathogen genomic analysis and have been extensively employed in many fields of molecular plant pathology. Molecular markers offer also the possibility of faster and accurate identification and early detection and characterization of plant pathogens (Setti et al., 2011).

Among other important applications of these technologies which are increasingly developed as resourceful tools for quickly and sometimes cheaply assessing diverse aspects of plant pathogen genomes. These include genetic variation characterization, genome finger printing, gene mapping and tagging, genome evolution analysis, population genetic diversity, taxonomy and phylogeny of plant pathogen taxa. Ever since the introduction of both the DNA polymerase and the primer sequences (Mullis and Faloona, 1987), the use of PCR in research laboratories has increased tremendously. One of the PCR based DNA polymerase techniques is random amplified polymorphic DNA (RAPD).

Random amplified polymorphic DNA (RAPD)

RAPD is the first PCR based marker developed simultaneously by Williams (1987) and Welsh and McClelland (1990). These markers have been used to amplify the template DNA without prior knowledge of the sequence fragment. These techniques also relay on the use of short identical pairs of primers generally of 5 to 15 bp in length commonly used in the characterization of obligate parasites like rusts (McDonald and McDermott, 1993). The main advantage of RAPDs is that they require no prior knowledge of the genome as the same primers can be used to any organism. On the other hand, the technique is easy and quick to assay, hence a very large number of markers can be screened in very short period. Further as this technique is PCR based, it is very sensitive and very small quantities of DNA are needed, which is about 5 to 50 ng per reaction (Williams et al., 1993).

The amount and distribution of genetic variation within and among populations constitutes the first step in the studies of fungal population genetics (Setti et al., 2011). Genetic variation in plant pathogen populations is shaped by sexual recombination, mutation resulting in new genetic variants, migration of genetically distinct individuals between and within crop production regions, genetic drift and extinction events, and agricultural practices that have selective effects on their associated pathogens (Kolmer and Ordoñez, 2007).

Park et al. (2000) studied population structure of *Puccinia recondita* in Western Europe and assessed the variability in pathogenecity of the pathogen using RAPD molecular markers. Similarly, in yellow rust of wheat

population study, McDonald and Linde (2002) have used RAPD markers to assess population diversity of *Puccinia striiforims* f.sp. *tritici* populations sampled on local scale in USA and Australia. Péros et al. (2006) has also used the RAPD markers to assess the genetic structure of *Erysiphe nector*, collected from different regions in south France where the most variation occurred among the individuals within population, although variation between regions was highly significant.

Onfory et al. (1999) also used the RAPDs to investigate genetic structure within and among natural populations of *Mycosphaerella pinodes* in France where a significant genetic variation within and among regions were observed. Thus, application of molecular markers in plant pathology has hastened the knowledge of plant disease studies at molecular level in the genomic marker era (Setti et al., 2011).

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests

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