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SURVEY AND MANAGEMENT OF WHITE MANGO SCALE (Aulacaspis tubercularis) ON MANGO (Mangifera indica) PRODUCTION AT ASSOSA AND BAMBASI DISTRICTS, IN BENISHANGUL GUMUZ REGION

Bizuayehu, Jemaneh

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BAHDRAR UNIVERSITY COLLEOGREGRICULATINUERENVIRONMENTASL SCIEN DEPARTEMENT OF PLANT SCIENCE PLANT PROTECTION GRADUATE PROC

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M.Sc. Thesis

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Bizuayehu JKeVno-aldheeshenbet

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BAHDRAR UNIVERSITY COLLEOGREGRICULATINU DENEVIRONMENTAL SCIEN DEPARTEMENT OCIFERNICAENST S PLANT PROTECTION GRADUATE PROC

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M.Sc. Thesis

Βу

Bizyuahu Jem Watorechesenbet

SUBMITTED IN PARTIAL FULFILLMENT OF THE R DEGREE OF MSASITEENRCSENF(MIR) LANT PROTECTION

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THESIS APPROVAL SHEET

As member of the Board of Examinseof the Master of Sciences (SVc.) thesis opediefence examination, we have read and evaluated this thesis prepalved Bijzuayehu Jemaneh WoldesenbetentitledSURVEY AND MANAGEMENT OF WHITE MANGO SCA LE (Aulacaspis tuberculari); ON MANGO (Mangifera indica) PRODUCTION AT ASSOSA AND BAMBASI DISTRICTS, IN BENISHANGUL GUMUZ REGION, WESTERN ETHIOPIA. We hereby certify that, the thesis is accepted full tilling the requirements for the award of the degréte/lester of Sciences (M.Sc.) Prlant Protection.

Board of Examiners

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DECLARATION

This is to certify that this thesis entitle **B** (Aulacaspis tuberculari) ON MANAGEMENT OF WHITE MANGO SCALE (Aulacaspis tuberculari) ON MANGO (Mangifera indica) PRODUCTION AT ASSOSA AND BAMBASI DISTRICTS, IN BENISHANGUL GUMUZ REGION, WESTERN ETHIOPIA .• submitted in partialfulfilment of the requirements for the award of the degree of Master of Scien Relative Protection• to the Graduate Programe partment of Plant scien College of Agriculture and Environmental Sciences, Bahir Dar University by Mr.Bizuayehu Jemenah Woldesenbet (ID.No.BDU1018408P) is an authentic work carried out by him under our guidance. The matter embodied in this project Wichas not been submitted earlier for award of any degree or diploma to the best of our knowledge and belief.

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Wishing all Holy blessings from Jesus Christ and be considered in His eternal Government.

DEDICATION

To my wife Hana Kelifa Elias for heredicated partnership in the success of myalifedmy son ElnatharBizuayehufor his affection.

ABBREVIATION SAND ACRONYMS

BGR	BenshunguGumuz Region
BoA	Bureauof Agriculture
CIMMYT	Centro Internacional De Mejoramiento De Maiz Y Trigternational
	Maize And Wheat Improvement Centre
CSA	Central Statistical Agency
FYM	Farm Yard Manure
GLM	General Linear Model
GPS	Global Positioning System
IPM	Integrated Pest Managemet
Ltd	Limited
MoA	Ministry of Agriculture
MRR	Marginal Rate OReturn
NMA	National Meteorological Agency
QGIS	Quantum Geographical Information System
SAS	Statistical Analysis System
SNNPR	Southern Nations, Nationalities, And People's Region
SPSS	StatisticalPackageor The Social Sciences
SRA	Small Research Airvity Report
UAAIE	Upper Awash Agro Industry Enterprise
WMS	White Mango Scale

SURVEY AND MANAGEMENT OF WHITE MANGO SCALE Aulacaspis tubercularis) ON MANGO (Mangiferaindica) PRODUCTIONAT ASSOSAAND BAMBASI DISTRICTS, N BENISHANGUL GUMUZ REGON, WESTERN ETHIOPIA

ABSTRACT

Mango (Mangifera indicaL.) is grown commercially on large scale across all tropical and subtropical lowland areas throughout the world a good source of vitamin A and C, and is rich in carbohydates, potassium and paphorus. It is the major fruit crop grown in Benshangul Gumuz Region of western Ethioptian family consumption and markets The production in the region is currentlyconstrainted byinfestation of white mango scaleAulacaspis tubercularis NewsteadThisresearch was conducted assesslamage status and evaluation management optionsin Assosand Bambasfrom August 2018 to April 2018 urvey data of white mango scale infestation status and groweassessmentollected from randomly selected 7 kebele administrates of Amba_14, Amba_5, Amba_8 and Megele_32 from Assosa district and Mender 47, Mender 48 and Sonika from Bambasi distant 35 household with their respective mango orchards per kebele administrates within 5 • 10 km interval A wellstructured guestionnairend faceto-face survey approach were used assessmenStratified sampling method was used for selectingleavesper treefor 9 consecutive monthisence 90 leaves from each treamd 3150 sample leaves from 35 mango traces counting the clusters of white mango scale insect pest for the study of infestation domized complete ock design (RCBD) was used for evaluation of Imidacloprid 20SL, Dimethoate 40%EC, Whitest calct Pruning, Imidacloprid 20SL + Pruning, Dimethoat@%EC + Pruning and White odtract+ Pruning. The survey result showed that growers€ perceived that the are easy infestation of white mango scalessect pest which is a new pest and inly dispersed by planting material due to unmanageable mangoze nature and backyard farm production made management difficult which results a significant yield reductionWhite mango scale insect pest infestation wassignificantlyhigher at Assosa than at Bambasi orchaads more abundant on upper leaf than on lover leaf surface infestation status was significantly varied amongstudy months; lowestand highestecord during December and Apriespectively Temperature influence the infestation positivelya maximum record during maximum temperature of the studthrapril. High amount and continued rain fall and relative humidity influence infestation negatively Optimum rain fall and elative humidity and also unmanaged mango orchards conditionade the infestationserious. Experiment against white mango scales is a mango trees using Dimethoate40%EC white oil + pruning, Imidacloprid 20SL, and Dimethoate6%EC + pruning treatments gave higher yield and statistically significant different from pruning and white oil treatments but their costs were such that their not provide an acceptable rate of return. Imidacloprid20 SL+ pruning treatment was the most significantly effective which also provide a promising alternative cost to producers against white mango scale insect pest than other treatments.herefore tis recommended togular inspection and monitoring, develop a strong domestic guarantine, investigate resistance mango varieties and further screening of IPM compatible insecticide for roviding sustainable management approach of white mango scales insect pest.

Keywords: White mango scaleMango orchardDistribution, Abundance, Severity status

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Chapter 1. INTRODUCTION

1.1 Background and Justification

Mango is a member of the family nacardiacea within the genus Mangifera which consists of over25 species. Among the several speof mango, Mangifera indica (Linnaeus)'s the only species grown commercially on large scale (Griesbach, 2003). Matagogi (era indica L.) originated in tropical Asia and is currently distributed across all tropical and subtropical lowland areas through the world (Dirou 2004; Okothet al., 2013; Ubwaet al., 2014 and Craneet al, 2017). Mango isone of the most cherished fruits, not only for its flavour and taste, but also for its nutritional value. Mango is a good source of vitamin A and C, and isrich in carbohydrates, potassium and phosphorus (Grie 2000) and Nabil et al, 2012). Mango serves as a fruit crop and asulasistence crop for family farms. As it ripens at the end of the dry season and at the start of the rainy season, the matigodias mental source of nutrition for rural population (Vayssièreset al, 2012).

Mango is traditionally grown in Ethiopia primarily for family consumption and local markets, but some emerging modern farms have started to produce mango for bothd local an exportmarkets Alemayehu Chalæt al. 2014). Ethiopia exports mango to Djibouti, Saudi Arabia, Yemen, Suath and the United Arab Emirate Ee (wodros Bezuet al., 2014). Total world mango production is more than 40 million tons, with only 3% of the caupedr around the globe (Evans and Mendoza, 2009; Gallo, 2015; Galán Saúco, 2015e Balyan 2015 and Mitra, 2016).

In Ethiopia mango is one of the second potential fruit crop next to banana which is the first fruit crop produced in large quantity an dopluced mainly inwest and east of Oromia, SNNPR (Southern Nations, Nationalities, And People's Re)gio GRS (Benshungul Gumuz Region) and Amhara National Regional Sate (Takele Honja 2014) According to CSA (Central Statistical Agency)(2017) report 15,41376 hatotal area allotted for mango and 1,046,461.25 quintals annual production Similarly in BGR (Benshungul_Gumuz Region) area cultivated and production reference and 79511.96 unitals respectively.

Different literature showed that mango tsaaked by a variety of insect pests such as stone weevil (Sternochetuspp.), mealy bugs, fruit flies, scales, and mites, and various diseases of which fungal diseases reathe common (Griesbach, 2003 aFrAdO, 2010). In Ethiopia

Mango production is constrated by insect pests such as fruit flies, mango seed weevil, mites, thrips, mealogs and scalessects \$eid Hussen and Zeru Yimer, 201and Alemayehu Chala et al. 2014). Among these insect pests of mango, white mango **\$eale** caspis tubercularisNewstead) is the most important of hard scale insects which is reported to have damaged mango in various paof the world \$RA, 2006; Germainet al, 2010 and Abo-Shanab, 2012).

