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Survey of white mango scale (*Aulacaspis Tubercularis)* distribution on mango (*Mangifera Indica) production* at Assosa and Bambasi districts, in benishangul Gumuz region, western Ethiopia

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Abstract
The research was conducted to assess white mango scale distribution status from August 2019 to April 2020. Survey data was collected from randomly selected of 7 *Kebele* Administrations and 35 mango orchards as 5 per *Kebele* Administrations within 5–10 km interval. Stratified sampling method was used for selecting 3,150 sample leaves from 35 mango trees for counting the clusters of white mango scale. The survey result showed that white mango scale infestation was observed throughout the study period of all the study sites. The abundance and severity status were significantly higher at Assosa than at Bambasi district orchards and more abundant and severe on upper leaf than on lower leaf surface. Infestation status was significantly varied among study months; lowest and highest record during December and April respectively. Therefore it is recommended to develop regular inspection and monitoring for providing sustainable management approach.

Keywords: white mango scale, mango orchard, distribution, abundance, severity status

Introduction
Mango is a member of the family Anacardiaceae within the genus Mangifera which consists of over 25 species. Among the several species of mango, *Mangifera indica* (Linnaeus) is the only species grown commercially on large scale [1]. Mango (*Mangifera indica* L.) originated in tropical Asia and is currently distributed across all tropical and subtropical lowland areas throughout the world [2, 3, 4, 5]. Mango serves as a fruit crop and as a subsistence crop for family farms. As it ripens at the end of the dry season and at the start of the rainy season, the mango is a fundamental source of nutrition for rural populations [6]. Mango is traditionally grown in Ethiopia primarily for family consumption and local markets, but some emerging modern farms have started to produce mango for both local and export markets [7]. Ethiopia exports mango to Djibouti, Saudi Arabia, Yemen, Sudan and the United Arab Emirates [8].
Mango is attacked by a variety of insect pests such as stone weevil (Sternochetus spp.), mealy bugs, fruit flies, scales, and mites, and various diseases of which fungal diseases are the common [1, 9]. In Ethiopia Mango production is constrained by insect pests such as fruit flies, mango seed weevil, mites, thrips, mealybugs and scale insects [7, 10]. Among these insect pests of mango, white mango scale (WMS) (*Aulacaspis tubercularis* Newstead) is the most important of hard scale insects which is reported to have damaged mango in various parts of the world [11, 12, 13].
The WMS (white mango scale) insect pest morphological description is opaque white female armour which is circular, flat, thin and often wrinkled and Exuviae is near the margin, and is yellowish-brown, with a median black ridge, forming a dark distinct median line; Male armours are small, white, sides nearly parallel and distinctly tricarinate and crawlers are deep bright brick red [14]. The pest reproduces during both dry and wet seasons [15]. The damage caused by WMS (white mango scale) includes yellowing of leaves, appearance of conspicuous pink blemishes on mature and ripe fruits, and dieback of the plant [13, 16,]. Infestation in young trees may lead to excessive fall off leaves, retarded growth and death of the whole plant [17]. The development of conspicuous blemishes on mango fruit skin which was infested by WMS (white mango scale) markedly damages mango fruit export potential and eventually leads to economic loss [18,19].
Infestation of mango by WMS (white mango scale) insect pest in Ethiopia was first reported in 2010 in a mango orchard owned by Green Focus Ethiopia Ltd [20]. which used to import mango seedlings from India and hence it is deduced that te inhsect pest probably entered Ethiopia accidently on imported seedlings. Within one year of first record, WMS (white mango scale) was reported to have dispersed 100 km west and to northern and central Ethiopia, with the infested area in the north being about 1500 km away from the place of initial infestation [21, 22, 23].
Mango fruit yield was reduced from 10 quintal to 2-3 quintal per tree or may not be obtained due to the heavy infestation of white mango scale [20]. Mango production in western Ethiopia is highly constrained by WMS (white mango scale). The damage of WMS (white mango scale) induced panic and frustration in Western Ethiopia for the loss in crop production and indirect sociological consequences, since mango plantation serves as shade for animals and conference hall for the people, in addition to generating income and serving as food in the region. The insect has become a growing concern among various government organizations and civil societies and communities. The problem is no more regarded as economic one as it has social, environmental, and other repercussions [24, 25]. Therefore the objective of this research was to study spatial and seasonal severity of infestation status, abundance and develop distribution map of white mango scale at Assosa and Bambasi districts in Benshungul-Gumuz Region, Western Ethiopia.

Materials and Methods

Survey of white mango scale

Description of survey area

The study area is located in the Benishangul-Gumuz Regional State. The region has three Administrative zones and one especial district. Benishangul-Gumuz Regional State is found at 687 km away from the capital city of the country, Addis Ababa, in the west. It is located at 9°30′ - 11°30′ latitude and 34°20′ - 36°30′ longitude. The region is bordered with the Sudan in the west, Amhara Regional state in the east and north, Oromiya Regional state in the East and south east and Gambella Regional state in the South. It covers a total area of about 50,380km^2. Plain undulating slopes and mountains characterize the topography of the region. The altitude of the region ranges mainly between 580 and 2731 meter above sea levels. The average annual rainfall is 860-1600 mm and the annual ambient temperature varies from 17-29°C [26]. The agro climatic zonation of the region can be categorized as 75% *Kola* (lower altitude), 24% *Woina Dega* (mid-altitude) and 1% *Dega* (higher altitude). Major crops grown include: Maize, sorghum, soya bean, Mango, Banana, Lemon, Orange and others [27]. Farmers of the region about 96,399 holds mango trees and productivity is about 5.5 ton/ha [28]. Major mango growing administrative zones in the region are Assosa and Metekel Administrative Zones and almost half of the growers are from Assosa administrative zone [29].

Bambasi district is one of the districts in Assosa Administrative Zone in the Region situated 45 km in North East part of the Assosa town and located at a distance of 610 Km from Addis Ababa and 45 Km from administrative city of the Region Assosa. The district geographically lies between 9°45' latitude and 34 45' longitudes. The total area is about 2100km2 of land [27]. It is located in 1100-1450 meter above sea level. The average annual rainfall is 1350-1450 mm and the annual ambient temperature varies from 21-35°C [26]. The major crop grown in the area are Maize, sorghum, soya bean, Mango, Banana, Lemon, Orange and others [27].

Assosa is the district in western Ethiopia and capital of the Benishangul Gumuz regional state located in Assosa Administrative zone. The district is geographically lies between 10°04′ -10.0670 latitude and 34°31′ - 34.5170 longitudes. It is 687 km away from Addis Ababa. The total size of the area is about 2317 km^2 [27]. It is located in 1401-1544 meter above sea level. The average annual rainfall is 900-1200 mm and the annual ambient temperature varies from 21-31°C [26]. The major crop grown in the area are sorghum, maize, soya bean, ground nut, sweet potato, banana, mango and others [27]. Figure 1 showed the study Location map of both Bambasi and Assosa districts.

