Carmine cochineal: fortune wasted in northern Ethiopia

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ABSTRACT

Carmine cochineal, *Dactylopius coccus* Costa, was introduced to northern Ethiopia to add considerable value to existing cactus pear vegetation that in places like the southern Tigray was becoming an invasive plant. It became an investment opportunity where Foodsafe, a Chilean company was involved. Company was granted 300 ha at the cactus pear infested plains of southern Tigray. Foodsafe was also expected to expand cochineal production through an outgrower scheme. It created employment opportunity for the locals and started exporting dried cochineal to Mexico and Germany bringing in foreign currency. As cactus pear grows in communal lands, conflict of interest arose and it polarised the community. The company was forcibly closed and it was a tragedy that a one time commercial insect became a full-fledged invasive insect pest. Attempts to contain the insect with mechanical and chemical control were not successful. So far more than 16,000 ha of cactus pear land was infested with carmine cochineal. 13,000 ton of dried cochineal could have been harvested in a single year, generated USD $52 million, and part of that money could have been used for its management.
Keywords: Cactus pear, *Dactylopius coccus*, useful insect, invasive pest, Africa.

INTRODUCTION

The carmine cochineal, *Dactylopius coccus* Costa, belongs to family *Dactylopidae* in the Order Hemiptera and is the only species reared for the purpose of carminic acid production (Rodriguez *et al.* 2002). Cochineal is the name of the insect and its pigment (Portillo and Vigueras, 2003). Cochineal was the most widely traded; next to gold and silver, the most valuable product of the Spanish Indies (Donkin, 1977). Females lay between 300-450 eggs from which nymphs emerge within one to two hours (Marin and Cisneros, 1977; Flores-Flores and Tekelenburg 1995). They insert their long stylets into the cactus tissue to feed. Nymphs take 3-4 months to mature depending on temperature (Marin and Cisneros, 1977; Moran and Cobby, 1979). Cochineal feeds on *Opuntia tormentosa* Salm-Dyck and *O. ficus-indica* (L.) Miller (De Lotto, 1974). *O. ficus-indica* (Figure 1) is the only suitable species found in Ethiopia.

Cactus pear (*O. ficus-indica*) originated and was domesticated in central Mexico (Griffith, 2004). Cactus pear, locally known as “beles” or “qulqual-baheri”, is therefore an introduction to Ethiopia. Cactus pear is believed to have been introduced to northern Ethiopia in 1848 by catholic missionaries (Strebel, 2010). The name beles was coined to cactus pear in eastern Tigray of northern Ethiopia. The name beles is not that specific to cactus pear because there is another plant known by the same name that belongs to the genus *Ficus* that has got edible fruits. Its common English name is “fig”. Cactus pear was introduced to the Spanish as *Ficus indica* or fig of the Indies referring to common use of fruit as food by native Americans of the West Indies (DeFelice, 2004).

Figure 1. Cladode and fruit of *Opuntia ficus-indica* from northern Ethiopia.

The name beles to mean fig might therefore been given by the Catholic missionaries. While, qulqual-baheri is very specific to cactus pear and the suffix baheri in Tigrigna language of northern Ethiopia means sea, refering to the fact that cactus pear has come from overseas. Similar namings for maize and faba bean as meshela-baheri and ater-baheri, respectively, indicate exotic sources. Maize originated in Mexico (Mercer and Wainwright, 2008) while faba bean is in the Near East, Iraq and Iran (Cubero, 1974).

Cactus pear is abundantly found in south Tigray, also found in eastern and southern parts of Ethiopia. Recently Habtu (2005) reported that Muslim pilgrimages from Mecca (Saudi Arabia) to have introduced cactus pear to the lowlands of southern Tigray in 1920. In Tigray *O. ficus-indica* is the only species found while in other parts of Ethiopia, *O. stricta* was reported from eastern Ethiopia. All these information indicate multiple introductions of the genus *Opuntia* to Ethiopia.

Once introduced, spread of cactus pear within the country should have been aided by birds, wild animals and humans themselves. This is evident from the fact that you can find cactus pear growing in mountain tips, inaccessible cliff and rocky mountains. Birds, baboons, monkeys and other wild animals eat fruits and drop the seeds anywhere with their feces. According to Mellink and Riojas-Lopez (2002), the cladodes and fruits are consumed by 89 species of vertebrates: nine species of reptiles, 26 species of birds and 54 species of mammals. Strebel (2010) in his work on cactus-farmers and goat-herders of the Buknaiti-Area (northern Ethiopia) in the 1970s described that the Erob people competed with the ape-population for the fruits of wild cactus pear stands.

The passage of the seeds through the digestive system of birds, wild animals and even humans should have helped their germination and success in their establishment in new areas. The hardiness and invasive nature of the plant should have helped it to survive and endure in the wild without the support of human beings. Cactus pear coverage in northern Ethiopia alone was 34,723 ha (Tesfay, 1994).