Themango white scale insequest morphological description is opaque white fenaul nour 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 tricæriaad crawlers are deep bright brick red (Hamon 2016). The pest reproduces during both dry and wet seasons (Halteren, 1970)White Mango Scale is a sucking insect that poses severe threat to mango plantations in various mango growing countries (Labusœhatent). 1995; Penæt al 1998; Nabil et al 2012 andJuárezHernándeæt al 2014). The damage caused by White Mango Scale includes yellowing of leaves, appearance of conspicuous pink blemishes on mature and ripe fruits and dieback of the plant (Eventually et al. 2011 andAbo-Shanab 2012). Infestation in young trees may lead to excessive fall off leaves, retarded growth and death of the whole plant (Nabiet al., 2012).

The population density of white mango scale was formerly recorded on **trraegio** few parts of the world. However, it has been spread by the transport of infested plant materials and widened its scope and has become an important mango pest in many mango growing countriessuch as Mexico, India, Pakistan, Italy, Ghana, Kenya, Madagakaaaritius, Tanzania, Uganda and Zimbabwe, among others (Labuscleagate 1995; Penæt al, 1998; EłMetwally et al, 2011; Salemet al, 2015 andHodges and Haon, 2016). Infestation of mango by by freen Focus Ethiopia MtdhámmedDawwd et al, 2010 in a mango orchard owned by Green Focus Ethiopia MtdhámmedDawwd et al, 2012) which used to import mango seedlings from and hence it is deduced that the ectpest probably entered Ethiopia accidently on imported seedlings. Wother northern and central Ethiopia, with the infested area in therth being about 1500 km away from the place of initial infestation(TemesgerFita, 2014andGashakaezaAyalew et al. 2015).

Different literatures were indicated for annagement of white mangscale such as a recommendation of applaud and white oiby Ambo Plant Protection Resear Chentre (Tesfaye Hailuet al., 2014). Mineral oils such a Diver®, CAPL2® and super masrona® and insecticide such Deltametrine and pyrethrin in Kenyehloropyrifos, methidathion, Dimethoate 40% ECMovento, Folimat 500 SL, D-C-Tron and Closer insecticides were different effectivenessin reducing the insect numb (Howard, 1989, Findlay, 2003; Abo-Shanab, 201; Cashawbez Ayalew et al. 2015 and Ofgaa Djirata 2017).

1.2 Statement of the problem

Mango production in western Ethiopia highly constrained by white mango scallehe damageof white mango scale induced panic and **fratiso**n in Western Ethiopia for the loss in crop production and indirect sociological consequences, since mango plantation serves as shade for animals arconference hall for the people, in addition to generating income and serving as food in the regionThe insect hasbecome 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 reperc**Tiesfayse** (Hailu et al., 2014 ancOfgaaDjirata and Emana Getu, 2015).

The development of conspicuous blemishes on mango fruit skin which was infested by white mango scale markedly damages mango fruit export potential and eventualsytolead economic loss (USDA, 2006 an 2007). According to the information obtained from farmers, they use to harvest up to 10 quintal of fruits per tree before the occurrence of this new insect pesBut the fruit yieldreduced to 2-3 quintal per tree may not be obtained to all due to the heavy infestation of intermango scale (Mohammedawd et al., 2012).

For control of white mango scale pest in Ethiopia no single insecticide has been registered. Insecticides currently in use against white mango scale in the infested mango orchards are insecticides recommender the control of armoured scales such as the red scale (Aonidiella aurant) on citrus in the early 1980s (Tsed & the red scale 1994 and Ferdu Azerefegne et al., 2009). Of gaa Djirata (2017) eported that imited report of experiments performed regarding insectide screening against white mango stratect pest Ethiopiasince the insect introduced in the country has been less than a decard beere forethere is limited information on effective management option for the control of white mango scale in BGR (Benshungul Gumuz Region). Besides to this, regular assessment of the pest will tell us the severity of infestation and distribution over time and across location of the pest and also farmers, knowledge and management practices of the pest.

1.3 Objectives of the Study

1.3.1 General objective

To assess the white mango scale and agestatus and evaluation of management options mango scale at ssosa and Bambasi districts Brenshungu Gumuz Region

1.3.2 Specific objectives

- ð§ To develop spatial and seasomalpof white mangoscale distribution
- ð§ To determine the main and alterinvethosts of whitemangoscale
- ð§ To determine the infestation levelcidencænd damagetatusof white mango scale
- ð§ To evaluate the effective management tethod on white mangoscale
- 1.4 Research questions

The research question of the survey and management of mango white scale in the study area arelisted as the following:

- ð§ Whatarethe spatial and temporal distribution of whitte angoscale?
- ð§ Whatarethe main and alterniate hosts of whitemangoscale?
- ð§ How are the infestation levelincidenceand damagetatusof white mangoscale in the study area?
- ð§ Whatarethe effective management options to manage mango white scale?

Chapter 2. LITERATURE REVIEW

2.1 Mango Origin, Biology, Ecology and Production

2.1.1 Mango origin and taxonomy

Mango (Mangifera indica) is a member of the famil/ynacardiacea@rom Asia and has been cultivated for at least 4000 years (Crane, 2008). It is one of the most important members of this family (Normandet al., 2015). The maintenterof origin for mango iswithin the region between northeast India and Myanmar (Crane, 2008; Bompard, 2009; Dietesch 2015; Shermaret al., 2015; Krishnapillai and Wijeratnam, 2016 a&ahuet al., 2016). Many of the cultivars grown in India are at least 400 years old (Marjkebet al., 1968). There are more than 100 ifferent cultivars in some parts of India, including West Bengal (Matral, 2015). All mango cultivars belong to the specMangifera indica Thetaxonomy of mango is described aKingdom, Plantae; Class Mangoliopsida; Phylum, Mangoliophyta; Order, Sapindales Family, Anacardiaceae Genus Mangifera and Species Indica (Litz, 2003).

2.1.2 Mango bology

The tree is a deeppoted, evergreen plant which can develop into huge trees, especially on deep soils. The **hight** and shape varies considerably among seedlings and cultivars. Under optimum climatic conditions, the trees are erect and fast growing and the canopy can either be broad and rounded or more upright. Seedling trees can reach more than 20 m in height while grafted ones are usually half that **sizer**(and Schnell2009).In deep soil the taproot descends to a depth of **202et**, and the profuse, wiekspreading feeder roots also send down many anchor roots which penetrate for several feet (Matsuoka, 2000).

The tree is longived with some specimens known to be over 150 years old and still producing fruits. The mature leaves are simple, entire, leathery, dark green andtigeoussy; are usually pale green or red while young. They are stroom ted, oblong and acheeolate in shape and relatively long and narrow, often measuring more than 30 cm in length and up to 13 cm in width (Salimet al., 2002). The mango inflorescence is a branched terminal panicle, 4*f*24 in. long, bearing what has been variously estimated from 500 to 10,000 (McGregor, 1976), 200 to 6000 (Free, 1993), and 1000 to 6000 (Mukherjee, 1953) individual flowers per panicle. The umber of panicles range from 200 to 3000 per tree depending on tree size and extent of branching (McGregor, 1976) vividual flowers are borne

collectively on panicles or thyrs & berling, 1989) Individual mango flowers are small, ranging in size from five to ten mm in diame & CGregor, 1976; Scholefield, 1982; Mukherjee and Litz 2009 and Ding and Darduri, 2013)

The fruits can be oval, egg shaped and round depending on the variety with smooth and soft skin. When ripe, the skin is usually a combination of green, red, and yellow depending on the variety (Matsuoka, 2000). The interior flesh is bright orange **aftodvit**h a large, flat pit in the middle in all ripe varieties. The fruit has a rich luscious, aromatic flavor and a taste in which sweetness aradidity are pleasantly blend dobsonand Grierson 1993). Mango trees are often irregular in their cropp **ing**bit, with no clear pattern across different years. Plantings can also suffer from alternate or biennial bearing, where a tree or an orchard produces a large crop in an-**ge**ar followed by a small crop in the following **ofé**ar (Souza et al., 2004). There an be periods of irregular bearing and periods of alternate bearing in the same orchard (Fitche#t al., 2016).

2.1.3 Mango cology

Mangogrow well from sea level up to 1,200 m above sea level, however, fruit production decreases at higher altitudes angoes are naturally adapted to tropical lowland between 25 N and 25S of the equator and up to 915 meters above sea level (Joetneslon1997). Mango is successfully cultivated under conditions which vary from very erroy thumid to cool and dry or arid areaiss mean annual rainfall is between 400mm and 3600mm (Bally, 2006). The average temperature must be at leas 2 with an optimum of 25C (Samson, 1986). Well drained soil with pH ranging from 5.5 to 7.5 is suitable for mango. Mango is drought tolerant and survives on as little as 300 mm of rainfall per year (Johnes carl, 1997).

Sarwar (2015) recorded nearly, 200 known insect and **inse**ct pests in mango. The foremost insect pests of mango recorded as hopper, mealy bug, inflorescence midge, fruit fly, scale, shoot borer, leaf Webber and stone weevil. Among **these**opteransand coleopteranswere principal insect pests considered for integra**ted p**nanagement. Also Chowdhury (2015) recorded various insect pests on maxigo hopper, mealy bug, inflorescence midge, fruit fly, scale, shoot borer, leaf Webber, leaf Webber and store weevil. Sahoo and Jha(2008) reported 26 insect species in nursery bed and orchard of mango. These are fruit borer, hopper, hairy caterpillar, nest forming caterpillar, slug caterpillar, slug caterpillar, bag

worm, hopper, painted bug, aphid, mealy bug, leaf eating weevil, grey weevil, fruit fly and gall insect. These insects infesting the crop during flowering and fruiting periods and cause severe damage.

