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A Review on the Distribution, Biology and Management Practices of Parthenium Weed, (Parthenium hysterophorus L.) in Ethiopia

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1. INTRODUCTION

Parthenium weed, *Parthenium hysterophorus* L. (Asteraceae;Heliantheae), is an annual or short-lived perennial herbaceous plant that native to Mexico, Central and South America. Parthenium hysterophorus was accidentally introduced into several countries including Australia, India, Taiwan and Ethiopia. Young plants form a basal rosette of strongly dissected leaves that are up to 30cm in length. Once stem elongation is initiated, smaller leaves are produced and the plant becomes much branched in its extremities. In some areas it has become an extremely serious agricultural and rangeland weed (Adkinsa and Shabbir, 2014).

It invades disturbed sites, degrades natural ecosystems, can cause serious allergic reactions in people and domesticated livestock, and is a significant problem in rangelands, crops and forestry. It is a major invasive weed in many parts of the world, with the potential to spread to many more regions, and it causes immeasurable ecological and agricultural losses each year. It is the major invasive weed both in arable and grazing lands in Ethiopia (Taye *et al*., 2005). It is an annual diffused leafy herb that germinates any time of the year growing rapidly. It has been classified under the family Compositae, tribe Helianthae and sub tribe Ambrosiinae.

In Ethiopia, it was first observed, around Dire Dawa area in 1980s (Fessehaie1 *et al.,* 2005) and it was first reported from Ethiopia in 1988 at Dire-Dawa and Harerge, eastern Ethiopia (Seifu, 1990). Since then it has spread to several parts of the country in alarming proportion, through vehicular traffic, wind, water and urban waste. From non-agricultural areas, it has now entered into agricultural fields (Fessehaie1 *et al.,* 2005). The objectives of the review were to present the distribution, biology, management practices and problems of Parthenium in Ethiopia.

2. BIOLOGY OF PARTHENIUM WEED

2.1. Biology

Parthenium hysterophorus is an annual herb, erect, up to 2 m in height; the stem is branched and covered with trichomes. Leaves are pale green, lobed, hairy, initially forming a basal rosette of strongly dissected leaves that are up to 30 cm in length, close to the soil, alternate, sessile, irregularly dissected and bipinnate, having small hairs on both the sides, resembling the leaves of carrot. The number of leaves per plant ranges from 6 to 55. Flower heads are creamy white, about 4 mm across, arising from the leaf forks. Flowering occurs about a month after germination. The fruit is cypsella. Each flower contains five seeds, which are wedge-shaped, black, 2 mm long with thin white scales. A large single plant produces up to 100,000 seeds in its lifecycle which are small in size (1-2 mm diameter) and light in weight (50 g g) to travel long distances through wind, water and other means (K.V. Sankaran *et al.,* year not stated). More than 340 million seeds per ha can be present in the surface soil. Seeds do not have a dormancy period and are capable of germinating anytime when moisture is available. The highest germination rates are at temperatures ranging from 12 °C to 27 °C. The root system has one main branched taproot and many finer roots (FAO, 2002).

2.1.1. Habit

Parthenium grows luxuriantly in wastelands, public lawns, orchards, forestlands, flood plains, agricultural areas, urban areas, overgrazed pastures, industrial areas, playgrounds, roadsides, railway tracks and residential plots. Drought and subsequent reduced pasture cover, creates the ideal situation for the parthenium weed to establish itself. Although parthenium weed is capable of growing in most soil types, it is most dominant in alkaline, clay loam soils (Kaur *et al.,* 2006; Tefera, 2002).