It should have taken years to accept cactus pear as a food plant, taking into consideration the traditional nature of rural northern Ethiopia. Probably, the Catholic missionaries that stayed long in Erob area should have spent a lot of energy, strength and time to convince people accept cactus pear as a food plant. The cactus pear plant itself had passed through several phases in its acceptance by the people in the North. In certain parts of the Tigray region it used to be called as the fruit of the poor. In other parts, it used to be a fruit that people would not eat in public. In the recent past, farmers used to call cactus pear "hinzi", in South Tigray meaning difficult to handle. In the 1990s, the Tigray region Bureau of Natural Resources considered cactus pear an invasive plant and wrote a circular that state cactus pear should not be planted on farm lands and this circular is still valid as there was no other official statement released by the same Bureau nullifying the previous decision.

Cactus pear utilization

Cactus pear fruits are eaten fresh by humans, cladodes or stems fed to cattle at times of feed shortage after spines are removed using fire and cactus stands as live fence to protect farm land or backyards from herbivores (Haile *et al.* 2000). Cactus pear production is however traditional with no improved orchard management. Cactus pear backyards are not spaced, prunned, thinned and fertilized. The only care people give to planted cactus pear is to protect them with stone fences from being eaten by herbivores. In some cases spinesless cactus pear planted in backyards are fenced by spiny cactus. Fruits are damaged during harvesting because of traditional equipments used (Habtu, 2005).

Cactus pear was a neglected plant and there was no research or extension support to cactus pear in the country. In 1997, however, an international workshop on "*Opuntia* in Ethiopia: State of Knowledge in *Opuntia* Research" was organized for the first time by University of Mekelle and University of Wiesbaden-Polytechnic Germany to encourage alternative uses and control measures (Mintesenot and Firew, 1997). The workshop recognized *Opuntia ficus-indica* as a very serious aggressor where thousands of hectares are invaded both on steep

mountain slopes and also in the fertile lowlands (Zimmermann, 1997). One of the workshop recommendations was introduction of the carmine cochineal (*Dactylopius coccus*) for the production of red dye as this may add considerable value to existing stands and also lessen the expansion of cactus pear to grazing lands and enclosures in southern Tigray. Other incentives for the promotion of cochineal production were the healthy conditions of the plants, a favourable climate and availability of cactus pear in most small farming communities (Haile *et al*. 2000). The aim of this paper is to address the current situation of carmine cochineal in northern Ethiopia.

METHODOLOGY

The methodology employed in the acquisition of the relevant information include secondary data from the Bureau of Agriculture and Rural Development of the Tigray region, the various cochineal control committies and a number of published sources. The primary information related to the developments concerning the conflict of interest at Hintallo-wejerat was obtained from key informant farmers and persons working for the Foodsafe company. An analysis of the situation was also delivered by the author as he had commensurate experience in the development and promotion of cochineal technology in Ethiopia.

RESULTS AND DISCUSSION

Carmine cochineal introduction

Following the workshop recommendations, Mekelle University implemented a project on cactus pear production and utilization in Ethiopia during 2002-2004 (Chipeta, 2010) financed by the Food and Agriculture Organization of the United Nations (FAO). In fact FAO was requested for support by the Ethiopian Federal Government and Tigray Regional Government. One component of the FAO project was the introduction of a carmine cochineal (*Dactylopius coccus*) that would be based primarily on the abundant cactus pear resources in southern Tigray. All requirements starting from pest risk analysis, quarantine, import permit, permit for experimental and final release for commercial use were pursued from the competent authorities (Tesfay, 2010). The performance of the carmine cochineal in the field was very encouraging and the insect was host specific (Tesfay, 2006). In Australia and South Africa *D. opuntiae* was introduced for the control of invasive cactus species like *Opuntia stricta* and *O. ficus-indica* (Githure *et al*. 1999; Volchansky *et al*. 1999). While in Brasil, *D. opuntiae* is the number one insect pest that limits productivity of *O. ficus-indica* (Lopes *et al*. 2009; Borges *et al*. 2013).

Linking carmine cochineal to markets

The introduction of the carmine cochineal to Ethiopia was mainly for export purposes because there was no knowledge about its use in Ethiopia. So companies that buy and multiply the insect were sought. A partner from the Plant Protection Research Institute of

South Africa, Dr. Helmuth Zimmermann, identified two companies: Roeper from Germany and Foodsafe from Chile that showed interest in cochineal production in Ethiopia (Tesfay, 2011). Both companies did visit the site and showed strong interest in carmine cochineal production. But only Foodsafe was able to present its letter of intent to the Tigray Regional Government and got a license in 2007. It immediately got a pledge 300 ha of land covered with cactus pear in southern Tigray (Figure 2), a tax exemption of 5 years and investment protection for about 10 years i.e. no other company will be involved in cochineal production without a prior consent of the company (Tesfay, 2011). The Tigray Agricultural Marketing and Promotion Agency, a wing of the Tigray Regional Government, helped Foodsafe with the facilitation and paper works required so that the company sets foot in a foreign country. Included in the letter of intent of Foodsafe was to provide a cochineal production training to farmers in the project area so that they will be involved in an outgrower scheme and sell their produce to the company at reasonable prices.

