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Review

Electromagnetic radiation (EMR) clashes with honeybees

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Apiculture has developed into an important industry in India as honey and bee-wax have become common products. Besides, honey bees do great environmental service by pollinating flowers. Bee keeping proves worthwhile from a monetary point of view as honey and wax command rewarding profits. In an average colony, there may be between 20000 to 31000 bees consisting normally of a queen and a few hundred drone. 90% of the population is made up of the workers. Recently, a sharp decline in population of honey bees has been observed throughout the Indian subcontinent resulting in devastating loses. For example, Kerala province has seen around 60% plunges in its commercial bee populations. Although the bees are susceptible to diseases and attack by natural enemies like wasps, ants and wax moth, constant vigilance on the part of the bee keepers can overcome these adverse conditions. The present plunge in population was not due to these reasons, it was caused by man.

Key words: Honey bees, bee-wax, population,

INTRODUCTION

Bees and other insects have survived and evolved complex immune system on this planet over a span of millions of years. It is not logical that they would now suddenly die out now due to diseases and natural parasites. This suggests that another factor has been introduced into their environment that disrupts their immune system. This man made factor is the mobile towers and mobile phones.

The public is not being informed of the threat due to deliberate attempts on the part of mobile phone makers to mask the direct causal relationship. Over the past several months, a cadre of scientists, funded by the deep pockets of the mobile phone industry, has suggested that viruses, bacteria, and pesticides are to be blame for the unprecedented honey bee decline. Rather than critically assessing the problem, the industry is dealing with it as a political and public relation problem thus manipulating

perception of the appropriate remedy. Sadly, this deceptive practice is business as usual for the mobile phone industry.

If the reason behind the population decrease were biological or chemical, there would be a pattern of epidemic spread. Observers would be able to trace the spread of bee disappearance from a source similar to the spread of severe acute respiratory syndrome (SARS) a few years ago. This pattern did not occur, however mobile towers and mobile phones meet the criterion.

New experiments suggest a strong correlation between population decline and cellular equipment. In one experiment, a mobile device was placed adjacent to bee hives for 10 min, for a short period of only 5 to 10 days. After few days, the worker bees never returned home.

The massive amount of radiation produced by towers and mobile phones is actually frying the navigational skills of the honey bees and preventing them from returning back to their hives. The thriving hives suddenly left with only queens, eggs and hive bound immature worker bees. Thus, electromagnetic radiation (EMR) exposure pro-vides a better explanation for Colony Collapse Disorder (CCD) than other theories. The path of

Abbreviations: CCD, Colony collapse disorder; BSNL, bharat sanchar nigam ltd; RFR, radio frequency radiation; KMC, Kootenai medical center; EMR, electromagnetic radiation; SARS, severe acute respiratory syndrome; WHO, world health organization.

CCD in India has followed the rapid development of cell phone towers, which cause atmospheric EMR.

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Insects and other small animals would naturally be the first to obviously be affected by this increase in ambient radiation since naturally they have smaller bodies and hence less flesh to be penetrated by exposure to microwaves. The behavioral pattern of bees alters when they are in close proximity to mobile phones and towers. The vanished bees are never found, but thought to die singly far from home. Bee keepers observed that several hives have been abruptly abandoned. If towers and mobile phones increase, the honey bees might be wiped out in ten years. Radiation of 900 MHz is highly bioactive, causing significant alternation in the physiological function of living organisms.

Some countries have sought to limit the proliferation of mobile towers with strict rules. But in India, no such rules have been formulated or implemented. Given the proliferation of mobile phone towers and their vital role in communications, solutions to the problem will not be as simple as eliminating the towers. One possibility is shielding. Experiments confirmed that light aluminium does effectively block microwave radiations from hitting the hive directly. Since wrapping mobile phone and towers in aluminium foil would prevent communication, it would be better for mobile companies to pay bee keepers to protect their bee colonies to some extent from mobile phones and towers radiations with aluminium shielding. While this option could be easily implemented and has low costs, it proves less than optimal because worker bees will still be exposed to radiation as they fly to and from the hive.

Another solution would be granting local communities the ability to control whether or not to install mobile towers. On one hand, community members would be able to exert some control over their environment and determine whether the benefits outweigh the costs and risks. On the other hand, it is highly susceptible to manipulation by powerful influences, especially since the bee keepers have significantly less influence, power and wealth than the mobile phone companies.

However, Indians could risk losing even this right to self determination if the cellular providers can impose a country wide mandate prohibiting regulation against them, similar to the Telecommunications Act of 1996 in the United States. The Act prohibited local governments from making sitting decisions based on the perceived health impacts of wireless facilities. Indian advocates are concerned that such regulations might be upheld in India as they were in the United States in order to "eliminate service gaps in its cellular telephone service area."

In Kerala, there are about 600,000 bee hives, and over 100,000 workers are engaged in apiculture. A single hive may yield 4-5 kg of honey. Moreover, the destruction of bee hives could be a major environmental disaster. Honeybees are responsible for pollinating over 100

commonly eaten fruit and vegetable crops, and without bees, the food system would be in serious trouble. Rural village dependent on locally grown foods would be most

vulnerable. The need of the hour is to check unscientific proliferations of mobile phone towers. More research is essential on how to protect the bee hives from the electromagnetic exposure, but perhaps more to study the impacts on humans.

