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Introduction of carmine cochineal to Northern Ethiopia, Current status of infestation on Cactus Pear, and Control Measures

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Abstract
The importance of cactus pear (Opuntia ficus indica) to the arid environment made it famous in Tigray, Northern Ethiopia, as source of food and feed, source of income and used as soil and water conservation plant. In some parts of Tigray, it becomes a substitute of staple diet demand of the community for four to five months serving as a life-saving crop to humans and animals. Cactus pear comprises about 25% of rural households' income. It has been neglected in research and development for a long time. Only recently, there are some development works on expansion of plantation, diversification of utilizations and establishment of research institutions. However, currently the plant is suffering from attack of an exotic insect pest, Cochineal (Dactylopius coccus), since 2011, which was introduced for the purpose of carmine production. Infestation by carmine cochineal increased from 3.8 ha in 2011 to 75000 ha in 2019 which indicate that the infestation is expanding at an alarming rate. This review article deals with the introduction of carmine cochineal to Tigray, its consequences in terms of status of infestation, control methods, production status and prospects on the contribution of cactus pear for sustainable agricultural production in the region.

Keywords: Carmine cochineal, Dactylopius coccus, cactus pear, control strategies

1. Introduction
Cactus pear (*Opuntia* species), in the family Cactaceae, also locally known as "Beles" or "Qulqal Bahri", was introduced to Ethiopia between 1848 and 1920 (Habtu 2005) [7]. The plant is widely distributed in the arid and semi-arid regions of the country; especially in Eastern and Southern zones of Tigray Regional State, Ethiopia. Interest in cactus pear as food and feed has increased in the region due to its drought resistance, high biomass yield, high palatability and tolerance to salinity (Barbera 1995) [1]. Stintzing and Carle (2005) [10] described cactus pear as a "*miracle plant, dromedary of the vegetation world, and the bank of life"* as it can contribute to livelihoods of rural populations in dry areas. Therefore, cultivation of the plant may assume greater agricultural importance in dry areas since a larger part of the land is destined to become arid or semi-arid due to climate change (Snyman 2006 [9] cited in Gebremeskel *et al.* 2013) [6]. Almost all rural communities of Eastern zone of Tigray and some part of Central Tigray use cactus as staple food for about four months and as cash crop (Brutsch 1997) [2]. Cactus pear has become an integral part of the culture and economy of Tigray and is utilized in many ways although not as a vegetable nor is processed much showing that the level of utilization needs to be improved and researched (Gebremeskel *et al.* 2013) [6]. The cactus industry in Tigray Regional State is facing several challenges in both production and marketing aspects. Some of the production constraints include backward production system because of lack of skills and knowledge in the production and management practices, inadequate research and extension support, low absorption of modern technology, inadequate budgetary allocation, reducing effects of extension services, limited linkages among value chain actors, absence of developed collection and marketing centers, limited use of cactus to the fruit only, improper harvesting and harvest handling; poor packaging, sorting, and processing which do not add value to the products and do not increase the shelf life and safety of the products, seasonality of production and poor perception on input like fertilizer, irrigation, seed, and infestation by insect pests are mentioned. Particularly, the intentional introduction of an insect known as carmine cochineal (*Dactylopius coccus* Costa, Hemiptera: Dactylopidae) in 2011 to produce carminic acid severely decreases the production and productivity of the crop. *D. coccus* aggressively disseminated and destroyed thousands of hectares of cactus pear in just few years period because of favorable climatic condition (long dry period), abundant cactus vegetation, absence of natural enemies, absence of local quarantine, and lack of adequate control methods. The scale of invasion by the insect has been so severe that there are areas that no more produce cactus pear fruit and no more serve as sources of livestock feed. In some localities, the infestation has led to sever soil erosion in areas that used to be covered by cactus pear. As a result, the insect has been labeled as "*a threat to cactus pear production in Tigray region*" which has around 360,000 hectares of cactus plantations (Brutsch 1997) [2] of which half are managed on farms. Hence, this review article deals with the introduction of carmine cochineal to Tigray, its consequences in terms of status of infestation, control methods, production status and

prospects on the contribution of cactus pear for sustainable agricultural production in arid and semi-arid areas of the region.

2. Methodology

Attainment of the pertinent information for this review article was through collection of secondary data from published and unpublished sources. Besides, primary information was collected through key informant discussion, field observations and practical experiences.