Development of cochineal nurseries at Raya-Valley (South Tigray)

The insect was multiplied to a limited extent at the experimental sites and the plan was for Foodsafe to entirely remove the insect to the nursery sites. This source was not enough for the planned area of production and Foodsafe was contemplating introduction of additional cochineal colonies from Chile. So the company started developing nurseries with insects collected from the experimental sites (Bustamante, 2008). The company also started shaping the wild growing cactus pear stands at the Fachagamma site of Raya-Azebo (Figure 2) so as to make it accessible for laborers during infesting and harvesting as cochineal production on existing cactus pear stands reduces cost of production.

New cactus plantations started by Foodsafe indicated the substantial value placed to the abundant but neglected cactus resource in the area. In a time span of 2-3 years the company developed 135 ha of the pledged 300 ha with new plantations of cactus pear that were infested with cochineals. Within a short period of time the company started harvesting carmine cochineals. Tigray Agricultural Marketing and Promotion Agency (TAMPA) supported by FAO initiated Tele Food project, trained and provided farm equipments to 80 farmers at Raya-Valley that were involved in cochineal production (Tesfay and Bustamante, 2010).

Similarly, the Tigray Regional Government through TAMPA requested the engineering capacity building project of the German Government (GTZ-Germany) for support in training and provision of some equipments to landless youth so that they get involved in cochineal production through an out grower scheme (Tesfay and Bustamante, 2010).

Foodsafe was an important partner in the projects by training farmers in cochineal production and harvesting. With GTZ support it was possible to train 380 farmers and was also provided with starter insects from Foodsafe to multiply them on the Maichew-Mehoni mountain chains on plots of land given to the youth by the local administration. Farmers were landless youth selected by the local administration to be organized into cooperative to take cochineal production as their livelihood.

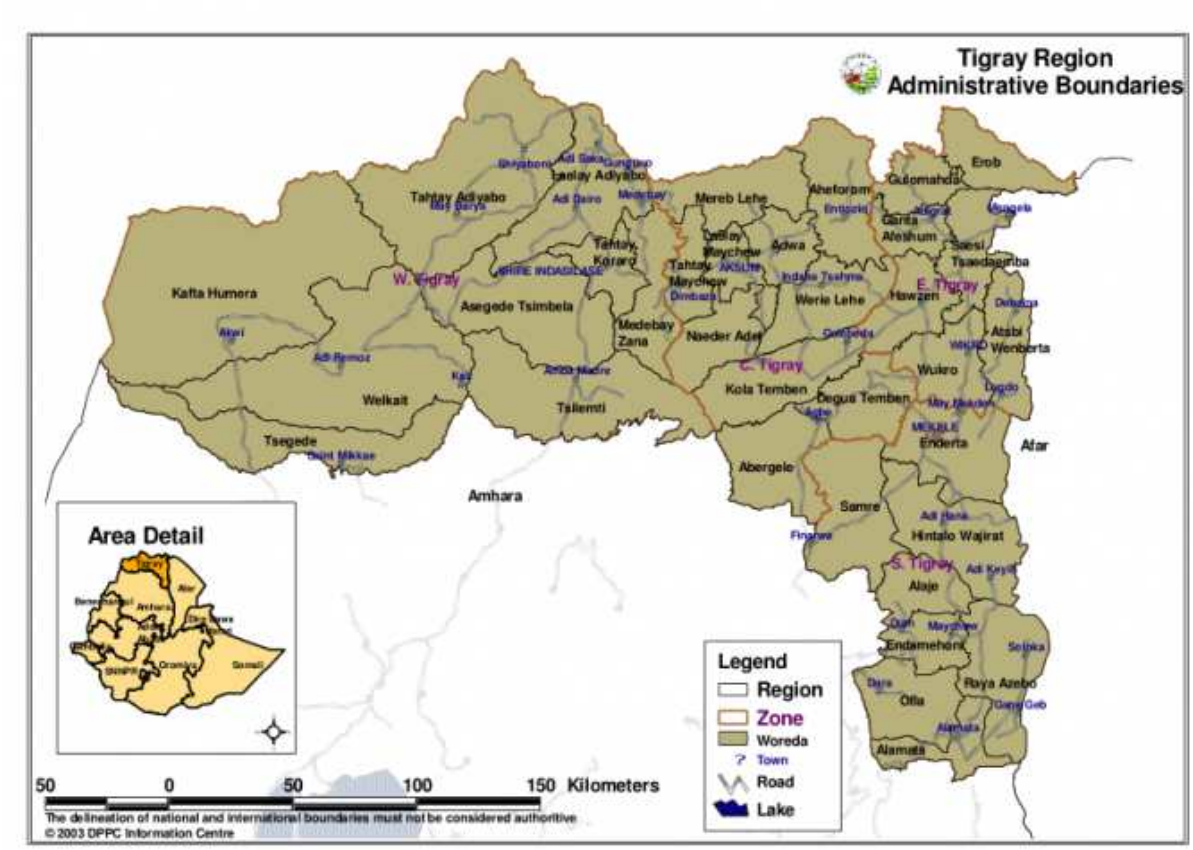

Figure 2. Map showing cochineal infested districts (Hintallo-Wejerat, Raya-Azebo, Endamehoni and Enderta) in the Tigray region (Source: http://reliefweb.int/map/ethiopia/ethiopia-tigray).