Recently, the Bharat Sanchar Nigam Ltd. (BSNL) has suggested that the mobile phone towers that have been erected across the Kerala State do not cause health problems. Although the BSNL contends that it is safe, yet the government agencies involved in regulating radio frequency radiations have yet to prove that the towers were harmless. Keeping on these as the focal point, a field study has been undertaken by the Kerala Environmental Researchers Association (KERA) in Kollam Taluk areas. The study was conducted in more than 2000 houses situated within a kilometer of the towers in Kollam Taluk. In Kollam Taluk alone, there were more than 80 towers. In many places, more than three of them were present within half a kilometer radius. This unprecedented proliferation and construction of several towers across the state has raised the question of potential adverse health effects of microwave radiations emitted from these towers. The study showed that more than 40% of the people living in the vicinity of the towers, especially those of the middle age group and children, complained of eye problems, oblivion, sleep disorders, headache, etc. The people said that this predicament has emerged two years after the installation of the towers.

All mobile phone towers emit microwave radiations, which is in the radio frequency radiation (RFR), part of the spectrum of electromagnetic waves. Though RFR like ultra-violet (UV) and infra-red light, is a source of non-ionizing radiation, these radiations, together with ionizing EMR such as X-rays and gamma rays make up the electromagnetic spectrum. Radio frequency of the electromagnetic waves ranged from 100 kilo hertz (KHz) to 300 Giga hertz (GHz). RFR is a source of thermal energy and in adequate doses, has all the known effects of heating on biological systems, including burns and cataracts in the eyes. Human and animal studies in America indicate that radio frequency fields can cause harmful effects because of excessive heating of internal tissues. For most of the range of RFR, the skin does not easily detect the heating caused by these fields. The heating effect of RFR can become a problem in individuals with metallic implants such as rods in bones and electromagnetic interference can interact with cardiac pace makers. Acute high dose exposure to RFR may cause injury to the eyes. The cornea and lens are particularly susceptible to frequency of the 1- 300 GHz range, and formation of lesions in the retina is also possible. Long-term exposure to low level RFR has induced a variety of effects in the nervous system and

components of the immune system of small animals. However, significance of these in humans is still not clear. A research study in Britain has suggested that RFR may act as a cancer promoter in animals. International

they have their schools and play grounds irradiated by nearby transmitters, they are getting a double whammy.”

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organizations such as the world health organization (WHO) recognized the biological effects from exposure in the RF range that may affect health. In the Freiburger report, over 3000 German doctors have linked wireless phones and cell tower radiation to dramatic increase in disorders of learning, concentration and behavior among their patients.

Dr. Henry Lai, a leading radiation and biomedical researcher working at the University of Washington, stated that numerous medical studies show serious health effects can occur at irradiation levels far below current exposure standards. Anderson points to a December 2006 article in *Coeur d'Alene Magazine* which disclosed that the Kootenai Medical Center (KMC), serving as a magnet hospital for the five northern Idaho countries, is now inundated with cancer conditions of all types. The article reported that an average of 210 patients are cared for daily at KMC's North Idaho Cancer Center, and that more than 100 new cancer patients join the ranks of the "Big C" club every month.

According to the article, crushing is the cancer case load in North Idaho, that other cancer centers are being rapidly expanded in post falls and sand point. "One hospital worker told us that experienced medical personnel talk among themselves as having never before seen so much cancer among young people," Anderson said. "Our city has been increasingly saturated with microwave radiations from wireless tower and roof top transmitters since about the mid 1990s. Scientists say cancers can have a latency period of around 10 years, which computes with our area's growing cancer epidemic, she observed.

Dr. Lai's research group reported findings that microwave radiations can actually be physically addictive. The cell phone "high" is triggered by endorphins released into the brain when microwaves enter through the ear. Wireless industry adds, and promotions continually prod kids to buy new glitzy wireless hardware for watching TV, downloading music and texting. Kids know nothing about wireless health hazards because the industry is not required to warn them that at least 17 epidemiological studies show cell phone usage greatly increases their risk of developing brain cancer. "It's a real problem," said Anderson. "The more kids get hooked on wireless toys, the more towers are needed to service those toys, and if,

CONCLUSION

Despite a growing number of warnings from scientists, the Government has done nothing to protect people and the environment. Steps must be taken to control the near thickly populated areas, educational institutions, hospitals, etc. Sharing of towers by different companies should be encouraged, if not mandated. To prevent overlapping high radiations fields, new towers should not be permitted within a radius of one kilometer of existing towers.

More must also be done to compensate individuals and communities who are put at risk. Insurance covering diseases related to towers, such as cancer, should be provided for free to people living in 1 km radius around the tower. Independent monitoring of radiation levels and overall health of the community and nature surrounding towers is necessary to identify hazards early. Communities need to be given the opportunity to reject cell towers, and national governments need to consider ways of growing their cellular networks without constantly exposing people to radiation.

Perhaps most importantly, bee keepers and humans have an inherent right to live without being exposed to radiation that affects their natural behavior and increases their risks of developing biological deformities, like cancer.

REFERENCES

- Aday WR (1975). Introduction: Effects of electromagnetic radiation on the nervous System". Ann. NY Acad. Sci., 247: 15-20.
- Goldsmith JR (1996). Epidemiological studies of radio-frequency radiation". Current status and areas of concern. Sci. Total Environ., 180: 3-8.
- Leffell DJ (2000). "The scientific basis of skin cancer". J. Am. Acad. Dermatol., 42(1-2): 18-22.
- Maes A, Collier MD, Verschaeve L (1995). Cytogenetic effects of Microwaves from mobile communication frequencies M Electro. Magnetobil., 954(14): 91-98.
- Repacholi MH, Basten A, GebSKI V, Noonand Finnie J, Harris AW (1997). "Lymphomas in Emupim I transgenic mice exposed to pulsed 900 MHz Electromagnetic field" Reat. Res., 147(5): 631-640.
- Ross, Adey W (1998). "Cell Membranes, The Electromagnetic Environment and Cancer promotion". Neurochem. Res., 13(7): 671-677.
- Wallaczek J (1992). "Electromagnetic Field effects on cells of the Immune System" The role of calcium signaling. F/ASEB J., 6: 3176-3185.

