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Assessment of *Prosopis juliflora* infestation and management options at Tendaho Sugar Estate

Samuel Tegene[1*], Nestanet Ayele[2] and Leul Belay[3]

[1,2,3]Ethiopian Sugar Corporation, Research Directorate, Agronomy and Crop Protection Team, P.O. Box 336, Wonji, Ethiopia

Abstract

Invasive Alien Species are great concern in the Ethiopian Sugar Cane plantations and among these *Prosopis juliflora* is a noxious alien weed and has become a great challenge at Tendaho Sugar Estate. Consequently, an assessment was made on its distribution and spread to generate comprehensive and objective data to assist researchers and decision makers set priorities and measure outcomes of the invasive weed research and control strategies. To meet these objectives, a total of 32 fields were sampled based on their diversity of infestation and land use categories. Hence, diverse land use categories such as cultivated lands, irrigation canals, drainage lands, harvest roads and road sides', residential and office areas were assessed for infestation level. Accordingly, very severe infestation with 5 density category having coverage of >50% was observed at the side of irrigation canals, at the side of the roads and at drainages of the farms. While the lowest density category that ranges from 1-3 having nil to 10% coverage was observed in cultivated lands with different management level, near residential and offices. Furthermore, in most of the highly infested fields, the weed had produced large amount of seed and; bushy and tree growth stage predominate. The assessment also indicated that various utilization of the weed by the local communities for different purposes such as fuel wood, construction, fence, shade and charcoal. Furthermore, questionnaires filled by supervisors and formans on previous management history of the weed and the weeds' effects on agricultural operations indicated that the weed had not been well managed by the Sugar Estate and has been incurring a lot of additional cost which is estimated to be 10% of the production cost due to damaging farm implements, tyres and fuel tanks; and additional labour for clearing. In general, from sustainability and production point of view, the management practice that has been utilized by the project was unable to reduce the risk posed. Therefore, it is recommended that integration of different management practices such as chemical, cultural, mechanical, biological and replacement with beneficial plants is very crucial. The integration of the above aforementioned practices that focus from eradication of the weed from its low infestation to reduction of the population and interruption of reproduction from all infested areas through creating awareness, involving different stakeholders and allocation of enough resources should be practiced in order to minimize the disastrous effect of the weed on the agricultural operation in general and on sugar cane production in particular.

Keywords: *Prosopis juliflora*, alien invasive species, assessment

Introduction

Among the 22 invasive alien species in Ethiopia, mesquites (*Prosopis juliflora*), parthenium weed (*Parthenium hysterophorus*) and water hyacinth (*Eichhornia crassipes*) are causing major problems in the Ethiopian sugar plantations. Of the three invasive alien species in the Ethiopian sugar plantations again, *Prosopis Juliflora* has extensively found in the Tendaho Sugar Estate. *P. Juliflora* was thought to have been introduced to Ethiopia during the establishment of irrigation water development project at Middle Awash from Sudan (Rezene, 2006). In contrast to this Demisew, 2010 reported that its first introduction is believed to have been in the late 1970s at Goro nursery, Dire-Dawa, possibly from India. In Afar, it may have been introduced possibly from Dire-Dawa or independently from Kenya or Sudan by foreigners working in the Middle Awash irrigation project in the late 1970s and early 1980s (Demisew, 2010). It was reported that the species has been increasing in density as well as area coverage from year to year even from month to month in Afar Region. Currently, this noxious weed heavily infests most agricultural as well as potential rangeland of the Afar Region. The thorny nature of the plant, remarkable its ability to withstand adverse condition, non- browseable nature, and above all, the nomadic nature of the people have paved the way for the species to invade most potential lands of the region (Hailu, *et. al*, 2004). In the Awash basin of Ethiopia, it is aggressively invading pastoral areas in the Middle and Upper Awash Valley, and Eastern Hararghe. It is one of the three top priority invasive species in Ethiopia and has been declared a noxious weed (Esther and Brent, 2005).