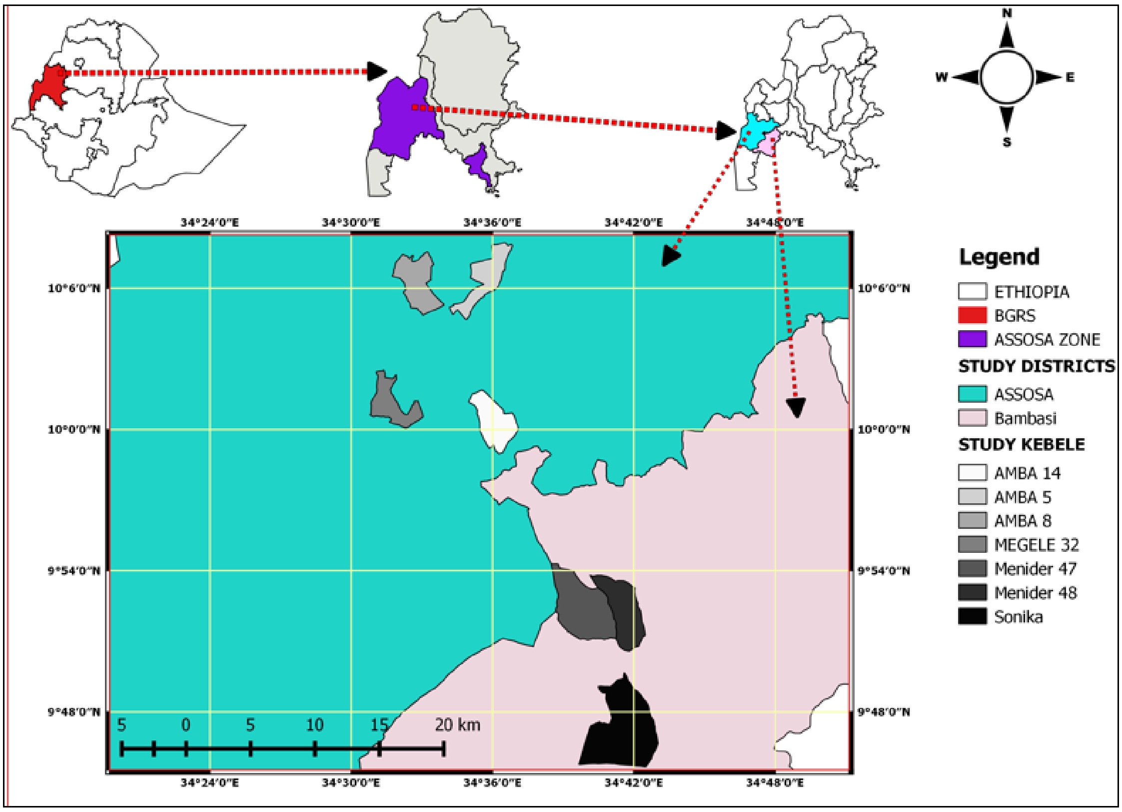

Fig 1: Location map of the study site

Assessment of mango orchards for scale

White mango scale infestation assessment was conducted from August 2019 to April 2020 for nine consecutive months. Multi stage sampling procedure was adopted in the choice of sample mango orchards and household heads for this study. At first stage Assosa Administrative zone was selected purposively on the basis of being a prominent mango producing and white mango scale infestation areas. In the second stage the study districts of Assosa and Bambasi districts were selected by purposive sampling technique based on major mango farm production and white mango scale infestation problem in the Administrative Zone. In the third stage the study *Kebele* administrations were selected by proportional sampling technique based on area coverage of mango production in two areas that means more number of *Kebele* administrates were selected in the highest production areas and less number of *Kebele* administrates in low production areas. Mango producing *kebele* administrates 10% from each district four in Assosa district such as: Amba_14, Amba_5, Amba_8 and Megele_32 and three in Bambasi district such as: Mender_47, Mender_48 and Sonika a total of seven *Kebele* administrates were selected by using a commonly accepted approach known as the rule of the thumb [30]. In the fourth stage a total of 35 mango orchards holding a minimum of ten mango trees per orchard in the two mango producing districts, five mango orchards from each *Kebele* administrate within 5-10km interval along the main and accessible road side were selected by systematic sampling method. Within each orchard of assessments, one mango tree was selected and tagged from more or less the most central point of the orchard. Hence, 20 (57.15%) and 15 (42.85%) of the sampled mango orchards were from Assosa and Bambasi districts respectively.

Even though the leaves, twigs and fruits of mango tree were attacked by white mango scale for easy count rating had been done by counting the clusters they form on the leaves to study the infestation status of white mango scale. The sample leaves were selected from the top, middle and bottom mango canopy horizon by stratified sampling method. So that ten leaves were randomly picked three at the top, four at the middle and three at the bottom parts from each tree once within a month for nine consecutive months for counting the clusters of white mango scale formed on leaves. Hence, 90 leaves from each tree and a total of 3150 sample leaves, 1800 and 1350 sample leaves were selected from Assosa and Bambasi respectively. These samples leaves were kept in polyethylene bags and transferred to the laboratory for counting procedures as the method used by [21, 31, 32, 33]. The presence or absence of cluster was observed by hand lenses observation on both upper and lower surfaces. When present, the number of the cluster on every leaf was recorded.

The infestation and the degree of damage was recorded by using a scoring method from 0 to 5 scale as; free= <5% of the panicle destroyed, minimal damage = 5 to 24% of the panicle destroyed, moderate = 25 to 50% damage, severe = 51 to 70% damage and very severe = 71 to 100% damage [34]. So severity status of the infestation as used by [21] was rated and categorized based on cluster number per leaf can be related to each other as: <1= < 5% (Free or Zero for less than one cluster formation), >1.0 - 2.0 = 5 to 24% (Minimal for greater than one and less than two clusters formation per leaf), >2.0 - 4.0 = 25 to 50% (Moderate for greater than two and less than four clusters formation per leaf), >4.0 - 5.0 = 51 to 70% (Severe for greater than four and less than five clusters formation per leaf) and >5 = 71 to 100% (Very Severe for greater than 5 clusters formation) of leaves damaged as seen in Figure 2. During the assessment, the coordinates of each assessed site was recorded by the use of Global Positioning System (GPS).

Fig 2: Severity status of white mango scale

Collected survey data

The quantitative data was collected during mango tree assessment of each mango orchards. Data collected for white mango scale infestation status from the assessed mango trees were sampling date, mean number of white mango scale cluster per leaf, Spatial data like Altitude, latitude and longitude; and infestation status like free, minimal, moderate, severe and very severe severity status.

Statistical analysis of the survey data

The severity of the pest and its distribution in the study areas were tested by counting white mango scale cluster formed on mango leaves and analysed using a general linear model (PROC GLM). Whenever the F-test was significant, significant means were separated by Fisher's Least Significant Difference (LSD) at 5% or 1% error level. For two different groups't-tests was used for comparison using PROC TTEST at 5% or 1% error level. Count data of white mango scale was subjected to square root transformation ($\sqrt{}$(x+0.5) before analysis to stabilize the variance. Homogeneity of variance of the sample was tested using levene's test before and after data transformation (p >.05) [35, 36]. The data were reported in the text using the back transformed values. Spatial and seasonal distribution map of white mango scale was drawn by Quantum Geographical Information System (QGIS) software from the Global Positioning System (GPS) file using the recorded coordinates of each surveyed site.

Results

Spatial distribution of white mango scale

Abundance of white mango scale

Mean±SEof WMS cluster was highly significantly higher at Assosa 6.59 (2.50) ± 4.85(0.93) than at Bambasi 5.07 (2.14) ± 0.4(0.09) (t_{313}=3.31, p<.01) (Table 1).

Table 1: White mango scale cluster per leaf (pooled data, Assosa and Bambasi)

							Pooled *t* test		
Districts	**N**	**Mean**	**SD**	**SE**	**min**	**max**	**DF**	***t* Value**	**Pr > |t|**
Assosa	180	6.59 (2.5)	4.85(0.93)	0.36(0.07)	0.3	16.8	313	3.31	0.001
Bambasi	135	5.07 (2.14)	4.67(1.01)	0.4(0.09)	0	15			

The mean the number of clusters of the pooled data of orchards was statistically highly significant ($F_{6,252}$ = 395, p < 0.01) different. Comparative mean clusters of WMS among orchards were maximally abundant in Amba_14, 7.28(2.65) in Assosa Districts and lowest mean cluster record in Sonika 4.59(2.00) in Bambasi districts. Mean clusters between Amba_8, 6.15(2.39) and Megele_32, 6.12(2.39) and also Mender_47, 5.30(2.19) and Mender_48, 5.33(2.20) were the insignificant difference. Mean clusters in Amba_8, 6.15(2.39) and Megele_32, 6.12(2.39) were less abundant than Amba_14, 7.28(2.65), and Amba_5, 6.82(2.55) and more abundant than Mender_47, 5.30(2.19) and Mender_48, 5.33(2.20) (Table 2).