Full Length Research Paper

A survey of geographical distribution and host range of white mango scale, *Aulacaspis tubercularis* Newstead (Hemiptera: Diaspididae) in Western Ethiopia

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White mango scale (WMS) is a sucking insect which poses severe threat to mango plantation. A survey of the distribution and host range of WMS, *Aulacaspis tubercularis* was conducted in western Ethiopia from May 10, 2016 to July 15, 2016. The surveys were started from Loko village, the focus of its first record, and extended over series of mango farms in the four cardinal directions. This study showed that WMS has already spread from Loko, the focus of its first record in the four cardinal directions. It spread over the air distances of 97, 98, 92 and 43 km to the east, south, west and north directions, respectively, with high and very high levels of severity statuses in most of the localities surveyed. It was found out that mango was the only host for WMS in western Ethiopia. It is recommended that understanding the mechanism by which WMS is spread is crucial to controlling it.

Key words: Infestation, Loko, severity, survey, Wollega, distance.

INTRODUCTION

Mango, *Mangifera indica* L., is widely consumed as a fresh fruit and various forms of beverages for its high contents of sugar, protein, fats, salts and most of the vitamin types (Griesbach, 2003; Nabil et al., 2012). Mango is grown in many parts of Ethiopia, of which most of the productions come mainly from the Rift Valley, western and south western areas (Honja, 2014). Mango production in Ethiopia is at small scale level with primary

purposes of family consumption and local markets; whereas, very few modern farms produce mango for fresh fruit export (Chala et al., 2014).

Mango production in Ethiopia was reported to have been constrained by a variety of insect pests and pathogens. These include the fruit fly complex, termites, thrips and various fungal diseases, among others (Hussen and Yimer, 2013; Tucho et al., 2014; Bezu et al.,

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2014).

Infestation of a new insect pest on mango was reported in 2010 from an orchard owned by Green Focus Ethiopia LTD, an Asian company located at Loko village in western Ethiopia, which was later identified at California Department of Agriculture as white mango scale (WMS), *Aulacaspis tubercularis* Newstead (Hemiptera: Diaspididae) (Dawd et al., 2012). It was stipulated that the insect could most likely be introduced to Ethiopia accidentally from Asia, with the mango seedlings imported by the aforementioned company. WMS spread from the focus of its first record to western Ethiopia and constrained mango production (Fita, 2014; Dako and Degaga, 2015).

WMS is distributed throughout the world wherever mango grows (USDA, 2007, El-Metwally et al., 2011, Ha et al., 2015). These include northern part of South America, the Caribbean, the east and west coasts of Africa, Asia, and Italy, among others. Benin, Ghana, Kenya, Madagascar, Mauritius, South Africa, Tanzania, Uganda, Zimbabwe and Zanzibar, are among 21 African countries from where WMS infestation on mango was confirmed (Germain et al., 2010; Haggag et al., 2014, Hodges and Harmon, 2016).

Infestation of WMS causes discolouration of mango fruit, leaves fall off, dieback, retarded host plant growth and death of the young mango trees (El-Metwally et al., 2011; Nabil et al., 2012; Abo-Shanab, 2012). Heavy WMS infestation causes development of conspicuous pink blemishes on the fruit skin and affects export potential of the fruit and may eventually result in economic loss (USDA, 2006). Some sources indicated that infestation of WMS is not limited to mango plantation. Accordingly, Malumphy (2014) asserts that WMS is a polyphagous pest which feeds on plants belonging to 18 families. On the other hand, Borchsenius (1966) cited from Abo-Shanab (2012) said that WMS has been recorded from four plant families, namely Palmae, Lauraceae, Rutaceae, and Anacardiaceae. Erichsen and Schoeman (1992) reported that WMS was found feeding on avocado in South Africa. There has been very limited or no data on the geographical distribution of WMS in western Ethiopia, and moreover there has been no study performed on the host range of the pest in the region. Therefore, this study was conducted with the objectives of identifying host range of WMS and preparing its distribution map in western Ethiopia, which are immediate requirements for management practices of the pest.

MATERIALS AND METHODS

Study area

The surveys on geographical distribution and host range of WMS were conducted from May 10, 2016 to July 15, 2016 in four adjacent administrative zones of Oromia National Regional State in western Ethiopia. These included West Shoa, Illubabor, East and West Wollega Administrative Zones. Most of the western Ethiopian

regions receive bimodal pattern of rainfall. The monthly average precipitations during the study period were 170 and 310 mm for May and July, respectively (Ethiomet, 2016). The minimum and maximum monthly temperatures were 16 and 31°C for May and July, respectively. Likewise, July had monthly minimum temperature of 15°C and a maximum monthly temperature of 28°C during the study period.

Study design and sampling procedures

Survey on the geographical distribution of WMS was started from Loko Kebele Administration, Guto Gida district of East Wollega administrative zone (09° 19.226' N and 036° 31.619' E) which was the focus where WMS was first recorded in Ethiopia. The survey was extended toward the four cardinal directions as shown in Figure 1. Since the mango farms in the study area were patchy in distribution or not continuous, farms at spots within intervals of 25 to 40 km land distance were considered for sampling. The mango trees were broadened at base and tapered upward and as a result, a total of ten leaves (4 from lower, 3 from central and 3 from upper canopies) were picked from every mango tree purposively selected from the central position within each farm. Female WMS was observed by hand lens, and its number recorded. Sampling continued as far as there were mango farms and infestation of WMS along, but terminated where there was no mango plantation or no infestation, after the land distance of about 50 km from the spot of the last sampling. However, considering a prior report on fast spread of the pest toward the west (Fita, 2014), survey continued in that direction up to a distance of about 100 km from the last spot of confirmed infestation.

