Parthenium Distribution, Biology, Hazards, and Control Measures In Ethiopia

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Summary

Parthenium hysterophorus L.sub-tribe Ambrosiinae, tribe Heliantheae and family Asteraceae) is an annual herbaceous, naturalized and poisonous weed. Having originated in tropical North and South America (Mexico, USA) and West Indies, it has spread like a wild fire in Australia, Asia and Africa. Initially, parthenium weed used to appear only in non-crop situations, but its gradual encroachment into crop fields and grazing land in recent years cast a serious concern. Its invasion is attributed to wider adaptability, high capacity of seed production, photo-and thermo-insensitivity, absence of seed dormancy, high competitiveness and allelopathy. This review addressed the biology, distribution, and ecological, health and agricultural hazards it causes in Ethiopia and control measures currently available in both crop and non-crop situations. Prospects in parthenium weed research and control are also emphasized with special reference to Ethiopia.

Key words: Biology, control, parthenium weed, *Parthenium hysterophorus,* prospects
Running title: Biology and control of parthenium weed

Introduction

Parthenium weed, *Parthenium hysterophorus* L., is herbaceous, annual and poisonous weed. It is a native weed of tropical North and South America (Mexico, USA and West Indies), but it has spread to Africa, Australia and Asia during the last five decades (Aneja et al. 1991). Currently, it is widely distributed in South and East Africa (South Africa, Ethiopia, Kenya), South and Southeast Asia (India, China, Vietnam, the Pacific Islands), Australia (Queensland, Central Highlands and North Clermont, New South Wales) and in many other parts of the world, cutting across country-boundaries and climate-barriers. It, therefore, bears a number of common names, *viz.*, parthenium weed in Australia; congress grass, carrot weed, bitter weed, broom-bush, and star weed in India; false ragweed, ragweed and parthenium in the USA; white top, escobar amarga, and feverfew in the Caribbean (Navie et al. 1996).

Parthenium proved more destructive, more proliferated and highly adaptive, with huge standing population year round, in its new places of introduction than in its original homestead. Taye (2002) stated that the high parthenium infestation in Ethiopia is attributed to the disturbance and clearing of large areas, presence of neutral to alkaline soils that are favourable for its growth and the absence of natural enemies and competing vegetation that would suppress the weed below its damaging level. It is, therefore, usually called a naturalized weed.

In the initial years of encroachment, parthenium weed remained absent in the crop fields and used to grow in the undisturbed wastelands, neglected fields along fence lines, irrigation and drainage ditches, bunds, rocks and crevices, railway tracks, public places like roadsides, parks and recreational grounds, and other non-crop situations. Therefore, it was considered to be a stray weed, which does not withstand close crop competition in the fields (Singh 1997). It, however, proved wrong. It has slowly encroached into the agricultural lands particularly rangelands, forests, orchards and poorly managed arable crop fields. Parthenium has become a matter of serious concern in recent years based on its rampantly increasing population year after year.

Invasion of parthenium weed is attributed to its wider adaptation across climates, photo-insensitivity, thermo-insensitivity (Mahadevappa 1997), drought tolerance (Kohli and Daizy 1994) and absence of seed dormancy (Haseler 1976). It has become a major weed of regional, national, and international concern within short period because of its prolific seed production ability and small and light weight seeds that are capable to travel long distances through wind, water, birds, other animals, traffic and transported goods.

The purpose of this paper is, therefore, to review literature about its biology; distribution across the world; hazards, viz., ecological, health and agricultural; its causes and control measures in both cropped and non-crop situations, and also to indicate its prospects in research and control. Wherever information is available, reference is given to Ethiopia's condition.

Biological Characteristics

Parthenium hysterophorus L belongs to the family Asteraceae, tribe Helianthae and sub-tribe Ambrosiinae. This sub-tribe includes two important weed genera, *Ambrosia* and *Xanthium*. The genus *Parthenium* contains 15 species, which are native to North and South America. *Parthenium hysterophorus* is an annual, diffused leafy herb that germinates at any time of the year and grows rapidly to a height of 0.5–1.5 m, and reaches a maximum of 2.5 m in good soils. The young plant forms basal rosette of leaves, which spreads rapidly very close to the ground. The leaves are pubescent and dissected into narrow pointed lobes and measure up to 20 cm long and 4–8 cm broad. The leaves and the stem are covered with hair called trichomes. Mature plants are much branched, and axillary branches also form down the stem, as the plant gets older. Parthenium weed also produces a long tap root system that enables it to obtain water from deep soil profile. Further, this taproot stores energy reserves for the rapid growth of the plant if slashed or grazed.

