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Research paper

Distribution and population dynamics of Coccinellidae predators associated with white mango scale, *Aulacaspis tubercularis* (Newstead) in southwest Ethiopia

Teshale Daba Dinka [1], Tariku Tesfaye Edosa [1]*, Tesfaye Hailu Terefe [1], Belay Habtegebriel Wendafrash [2]

[1]Ethiopian Institute of Agriculture Research (EIAR), Ambo Agricultural Research Center, P. O. Box, 37 Ambo, Ethiopia.
[2]Ethiopian Agricultural Research Council Secretariat, P.O.Box, 8115 Addis Ababa, Ethiopia.

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Correspondence
Tariku Tesfaye Edosa
bunchk.2000@gmail.com

The survey was conducted in Southwestern Ethiopia, to study the distribution and population dynamics of Coccinellidae predators associated with White Mango Scale (WMS). The identification of the predators was done by collecting infested mango leaves from the targeted fields. In all surveyed areas, three *Chilocorus* beetles spp. (*Chilocorus* spp. 1, 2, and 3) and one unknown beetle were identified feeding on all stages of WMS. The number of *Chilocorus* spp. 1 was higher compared with the other identified predators in all surveyed areas. Among the surveyed areas, East Wollega had the highest population of *Chilocorus* spp. 1. The peak population of the identified Coccinellidae predators and WMS varied from March to May depend on the species and areas. Overall, during the rainy and high temperature seasons, the number of both WMS and predators declined. The correlation study showed that the populations of the predators were positively correlated with weather factors and WMS, as prey factor. Altogether, the current study suggests that identified Coccinellidae *Chilocorus* spp. 1 was considered as the potential predator to control WMS. Therefore, future studies need to be focus on predacious efficacy, mass rearing and field release mechanism and compatibility with other management options.

Key words: *Coccinellidae, predators, distribution, population dynamics, WMS*

INTRODUCTION

In Ethiopia, mango is produced mainly in Harari region, west and east Oromia, Southern Nations, Nationalities, and People's Region (SNNPR) and Amhara (Honja, 2014). White Mango Scale (WMS) (*Aulacaspis tubercularis* Newstead (Hemiptera: Diaspididae) is the most important pest threatening mango production in Ethiopia (Ayalew, Fekadu & Sisay, 2015; Temesgen, 2014). Initially it was confined to Eastern Wollega, where local mango trees of old age exist, but now it has invaded several mango production areas, mainly in the western and southwestern parts and central rift valley of the country (Ayalew et al., 2015). The insect attacks all parts of mango trees at all growth stages, which may lead to death of a whole plant. During severe infestation, it covers about 33 % of the mango canopy and as a result it limits the plant's active photosynthetic leaf area (Mohammed Dawd, 2012).

In different areas, various potential natural enemies have been identified for the management of WMS. For instance, in South Africa, Aphelinid parasitoid, *Aphytis chionaspis* Ren with parasitism level of over 50% and the predatory beetle *Cybocephalus binotatus* were effective in reduction of WMS populations to a level with 50 % and 2-3%, respectively (Daneel & Joubert, 2006). Natural enemy maintenance in a mango plantation, plays an important role in suppressing insect pest population(Hajek & St. Leger, 1994; Rezk, 2009). However, the existence of diverse natural enemy species mainly in the undisturbed mango ecosystem is very important for the success of natural enemy activity (Neuenschwander & Markham, 2001; Zeki, Ülgentürk, Noyes, & Kaydan, 2004). Accordingly, conditions in the Didesa Valley in Ethiopia provides an ideal ecosystem for a diverse natural enemy community. Even though, there is such an ideal ecosystem, there are few documented reports on the associated natural enemies of WMS in Ethiopia. Therefore, the present study was conducted to search and identify the natural enemies associated with WMS and study their distribution and population dynamics to determine their population peak.

MATERIALS AND METHODS

The survey on natural enemies of WMS and their population dynamics was conducted in four major mango producing regions (Table 1).