Benefits of the carmine cochineal business

The company started its first export of dried cochineal insects to Mexico in April 2009 (Bustamante, 2010). Mexico, the land of Aztecs and home of cactus pear and the carmine cochineal, has become an importer of cochineal. According to Miller (1976), the biological control of natural enemies over carmine cochineal in Mexico is very strong and frequently hold cochineal populations in check. Cochineal for Ethiopia became one of the items that the country earns hard currency. The carminic acid content of the cochineals produced in the Tigray region ranged from 21-23% (Tesfay and Bustamante, 2010) and was much higher than what was reported in the literature (Anonymous, 2014). The environmental conditions should have contributed to the higher carminic acid content of the cochineals produced in the Tigray region of northern Ethiopia, and according to Artesaga (1990), higher carminic acid is associated with higher phosphorus content of soils in the cactus pear growing areas.

Habtu *et al*. (2005) found highest phosphorus (8 fold) on dense cactus lands compared to arable lands in northern Ethiopia. The higher carminic acid content should have fetched acceptability in the market and higher prices.

The cochineal business created job opportunity for 32 full time workers and more than 136 casual labourers at pay rates of USD $2/day and 57 were women both young and old. They were also paid a bonus of USD $25-83.3/person/month and that would make a monthly gross income in the range of USD $71-130/person/month in the years 2007-2009, that was expected to increase over the years (Tesfay, 2011).

The cochineal based employment was something for the youth in a country where many people live on USD $1/day, job opportunities are scanty, and people also risk their lives crossing the red sea in search of illegal jobs in Arab countries. The company introduced and demonstrated a skill on the rearing and production of carmine cochineal to the area, much known for rain failures. Farmers were involved in cochineal production through an outgrower scheme and were selling their produce back to Foodsafe.

Opportunities to cochineal expansion

Cochineal insect was first introduced to the experimental sites at Tsehafti and Embachara areas of southern Tigray. It was taken further to *Fachagama* area for production on a commercial scale by Foodsafe Ethiopia. Environmental conditions at the experimental and commercial release sites were suitable to cochineal production as witnessed by the excellent adaptation and proliferation of the insect.

There was abundance of wild cactus outside of the arable lands and this resource was least utilized. Cactus pear in the wild was dominating indigenous trees, herbaceous and grass species and is a threat to biodiversity. According to a study by Habtu (2005), the average cover of ten dominant woody species in South Tigray declined as infestation of cactus increased and this would obviously signify the threat of cactus pear if expansion is not checked or utilized.

Farmers are also well aware of the fact that cactus suppresses and inhibits growth, occupies space and suffocates other plant species including grasses and field crops (Habtu, 2005). Cactus pear that farmers introduced into their farms as hedges was also encroaching to their farm lands and farmers spend a lot of energy or labor removing cactus bushes. The chains of mountains in Mehoni and Wejerat areas of southern Tigray are predominantly invaded by cactus (Figure 3) and while the cover may be good for arresting soil erosion and degradation, indigenous biodiversity is at risk (Tesfay and Bustamante, 2010).

With the coming of Foodsafe to Ethiopia, market opportunity for cochineal was created. Foodsafe had an office at Mekelle and was ready to purchase fresh or dried cochineal collected by farmers or other interest groups. There were many landless youth that took cochineal production as their business, besides the subsistence farmers considered cochineal production and harvesting on wild cactus as an off-farm income activity. Cochineal insect favours the dry period and become an ideal off-farm activity for farmers. As cochineal is an introduced insect, there are no natural enemies that can infest cochineal in Ethiopia. This was a very good opportunity for the expansion of the cochineal business in the region.

Figure 3. Cactus pear infested Maichew-Mehoni mountain chains in southern Tigray, Northern Ethiopia.

Dried cochineal insects were exported. With increase in harvest it was thought that the interest might shift to cochineal processing. Similarly, with the increased focus of the Ethiopian Government on utilizing the huge livestock resource (AACC, 2006), beef proceesing factories could come into the picture. According to some sources, beef industries consume about 75% of the cochineal produced in the world and rest is used by cosmetics, pharmaceuticals and liqour industries (Tesfay and Bustamante, 2010). For example Saba-Har, a small cottage industry in Addis Ababa, started using cochineal for dying silk clothes (Sabahar, 2014). Saba-Har, beneficiary of the African Growth and Opportunity Act (AGOA) of the United States Government that gives trade benefits to Sub-Saharan countries (Williams, 2014), exports its silken clothes to the USA.