Srivastava(1997) observed spidecoccinelids black ant, red antChlrysoperala carnea, praying mantid, predatory bug as a predator on different insects of notachard. Peng and Christian (2005) observed survey of natural enemies in mango orchards in Australia and observed that common bereifil predators and parasitoids like lady bird beetles (its feed on aphids, leaf hoppers, scales, mealy bug and Lepidoptera eggs), lace wing (its larvae very important role in controlling thrips, mango hopper, aphids, mites, immature scales, mealy bug and snall caterpillar) Hoverflies (its larvae feed on mealy bugs, aphids, and thrips) Spiders (its prey on the mango hoppers, mango tip borers, thrips, plant hoppers, moth, bug and flower caterpillars, leaf hoppers, pest bugs, aphids, and insect eggs) franting (its feed on grasshoppers, leaf hoppers, plant hoppers, fruit spotting bug, tea mosquito bug and moth etc.) Ants (these are effective predators of a range of arthopods including the major insect pests) and other predators like dragon fly, dafhsedround beetle, rove beetle, insectivorous birds. Also observed parasitoids, like many species of parasitic wasp that parasitizes eggs, pupa and larvae of insect pests. They play important role in the northern territory of mango orchards in controlling e mango hoppers, mango tip borers, fruit spotting bug, scale insect and flower caterpillars.

2.1.4 Mango production practice

The number of trees per household varies from 50, depending on size of the farm land and preference of farmers lowever, majority of growers have less than 20 trees while few have more than 40 tre(Esewodros Bezuet al., 2014). Similar holdings by peasant growers have also been reported by Semwaetgal. (2008) in Assosa (western Ethiopia) and Seid and Zeru (2013) in Bati (norther Ethiopia). Tewodros Bezuet al. (2014) reported mango production has a long history in eastern Ethiopia particularly in eastern Har Engine lso supported by Salimet al. (2002), Griesbach (2003) and Merkuz Abera (2017) smango tree is long-lived with some specimens known to be over 150 years old and still producing fruit.

Most of the time Ethiopian farmers did not give attention to spacing. Orchards growth were not well space, daccording to the oldness of the es agemost of the farmers had no knowledge about spacing. Space plays significant role for all activities, absence of proper

spacing create difficulties for productios (id Hussen and Zeru Yimer, 2013) laniyan (2004) reported that manguree spacing appears to be an important consideration production Mango orchards are normally planted at fairly wide spacing because the trees can grow into large specimens (Kheatnal, 2015). Mango fruits grown under high ensity planting show a progressive decline in crop yielder 14/15 years, dueotovercrowding of canopies, which suggesst regular canopy nanagement/vasnecessary (Sharmæt al., 2006 and Merkuz Abera 2017). Overcrowding results in the production of fewer fruits which are apt to be poorly colored and infected wites to Tall trees also present a harvesting problem and create difficulties during spraying and pruning (Griesbach, 2003). In general, well managed orchard trees require regular annual pruning to maintain an open canopy of manageable size. This allows air and sunlight treprete, which reduces pests and diseases and improvefruit color (Bally, 2006).

Significant numbersof mango producers in Ethiopia use river water and a small portion of smallholders use pound water. The yield is greater in river water irrigation the drawater irrigated crops. The quantity and quality of water available is on factors that determine the yield. Frequency and amount of irrigation need depends on soil type, property, **dird**ate others (Seid Hussen and Zeru Yimer, 2013) he same study shower that fertilizer application, irrigation, pest and disease contword break and pruning are the mango production practices adopted by the smallholder farmers in the area. However, regression and inorganidertilizers for the mango production purpossis rare except some novative farmers that use organic fertilize/Similar study conducted by yelech Tadess (2011) indicated that FYM (Farm Yard Manure) rincipally transported from homestead to the field mostly during the dry season and spread inbute on of each tree in circular form. The assessment porthighlighted that chemical inputs entirely evaded neither for fertilization nor for pest treatment. The same study indicated that smallholder farmers in the area intercrop mango with maize, targinger, chat, cabbage and banana **aty star** ge.

Mango trees in most parts of Ethiopia are developed from seedlings and are inferior in productivity and in fruit quality. To alleviate these problems improved varieties named Kent, Keitt and Tommy Atkins wer introduced from Israel in 1983 and are being commercially produced by the Upper Awash Agro Industry Enterprise (UAAIE). These varieties are widely distributed to different parts of Ethiopia by UAAIE. Green Focus Ethiopia Limited private farmintroduced anew mango cultivar Alphans(@001/2002)rom India and planted in its farm at Loko in Guto Gida district of East Wollega zone of Oromia, western Ethiopia

(MohammedDawd et.al2012). The farm cultivates Keitt, Kent, Tommy Atkins, Apple, Dodo and Alphans (Temesgen Fita, 2014).

Knight (1997) reported that mange fruit matures in 100 to 150 days after flowe and he fruit will have the best flavor if allowed to ripen on the tree back (1992) reported that commercial marketabilityequires 13% dissolves blids or sugars and he fruit ripens best if placed stem end down in trays to prevent the sap from spreading to other parts of the fruit and also to encourage even ripening at room temperatures (20) and covered with a dampened cloth to avoid shrived. Rosals (2005) found that loss of fruit increases dramatically after harvest as the fruit maturity increased. Methods of harvesting adopted by the smallholder farmers in Ethiopia are hand picking, cut by scissor and using stick. Hand picking method of arvesting produce can maintain good quality of fruit and protect the fruit from mechanical damage. Hand picking can produce the fruit with stem and reduce fruit bruising and damage but stick structure result in fruit dropping and leave the fruit without stem which facilitate fruit bruise and mechanical damage (**Beiss**enand ZeruYimer, 2013). Ayelech Tadesse 2011) showed that harvesting usually start after fruit dropping which is principal maturity index. FAO (2005) which indicated cuts, punctures aises has increased ethylene production and hastened fruit softening and ultimately caused mechanical injuries and decay.

2.2 Production Constraints of Mango

Mango production constrainted by different biotic and abiotic factors. Among the biotic factors that rango tree damaged werdifferent insects and diseases sachAnthracnose, Bacterial Black spottone weevil \$ternochetuspp.) fruit fly, mango gall flies, Mango leaf coating, Mites, Mango seed weevil, Mealy bug, Powdery mildew, Scale, Spider mites, Mango tip borer, Stemend rot, Termite, Thrips and White flies (Borchsenius, **1986**bock and Kozuma, 1963; lalteren, 1970; Griesbach, 2003 afrido, 2010). Among these insect pests of mango, white mango scale is the most important of hard scale insectisis whi reported to have damaged mango in various parts of the world (Cunning) SRA, 2006; Germairet al., 2010 and Abo-Shanab, 2012).

In Ethiopiamango production is constrained by insect pests such as fruit flies, mango seed weevil, mites, thripsmealybugs and scale insects d reported tohave caused damages ranging from significant vegetative damage to total mango yield losses Hussen and

Zeru Yimer, 2013and Alemayehu Chalæt al. 2014). Also Tewodros Bezuet al. (2014) reported thrips, fruit flies, termites, and various fungal diseases constrain mango production in Ethiopia in the absence of proper management practices. Mango anthracnose, caused by Colletotrichum gloeosporioide was reported to be 100% prevalent in the humid -agro ecology of southwest Ethiopia, and found causing sevelance age to the fruit crop (Ayantu Tuchoet al., 2014). White mango scale is among insect pests inflicting damage to mango treesin BGR (Benishangu Gumuz Regio)).

The studyin the East and West Wollegådministrative Zonesby Temesgen Fita(2014) who reported thatus vey in the infested districts mango yield obtained besidmie mango scale emergence was significantly higher these the mango scale emergence Mohammed Dawd (2012) also reported that farmes responded that fruit harvest up to 10 quintal before the occurrence of white mango scale had been decreased to 2 to 2 to 10 not at all after the occurrence of mango white scale ges and Harmor(2016) reported that in 2001, losses caused by fruit jection from Nayaritdue to white mango scale infestation were anged from 50 to 100%.

2.3 White Mango ScaleOrigin, Taxonomy and Biology

2.3.1 Origin and taxonomy

White Mango scales a tropical species that may have originated in Asia (Borchsenius, 1966) and has been firstly reported in India on mangoes (**Ben** et al., 2006). The taxonomy of white mango scale is described as domain: Eukaryotakingdom: Metazoa; phylum: Arthropoda sub phylum: Uniramia; class: Insecta; order: Hemiptera; sub order: Sternorhyncha; Unknown: Coccoide family: Diaspididae; Genus: Aulacaspis as probable cies: Aulacaspis tuberculari (SCABI, 2018).

White mango scale is known by its accepted n**Ande**caspis tuberculari**b**lewstead, 1906 (Varshneyet al., 2002). However, there were times whitewas known by several different names, namelyAulacaspis cinnamonNiewstead, 1908Aulacaspis cinnamomi mangiferae Sasscer, 1912Aulacaspis mangiferalelacGillivray, 1921, Aulacaspis sinnamonNiewstead, 1909Diaspis cinnamomiHall, 1928, Diaspis cinnamomi mangiferablewstead, 1911, among othe®A(BI, 2018andHalteren, 197)

2.3.2 White mango scaleiblogy

White mango scale differs from false mango scale mainly by females which are described as being red with scale œrvage thats flat, white and circular with a black oval shaped caste skin and males white and rectangular in shape with two or three distinct ridges usually clustered round a single female (Northern Territory Government Department of Resources, 2010). White mango scale is hard scalesacronored scale which do not produce honeydew (Mark et al, 2019). White mango scale secretes waxy protective covering under which it lives and feeds. The coat is attached to the plant surface, while the insect is freetheithi cover. The waxy cover is tough; thus, white mango scale is known as armoured or hard scale insect. Sizes of scale insects range from 1.5 mm to 25 mm in length, and they also vary in shape and colour (Varshnetyal, 2002 and Moharum, 2012).

