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OPEN ACCESS JOURNALS

Journal of Agricultural Science & Crop Research

Review | Vol 2 Iss 1

Impact of Invasive Cochineal Insect (*Dactylopius coccus* Costa) on Cactus Pear, and Socio-Economic Aspects in Tigray, Ethiopia: A Review

Daniel Keskse*

Department of Plant Science, College of Agriculture and Natural Resource, Raya University, Maichew, Ethiopia

***Corresponding author:** Keskse D, Department of Plant Science, College of Agriculture and Natural Resource, Raya University, Maichew, Ethiopia, Tel: +251 99 644 2435; Email: danielkeskse2010@gmail.com

Received: November 15, 2021; **Accepted:** November 29, 2021; **Published:** December 06, 2021

Abstract

In Northern Ethiopia, cactus pear is the most important plant used as food, forage, source of income, soil and water conservation, carbon sequestration, medicinal, cosmetics, and drought insurance crop. The annual production of cactus pear was reaches 48,300 tons and the productivity is about 6.7 tons ha- of fruit. However, currently the plant is suffering from the infestation of a cochineal insect pest, which can reduce its production and productivity. The insect has sucking mouth part, which can feed cactus juices. It causes a negative impact on cactus pear and socio-economic aspects in Tigray region as the reduction of fruit production, shortage of forage, decreased income of small-scale farmers and it also causes erratic rainfall and distribution, which aggravate soil erosion. Accordingly, this paper focused on the impact of D. coccus on cactus, and socio-economic attributes in Tigray, northern Ethiopia.

Keywords: ***Cactus pear; Dactylopius coccus; Pest management; Socio-economic***

1. Introduction

Cactus pear (*Opuntia ficus-indica* (L.) Mill.) plant is the most important horticultural crop in arid and semiarid parts of the world [1]. It was originated and cultivated in central Mexico [2]. It also distributed and cultivated in the world as Italy, Spain, Portugal, Morocco, Algeria, Tunisia, Egypt, Ethiopia Israel, Turkey, and Greece [3]. Cactus pear was introduced to northern Ethiopia in 1848 by catholic missionaries [4]. In Ethiopia, cactus pear is locally known as “beles” or “qulqual-baheri”. It has an important economic and cultural role, reflected in traditional songs and sayings. It plays greater economic role as a source of food, animal feed, soil conservation, fencing, fuel wood and it is also important for carbon sequestration for semiarid areas, and it is a source of additional income for small scale and low-income farmers [5]. It is a crassulacean acid metabolism (CAM) plant that plays greater role in the future [6], which means it increased the demand of humans and livestock through reducing

drought, famine risk and ensures food security. It considers as a “miracle plant, dromedary of the vegetation world, and the bank of life” which can contribute to livelihoods of rural populations in dry areas [7]. Cactus pear was covered more than 379,338 ha of land, i.e., 7.4% of the total land area of the Tigray region [6,8,9], which about 56% is found in southern Tigray. The annual cactus pear fruit production in the Tigray region reaches 48,300 tons and the productivity is about 6.7 tons ha- of fruit [7]. Based on this cactus pear coverage and production, cochineal insect (*Dactylopius coccus*) project has been interested to investment in the northern Ethiopia especially, southern Tigray [10]. It was introduced and cultivated to northern Ethiopia in early 2003 by a food safe company [8].