Interest in cochineal production and harvesting

The cochineal business itself and the series of trainings delivered to farmers enabled communities to acquire knowledge on cochineal production. This knowledge combined with the already established market opportunity by Foodsafe encouraged the youth to spread cochineal to different places where there was cactus pear. The initial price for the fresh produce (cochineal insects) was USD $2/kg (Tesfay and Bustamante, 2010). The youth and the women showed strong interest in cochineal harvesting. They were not discouraged by the low price but were happy to get quick cash soon after they have harvested their produce from the communal lands. Middle men/women that collect the fresh cochineal from different areas and sell to Foodsafe helped facilitate the cochineal trade. Foodsafe increased the price of fresh cochineal insects from USD $2 to 6/kg (Tesfay and Bustamante, 2010). This increment

might be due to increased price of cochineal in the world market. However, there was no provision made for training or other supports by the government to the cochineal collectors and suppliers. Cochineal collectors were not recognized by the local government into sort of co-operatives and as a result they had no bargaining power in setting the price of the dried cochineal and were often exploited by the middlemen.

Cochineal become the latest source of foreign exchange earning for the country and the total amount of US dollars earned from the export of dried cochineal insects in a space of 10 months from a cochineal farm of 135 ha owned by the company and 100 ha wild cactus at Tsehafti area in South Tigray was USD $553,900 (Tesfay, 2011). This is based on information from Foodsafe and it does not include, however, the amount earned from export of cochineal in the months of May to September 2010.

Conflict of interest among community members

The conflict of interest among community members arose as the benefit from the cochineal business increased. The wild cactus plantation in South Tigray was on communal lands. Two groups were identified in the community. The young, the landless and women belonged to the first group that favored cochineal harvesting. This group was inspired by the quick income they generated from the cochineal harvesting and sale. They were not however trained and did not acquire the skill required to efficiently harvest cochineal without damaging the cactus stands. So the young and the women were cutting the cactus cladodes in order to harvest the cochineal and throw the cladodes on the ground after they harvested the cochineal insects.

The second group consists of the elderly and backed by the Coptic Church in the area. They believe the cochineal business is outside of their tradition or culture and would value their cactus for livestock feed and human food. This group had the backing of the local administration. This group was privileged in that they also enjoyed the support of a local Non-Governmental Organization (NGO) known as *Maheber-Wejerat,* which is an association of individuals that live in Mekelle city but were originally from the Wejerat; locality where the conflict of interest first arose.

The NGO was even threatening researchers that attempt to justify the benefits of the cochineal business. So this group had the upper hand because they are represented by the *Maheber-Wejerat* association and were always lobbying for the Regional Government support, so that the spread of the insect is checked. Because they had the support of the Church they were influential in forcing the community members to contribute money for their representative to travel to Mekelle and make their case about the spread of the insect to the Regional Government. Therefore it was possible to find dads and moms in the second group while their sons and daughters were in the first group.

Extent of the conflict

The conflict concerns to the right of use on a communal resource that is cactus pear. The conflict first involved taking hostage of Foodsafe company manager while on a cochineal

collecting mission at Wejerat area and was later on freed with the involvement of the Regional Government. Farmers from this community that collaborated with Foodsafe were prohibited from participation in community affairs. However the increased income of farmers who worked for Foodsafe became an incentive for others to be involved in cochineal harvesting and sale.

The young and women started harvesting and selling cochineal to Foodsafe at a nearby town of Mehoni. The elderly and church came up with a new idea that those involved in cochineal harvesting and sale will not get church services and are no more members of the Coptic Church. This information was conveyed to the community members during the Sunday church services. The cochineal issue divided members of the same family; while the young were involved in cochineal harvesting, the elderly were bound by the church decisions and were against the cochineal harvesting. Yet the family heads cannot influence their children probably because of the income.

Another possible reason could be because there were middlemen formed in the village that buy fresh cochineal, the young might be selling the fresh cochineal immediately after harvest without the knowledge of their families. Young men were also attracted from afar communities to collect and sell cochineal because the cactus is on communal land. So with increased intensity of the conflict, the young men who came from faraway places took the cochineal and introduced it to their cactus backyards. This way the cochineal spread became very fast in a space of few years.

As the church initiative is about to fail, the community came up with a new bylaw, to guard cactus communal lands and fining those involved in harvesting cochineal. They set up a schedule where every member of the community is assigned a date when they will be engaged in guarding the cochineal infested cactus lands. This was the worst part as they are about to reach the turning point. Because those assigned to guard were chasing the children and the young were running to escape capture and fining, some failed onto rocks and sustained wounds. Retribution as a tradition is deep rooted in the community and they were worried because they knew where they are heading as someone could die while escaping arrest by those guarding the cactus plantation. According to Brinkerhoff *et al*. (1988) within group conflict have adverse effects on social cohesion. So the new idea supported by bylaws was also destined to failure.

Cochineal really became a challenge to the community and community church leaders. The interest of the youth and also the spread of the cochineal became beyond control of the community. Members of the same community that were against cochineal harvesting and sale became themselves involved in the business after they observed an increase in the price of cochineal and also income of those involved in cochineal business. The community elders and church leaders, backed by the *Maheber-Wejerat* association, finally demanded that the market link be disconnected *i.e.* the company be closed. The *Maheber-Wejerat* association complained about false claims; livestock bleed to death after eating cochineal infested

cladodes and the cochineal insect spread to indigenous vegetation while it is known that humans eat food and take drinks colored with cochineal and is host specific to the genus *Opuntia*.