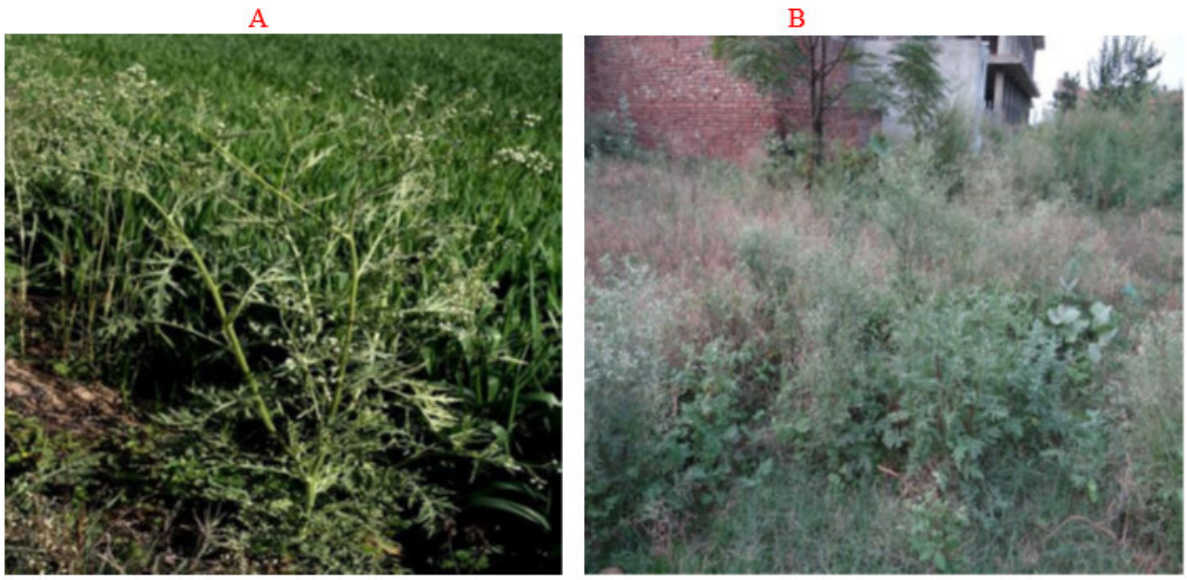

Figure 1: Area of infestation of parthenium; (A) Crop field infestation; (B) Residential plot (Kaur et al., 2006).

2.1.2. Reproduction and Dispersal

Parthenium hysterophorus reproduces by large numbers of seed: 10 - 25, 000 per mature plant (Navie *et al.,* 1996). These seeds are dispersed by wind, water, animals, vehicles, tools and machinery and on clothing. They are sometimes also spread in mud and contaminated agricultural produce (e.g. fodder and food grains). The seeds are mainly dispersed through water currents, animals and the movement of vehicles, machinery, livestock, grain, stock feed and other produce, and to a lesser extent by the wind. Most of the long distance spread is through vehicles, farm machinery and flooding (Weller and Ashton, 2001).

2.1.3. Germination Ecology

Germination ecology of *Parthenium hysterophorus*, recently introduced to Ethiopia, was studied in a series of experiments. Viability of the seeds was greater than 50% after 26 months of burial in the soil indicating the potential build-up of a substantial persistent soil seed bank. A short period of dry storage was sufficient to overcome a light requirement for germination in a minor fraction of the seeds. Likewise, seeds exhumed from burial showed an increase in germination ability in darkness over time, with a weak tendency for seasonal cyclicity in dormancy level at one of two sites. Germination occurred at the mean minimum (10°C) and maximum (25°C) temperatures of the collection sites, as well as over a wide range of fluctuating (12/2°C-35/25°C) temperatures in light. No germination of *P. hysterophorus* seeds occurred at osmotic potentials < -0.52 MPa (at 27°C), the species being less tolerant to moisture stress than sorghum grains. Most seedlings emerged from shallowly buried (< 0.5 cm) seeds and none from more than 5 cm depth (Tamado *et al.,* 2002).

Naturally dispersed seeds required about 60 days, at a hot lowland site, to start emergence despite the presence of adequate rainfall, and higher number of seedlings emerged in undisturbed plots than in hand hoed plots. These experiments and field observations suggest that there are no obvious climatic conditions that may limit the germination of *Parthenium hysterophorus* in Ethiopia, but a high moisture requirement of the seeds for germination could be the major factor limiting germination during the dry season (Tamado *et al.,* 2002).

3. DISTRIBUTION

The weed has now invaded more than 20 countries around the globe, including five continents and numerous islands. Recent developments have indicated that African countries are at high risk of invasion. It is now also present in eight provinces of China and spreading at an alarming rate (Aneja, 1999).

In Ethiopia, parthenium weed is believed to have been introduced in the 1980's (Berhanu, 1992) and currently is covering almost all parts of the country causing up to 97 % yield reductions in certain field crops and 100 % reductions in certain forage crops. The weed has become a problem within rangelands, forest regions and cropping lands. Parthenium has spread throughout Ethiopia after its noticeable occurrence in Dire Dawa in 1980s. It is found in varying dimensions on waste-lands, along roadsides, railway tracks, cultivated fields, residential areas, industrial areas and other fallow lands as well as abandoned fields. Now it has achieved a status of a 'worst weed' in the country owing to its adverse effects on man and animals. Parthenium has several built-in properties and efficient behavioral mechanisms, which enable this plant to overcome many ecological adversities and thus continue to survive under stress. Hence, in the absence of any effort, Parthenium may be able to survive for comparatively a period longer than what is hither to record with other species (Fessehaie1 *et al.,* 2005).