For researchers or decision makers to set priorities and measure outcomes of the invasive weed research and control, they need a comprehensive and objective data on distribution and spread. Hence, systematic records of weed infestations can help support the understanding of what weed is found, where and when; changes in the area and density over time; and the effect of land management practices and weeds management programs. Generally, a proverb "*we can't manage what we can't measure*" justifies the importance of survey and assessment to develop a strategy for the control of a given species of weed. Hence, weed survey information is collected and compiled into summarized data showing the distribution and severity of the infestations. Therefore, this study was conducted to assess the infestation level, the spread, the impact it posed and possible courses of action for the control of *P. juliflora*.

Materials and Methods

Site description

Survey and assessment of Prosopis was conducted at Tendaho Sugar Estate in Afar Regional Estate sugar cane plantation in March, 2015/16. The site is found in the Rift Valley of Ethiopia at an altitude and longitude of 11^0 $30^{'}$ to 11^0 $50^{'}$ N and 40^0 $45^{'}$ to 41^0 $03^{'}$ E, respectively, with elevation ranging from 340 m to 365 m asl. The area has mean minimum and maximum temperature of 21.88 and 37.20 ^{0}C; respectively, with long-term average annual rainfall and relative humidity of 221.8 mm and 60.4%, respectively. The area has mean sunshine hours of 8.9 hr per day. The soil type of the area is predominantly fluvisol.

Assessment Methodology

A total of 32 sample fields were assessed based on their diversity of the infestation and land use categories. Diverse land use categories such as cultivated lands, irrigation canals, drainage lands, harvest roads, road sides', resident and office areas were assessed for infestation level by the Prosopis. Purposive sampling method was utilized to select fields to be assessed and to take samples from the selected fields. From each selected fields, five samples were taken by going in 'X' fashion inside a given field by taking samples in the range of 1X1($1m^2$) to 4x4m($16m^2$) area at each point depending on the accessibility and area of the infestation. Furthermore, the source for the infestation of the lands and ways of spread of the weed was investigated.

Twenty questionnaires dealing on the previous management practices with regard to Prosopis and other weeds, on the effect of Prosopis on agricultural operation were filled by the field foremen and the supervisors. Moreover, data on location, density per meter square, area of infestation, stage of weed, stage of crop, seed source for infestation, observable crop suppression due to the weed, economic impact of the weed such as machinery spare part break, damage of tyre, fuel tank of cars were recorded following standard procedure. The effect of the weed on quality and quantity of agricultural operation such as land preparation and furrow making were also recorded by the agricultural operation and plantation supervisors and formen. Density data collected from the field were

arranged in to five categories as adopted from IUCN, 2004 to visualize the infestations of each field (Table 1). Moreover, among the 32 sample fields assessed the fields falling in each category of infestation level were counted and put in percentage in order for the collected data to clearly reveal where to allocate ample resource to manage the weed and to decide on the management option to reduce the infestation.

Table 1. Category, coverage and density levels of Prosopis infestation (IUCN, 2004)

Category	Coverage	Density Level
Category 1	nil% coverage	Nil
Category 2	less than 1% coverage	Low density (or sparsely populated plants)
Category 3	>1 but less than 10% coverage	Low density (or isolated plants)
Category 4	>10 but less than 50% coverage	Low density to Medium
Category 5	> 50% coverage	Med to high density

Data Analysis

The collected data were summarized using descriptive and MS Excel so as to give a clear picture of the problem the weed imposes in the area.

