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Infestation, Damage and Distribution of Blue Gum Chalcid on *Eucalyptus camaldulensis* Dehnh in Eastern Amhara, Ethiopia

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ABSTRACT

Blue Gum Chalcid (BGC), *Leptocybe invasa* Fisher and La Salle (Hymenoptera: Eulophidae), causes high damages on *Eucalyptus camaldulensis* Dehnh in many countries including Ethiopia. This study aimed to determine the damage, damage severity and distribution of the BGC on *Eucalyptus camaldulensis* plantations in Eastern Amhara, Ethiopia. The assessment was conducted at Tehuledere (South Wollo zone), Habru (North Wollo Zone) and Dawa Chefa (Oromia adminstration zone) districts. These districts were selected purposively for continuous infestation. Three sites per district with a total of nine sites were selected. Assessments were done from four coppiced and five plantations. A minimum of 0.25 ha and five trees per site were assessed in a monthly interval.. The assessment result revealed that BGC was found in all the three districts of the three zones. During the assessment, it was found that from five trees the damage severity were 20% nil, 15.6% low, 20% medim, 22.2 high, and 22.2% high. Severity and damage of the pest varied across the study sites and the assessment months. Lower and higher severity damages were observed at Amumo (0.48) and Passo sites (3.26) of Tehulederie district, respectively. Increment in damage severity was observed from November to February except at Amumo (from 0.48 to 0.87), with higher increments in January and February 2019 (averagely from 2.24 to 3.23).

Keywords: Distribution; *Eucalyptus camaldulensis*; infestation; *Leptocybe invasa*; severity.

INTRODUCTION

Eucalyptus is among the most widely cultivated forest trees globally and it comprises more than 900 species and unknown hybrids and varieties (Boland et al., 2006). In Ethiopia, planting of exotic species was commenced with the introduction of *Eucalyptus camaldulensis* (*E. globules* Labill), approximately 110 years ago (Hedberg et al., 2009). Plantations of exotic Eucalyptus make up more than 30% of Ethiopia's plantations, providing fuel and construction timber to the country (Alemu et al., 2003). The wood from Eucalyptus plantations is commonly used for construction purposes, fuel, poles and posts and is an important resource for subsistence farmers (FAO, 2000; Gessesse et al., 2016).

Over time, the incidence and impact of insects have increased and now poses a major threat to the continued expansion of this important industrial tree species. Alemu et al. (2006) reported several insect pests of Eucalyptus in Ethiopia. These include soil dwellers, defoliators, bark and timber borers, sap sackers, gall makers. Among the gall makers, the BGC, *Leptocybe invasa* (*L. invasa*) Fisher and La Salle (Hymenoptera: Eulophidae) is becoming one of the major insects on Eucalyptus tree species (ICFR, 2011). *Leptocybe invasa*, which was first identified by Mendel et al. (2004), is a new gall forming invasive wasp, commonly named as Blue gum chalcid. It is presumed to have originated from Australia which has spread to many parts of the world where its host trees are found (Chilima et al., 2017; Petro & Iddi, 2017); such as in Africa, Asia and the Pacific, Europe, North America and the Near East (Sankaran & Durst, 2017).

In Ethiopia, BGC was reported for the first time and become a threat of Eucalyptus species since 2000 (ICFR, 2011). However, according to Giliomee (2011) this insect was first observed in Ethiopia since 2002. Although there was a difference in the year of first records, their findings agreed on that the insect becomes a threat to Eucalyptus species in the country. At the moment, BGC is a major insect of Eucalyptus species and it mainly infests *E. camaldulensis*. The distribution and nature of infestation of BGC is strongly related with the

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climatic conditions of an area (Mutitu et al., 2007; Giliomee, 2011; Petro & Iddi, 2017).