For survey of alternative host of WMS, fields covered with vegetation, both natural forest and agricultural fields were purposively selected from the four administrative zones in the study area. Altitudinal variation was considered as the main reference to include as many vascular plant species as possible (Hurni, 1998; Cavieres et al., 2000; Fosaa, 2004; Habib et al., 2011). Sampling began from Loko and addressed five additional districts in the study area. During the assay, whether vascular plants other than mango were infested by WMS or not were investigated. For this purpose, 50 leaves, 10 twigs and 5 fruits (when present) found at different heights were cut from every vascular plant found within the proximity of infested mango trees and checked by hand lens for the presence/absence of WMS. Assessment diameter was broadened in all directions by 10 m successive intervals and terminated at about 100 m distance from the starting spot. Moreover, infestation of WMS of vascular plants found within the vicinity of infested mango farms were checked at roadside farms, while travelling within the study area for the survey. In the meantime, plant samples investigated for probability of infestation of WMS were collected, pressed and mounted, and taken to Addis Ababa University, Department of Plant Biology and Biodiversity Management, National Herbarium of Ethiopia for identification. During the surveys, coordinates and altitudes of each sampling site were recorded by the use of GPS.

Data analysis

Geographical distribution

ArcGIS 10.4 was used for spatial data management and mapping of WMS distribution (<http://www.esri.com/arcgis>). Relative frequency of WMS occurrence at each locality (mango farm) was calculated by the use of equation adopted from Kataria and Kumar (2012). This value was used to define severity index from which severity status at each farm was determined as indicated in Table 1.

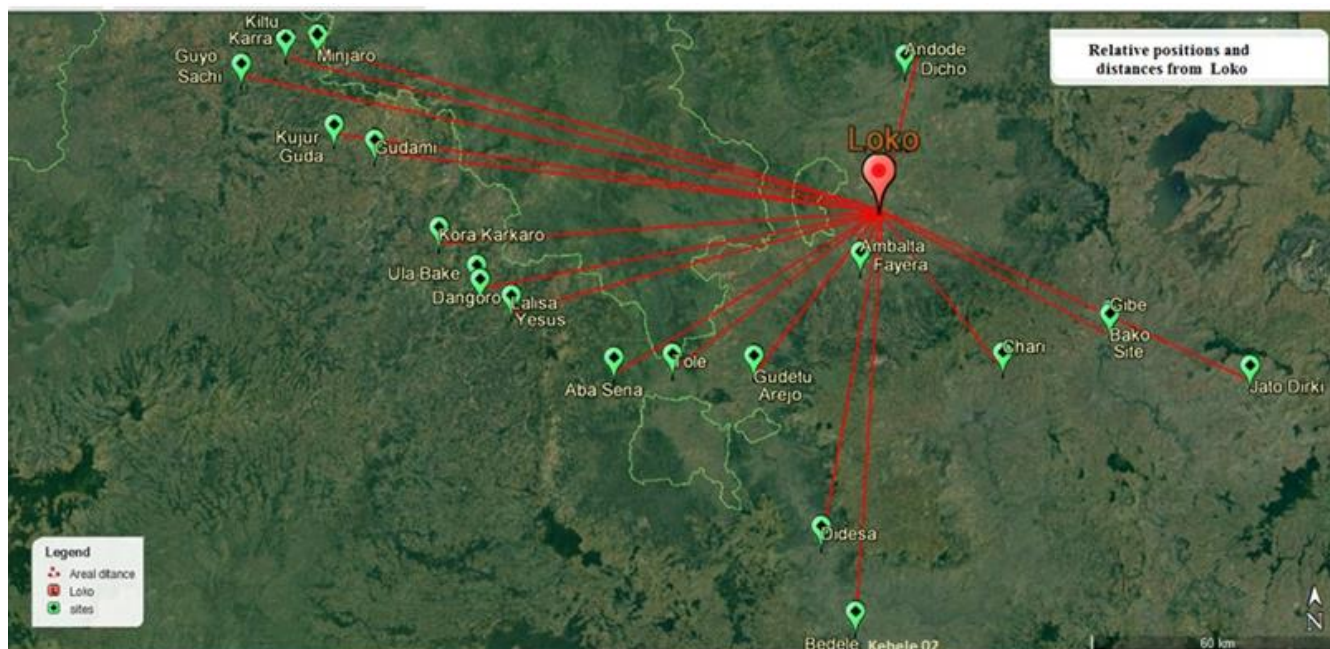


Figure 1. Spatial design of WMS distribution survey in western Ethiopia.

Table 1. Method of data summary used for determination of WMS severity status.

Relative frequency of mango scale occurrence	Severity index	Grades of severity status
0	0	No infestation
1-5	1	Mild infestation
6-10	2	High infestation
≥ 11	3	Very high infestation

$$\text{Relative frequency of WMS occurrence} = \frac{\text{Number of WMS recorded per mango farm}}{\text{Total number of WMS recorded from survey area}} \times 100$$

Mean numbers and standard deviations were used to show the spread of mango scale within each administrative zone.