Table 1. Surveyed zones and districts in southwestern Ethiopia during 2016/2017 cropping season (throughout the year)

Regions	Zones	Districts
Oromia	East Wollega	Gida Ayene
Oromia	East Wollega	Guto Gida
Oromia	East Wollega	Wayo tuka
Oromia	East Wollega	Sibusire
Oromia	East Wollega	Gobu sayo
Oromia	East Wollega	Arjo
Oromia	Horo-Guduru Wollega	Abe-dongoro
Oromia	West Wollega	Lalo Asabi
Oromia	West Wollega	Gimbi
Oromia	Buno-Badale	Badale
Oromia	Buno-Badale	Debohena
Oromia	West Shoa	Bako tibe
Oromia	West Shoa	Ilu gelan
Benishangul-Gumuz	Assosa	Homosha
Benishangul-Gumuz	Assosa	Bambasi
Gambella	Zone1	Gambela town
Gambella	Majang	Godere
SNNP	Bench-Maji	Shoka
SNNP	Bench-Maji	Shebench

From each district three sites and from each site five mango trees were selected and from each tree sixteen infested leaves were collected near to middle canopy of the tree from four cardinal directions (North, South, West and East) to record predators. A pocket lens (10X Magnifier), camel brush, glass vials and polythene bags were used for collection of samples. A digital camera was used to take external images of predators during field and laboratory diagnoses. The collected samples were transported to the Entomology laboratory at the Ambo Plant Protection Research Center, (now Ambo Agricultural Research Center, Ambo, Ethiopia), to record data of predators for further identification. Leaves were examined under a stereomicroscope and small larvae predating on WMS were collected. After all life stages had been recorded, the collected leaves were placed in jars for adult emergence (Figure 2). Predators developed from WMS and predators collected from leaves were counted and identified. Preliminary identification was made at their site using identification keys and morphological identification up to genus level were made at Ambo Agricultural Research Center entomology laboratory, using Dichotomous identification. In addition, Crop Protection Compendium (2007 Edition) (WWW.cabicompendium.org/cpc) was used as reference during identification. ArcGIS 10.3 was used for spatial data management and mapping of surveying area (Figure 1). Weather factors such as maximum, minimum and mean of both temperature and relative humidity in each site were collected using /HygroThermometer (Delta TRAK$_{R,}$ Model # 13301).

Population Dynamics

The survey of WMS associated natural enemies was carried out during the period from October 2016 to September 2017, in Western Oromia: East Wollega (Didesa valley (governmental protected farm) and Green focus (Raji Agro industry) and West Shoa (Bako research station). Pesticides application was not allowed throughout the study period in all selected sites. Five mango trees similar in size and age were selected and marked at each site for this study. Samples were collected monthly from the middle canopy of the tree. Five infested leaves were picked up at random from each cardinal direction (north, south, east and west) of the trees. From each tree 20 leaves were collected in paper bags, and transported to Ambo Agricultural Research Center to record associated natural enemy. Leaves were examined under a stereomicroscope to observe early hatched grubs and WMS life stages. After all WMS life stages and Organism predating WMS recorded, leaves were placed in jars for adult emergence. Then identification was made using recommended expert keys. Monthly data Coccinellidae predator's population were correlated with the prevailing climatic factors such as,

Figure 1. Map showing Coccinellidae predators associated with WMS in surveyed area

mean temperature, mean relative humidity and WMS as prey factors in the mango fields. Pearson correlation was carried out to summarize correlation coefficient (r) analysis by using Microsoft SAS 9.0. correlation coefficient range: -absolute value of r: 0.00-.19 "very weak", 0.20-.39 "weak", 0 .40-.59 "moderate", 0 .60-.79 "strong" and 0 .80-1.0 "very strong" were used to describe correlation coefficient strength (Wuensch, 1996).

RESULTS AND DISCUSSION

Distribution of Coccinellidae Predators Associated with WMS

The present survey studied the distribution, population density, and predatory-prey ratio of Coccinellidae predators and WMS in southwestern Ethiopia. Accordingly, four species of coccinellidae beetles: -