Currently, reports showed that the BGC is distributed in Amhara, Tigray, Oromia and South Ethiopia. In Amhara region, its distribution is reported in West Gojam, Awi, South Gonder, South and North Wollo and Oromia administrative zones where Eucalyptus species are dominantly grown (Adane, 2018). The insect infestation, damage and distribution were reported to be site and time specific (Kim et al., 2008; Eyidozehi et al., 2014). However, in Ethiopia, the spatial and temporal distribution of the BGC within the different administrative zones and districts was not studied. Therefore, this study was initiated to assess the infestation, distribution and damage severity of BGC insect across the different sites of northeastern Amhara region.

MATERIALS AND METHODS

Description of the study area:

The study was conducted in three selected districts (Dawa Chefa from Oromia, Tehuledere from South Wollo, and Habru from North Wollo) of Northeastern Amhara region (Fig. 1). Dawa Chefa district is located around Kemessie town and situated in between 59°8′ 318"E longitude and 11°92′177"N latitude with an elevation of 1435-2970 m. The annual average rainfall was 600-900 mm per year and the minimum and maximum temperatures were 18 and 34^{o}C, respectively.

Habru district is located around Mersa town and is situated in between 58°7′ 600"E longitude and 12°29′530"N latitude with an elevation between 700-1900 meters. Annual average rainfall is about 923 mm per year. The yearly average temperature ranges in between 21-33^{o}C (Andualem, 2018). Tehuledere district was located around Haiq town and situated in between 42°3′ 616"E longitude and 13°6′879"N latitude with an elevation between 1400-2934 meters. Annual average rain fall ranges from 1000-1100mm per year and have 15 and 20^{o}C minimum and maximum temperature, respectively (KDOA, 2010).

Sampling methods and data collection

Assessments to determine the infestation, damage status and distribution of the BGC across the different sites were conducted four times in monthly interval from November 2018 to February 2019. The first assessment was at the beginning of the dry season (November 2018) and the last was conducted in February 2019.

The observation was made in areas, which have plenty of *E.camaldulensis* plantations within the selected districts. Further, three sites per each district were selected purposively based on the availability of enough number of trees (minimum of 0.25 ha). Thus, the sites were Jaranyo, Kemessie and Messena from Dawa Chefa distric; Mersa, Girana and Sirinka from Habru distric; and Amumo, Haiq and Passo from Tehuledere district were continuously assessed.