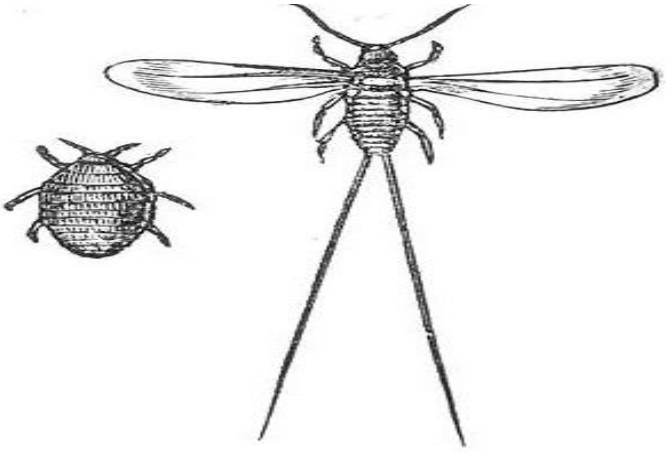
This cochineal insect is a scale insect used for production of a natural dye (carminic acid) that can be used for cosmetic, pharmaceutical, textile and food industries [11,12]. Cochineal insect has about 19%-23% of carminic-acid [13,14]. The food safe company has exported 2000 tons of dried carmine cochineal for three years in the Tigray region [10]. Cochineal lives and feeds on the cactus plant moisture and nutrients [15,16]. The insect is host specific and only feeds on Opuntia species [8]. It causes negative impact on the multipurpose cactus plant and currently there is not an effective management. The plant is now at higher risk of damage due to this exotic insect. Nowadays, in northern Ethiopia especially, South Tigray zone, cochineal infestation problem is the urgent issue in cactus growing areas, which has most devastating on fruit and forage production losses of the cactus pear. The status of cochineal insect infestation in 2016 was reached about 31,184 ha and the infestation level increased alarmingly by 263% in area coverage, 80% and 47% district and station wise, respectively [8]. Currently, in Tigray region, the cochineal insect infestation increased up to 75000 ha in both wild and private plantations which indicate that the insect is expanding at an alarming rate [7]. The wide spread of the insect is assumed through biotic (human and livestock) and abiotic (wind) factors [17]. The damage to fruits and cladodes became severe killing the host plant [8]. In Tigray, 90% of cactus grower’s areas infested cochineal insect, which is cause 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 [7]. In South Tigray zone, the cactus pear yield per hectare is low as compared to the productivity of the other country, which is totally out of production due to the infestation of cochineal insect. In this paper focused on the impact of invasive cochineal insects has been negative effect on cactus pear production and socio-economic aspect. The destruction of cactus pear has cause aggravated soil erosion, food and forage insecure, reducing soil structure and accumulation of carbon concentration on the environment that causes a global increase temperature, which declared as a socio-economic crisis on Tigray region. Hence, to maintain the cactus plant and its socio-economic high values, it is essential to have effective, cheap, and available control measures [18].

2. Taxonomy and Biology of Cochineal Insect

One hundred and ten sweet potato genotypes TABLE 1. were evaluated in highland areas specifically known as Gubeta at an altitude of 2350 masl. The study materials were obtained from different backgrounds such as advanced lines (developed from polycross breeding), introduced varieties (released abroad) and most varieties that have been released in Ethiopia. The field experiment was conducted using augmented block design with un-replicated entries and replicated check varieties that occurred once in every block in the experiment [8]. The experimental area was divided in to10 blocks each consisted of 14 rows in such a way that each row in each block was treated as a single plot. Each genotype was represented by a plot size of 3 m2 i.e., 3 m long and 1 m width. The spacing between rows and plants was 1 m and 0.3 m, respectively. Ten holes per row were prepared

and vine cuttings of 30 cm long were used for planting the trial. Three recently released varieties, namely Alamura (Ukr/Eju-10), Dilla (Ukr/Eju-13) and Kabode were included in the study as checks. The three check varieties were planted at random on rows in a way that the same check variety appeared in every block only once. The remaining 11 rows in each block were assigned to the new entries (genotypes). All plots received the recommended cultural practices uniformly and no fertilizer was applied [5]. Hilling- up was done after fourth weeks of planting and all plots were kept weed free with regular hand weeding and cultivation.

Data were recorded on SPVD severity using a scale of 1 to 5, where 1 = no visible symptoms, 2 = mild symptoms (a few local lesions on a few leaves), 3 = moderate symptoms (mosaic symptoms on leaves), 4 = severe symptoms (mosaic symptoms with plants showing stunted growth) and 5 = very severe symptoms of purpling/yellowing or mosaic on leaves, severe leaf distortion, reduced leaf size and severe stunting [9]. Root flesh colour (FC) was estimated based on sweet potato descriptors developed by Huaman [10]. Data on root yield and number of roots per plant was taken at harvest from the entire row and the yield was converted and expressed in ton per hectare.