High reproductive ability is one of the most important biological characteristics of parthenium weed. Seeds are small, 1–2 mm long and about 50 μg weight, flattened with short wing-like structures and are without hooks or pappus. It is an extremely prolific seed producer with upto 25,000 seeds per plant (Navie et al. 1996), but unable to reproduce by vegetative means. Four or more successive cohort of seedlings can be produced in a season (Pandey and Dubey 1989). Wind, water, birds and other animals, traffic, and transported goods serve as vectors for the dispersal of seeds. Seeds require bare soil to germinate with no or little dormancy (Butler 1984). However, viability of the seeds was greater than 50% after 26 months of burial; and half-life of the seeds in the soil was predicted to be approximately 3–4 years—indicating the potential build-up of persistent soil seed bank (Tamado et al. 2002b). In Australia, McFadyen (1992) noted that flowering begins 6–8 weeks after germination in summer and continues until drought or frost kills the plant. However, it can germinate, grow, mature and set seed within 28 days (PAG, 2000). Under unfavourable conditions, the lifespan might take up to 335 days compared to 86 days under optimum conditions.

Allelopathic effects of parthenium weed on other plants through the production of soluble phenolics (caffeic acid, ferulic acid, vanicillic 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 the weed (Patil and Hegde 1988. Pandey et al. 1993). Its allelopathic nature enables it to be very competitive and exclude the growth of other species (Kanchan & Jayachandra 1979).

Parthenium weed occurs in at least two biotypes in its natural range: the North American and the South American biotypes (Dale 1981). The South American type is characterized by large flower heads and disc florets, yellow flowers rather than white, less development of axillary branches and a sesquiterpene lactone hymenin as opposed to parthenin that is found in North American type. The form of parthenium exotic to the Old World originated from North America with its evolutionary centre being northern Mexico and southern USA (Cock and Seier 1999).

Parthenium Weed in Ethiopia

In Ethiopia, parthenium has become notorious weed since its discovery as exotic invasive weed in the 1980s. It has been observed spreading from introductions through the eastern route of Ethiopia, particularly along the Dire Dawa-Addis Ababa railway line presumably between 1974 and 1980. It is suspected that the seeds were brought into the country with grain imported and/or donated for relief aid (Seifu 1990, Fasil 1994, Frew 1997, Tamado and Milberg 2000).

Another speculation suggests its introduction during the Ethio-Somali war in 1976/77 along with army vehicles. From the presence of parthenium in Kenya and Somalia (Frew et al. 1996, Njoroge 1986) and the capacity of parthenium seed to travel long distances through wind, water and other means, it is also possible that parthenium weed could easily be introduced to Ethiopia from these neighboring countries. The presence of *Puccinia abrupta* on parthenium weed in Ethiopia (Taye et al. 2004b) might also explain indirectly the introduction of parthenium weed from neighbouring countries, Kenya and/or Somalia, as the presence of *P. abrupta* was long known in Kenya (Evans 1987). Although these observations confirms parthenium entry and its escalation on a larger scale, so far there is no concrete justification with regard to the question of how and when it got introduced into the country.

Parthenium weed has different vernacular names in different languages and regions in Ethiopia that imply its allelopathic potential, physical form, contaminations and strong competitive nature and/or its introduction (Taye 2002). For example, it is called "Kinche arem" for resemblance of its flower head to ground wheat grain; "Merrerta" for the taint it imparts on taste of cow milk; "Biyabassa", meaning leave the place or a region for its contaminations and competitive nature; "Faramssiissa" meaning sign to leave the land, and "Kalignole", which means living alone. It has been affecting the rural community most although it has potential bearing on urban dwellers as well.

The establishment and spread of parthenium weed began from the transportation terminals and highways that lead to drought prone areas. Taye (2002) stated that it was observed to grow from hot arid and semi arid low altitude to humid high mid altitude (900–2500m) areas. It grows on any type of soil (sand, loam or clay) and in different habitats (roadsides, wastelands, rangelands, villages and gardens, and crop fields) — indicating its adaptability to different soil types and climate. However, severe infestation of the weed occurred in areas below 1900m altitude and on heavy clay soils in eastern Ethiopia (Tamado & Milberg 2000).