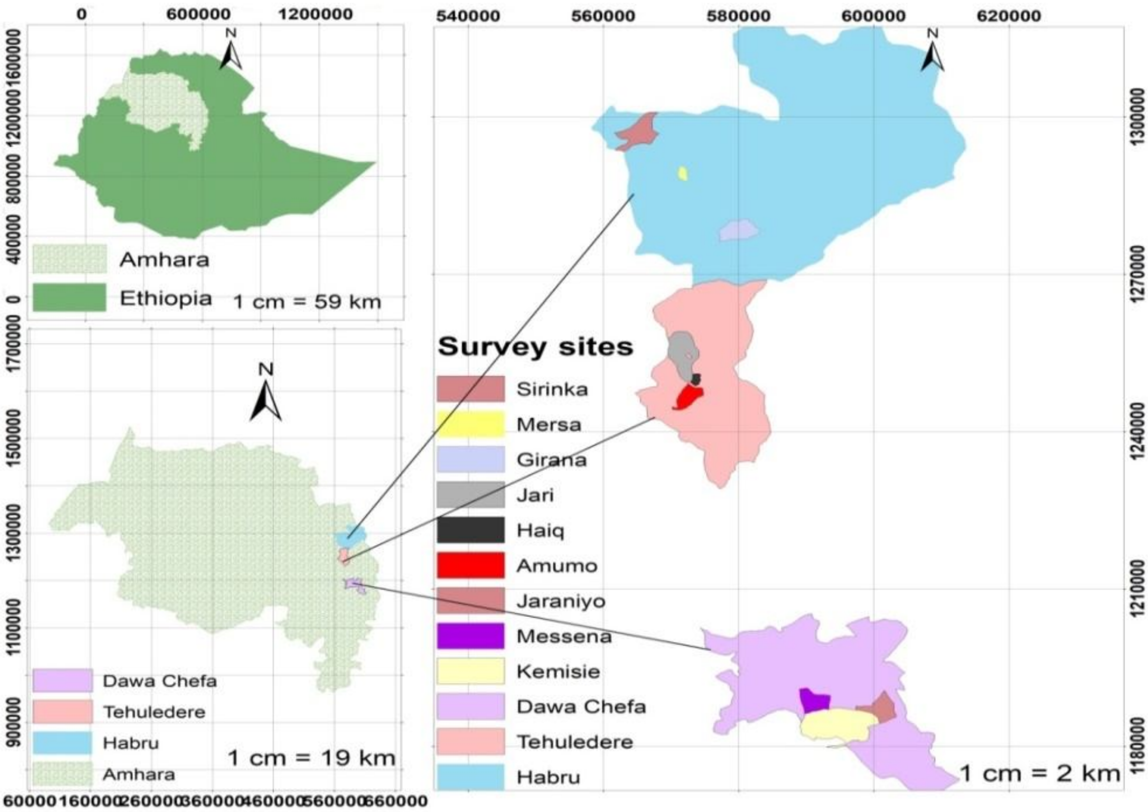

Fig. 1: Map of the study areas

Four coppiced (Jaranyo, Kemessie, Passo and Mersa) sites and five planted saplings (Messena, Amumo, Haiq, Girana and Sirinka) of *E.camaldulensis* with a total of 720 and 1040 stands respectively were assessed. A total of 20 trees from the coppiced and 25 trees from the plantations were used to collect all the necessary data. The age of both the coppices and saplings was 1-3 years and the plot sizes were from 0.25 up to 0.5ha (Table 1).

In the selected sites, sample tree was selected randomly and visual observation and assessments were conducted along a diagonal walk to record the present or absent of the BGC and level of infestation on the Eucalyptus tree species every 10-15 meters. At each sampling points, five Eucalyptus trees (Asfaw, 2018), were randomly selected and assessed.

Individual trees were considered as replications during the assessment. After counting total number of their branches per tree, 50%of the total number of the branches was leaned and their total number of leaves counted. then, 10 percent of the total number of leaves were used for data collection and for analysis (Asfaw, 2018).

The selected individual trees with galls were subjected for further assessment for number of leaves with and with-out galls, number of galls, gall color and type of galls (unopened and opened galls). The severity of damage in the selected trees due to gall formation, as shown in Table 2, was scored using the method adopted from (Thu et al., 2009).

Incidence and severity of the data collected from the filed survey were calculated according to the methodologies of Thu et al., (2009) and Sankaran and Durst, (2017) (eq-1) and (eq-2).

$$\text{Incidence} = \frac{\text{number of infested branches}}{\text{total number of assesed branch}} * 100 \ldots. (1)$$

$$\text{Severity} = \frac{\sum n_i \; v_i}{NV} * 100 \ldots (2)$$

Where: ni=number of trees infested at level i, vi= severity level at level i, N=total number of assessed trees, V= maximum rating scale

Based on this, damage severity levels (DSL) were identified as:

None for ADI=zero (no gall formations in foliage), Low for ADI<1 (<25% of foliage with galls), Medium for ADI=1.1-2.0 (26-50% of the foliage with galls), Severe for ADI= 2.1-3.0 (51-75% of the foliage with galls), and very severe for ADI>3(76-100% of the foliage with galls) (Thu et al., 2009).

Laboratory Examination

Laboratory examinations were undertaken to determine the number of galls per leaf in the green and pink color galls. For each color type 10 matured leaves with unopened galls were selected and collected randomly from plantations of *E.camaldulensis* trees grown at Chorisa, Kalu district.