(Source: Wikipedia, 2020)

FIG. 1. **Female (left) and Male (right) Cochineals.**

3. Impact of Invasion Cochineal Insect on Cactus in Tigray Region

Northern Ethiopia has large number of cactus pear biodiversity due to this reason; D. coccus projects have been interested to the investment on production of carminic acids [10]. Plant Protection Research Institute of South Africa, Dr. Helmuth Zimmermann, identified two interested companies: Roeper Company from Germany and Food safe company from Chile that showed interest in cochineal production in Ethiopia [10]. Food safe company was introduced the *D. coccus* insect project in the early 2003 and cultivated among farming communities [8]. The introduction of this project was mainly for export purposes because there was no awareness about its use in Ethiopia. So, companies that buy and multiply the insect were collected. Food safe company was exported 2000 tons of dried carmine cochineal for three years [10]. In Ethiopia, this project was the most earns hard currency and interested to cochineals' production increased from 21%-23% in the Tigray region [13,10]. However, the conflict interests are occurring between two groups of community members. The first group is the young landless men and women fit with food safe company are cochineal collectors and exporter. The second group is the elderly and backed by the

Coptic Church that support to local Non-Governmental Organization (NGO) known as MaheberWejerat that believed cochineal business is outside of their tradition or culture and would reduce the value their cactus for livestock feed and human food [10]. During these conflicts company has closed then the cochineal insect became widespread very fast in a space or areas coverage of few years and difficult to control. These insects are parasites in the cactus pear and can very large numbers damage and mortality of cactus pear plants. The cochineal insect also limits spread and propagation of the plant by decreasing production of cladodes [19]. The most common symptoms are chlorosis (yellowing), dehydration, and weakening of the plant. The infestation level is illustrated in FIG. 2. Cochineal invasion was also affected by both climatic variables and cactus pear presence. Rising temperature and rainfall variability are also leading factors that facilitate the invasion of pests [20]. The annual average temperature ranging from 8 to 24°C is to be suitable for the cochineal multiplication and invasion. The temperature ranging from -5°C to 40°C are suitable areas for cochineal invasion [21]. In Tigray area having annual average temperature of 22°C is suitable condition for the cochineal invasion [21]. It also wide spreads through biotic (human and livestock) and abiotic (wind) factors. Estimated infestation being 3,317 ha cactus in Raya-Azobo district only, the damage to fruits and cladodes became severe killing the host plant [8]. Nowadays, the invasion of cochineal insect is highly and not easy to control in northern part of Ethiopia especially, south Tigray.

A **B**

FIG. 2. **Source A: Own observation and Source B: Portillo et al. 2016, infestation levels of cochineal insect on cactus.**

4. Impact of Cochineal invasion on Socio-Economic Attributes

In Ethiopia especially, Tigray region socio-economic aspects should be dependent on cactus pear. It is drought insurance crop as source food. The fruit contains 3%-10% of protein and 6%-13% of fatty acids [22,23]; and also, it contains vitamin C (25 mg-30 mg) [24]; betalains (betanin & indicaxanthin), flavonoids (quercetin & isorhamnetin) [25]. The leaves (cladodes) are burning with fire as source of animal's forage. Cactus pear used as compost to improve soil physical properties to enhanced water storage capacity and soil nutrients [26]. It also important in slope areas for soil conservation to reduce runoff and erosion and it also used as boundary fence. So, cactus pear plantations also have a positive impact on plant growth of other plant species by improving environmental conditions. Cactus pear is known as a CAM plant that can use much more efficiently water and CO_2 uptake [27]. The potential of CAM system to bio accumulate of CO_2 is higher than C_3 and C_4 plants [28]. The annual capacity of CO_2 uptake is 144 mol m^{-2} [29]. The capacity of this plant is more suited for arid and semi-arid areas. Cactus plants are also important for carbon sequestration [30]. It can generate a carbon sequestration about 20 tons of dry matter per ha and per year those prevalent environmental pollution in many African arid regions [27]. But after introduction of the cochineal insect over 300 ha of cactus pear was infested and out of production in southern Tigray [6,10,8]. Due to this insect infestation the production of cactus pear is declined from year to year. The destruction of this plant caused reducing their diversity and fruit production, forage. And also, CO_2 accumulation was rising at atmosphere which means an average decade years of

temperature is increasing at the rate of 0.54ºC which is more than double, compared to the countrywide average of 0.25ºC per decade [31,21]. The rising of temperature and rainfall variability are also leading factors that facilitate the invasion of pests [20]. Eastern areas of northern Europe could insect damage to leaves increase by up to 5% and, in Scandinavia, an increase in temperature of 1ºC in summer could almost double insect damage to the leaves of this birch species [32]. This increasing of temperature results a drought [33]. The rainfall pattern was unpredictable and erratic from 18% to 42% [34]. Droughts and floods are very common occurrences every 3-5 years [35]. The change in rainfall distribution and pattern had contributed to the change in cropping pattern and crop yield. It causes chronic food shortages in Tigray region [36]. Therefore, the negative impact of cochineal insect that loses the benefits of cactus pear, so it causes socio-economic crisis. Due to this reason cochineal insect management is need attention.