As cited by Abo-Shanab(2012) and shown in Figure 2.1 bytamon(2016) white mango scale shows sexual dimorphism. Adult female is larger in size than the male; with thin and nearly circular body shape and white armour that possesses dark and oval terminal exuviae. The naked adult female's body is wrinkled, with quadrate and enl**prged**ma. Takagi (2010) describethe body of fullygrown adult femalecosaetype, as its prosoma (the fused head, prothorax and mesothorax) is swollen and wider than the postsomaus(ebde f metathorax and abdomen). Adult female has neither wing nor appendage for locomotion. It glues itself to the plant part by the use of its armour and remains sucking sap from the plant tissues. Like most species of armoured scale insects, adult matemating scale is smaller in size than the female; its body is elongated and nearly rectangular in shape with three raised parallel dorsal ridges on its cover (Takagi, 2010 and Bern, 2012).

Figure2.1 Imageof white mango scale Source: (Hamon, 2016) Unlike the female, male mango scale possesses one pair of wings. They occur in groups gathering around the female, while the female usually occurs singly. The reproductive biology of scale insects in genetexhibits marked diversity. A variety of sexual and asexual modes of reproductions are present in scale insects (Rass2012). Hermaphroditism is among the sexual modes of reproduction in this group of insects. Adult female of some scale insects ma lay eggs or give birth directly to live first instars (Gyeltshen and Hodges, 2006). In the course of development, female scale insects undergo incomplete metamorphosis with a total of three to four instars; whereas the male passes through five in**stibiting**xa metamorphosis which resembles the complete one. However, it is evident that members of the orderHomopteranormally undergo incomplete metamorphosis. The life cycle of white mango scale begins when the female lays fertilized eggs under its woixer may be about 80-200 depending on variations in temperature (Sayed, 2012).

The newly hatched nymph is very small, elongate, oval, and totally bare of any wax secretionAfter an incubation period of 78 daysthe first instars hatchend move out otheir mother, s coverand the crawlers moves about until it discovers a suitable place to settle on. After settling, fine threads of wax which appears cottony; begin to exude from the body and this secretion continues until the insect is completely coweited the white filament. Hence the common name iswhite cap,, (Halteren, Worka)rum (2012) described the external morphology of first instar white mango scale. Accordingly, the newly hatched nymph is small in size, elongateval and totally bare of wax secretion. It has well developed functional legs, antennae and eyes. Claws and tarsus on the legs have setae. The presence of such structures may help the nymph to attach itself to body of other animals to disperse phoretically. It was reported thataverlers of armored scale insects could remain attached to flying insects for certain periods of time, which may be an indication that phoresy might help them disperse (MagsQastillo et al, 2010).

In scale insects first instars of both sexes usually **abide**, but sexual dimorphism becomes evident as of second instar (Gyeltshen and Hodges, 2E06) er study by Great head (1990 and 1997) also confirmed that white mango scale can move with the help of external forces like wind, birds and insect pestAlso Haggaget al. (2014) cited that only the crawler stage can move to a new host (adult males can fly but cannot establish a colony), but scale insects can move to new hosts as a result of wind, birds, and insects. Crawlers are capable of moving distances of tens of kilometres on wind currents to infect clean crops. The crawlers move

about until they get suitable feeding site on the plant where they settle and continue molting. Following its settlement, cottony filamentous wax exudes from body of the infistar nymph, and covers it externally, completely. White mango scale is enclosed within this tough coat, where it remains feeding and molting until fully develops. The male crawlers settle in groups, while the females settle randomly (Letval, 2008). The wax develops into tricarinate puparia in the male. The settlement clearly described by Halteren (1970) as male crawlers settle in groups of **f @**0, often near females; these groups are conspicuous due to the white scale covers they produce.

The mate passes through two pulpike stages after which the winged adult emerges out. But, the settled female nymph moults first in to-prepositional immature and then into ovipositional adult, and remains the rest of its life attached to the host planov **Enabl** generation time (from egg to egg) is reported to b**4**@5and 2328 days in the female and male white mango scales, respectively, indicating relatively longer period in the female (Halteren, 1970). As showed inigure 2.2the scale have a joined dicycle where, from eggs to first moult, the sex is notefined however roughly 80% of crawlers will become males and follow one path of the life cycle, while the remaining 20% will be become females and follow a different lifestyle path (Owens, 2016 **#rod**mes, 2016)

Figure 2.2. Life cycle of mango white scale

Source: (Holmes, 2016)

In bi-parental species of scale insects, like white mango scale, the male insect does not have functional mouth part to feeachd hence lives for only few hours after begins flying, while the female normally feeds and lives longer (Beardsley and Gonzales, 1975 and Bautista Rosaleset al., 2013). Infestation of a new feeding site on the same or another host plant to establish a new population is the responsibility of crawlers. Though the male is capable of moving, it is unable to establish a new population. Population of white mango scale shows overlap of generation. One of the main explanations for such overlapping is long ovipositional period which allows the female offspring to reach reproduction, while the first adult female is still laying eggs (Labuschageneal, 1995).

2.3.3 Ecological adaptation

White mango scale can produce five to six generations per year, at a maximumeday tim temperature of 26°C and night time minimum temperature of 13°C (Miller and Davidson, 2005). White mango scales been spread by the transport of infested plant material and it is now widespread in many mango growing countries. The scale was introduced da and Australia with the importation of mango fruit from India (Suit, 2006). Various reports indicate that white mango scale is distributed throughout the world wherever mango is grown (USDA, 2007, ElMetwally et al., 2011 and Hæt al., 2015). The include northern part of South America, the Caribbean, the east and west coasts of Africa, Asia, and Italy, among others. In Africa alone, the pest is reported to have infested mango in about 21countries (Abo-Shanab, 2012 cited from Borchsenius, 1966) nese include Ghana, Kenya, Madagascar, Mauritius, Tanzania, Uganda, Zimbabwe, and Zanzibar, among others (Hodges and Harmon, 2016).

The year of first report of infestation of white mango scale on its host markedly varied among African countries. White mago scale was first recorded on one cultivar of mango in South Africa in 1947 (Waafæt al., 2014), but it was reported to have been recorded infesting mangos in Ethiopia in 2010 (Mohammed Daætcal, 2012). In Benin, white mango scale was recorded from ango during 2002007 (Germainet al., 2010). This pest is currently posing sever threat to mango plantations in various mango growing countries (Labuschagne et al., 1995; Penet al., 1998; Nabilet al., 2012; Tesfaye Hailet al., 2014 and Ofgaa Djirata and Emana Getu, 2015).

2.3.4 White mango scale infestation and a mage

Infestation fluctuation Field infestation assessment Onuto Gida and Diga Districts of East Wellega Zonshowed that during rain fall male and female were less but crawlers and eggs werchigh. After the rain stop the crawlers changed to adult which indicates that the presence of mango scale with the mango tress all year round, with overlapping generations throughout Peak population observed during the flowertinge of spring and harveistig period (Tesfaye Hailuet al., 2014). The studyin the East and West Wollega Zonteys Temesgen Fitt (2014) reported that there was infestation variation among the study sites. Tsegaye Babeget al (2017) reported that the study in Bench Maji Zone SoWtest Ethiopiamajority of respondents replied that the mango scale infestation varied among the study districts and seasonigh level of pest prevalence was occurred in wintervever field survey result at Kujatebeleindicated the rate of pest infestion was sever in spring while the majority of mango trees in the study area were severely damaged.

In contrary tothese results AbeShanab (2012)eported the lowest population density was observed in the beginning of spring season during the two **stydears**. Studyin western Ethiopiaby Ofgaa Djirata and Emana Ge(12015) reported that Infection of white mango scale on mango fruits at differentages offruit development studyevealed that white mango scale has become a devastating pest to **rfraintgo** western EthiopiaThe study in Central and Eastern Kenyay Ofgaa Djirataet al. (2016) also reported that become said that level of the damage showed variateiotisnevsince first recognized and so the infestion was varied spatially among the study site.

The study by Nabilet al. (2012) on mango in Egypt who recorded twatte mango scale Newsteadpreferred the upper leaf surface compared to the lower one. The stublesway et al. (2017) also strengthernet above that mango upper leaf surfaces were heavier infestation compared with the lower surfabre Ethiopia study in Arjo and Bako by Ofgaa Djirata et al. (2018) proved hat all developmental stages of mango white scale were found to be more abundate on the upper leaf surfaces.

Population of white mango scale remained at an extremely low level when average monthly rainfall was below 10 mm which implying that white mango scale is highly affected by drought (Ofgaa Djiratæt al., 2018). Ofgaa Djirata and mana Getu (2015) reported that maturation and ripening of mango fruit begin during the first months of rainy season, that is,

in March to April and continues for few months, **bis** is significant infestation of mango fruits by white mango scale, in Westle Ethiopia. Ofgaa Djiratet al. (2018) also strengthen the above report that the built of mango scale population is affected by rainfall, a minimum average monthly rainfall of about 50 mm is required to initiate **bupild** f the scale population. The tipnum rainfall for the insect to reach its peak population may vary spatially and temporally, as it was found to be 110 mm in April at Arjo and 140 mm in May at Bako. The build of the scale population coincides with the physiological maturity of mango fuit, both happening at the beginning of the rainy season in the study area. Also in his study stated that a swift population decline of mango scale followed prolonged heavy rain probably because the rain washes the scale off mango leaves. This finder gravely study result of other countries such as Sateral (2015) who stated that low population density of white mango scale from the end of rainy season in EgyMetEvally et al (2011) also recorded low population of white mango scale during the season. This condition was also supported by earlier study Mortael (1987) as it is evident that strong rain can kill small or immobile stages of insects.