Data analysis

The data on number of galls per leaf and number of infected leafs and infected branches were arranged and organized in Excel spread sheet, make ready for analysis and were used to determine the severity of BGC insect pest. The difference in infestation, distribution and damage of the BGC on *E.camaldulensis* across the different assessment sites and months were analyzed and presented using the simple descriptive statistics.

Table 1: Age of assessed *E.camaldulensis*, types of plantations and number of tree assessed

Zone	District	Site name	Types of plantation	Age (year)	Total no. of trees/site (plot size ha)
South wollo	Tehulederie	Amumo	Planted saplings	2	170 (0.5ha)
		Haiq	Planted saplings	1	169 (0.5ha)
		Passo	Coppiced	3	203 (0.375ha)
North wollo	Habru	Girana	Planted saplings	2	195 (0.25ha)
		Mersa	Coppiced	1	154 (0.25ha)
		Sirinka	Planted saplings	2	248 (0.25ha)
Oromia zone	Dawa Chefa	Jaranyo	Coppiced	2	198 (0.25ha)
		Kemessie	Coppiced	2	165(0.25ha)
		Messena	Planted saplings	1	258 (0.5ha)

Table 2: Damage severity score of the assessed *E.camaldulensis* trees

Percentage leaves infected	Damage score	Severity scale
Healthy trees, no damage	0	Nil
< 25% of leaves and twigs of the crown with galls	1	low
25-50% leaves and twigs of crown infected with galls	2	Medium
50-75% leaves and twigs of crown infected with galls	3	Sever
>75% leaves and twigs of crown infected with galls8	4	Very sever

Source: Adopted from (Thu et al., 2009)

RESULTS

Incidence:

Assessment on distribution of BGC was conducted in monthly interval starting from the first week November 2018- February 2019 in Eastern Amhara, Ethiopia. BGC was distributed in all sites, where, *E.camaldulensis* is grown dominantly.

Coppices of *E.camaldulensis* were highly damage by BGC insect pest infestation more severe as compared to saplings of the direct plantations. Of the total sampled trees, most damages were sever and very severely but few of them were not severely affected. During field assessment, it was observed that, BGC insect pest caused severe injury to young foliage.

Table 3: Percentage of severity damage and damage level of scale of the 45 *E.camaldulensis* trees assessed

% Severity of damage (Nov. 2018)	No. of trees damaged (%)	Damage level
0	9(20)	Nil
<25	7(15.6)	Low
25-50	9(20)	Medium
50-75	10(22.2)	Sever
>75	10(22.2)	Very sever

N.B: Values in the brackets are percentage of damage, while those out are their numbers

Highest number of galls was observed in near the midrib and petiole than the stem part of the tree. Mostly two colors of galls were manifested throughout the infestation time of BGC insect pests such as; green (before maturity) and pinkish (when mature) (Fig. 2).

Severity:

The assessment results in the different sites revealed that the distribution, severity and damage of the BGC insect pest where different from one site to the

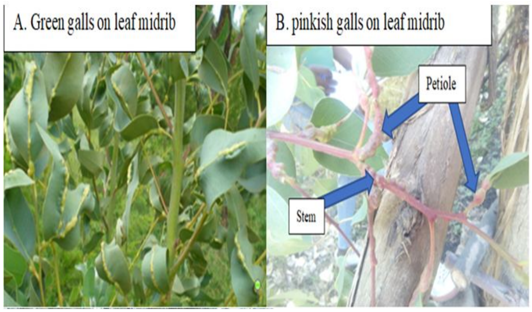

Fig. 2: Green and pink color galls on different tree parts; photo taken from *Haiq* site