In a workshop organised at Kobo in 1996, by North Wollo Department of Agriculture, Ethiopia, it was reported that the spread of parthenium weed was aggravated by the uncontrolled movement of livestock, farm implements and by the recently established irrigation network. Moreover, regular maintenance of verges along the high ways and gravel roads of several kilometres is carried out every year in Ethiopia. Therefore, the extensive dense stands along roadsides in Ethiopia might be due to the routine disturbance and grading of road verges and transportation of sands and gravel from parthenium-infested to non-infested areas (Taye 2002).

Despite its recent introduction, parthenium has been found as the second most frequent weed after *Digitaria* spp. and was ranked as the most important weed in by 90% of the interviewed farmers in crop lands and grazing areas in eastern Ethiopia (Tamado & Milberg 2000).

Hazards of Parthenium Weed

Crop production

In India, yield decline of 40% in agricultural crops and 90% reduction in forage production has been reported (Khosla and Sobti 1981). In eastern Ethiopia, sorghum grain yield was reduced from 40 to 97% depending on weather conditions of the year and the location if parthenium weed is uncontrolled (Tamado et al. 2002a). However, its overall impact on crop production system is multifaceted, both direct and indirect, thus making it difficult to quantify losses (Evans 1997).

Other than competition for nutrients, parthenium weed is known to release allelochemicals to the sub-stratum via root exudation, volatilisation or rain-wash from aerial parts, and via leaching in the soil. These chemicals have been observed to exhibit an inhibitory effect on both the germination and growth of a wide variety of crops including pasture grasses, cereals, vegetables, other weeds and tree species (Evans 1997, Navie et al. 1996).

Kanchan and Jayachandra (1981) and Dayama (1986) reported that parthenium weed inhibited the growth and nodulation of legumes because of the inhibitory effect of allelochemicals on nitrogen-fixing and nitrifying bacteria. Aqueous extracts of parthenium weed from leaf and flower inhibited seed germination and caused complete failure of seed germination of tef (*Eragrostis tef*) when the leaf extract concentration of parthenium weed was

10% (Tadele, 2002). Further, its pollen was found to reduce the chlorophyll content of leaves with which it comes into contact and can interfere with the pollen germination and fruit set of the nearby species (Kanchan and Jayachandra 1980). Towers et al. (1977) reported that heavy deposition of parthenium pollen on the stigmatic surface caused 40% reduction in the grain filling of maize and indicated that the weed may still exhibit an inhibitory influence on crops even when grown at a considerable distance.

Animal production

Evans (1997) indicated that the impact of parthenium weed on livestock production is direct and indirect by affecting grazing land, animal health, milk and meat quality, and marketing of pasture seeds and grain. In Australia, parthenium weed could completely dominate grazing land, resulting in a weed monoculture and reduced stocking rate of up to 80%, with a net annual loss of AU$ 16.5 million (Chippendale and Panneta 1994). Cattle grazing in parthenium-invaded pastures were marketed with a lower weight than cattle grazing in parthenium free areas. In addition, the presence of parthenium weed caused the need for establishment of new improved pastures and production of extra-cultivated forage, both of which added to the cost of beef production (Chippendale and Panetta 1994). A supply of pasture seed and forage may be hampered since there is a legislation to prevent the sale or movement of goods because of their contamination by parthenium weed seed (Evans 1997).

Although animals usually avoid parthenium weed, it may be consumed in situation where the weed forms almost pure stands. Studies in India on toxicity of the weed to cattle and buffaloes have shown that a significant amount (10–50%) of the weed in the diet can kill these animals within 30 days (Naarasimhan et al. 1977). Animals developed dermatitis with pronounced skin lesions and eventually died due to the rupture of tissues and haemorrhage in their internal organs (Nisar Ahmed et al. 1988). Taints of meat have been detected from sheep given a diet of 30% parthenium weed (Tudor et al. 1982) and tainting of milk has also been reported from cows (Towers and Suba Rao 1992).

Human health

Parthenium weed is also known to cause human health problems like asthma, bronchitis, dermatitis, and hay fever (Sriramarao et al. 1991; Kololgi et al. 1997). Continued close contact with parthenium weed 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 1997). Parthenium weed is the causative agent of the above reaction, and is one of the very reactive toxic classes of compounds known as sesquiterpene lactones (Towers 1981).