Results and Discussion

Distribution and infestation level of the weed

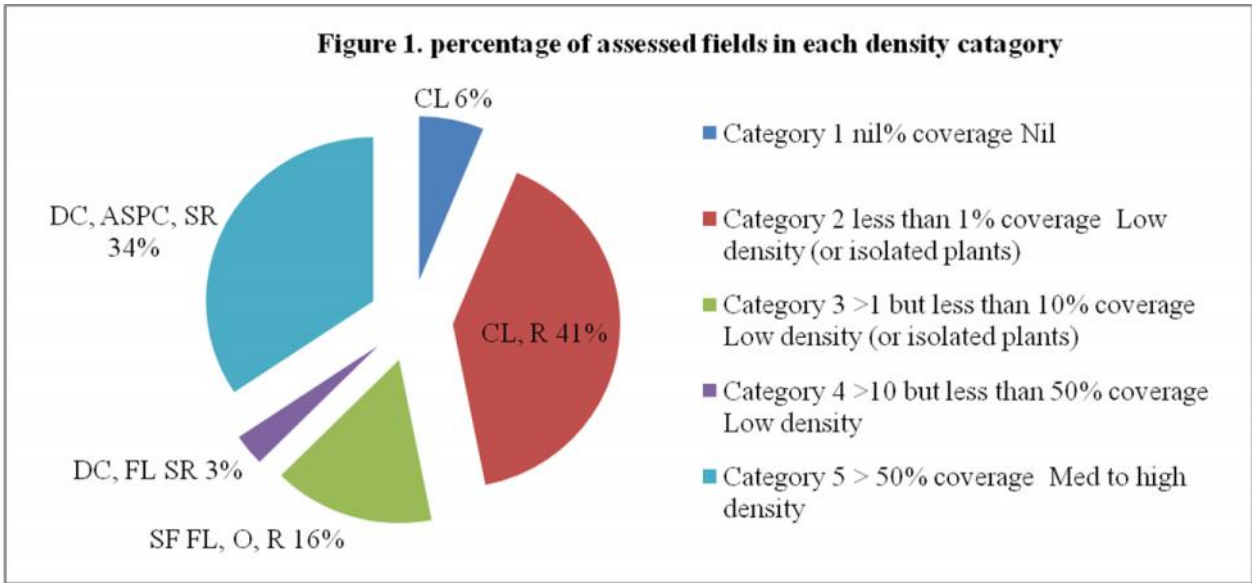
It was observed that *P. juliflora* was widely distributed in the area regardless of the land use categories. The weed was distributed over diverse land use categories such as cultivated lands, areas along irrigation canals, drainage lands, harvest roads sides', resident and office areas showing various infestation level in the range of nil to high infestation (Table 2). The infestation level was observed to be nil to 15 percent and grouped in the categories of 1-3 on cultivated lands and around residential areas and offices (Table 2). Nil infestation of Prosopis was observed in the sugar cane farms and their borders with their management accomplished according to Operation Standard. On the other hand, in farms with poor management practices scattered Prosopis plants with vigorous growth suppressing the sugar cane plants was observed.

High infestation level of the weed with 3-5 density category was observed in areas such as along irrigation canals, drainage lands, harvest roads and road sides' (Table 2). The average number of plants per sampled area ($16m^2$) varies in the range of 0-24. Lower number of plants per sampled area (0-4) was found in cultivated land, near residential areas and offices. While higher number of plants per sampled area (7.1-24) was observed on road sides (Table 2). At the side of irrigation canals, soils taken away from the water ways were not covered with other beneficial plants except along some of the water ways. The fertile soil taken away from water ways and seepage of water at their side favour the vigorous growth of the Prosopis forming un-penetrable mat and bear a lot of seed that could be re-allocated to other non- infested and cultivated areas. Moreover, drainage ditches around cultivated fields were also the place where this weed established very well and bear a lot of seed. In line with the above report, assessment made by Esther and Brent, 2005 in Kenya confirmed that the high infestation of the weed in the above aforementioned areas unlike cultivated lands.