Currently the weed is spreading at an incredible pace and is heavily infesting most agricultural areas, range land and wasteland in the affected regions. This is partly attributed to the high reproductive and dissemination potential of the weed. It seems also that the unsightly expansion and prolific growth on non-arable land permit the weed to colonize large expanses. However, its problem persists in poorly managed fields, broad spaced crops, in plantations, and grasslands. The problem is more serious in non-crop areas, neglected fields, along fence lines, irrigation or drainage ditches and wastelands (Fessehaie1 *et al.,* 2005).

Parthenium is currently spreading at an alarming rate in Ethiopia. When and how it is introduced into the country is a matter of speculation. The species is introduced into Ethiopia: Either through the Djibouti - Dire Dawa railway line or the Dire Dawa Air Port around 1980 (Mesfin, 1991). According to Parker (1989) the occurrence of the weed was observed for the first time around Dire Dawa, Harer and Meiso. Occurrence of the weed in south Welo starting from the air - strip in Kombolcha and settlement sites down to Jijiga (Frew *et. al.,* 1996) strengthen the view that the seeds of this species are brought into Ethiopia via the various food aid programs (Mesfin, 1991 ; Medhin, 1992).

Parthenium is now widely spread in eastern Ethiopia; the central rift valley and neighboring localities of Afar Region, East Shewa, Arsi and Bale in southern Ethiopia. It is gradually creeping to areas closer to Addis Ababa, Western part of Ethiopia; some districts in west Shewa, south, north, and central Tigray; north Gojam and south Gonder; north and south Welo of northern part of Ethiopia. The weed is also spreading in series of small to large jumps to the southern regions of the country, notably areas around Awasa, Jimma and Gambella **(**Fessehaie1 *et. al.,* 2005). Worku, (2002) reported that Parthenium has become the major weed of market areas, road sides, and arable, grazing and waste lands of Sheka area, particularly the Yeki Woreda with prevalence of 23.1%.

4. MENACE

Parthenium is a major new agricultural weed in Ethiopia. It is spreading rapidly and having substantial impact in arable land, pasture and grazing land. The occurrence of the weed in grasslands is reported to reduce forage production up to 90% besides making land less fertile; affecting grazing land, animal health, and milk and meat quality. Medical and veterinary effects are just starting to come to light in some localities of the country. Parthenium has become an increasingly serious problem in major crops in eastern part of Ethiopia in addition to being a major problem on range and waste lands. Previous reports indicated that although the prevalence and distribution of the weed was extremely high, the infestation is minimal in arable land. Even then, several hectares of agricultural and rangeland in eastern part of Harerege were infested by this pernicious weed (Frew *et al.,* 1996).

The weed is known to affect animal and human health. It causes loss of biodiversity and therefore it has been recorded as an invasive alien weed species in Ethiopia (Wakjira *et al.,* 2009). Parthenium an obnoxious weed, is of growing concern in Ethiopia. This weed affects the rural poor most, and because of its ability to cause allergenic reaction has potential implications for the urban poor as well (Fessehaie1 *et al.,* 2005).

The common allergens found in this weed are parthenin, cornopilin, tetraneurin and ambrosin. Pollens of parthenium cause asthma (allergic bronchitis) especially in children playing outdoors and in adults and old age persons. Contact of plant with the body causes dermatitis and the spread of the problem all over the body causes great discomfort (Kaur *et al.,* 2006).

Figure 2: Four of the five types of symptoms of commonly known parthenium dermatitis; (A, B) Air Borne Contact Dermatitis; (C) Chronic Actinic Dermatitis in a female; (Kaur et al., 2006).

5. MANAGEMENT PRACTICE

In spite of the recognized importance of Parthenium in the country, almost no control alternative measures are available. Manual labor is the only control practice used by farmers to manage the weed in agricultural areas. As the weed causes contact dermatitis, asthma and fever to human being, hand weeding is not advisable. Besides, hand weeding is costly, as it requires frequent operations owing to the emergence pattern of the weed. Hoeing can also be used but repeated operations are needed as long as weed seeds existed in the soil. Some studies in India have shown that repeated cultivation is less effective than control by chemicals. Furthermore, chemical could offer a valuable option to economical control this troublesome weed (Fessehaie1 *et al.,* 2005).