There has been an epidemic of hundreds of cases of parthenium weed dermatitis in India and several cases have been reported from USA (Suba Rao et al. 1976, Towers 1981). In Australia, many individuals were also affected by parthenium weed dermatitis though human population density in the parthenium-affected areas is very low (McFadyen 1992). It is also reported that respiratory problems, usually starting with hay fever but progressing to asthma and allergic bronchitis after 3–5 years are increasing. McFadyen (1992) indicated that about 15% of individuals regularly exposed to parthenium weed would develop the dermatitis, with another 7–15% developing respiratory problems.

Affected individuals have no alternative except leaving the area. Due to its chronicity, reports of committing suicide are available in India and other parts of the world (Kolologi et al. 1997). In Ethiopia, it is also reported that individuals who handweed hoe in parthenium infested crops suffer from dermal allergy, fever and asthma (Taye 2002).

Case Reports from Ethiopia

Control of parthenium weed

Non-crop situations

It is true that the spread of parthenium weed in the crop field could be checked to a great extent if it is controlled at non-crop areas. Therefore, first attempt to control parthenium weed should aim at non-crop situations with possible integration of various methods described in this section.

Prevention: It is the easiest way to protect parthenium weed from establishing. Simple precautions such as sowing uncontaminated crop and pasture seeds, cleaning cultivating and harvesting vehicles before moving them to non-infested areas, and short term quarantine of stock that have been in parthenium infested areas reduce the spread of parthenium weed (Parsons and Cuthbertson 1992, Navie et al. 1996). Maintenance of grass crown covers in problem areas and spot spraying of isolated outbreaks with a residual herbicide are recommended as they reduce the occurrence and distribution of parthenium weed (Anonymous 1976).

Manual and mechanical control: Manual and mechanical control methods are very expensive as parthenium weed usually covers large areas, and the relief from this method is temporary and needs to be repeated (Bahn et al. 1997). Besides, mowing or slashing of parthenium weed is not recommended because it results in rapid regeneration of plants from lateral shoots (Gupta and Sharma 1977). It is suggested that parthenium plants should be uprooted to prevent regeneration from the remaining lateral shoots and that such operation should be done before flowering and when the soil is moist enough to facilitate easy removal. Mahadevappa (1997) and (Bahn et al. 1997) recommended that only persons insensitive to parthenium allergy shall be engaged. Gupta and Sharma (1977) suggested wearing protective clothing and subsequent washing to prevent the possibility of allergic reaction.

Spraying of common salt followed by burning: In India, spraying 15% common salt (brine) solution followed by controlled burning resulted in good control (De and Mukhopadhyay 1983). High concentration of common salt brings about plasmolysis, which leads to desiccation of the treated parthenium plants. Then they are put to fire. This results in complete destruction with no scope for regeneration.

Use of bio-control agents: Navie et al. (1996), Dhileepan and McFadyen (1997) and Cock and Seier (1999) listed the insects and pathogens so far introduced into Australia with details of their origin, release date, and establishment. Among them, the leaf-feeding beetle, *Zygogramma bicolorata,* a seed-feeding weevil, *Simycronyx lutulentus*, a stem-galling moth, *Epiblema sternuana*, a leaf mining moth, *Bucculatrix parthenica*, and a sap-feeding plant hopper, *Stobaera concinna,* and a stem-boring curculionid weevil, *Listronotus setosipennis* from Mexico, Brazil and Argentina were introduced and successfully established in Australia. Besides, two species of pathogenic rust fungi, *Puccinia abrupta* var. *parthenicola* and *Puccinia mealmpodii,* were introduced and established. *Puccinia abrupta* and the phyllody caused by Faba Bean Phyllody (FBP) group were the two most important diseases infecting parthenium weed in Ethiopia (Taye 2002). The rust was commonly found in mid altitude (1500–2500 m) areas with 5–100% incidence (Taye et al. 2004a) while phyllody was observed in low to mid altitude regions (900–2300 m) of Ethiopia with 5–75% incidence (Taye et al. 2004b).

Use of competitive harmless plants: Research in the University of Bangalore, India, confirmed that plant bio-agents like *Cassia* spp could exert allelopathic impact and hinder germination and growth of parthenium weed (Singh 1997). He indicated that rapid rate of growth, wide range of ecological adaptability, sufficient quantity of seed production and its utility for protection of soil erosion and green manure were considered for its choice to suppress parthenium weed. However, some people argue that plant bio-agents are weeds and do not deserve to be encouraged and that the allergens in the plant species should also be investigated before they are recommended.