Exacerbating factors

Maheber-Wojerat association was pivotal in the movement against cochineal. In fact they were the ones that promote evicting the company in an attempt to bridge the polarization of the community members. One can assume that *Maheber-Wejerat* might have other interests. According to Tarekegne (2007), the land of Wejerat was an autonomous political entity until the 1943 peasant uprising partly in protest of the political imposition of the central government against their traditional system of local governance, and prior to 1993 Wejerat had a status of woreda adminsitration centered at Debub (Bahri-Hatsey) (Tarekegne, 2007). So *Maheber-Wejerat* association might have feeling of resentment and often times people resort to other means of expressing their disatisfaction with the local governance and cochineal became one even though the people in Wejerat area were finally involved in cochineal harvesting and sale.

Another aggravating issue working behind the scene concerns Adigrat area, where farmers maintain cactus backyards and consider it a lifeline for the periods of June to August. They were worried that the insect will spread and devastate their orchards (Shushay, 2014); a feeling shared by the Tigray Regional Government. Some individuals might be in collusion with the *Maheber-Wejerat* association cheering them to put their complaints to the Regional Government. The *Maheber-Wejerat* association thought the government is concerned about its spread to Adigrat area while doing nothing to control cochineal at Wejerat.

The last factor was related to land. Foodsafe signed an agreement with the Regional Government granting them 300 ha at Mehoni plain. Foodsafe developed 135 ha and were requesting for the remaining 165 ha. The local adminstration had already allotted nearby land to other investors and there was no available land nearby. The local adminstration was suggesting to give Foodsafe land on faraway places with cactus pear or move them to other less fertile areas which Foodsafe refused on grounds that the new land was not fertile and has no underground water.

Regional Government response

The first response of the Regional Government of Tigray in 2009 to the perceived conflict was to limit the insect to the investment areas. The government advised Foodsafe to plant windbreak trees to prevent spread of the insect to nearby areas and also develop boreholes for cultivation of cactus pear. With continued expansion of the cochineal insect and increased pressure from the community, however the government in 2010 decided to implement an insecticide spray program with free labor from the communities in Wejerat area. Insecticides sprayed included Dimethoate 40 EC, Fenitrothion 50 EC and Malathion. In certain spots insecticide suppressed cochineal population but in others insecticidal sprays did not mitigated the infestation. Insecticide sprays did not worked partly because farmers were not supervised

by professionals and one can doubt if it was properly applied. Farmers were not happy with the insecticide application because of its effect on bees. Insecticide use is repetitive in nature to be effective. Cactus stand was dense, impenetrable and inaccessible for insecticidal sprays. Ensuring complete coverage of cladode with insecticides was also difficult. Rugged terrains and incised river valleys were natural barriers that limited effectiveness of insecticide control methods. These factors created favorable condition for the cochineal to resurge and destroy more cacti.

As the complaint from the community and the association intensified combined with the exacerbating factors mentioned above, the Regional Government revoked the license it gave to Foodsafe and closed their farm in 17 December 2010 (TBOARD, 2010). In 2011 the Regional Government organized a team that worked on an action plan for cochineal control (CCC 2011). The action plan included awareness raising workshops to the community, trainings on cochineal biology and identification to extension agents and possible control options. Present in the awareness raising workshops were Woreda administrators, community representatives, NGOs from cochineal infested and non-infested areas. Control options focused on mechanical including cutting cochineal infested cactus and piling it, burning and burying cochineal infested cactus (Figure 4).

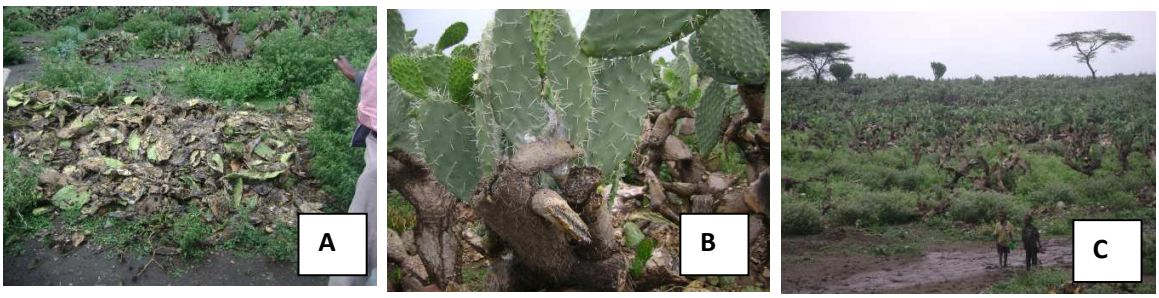

Figure 4. Cut and chopped cochineal infested cactus pear (A) and re-infested cladodes (B) at Raya-Azebo district (C).

For areas not infested, farmers were trained so that they do not take cochineal infested cladodes from one place to another and report the first sighting of the insect in their localities to the local authorities for immediate action.