Table 2. Distribution, infestation level and population per 16 meter square of Prosopis at Tendaho Sugar Project

No	Land use category	Category	Density level	Coverage	Average number of plants per 16 m^2
1	Cultivated land	1-3	nil% coverage - >1 but less than 10% coverage	Nil- Low density (or sparse plants)	0-4
2	Resident and office area	1-3	nil% coverage - >1 but less than 10% coverage	Nil- Low density (or isolated plants)	0-4
3	Drainage areas	3-5	>1 but less than 10% coverage - > 50% coverage	Low density (or isolated plants) - Med to high density	4.1-7
4	At the side of irrigation canals	3-5	>1 but less than 10% coverage - > 50% coverage	Low density (or isolated plants) - Med to high density	4.1-7
5	At the side of harvest roads	5	> 50% coverage	Med to high density	7.1-24

From the 32 fields assessed, 6% and 41% of the assessed fields had infestation level of nil % and less than 1% density category respectively (Figure 1) and these fields were sugar cane fields with different level of management; hence these types of fields require protection of entrance of the seed of the weed in to the fields with different disseminating agents and eradication of the existing one from the fields. On the other hand, 34% of the assessed areas had an infestation category of 5 with sever infestation of the weed and were areas that needed special attention and resource to reduce the infestation (Figure 1). Furthermore, these areas were a good source of seed for infestation of new areas also. This level of infestation was redundantly observed at the side of roads, drainage areas, and at the side of irrigation canals (Figure 1).

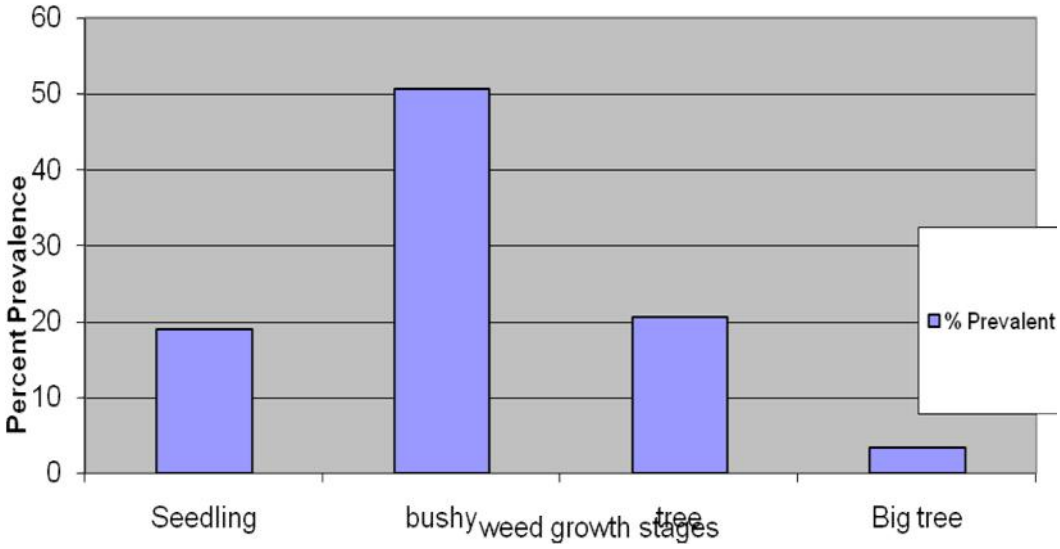


NB: CL=Cultivated lands, DC drainage areas, ASPC- At the side of primary irrigation canals, SR=Side of roads, SF=Side of farms O=near offices R= near residents