The segregated data of WMS cluster of the study orchards in Assosa and Bambasi districts were statistically highly significantly different (F 3,168 = 119, $p < .01$) and (F 2,124 = 88, $p < .01$) respectively. Comparative mean clusters at Assosa district orchards were more abundant in Amba_14, 7.28(2.65) than Amba_5, 6.82(2.55) but Amba_5 were more abundant than Amba_8, 6.15(2.39) and Megele_32, 6.12(2.39). The mean cluster of WMS was insignificant difference between Amba_8, 6.15(2.39) and Megele_32, 6.12(2.39) in abundant. The Comparative mean cluster at Bambasi district orchards was insignificantly different between Mender_48, 5.33(2.20) and Mender_47, 5.30(2.19); but both orchards significantly more abundant than Sonika 4.58(2.00) orchard (Table 2).

Table 2: Mean number of white mango scale clusters per leaf in the study orchards

Kebele Administration	Mean		
	Pooled data	Segragated data of Assosa	Segragated data of Bambasi
Amba_14	7.28(2.65)a	7.28(2.65)a	
Amba_5	6.82(2.55) b	6.82(2.55) b	
Amba_8	6.15(2.39) c	6.15(2.39) c	
Megele_32	6.12(2.39) c	6.12(2.39) c	
Mender_48	5.33(2.20) d		5.33(2.20) a
Mender_47	5.30(2.19) d		5.30(2.19) a
Sonika	4.59(2.00) e		4.58(2.00) b
Mean	5.9(2.3)	6.6(2.5)	5.1(2.1)
SEm	0.11(0.04)	0.15(0.05)	0.17(0.06)
LSD	0.13(0.03)	0.12(0.03)	0.124(0.034)
CV%	5.11(3.20)	4.51(3.05)	5.87(3.79)
Sign.difference	**	**	**

Values given in parenthesis are square root transformed values; Values in each column of the same letter are not significantly different; SEm=Standard error of mean; LSD=Least Significant Difference; CV=Coefficient of Variation; * significant at P < 0.05,** significant at 0.01

Table 3 and Figure 3 illustrate the comparative mean number of WMS clusters on the leaf surface. The mean number of WMS clusters of the pooled data was highly significantly higher on the upper leaf surface than the lower leaf surface (t 314 = 11.48, $p < .01$) in all orchards. The mean number of WMS clusters was more abundant on the upper leaf surface than the lower leaf surface for all the study orchards.

Fig 3: Infestation patterns of white mango scale on upper and lower leaf surface

Table 3: White mango scale cluster number on upper and lower leaf surface (pooled data, Assosa and Bambasi)

							Cochran *t* test		
Leaf surface	N	Mean	Std Dev	Std Err	Min	Max	DF	*t* Value	Pr > |t|
Upper	315	4.2(2)	3.4(0.8)	0.2 (0.04)	0	11.76	314	-11.48	<.0001
Lower	315	1.8 (1.4)	1.45 (0.48)	0.08 (0.03)	0	5.04			

Severity status of white mango scale infestation: The WMS severities of infestation status for free severity status of the pooled data from Assosa and Bambasi study orchards were statistically highly significant different (F 5, 45 = 31.7, $p < .01$). The comparative mean cluster of WMS per leaf showed that the severity status was maximum at Amba_5, 0.93(1.19), and lowest at Sonika 0.27(0.9) compared with other orchards. The severity status was insignificantly different between Amba_8, 0.67(1.07) and Megele_32, 0.68(1.09) but both significantly different and less severe than Amba_5, 0.93(1.19). Similarly there were insignificant different between Mender_47, 0.46(0.97) and Mender_48, 0.51(0.99), but significantly different and less severe than Amba_8, 0.67(1.07) and Megele_32, 0.68(1.09).

No zero cluster formation at Amba_14 orchards (Table 4).

The WMS severity of infestation status for minimal severity status of the pooled data from Assosa and Bambasi study orchards were statistically significantly different (F 6, 24 = 3.16, $p < .05$). The comparative mean WMS cluster per leaf was maximum at Amba_8, 1.72(1.49) and Amba_5, 1.74(1.49) and lowest severity status at Amba_14, 1.22(1.31) compared with other orchards. Comparative minimal severity status between Amba_8 and Amba_5 was insignificantly different. The minimal severity status in descending order was Amba_5, 1.74(1.49) and Amba_8, 1.72(1.49); mender_48, 1.64(1.45); Sonika 1.58(1.44); Mender_47, 1.4(1.38); Megele_32, 1.28(1.33) and Amba_14, 1.22(1.31) respectively (Table 4).

The WMS severity of infestation status for moderate severity status of the pooled data from Assosa and Bambasi study orchards were statistically highly significant different (F 6, 42 = 21.08, $p < .01$). The comparative mean WMS for moderate severity status were maximum in Sonika 3.58(2.02) and lowest severity status in Mender_47, 2.4(1.7) compared with other orchards. Comparative moderate severity status Amba_8, 3.11(1.9) with Amba_14, 3.05(1.88) and Megele_32, 2.82(1.81) with mender_48, 2.84(1.82) were showed the insignificant difference. The moderate severity status in descending order was Sonika 3.58(2.02); Amba_5, 3.28(1.95); Amba_8, 3.11(1.9); Amba_14, 3.05(1.88); mender_48, 2.84(1.82); Megele_32, 2.82(1.81) and Mender_47 2.4(1.7) respectively (Table 4).

The WMS severity of infestation status for severe severity status of the pooled data from Assosa and Bambasi study orchards were statistically insignificant different (F 5, 17 = 1.05, ns). All the study orchards had the same severe severity status excluding Megele_32 in which there was no severe severity status recorded during the study month (Table 4).

The WMS severity of infestation status for very severe severity status of the pooled data from Assosa and Bambasi study orchards were statistically highly significant different (F 6, 141 = 168.65, $p < .01$). The comparative mean WMS cluster per leaf showed that the severity status was maximum in Amba_14, 10.74(3.31) and lowest severity status in Megele_32, 9.52(3.11) and Mender_47, 9.7(3.14) compared with other orchards. Comparative of very severe severity status of Sonika 10.25(3.25) with Amba_5, 10.26(3.31); mender_48, 9.94(3.19) with Amba_8, 9.96(3.18) and Megele_32, 9.52(3.11) with Mender_47, 9.7(3.14) were insignificantly different. The very severe severity status in descending order were Amba_14, 10.74(3.31); Sonika 10.25(3.25); Amba_5, 10.26(3.31); Amba_8, 9.96(3.18); mender_48, 9.94(3.19); Mender_47, 9.7(3.14) and Megele_32, 9.52(3.11) respectively (Table 4).

The WMS severities of infestation status for free severity status of the segregated data of Assosa study orchards were statistically significantly different (F 2, 13 = 5.45, $p < .05$). The comparative WMS mean cluster per leaf showed that the severity status was maximum in Amba_5, 0.93(1.19) and lowest in Amba_8, 0.67(1.08) and Megele_32, 0.68(1.09). The severity status between Amba_8 and Megele_32 was insignificantly different. No zero cluster formation was found at Amba_14 study orchards (Table 4).

The WMS severity of infestation status for minimal severity status of the segregated data of Assosa study orchards was statistically highly significantly different (F 3, 13 = 11.32, $p < .01$). The comparative mean clusters per leaf showed that the minimal severity status was maximum at Amba_8 (1.72(1.49)) and Amba_5, (1.74(1.49)) and lowest at Amba_14, (1.22(1.31)) and Megele_32, (1.28(1.33)). Mean cluster records at Amba_8 with Amba_5 and also at Amba_14 with Megele_32 were similar (Table 4).