3. Importance and productivity of Cactus Pear in Tigray

In Tigray Region, Northern Ethiopia, cactus pear is adapted perfectly to arid zones that are characterized by erratic rainfall, drought and poor soils subject to erosion (Brutsch 1997, Gilbertese *et al*. 2013) [2]. In the region, typically, There are three main production systems of cactus: 1) Wild Beles communities; 2) Family orchards; and 3) intensive commercial plantations. In times of drought, cactus pear serves as lifesaving crop for both humans and animals. Generally, there is increasing interest in cactus pear for the important role it plays and is likely to contribute for the success of sustainable agricultural systems in arid and semi-arid zones. Cactus pear is a valuable natural resource, which in many countries is yet underutilized. Regardless, it contributes to the food security of populations in agriculturally marginalized areas. It can grow on shallow soils with little soil (Fig. 1) indicating its` importance for biomass production in marginal lands with marginal climatic conditions. Tigray region has around 360,000 hectares of cactus plantations of which half are managed on farms (Brutsch 1997) [2]. The hardy plant can thrive despite degraded soils and hot temperatures (FAO 2017) [4].

Fig 1: Beles growing on rock with little shallow soil, Adigrat, 2018

In some parts, it is a source of diet for four to five months serving as a life-saving crop to both humans and livestock and around two million people depend on Beles directly or indirectly (CSA 2007, unpublished) [3], especially those are found in the production belt (Fig. 2). Cactus pear also plays a significant role as a source of nectar and pollen for bees, serves as live fence and creates employment opportunities. Cactus pear is, therefore, economically and environmentally important and a wonder plant for the community of Tigray where 80.5% of the population lives in rural areas, mostly at subsistence level and the production and productivity from agriculture practices is low because of multiple factors such as small land holding per household, mostly degraded and less fertile soil, and low and erratic rainfall. Moreover, recently, the commercialization of products from different parts of the plant for different purposes is growing in the region. The annual Cactus pear fruit production in the Tigray region reaches 48,300 tons while the productivity is about 6.7 tonsha^{-} of fruit. The contribution to household income accounts to 25%. The Cactus pear yield per hectare in the Tigray region, as compared to the productivity of other crops and related income sources in areas where Cactus pear production is well established, is quite low. For example, the average fruit harvested from a hectare in Argentina is 23.4 tons (Felker and Guevara 2001).

Table 1: Share of income from Cactus pear compared to other crops in growing areas

No	Income Components	Sample Growing areas In Tigray						%
		H/Selam	Mesebo	Kihen	Negash	Belesa	K/Keren	
1	Crops	688	8400	1170	833	1203	163	21
2	Livestock	2023	5700	1440	654	715	715	19
3	Cow dung	0	350	0	0	0	0	1
4	Cactus pear	1470	250	1080	1150	1800	533	25
5	Straw	0	0	0	0		220	0
6	Eucalyptus	0	825	0	0	2063	350	5
7	Off-farm	0	8800	0	0	2063	0	16
8	Psnp	1350	0	230	471	587	1457	7
	Total	5531	24325	12920	3109	6868	3438	

Source: UNIDO (2012, unpublished data)

The utilization and diversity of Beles products is very Limited and focuses only on the fruit for food and the pad for animal feed though diverse products can be produced from cactus pear, ranging from livestock feed to human food, cosmetics and medicinal to different drinks.