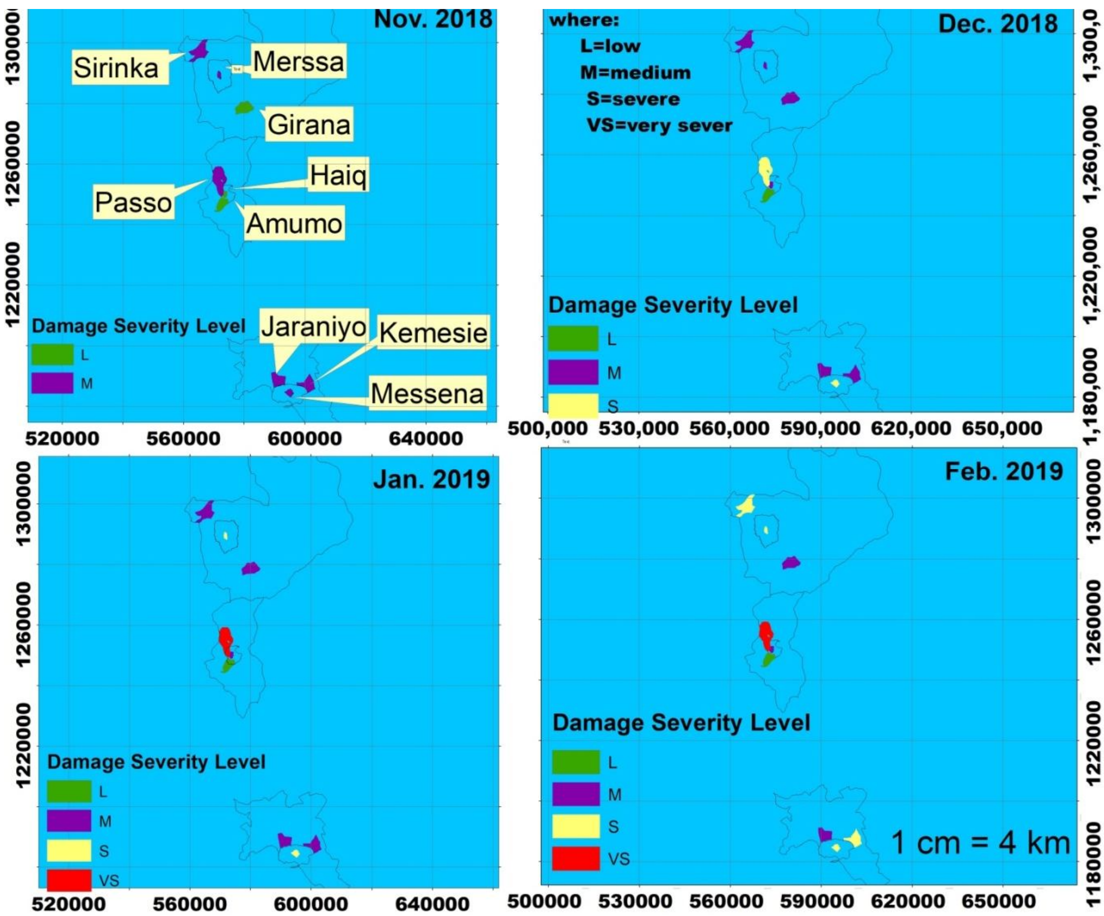

Fig. 3: Spatial and temporal distribution of BGC insect pest: Nov. 2018- Feb. 2019

other. Lower damage severity was observed at Amumo and severe and very sever damages was recorded at Mersa and Passo sites respectively, while in the other sites damage severity was from lower to medium.

In addition to infestation, damage severity and spatial and temporal distribution of BGC insect pest showed increments from November 2018 to February 2019 almost in all assessment sites, with a varying severity levels except at Amumo. Highest increments were observed in January and February 2019.

During the survey, another gall making wasp, Eucalyptus Gall Wasp (EGW) (*Ophelimus maskulli*) commonly called *Ashmed* (Doganlar & Mendel, 2007; Asfaw, 2018), (Fig. 4, A), and scale insect (*Red Gum Psyllid; Glycaspis brimblecombei*, (Chungu, et al., 2016; Sookar et al., 2014) (Fig. 4, D-E) were observed on *E.camaldulensis* in Kalu, Dawa Chefa, Mersa and Tehuledere districts.