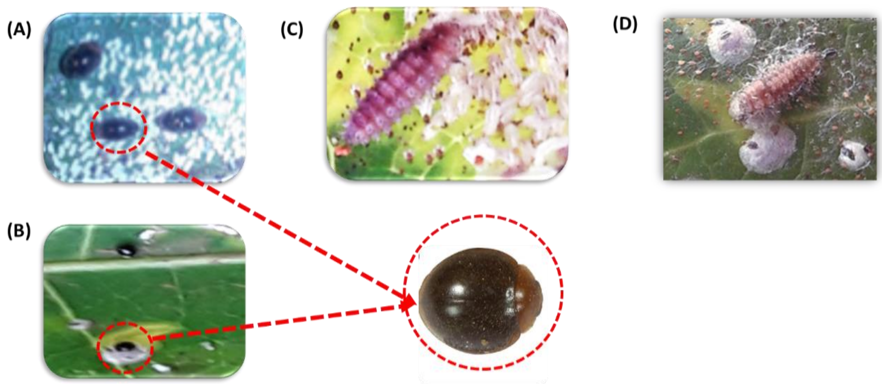

Figure 2. Coccinellidae: Coleoptera Predators, *Chilocorus* spp. 1 recorded in the surveyed area. A) Adult chilocorus spp. 1 feeding on the male colony of white mango scale; B) Adult of chilocorus spp. 1 feeding on the female of white mango scale; C) larvae of chilocorus spp. 1 feeding on the male colony of white mango scale; D) larvae of *chilocorus* spp. 1 feeding on the female of white mango scale

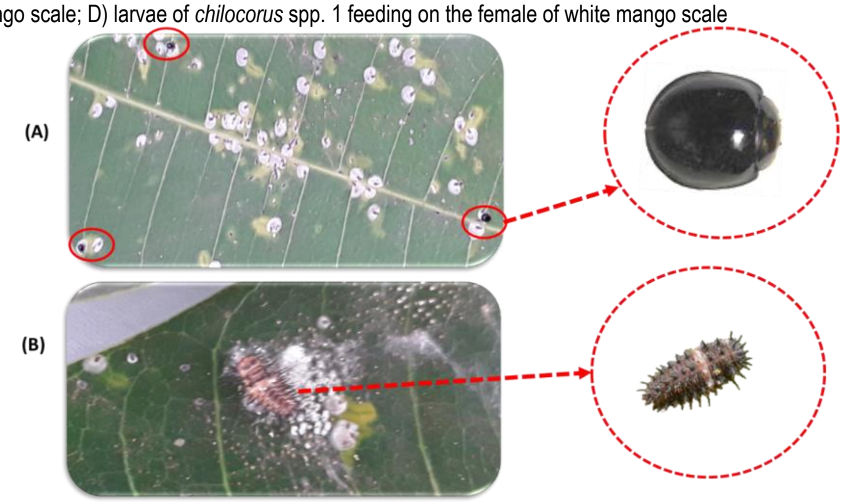

Figure 3. *Chilocorus* spp. 2 recorded in the surveyed area. A) Adult *chilocorus* spp. 2 feeding on the female of white mango scale; B) larvae of *Chilocorus* spp. 2 feeding on the male colony of white mango scale. Red circle indicates the adult of *Chilocorus* spp. 2 feeding on female of white mango scale

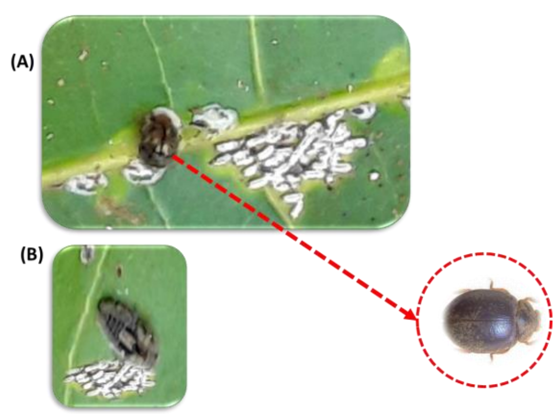

Figure 4. *Chilocorus* spp. 3 recorded in the surveyed area. A) Adult chilocorus spp. 3 feeding on the male colony of white mango scale; B) larvae of *Chilocorus* spp. 3 feeding on the male colony of white mango scale

Chilocorus spp1 (Figure 2A, B, C, D), Chilocorus spp2 (figure 3A, B,), *Chilocorus* spp3 (Figure 4A, B) were recorded when feeding on all stages of the WMS insect. *Chilocorus species* (Coccinellidae) are known as potential predators of WMS (Abo-Shanab, 2012; Erkiliç & Uygun, 1995; Labuschagne, Van Hamburg, & Froneman, 1995). In addition to direct feeding, the adult beetles and larvae were found feeding on scale of female and male clusters, exposing the scale insect life stages to external environmental condition, such as, rain and sun light. In line with this survey, it has also been reported as the larvae of *Chilocorus* spp. (Coleoptera: Coccinelidae) feed on live mango scales (Djirata, 2017).