The WMS severity of infestation status for moderate severity status of the segregated data of Assosa study orchards was statistically highly significant different (F 3, 31 = 21.65, $p < .01$). The comparative WMS mean clusters per leaf showed that the severity status was maximum in Amba_8, 3.11 (1.89) and Amba_5, 3.28 (1.94) and lowest severity status in Megele_32, 2.82 (1.81) compared with Amba_14, 3.05 (1.88) orchards. Mean cluster records of Amba_8 and Amba_5 were insignificantly different. The severity status for moderate severity status in descending order was Amba_5 3.28 (1.94); Amba_8 3.11 (1.89); Amba_14 3.05 (1.88) and Megele_32, 2.82 (1.81) respectively (Table 4).

The WMS severity of infestation status for severe severity status of the segregated data of Assosa study orchards was statistically insignificant different (F 2, 6 = 3.39, ns). All study orchards had insignificantly different severe severity status excluding Megele_32 in which there was no record of severe severity status (Table 4).

The white mango scale severity of infestation status for very severe severity status of the segregated data of Assosa study orchards was statistically highly significant different (F 3, 90 = 89.83, $p < .01$). The comparative WMS cluster per leaf showed that the severity status was maximum in Amba_14, 10.74 (3.31) and lowest severity status in Megele_32, 9.52 (3.11) compared with other orchards. The severity status for very severe severity status in descending order was Amba_14, 10.74 (3.31); Amba_5, 10.26 (3.23); Amba_8, 9.96 (3.18) and Megele_32, 9.52 (3.11) respectively (Table 4).

The white mango scale severity of infestation status for free severity status of the segregated data of Bambasi study orchards was statistically highly significant different (F 2, 31 = 21.81, $p < .01$). The comparative WMS mean cluster per leaf showed that the severity status was maximum in Mender_48, 0.51(0.99) and Mender_47, 0.46(0.97) compared with Sonika 0.27(0.86). The Mean cluster of WMS between Mender_47 and Mender_48 orchards was not significantly different (Table 4).

The WMS severity of infestation status of the segregated data of Bambasi study orchards for minimal severity status (F 2, 11 =0.84, ns), for moderate severity status (F 2, 11 = 0.79, ns), and severe severity status (F 2, 11 = 0.95, ns) were insignificantly different respectively (Table 4).

The WMS severity of infestation status for very severe severity status of the segregated data of Bambasi study orchards was statistically highly significant different (F 2, 48 = 30.97, $p < .01$). The comparative WMS clusters per leaf showed that the severity status was maximum in Sonika 10.25 (3.25) and lowest severity status in Mender_47, 9.65 (3.14) compared with Mender_48, 9.94 (3.19). The severity statuses for very severe severity status in descending order were Sonika, Mender_48, and Mender_47 respectively (Table 4).

Table 4: Severity of infestation of white mango scale in the study orchards

Kebele	**Mean of pooled data, Assosa and Bambasi Districts**				
	Free	**Minimal**	**Moderate**	**Severe**	**Very Sever**
Amba_14	N_r	1.22(1.31)d	3.05(1.88)bc	4.54(2.24) a	10.74(3.31)a
Amba_8	0.67(1.07) b	1.72(1.49) a	3.11(1.9) bc	4.75(2.29) a	9.96(3.18) c
Amba_5	0.93(1.19) a	1.74(1.49) a	3.28(1.95) ab	4.25(2.18) a	10.26(3.31) b
Megele_32	0.68(1.09) b	1.28(1.33) cd	2.82(1.81) c	N_r	9.52(3.11) d
Mender_47	0.46(0.97) c	1.4(1.38) bc	2.4(1.7) d	4.4(2.21) a	9.7(3.14) d
Mender_48	0.51(0.99) c	1.64(1.45) ab	2.84(1.82) c	4.64(2.27) a	9.94(3.19) c
Sonika	0.27(0.9) d	1.58(1.44) ABC	3.58(2.02) a	4.58(2.25) a	10.25(3.25) b
Mean	0.5(0.99)	1.5(1.41)	3.0(1.87)	4.5(2.24)	10.0(3.2)
SEm	0.05(0.04)	0.09(0.04)	0.11(0.04)	0.11(0.024)	0.11(0.021)
LSD	0.165(0.081)	0.32(0.113)	0.31(0.09)	0.45(0.10)	0.18(0.032)
CV%	31.06(7.78)	15.6 (5.99)	9.195(4.034)	6.1(2.83)	2.95(1.63)
Sign.difference	**	*	**	ns	**
Mean of Assosa study site					
Mean					
Kebele	Free	Minimal	Moderate	Sever	Very Sever
Amba_14	N_r	1.22(1.31) b	3.05(1.88) ab	4.54(2.24) a	10.74(3.31) a
Amba_8	0.67(1.08) b	1.72(1.49) a	3.11(1.89) a	4.75(2.29) a	9.96(3.18) c
Amba_5	0.93(1.19) a	1.74(1.49) a	3.28(1.94) a	4.25(2.18) a	10.26(3.23) b
Megele_32	0.68(1.09) b	1.28(1.33) b	2.82(1.81) b	N_r	9.52(3.11) d
Mean	0.74(1.1)	1.5(1.41)	3.06(1.88)	4.5(2.24)	10.12(3.21)
SEm	0.07(0.05)	0.07(0.027)	0.13(0.04)	0.1(0.022)	0.14(0.022)
LSD	0.197(0.095)	0.21(0.08)	0.25(0.067)	0.44(0.098)	0.16(0.027)
CV%	20.29(6.5)	9.92(3.81)	8.69(3.75)	4.44(1.99)	2.86(1.5)
Sign.difference	*	**	**	ns	**
Mean of Bambasi study site					
Mean					
Kebele	Free	Minimal	Moderate	Sever	Very Sever
Mender_48	0.51(0.99) a	1.64(1.45) a	2.8(1.82) a	4.64(2.27) a	9.94(3.19) b
mender_47	0.46(0.97) a	1.4(1.38) a	2.4(1.7) a	4.4(2.21) a	9.65(3.14) c
Sonika	0.27(0.86) b	1.58(1.44) a	3.58(2.02) a	4.58(2.25) a	10.25(3.25) a
Mean	0.39(0.93)	1.54(1.42)	2.94(1.84)	4.5(2.24)	9.92(3.19)
SEm	0.1(0.045)	0.18(0.06)	0.18(0.05)	0.57(0.06)	0.18(0.032)
LSD	0.14(0.068)	0.43(0.15)	0.43(0.12)	0.43(0.0998)	0.21(0.036)
CV%	41.04(8.55)	20.14(7.8)	10.54(4.77)	6.83(3.19)	3.199(1.66)
Sign.difference	**	ns	ns	ns	**

Values given in parenthesis are square root transformed values; Values in each column of the same letter are not significantly different; SEm= Standard error of mean; LSD=Least Significant Difference; CV=Coefficient of Variation; * significant at P < .05; ** significant at .01; ns=Non_significant

Seasonal fluctuation of white mango scale

Seasonal fluctuation of white mango scale abundance

Mean WMS cluster of pooled data from Assosa and Bambasi during the study month were highly significantly different ($F_{8,252}$=6313, p<.01). The mean cluster was peak in April 15.1 (4.0) and lowest record during December 0.57 (1.01). The mean cluster of WMS record during the study month from August/2019 to April/2020 in descending orders were April 15.1 (4.0), March 12.1 (3.6), February 8.1 (2.3), January 6.1 (2.6), August 5.097 (2.4), September 3.097(1.9), October 2.097 (1.6), November 1.23 (1.3) and December 0.57 (1.01) respectively (Table 5).