Damage symptoms of EGW were also observed together with BGC insect pest on a single tree and even in a single leaf (Fig. 4, B). In addition, sever infestation of leaf spot disease on *E.globulus* were also observed around Bededo and Sulula (Fig. 4, C).

Laboratory examinations

Number of galls per leaf

After the collected specimens were dried within 8 days no open galls were observed in the green color galls and no emerged adult dead insects were counted from the petri dishes. The number of galls per leaf was counted directly from each leaf. The pink color galls were opened and insects were found dead in the petri dishes. To determine the total number of galls per leaf, insects in the petri dishes and the un-open galls were summed up. From the pink color galls averagely 38 galls per leaf was observed with a minimum of 28 and maximum of 52 galls per leaf (Table 4).

Table 4: Number of galls per leaf

Leaf no.	Leaves with green color galls	leaves with pink color galls
1	20	33
2	28	39
3	27	28
4	33	43
5	22	31
6	20	44
7	30	28
8	29	46
9	29	52
10	34	32

DISCUSSION

The incidence of infestation and effect of BGC insect pest was only in *E. camaldulensis*, where *E. globulus* was not found infested which is in agreement with the findings of Thu et al. (2009) and TPCP (2011). This is directly related to the plant host resistance, the sources of resistance against phytophagous insects (secondary metabolic substances (phenolics) (Jacob, 2009). These includes terpenes, phenolics and nitrogen and sulphur containing compounds (Schafer & Wink, 2009).

At the field, severe injury was observed on the young foliage’s of *E. camaldulensis* plantations and the result is similar with Mendel et al. (2004) and Kim et al. (2008), which reported that these parts are the most susceptible parts to BGC insect pest. Mostly two colors of galls were manifested

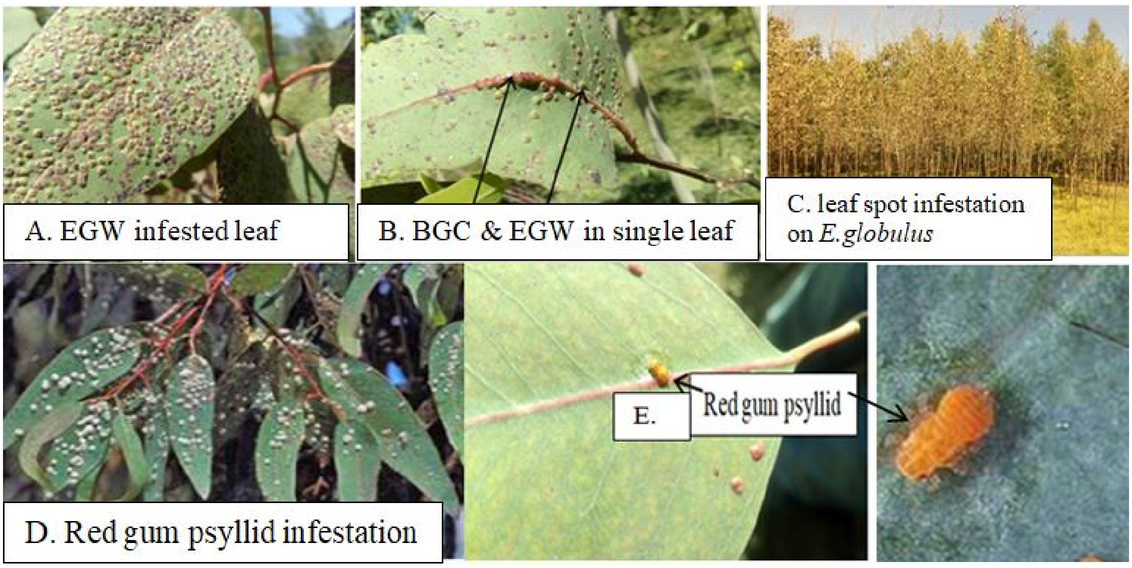

Fig. 4: EGW and BGC in a single leaf of *E.camaldulensis*, & *E.globulus* affected by leaf spot

throughout the infestation time of BGC insect pests such as, separated green (before maturity) and pinkish (when mature) galls according to the findings of (Mendel et al., 2004)