The study by Ofgaa Djirateat al (2018) 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 begin to build up towards its peating second phase, in August, September and October was characterized by sharp decline of ptopeulation and the lastone was from November to January during which the population remained low and inconspicuous. 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 seconset 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 stud way iz and Fayz (2009) who stated that white mango scalead 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 midJuly. And also Ab Shanab (2012) corded four annual peaks of seasonal abundance forwhite mango scalen mango trees in Egypt. These peaks were occurred on March, June 30(2012) corded four annual peaks of seasonal abundance forwhite mango scalen mango trees in Egypt. These peaks were occurred on March, June 30(2012) corded four annual peaks of seasonal abundance forwhite mango scalen 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.

Temperaturevariation also affect the mango white scale populations, as stated by Ofgaa Djirata et al (2018) peak populations were recorded in the months with maximum monthly temperatures of 35 and 31°C at Arjo and Bako of western Ethiopia, respectively, indicating that white mango scaltolerates higher temperatures. But this contradicted with the earlier finding of Labuschagnet al (1995) that white mango scale had a low tolerance to high temperature, and as a result its population declined in temperatures3060veThe study by BautistaRosaleset al (2013)stated that males were mostly in the lower canopy of the trees, while females were distributed more homogenously. But as the temperature warmed, females moved toward the lower canopy, which is the co**ples**tof the tree

Labuschagnet al (1995) stated that white mango scale stays as crawler for shorter period of time compared to sessile stages. This finding also supported by latest study Ofgaa Djirata et al (2018) who stated that crawletage populatin of mango scale was much smaller than any of the other developmental stages throughout observation; because crawlers move to different parts of the host plant in search of suitable settling sites and may also be dispersed away from the plant by various dtors all of which would reduce their numbers on the sampled leaves.

Damage symptomsthe study inBenchMaji Zone of south west Ethiopia by Tsegaye Babegeet al (2017) reported thatarmers identified the pest by colors and symptoms observed such as **yee**/wing, defoliation, die back and white colors. The study in east Wollegaby Tesfaye Hailuet al (2014) also reported that the discussants of mango growers described the symptoms of the pest infestation on leaves whitish materials, spots and drop down from the tree, attack the stems basement of the leave, fruit with conveying its original color with varies spot, change color of the leaf after penetrate inside, fix on the root of the tree along by covering of white small fibers and increasingly substamfiested to poor growth and finally drying out the tree. The studyQentral and Eastern Kenybay Ofgaa Djirata et al (2016) also reported that damages that the respondents believed to have been caused by the pest to mango plantation were spotsits; yellow spots on leaves, drying and falling off of leaves, and drying of young twigs.

The study in Western Ethiopia **W**fgaa Djirata and Emana Getu (2016) orted that the heavily infested premature fruits dropping and the mature fruits becameins resize with lacking of juice. Mango white scale attacked the fruit leaving pinkish blemish on skin of matured and ripe fruits. White mango scale insect pest feeding style is by inserting its stylets

in the soft parts of mango tree and sucks saps. Asuat ite causes yellowing of leaves, development of conspicuous pink blemish on mature and ripe fruit and dieback to mango plantation (ElMetwally et al., 2011and AbcShanab, 2012). Juáretærnándeæt al (2014) described high level of nutrient exploringtential of white mango scale by stating that it can pierce cell walls, even the lignified secondary walls of xylem by the use of its stylet bundles, resulting in severe damage to the crop. They described that the stylet bundles of the female insect is abud 3 millimeters, which may be 3x the length of the insect body. Infestation in young trees may lead to excessive fall off leaves, retarded growth and death of the whole plant (Nabiet al., 2012).

The study in Mango Orchards of Nayarit in Mexico by Hoxdgred Harmor(2016) also reported that white mango scale does not cause direct internal damage to mango fruit but produces chlorotic spots. The discoloration and consequent appearance of conspicuous pink blemishes on ripe mango fruit results in resistation fruit market, including export potential, and eventually leads to marked economic loss (USDA, 2006 and configha 2016). Haggaget al (2014) reported that white mango scale ttacks mango leaves, branches and fruit, where it causes superficial pior yellow blemishes to develop, making the fruit unmarketable. In line with this, United States entered white mango scale in the list of pests that were of quarantine significance and underlined that further analysis should be put in to effect when mangrand fresh longan fruits are imported in to the nation from India and Taiwan, respectively (USDA, 2006 and 2007).

Farmers, perception study Byesfaye Hailuet al. (2014) reported that farmers, observation was taken as the pest is not selective for onenother type of mango varieties. Both improved grafted and local orchards were invariably attacked by the pest. Also Study by Ofgaa Djiratæt al. (2016) that the espondents reported that all the mango varieties were affected by white mango scaleut some stressed that the damage to Apple mango was more serious than other varieties owever t is reported that damage by the pest is not limited to mango plantation. However Erichsen and Schoeman (1992) reported that white mango scale was found feeding on availation in South Africa. According to Borchsenius (1966) cited in Abo-Shanab (2012) stated that the pest has been recorded mainly from four plant families such as Palmae Lauraceae Rutaceae and Anacardiaceae particularly from mangos and cinnamon. Malumphy 2014) white mango scale is a polyphagous pest which feeds on plants belonging to 18 families, even though it is a serious pest of mangos. The latest pest alert

reported byHamon (2016) stated thathosts of white mango scale aAceraceaeAcer kawakamii AnacardiaceaeMangifera indica Mangifera sp. ArecaceaeCocos nucifera Iridaceae: Dietes prolongata Lauraceae: Cinnamomum camphora Cinnamomum ceylanicum Laurus nobiliş Litsea laurifolia, Litsea polyantha Litsea pungensLitsea sebifera Machilus sp., Phoebesp. PittosporaceaePittosporumglabratum and Rutaceae: Citrus sp. Sapindacea@imocarpus longan

2.4 Introduction of White Mango Scale in Ethiopia

In 2001 and 2002, a private farm called Green Focus Ethiopia Ltd introduced a new cultivar called Alphanso from India and was planted at Lako in Guto Gida Woreda of East Wollega zone of Oromia region, western Ethiopia. A study made in western Ethiopia confirmed that the variety introduced was highly infested with a new insect pest called white mango scale (MohammedDawwdet al., 2012). Temesgen Fita (2014) also confirmed that farmers in the neighborhood of Green Focus mango farm land witnessed, for first time this insect pest on Green Focus mango plant and after a while it spreads to adjacent old containego plantations of the local farmers through seedling distributiAccordingly, Mizan plant protection laboratory has reported the occurrences of this pest in-BtanjicZone in 2014. The pest was first observed in Guraferedistrict where commerciathango farm Seka is located(Tsegaye Babeget al., 2017)

Tsegaye Babeget al. (2017) reported thatatural outbreak and spread of most scale insects are very minimal but survey from Ben Whaji zone indicated that the outbreak and spread of the pest isikely to be with planting materials that are hosts to this pest. Similar arguments were made by Gashawbe Agalew et al. (2015) reported that the threest introduction to the country is likely to be with planting materials or fruits that are hosts to white gon action and the statements.

The study inBenchMaji Zone of south west Ethiopia by Tsegaye Babegal (2017) reported thatMajority of the respondent indicated that the pest is new for the locality. Tesfaye Hailuet al (2014) reported that farmers had never ever **seeh** kind of problem in their mango farm and considered it as new experience for the people of east Wollega. The studyin East and West Wollega Zonleys Temesgen Fita (2014) also reported that majority of the respondents did not know the name and typecontentioned insect pest. In Ethiopia white mango scale ispersed 100 km west of the original site, Green Focus Ethiopia Ltd. (Temesgen Fita, 2014) and has spread to northern and central Ethiopia, with the infested area

in the north being about 1500 km aywfatom the place of initial infestation (Gashawbeza Ayalew et al. 2015).

2.5 Management of White Mango Scale

2.5.1 Managemenpracticein Ethiopia for white mango scale

The study inGuto Gida and Diga Distrcts indicated to the pest in mango production. Cultural variety of cultural practices on mitigate the effect of the pest in mango production. Cultural practices that growers, used such same of mango tree for chess out the pest from the tree, washing with soluble ash and soaphirtning for spacing among the ptend trees through removing the treed daing the urination of goat over attacked mango tree under the tree normal tree or part of the tree, burning angle pring the same of soil under the tree However the farmeresponded that the whole range of efforts made to combat the pest was only gave a temporarily reliefT (esfaye Hailuet al., 2014) Also Temesgen Fita (2014) reported that mango growers were undertaken culture methods like pruning, smoking and site clearing incollegaarea.

Tsegaye Babeget al (2017) reported thatefw farmers undertook control measure like pruning of heavily infested twigs and dense branches to eliminate infestations when infestations are on limited parts of the plant. After the occurrence of mango white scale in the commercial farm of Seka located in Benddaji Zone Gurafereda administrative districts in 2014 the farm sprays two broad spectrum synthetic chemicals such as Diadnon an Dimethoate to reduce pest damage. The farm also undertook cultural practice such as pruning of heavily infested branches and leaves. Meanwhile, field inspection made by the expertise team from fizan Tepi University had been realized that such managemeents unable to avoid the pest in the entire farm and in fact in some tree the infestation even got worsen (Tsegaye Babeget al, 2017) It has been reported that commercial farms and government offices use a variety of broad spectrum insecticides tcerthdupest's damage in western Ethiopia (Mohammed Dawdal, 2012 and Temesgen Fita, 2014).