However community members from Wejerat area, severely cochineal infested area, were not satisfied with action plans and were pessimistic about the effectiveness of the control options and were of the opinion that cochineal cannot be eradicated through mechanical and chemical means. Communities were mobilized for the mechanical control campaigns. In the severely infested areas, the communities failed to collaborate with the local administration while they resisted use of insecticides because of its negative impact on bees and livestock. Large cochineal infested areas combined with the reluctance of the communities to engage in mechanical control and the campaign nature of the control operation, it was in no way near to

attempt let alone to control the spread of the insect. The operation was only executed for one season and the extension system did not pick it up and consider it as a routine activity. Soon cochineal became a contraband item where people harvest it unseen from others and sell it to unidentified middlemen. Isuzu truck loads of dried cochineal transported at night were caught by police. Law enforcement agents were puzzled on how to treat the cochineal trade and later set the men free because the legal system they thought had no premise to prosecute people involved in cochineal trade that used to be legal. The loads of the Isuzu trucks originated to the areas where the communities refused any form of control intervention: be it chemical or mechanical. One can question if entire communities that were against insecticidal spray and refused to participate in control exercises do have real interest in cochineal eradication. It was absurd because it was these communities that spearheaded resistance against the cochineal business.

Unsuccessful by the control exercises of 2010-2011, the Regional Government again formed team of experts to work on a detailed action plan for cochineal control in 2012. This time the team took stock of the challenges and strengths of the past efforts (TBOARD, 2010).

Challenges identified include:

1) Discontinuation of the operation by the woreda office of agriculture without making follow-up plans.
2) Stand of certain communities that cochineal cannot be eradicated by mechanical and chemical control.
3) Communities against cutting of their cactus backyard and fences.
4) Lack of systemic insecticides for cochineal control.
5) Hilly and incised-river valleys not suitable for mechanical control.
6) Interest of the youth in cochineal business and taking cochineal to new areas.
7) Lack of dedication to engage in cochineal control starting from farmer to highest local administration official.
8) Politicizing the cochineal issue: government was not giving attention to cochineal infested areas.
9) Too much focus on mechanical control and lack of cutting and digging tools and protective devices.

Strengths:

1) Cutting and exposing cactus to the sun proved good in controlling cochineal.
2) In certain spots where chemicals were properly applied improvements were seen.
3) Greater community mobilization at Mekelle city that made significant control exercise.
4) Revoking investor license considered to have positive impact as it discouraged the youth from harvesting.
5) Workshops conducted and FM radio broadcasts did raise awareness of communities and commitments.
6) Communities at Raya-Azebo and Mekelle city were confident that mechanical control reduced cochineal infestation.

7) Cochineal control committees set up at regional, zonal and district levels positively impacted the operation as technical and financial problems were immediately brought to the attention of decision makers.
8) Good level of coordination among sectors of the Regional Government was observed.

So in 2012 a revised cochineal control plan for the short and long term was prepared. The short-term recommendations (CCC, 2012) include:
1) Increase awareness and provide information through workshops, technical trainings, media, etc.
2) Strengthen existing institutional set-ups defining roles and responsibilities.
3) Create legal premise for contraband cochineal trade.
4) Strengthen regional quarantine to limit movement of infested cladodes to new areas.
5) Seek support from the Federal Government, non-governmental organizations and FAO.
6) Mobilize communities for further mechanical control campaign.
7) Conduct quick surveys to determine area of infested cactus.

For the long term, the need to embark on a cochineal control research program at universities and research institutes on biology of the carmine cochineal, identifying suitable and environmental friendly insecticides, biological control agents and their introduction, sterile insect technique, etc., were suggested.

In 2012, mechanical control with community labor was the targeted control exercise. The area treated with mechanical control through mass mobilization of communities is presented in Table 1. The total area infested with carmine cochineal was about 16,255 ha *i.e.* half of the area under cactus pear in Tigray. It was only possible to clear 9.3% of the area and new cladodes that come out of the stool in the next season became infested with cochineal from nearby areas. Mechanical control with human labor might work for a small farm and not for an infestation of this scale on rugged and mountainous. So the need to look for other options that will specifically target cochineal without harming the cactus pear and the environment was imperative.

Efforts to control cochineal with chemical and mechanical control options during the last five years were a failure. Planned activities were perhaps either not fully implemented or were not efficient as a result of which cochineal kept on expanding to new areas and cactus fruit and feed production was significantly affected. Therefore, the Tigray Regional Government established a new national taskforce consisted of professionals from the Ethiopian Institute of Agricultural Research (EIAR), Tigray Agricultural Research Institute (TARI), Food and Agriculture Organization (FAO) and the Ethiopian Science and Technology Ministry, Mekelle University and the Tigray Science and Technology Agency to come up with possible solutions. Recommendations were broadly categorized for cochineal uninfested zones and infested areas. Detailed activities (not included in this paper) were formulated under each recommendation and the report was submitted to the Regional Government.

Table 1. Area cleared of cochineal with mechanical control in the Tigray region of northern Ethiopia, 2012.