5. Management Method of Cochineal Insect on Cactus

Currently, the major problems cochineal insect managements in Ethiopia are lack of adequate knowledge of the pest management options in the Ethiopian context; limitation of financial and material resources, biology of cochineal insect which, producing white waxy coating and covering their body to protect insect from contact insecticides, water, rain splash and excessive sun [37]. In addition, the perennial life cycle of cactus and the favorable whether condition is important for the insect to quickly multiply and spread to more areas. In the above case once establishment of cochineal insect is difficult to eliminate but we are reducing its infestation level through different control methods. Hence, the researcher and government are to give more emphasis to minimizing its population. Different research has been done to manage this cochineal insect. One of the most effective control methods is mechanical control which involves manual brushing with the mixture soap, salt and water, removal of infested plant part by burning off infested plant part or a bury infested plant part for prolonged in deep hole to converted compost. But this method has some limitation (time taken and labor intensive) it creates suitable condition for spread of cochineal insect. Biological control method is another cochineal control through the use of host-specific organisms such as birds, insects, spider or pathogens but they also found in the origin of its host [38]. Several species of predators (insects and spiders) have been important for controlling of cochineal [39]. From this insects, Coleoptera (beetle species) as *Hyperaspis trifurcata, Chilocorus cacti, Coccidophilus citricola* and *Zagreus bimaculosus* and also other order of insects as *Leucopis bellula* & *Eosalpingogaster cochenillivora* (Diptera) and *Sympherobius barberi* (Neuroptera) are feed on the nymphs of the cochineal, whereas *Laetilia coccidivora* (Lepidoptera) are feeding on adults stage [40]. Some pathogen is predator as Fusarium spp. used as biological control agents of cochineal [41]. This biological control method has not completely succeeded we are shift to chemical control methods, but it cannot completely succeed due to the biology of insect and also the improper use of insecticides cause induces resistance the target pests, killing beneficial organisms [42]. It also causes underground and surface water pollution [43], the poisonous effects on human health through dietary exposure [44,45]. Therefore, there is need an urgent safe alternatives solution to control of cochineal insect on cactus by using botanical extracts insecticides. These botanical insecticides like Neem (*Azadiracta indica* L.) and Nicotiana are generally considered having low toxicity to mammals [46]. *Azadirachta indicaare* very effective and proved to be the best with 28.09% and 21.13% reduction of mussel scales insect population [47]. Arifa et al. [48] also reported that extraction of novel herbal pesticides was very effective for the control of adult scale insects. Therefore, the effect of botanical extracts viz., *Azadiracta indica* L., *Tagetes minuta* L., *Nicotiana glauca* G., mixed with soap, *N. glauca*, dimethoate 40% E.C, karate 5% E.C and control (only water) against cochineal insect on cactus [8]; but not eliminated so, there is no a single pest management method is fully effective control the infestation of cochineal

insect due to the pest behaviors. Integrated pest management method approach is sustainable to manage the extent of the unfamiliar insect species and safe and sustainable environment.

6. Conclusion

Cochineal insect is one of the most invasive insect species in Ethiopia. This insect caused huge damage to cactus pear from 2003 E.C. up to now in Tigray region. Because in northern Ethiopia, plant life cycle, morphology of the pest and favorable environment are important for the insect to quickly multiply and spread to more areas. The consequences of this pest reducing cactus pear production and its diversity, the negative impact on climate change and socio-economic attributes in the community in Tigray region. Therefore, there is needs an urgent control method to eradication of this insect population. But it is impossible to avoid this pest unless developing sustainable management. In Tigray region, the major concern is management of cochineal insect by advertising within social Medias such as Television program, large billboard, radio and prepared official calendar. These methods important for helping the awareness communities to reducing the impact of cochineal insect on cactus pear production, socio-economic attributes, and climate change in the Tigray region.

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