The Mean cluster of WMS from the disagregated data of Assosa study orchards during the study months were showed highly significantly different (F 8, 168 = 3230, p < .01). The comparative mean cluster was the peak in April 15.82 (4.0) and lowest record during December 0.86 (1.2). The mean cluster of WMS among the study month in descending order were April 15.82 (4.0), March 12.82 (3.7), February 8.82(3.1), January 6.82 (2.7), August 5.82 (2.5), September 3.82 (2.1), October 2.82 (1.8), November 1.78 (1.5) and December 0.86 (1.2) respectively. The mean cluster of WMS from the segregated data of Bambasi study orchards during the study months was showed highly significantly different (F 8,124 = 2575.15, p < .01). The mean cluster was the peak in April 14.14 (3.8) and lowest record during December 0.19(0.8). The comparative mean cluster abundance among the study months in descending orders was April 14.14 (3.8), March 11.14 (3.4), February 7.14 (2.8), January 5.14 (2.4), August 4.14(2.2), September 2.14 (1.6), October 1.14 (1.3), November 0.5 (1.0) and December 0.19 (0.8) respectively (Table 5).

Table 5: Mean number of clusters of white mango scale during the month of the study period

Month	**Mean**		
	Pooled data for Assosa and Bambasi Districts	**Assosa**	**Bambasi**
August	5.097(2.4) e	5.82(2.5) e	4.14(2.2) e
September	3.097(1.9) f	3.82(2.1) f	2.14(1.6) f
October	2.097(1.6) g	2.82(1.8) g	1.14(1.3) g
November	1.23(1.3) h	1.78(1.5) h	0.5(1.0) h

December	0.57(1.01) i	0.86(1.2) i	0.19(0.8) i
January	6.1(2.6) d	6.82(2.7) d	5.14(2.4) d
February	8.1(2.3) c	8.82(3.1) c	7.14(2.8) c
March	12.1(3.6) b	12.82(3.7) b	11.14(3.4) b
April	15.1(4.0) a	15.82(4.0) a	14.14(3.8) a
Mean	5.9(2.3)	6.6(2.5	5.1(2.1)
SEm	0.1(0.03)	0.1(0.03)	0.1(0.03)
LSD	0.14(0.035)	0.19(0.047)	0.1867(0.82)
CV%	5.11(3.20)	4.51(3.05)	5.87(3.79)
Sign.difference	**	**	**

Values given in parenthesis are square root transformed values; Values in the column of the same letter are not significantly different; SEm= Standard error of mean; LSD=Least Significant Difference; CV=Coefficient of Variation; * significant at P < .05; ** significant at .01; ns=Non_significant

White mango scale mean cluster variation across orchards during same study periods: Mean cluster record during same month across each orchardshowed a highly significant varation ($F_{48, 252}$ = 4.85, p< .01). Themean cluster across orchards during same study periods in decreasing order was shown asOctober ($F_{6, 252}$ =99.51, p<.01), November ($F_{6, 252}$=89.98, p< .01), September ($F_{6, 252}$=68.4, p< .01), August ($F_{6, 252}$=42.91, p< .01), December ($F_{6, 252}$=36.67, p< .01), January ($F_{6, 252}$=36.03, p< .01), February ($F_{6, 252}$=27.64, p< .01), March ($F_{6, 252}$=18.35, p< .01), April ($F_{6, 252}$=15.27, p< .01) respectively (Table 6 and Figure 4).

Table 6: Infestation variation across orchards during study periods

	Least Squares Means (square root transformed value)				
Interaction	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
month**kebele*	48	1.31	0.02	4.85	<.0001
April**kebele*	6	0.52	0.09	15.27	<.0001
qAugust**kebele*	6	1.45	0.24	42.91	<.0001
December**kebele*	6	1.24	0.21	36.67	<.0001
February**kebele*	6	0.93	0.16	27.64	<.0001
January**kebele*	6	1.22	0.20	36.03	<.0001
March**kebele*	6	0.62	0.10	18.35	<.0001
November**kebele*	6	3.04	0.51	89.98	<.0001
October**kebele*	6	3.36	0.56	99.51	<.0001
September**kebele*	6	2.31	0.38	68.4	<.0001

The fluctuation of white mango scale cluster across orchards during study periods: Figure 4 showed that the abundance of WMS mean cluster during the study periods across orchards showed a rapid decrease from August to October and during November and December were stayed low and being undetectable. The clusters were started a progressive increase from January to February and a rapid increase to peak from March to April.

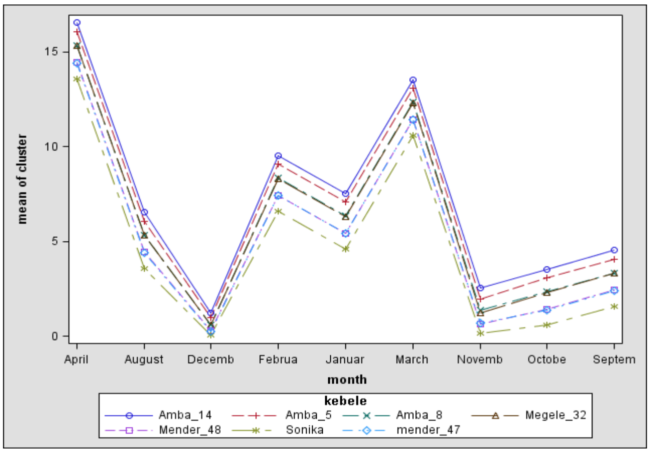

Fig 4: Fluctuation of white mango scale cluster across orchards during study periods

Seasonal fluctuation of severity status of white mango scale infestation: The white mango scale severity of infestation status of the pooled data from Assosa and Bambasi study orchards during the study months for free severity status were statistically highly significantly different (F 2, 45 = 43.89, p < .01). The Mean WMS cluster per leaf was maximum in October 0.65(1.07) and November 0.57(1.02) and lowest in December 0.44(0.954). The severity statuses during October and November were insignificantly different but both significantly higher severity statuses than December. Free severity status was not recorded during the study months of August, September, January, February, March, and April (Table 7).

The white mango scale severity of infestation status of the pooled data from Assosa and Bambasi study orchards during the study months for minimal severity status were statistically significantly different (F 3, 24 = 3.15, p < .05). Mean WMS cluster per leaf was insignificantly different during September 1.65 (1.46), November 1.61 (1.5), and October 1.52 (1.42) but significantly higher than December 1.22 (1.31). Minimal severity status was not recorded during the study months of August and January to April (Table 7).

The white mango scale severity of infestation status of the pooled data from Assosa and Bambasi study orchards during the study months for moderate severity status were statistically highly significant different (F 3, 42 = 37.99, p < .01). Mean WMS cluster per leaf showed that the severity status was maximum during August 3.65 (2.04) and lowest during November 2.5 (1.74). The severity status was insignificantly different between September 3.06 (1.88) and October 2.9 (1.85). Moderate severity status was not recorded during the study months of December to April.

The white mango scale severity of infestation status of the pooled data from Assosa and Bambasi study orchards during the study months for severe severity status were statistically insignificant different (F 2, 17 = 2.19, ns). The mean WMS cluster formation was similar among August 4.52 (2.24), September 4.46 (2.22), and January 4.7 (2.3). Severe severity status was not recorded during the study months of October to December and February to April (Table 7).

The white mango scale severity of infestation status of the pooled data from Assosa and Bambasi study orchards during the study months for very severe severity status were statistically insignificantly different (F 4, 141 = 4241, p < .01). Mean WMS cluster per leaf showed that the severity status was maximum during April 15.1(3.95) and lowest during August 5.9 (2.5). The severity status in descending order was April 15.1 (3.95), March 12.1 (3.6), February 8.1 (2.93), January 6.4 (2.62), and August 5.9 (2.5) respectively. No very severe severity status was recorded during the study months of September to December (Table 7).