The study by Temesger Fita (2014) indicate that white mango scale management practices of Green Focus Ethiopiat d which is found at Loko Adminstrative bele Guto Gida district since the infestation observed in the early 2008 the farm started application of broad spectrum synthetic chemical insecticides (organo phosphates) by using tractor mounted
sprayers and manual spray methods. The farm sprays Diazn**D**iraethoate chemicals two times a year before flower setting and after harvest. Additionally the farm practice opening of mango canopies (pruning) and mulching with savannah grass. With such continuous management practices the pest distribution and sestatity was reduced when compared to small growers, farms, but still the farm does have the problem of the insect pest due to the spraying was carried throughout day time and the type of spray practiced by the daily workers did not completely cover the sprayed plants. However the farm is situated at hot and low land area having an average altitude of 1384 m.a.s.l and average minimum temperature of 264%. As a result chemicals sprayed at mid_day can simply evaporate and this condition can create pest estance. So that it is suggested that complete spray coverage of infested plants (such as the underside of leaves) and knowing time of spray is needed to have good control. Thorough spray coverage is especially critical when treating species of armored scales like white mango scale, as these scales are generally less susceptible to pesticides than soft scales.

However he use of old broad spectrum insecticides for controlling WMS should be discouraged as they are ineffective in most cases and negativedythatfenatural enemy population that aid in the natural control of the pest (Gashawabyeatew et al., 2015). Bench Maji Zone had been taken to resolve the problem of white mango scale infestation using destruction of infected seedlings and restrictiontrainsfer of planting material. However, such measures were unable to reduce the prevalence and in fact in some district the pest infestation every two see and worse over timesegaye Babeget al., 2017) There wasno proper control methopatactized by the farmers. The main reason for this may be due to the unmanageable size of local cultivEste(gaye Babeget al., 2017)

2.5.2 Different managementapproach forwhite mango scale

Cultural control:Cultural pest control is a practice of manipulation of a **ga**'sdplanting, growing and cultivation with the purpose of reducing pest number and its damage to the crop under consideration (Waskom, 1995) esfaye Hailuet al. (2014) from expertise point of view recommends learing of different weed species from tsuerrounding and other plant residue and cutting of the all infected canopy of the tree and good management practice for newly emerging coppice can be used the control of white mango scale nly propagate from clean mother stock plants move crop debar and disinfest the growing area since scale may survive for weeks on crop debris and in egg masses that have fallen off plants;

avoid movement of infested plant material within the growing arawaid staff movement in areas known to be infested withatac insects; If necessary, disinfest clothing and equipment after working in such areas; Provide an optimal growing environment, including appropriate nutrition, water, growing media and other conditions; weak plants are more susceptible to damage at lowperpulations of pestscpntrol ants as they spread crawlers and protect scale insects from natural enemkesep the growing area and surrounds free of weeds; ensure adequate plant spacing which allows greater air movement and increases pesticide coveragend also reduces ideal environments for scale insects to develop and increases the ease of detection (Andrew, 2016).

Postharvest pruning is an effective control measure and also helps the penetration of chemical sprays through the tree canopy (Cunninghada). The study of Bautist Rosales et al. (2013) stated that punning significantly reduced the number of females per leaf in both kinds of conventional and organic management of mango plantations, but was most evident in organic plantations where fere per leaf decreased significantly and the increase in abundance of males per leaf was not significated that reprint is recommended before the flower induction and right after harvets can be done by removal of undesirable vegetime parts, crowded branches, insertested and diseased branches, leaves, flowers and other plant parts. Small branches were cut first followed by large branches and all debris will be removed to clean the surroundings (Wieliamh\$2009).

Pruning is an important cultural operation for obtaining quality yield from the fruiting trees, which involves judicious removal of vegetative parts. An unpruned tree becomes very large, which inhibits light penetration inside the canopy. As a result, leaf speculate interested, photosynthetic activity remains low and high incidence of pests and disease occurs due to high relative humidity (al and Mishra, 2007)Sunlight not only influences the flowering and fruit set, but also enhances quality and colour developménuits (Hampsonet al., 2002). For this reason, fruits in the top of the tree always have better quality than fruits in the lower shaded part of the canopyritostoeet al., 1997) Several studies have been conducted on pruning in the mango tree **lative** no better light penetration, fruit set and yield in pruned trees(haban, 2009 and Sharmadabingh,2006). Lal et al. (2000) reported poor mango fruit yield during the first year after pruning, which kept increasing in the successive years: ruit yield of unpruned trees; later objectomeincreased during the first year compared with the fruit yield of unpruned trees; later objectomeincreased during the

second year. Pruning resulted in significantly higher fruit weight, fruit firmness, total carotenoidsantioxidant capacity and total phenolic contendation al, 2013)

The study by Bautist&osaleset al. (2013) recommends that agronomic practices used in the conventional plantation to combat the white scale did not offer better results than those usedin organic plantations against white mango scale. However, these seemed to be more efficient than excessive fertilizer use. A proposal for management of white mango scale is rational use of the compounds and appropriate pruning. These can be done **adjuny** the season when white scales are least abundant.

Mechanical ControlMechanical methods bring about reduction or suppression of insect populationsMinor scale infestations on small houseplants can be removed using cotton balls or swabs to brush rubbgralcohol onto the plant (Mart al., 2019). Tesfaye Hailu, et al. (2014)from expertise point of view recommercent that kill white scales by rubbing then off with fingers and possible; dislodge scales by hosing down plants frequeent dy use a high pressure stream of water to dislodge scales by hosing down plants frequeent dy use a scale infestation. Crawlers that are moving to new locations will become caught on the tape. Crawlers move toward light. Placing the tape above the scale infestation moves have a scale monitoring of scale crawlers (Mart al., 2019). And rew (2016) reported that when only a small number of plants are present with a low rate of infection, squash scale insects and egg batchesusing rubber gloves The presence of a small number individuals should prompt regular and rigorous inspections of the consignment

Physical Control Physical control methods in crop protection comprise techniques that limit pest access to the crop, induce behavioural changes, or cause direct pest damage or death. The primary action is attained through stress responses use pest populations by affecting pest physically or alter their physical environment, viz. application of heat, application of cold, and manipulation of moisture (Charles and Guy, 2009) faye Hailu, et al. (2014) from expertise point of view recommends through through the enemies and soil fertility for checking white mango scale population.

Biological control Mango white scale inseptest is under good biological continumost other mango producing countries and therefore it was decided to introduce an exotic biological control agent and try to establish it in different mango producing areas. Both the parasite and predators were successfully augmented, released ingto onemarks and

became well establishedta(buschagne and Pasques, 1884 Daneel and Dreyer, 1998). The predatory thrips (Auleurodothrips fasciapennisFranklin) and the parasitoid (Aspidiotiphagus citrinu)swere reported as the most important biocontgeines of white mango scalen South Africa (Labuschagne and Pasques, 1994)as been demonstrated that someChilocorusspecies are important biological agents for the control of armoured scales (Greathead and Pope 1977; Chetlaes1995; Boothe and Pasques) 2006; Ponsonby 2009 and Entocaraend Wageninger2015). However study bogfgaa Djiratæt al. (2017) reported tha Chilocorusspecies larvae preying on tubercularisin Ethiopia were recorded for the first time. The density of the predatory beevpopulation recorded in the study area was very low, probably due to recent introduction Aoftubercularis to Ethiopia and consequently a very recent association of the predator with the pest. Therefore, population of Chilocorusspecies may gradually bod up in the future

Nabil et al. (2012) recorde Aphytisand Encarsias pecies (aphelinida), Habrolepis diaspidi Risbec Encyrtida) as parasitoids an Gybocephalus micar Beitter as predator of white mango scale in Egypt. Similarly, Abshanab (2012) ecorded little numbers of natural enemies which included parasitoids such Aphytis mytilaspidis Baron and Encarsia citrina Craw, and a predatory beet Bcymnus syriacular larseul in the same country. The predatory thrips Aleurodothrips fasciapenn Franklin and parasitoi Encarsia citrina Craw were also recorded as natural enemies of white mango scale in South Africa (Labuschagne et al., 1995).

Botanical Control:Botanical insecticides can be recommended as an Eco chemical and sustainable strategy it me management of insect pests. Because of their biodegradable nature, systemicity after application, capacity to alter the behaviour of target pests and favourable safety profile? (rasannath, 2016) cale insects veresulfocated by oils and dried out by insecticidal soap disrupt the waxy cuticle or €skin• of the insect, which eventually causes the insect to dry out or desiccate and die (Netardal., 2019). White oil is recommended for control of white mango scaleAmbo Plant Protection Research Center (Tesfaye Hailu et al., 2014). White oil extractan be prepared by taking an empty jar or plastic bottle, ordinary cooking oil is poured in a cup (approximately 250ml) and mixed with ¼ cup of dishwashing liquid and shaked well finally turned to white sphereyer tank is first half filled and then one tablespoon or approximately 10ml per 1 liter of water will be added and mixed well. Dosage rate of white oil should be taken as care because too much oil will

cause leaf burn and the spraying time should **bent** place after 11 hours to avoid using it in very hot weather (over 25°C) because it can also burn foli**h** grest// www. organicgardener.com.au/ blogs/homedepestremedies retrieved on 01 June 2018). Tesfaye Hailu,et al. (2014) from expertise point of view recommends the battanical insecticidelike pyrethrums and rotenone be used for the control of white mango scale Pyrethrums are effective against many sucking insect pests which kill insects by interrupting their nerve impulses. Renone is a powerful inhibitor of cellular respiration, the process of converting cell nutrients into energy. It acts primarily in insects, nerve and muscle cells, causing them to stop feeding quick (David, 2019)

Using of PesticideChemical control usig insecticides was the most efficient method to minimize sucking pest damages to crop production, although such practice is hazardous to water, soil, environment and human health. That may be due to the misuse of chemical insecticides. On the other handle increasing incidence of resistance to many conventional insecticides has led to the development of large number of new active compounds such as the neonicotinoides which were introduced as an alternative to the organophosphate, carbamate and psythroidinsecticides. Nonicotinoides have been the fastest growing class of insecticides in modern crop protection with wide spectrum effect against sucking and certain chewing insect pests (Jeschke and Nauen, 2009) nophosphates insecticides elik chloropyrifos, methidathion, inhethoate 40% EC, to control white mango scale on mango tree match with many earlier studies (Howard, 1989) AID Kenya Business Development Services Program recommendeeltalmetrine and pyrethrin to be used for the control of white mango scale in Kenya (Findlay, 2003).