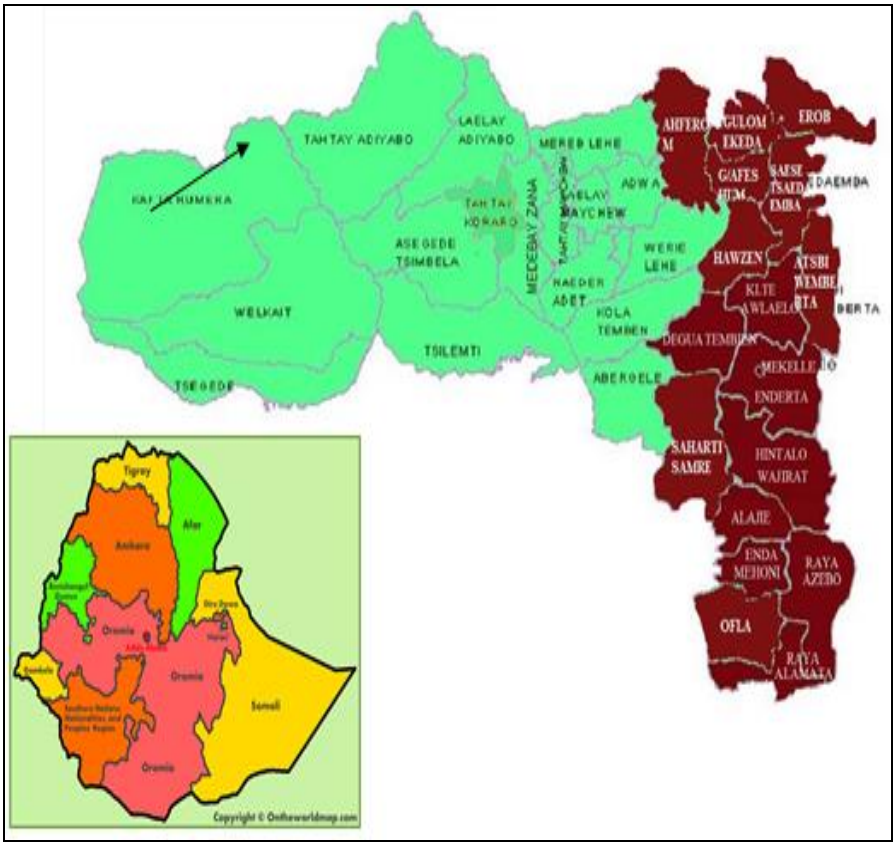

Fig 2: Cactus coverage in Tigray región, Ethiopia indicated by the Brown color

4. The Intention of Carmine Cochineal Introduction to Tigray and the unintended outcome as a devastating insect pest

The introduction of carmine cochineal (Dactylopiuscoccus) was supported by the FAO project hosted by Mekele University. Once introduced, the cochineal insects were kept in partly conditioned glass house. The permission for field release was obtained from federal ministry of agricultural and rural development. Accordingly, the insect was released at three locations namely Tsehefti area of Wojerat, Embachera area of Mochoni and Endaeyesus campus of Mekele University on the 12th September 2004. The performance of the insect in the field of the insect was host specific which means it only eats cactus (Tesfay *et al.* 2006) [14]. The carmine cochineal insect was then allowed to multiply at the inoculation sites of Endayesuscompus, Tsehafti and Mechoni areas were the insect was originally introduced for experimental release (Tesfay 2015) [13]. However, the insect has dispersed out of the experimental site where purposely introduced for the purpose of carmine production to many areas of cactus pear production. Currently the cactus pear production is suffering from the attack of *D. coccus* and the area coverage by cactus pear significantly reduced due to the fast spread of the insect pest in less than a decade as shown in Table 2. Infestation increased from 3.8 ha to 75000 ha in both wild and private plantations which indicate that the insect is expanding at an alarming rate (Table 2 and Fig. 3).

The number of districts and areas (in hectare) affected by the *D. coccus* has increased year after year. Favorable climatic condition such as long dry period and abundance of cactus vegetation in wild and dense, absence of natural enemies and in effective local pest quarantine and control aggravated the colonization (Cochineal control committee 2018, unpublished data). The main spread is by animals and humans intentionally and unintentionally. Tesfay (2015) [13] stated that there were many landless youths 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. Though the carmine production is banned temporarily by the regional government due to its rapid and vast infestation which affects the total cactus production, still it is a threat insect pest in the main cactus pear production zones of the region. It is also controversy that the introduction had technical limitations on predicting the impact of the insect overall cactus in Tigray. Consideration of cactus as weed in lowlands of Tigray could be considered also as misleading or exaggerated conclusion, which led to search of this biological enemy of cactus (cochineal). Despite very serious invasions of *O. ficus-indica* in the lowlands of Tigray, Ethiopia, it was decided not to resort to any biological control in view of the agricultural importance of this plant in the highlands where it is less invasive (Behailu and Tegegne 1997 cited in Zimmermann and Olckers 2003).

Table 2: Trend of D. coccus infestation in terms of number of Woredas, Kebeles and area coverage

Years	Number of Woredas	Number of Kebeles	Area in hectar
2011	4	17	3,805
2012			NA
2013	5	24	11,831
2014	8	59	24,825
2015		66	31,184
2016	12	95	60,059
2017	14	137	64,824
2018	14	139	75,790

Source: Cochineal Control Committee (2018, Unpublished data)
NA: Data not available