Host range

Samples of the vascular plants checked for occurrence of WMS infestation were sorted out and classified to species level. Summarized data regarding presence/absence of WMS on the plants was presented.

RESULTS

Geographical distribution

From 20 localities of the 15 districts surveyed for WMS in western Ethiopia, 13 localities found in 11 districts were confirmed to have been infested by the pest as shown in Figure 2. WMS was found already spread to the surrounding areas of Loko, up to the maximum air

distances of 97, 98, 92 and 43 km to east, south, west and north directions, respectively. There was no mango farm in the east beyond Jato Dirki of Illu Gelan district and to the north in the neighbouring villages of Andode Dicho of Gida Ayana district, and as a result, survey was terminated provisorily.

The pattern of spread of WMS within each administrative zone was found to be irregular as can be seen from relative sizes of means and their standard deviations as shown in Table 2. Such irregular distribution was found to be more evident in West Wollega.

Severity status

Severity status of WMS was found to be high and very high in most of the survey localities in all the directions, except to the east where infestation was only mild as presented in Table 3. The numbers of female WMS

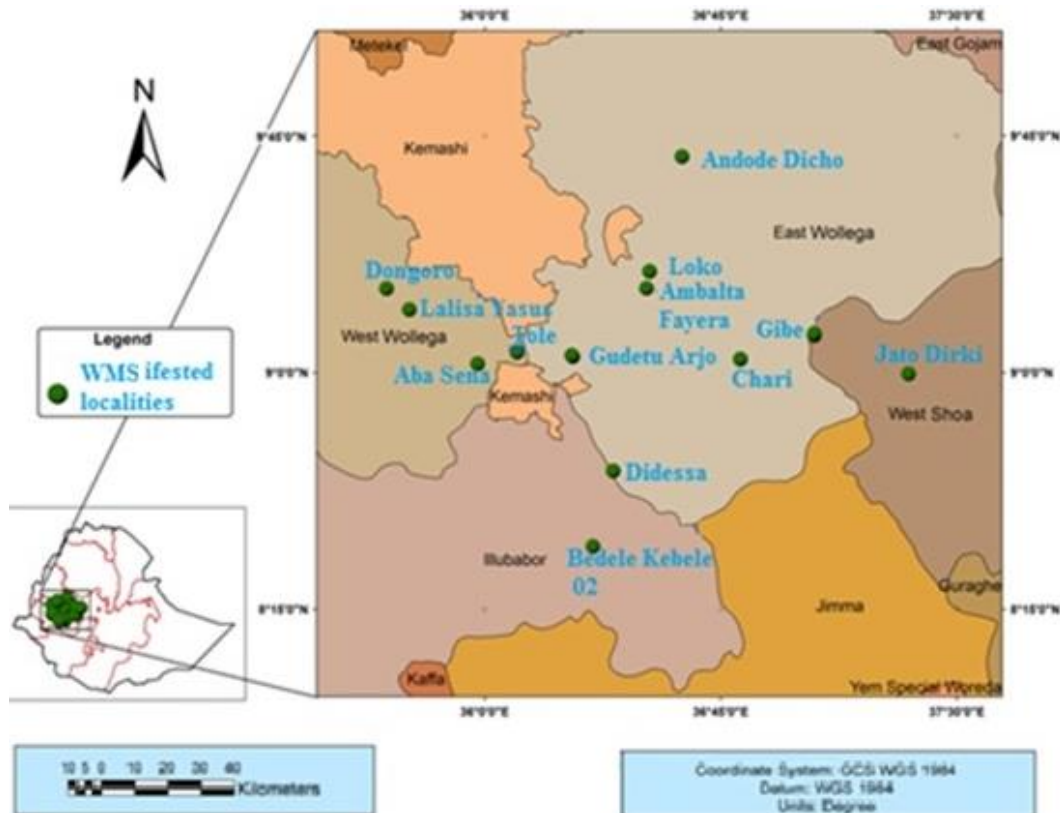


Figure 2. Distribution map of WMS in western Ethiopia.

Table 2. Mean numbers of female WMS per leaf within each administrative zone in western Ethiopia.

Administrative zone	Mean±SD
East Wollega	35.00±26.10
Illubabor	45.90 ±19.03
West Shoa	5.00±5.40
West Wollega	16.90±24.50

recorded per 10 leaves showed big differences among the localities; the maximum being 723 at Didessa locality, while the minimum was 32 at Chari locality.

Host range

A total of 120 plant samples in fields located within altitudinal gradients ranging from 1150 to 1755 m.a.s.l. were checked for WMS infestation. No WMS infestation was detected from any of the plants checked in the whole survey area. The plants were classified into 25 species and presented in Table 4.

DISCUSSION

WMS has spread from Loko, the locus of its first record in

Ethiopia to all cardinal directions. Spread of WMS in south direction covered about 98 km air distance. In the west, it was recorded from Dongoro locality in Lalo Assabi district, which is found at air distance of about 92 km from Loko. However, the spread of WMS infestation didn't pass beyond 67 km air distance from Loko to the west, two years before this investigation as depicted by a survey conducted in the area (Fita, 2014). This shows that WMS is spreading very fast in western Ethiopia. It is therefore possible to realize that there are enabling environmental conditions for WMS to spread and establish its population in western Ethiopia, as far as there is mango plantation. The rate of establishment, dispersal and colonization of alien invasive species in a new habitat is likely to become tremendous when the new environment is bioclimatically favourable to the pests (Satti, 2011; Pratt et al., 2017).

Table 3. Severity status of white mango scale in western Ethiopia.