While some measures of control is adopted by farmers in farmlands, the problem in wastelands and in public places like parks, roadsides and railway tracks where it is most serious is not tackled by anybody. In these areas the control has to be attempted on a community basis by local administration involving schoolchildren, public, NGOs etc. To be effective it has to be done on regular basis until it is eradicated. This has not been done currently **(**Fessehaie1 *et al.,* 2005). The pollens, air borne dried plant parts and roots of parthenium cause various allergies like contact dermatitis, hay fever, asthma and bronchitis in human beings.

The management of weeds has resulted in great dilemma to many countries. On the one hand, there is a higher risk of exotic weed introduction due to interactions with other global changes such as increasing globalization of markets, explosive rises in global trade, travel, tourism, and exchange of goods. On the other hand, many countries are attempting to reduce the reliance on herbicides for weed management, for economic, environmental, health and sustainability reasons (Taye, 2007).

5.1. Cultural Practices

5.1.1. Deep Ploughing

In infested crop areas deep ploughing during the land preparation can reduce the stand of parthenium weed. The seeds are not able to germinate in soil below a depth of 5cm (Tamado *et al*., 2002).

5.1.2. Smother Crop

Use of cowpea as smother crop reduced parthenium biomass, but the reduction was only substantial when combined with hoeing. Variation in efficacy by the smother crop could be attributed to the interference of the heavy infestation of parthenium with the establishment of cowpea, especially at Dire Dawa. Abdin *et al.,* (2000), investigating the effect of inter-seeded cover crops on weed control in short-season corn (*Zea mays* L.), also reported a similar result and suggested the control of weeds before seeding cover crops to get better cover crop establishment. The major mechanism of parthenium biomass reduction by the smother cowpea could be through competition for light by shading because the weed is reported to be sensitive to shading (Tamado 2002; Williams and Groves, 1980). Although growing cowpea as the smother crop reduced parthenium biomass, there was no associated increase of sorghum grain and stalk yields. On the contrary, it substantially reduced grain yield compared with the weed-free control this indicates that both the cowpea used as a smother crop and the parthenium it replaced interfered with sorghum.

The possible reason for such a depressive effect of cowpea on sorghum grain and stalk yields could be that the soil moisture was too low to meet the combined demand of both the cowpea and the sorghum. Moisture limitations have previously been shown to make weed control through intercrops less efficient in improving yields (Ayeni *et al*., 1984). In contrast, under sub-humid high-rainfall conditions in Nigeria, Zuofa and Tariah (1991) reported increased income and reduced cost of weed control in corn from cowpea grown as a smother crop.

5.2. Hand Hoeing

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 labour required and the sensitivityof people to allergens contained within the weed. Manual uprooting of parthenium before flowering and seed setting is most effective method. Uprooting the weed after seed setting will increase the area of infestation. Some landholders have achieved success in ploughing the parthenium weed in the rosette stage before it seeds, but this must be followed up by sowing a crop or direct seeding the perennial pasture. Physical control involves hand weeding, a time consuming and unpleasant job, made worse by the health hazards involved with handling parthenium weed (Kaur *et al.,* 2006). Tamado and Milberg (2004) reported that hand hoeing at least twice gave good control of parthenium and satisfactory sorghum yields**.**

Manual control of parthenium by farmers resulted in some of them developing skin allergies, itching, fever, and asthma. Disability Adjusted Life Years measured the social cost of parthenium in Ethiopia and its equivalence in terms of monetary value estimated at 2,535,887 - 4,365,057 USD. More resources have to be invested to tackle the IAS problem, as the estimated loss is disproportionate to the cost of investment on IAS research and development activities (Taye *et al.,* 2005).

5.3. Chemical Control

Kaur *et al.*, (2006) reported that in India, the most effective treatments for parthenium weed control were glyphosate and metribuzin, having higher mortality at 4 weeks after treatment (WAT) at both rosette and bolted stages than 2, 4-D, triasulfuron+terbutryn, bromoxynil+MCPA and atrazine+s-metolachlor, atrazine, s-metolachlor. Pendimethalin was the least effective treatment for both growth stages. Overall, the efficacy of herbicides was promising on rosette parthenium plants than bolted plants. The mortality rate by different herbicides at rosette and bolted stage is given in. In open wasteland, noncropped areas and along railway tracks and roadsides, the spraying of a solution of common salt (Sodium chloride) at 15- 20% concentration has been found to be effective(Kaur *et al.,* 2006).