	Woreda (District)	Area infested (ha)	Area cleared of infested cactus (ha)	% controlled
1	Endamehoni	1,600.00	655.00	40.9
2	Raya-Azebo	3,415.00	276.00	8.1
3	Amba-Alaje	161.25	45.00	27.8
4	Hintalo-wajerat	1,0662.00	484.00	4.5
5	Mekelle city	208.00	39.00	18.7
6	Enderta	200.00	0.00	0.0
7	Degua-tembein	10.00	9.00	85.0
	total	16,255.25	1506.42	9.3

Source: TBOARD, 2012.

Recommendations for uninfested/free zones include:

1) Establishing taskforce responsible for monitoring cochineal incidence and eradication if the insect is detected (in the buffered zone),
2) Establishing intra-regional quarantine (enforcement) to limit the movement of cactus planting materials, fruits and containers from infested to new areas,
3) Establishing/strengthening regional plant and animal quarantine offices, plant health clinic,
4) Creating awareness about the undesirable impact of cochineals through training, distribution of brochures and leaflets, and mass media,
5) Modernizing cactus production and marketing system, and
6) Delineate a buffer zone for non-infested area.

Recommendations for infested cactus in homestead and fences include:

1) Training of farmers with mechanical control measures (flaming, cutting, chopping, burying) as well as sanitary measures,
2) Introduction of judicious use of insecticides on cactus for the control of cochineal,
3) Improving or changing the existing cactus production and handling systems to increase productivity of cactus,
4) Introduction of integrated pest management system, and
5) Enact regulatory framework that would enable/enforce individual farmers to keep their homestead cactus free from cochineal.

Separate set of recommendation for cochineal infested grazing and forested areas include:

1) Biological control: Introduction, evaluation and release of natural enemies of cochineal,
2) Applying mechanical control measures in highly infested area,
3) Limit movement of livestock and human from infested to none infested areas,
4) Rehabilitation efforts for devastated localities e.g Tsehafti (provision of animal feed, safety net program), and

5) Supervised insecticide application in accessible areas.

On the basis of these recommendations, the Regional Government approached the FAO regional office for eastern Africa for support in the control of cochineal. But it would be difficult for FAO to participate in the control of a commercial insect that it promoted its introduction and utilization.

Missed benefits

The total infested area by carmine cochineal according to the Tigray Bureau of Agriculture and Natural Resources is 16,255.3 ha. The highest infested woreda was the Hintalo-Wejerat and followed by Raya-Azebo. The average dried cochineal yield in Chile was 336 kg/ha while in it was 265 kg/ha in Peru (Tesfay and Bustamante, 2010). Cactus plantation in Peru is similar to that of Tigray and practically no care is given to cactus. So taking the Peru production model as a benchmark, 4,307.6 tons of dried cochineal could have been harvested in one season. Three harvests per year were possible in Tigray and that would give 12,922.9 tons dried cochineal. When sold at a fresh cochineal price of USD $4/kg, $51'691,695/year could have been obtained but missed (Table 2).

Table 2. Expected yield and revenue from cochineal, northern Ethiopia (2014).

	Woreda (District)	Infested area (ha)	Expected cochineal yield (265 kg/ha/year)	Expected USD $/year
1	Endamehoni	1,600.00	1'272,000.00	5'088,000.00
2	Raya-Azebo	3,414.50	2'714,527.50	10'858,110.00
3	Amba-Alaje	161.25	128,193.75	512,775.00
4	Hintalo-Wajerat	10,662.00	8'476,290.00	3'390,5160.00
5	Mekelle city	207.50	164,962.50	659,850.00
6	Enderta	200.00	159,000.00	636,000.00
7	Degua-Tembein	10.00	7,950.00	31,800.00
	Total	16,255.25	12'922,923.75	51'691,695.00

CONCLUSIONS

Cactus pear has become an invasive plant in northern Ethiopia. Though fruits are harvested and used as food, it is not cultivated. People harvest fruits from the wild. There were several initiatives to improve production and utilization. Most significant was that of FAO for they introduced improved forage use, orchard practices, cactus-based food processing techniques and carmine cochineal.

Carmine cochineal was a world known commercial insect cultivated for the production of carminic acid, a pigment used in the production of carmine; a colourant applied in food, liquor, pharmaceuitical and textile industries. Carmine cochineal was introduced to Ethiopia to add value to an abundant but underutilized resource, cactus pear. It was a legal commodity where

investment from foreign sources were sought and found. It was cultivated in southern Tigray and interested youth spread the insect to different places. Conflict of interest arose and combined with certain exacerbating factors, the cochineal investment was shut down thus transforming the once commercial insect into a full-fledged pest.

More than 16,000 ha of land is now infested with cochineal. Mechanical and chemical control so far employed were ineffective. More than 12,900 ton/year of dried cochineal could have been harvested and that could have fetched about USD $52'000,000. While the spread of the cochineal could have been lessened by frequent harvesting of the insect, money generated from the sale of cochineal itself might have financed its long-term management programs including the search and introduction of biological control agents from Amercia. The progress as regards the control of spread or future utilization of the carmine cochineal also need to be followed up and documented.

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