Application of suitable herbicides: The growth and spread of parthenium weed is low up to 75^{th} day from germination; and this stage is assumed to be vulnerable for early chemical control (Muniyappa 2000). Brar and Walia (1991) have identified several potential herbicides for the control of parthenium weed in non-crop situation (Table 1). Glyphosate and glufosinate-ammonium at 1.0–1.2 kg/ha and metribuzin at 1.0–1.5 kg/ha applied post-emergence at the "rosette" stage have been found effective in controlling parthenium weed in non crop waste lands, bunds, roadsides or railway tracks.

Pasture and grazing management: As there seems to be a definite relationship between the invasion of parthenium weed and the vigor of pastures, it is apparent that pasture management is fundamental to the control of this weed. Pastures should not be grazed heavily as this increases the likelihood of invasion by parthenium weed and the severity of existing infestations (Parsons and Cuthbertson 1992). Parthenium weed infested pastures should be rehabilitated by sowing pasture species to encourage restoration of pasture. Once cover is established, stocking rates have to be carefully adjusted according to season and rainfall to maintain grass dominance.

Control through utilization: Attempts have been made to use parthenium for bio-pesticides, bio-gas generation and green manuring (Pandey and Das, in press). Incorporation of parthenium weed residue in rice field increased rice grain yield (Pandey 1994). Utilization of parthenium weed as mulch for checking evaporation from crop field, particularly in dryland areas, opens up another possibility. Parthenium plants, which are sufficiently grown-up should be used for mulching before they reach flowering stage. However, choice of crops may be limited since parthenium weed exerts allelopathy. This requires researchers' increased attention and intensive researches have to be carried out across crops for desired results. Besides, the potential of parthenium for medicinal properties such as antitumor and antiamoebaic activities and use of a decoction of boiled roots to cure dysentery. Seier and Djeddour (2000) indicated that in Caribbean and Central America it is used to treat skin disorders and other ailments. Parthenium is also known to be used against dysentery.

hepatic amoebiasis, neuralgia and certain types of rheumatism (SOPAM 2004).

Crop situations

Manual and mechanical control: The cheap and available labour in Ethiopia suggest that manual and mechanical control would be feasible where intensive cultivation is practiced although this presents a health risk. The time and condition for hand weeding is similar to non-crop situation. Deep ploughing to a depth of greater than 7 cm (Tamado 2001) could also be employed to bury parthenium seeds thereby reducing its germination. This operation, however, necessitates the modification of our local farm plough used by smallholders in Ethiopia. With the onset of rainfall, however, repeated shallow cultivation with the local oxen plough can destroy the newly emerging seedlings and at the same time, can give favourable conditions for germination of the seeds on the upper soil surface and consequently exhaust the weed seed bank. Hand-hoeing twice consistently suppresses parthenium weed and gives better sorghum yields than application of 2,4-D and growing smother crop in eastern Ethiopia (Tamado and Milberg 2004). It is possible that hoeing, apart from controlling the weed, created better soil conditions for water infiltration.

Use of herbicides: In crop situation, selective herbicides have to be applied (Table 1). Atrazine applied pre-emergence at a rate of 1.5kg/ha takes care of parthenium weed along with other annual weeds in maize, sorghum and pearl millet. In rice, wheat, pulses and oilseeds, pendimethalin at 1.0–1.5 kg/ha applied pre-emergence proved quite satisfactory. Selective post-emergence herbicides like 2,4-D and MCPA are also recommended for controlling this weed in cereal crops. Herbicides need to be applied repeatedly to prevent weed germination from seed bank across the crop-growing season. However, continuous use of herbicide may cause development of resistant biotypes and may cause shift in weed flora apart from residue hazards on the environment (Das and Duary 1999). Therefore, herbicide use must be integrated with other control methods. Tamado and Milberg (2004) reported that application of 2,4-D occasionally failed to control parthenium weed in grain sorghum in eastern Ethiopia, probably because of substantial re-emergence from the soil seedbank after control. A residual herbicide may help to overcome the problem of repeated application, but since parthenium weed covers usually very large areas, herbicide is unlikely to be an economically and environmentally viable option.