Chilocorus spp. 1 and 2 recorded with the highest population densities in all surveyed district except Gembela and Lalo asebi where comparatively low density was observed. Among surveyed districts Gida Ayene, Gutu Gida, Wayo Tuka, Sibusire, Arjo, Abe-dongoro and Debohena are the districts where more population density of *Chilocorus* spp. 1 and 2 were recorded whereas the unidentified spp. was recorded only in 5 districts (Gida ayana, Arjo, Abe-dongoro, Gimbi and Homacho). When these predators summarized at Zone, more populated density of recorded from East Wollega compare to other Zones (Figure 5B).

The distribution of these predators and their population density in some districts indicate that these predators particularly *Chilocorus spp1* becoming promising predators in future as it emerged and building itself with recently introduced WMS in Ethiopia. In the past many *Chilocorus spp such as Chilocorus distigma; Chilocorus schioedtei* and *Chilocorus nigritus* were introduced and distributed in East Africa because of their potential as biological control agent on armoured scales (D. Greathead & Pope, 1977; D. J. Greathead, 1997). Many researchers suggested that *Chilocorus* spp. are potential predator as it may gradually build up to control WMS in the future (Djirata, 2017; Omkar & Pervez, 2003). In addition, the reported that the coccinellid predators *Chilocorus nigrita* (Fabricius) (Coleoptera*:* Coccinellidae) play major role in reducing WMS population along other bio-agent in South Africa (Daneel & Dreyer, 1998). Current mango farming system, environmental variability and a size of mango tree (in our case big tree with wide canopy) also one of a factor that probably contributes predators population density vary and instability in surveyed area (Figure 3). Natural enemies keep insect population at a low level mainly in the relative undisturbed mango ecosystem (Neuenschwander & Markham, 2001).

In this survey, *Chilocorus* spp.1 relatively recorded with higher population than other *Chilocorus spp* in all surveyed Zones (Figure 5A). From surveyed zones, Predators recorded with high population density in East Wollega zone, where WMS first emerged and established. Hence, there is probability that these predators emerged with WMS in this area and distributed following the distribution of their prey (WMS). Overall, the current studies indicate that *Chilocorus spp* populations are increasing in all studied sites as it may build itself to regulate WMS population. Greathead and Pope reported that *Chilocorus nigritus* and C*hilocorus bipustulatus* (L.) caused mortality on armoured scales and *Parlatoria blanchardi* (Homoptera: Diaspididae) respectively, which resulted in reduction of pest infestation in date palms in Northern Niger of West Africa (D. Greathead & Pope, 1977). On the other hand, available literatures underline that some *Chilocorus* spp. were important biological agents for the control of armoured scales. In addition, The same authors