According to Tamado and Milberg (2004), 2,4-D (dimethylamine salt) applied 6 wk (eight-leaf stage) after emergence of sorghum (1,440 g ai/ha, applied with a knapsack sprayer calibrated to deliver a spray volume of 200 L/ha). The outcome of the 2, 4-D treatment varied from total control at Babile in 2000 to relatively poor control at Dire Dawa in 2000. There are a number of herbicides registered to control parthenium, but for the smallholder farmers of eastern Ethiopia, where the average farm size is 0.65 ha, use of herbicides to control parthenium is not economically feasible. If herbicides are used, multiple applications are necessary as plant replacement from the seed bank occurs rapidly. In addition, appropriate herbicides are not available in all areas where the weed is a problem (Tamado *et al*., 2004). Especially, when the parthenium weed spreads, farmers may not be able to invest in management options for over large rangeland areas, within fallow and wasteland, and by the roadside.

5.4. Biological Control Method

The use of biological control insects, pathogens and other plants, in an integrated parthenium weed management system is one possible solution (Taye *et al*., 2004) for future management in Ethiopia. Ethiopia is one of the countries affected by invasive plant species, which have been clearly identified as one of the emerging problems facing the country (EARO, 2004). A national stakeholder workshop conducted in August, 2002 identified and

prioritized Invasive Alien Species (IAS) in Ethiopia to be *Prosopis juliflora*, *Parthenium hysterophorus*, *Striga spp*., *Eichhornia crassipes*, *Lantana camara* and *Acacia spp*. Prioritization of IAS was done by considering facts such as the magnitude of invasiveness, threats to local biodiversity, socioeconomic and health impacts (Taye, 2007).

As cited by Taye (2007), biological control is defined as the "utilization of organisms for the regulation of host plant densities." It is also defined as 'the action of predators, pathogens, and/or parasites in maintaining another organism's population density at a lower average level than would occur in their absence.' It may be achieved via direct or indirect action of the biotic agent that can bore into the weed and weaken its structure, consume or destroy vital plant parts, reduce weed vigor and reproduction, or enhance conditions that favor pathogen attack (Taye, 2007).

Weed biological control is usually aimed at reducing birth rate or increasing death rate. Migration rates could be affected by biological control agents that interfere with the biology or mechanics of seed or fruit dispersal, but the aims of weed biological control are usually more direct. Conceptually, it is the introduction of natural enemies of a target weed that will reduce the density of the weed to a level that is acceptable and that will maintain the weed density at that level (Julien, 1997). Thus, the objective in biological control is never eradication; it is reduction of weed density to non-economic levels. Use of biological control is environmentally friendly, i.e., reduces use of pesticides, reduces environmental contamination, and health risks to humans and animals. It is relatively inexpensive and self-sustaining. It is particularly useful for invasive alien weed species that cannot otherwise be controlled (Dubios, 2006).

The International Institute of Biological Control (IIBC) under contract to the Queensland Department of Lands (QDL) and Alan Fletcher Research Station, respectively (McClay, 1985; McFadyen, 1992), in Mexico (1978 – 1983) and in Brazil and Argentina in (1977 – 1981) entomological surveys and screening of the selected natural enemies for Parthenium where undertaken. McFadyen (1992) reviewed the biology, host specificity and effects on the host-plants for the biological control agents. Dhileepan and McFadyen (1997) listed eight species of insects introduced so far into Australia with details of their origin, release date, and establishment. Among them, the leaf-feeding beetle, Zygogramma bicolorata Pallister (Chrysomelidae), a seed-feeding weevil, Simycronyx lutulentus Dietz (Curculionidae), a stem-galling moth, Epiblema sternuana Walker (Torticidae), a leaf mining moth, Bucculatrix parthenica Bradley (Lepidoptera: Buccalatricidae), and a sap-feeding plant hopper, Stobaera concinna Stål (Delphacidae) from Mexico and a stem-boring curculionid weevil, Listronotus setosipennis from Brazil/ Argentina have been released and successfully established (Taye, 2007).