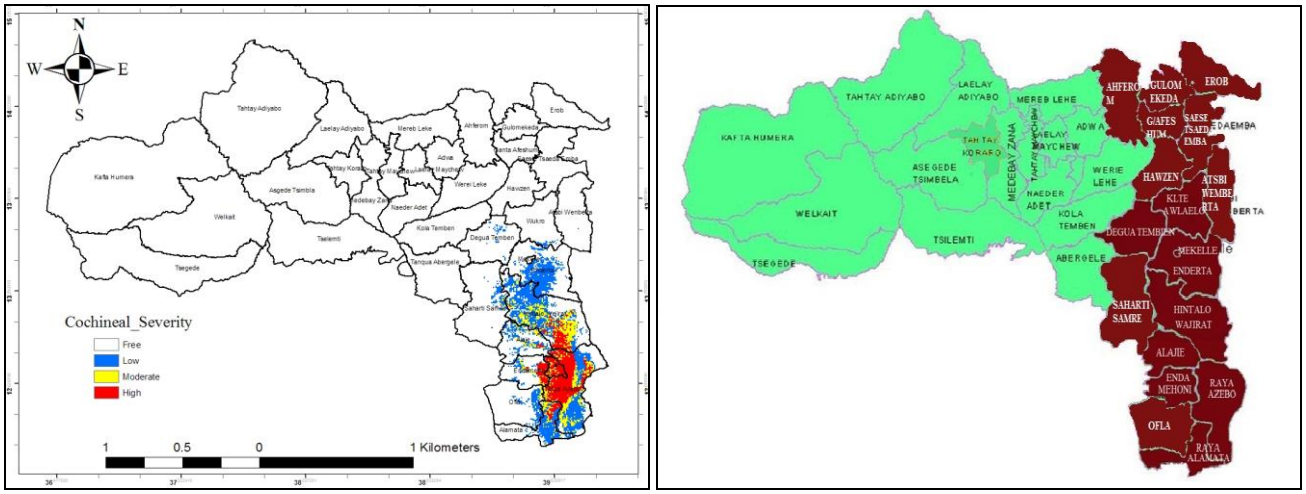

Fig 3: Image of cochineal expansion (left) compared to the overall cactus coverage (right)

Cochineal insect favors 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 (Tesfay 2015) [13]. This is why it is spread to 11 woredas and 79 kebelles.

Fig 4: Sever damage of cochineal on Bels in Hintalo Wajirat, Southern Tigray

As the above (figure 4) shows the plantation is severely affected and going to die (the left) and the mountainous area become bared which is exposed to soil erosion. This soil erosion also resulted in arable land damage at the downstream schemes (as key informants explained)

5. The Impact of D. coccus on cactus pear and the society

According to a study made by FAO, 90% of cactus growers' attitudes with cochineal problems remain ambivalent and confused and 45% may ask a displacement, because they strongly believe on cactus for survival (FAO 2014). According to discussion survey made at Southern and South Eastern Zone of Tigray,the respondents involving farmers, experts and officials the impact of the *D. coccus* involves Economic loss, social loss, and natural resources degradation. The economic loss caused by the insect pest involves reduced income, reduced number of livestock, crop yield reduction due to attack by large animals which had been fenced by cactus pear and lack of oxen for ploughing, and dependency for food aid. Youth migration, conflicts among neighbors due to fence break, insecurity of houses and moral loss and frustration are among the social impacts of *D. coccus*. As cactus pear plays great role in soil conservation, due to the infestation by the insect pest, soil degradation became devastating not only losing the soil, but also damaging crop land. The mountainous areas are

changed to a bare land exposing the area to direct rain wash and flooding.

6. Management Strategies Employed for the prevention and control of D. coccus

The management strategies of *D. coccus* focused on prevention from spread to uninfested areas and devising control methods for eradication. The prevention methods involve identification of buffer zones between the infested and uninfested areas, awareness creation to producers (farmers) and agriculture experts, scouting, mechanical methods such as cutting cladodes or the whole plant which has shown sign of cochineal infested cactus and pulling it, burning and burying a cochineal infested cactus. Besides, limiting movement of livestock and human from infested to non-infested areas and introduction of the integrated pest management are the points the regional government approached the FAO for regional office to support in the control of cochineal (Tesfay 2011) [13]. To eradicate *D. coccus* in medium- to long-term, the classical introduction of biological control agents (natural enemies) is considered as a primary option by involving different stakeholders mainly, Mekelle University, Beles Institute of Adigrat University, Tigray Agricultural Research Institute (TARI) and Tigray Bureau of Agriculture and Rural Development. Specifically, the following management strategies has been employed since the insect pest was considered as a threat to the cactus pear production.