Ofgaa Djirata (2017) reported thämited experiments performed regarding insecticide screening against white mango scale in Ethi**spia**e the insectitroduced in Ethiopia has been less than a decade. GashawbezæAyetalal (2015) tested movento and thidathion, and reported they had equal efficacy in reducing white mango scale infestation on mango in Central Rift Valley of central Ethiopia. Study by Ofgaa Djirata (2017) reported Folimat 500SL was found to be theoret effective compared with-**D**-Tron and Closer insecticides. It was reported that mango farmers in central and eastern Kenya were using this product to have controlled white mango scale. In general, pertaining to its waxy covering, the commonly used conta insecticides canot penetrate into the body of white mango scale from its cuticle (Buss and Turner, 2006). Therefore systemic insecticides and horticultural

oils that may suffocate the pest are the most used formulations for the control of white mango scale. Applaud is recommended for control of white mango scalerby Plant Protection ResearclCentre(Tesfaye Hailuet al., 2014).Insect growth regulators like azadirachtin and pyriproxyfen interfere with an immature scale insect, ability to moled(sits outer skin to allow for growth); in some cases, siect growth regulators suppress egg development. Although these insecticides often act more slowly than contact insecticides, they can effectively control scales (Market al., 2019). And rew (2016) reported that imidaclopride and Dimethoate ingredients are registered for scale control for fruit and citrus crop in Australianagriculture

Imidacloprid, a new class of neonicotinoid insecticides, is potently replaced with different toxic and hazardous insecticides due to their unique mode of action (nicotinic acetylcholine receptor agonist or acetylcholine mimic) and comparatively less toxicity to human and environment midacloprid is a new class of insecticide **as** potency against sucking insect is well reported in different countries of the world (Hegde and Nidagundi, 2009 and Patiet al, 2009). Some recent studies show that imidacloprid gives an outstanding result against sucking insects (Maraddai and Balikai, 2012 adadshi and Sharma2009. Qureshiet al. (2011) reported that the populations of nymphs and adults of mango leaf hoppers and scale insects were significantly reduced by thiamethoxam and imidacloprid. It is comparativel safer than other conventional insecticides and once it is applied, the action continued for a longer period. On the other hand, the action of imidacloprid persisted at least up to day 10 which raises the possibility that once it enters into the plant system, the imidacloprid remains comparatively for a longer period of time (Robsoret al, 2007 and Shet al, 2011). Varghes(2000) conducted experiments on mango varieties. Alphanso and Bangampalli showed that imidaclopromenation dosage between 0.2 to 0.8 ml/liter viras nd effective. Imidacloprid 20Sis registered for the control of aphids (Macrosiphum euphorbiae) on potatoes in Ethiopia (MoA, 2016).

Swaminatharet al. (2010) reported that dimethoate was effectiveeiducing theeffect of sucking insect pesEarlier study by Howard(1989) showed that Dimethoate 40%EC was used for control of white mango scale imethoate 40% EC which is egistered for the control of beanfly (Ophiomiya phase) Bean aphid (Aphis fabae); Thrips (Taenothrips spp) ABW (Helicoverpa armiger) and 26 French beansfor the control of aphids (yzus persica) and ABW (Helicoverpa armiger) and tomato and frequencies of the control of cabbage Aphid and various aphids on cabbage and potato, respectively, (2016).

Mineral oils against homopterous insects is encouraged. Mineral oils are valuable insecticide materials because they have little residual toxicity for beneficial insects as mentioned by (Abo-Shanab, 2005 and Helmer al., 2006). Abo-Shanab (Q12) describes that a series of field test of three mineral oils against white mango scale showed effectiveness by the following descending order of efficacy : Diver® > CAPL2® > super masrona®, the first two being statistically not different from each orthehe timing of oil sprays is important, as adverse effects such as reduced flowering, oil burns and fruit drop may occur if timing is incorrect (Brooks, 1992).

Integrated pest managemelinitegrated pest management is a pest management philosophy that utilizes all suitable pest management techniques and methods to keep pest populations below economically injurious levels integrated pest management alternative could be applied that would consist of a combination of pesticides, cultural practices and ethof biological control agents (Dale, 2002) onitoring of mango white scale monthly throughout the year helps to prevent severe problems from occurring asating oscale is present all year round become peak during flowering and harves (aye Babge et al, 2017). Population peaks of scale crawlers is an essential finding for control of the pest through targeting the crawler stage, which is sensitive to both systemic and contact insecticides (Buss and Turner, 2006).

Pesticide application in mangorchards resulted in high mortality of endemic parasitoid (Labuschagne and Pasques, 1994, Labuschagne and Froneman, The 23) udy by BautistaRosaleset al. (2013) recommend biological control by conservation can be implemented using natural enemies the insect pest, combined with products such as soap and citroline that have low toxicity and less environmental impact than insecticides such as Malathion. Sureshet al. (2007) reported that efficacy of insecticides on sucking insect increased when apped in combination with soaps and oil explementation of integrated pest management based on organic inputs and biological control would more safely produce mango with added valueScales infesting houseplants can be controlled using a commercially available insecticidal soap or make your own soap solution by diluting a mild dishwashing detergent. If possible, dip the entire plant into the soap solution, otherwise thoroughly cover all plant parts using a hand sprayer (Market al., 2019). Management of mango white scale requires strict inspection of planting materialsfer and destroying any planting materialafter proof of WMS presence and provide farmers with high quality

planting material, and multiply the local cultivar in large number by **iggate** chnique using desirable characters of which may shorter in heightch facilitate various cultural operations and chemical spraying segaye Babeget al, 2017)

3 MATERIALS AND METHODS

3.1 Survey of White Mango Scale

3.1.1 Description of surey area

The study area is located in the Benishar@uthuz Regional State. The region has three zones and one special district. Benishar@uthuz Regional State is found at 687 km away from the capital city of the country, Addis Ababa, in the west.ltidiated 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 no@utomiya Regional state in theeset and south east andGambella Regional state in the util to covers a total area of about, 380 km². Plain undulating slopes and mountains characterize the topography of the region. The altitude of the region ranges mainly between 580 and 27@uternabove sea leveThe average annual rainfall is 860600mm and the annual ambient temperature varies from 17 29°C (NMA, 2015).The agro climatic zonation of the region can be categorized as 75% Kola, 24% Woina Dega, and 1% De@utajor crops grown includeMaize, sorghum, soya bean, Mango, Banana, Lemon, Orange and st(feeGRS BoA, 2017). Major mango growing zones in the region are Assosa and Metekel Zones and mango is produced by 87,230 smallholders and covered an estimated area 1091.68ha and almost half of the growers are from Assosa zone (CSA, 2017).

Bambasi is **be** of the district in Assosa Administrative Zone in the Regi**itn**ated 45 km in North East part of the Assosa towand located at a distance of 610 Km from Addis Ababa and 45 Km from administrative city of the Region Assosa. The distrige ographically les betweer 9±45, latitude and 34 45 Jongitude The total area is about 20 km² of land (BGRS BoA, 2017). It is located in 1001450 meter above sea leve The average annual rainfall is 13501450 mm and the annual ambient temperature varies from 52°C (NMA, 2015). The major crop grown in the area are Maize, sorghum, soya bean, Mango, Banana, Lemon, Orange and othe (SBGRS BoA, 2017).

Assosa is the district in western Ethiopia and capital of the Benishangul Gumuz regional state located in Assosa Administive zone. The district is geographically lies between 10°04⁺- 10.067⁹ latitude and 34°31⁺- 34.517⁹ longitude It is 687 km away from Addis Ababa. The total size of the area is about 231²7(BrogRS BoA, 2017). It is located in 401-1544 meter above sea leve The average annual rainfall 9600-1200 mm and the annual

ambient temperature varies from-**21**°C (NMA, 2015).The majorcrop grown in the area are sorghum, maize, soya been, ground nut, sweet potato, banana, maortgers(BGRS BoA, 2017). Figure 3.1 showed the study Location map of both Bambasi and Assosa districts.