Cultural management: Indirect weed control methods such as use of clean seed, use of more competitive varieties, choice of appropriate sowing rate and date, and increased amount of fertilizer (Tamado 2001) can be adopted to favor crop growth relative to the weed. Kandasamy and Sankaran (1997) reported that growing of maize, sorghum and sunflower significantly reduced the parthenium weed population by reducing its branching, growth and flower head production as compared to other crops. Besufekad (2001) reported that the use of intercrops in sorghum reduces parthenium weed infestation and effected high yield. He reported that cowpea intercropped with sorghum and cowpea intercropped with sorghum + pre-emergence spray of pendimethalin at 1.0 kg/ha, among other observations, appeared most promising in terms of suppressing parthenium growth and improving sorghum yield. However, Tamado and Milberg (2004) reported that growing cowpea as smother crop suppressed parthenium weed, but depressed sorghum grain yield in eastern Ethiopia possibly due to low soil moisture that could not support the combined demand of both cowpea and sorghum.

Integrated parthenium management: So far, no single method of controlling parthenium weed proved satisfactory as each method suffers from one or more limitations such as inefficiency, high cost, impracticability, environmental safety and temporary relief (Mahadevappa 1997, Bahn et al. 1997). Hence, integrated parthenium weed management that involves the use of different control options is mandatory.

Prospects of Parthenium Weed Management in Ethiopia

Parthenium weed has already achieved the status of being a major invasive weed in Ethiopia as it grows abundantly in wasteland, grazing land, and crop fields in northern, central and eastern Ethiopia. It is also expected to continue spreading to all suitable habitats. So far, there are no adequate and appropriate control methods at national level. Experiences in Australia and India show a range of control measures being employed in order to manage parthenium weed more successfully, and the emphasis has always been on using an integrated management strategy.

There is an urgent need to develop and adopt an integrated management system for parthenium weed in particular, and for weeds in general in Ethiopia by amalgamating more than one option. This must be developed based on the habitat of parthenium infestation (different crop types, roadsides, grasslands, wastelands, gardens and orchards), category of the infested areas (where the plant must be destroyed, reduced or prevented), agroecology (lowland, midland, highland), and the farming system. Also, the choice of weed control method appropriate for smallholder farmers requires a detailed socio-economic evaluation. On the basis of these situations, integrated parthenium weed management, involving prevention of spread or establishment, manual and mechanical control, agronomic practices, biological control, and herbicide use should be developed and adopted.

In the already infested crop fields of eastern Ethiopia, taking sorghum as an example, integrated parthenium weed management strategy (Figure 1) can be proposed and adopted. During fallow period, parthenium weed population remains relatively low and, therefore, hand weeding and/or hoeing or spraying non-selective herbicides like glyphosate can be used to reduce parthenium intensity in the forthcoming season. Deep ploughing to a depth of greater than 7 cm (Tamado et al. 2002b) could also be employed to bury parthenium seeds—and thereby reduce its germination. This operation, however, necessitates the modification of our local farm plough 'Maresha' used by smallholders in Ethiopia. With the onset of rainfall, however, repeated cultivation with the local oxen plough can destroy the newly emerging seedlings and at the same time, could give favourable conditions for germination of the seeds on the upper soil surface and consequently exhaust the weed seed bank. But farmers should be advised about the importance of parthenium weed control during the fallow for smallholder farmers might not want to invest their time and energy.

During sowing of maize or sorghum, indirect weed control methods such as use of clean seed, use of more competitive varieties, choice of appropriate sowing rate and date, and increased amount of fertilizer (Tamado 2001) can be adopted to favor crop growth relative to the weed. After emergence of the maize or sorghum, farmers using smother crops like cowpea and mung bean or intercrops such as common bean, sweet potato, groundnut and chat between rows of sorghum or maize may suppress parthenium as the weed is sensitive to shade from the main crops (Tamado, 2001) and possibly due to the coverage of inter-row spaces by the intercrops. Moreover, smother crops and intercrops have additional food and feed values. Sorghum and sweet potato stay in field relatively longer than maize and common bean. This suggests that proper crop rotation scheme can also reduce the interval of fallow period—thereby reducing growth of parthenium weed during fallow. After emergence of the crop, use of post-emergence herbicide in sole crop (sorghum or maize alone) or two times hoeing during the flush period of weed emergence, i.e. at 4 and 8 weeks after crop emergence, either in sole crop or in inter-crops, shall be applied (Tamado and Milberg 2004).