6.1 Awareness creation and public mobilization

For effectively eradicating incipient populations of cochineal active participation by all the stakeholders at all levels is essential. Thus, it is important that all the stakeholders are aware of the insect pest's introduction, spread and the economic damage it may or has been causing. It is when they are fully aware of what the insect pest will do to the target crop that they will involve in the work and mass mobilization of people to participate in the control campaigns. In Tigray, cactus pear is grown as natural vegetation and as homestead crop owned by small-holder farmers. Therefore, devising an effective approach to mass mobilize the public to eradicate incipient populations of cochineal is essential. To this end, trainings has been and is being given to farmers, farmers leaders, experts, scouts, school principals and administrators at region, zonal, woreda and kebelle levels. In addition, different published materials has been distributed to farmers, experts and all concerned stakeholders. The trainings created skill how to manage the insect pest and attitude to solve the public problem by the people in coordinated campaign (Cochineal control committee 2018, unpublished data). In addition, the trainings different workshops have been conducted.

Table 3: Training given to stakeholders in 2018 by Beles Institute of Adigrat University

No	Trainees	District			Sum
		Kilteawalaelo	Hawzen	Gantafeshum	
1	Farmers	57	55	65	177
2	Wereda /district experts and officials	45	43	43	131
	Total	102	98	108	308

Source: Beles Institute, Adigrat University (2018, Unpublished data)

The above table indicates that a training was given for the districts found in the free zone. The trainees are from district officials who mobilize the community, experts at district and kebelle level who takes technical responsibility for monitoring, reporting and action on infestation and farmers who have full responsibility to work individually and as community (Beles Institue 2018, unpublished).

6.2 Mechanical and Chemical methods to control new infestations

Mechanical control strategy like burning, cutting and burying; chemical-using detergents, salt, biological pesticides and synthetic pesticides has been hugely employed.

Table 4: Different chemicals tested for effectiveness in 2016

Candidate technology	Rank		Remark
	1st Evaluation 19/09/08 E.C	2nd Evaluation 30/09/08 E.C	
Closer 240 SC	1st	1st	
Herbal chemical	2nd	2nd	
Salt and Soap	.	3rd	Single evaluation
SMZ botanical	NE	NE	Not Effective for Cochinal Cantrol

Source: Cochineal Control Committee (2016, unpublished data) NE: Not effective for cochineal control

As the above table indicates different chemicals including synthetic, botanicals and detergent with salt was tested by the cochineal control committee, technical team. According the observations, the team recommended to use the closer 240 SC and herbal chemical (botanical), if they are available. However, for the immediate use rock salt with detergent was selected. It was also noted that infestation was happened at all sprayed orchards. This is true that most scale insects need repeated spray.

6.3. Deployment of scouts for monitoring and surveillance of cochineal infestation

The control program requires the skill to early detect incipient population of the pest, contain the spread and eradicate it altogether. Cochineal eradication requires active participation of all relevant stakeholders in an area where the pest may be intercepted for the first time. The gaps in implementing any eradication program has been the shortage of quarantine facilities and enough personnel who could do risk assessment, intercept/detect a new pest early and act decisively to eradicate incipient populations. In general dealing with introduced pests is successful only when the task is handled by government institutions. Therefore, this work has to continue to eradicate the pest in

places where it has not been established. This requires strengthening the domestic quarantine system, continuing to deploy scout and conducting routine monitoring and surveillance in parts of Tigray wherein cactus pear is an important plant and creating cactus pear fruits production and distribution system, which can help avoid the movement of cochineal to new places and also movement of planting materials. Accordingly, scouts employed and have been effective in the new infestations to control the pest and further spread (Cochineal control committee 2018, unpublished).

6.4. Enhancing collaborative research

Screening of herbal insecticides, Mixture of salt and Soap to kill crawlers at an early stage, testing of new insecticides such as "Closer™", petroleum-based insecticides are among the collaborative research by experts from the different stakeholders for the control of *D. coccus*. Alem *et al* (2016) found that that botanical pesticides such as tree tobacco (Nicotiana glauca) could be a promising candidate to control cochineals and reduce the use of chemical application to minimize its side effects on the environment. The attempt to find a best controlling option remained unattainable for the time being except the mechanical based protection in new sites of infestation. However, it is proven that protection is possible at early stage of infestation by destructive method (burning, cutting and then burying of infested plants/patches).