Up to now there are no potential native insect species observed in Ethiopia that feed on parthenium. The species of insects indicated above were found sufficiently host specific in Australia (McFadyen, 1992) and some of them were also introduced into India and South Africa. Thus, Maximum effort should be directed towards importation of host specific insects that are rigorously tested and already in use in these countries. These should, however, be extensively tested in quarantine for their feeding on economic plants of Ethiopia and subsequent assessment of the potential benefits and risks, as well as decision-making (Taye, 2007).

The introduction of microcyclic rust, Puccinia melampodii that occurs in the humid lowland areas of Mexico (Seier et al., 1997) to complement P. abrupta, which rarely occurs in low land areas of Ethiopia could be recommended after a thorough study of its host specificity. This could greatly reduce the cost of any biocontrol program in Ethiopia, which would otherwise be too expensive (3.5 million AD in Australia) to initiate in Ethiopia. With the right combinations of natural enemies and favorable climatic patterns, the pieces in biological control jigsaw may fall into place to form integrated biocontrol of parthenium (Evans, 1997) that in turn would form a major component of integrated parthenium management. Weed biological control in Ethiopia is at experimental stages (Taye, 2007). After the facility was inspected by IPM CRSP team and South African scientists the leaf feeding beetle (Zygogramma) introduced in October, 2007.

It was observed that P. abrupta was successfully infecting parthenium in many infested areas with significant reduction on seed production and morphological parameters in the field. The rust was commonly found in cool mid altitude (1500-2500 m) regions of the survey areas where the rainfall varies from 700-400 mm and the frost occurrence is frequent. This could be due to the requirement of low temperature and leaf wetness in the form of dew for germination of spores and subsequent development of infection. In this study, spore germination test showed that germination started 5 hours after incubation at 20 C and an increase in percent germination occurred with an increase in time of incubation indicating that a dew period of at least 5 hours is needed to initiate P. abrupta infection (Data not shown) (Taye et al., 2005).

In the study, rust incidence is low or does not exist at all in warm temperature areas with the altitude less than 1400 m. This might be due to high night temperatures that result in unavailability of dew that stimulates spore germination. The disease incidence was invariable in different habitats such as on roadsides, grassland and crop field indicating its uniform spread. Similarly, Parker et al. (1994) reported that P. abrupta occurs only at elevated sites in Mexico (> 1000 m), Kenya (1490 m) and India (930 m) and that it was not recorded from Texas or Madagascar where parthenium occurs at low altitudes. Thus, P. abrupta can infect the weed in mid-cool altitude

regions and can, therefore, be utilised in integrated parthenium management in these areas where its occurrence is not confirmed by inoculating the plants with uredospores from infected area (Taye et al., 2005).

P. abrupta has significantly reduced plant height (11.1%), leaf number (17.1%), and leaf area (26.7%), number of branches (11.23%), dry matter yield (24.8%), and seed production (42.7%). The reduction in leaf number and leaf area due to P. abrupta might reduce the amount of photosynthate produced, which in turn reduces plant height, number of branches that bear flowers and seed. Since parthenium reproduces by seed, rust infection is likely to curtail the seed production to a certain extent and spread of the weed. In addition, rust infected plants would be subjected to increased stress, and reduced competitiveness to the crop and other native plant species (Taye et al., 2005). To introduce natural enemies of a target weed that will reduce the density of the weed to a level that is acceptable and that will maintain the weed density at that level.