District	Locality/mango farm	Altitude (m.a.s.l)	Location		Female WMS/10 leaves	Severity index	Severity status
			North	East			
Ilu Gelan	Jato Dirki	1747	08° 59.74'	037° 20.973'	58	1	Mild
Bako Tibe	Gibe	1612	09° 07.409'	037° 03.025'	58	1	Mild
Sibu Sire	Chari	1748	09° 02.567'	036° 48.935'	32	1	Mild
Sasiga	Ambalta Fayera	1565	09° 16 .006'	036° 31.032'	418	3	Very high
Guto Gida	Loko	1375	09° 19 .226'	036° 31.619'	596	3	Very high
Gida Ayana	Andode Dicho	1483	09° 41.013'	036° 37.794'	336	2	High
Diga	Gudetu Arjo	1320	09° 03.277'	036° 16.824'	368	2	High
Dabo	Didessa	1278	08° 41.339'	036° 24.72'	723	3	Very high
Bedele	Bedele Kebele 02	1988	08° 27.001'	036° 20.863'	431	3	Very high
Gimbi	Tole	1150	09° 03.840'	036° 06.364'	425	3	Very high
Gimbi	Aba Sena	1698	09° 01.687'	035° 58.88'	311	2	High
Gimbi	Lalisa Yasus	1821	09° 11.971'	035° 45.855'	37	1	Mild
Lalo Assabi	Ula Bake	1887	09° 14.146'	035° 41.893'	0	0	No infestation
Lalo Assabi	Dongoro	1857	09° 15.957'	035° 41.524'	47	1	Mild
Boji Dirmaji	Kora Karkaro	1800	09° 20.964'	035° 36.774'	0	0	No infestation
Nedjo	Gudami	1936	09° 32.397'	035° 28.770'	0	0	No infestation
Nedjo	Kujur Guda	1713	09° 34.535'	035° 23.538'	0	0	No infestation
Kiltu Karra	Minjako	1647	09° 41.123'	035° 19.601'	0	0	No infestation
Kiltu Karra	Kiltu Karra	1635	09° 41.490'	035° 15.817'	0	0	No infestation
Manasibu	Guyo Sachi	1597	09° 42.789'	035° 11.635'	0	0	No infestation

The absence of mango farm beyond Andode Dicho to the north and Jato Dirki to the east directions restricted spread of WMS beyond these localities. Even though mechanisms by which WMS could spread in west Ethiopia was not assessed under the current study, it can be deduced that active wandering of the crawler alone cannot be a possible explanation for its dispersal over such long distances. Magsig-Castillo et al. (2010) stated that the first instar active crawlers of diaspidides can wander a distance of less than one metre before settling to establish a new population. Beardsley and Gonzalez (1975) on the other hand, stated that wind, birds, insects and other animals including man can serve as accidental dispersal carriers for armoured scale crawlers. WMS may also be dispersed through mango fruit marketing among localities in western Ethiopia. It was shown that female WMS infestation of mango fruit is at its peak when the fruit is ripe and ready for sale in western Ethiopia (Dako and Degaga, 2015), an encouraging condition for the pest to be transported with the ripe-and-ready fruit for marketing.

Distribution patterns of WMS within each administrative zone were not regular. Moreover, there were differences in severity status of the WMS among the localities, which may indicate the probable presence of factors that may affect the insect pest populations at local habitat level differently. The fact that most of the observed *very high* severity statuses were localized at relatively lower altitudes, except at Bedele Kebele 02 of Illubabor zone,

may be a clue for further study in this regard.

In this study it was noted that mango plantation is the only host plant for WMS in western Ethiopia. Contrary to this finding, WMS was reported to have been infesting plants other than mango in different countries (Erichsen and Schoeman, 1992; Hodges et al., 2005; Malumphy, 2014). In line with this, Hodges and Hamon (2016) stated that plant species found under families Sapindaceae and Rutaceae served as host plants for WMS. In this study, however, *Casimiroa edulis* La Llave from Rutaceae and *Blighia unijugata* Bak from Sapindaceae were confirmed not to have been infested by the WMS across the study area. Erichsen and Schoeman (1992) listed avocado (*Persea americana* Mill.) among the fruits infested by WMS in South Africa. However, it has been confirmed by this study that avocado has not been infested by WMS, though found intercropped with mangos already infested by the pest at Chari field in Sibu Sire district of East Wollega, and in other observed roadside farms. Host plant abundance is known to positively influence host plant use, in both specialist and generalist herbivorous insects (West and Cunningham, 2002; Nobre et al., 2016). Likewise, abundance of mango plantation may be one possible explanation for the plant to have been preferred as host plant by WMS in western Ethiopia. It is indicated that western Ethiopia is one of the most known mango producing regions in the country (Ethiopian Ministry of Agriculture and Rural Development, 2009; Honja, 2014) and as a result, WMS crawlers could

Table 4. Vascular plants checked for WMS infestation and survey results in western Ethiopia