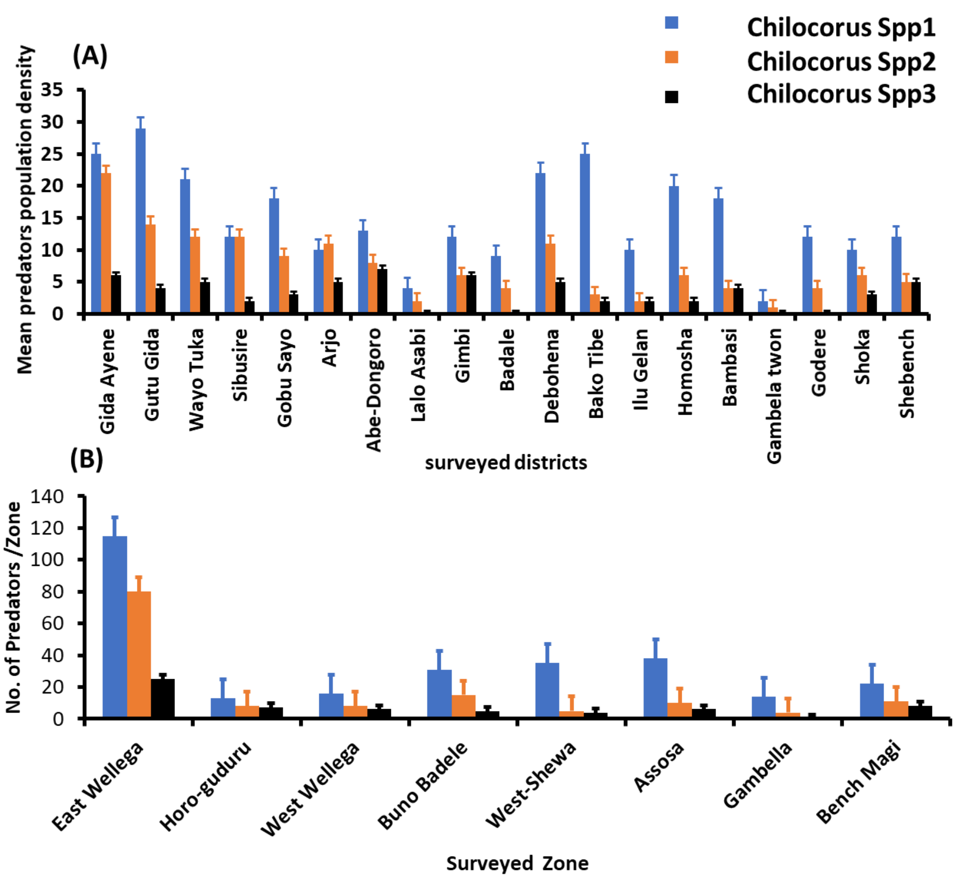

Figure 5. Predators recorded in Southwestern Ethiopia. A) Population of predators in districts, B) Summary of population in zones

stated that many *Chilocorus* spp. such as *Chilocorus distigma; Chilocorus schioedtei* and *Chilocorus nigritus* are potential as biological control agents to control armoured scales in East Africa.

Population Dynamics of Coccinellidae Predators Associated with WMS

The population dynamics of the identified predators were also studied to know the peak month and season of the year. The population dynamics study revealed that in all study areas, larvae of *Chilocorus* spp. 1 was highly populated than others (Figure 6A, B, C). The exponential increment of the population of both WMS and *Chilocorus* spp.1 started from December and reached peak in February and March in Didesa valley and Bako, respectively. In Green focus, both predators and prey population increase began in January and reached peak in April. Surprisingly, in Dedessa valley, the climax was continued from February to May. In all study areas, during summer and autumn months, the population of WMS and predators declined. The population of *Chilocorus* spp. 2 was low and constant through the year in Didesa and Green focus