The WMS severity of infestation status of the disagregated data of Assosa orchards during the study month for free severity status was statistically significantly different (F 2, 13 = 7.63, p < 0.05). Mean WMS cluster per leaf showed that the severity status of October 0.9 (1.18), November 0.9(1.18), December 0.7 (1.09) were the insignificant difference. The free severity status was not recorded during the study months of August, September, and January to April (Table 7).

The WMS severity of infestation status of the disagregated data of Assosa orchards during the study month for minimal severity status was statistically highly significantly different (F 2, 13 = 8.25, p < .01). Mean WMS cluster per leaf showed that the severity status was maximum during October 1.75 (1.5) and November 1.61 (1.45) and insignificantly different severity status between October and November but significantly higher than December 1.22(1.31). Minimal severity status was not recorded during the study months of August and September, January to April (Table 7).

The WMS severity of infestation status of the disagregated data of Assosa orchards during the study month for moderate severity status was statistically highly significantly different (F 2, 31 = 53.77, p < .01). Mean WMS cluster per leaf showed that the severity status was maximum in September 3.47 (1.99) and lowest in November 2.53(1.74). The severity status in descending order was September 3.47(1.99), October 2.93 (1.85), and November 2.53 (1.74) respectively. Moderate severity status was not recorded during the study months of August and December to April.

The WMS severity of infestation status of the disagregated data of Assosa orchards during the study month for severe severity status was statistically insignificantly different ($F_{2, 6}$ =0.8, ns). Severe severity status was not recorded during the study months of October to December and February to April (Table 7).

The WMS severity of infestation status of the disagregated data of Assosa orchards during the study month for very severe severity status was statistically highly significantly different (F 4, 90 = 3390.21, p < .01). Mean WMS cluster per leaf showed that the severity status was maximum during April 15.82(4.0) and lowest during August 5.93(2.54). The severity status in descending order was April 15.82(4.0), March 12.82 (3.65), February 8.82 (3.05), January 6.82 (2.7), and August 5.93 (2.54) respectively. No very severe severity status was recorded during the study months of September to December (Table 7).

The WMS severity of infestation status of the disagregated data of Bambasi orchards during the study month for free severity status was statistically highly significant different (F 2, 31 = 37.87, p < .01). Mean WMS cluster per leaf showed that the severity status was maximum during October 0.65(1.07) and lowest during December 0.19 (0.82) compared with November 0.5 (0.99). The severity status in descending order was October, November, and December respectively. Free severity status did not occur during the study months of August, September, and January to April (Table 7).

The WMS severity of infestation status of the disagregated data of Bambasi orchards during the study month for minimal severity status was statistically insignificant different (F 2, 11 = 1.67, ns). The severity status of September 1.65 (1.46), October 1.47 (1.39), and November 1.47 (1.39) were insignificantly different. Minimal severity status did not occur during the study months of August and December to April (Table 7).

The WMS severity of infestation status of the disagregated data of Bambasi orchards during the study month for moderate severity status was statistically highly significant different (F 2, 11 = 14.9, p < .01**)**. Mean WMS cluster per leaf showed that the severity status was maximum during August 3.65 (2.04) and lowest during September 2.47 (1.72) and October 2.47 (1.72). Moderate severity status did not occur during the study months of November to April (Table 7).

The WMS severity of infestation status of the disagregated data of Bambasi orchards during the study month for severe severity status was statistically insignificant different (F 2, 11 = 1.72, ns). The Mean WMS cluster per leaf was insignificantly different between August 4.47 (2.23), September 4.47 (2.23), and January 4.65 (2.27). Severe severity status did not occur during the study months of October to December and February to April (Table 7).

The WMS severity of infestation status of the disagregated data of Bambasi orchards during the study month for very severe severity status was statistically highly significant different (F 3, 48 = 1750, p < .01). Mean WMS cluster per leaf showed that the severity status was maximum during April 14.14(3.83) and lowest during January 5.47 (2.44). The severity status in descending order was April 14.14 (3.83), March 11.14 (3.41), February 7.14 (2.76), and January 5.47(2.44) respectively. No very severe severity status was recorded during the study months of August to December (Table 7).

Table 7: Severity of infestation of white mango scale during the month of the study period

	Mean of pooled data, Assosa and Bambasi Districts				
Month	**Free**	**Minimal**	**Moderate**	**Sever**	**Very Sever**
August	N_r	nr	3.65(2.04) a	4.52(2.24) a	5.9(2.5) e
September	N_r	1.65(1.46) a	3.06(1.88) b	4.46(2.22) a	N_r
October	0.65(1.07) a	1.52(1.42) a	2.9(1.85) b	N_r	N_r
November	0.57(1.021) a	1.61(1.5) a	2.5(1.74) c	N_r	N_r
December	0.44(0.954) b	1.22(1.31) b	N_r	N_r	N_r
January	N_r	N_r	N_r	4.7(2.3) a	6.4(2.62) d
February	N_r	N_r	N_r	N_r	8.1(2.93) c
March	N_r	N_r	N_r	N_r	12.1(3.6) b
April	N_r	N_r	N_r	N_r	15.1(3.95) a
Mean	0.5(0.99)	1.5(1.41)	3.0(1.87)	4.5(2.24)	10.0(3.2)
SEm	0.05(0.03)	0.08(0.03)	0.08(0.01)	0.09(0.021)	0.1(0.02)
LSD	0.13(0.06)	0.25(0.09)	0.26(0.071)	0.3(0.07)	0.16(0.027)
CV%	31.06(7.8)	15.60(5.99)	9.2(4.03)	6.1(2.8)	2.95(1.63)
Sign.difference	**	*	**	ns	**
	Mean of Assosa study site				
Month	Free	Minimal	Moderate	Severe	Very Sever
August	N_r	N_r	N_r	4.75(2.29) a	5.93(2.54) e
September	N_r	N_r	3.47(1.99) a	4.46(2.22) a	N_r
October	0.9(1.18) a	1.75(1.5) a	2.93(1.85) b	N_r	N_r
November	0.9(1.18) a	1.61(1.45) a	2.53(1.74) c	N_r	N_r
December	0.7(1.09) a	1.22(1.31) b	N_r	N_r	N_r
January	N_r	N_r	N_r	4.75(2.29) a	6.82(2.70) d
February	N_r	N_r	N_r	N_r	8.82(3.05) c
March	N_r	N_r	N_r	N_r	12.82(3.65) b
April	N_r	N_r	N_r	N_r	15.82(4.0) a
Mean	0.8(1.2)	1.5(1.41)	3.06(1.88)	4.6(3.4)	10.0(3.2)
SEm	0.05(0.03)	0.05(0.018)	0.09(0.024)	0.07(0.015)	0.09(0.015)
LSD	0.21(0.099)	0.23(0.08)	0.24(0.064)	0.3(0.07)	0.18(0.031)
CV%	20.29(6.5)	9.92(3.81)	8.69(3.75)	4.44(1.99)	2.86(1.5)
Sign.difference	*	**	**	ns	**
	Mean of Bambasi study site				
Month	Free	Minimal	Moderate	Sever	Very Sever
August	N_r	N_r	3.65(2.04) a	4.47(2.23) a	N_r
September	N_r	1.65(1.46) a	2.47(1.72) b	4.47(2.23) a	N_r
October	0.65(1.07) a	1.47(1.39) a	2.47(1.72) b	N_r	N_r
November	0.5(0.99) b	1.47(1.39) a	N_r	N_r	N_r
December	0.19(0.82) c	N_r	N_r	N_r	N_r
January	N_r	N_r	N_r	4.65(2.27) a	5.47(2.44) d
February	N_r	N_r	N_r	N_r	7.14(2.76) c
March	N_r	N_r	N_r	N_r	11.14(3.41) b
April	N_r	N_r	N_r	N_r	14.14(3.83) a
Mean	0.39(0.93)	1.54(1.42)	2.94(1.84)	4.5(2.24)	9.92(3.19)
SEm	0.06(0.03)	0.1(0.03)	0.1(0.03)	0.1(0.03)	0.11(0.018)
LSD	0.15(0.073)	ns	0.36(0.10)	ns	0.25(0.042)
CV%	41.04(8.55)	20.14(7.8)	10.54(4.77)	6.83(3.19)	3.199(1.66)
Sign.difference	**	ns	**	ns	**

Values given in parenthesis are square root transformed values; Values in each column of the same letter are not significantly different; SEm= Standard error of mean; LSD=Least Significant Difference; CV=Coefficient of Variation; * significant at $P < .05$; ** significant at .01; ns=Non_significant; N_r=Not Recorded Number of white mango scale cluster

Spatial and seasonal distribution map of white mango scale

Spatial distribution map of white mango scale: Figure 5 illustrates the spatial distribution of WMS in the study sites of Assosa and Bambasi districts. The spatial distribution from the reference of the experimental site, at Assosa Town, Assosa Poly Technique College was ranged from 5.003 km to 33.922km air distance.