Coordinate		Altitude (m.a.s.l.)	Botanical Name	Family name	WMS
North	East				
09° 07.409´	037° 03.025´	1612	<i>Cordia africana</i> Lam.	Boraginaceae	Nr
09° 07.409´	037° 03.025´	1612	<i>Solanum incanum</i> L.	Solanaceae	Nr
09° 07.409´	037° 03.025´	1612	<i>Croton macrostachyus</i> Del.	Euphorbiaceae	Nr
09° 07.409´	037° 03.025´	1612	<i>Jacaranda mimosifolia</i> D. Don	Bignoniaceae	Nr
09° 02.542´	036° 48.940´	1755	<i>Casimiroa edulis</i> La Llave	Rutaceae	Nr
09° 02.567´	036° 48.935´	1748	<i>Persea americana</i> Mill.	Lauraceae	Nr
09° 02.567´	036° 48.935´	1748	<i>Coffea arabica</i> L.	Rubiaceae	Nr
09° 02.567´	036° 48.935´	1748	<i>Psidium guajava</i> L.	Myrtaceae	Nr
09° 19.226´	036° 31.619´	1375	<i>Carica papaya</i> L.	Caricaceae	Nr
09° 19.226´	036° 31.619´	1375	<i>Vernonia amygdalina</i> Del.	Asteraceae	Nr
09° 19.226´	036° 31.619´	1375	<i>Syzygium guineense</i> (Willd.) DC.	Myrtaceae	Nr
09° 19.226´	036° 31.619´	1375	<i>Sapium ellipticum</i> (Krauss) Pax	Euphorbiaceae	Nr
09° 19.226´	036° 31.619´	1375	<i>Trichilia dregeana</i> Sond.	Meliaceae	Nr
08° 41.339´	036° 24.702´	1278	<i>Euphorbia cotinifolia</i> L.	Euphorbiaceae	Nr
08° 41.339´	036° 24.702´	1278	<i>Lonchocarpus laxiflorus</i> Guill. & Perr.	Fabaceae	Nr
08° 41.339´	036° 24.702´	1278	<i>Senna didymobotrya</i> (Fresen.) Irwin and Barneby	Fabaceae	Nr
08° 41.339´	036° 24.702´	1278	<i>Ficus sycomorus</i> L.	Moraceae	Nr
08° 41.339´	036° 24.702´	1278	<i>Grewia mollis</i> A. Juss.	Tiliaceae	Nr
08° 41.339´	036° 24.702´	1278	<i>Piliostigma thonningii</i> (Schumach.) Milne-Redh.	Fabaceae	Nr
09° 03.227´	036° 16.824´	1320	<i>Ficus carica</i> L.	Moraceae	Nr
09° 03.227´	036° 16.824´	1320	<i>Combretum</i> sp.	Combretaceae	Nr
09° 03.227´	036° 16.824´	1320	<i>Bridelia micrantha</i> (Hochst.) Baill.	Euphorbiaceae	Nr
09° 03.227´	036° 16.824´	1320	<i>Flueggea virosa</i> (Willd.) Voigt.	Euphorbiaceae	Nr
09° 03.840´	036° 06.364´	1150	<i>Bridelia micrantha</i> (Hochst.) Baill.	Euphorbiaceae	Nr
09° 03.840´	036° 06.364´	1150	<i>Blighia unijugata</i> Bak.	Sapindaceae	Nr

Nr = Not recorded.

probably find mango plantation easily and settled. Studies confirmed that some phytophagous insects showed host switching between plants in relation to nutritional quality for survival, nymphal development and reproductive performances of the adults (Velasco and Walter, 1993; Mody et al., 2007). The fact that only mango was infested by WMS within farms containing other plants which were formerly reported to have been host of WMS in other countries may mean that mango is a preferred host for WMS in western Ethiopia. However, comparative analysis of nutritional quality of mango and other plants was not within the scope of the current study.

Conclusion

It is possible to see that WMS is spreading very fast and has already covered mango farms over large geographical areas in western Ethiopia, with high and very high severity status in most cases. The trend of the spread is a reminder of urgency for devising and implementing control measures.

This study concludes that mango plantation is the only

host plant for WMS in western Ethiopia. Further studies are required to elucidate the reason for such single host preference of the pest in presence of other potential host plants in the study area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests

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REFERENCES

Abo-Shanab ASH (2012). Suppression of white mango scale,

- Aulacaspis tubercularis* (Hemiptera: Diaspididae) on mango trees in El-Beheira Governorate. Egyptian Academic Journal of Biological Sciences 5:43-50.
- Beardsley JW Jr, Gonzalez H (1975). The biology and ecology of armoured scales. Annual Review of Immunology 20:47-73.
- Bezu T, Woldetsadik K, Tana T (2014). Production scenarios of mango (*Mangifera indica* L.) in Harari Regional State, Eastern Ethiopia. Science, Technology and Arts Research Journal 3:59-63.
- Cavieres LA, Penaloza A, Arroyo MK (2000). Altitudinal vegetation belts in the high-Andes of central Chile (33°S). Revista Chilena de Historia Natural 73:331-344.
- Chala A, Getahun M, Alemayehu S, Tadesse M (2014). Survey of mango anthracnose in southern Ethiopia and in-vitro screening of some essential oils against *Colletotrichum gloeosporioides*. International Journal of Fruit Science 14:157-173.
- Dako ODJ, Degaga EG (2015). Infestation of *Aulacaspis tubercularis* (Homoptera: Diaspididae) on mango fruits at different stages of fruit development, in western Ethiopia. Journal of Biology, Agriculture and Healthcare 5(18):34-38.
- Dawd M, Hailegebriel B, Ayele L, Feleke K, Hailemariam S, Burka T (2012). White mango scale: a new insect pest of mango in western Ethiopia. In: Eshetu D, Asfaw Z, Lemma D, Zemedu W, Hailemikael KM, Getachew T, Yehene G (eds.), Proceedings of 3rd Biennial Conference of Ethiopian Horticulture Science Society, Addis Ababa, Ethiopia. pp. 257-267.
- El-Metwally MM, Moussa SFM, Ghanim NM (2011). 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. Egyptian Academic Journal of Biological Sciences 4:123-130.
- Erichsen C, Schoeman A (1992). Economic Losses Due to Insect Pests on Avocado Fruit in the Nelspruit/Hazyview Region of South Africa During 199. South African Avocado Growers' Association Yearbook, University of Pretoria, Pretoria.
- Ethiomet, National Meteorology Agency of Ethiopia (2016). Agrometeorological bulletin, Available at: http://www.ethiomet.gov.et/bulletins/dekadal/_agricultural_bulletins
- Ethiopian Ministry of Agriculture and Rural Development (2009). Crop Variety Register Issue No. 12. Animal and Plant Health Regulatory Directorate, Addis Ababa. 180p.
- Fita T (2014). White mango scale, *Aulacaspis tubercularis*, distribution and severity status in East and West Wollega Zones, western Ethiopia. Science, Technology and Arts Research Journal 3:1-10.
- Fosaa AM (2004). Biodiversity patterns of vascular plant species in mountain vegetation in the Faroe Islands. Diversity and Distributions 10:217-223.
- Germain JF, Vayssieres JF, Matile-ferrero D (2010). Preliminary inventory of scale insects on mango trees in Benin. Entomologia Hellenica 19:124-131.
- Griesbach J (2003). Mango Growing in Kenya. World Agroforestry Centre (ICRAF), Nairobi 122p.
- Ha S, Mahmoud Y, Ebadah I (2015). Seasonal abundance, number of generations and associated injuries of the white mango scale, *Aulacaspis tubercularis* (*Mangifera*) (Newstead) (Homoptera: Diaspididae) attacking mango orchards. Research Journal of Pharmaceutical, Biological and Chemical Sciences 6:1373-1379.
- Habib T, Malik ZH, Hussain MA, Khan MQ (2011). Plant species diversity along the altitudinal gradient at Garhi Dopatta Hills, Muzaffarabad. Journal of Medicinal Plants Research 5(20):5194-5196.
- Haggag WM, Shabaan AM, Nasr AK, Abd El-Salam AME (2014). Integrated pest management for sustainable mango production. International Journal of Pharmaceutical Sciences and Research 29(2):276-282.
- Hodges AC, Hodges GS, Wisler GC (2005). Exotic scale insects (Hemiptera:Coccoidea) and white flies (Hemiptera :Aleyrodidae) in Florida's tropical fruits: an example of the vital role of early detection in pest prevention and management. Proceedings of the Florida State Horticultural Society 118:215-217.
- Hodges G, Hamon A (2016). White Mango Scale, *Aulacaspis tubercularis* Newstead (Coccoidea: Diaspididae). Pest Alert, Florida Department of Agriculture and Consumer Services, Pest Alert Division of Plant Industry, Pest Alert.
- Honja T (2014). Review of mango value chain in Ethiopia. Journal of Biology, Agriculture and Healthcare 4(25):230-239.
- Hurni H (1998). Agroecological Belts of Ethiopia Explanatory Notes on Three Maps at a Scale of 1:1,000,000: Research Report. University of Bern, Bern.
- Hussen S, Yimer Z (2013). Assessment of production potentials and constraints of mango (*Mangifera indica*) at Bati, Oromia Zone, Ethiopia. International Journal of Sciences: Basic and Applied Research 11(1):1-9.
- Kataria R, Kumar D (2012). Occurrence and infestation level of sucking pests: aphids on various host plants in agricultural fields of Vadodara, Gujarat (India). International Journal of Scientific and Research Publications 2(7):1-6.
- Magsig-Castillo J, Morse JG, Walker GP, Bi JL, Rugman-Jones PF, Stouthamer R (2010). Phoretic dispersal of armoured scale crawlers (Hemiptera: Diaspididae). Journal of Economic Entomology 103(4):1172-1179.
- Malumphy C (2014). An annotated checklist of scale insects (Hemiptera: Coccoidea) of Saint Lucia, Lesser Antilles. Zootaxa 3846(1):69-86.
- Mody K, Unsicker SB, Linsenmair KE (2007). Fitness related diet-mixing by intraspecific host-plant-switching of specialist insect herbivores. Ecology 88(4):1012-1020.
- Nabil HA, Shahein AA, Hammad KAA, Hassan AS (2012). Ecological studies of *Aulacaspis tubercularis* (Diaspididae: Hemiptera) and its natural enemies infesting mango trees in Sharkia Governorate. Egyptian Academic Journal of Biological Sciences 5:9-17.
- Nobre PAF, Bergamini LL, Lewinsohn TM, Jorge LR, Almeida-Neto M (2016). Host-plant specialization mediates the influence of plant abundance on host use by flower head-feeding insects. Environmental Entomology 45(1):171-177.
- Pratt CF, Constantine KL, Murphy ST (2017). Economic impacts of invasive alien species on African smallholder livelihoods. Global Food Security 14:31-37.
- Satti AA (2011). Alien insect species affecting agriculture and natural resources in Sudan. Agriculture and Biology Journal of North America 2:1208-1221.
- Tucho A, Lamessa F, Berecha G (2014). Distribution and occurrence of mango anthracnose, *Colletotrichum gloeosporioides* Penz and Sacc) in humid agro-ecology of southwest Ethiopia. Plant Pathology Journal 13(4):268-277.
- United States Department of Agriculture (USDA) (2006). 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, USA.
- United States Department of Agriculture (USDA) (2007). 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, USA.
- Velasco LRI, Walter GH (1993). Potential of host-switching in *Nezara viridula* (Hemiptera: Pentatomidae) to enhance survival and reproduction. Environmental Entomology 22(2):326-333.
- West SA, Cunningham JP (2002). A general model for host plant selection in phytophagous insects. Journal of Theoretical Biology 214(3):499-513.

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