In non-infested crop fields, or in fields where parthenium weed exists as patches, simple precautions should be taken. These include field monitoring and sanitation; avoiding movement of vehicles and other machinery and limiting reach of stock, compost, sand or soil from infested areas to non-infested areas; use of clean crop seed; control of the isolated outbreaks through spot spray with persistent herbicides or repeated hand weeding or hoeing; and control of parthenium in other habitats like roadsides, and wastelands are mandatory.

Control of parthenium weed in fallow, wasteland, grazing land and roadsides in urban and rural situations is necessary. It is here that village communities, city councils, agricultural development agencies, and other groups should be organized to manage the weed. Such activity has been started in the northern and central parts of Ethiopia, but lacks continuity and technical operation. Development and enactment of acts in parthenium weed infested areas after publicizing the infestation well through mass media, seminars, schools and organization of peoples participation in uprooting and cleaning of infested areas and application of preventive methods in non-infested areas will reduce the risk of spreading parthenium weed. Maintaining pasturelands by avoiding overgrazing and developing vegetation stand in disturbed areas is mandatory in order to prevent the spread of the weed.

Classical biological control, involving the use of insects or pathogens for the control of parthenium weed, does not easily apply for protecting the weed in crop fields. However, it has great potential in rangelands, also where parthenium weed has become a serious problem. Mechanical, cultural and chemical control methods are not feasible under such ecosystem, where the weed covers a large area. Biocontrol seems the only safe, practical, economically feasible, and sustainable method in the long run (McFadyen, 1988. In this regard, the introduction of rigorously tested promising biocontrol agents from Queensland, Australia, can be considered. This would greatly reduce the cost of any biocontrol program, which would otherwise be too expensive to initiate in Ethiopia. This, however, requires thoroughly assessing the potential benefits and risks, as well as a decision on overall introduction policy.

Experience of Natural Resources Institute in Australia, suggests that parthenium problem necessitates the development of detail parthenium management strategy that best suits to the farming system of Ethiopia. This might be accomplished by creating parthenium weed action group at national, regional, district and kebele levels that comprise farmers' representatives, government institutions, and NGOs. This action group can be helpful to eradicate or contain the weed where possible; to improve communications between researchers and farmers, to educate farmers in best management practices and to promote community awareness about the weed problem and community-based weed control programs in order to reach sustainability.

Table 1. Herbicide recommendation for the control of parthenium in non-crop and cropland situations

Herbicide name	Application time	Application rate (kg a.i./ha)	Parthenium Growth stage	References
Non-crop land				
Diquat	Post-emergence	0.5–1.0	*Early vegetative	Muniyappa 2000
2,4-D (Na, amine and ester formulations)	Post-emergence	0.8–1.0	-- do --	-- do --
Dicamba	Post-emergence	1.6	-- do --	-- do --
Glyphosate	Post-emergence	1.0–1.2	-- do --	-- do --
2,4-D Na salt/MCPA + MSMA	Post-emergence	1.0 + 1.31	-- do --	-- do --
2,4-D Na salt/MCPA + Diquat/paraquat	Post-emergence	1.0 + 0.5	-- do --	Muniyappa 2000
Common salt (NaCl) followed by controlled burning	Post-emergence	15 % (w/v)	-- do --	Mukhopadhyay 1987
Metribuzin	Post-emergence	1.0–1.5	-- do --	Balyan, Ashok &
Glufosinate-ammonium	Post-emergence	1.0–1.2	-- do --	Mahadevappa 1997
Croplands **				
Atrazine	Pre-emergence	1.0–1.5	Maize, sorghum, pearl millet, sugarcane	Muniyappa 2000; Das 2000
Terbutyrine	Pre-emergence	1.0–1.5	Maize, sorghum, pearl millet, sugarcane	Muniyappa 2000
Butachlor	Pre-emergence	1.0–1.5	Rice	Muniyappa 2000
Pendimethalin	Pre-emergence	1.0–1.5	Almost all cereals, pulses and oilseeds	Das (in press); Besufekad 2001
Metribuzin	Pre-emergence	0.5–1.0	Soybean, potato, sugarcane	Das (in press)
2,4-D (Na salt, dimethyl amine and diethyl ester	Post-emergence, but 2,4-D (Na and amine salt) could also used as pre-mergence	0.8–1.0	Rice, wheat, barley, maize, sorghum, sugarcane	Mukhopadhyay and Bhattacharya 1985; Muniyappa 2000

* Rosette stage (early vegetative stage with no stem elongation, only when 3–4 leaves are emerged)

** The herbicides are tested against parthenium, but not under cropped situation. However, based on their selectivity, for the respective crops where they could be used safely are suggested.