Seasonal distribution map

Spatial distribution map

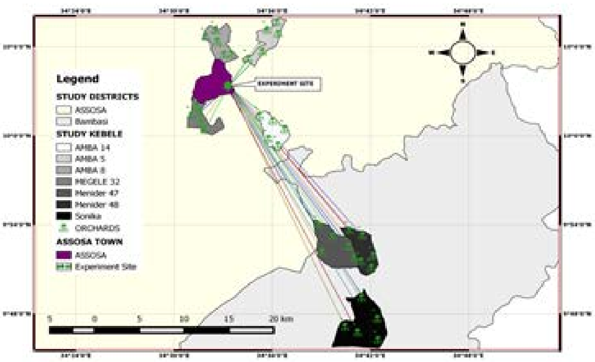

Fig 5: Seasonal and Spatial distribution map of white mango scale

Seasonal distribution map of white mango scale: Figure 6 illustrates seasonal WMS distribution map indicates that severity status was varied during the study month in the study orchards. WMS severity of infestation in the study month of August (Moderate to Very severe), September (Minimal to Moderate), October (Free to Moderate), November (Free to Minimal except in Amba_14 that was Moderate), December (Free to Minimal), January (Moderate to Very severe), and February to April (Very severe) severity status was indicated in the projected seasonal map.

Discussion

The study induced that spatial and seasonal distribution of white mango scale insect pest was varied among the study periods across all study orchards. Maximum severity and abundance of white mango scale was showed at Assosa than at Bambasi districts. Maximum infestation status recorded in Amba_14 and lowest infestation status recorded in Sonika mango orchards. The peak infestation status was showed during April while the start of mango fruit harvesting and lowest infestation status during December while the end of the rain fall and the start of new leaf initiation. These results also supported by different literatures such as: Field infestation assessment in Guto Gida and Diga Districts of East Wellega Zone by [24] showed that the presences of white mango scale with the mango tress all year round with overlapping generations throughout the year and peak population observed during the flowering time of spring and harvesting period. The study in the East and West Wollega Administrative Zones by [21] reported that there was infestation variation among the study sites. [31] reported that the study in Bench Maji Zone South West Ethiopia indicated that white mango scale infestation varied among the study districts and season. [13] reported the lowest population density was observed in the beginning of spring season during the two studies years. The study in Central and Eastern Kenya by [32] reported that considerable percentage of respondents said that level of the damage showed variations over time since first recognized and also the infestation was varied spatially among the study sites.

The study of white mango scale insect pest infestation status on mango leaf surface was indicated that more abundant on upper leaf surface than on lower leaf surface in all orchards throughout the study periods. Similar study result also reported by different literatures such as: The study by [17] on mango in Egypt who recorded that white mango scale preferred the upper leaf surface compared to the lower one. The study by [37] also strengthens the above that mango upper leaf surfaces were heavier infestation compared with the lower surface. In Ethiopia study in Arjo and Bako by [33] proved that all developmental stages of mango white scale were found to be more abundant on the upper leaf surfaces.

In the study of all mango orchards in Assosa and Bambasi districts white mango scale infestation status was showed four fluactuation phases as a rapid decreased from August to October, stayed low and undetectable between November and December and a progressive increased from January to February and a rapid increased from March to peak during April. These results also supported by different literature such as: The study by [33] in Arjo and Bako identified three phases of mango scale population fluctuation. In Arjo, the first phase was from February to July, when the population began to build up towards its peak; the second phase, in August, September and October was characterized by sharp decline of the population and the last one was from November to January during which the population remained low and inconspicuous [39]. In Bako, the first phase began in February as in Arjo but continued to May only. In June, July and August, the population declined abruptly, denoting the second phase. The last phase in which population remained low to undetectable was between September and January in Bako. Different studies in different countries were reported that different population fluctuations of mango white scale, some of these are study by [38] who stated that white mango scale had three peaks of seasonal abundance on mango trees in Egypt. These peaks were occurred on March, June and November, while the lowest population was occurred on mid-July. Also [13] recorded four annual peaks of seasonal abundance for white mango scale on mango trees in Egypt. These peaks were occurred on April, August, October and December, 2008, while these peaks were occurred on March, July, September and December, 2009.

Conclusions

White mango scale insect pest infestation was observed throughout the study periods of all the study mango orchards. The infestation status was significantly varied spatially and seasonally. It was significantly higher at Assosa than at Bambasi orchards and more abundant on upper leaf than on lower leaf surface. Infestation status was a rapid decreased from August to October, stayed low and undetectable between November and December and a progressive increased from January to February and a rapid increased from March to peak during April. Therefore it is recommended to regular inspection and monitoring of white mango scale insect pest throughout the year to come with sustainable management approach of white mango scale and the improvement of mango fruit yield in quality and quantity.

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References

1. Griesbach J Mango growing in Kenya, World Agroforestry Centre (ICRAF), Nairobi. Balock, J. W. & Kozuma, T. T. 1963. Notes on the biology and economic importance of the mango weevil, Sternochetus mangiferae (Fabricius), in Hawaii (Coleoptera: Curculionidae). Hawaiian Entomological Society,2003:3:1-12.
2. Dirou JF. Mango growing. NSW Centre for Tropical Horticulture, Alstonville,6,2004.
3. Okoth EM, Sila DN, Onyango CA, Owino WO, Muse mbi SM, Mathooko FM *et al*. Evaluation of physical and sensory quality attributes of three mango varieties at three stages of ripeness, grown in lower eastern province of Kenya – part 1. Journal of Animal and Plant Sciences,2013:17:2608-2618.
4. Ubwa ST, Ishu MO, Offem JO, Tyohemba RL. Igbum GO. Proximate composition and some physical attribute of three mangos (Mangifera indica L.) fruit varieties. International Journal of Agronomy and Agricultural Research,2014:4(2):21-29.
5. Crane JH, Wasielewsk IJ, Balerdi CF. Maguire I. Mango growing in the Florida home landscape. Horticultural Sciences Department, University of Florida, IFAS Extension,2017.
6. Vayssières JF, Sinzogan AAC, Adandonon A, Coulibaly O, Bokonon Ganta A. In: (Eds.) Sudha G Valavi, K Rajmohan, JN Govil, KV Peter and George Thottappilly. Mango vol: cultivation in different countries. Houston: Studium Press LLC,2012:2:260-279.