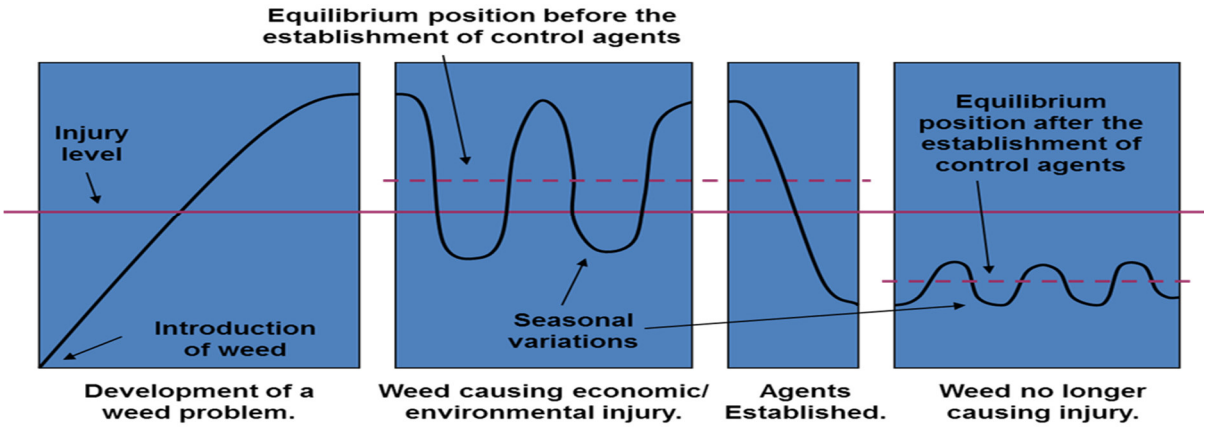

Fig 3. Changes in the population density of a weed before and after the establishment of biological control agents (Julien, 1997 (cited by Taye, 2007)).

Fig 4. *Zygogramma bicolorata* the leaf-feeding beetle

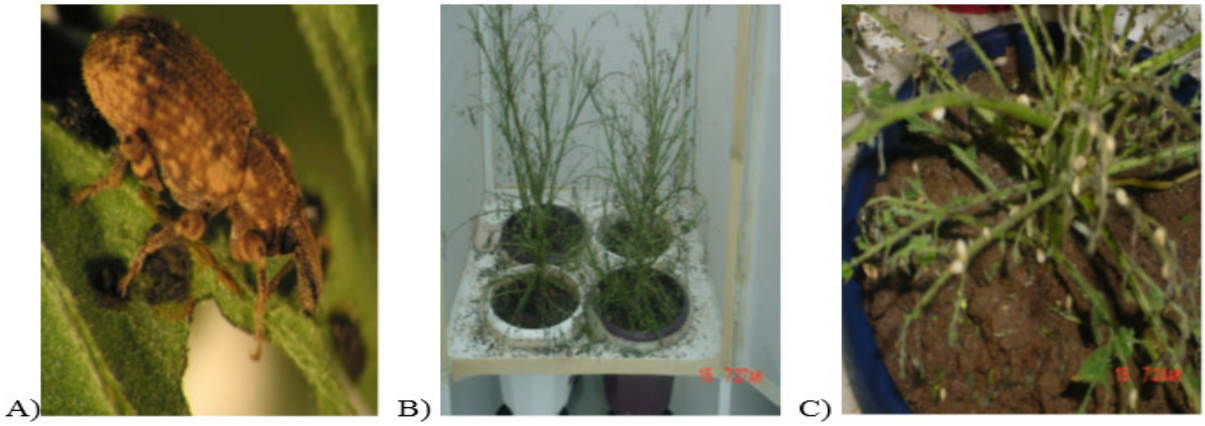

Fig 5. A. Listronotus setosipennis stem-boring B. Defoliated parthenium plants in rearing cage at PPRC C. Larvae of Zygogramma bicolorata feeding on parthenium at PPRC quarantine (Ethiopia) (Taye et al., 2004).