Dominant Growth and reproductive stages

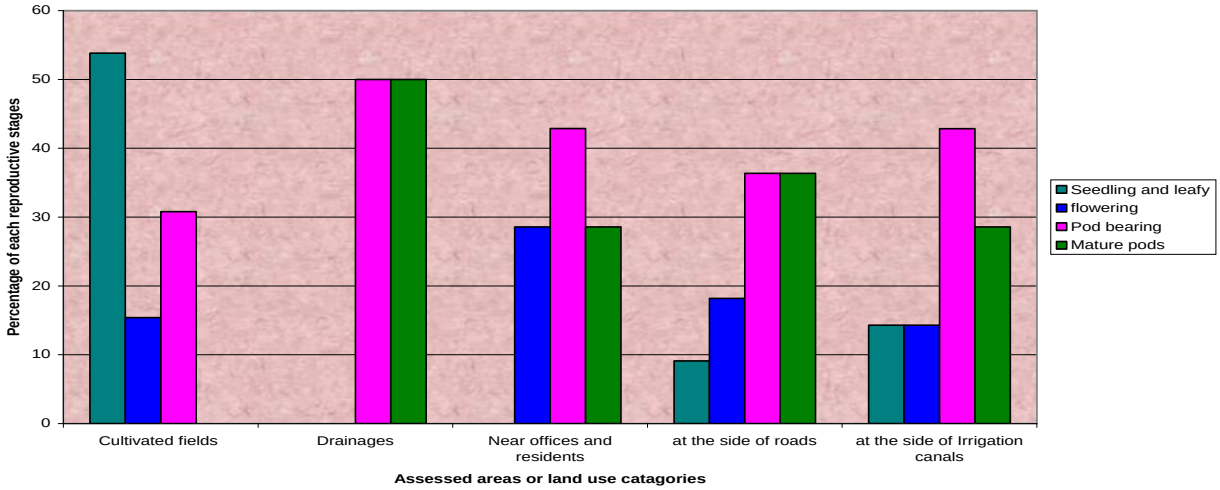
The growth and reproductive stages of a weed species must be taken into account when developing management strategies. Implementing control measures at the wrong time of year can significantly reduce both the short and long-term success of the management action, consequently increasing necessary investments. Hence, the growth and reproductive stage of Prosopis in each of the assessed fields were recorded. Accordingly, growth stage from seedling to big tree prevailed in the area (Figure 2) with 50.72% of the Prosopis were observed to be at bushy stage; followed by 20.56% of which tree growth stage (Figure 2). Only 3.31 percent of the infestation constitutes big tree growth stage (Figure 2). Therefore, the management strategy we design should compromise the growth stage of the weed.

Figure 2. Prevalence of each growth stages of prosopis in the assessed fields



With regard to the reproductive stage of the weed; all reproductive stages of the weed consisting seedling and leafy stage, flowering, pod bearing and mature pod stages were observed in isolation or in mixture in all assessed fields in different proportion. As a result, pod bearing and mature pods stage had prevailed predominantly in most of the assessed areas except in the cultivated fields (Figure 3). In most of the areas with high infestation of the weed pod bearing and mature pods predominated with great probability of the weeds future dispersal. High proportion of seedling and leafy stage was prevalent at cultivated fields (Figure 3). This was good indication of little intervention of management of the weed in areas other than sugarcane fields

Figure 3. Prevalence of each Reproductive stages in the assessed areas



Mechanisms of Reproduction and Dispersal of Prosopis

Prosopis reproduces primarily by seed. Flowers are pollinated by insects. The seed has a hard outer layer (exocarp) which requires damage to stimulate germination. It can also be propagated by cuttings of roots or stems. It is spread along water courses and run-off areas during periods of rain and then spreads laterally from these sites. Seed production is estimated at 630,000 to 980,000 seeds per mature tree per year (Felker, 1979, CABI, 2011). Prosopis seeds have a hard outer coating which requires physical, mechanical or chemical damage before the seed can absorb water and germinate. Fire, ingestion by animal or wet conditions can facilitate germination at any time of year, indicating that the timing of control and monitoring activities may need to be varied according to conditions and situations (Felker, 2003). In the area it was seen that a lot of matured pods dropped from the plant and cut by human being and left on the ground ready to be dispersed or grow at their placement (Figure 4). Hence, human being and farm machineries also play their own role in dispersing the seed. At the assessment, the workers were asked about the source of soil for levelling of new farms. They responded that soil was brought from upper Awash basin where soil has rich seed bank. Here also, no body investigated whether this soil come with Prosopis seed or not. Therefore, awareness creation work should be accomplished on workers working on land levelling not to bring Prosopis seed with the soil.