7. Chala A, Getahun M, Alemayehu S, Tadesse M. Survey of mango anthracnose in southern Ethiopia and in-vitro screening of some essential oils against Colletotrichum gloeosporioides. International Journal of Fruit Science,2014:14:157-173.
8. Bezu T, Woldetsadik K, Tana T. Production scenarios of mango (*Mangifera indica* L.) in Harari Regional State, Eastern Ethiopia.Science, Technology and Arts Research Journal,2014:3:59-63.
9. Atnafu Y. Management of white mango scale, *Aulacaspis tubercularis* (homoptera: diaspididae) using pruning, oils and pesticides in eastern wellega, Ethiopia. MSc thesis, Jimma University: Jimma Ethiopia,2020.
10. Tewodros BN, Fredah KRW, Wassu MA, Willis OO. Githiri SM Mango (*Mangifera indica* L.) production practices and constraints in major production regions of Ethiopia, African Journal of Agricultural Research,2019:14(4):185-196. 24 DOI: 10.5897/AJAR 2018.13608
11. Modesto del P, Claudia B, Juan RB, José MV. Biology, ecology and integrated pest management of the white mango scale, *Aulacaspis tubercularis* Newstead, a new pest in southern Spain - a review, Crop Protection,2020,133:105160, doi.org/10.1016/
12. Belay H, Dawit M, Teshale D, Tesfaye H, Ferdu A. Integrated Control of the White Mango Scale ThroughTree Management and Soil Drenching with a Systemic Insecticide in Western Ethiopia, Ethiop. J. Agric. Sci,2020:30(2)25-32.
13. Abo-Shanab ASH. Suppression of white mango scale, *Aulacaspis tubercularis* (Hemiptera: Diaspididae) on mango trees in El Beheira Governorate. Egyptian Academic Journal of Biological Sciences,2012:5:43-50.
14. Hamon A White mango scale *Aulacaspis tubercularis* Newstead (Coccoidea: *Diaspididae*), Pest Alart, FDACS-P-01697,2016.
15. Bakry M, Tolba E. Relationship between the population density of the white mango scale insect, *Aulacaspis tubercularis* (Newstead) (Hemiptera: Diaspididae) and the yield loss of mango trees in Luxor Governorate, Egypt. *Journal of Phytopathology and Pest Management*,2018:5(3):14-28. Retrieved from http:// ppmj.net/index.php/ppmj/article/view/174
16. El-Metwally MM, Moussa SFM, Ghanim NM. Studies on the population fluctuations and distribution of the white mango scale insect, Aulacaspis tubercularis Newstead within the canopy of the mango trees in eastern of Delta region at the north of Egypt. Acad. J. biolog.Sci,2011:4:123-130.
17. Nabil HA, Shahein AA, Hammad KAA, Hassan AS. Ecological studies of Aulacaspis tubercularis (Diaspididae: Hemiptera) and its natural enemies infesting mango trees in Sharkia Governorate, Egypt Acad J Biolog Sci,2012:5:9-17.
18. USDA (United States Department of Agriculture). Importation of Fresh Mango Fruit (*Mangifera indica* L.) from India into the Continental United States: a Qualitative, Pathway-Initiated Pest Risk Assessment. United States Department of Agriculture Animal and Plant Health Inspection Service, Plant Protection and Quarantine, Raleigh, North Carolina, U.S.A. 90,2006.
19. USDA (United States Department of Agriculture). Evidence-based, Pathway-Initiated Risk Assessment of the Importation of Fresh Longan, Dimocarpus longan Lour.From Taiwan into the United States.United States Department of Agriculture Animal and Plant Health Inspection Service, Plant Protection and Quarantine, Raleigh, North Carolina, U.S.A. 113,2007.
20. Dawd M, H/Gabriel B, Ayele L, Feleke K, Hailemariam S, Burka T *et al*. White mango scale: A new insect pest of mango in western Ethiopia. Eshetu Derso, Asfaw Zelleke, Lemma Desalegne, Zemedu Worku, Hailemichael K/ Mariam, Getachew Tabore and Ynew Getachew (Eds.). 2012.Proceedings of the 3rd Biennal Conference of Ethiopian Horticultural Science Society (EHSS). Volume III. 4-5 February 2011. Addis Ababa. Ethiopia,2012:257-267.
21. Fita T. White mango scale, *Aulacaspis tubercularis*, distribution and severity status in East and West Wollega Zones, western Ethiopia. Science, Technology and Arts Research Journal,2014:3(3):01-10.
22. Ayalew G, Fekadu A, Sisay B. Appearance and chemical control of white mango scale (Aulacaspis tubercularis) in Central Rift Valley.Science, Technology and Arts ResearchJournal,2015:4:59-63.
23. Merkuz A. Agriculture in the Lake Tana Sub-basin of Ethiopia, In K. Stave, Goraw Goshu and Shimelis Aynalem (Eds) Social and Ecological System Dynamics, Characteristics, Trends, and Integration in the Lake Tana Basin, Ethiopia, AESS Interdisciplinary Environmental Studies and Sciences Series, ISBN 978-3-319-45753-6, DOI 10.1007/978-3-319-45755-0_2, Springer International Publishing Switzerland,2017.
24. Hailu T, Tsegaye S, Wakuma T. White Mango Scale Insect’s Infestations and Its Implications in Guto Gida and Diga Distrcts of East Wellega Zone, ABC Research Alert,2014:2(2):1-32.
25. Djirata O, Getu E. Infestation of *Aulacaspis tubercularis* (Homoptera: Diaspididae) on Mango Fruits at Different Stages of Fruit Development, in Western Ethiopia. Journal of Biology.Agriculture and Healthcare,2015:5(18):34-38.
26. NMA (National Meteorological Agency). Monthly report on temperature and Rainfall distribution for Assosa Administrative Zone, Regional Metrological Office, Assosa, Ethiopia,2015:17-19.
27. BGRS BoA. BoA Annual report, Assosa.250 (Unpublished),2017.
28. Central Statistical Agency (CSA). Agricultural sample survey report on area and production of major crops for national and regional level. Addis Ababa, Ethiopia,2019:589(1):25.
29. Central Statistical Agency (CSA). Area and Production of Major Crops. Agricultural Sample Survey. Addis Ababa, Ethiopia,2017:116.
30. Mulat D, Tadele F. The Performance of Grain Marketing in Ethiopia: the Case of the Addis Ababa Central Market. Addis Ababa,2001.
31. Babege T, Haile B, Hailu A. Survey on distribution and significance of White Mango scale (*Aulacaspis tubercularis)* in Bench-Maji Zone, Southwest Ethiopia.Journal of Horticulture and Forestry,2017:9(4):26-32.
32. Djirata O, Getu E, Kahuthia-G. Trend in Mango Production and Potential Threat from Emerging White Mango Scale, *Aulacaspis tubercularis*, Journal of Natural Sciences Research,2016:6(7):87-94.

33. Djirata O, Getu E, Kahuthia-G. Population dynamics of white mango scale, *Aulacaspis tubercularis* Newstead (Hemiptera: *Diaspididae*) in Western Ethiopia, African journal of agricultural research,2018,13(31):1598-1605.
34. Williams B, Jocelyn E, Hernani G, Oscar S, Ernesto O, Elda B *et al*. Integrated pest management and supply chain improvement for mangoes in the Philippines and Australia,2009,1-139.
35. Gomez KA, Gomez AA. Statistical procedures for agricultural research (2 Ed.). John wiley and sons, New York, USA,1984,680.
36. SAS, SAS/STAT software [computer program], Version 9.2. Cary, NC, USA: SAS Institute. Inc,2009.
37. Marwa ES Amer, Salem MA, Hanafy MEH, Ahmed N. Ecological Studies on *Aulacaspis tubercularis* (*Hemiptera: Diaspididae*) and Its Associated Natural Enemies on Mango Trees at Qaliobiya Governorate, Egypt. Egypt. Acad. J. Biolog. Sci,2017:10(7):81-89.
38. Kwaiz A, Fayza A. Ecological studies on the mango scale insect, *Aulacaspis tubercularis* (Newstead) (*Homoptera: Diaspididae*) infesting mango trees under field conditions at Qalyubyia Governorate. Egypt. J. Agric. Res,2009:87(1):71-83.
39. Abaynew JJ, Emana G, Merkuz A. Butterfly diversity associated with seasonality at Menagesha-Suba state forest, Central Ethiopia. International Journal of Entomology Research,2020:5(3):75-83.