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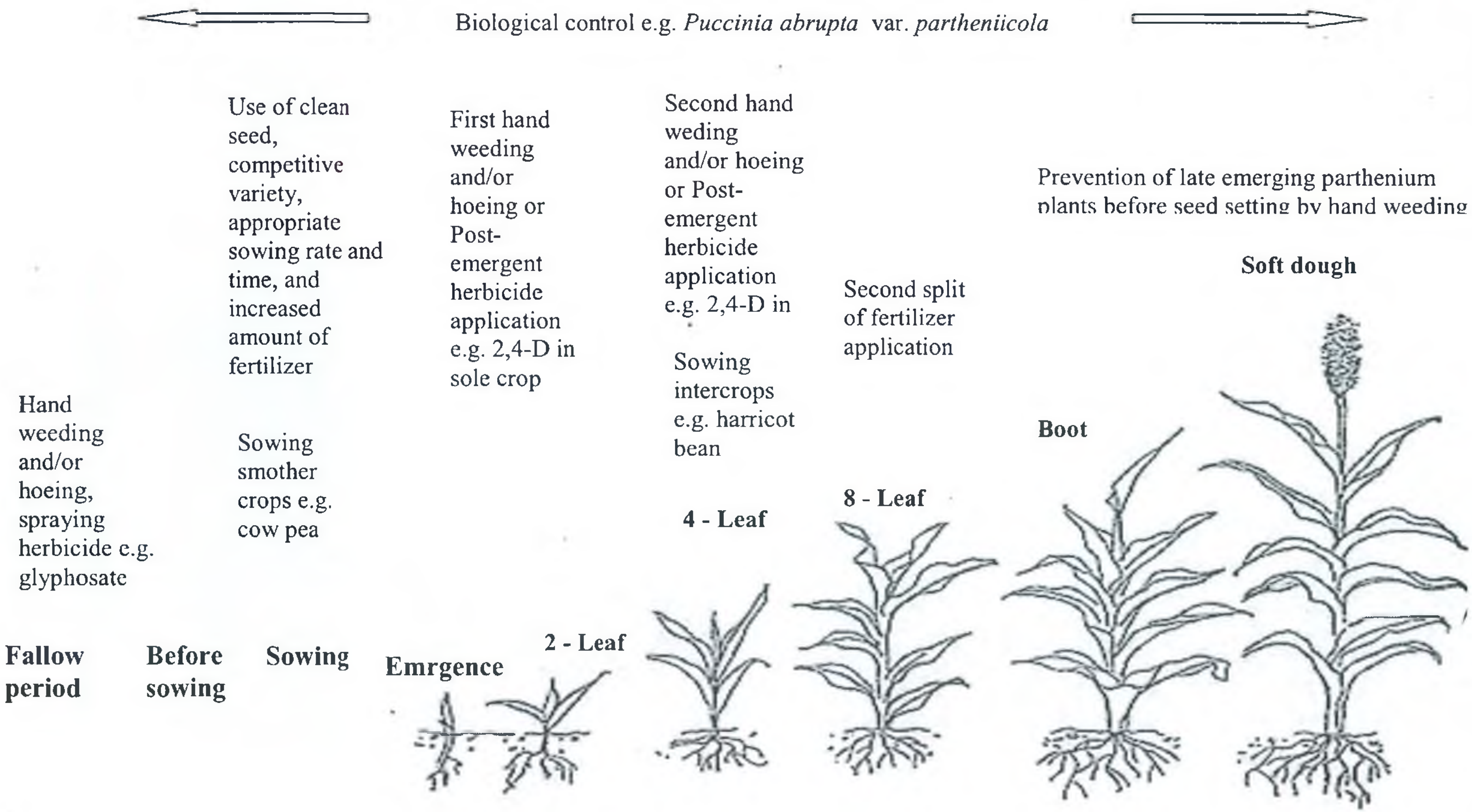

Figure 2. proposed integrated parthenum management option