Figure 4. Matured pods of Prosopis in the area dropped from the weed, immediately grow to seedling with the available moisture

Control Methods and Protection of Dissemination utilized by the Sugar Estate for Prosopis

Generally, it was observed that cutting, burning, uprooting using machineries, hand weeding at early stage with other weeds, use of herbicide Round up, and replacing with other trees or plants were the control methods utilized in the area. However, these methods were not observed to control the weed sustainably. This is due to lack of continuity in the accomplishment of these activities, lack of monitoring for the dissemination of the weed, the weeds special adaptation in terms resisting the control measures applied and application of control practice at inappropriate stage of the weed eg. after seed bearing. Most of the plantation people asked on dissemination protection responded as no action was taken to protect further dissemination of the weed, as a result the weed successfully occupy every vacant spots (Table 3). Hence, much has to be done to protect the weed's dispersal to non-infested areas through preventing movement of human, animal, water and farm machineries with the weed's seed unknowingly. Besides the dispersal of the weed through irrigation water should be protected by the use of wire mesh at the places where weed's seed is suspected to enter with irrigation water.

Table 3. Methods of dissemination protection utilized by the Sugar Estate

Dissemination protection	Number of workers using the methods
Early stage removal	1
early stage control, burning after cutting	2
No protection	6
no answer	1

Control methods utilized for other weeds and their effect on Prosopis

According to the plantation personnel, hand weeding, use of chemical herbicides and tillage are weed control methods they utilized to control other weeds. However, in most of the cultivated fields visited the weed control practices were observed to be very weak as a result the weed infestation in the cultivated lands as well as in the border of the fields were very severe. Hence, the weed population bear seed enriching the soil seed bank which make the future weed controlling activities difficult.

Besides, it was observed that fields with appropriate management for other weeds and where the sugar cane population was vigorous and have no gappy spots, no Prosopis weed was observed (Figure 5). This indicated that Prosopis could have been controlled with weed management practices applied for other weeds; provided that proper implementation of the weed control practice and other cane managements were applied according to Standard Operation. Hence, proper weed management practice accomplished for other weed had also control Prosopis. Furthermore, the Prosopis infestation was very sever where weed management practices were not accomplished at drainage ditches, at the side of irrigation canals, at the side of harvest roads and on fallow lands.

Figure 5. Prosopis infestation in cultivated lands with different level of weed management

Cost associated with Prosopis infestation

Questioners filled with the land preparation and plantation department workers of the sugar project indicated that the weed had incurred extra machinery maintenance cost due to breakage of implements, fuel tanks and damage on tyre. Moreover, it was also tried to estimate the extra cost due to Prosopis. Hence, it was estimated that the amount of money ranges from 100,000ETB to 10% of the operation cost. Furthermore, the weed affects operations of land preparation greatly. It was understood from the workers that the weed affected their operation at all stages of land preparation both in quality by disturbing implements not to function properly and quantity by increasing the time required to accomplish the job. Hence, underground roots of the weed inside the field affect uniformity of furrow depth and spacing. In addition, the plantation incurred additional costs to repeatedly remove from the farm as it was deep rooted and difficult to uproot. Similar study by Wise *et al.* (2011) estimated that in South Africa US$109.1 million and US$76.6 million (US$1 = c. R7 in March 2011) would be needed to clear the invaded uplands and floodplains respectively. Clearing costs per hectare vary from US$13–534 depending on the densities of the infestations.

Negative impacts of the weed

As any type of weed the presence of Prosopis in sugar cane fields highly suppressed the crop through its competition for inputs like light, air and nutrients. Therefore, the sugar cane plants were observed to be stunted and stressed (Figure 5). On the other hand, its dense mat of population in some areas made the lands inaccessible for other use for instance for roads, pasture lands, agriculture and for other purpose. Besides, its thorny nature affected greatly health of human, domestic animals and vehicle tyres. Furthermore, some of the local communities described that the animals (goats, sheep, camels and cattles) eating the pods of the weeds faced problem of health and sometimes even die. The weed has also greatly interfered with infrastructures like electric lines and roads (Figure 6)

Figure 6. Some of the observed negative impacts of the weed.