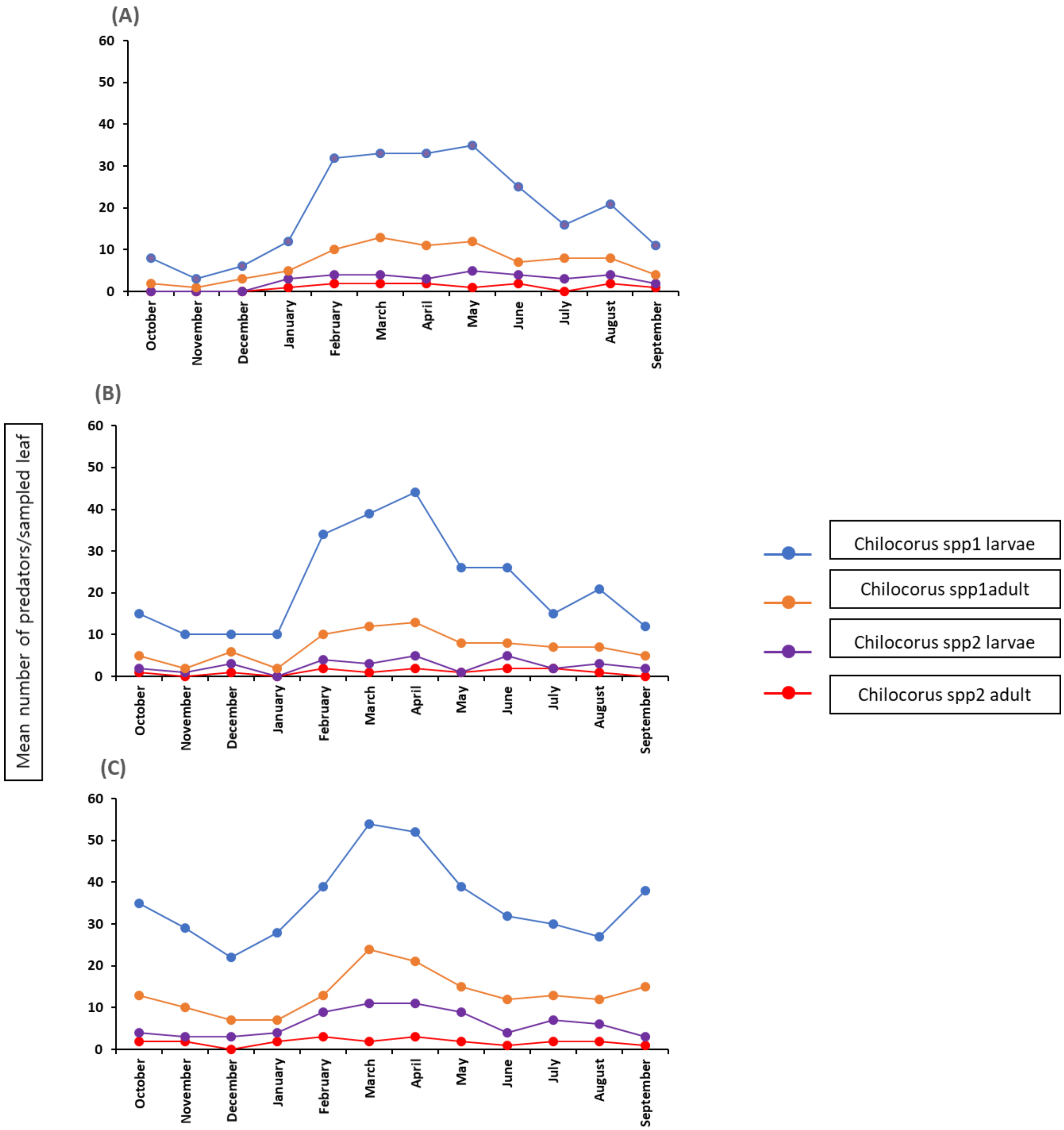

Figure 6. Coccinellidae Predators (*Chilocorus* spp1 and 2) populations dynamics. (A) Didesa valley, (B) green focus, (C) Bako

areas (Figure 6 A & B), whereas, in Bako, slight population increment was observed from January through May. Overall, the predator's population dynamics follow WMS population dynamics but population peaks month are area dependent.

Correlation of Chilocorus spp. and Weather Factors and WMS

Since the population density of *Chilocorus* spp.1 was comparatively high in all studied areas, we concentrated on the relationship of a predator and its host WMS population dynamics through the year. The correlation result of *Chilocorus* spp. 1 indicates that, the positive correlation percent of 82, 70 and 77% in Didesa valley, Bako and Green focus, respectively (Figure 7 A, B, C). In addition, the correlation of weather factors (mean temperature and relative humidity) with *Chilocorus* spp. 1 populations in all sites was investigated (Table 2). At Didesa valley (r=0.2) and green focus (r=0.22) area the correlation analysis showed that a weak positive correlation with mean temperature. The correlation of *Chilocorus* spp.1 population with relative humidity showed moderate positive correlation (r=0.50) in Didesa valley, and weak (r=0.34) and very weak (r=0.17) in green focus and Bako, respectively.

Starting from month June to September both predators' populations were low in all studied areas. The rainy season is in these months, so the low population occurred due to rain wash of mobile life stages, such as crawlers of WMS and predators. Similarly, during the months of October, November, and December both predator populations were low probably,