Fig 5: Scouting and monitoring at early infestation, Gantafeshum, 2018

7. Lessons on cochineal management and future prospects

To save the remaining cactus pear plantations control strategies are devised and organized which set holistic insect management strategies and categorized the infested areas. These involves creating buffer (free) zone to prevent spread of *D. coccus* from infested areas to uninfested areas, opening orchard and cutting highly infested plants and spraying with insecticides, and improving orchard management. Hence, the government is in action and has recorded remarkable results in preventing the insect pest from spread and reducing the infestation in the already affected areas. For instance, infestation in three new sites is under control through mass public mobilization. The area of infestation and severity decreased in buffer zones. Scouting and controlling in the free areas gave promising results restricting the insect pest from spreading. The study on the need for classical biological control agent especially for the plantations at mountainous areas is in progress. Introducing of resistance cultivars is also considered but not studied yet. Strengthening the involvement of all stakeholders, further training and awareness creation, mechanical methods for prevention and control of the insect pest, searching and introducing biological control agents as an eradication means and selecting resistance cactus genotypes are among the management strategies considered to restrict the spread and for the eradication, in medium- to long-term management/control of *D. coccus*. Besides, strengthening scouting and monitoring with management and logistics, modernizing cactus plantations and optimization of benefits including export and value addition, and conducting further research and investigation on control methods are quite important.

8. References

1. Barbera G. History ecology and agro ecological importance. *In* Barbera G, ingles panel pimento barrios E (Eds) Agro ecology, cultivation and uses of cactus pear. FAO plant production and protection paper. 1995; 13:1-11
2. Brutsch M O. The Beles or cactus pear (*Opuntia ficus indica*) in Tigray Ethiopia. J PACD. 1997; 2:130-141
3. Central statistical agency of Ethiopia (CSA). Population survey report, 2007.
4. FAO. Cactus pear deserves a place on the menu: Turning a useful food-of-last-resort into a managed and valuable crop, 2017. http://www.fao.org/fao-stories/article/en/c/1070166/
5. Felker P, Ingles P. Short term and long term research needs for *Opuntia ficus indica* (L.S Mill, utilization in arid areas. Journal of the professional Association for cactus development. 2001; 5:131-152.
6. Gebremeskel G, Getachew A, Firew T. Assessment of potential of cactus pear (*Opuntia ficus indica*) as lives tock feed in northern Ethiopia. Livestock research for rural development. 2013, 25 (2)
7. Habtu Cactus in southern Tigray current status, potential uses, utilization and threat M.S.c these is Addis Ababa University, 2005.
8. Mitku H, Tesfay B, Zimerman H G. current and potential use of cactus pear in Tigray, northern Ethiopia. In processing of 11th international congress on cactus pear and cochineal. 2002, 75-86 (Nefloui A, and ingles, Pedsacta Hort 581,15HS Hama met Tunisia.
9. Snyman HA. Root distribution with changes in distance and depth of two years old cactus pear opuntia (ficus India and opuntia robust on plants. South Africa journal of the botany. 2006; 72:434-441.
10. Stintzing FC, Carle R. Cactus stems opuntia special a review on their chemistry technology and uses. Molecular nutrition and food research. 2005; 49:175 - 194.
11. Tesfay B. Commercialization of carmine cochineal in northern Ethiopia paper presented at the third biennial conference of the Ethiopian Horticultural science society had on at Jumma university medicine, Jimma Ethiopia, 2011, 04-05.
12. Tesfay B, Mulugeta G, Tadesse A. Description of cactus pear (*Opuntia ficus indica*) cultivars from Tigray, northern Ethiopia. Research, Tigray Agricultural research institute Mekele, Tigray, Ethiopia, 2011. 1.
13. Tesfay B. Response of regional government against cochineal expansion Tigray Agricultural research

institute Mekele, Mekele Agricultural Research center September, 2015.
14. Tesfay B, Zimerman HG, Hailu T, Dserege A. Introducing the carmine cochineal /Dactylopiuscoccus costa to cactus pear plantations in Tigray, Northern Ethiopia in proceeding of the inaugural and first Ethiopian Horticultural science society conference (eds) Lema Desalegn *et al*. 27 – 30, March 2006, Addis Ababa, Ethiopia, 2006, 71-76.
15. UNIDO. Establishing industrial processing and marketing of Beles (*Opuntica ficus indica*) based food products for increased income in rural communities in northern Ethiopia, 2012.
16. Zimmermann H G, Olckers T. Biological Control of Alien Plant Invaders in Southern Africa: in (Peter, Neuenschwander, Christian. Borgemeister *and* Jurgen. Langewald (editors). Biological Control in IPM System in Africa. CAP Publishing, 2003.