Prosopis juliflora as an economic resource

In spite of its negative impact, the weed is observed to be utilized by the local communities for different purposes. The observed benefits are its utilization as a fence, fuel wood, for charcoal, for house construction, as a shade, for animal feed, as wind barrier against farm and soil conservation purposes (Figure 7). Similarly, Pasiecznik et al (2001) and Pasiecznik (1999) provide a comprehensive account of the economic uses of *Prosopis juliflora.*

Figure 7. Utilization of the weed for different purpose by the community.

Beneficial plant species potential possibility of replacing Prosopis in the future

It was observed that the weed was unable or highly suppressed to grow under beneficial trees species planted by the Estate previously. Those tree species are *Melia* species, *Moringa olifera* and others. This suppression was clearly prevailed in some of the assessed areas where by no or few Prosopis was prevalent under or in the vicinity the above mentioned trees and plants (Figure 8). Hence, planting those trees after cutting at the ground and burning should be part of the management of the weed in order to reduce its effect. Similarly, plant species such as *Cenchrus ciliarus, Chloris gayana , Chloris roxburghiana , Eragrostis superba , Leptochloa obtusiflora* and *Stylosanthes fruticosa are* potential herbs for replacing Prosopis serving as an animal feed (Mengistu 2010).

Figure 8. Beneficial plant species potential of replacing Prosopis weed

Conclusion and Recommendations

This assessment revealed that nil infestation of Prosopis was observed in the sugar cane farms and their borders with their management accomplished according to Operation Standard, while low to medium infestation of the weed with vigorous growth was observed on poorly managed fields. Hence, management of sugar cane fields and their borders according to Operation Standard is very crucial to minimize the infestation of the weed.

High infestation level of the weed in the range 3-5 density category was observed on lands such as along irrigation canals, drainage lands, lands left around the residents, harvest roads and road sides. The weed in these areas formed a dense and impenetrable mat making the land in accessible for any type of utilization. In general, the Sugar Estate should devote its valuable effort to control the weed sustainably by protecting the weed in the area from seed bearing and by preventing weed's seed entrance to the farm with water and soil. High Prosopis infestation in the boundaries of the Sugar Estate on communal lands and in the above aforementioned areas was observed to be severe and source of infestation for the entire farms. In this regard, management of the weed on communal lands with the active involvement of the communities, NGOs, GOs and other institutions is crucial for the sustainable management.

Borders of properly managed fields and areas around the residents were observed to be planted with some multipurpose adapted trees which functioned as a wind break for the farm and suppress the infestation of the Prosopis plants. Hence, it is important to give due attention in replacing vacant spaces in drainage areas and along irrigation canals with multipurpose and suppressive trees or plants like *Melia, Moringa olifera* and others in order to minimize the disastrous effect of the weed. Observation on the reproductive stage of Prosopis revealed that in most of the assessed fields with little intervention, the weed successfully produced seed which indicate the difficulty of future management intervention as a result of enrichment of the seed bank. Besides, it was observed that some of the offices, residents and experimental sites were fenced with this weed. However, regardless the importance of Prosopis as fence it will be source of infestation for other areas. Hence, replacing this weed with other beneficial plants adapted in the area will be crucial.

With respect to the involvement of stakeholders, Ethiopian Sugar Research and Training should take part in identifying environmentally-save, cost effective and efficient systemic herbicides that could be integrated with other control methods already utilized in the area so as to sustainably reduce the disastrous effect of the weed in the area. Furthermore, further studies should also be made in searching biological control (classical) for this weed as there was a literature on the availability of an insect that seriously affect the seed of this weed in other countries.

Finally, all efforts should be devoted, in utilizing all management options from prevention of un-infested areas from being infested through protecting seed dissemination, eradication of small infestation available in some areas to reduction of the infestation of highly infested areas before seed bearing is important. Moreover, all effort should be made in developing integrated weed management strategies through integration of different management practices such as chemical, cultural, mechanical, biological and replacement with beneficial plants is very crucial.

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