The severity and damage of BGC insect pest varies from site to site, which may be due to temperature, wind, humidity and altitudinal variations as reported by different authors (Mutitu et al., 2007a; Sankaran & Durst, 2017; Ndlela et al., 2018). These factors are the main affecting factors of the insect pest as reported by (Mendel et al., 2004). According to Mendel et al. (2004) and Nyeko et al. (2009) in the hottest climate and low altitudinal areas the infestation and distribution of the insect pest is high than the coolest climate areas. But contrasting study result was reported by Mutitu et al. (2007b), which showed increasing and higher infestation with increasing altitudes.

The infestation of the pest were also varies across the different assessment months. The infestation and damage of BGC varies with the increasing and decreasing T^{o} as it was reported by many scholars around the globe (TPCP, 2011; De Souza et al., 2018; Ndlela et al., 2018). The development and reproduction is slow in cooler seasons (Karunaratne et al., 2010) and it limits colonization capacity of the insect pest (Bale, 2010). For example, due to this reason, its spread was limited to a maximum of 2000m.a.s.l in Uganda according to the reports of Mutitu et al. (2007a) and 682 m.a.s.l in Turkey (Aytar, 2003).

Temperature and humidity, influences directly through limiting and stimulating the activity of larvae and adults, insect's dispersal in the environment, phenology and growing length (Bale et al., 2002; Menéndez, 2007). They also influences indirectly through climate influence on environment where insects appear, such as influence on plant formations, plant phenology, food quality, predators, parasitoids and activity of entomopathogens (Moore & Allard, 2008; Netherer & Schopf, 2010). Changes in temperature generally affect the insects metabolism, respiration, nervous and endocrine systems and additionally it also changes the behavior and their developments (Jaworski & Hilszczański, 2013).

In conclusion, continuous assessment study was conducted in three purposively selected districts and at nine randomly selected sites which have infestation of BGC insect pest. From the nine sites, five of them were plantations and four were coppiced *E.camaldulensis.* Results from the current study showed that *L.invasa* was distributed in all low altitude areas of eastern Amhara, were *E.camaldulensis* is dominantly grown. The distribution and severity of the pest varies from place to place, from month to month and also among the two modes of plantations. Of the 45 trees investigated, 20% were nil, and 22.2 and 22.2% of them were severely and very severely infested, whereas 15.6 and 20% were low to medium. Lower severity was observed at Amumo and very sever damages was recorded at Passo sites of Tehulederie district. Increment in damage severity was seen from November to February almost in all assessment sites, except at Amumo (in this site higher increment of infestation was recorded in January and February 2019). The pest affects the leaf midrib, petiole and stem of *E.camaldulensis*, but effects are higher on the leaf midrib than the other parts. Two types of gall colors, blue and pink galls were found in all the assessed trees and their parts. The effect becomes sever (showing drying symptoms) after the galls are changing to pink, a gall which represents the maturity of the pest. From the two modes of plantations the coppiced ones are affected more severely.

Finally, planting of *E.camaldulensis* is currently very severely affecting by the BGC insect pest. Therefore, in order to escape from the severe effect of this invasive gall wasp introduction of other resistant Eucalyptus species and high breads and conducting adaptation and adoption studies is essential in order to avoid the loss of Eucalyptus plantations. Further assessments of other insect pests and disease and their management options are also necessary in Amhara region, as infestation of some other insects and diseases were observed during conducting assessment of the distribution and damage with special reference to BGC insect pest.

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