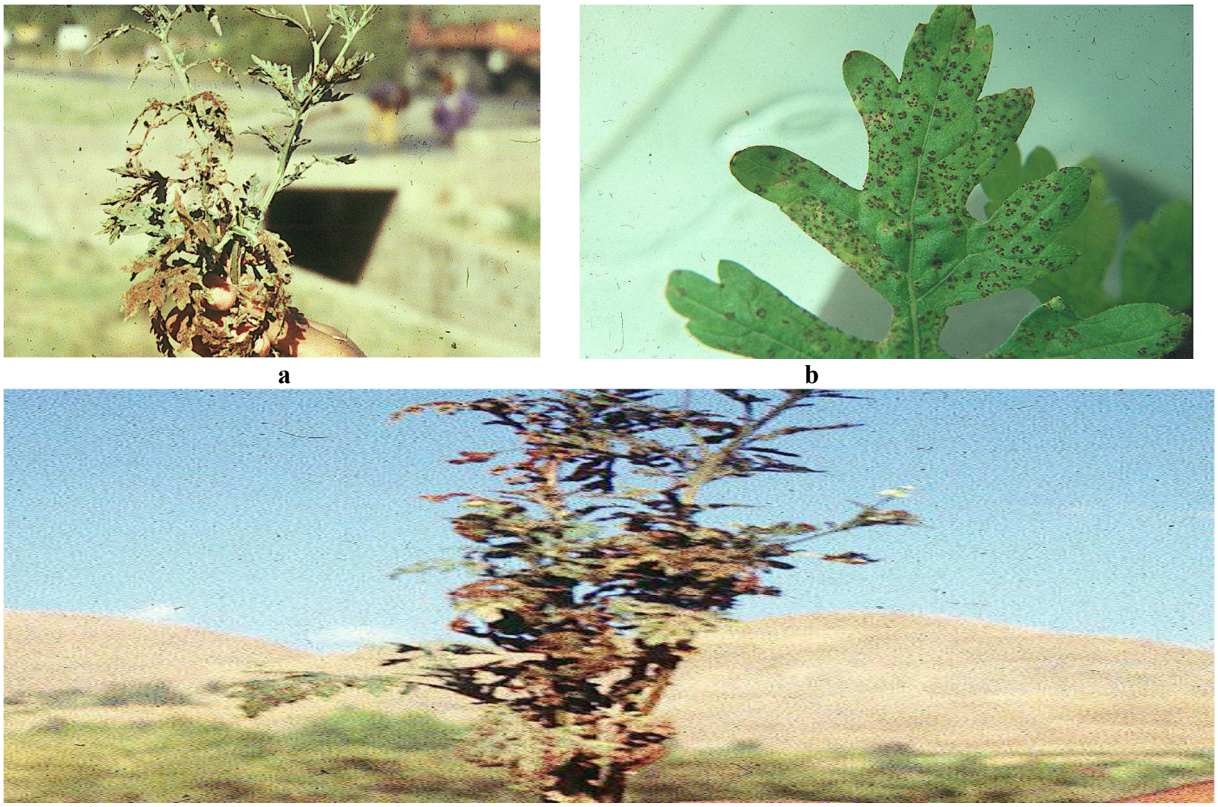

Figure 6. Puccinia abrupta var. partheniicola: a) and b) infection under field condition; c) pustules with uredospores produced 21 days after inoculation in the greenhouse (Taye et al., 2004).

5.5. IPM

Control of parthenium has been tried by various methods, but no single management option would be adequate to manage parthenium, and there is a need to integrate various management options. Successful management of this weed can only be achieved by an integrated approach with biological control as the key element Kaur *et al.,* (2006). Farmers may not be able to invest in management options for parthenium weed especially when the weed is spread over large rangeland areas, within fallow and wasteland, and by the roadside. The use of biological control insects, pathogens and other plants, in an integrated parthenium weed management system is one possible solution (Shabbir, 2012; Bekeko *et al*., 2012; Kahan, 2011; Taye *et al*., 2004) for future management in Ethiopia. A number of management approaches have been used to manage parthenium weed, but unfortunately each has its own limitations. Therefore, integrated weed management (IWM) approaches are considered to be the most effective in managing this weed (S. Adkinsa and A. Shabbirb, 2014).

6. SUMMARY

Parthenium is a major new agricultural weed in Ethiopia. *Parthenium hysterophorus* is the major invasive weed both in arable and grazing lands in Ethiopia. It is regarded as one of the worst weeds because of its invasiveness, potential for spread, impact upon human health, animal and economic and environmental impacts. It is distributed to all parts of the country and reproduces itself highly by seed. Parthenium has become an increasingly serious problem in major crops in eastern part of Ethiopia in addition to being a major problem on range and waste lands. Germination ecology of *Parthenium hysterophorus,* viability of the seeds was greater than 50% after 26 months of burial in the soil indicating the potential build-up of a substantial persistent soil seed bank. A short period of dry storage was sufficient to overcome a light requirement for germination in a minor fraction of the seeds. Likewise, seeds exhumed from burial showed an increase in germination ability in darkness over time, with a weak tendency for seasonal cyclicity in dormancy level at one of two sites.

Hand hoeing, suppress crop, deep plouging, chemical control are some recommended control measures in Ethiopia. For biological controls *Zygogramma bicolorata* the leaf-feeding beetle and *Listronotus setosipennis* stem-boring are introduced to the country. But yet now they are not delivered to the field, they are under trial in the green house. Control of parthenium has been tried by various methods, but no single management option would be adequate to manage parthenium, and there is a need to integrate various management options. Successful management of this weed can only be achieved by an integrated approach with biological control as the key element.

7. RESEARCH GAPS

Even though the invasiveness of *parthenium hysterophorus* is well known in Ethiopia still there no recommended economic threshold and injury level as well as any recommended integrated (set of tactics) for its management

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