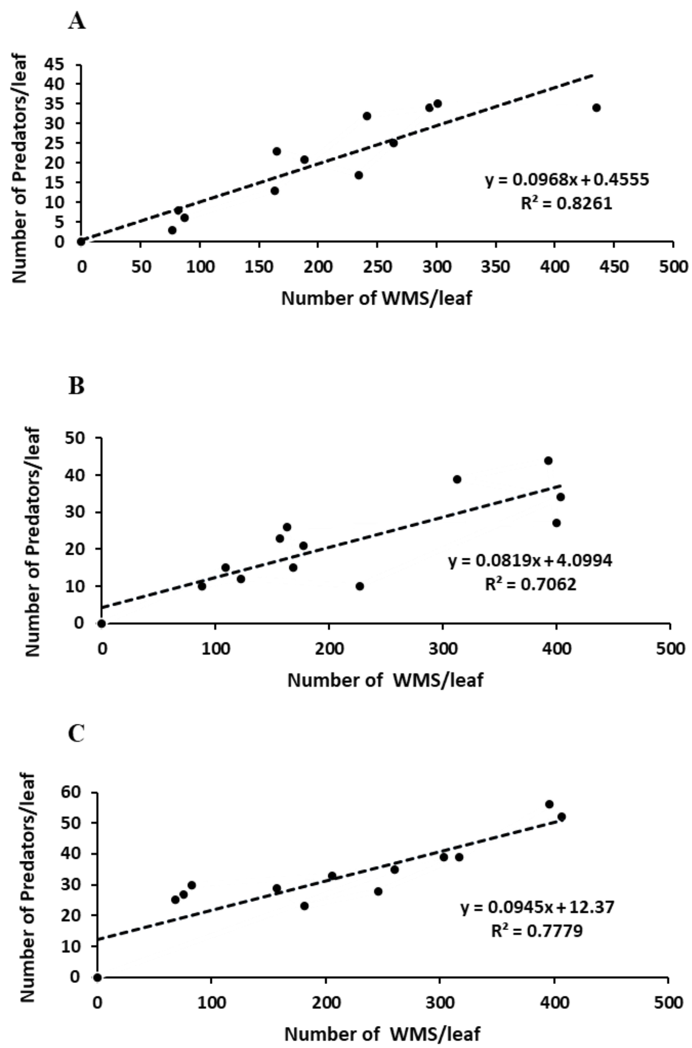

Figure 7. Correlation of *Chilocorus* spp. 1 and WMS insect. P-value < 0.001 (A) Dedessa valley, (B) Green focus and (C) Bako

Table 2. Correlation coefficient (r) of *Chilocorus* spp 1 larval population on Mango with prevailing weather parameters during, 2016/17 cropping season.

Factors	Location					
	Dedesa Valley		Green Focus		Bako	
	r	P	r	P	r	P
Mean Temp.	0.2	0.52	0.22	0.48	0.55	0.06
Mean R.H	0.50	0.09	0.33	0.28	0.17	0.6

Note: Absolute value of r: 0.00-0.19 "very weak", 0.20-0.39 "weak", 0.40-0.59 "moderate", 0.60-0.79 "strong" and 0.80-1.0 "very strong" (Evans (1996).

due to high temperature directly affecting the physiology of predators and WMS. Labuschagne and his colleagues also reported that scale insect population abundance is affected by rain and extreme temperature above 30°C (Labuschagne et al., 1995). Abiotic parameters are known to have direct impact on insect population dynamics through modulation of developmental rates, survival, fecundity, voltinism and dispersal (Karuppaiah & Sujayanad, 2012). The present population dynamics shows that current population densities of existing predators are not sufficient to suppress WMS which is highly populated in all studied area.

CONCLUSION

The survey provided some clues to understand existence of indigenous natural enemies associated with WMS in Southwestern Ethiopia. From the current survey, we recorded four species of *Chilocorus* spp coccinellid (beetles and larvae) of which *Chilocorus* spp. 1 and 2 are very important as they co-distributed with WMS in all surveyed areas. East Wolega zone was found to have potential areas for all identified predators because comparatively all of the predators were abundantly populated in districts of this zone. The average peak months of *Chilocorus* spp. 1 is from February to May. The correlation of the predator population and weather factors varies among study areas. It varies from weak to moderated correlation with both mean temperature and relative humidity. Maximum temperature negatively affects the population of *Chilocorus* spp. 1. Very strong correlation between predator and WMS was observed, which may confirm this predator fully depend on the availability of its host (WMS). Altogether, in current study, we recorded three potential predators of WMS with four peak months (*i.e.,* February, March, April and May) for *Chilocorus* spp in western Ethiopia. These predators were observed feeding on different stages of WMS. Therefore, from this survey we suggest that further studies on bio-ecology, predacious efficacy, and compatibility with other management options need to be investigated for the conservation, mass rearing and release.

AUTHOR CONTRIBUTIONS

Teshale Daba Dinka, Tesfaye Hailu Terefe, and Belay Habtegebriel Wendafrash conducted survey and collected data. Tariku Tesfaye Edosa and Teshale Daba Dinka analyzed the data and wrote the manuscript.

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COMPETING INTERESTS

The authors declare that they have no competing interest

ETHICS APPROVAL

Not applicable

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