Figure 3.1. Location map of the studyte

3.1.2 Assessment of mango orchards for scale

White mango scale infestation assessment as conducted from August 2018 o April 2019 for nine consecutive month Multi stages ampling procedure was adopted in the choice of samplemango orchards an tobusehold heads for this study first stage Assosa zone was selected purposively on the basis of being a prominent goproducing and white mango scale infestation areats. The second stage study districts of Assosa and the mango selected by purposive sampling technique based on major mango farm production and white mango scale infestation problem the Zone In the third stage the study ebele administrates were selected by proportional sampling techniques of an are coverage of mango production two areas that means more number of Kebele administrates were selected in the highest production areas and less number of some lead ministrates in low production areasMango producingkebeleadministrates10% from each dtsict four in Assosadistrict such as: Amba_14, Amba_5, Amba_8 and Megeland2three in Bambasi district such as: Mender_47, Mender_48 and Sonika a total of sketberheadministrates were selected by using a commonly accepted approach known as theofullee thumb (Mulat Demeke, 200)0 In the fourth stagea total of 35 mangoproducing households holding a minimum of ten mango trees per orcharthe twomangoproducing districts five mango orchardfrom eachKebeleadministratewithin 5-10km interval along the main and accessible road sivereselected ysystematic sampling method/vithin each orchard of assessments ne mango trees asselected and taggedrom more or less the most central point of the orchard Hence,20 (57.15%) and 15 (42.8%) of the sampled nango orchards and households were from Assosa abrembasi districts respectively.

Even though the leaves, twigs and fruits of mangowiere attacked by white mago scale for easy count rating had beetone by counting the clustethey form on the eaves to study the infestation status of white mango scale he sample leaves were selected from the top, middle and bottom mango canopy horizons by a tified sampling method. So thatten leaves were randomly pickethree at the top four at the middle and three at the bottom parts from each tree nee within a month for ineconsecutive month for counting the clusters of thite mango scale formed on leaves. Hence, 90 leaves from each tree and a total of 3150 sample leaves, 1800 ant d350 sample eaves were selected from Assosa and Bambasi respectively. These samples eaves were kept in polyethylene bags and transferred to the laboratory for counting procedures the method used Eigemesgen Fit (2014); Tsegaye Babeget al (2017) and Ofgaa Djirata et al (2016 and 2018). The presence or absence oth is terwas observed by hand enses observation on both upper and lower surfaces in given the field and set of the set of th

The infestation and the egree of damage varse corded by using a scoring method from 0 to 5 scale as free= <5% of the panicle destroyed inimal damage = 5 to 24% of the panicle destroyed, moderate = 25 to 50% damage, severe = 51 to 70% damage and very for e = to 100% damage Williams et al., 2009). So everity status of the infestation as used by Temesgen Fit (2014) was rated and categorized sed or cluster number per leaf can be related to achieve the ast 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 greatethan four and less than five clusters formation per leaf) and >5 = 71 to 100% / ery Severe for greater than 5 clusters formation) of leaves damaged as seen in Appendix Figure 1.

During theassessmenthe coordinates of eachssessesite was recorded byte use of GPS and metrological data like rain fall, relative humidity and temperature was tokerAfrsosa metrological station for both Assosa and Bambasi districts. However relative humidity was obtained from the station for only Assosa district.

3.1.3 Mangogrowers, assessment

The farmers assessment as done from September 20 to October 5, 20 Mango growers, of 20 (57.15%) and 15 (42.85%) from Assosa an Bambasi districts respectively which were used for field assessment of white mango scale survey wetter nused for farmers, assessement Assessment of farmers about white mango scale amage to mango tree, questionnaires were distributed to 35 mangor chard owner and interviewed A well-structured questionnaized faceto-face survey approachethods were conducted to gather information from the respondents while the grein their respective mango fields.

The characteristics of mangogrowers, used for the assessmentiver described in Table.1. The gender composition was 32 male and 2 female The age range of 27 and 8 mango growers, were 21 f 50 and above 51 years respective. The mango growers, holding household sizes df f 10, less than 5 and above 10 were 22, 11 and we schold number respectively. The education statude joined standard, informal and secondary education was 24, 6 and mango growers, number respectively. Mango trees holding of 10 f 20, 20 f40 and greater than 40 were possessed by 29, 3 mad gb growers, number espectively. Age of mango trees possessed by growers, aboye 20, between 1020 years and below 10 years were 17, 10 and 8 mango growers, number respectively mango trees majorly attacked by white mango scale insect pest.

Variable	Frequency	Percent
Gender		
ð§ Male	32	91.4
ð§ Female	3	8.6
Age of Respondent		
ð§ 21 f 30	8	22.9
ð§ 31 <i>f</i> 40	9	25.7
ð§ 41 <i>f</i> 50	10	28.6
ð§ 51 <i>f</i> 60	5	14.3
ð§ 61 <i>f</i> 70	3	8.6
Education		
ð§ No Formal Education (0 Grade)	6	17.1
ð§ Standard Education (-17 Grades)	24	68.6
ð§ Secondary Education (812 Grades)	5	14.3
Household Size		
ð§ <5	11	31.4
ð§ 5_10	22	62.9
ð§ >10	2	5.7
Age of Mango Plantation		
ð§ Below 10 Years	8	22.9
ð§ 10-20 Years	10	28.6
ð§ Above 20 Years	17	48.6
Number of Mango		
ð§ 10_20	29	82.9
ð§ 20- 40	3	8.6
ð§ >40	3	8.6
Major Pest		
ð§ White mango scale	25	71.4
ð§ Fruit Fly	13	37.1
ð§ Anthracnose	20	57.1
ð§ Powdery Mildew	18	51.4
ð§ not aware	10	28.6
Total	35	100

Table 3.1. Mango growerscharacteristics and angotree possession

3.1.4 Collected srvey data

The qualitative and quantitative data recollected during mango tree assessment their respective farmers interview. Datacollected for white mango scale infestation status from the assessed mango trees were (a)mpling dat(2) Mangoorchards characteristica(ge height, canopy size, plaing pattern, weed, intercropping conditi(a) Mangovarieties(4) meannumber of white mango scale luster leaf (5) Spatial data like Altitude atitude,

longitude (6 Severity of infestation(free, minimal, moderate, severe, very severe) (7) metrological data like Rain fall Relative humidity and Temperature

Mango growers, assessment data collected were 1) white mango scale insect pest introduction periods 2) Knowledge of the pest3) Yield loss estimation 4) Dispersal mechanism5) Pest tend over time6) Seasonal and farm site infestation variability would be mango scale insect pest infestation Management practices an 6) (Extension service condition.

3.1.5 Statistical analysis of the survegata

The data from the survey questionnaires værrælysed by descriptive statistics with SPSS software, version 20.The severity of the pest and its distribution in the study areas were tested by counting/hite mango scale/lusterformed on mango leaves and analyseid g a general linear model (PROCLQI). Whenever the f-test was significant significant means were separated by Fisher, s Least Significant Difference (Las 5% or 1% error level For two different groupst-test was used for comparison using PROC TTESS% or 1% error level. Countdata of white mango scale assubjected to quare root transformation (' (+ 0.5)) before analysis to stabilize the variance of variance of the sample was tested using levene, s test before and after data transformation50) (Gomez and Gomez, 1984andSAS Institute, 2009) The data were reported in the text using the back transformed values.

The effect of explanatory variable of mango orchard characteristic factors which determined the severity status of the responsive variable of white mangle categorical dataere analysed by odds ratio to measure the strength of the association in an angle is the significance at % error levelusing cumulative logit model of PROC LOGISTIC PROCEDURE(Gomez and Gomez,984 and SAS Institute,2009) Microsoft Excel was used to summarize urveydata

Spatial and seasonaistribution map of white mango scale was drawr(@GIS) software from the GPS ile using the recorded coordinates of each surde ite.

3.2 Field Experiment

3.2.1 Description of the experimental site

Field experiments were conducted Assosa district in Assosa Administrative Zone, woreda1 ketena5, Ethiopia. The specific experimental sites between 1⁰3,21,, to 10⁰3,16,,N latitude and 3⁴33,18,, to 34⁰33,20,,E longitude and a men altitude of 1554 meter above sea level The sites located in Assosa polytechnique mango orchard which wasselected purposively by looking accessible uniform size mangost meet urally infested by white mango scale and easy access to road for dayy toollow upof the site. It is 687 Km far from Addiss Abeba. The major crop grown round it areawassorghum, maize, soya been, ground nut, sweet potato, banana and meet for the site Box 2017).

Figure 3.2 Location map of the experimentsites

3.2.2 Experimental materials

The field experiment was conducted to evaluate the effective management opetight of treatmentssuch aslmidacloprid 20SL, Dimethoate 40% EC, white oil extract, pruning, Imidacloprid 20SL + Pruning, Dimethoate 40% EC + Pruning/bite oil extract + Pruning and untreated contro/Appendix figure 5.

Imidacloprid 20SL 0.8mper 1 liter of watedosage ratevas used for this experimentifierst 5 liter of water was filled in the sprayer taak then 4ml of midacloprid 20SL was added and well shaked and then sprayfed a single mango tree (a)/arghese, 2000) Dimethoate

40%EC 0.75ml per 1 liter of watedosage rate/as used for this experiment. First 5 liter of water was filled in the spray/eank and then3.75 ml Dimethoate 40%E@as added and well shaked and then spray/eank and then3.75 ml Dimethoate 40%E@as added and well shaked and then spray/eank and then3.75 ml Dimethoate 40%E@as added and well shaked and then spray/eank and then3.75 ml Dimethoate 40%E@as added and well shaked and then spray/eank and then3.75 ml Dimethoate 40%E@as added and well shaked and then spray/eank and then3.75 ml Dimethoate 40%E@as added and well shaked and then spray/eank and then3.75 ml Dimethoate 40%E@as added and well shaked and then spray/eank and then3.75 ml Dimethoate 40%E@as added and mixed spreared by taking an empty plastic bother edible is (Trade name: Sekinar) as poured in a 250mlcup and mixed with 62.5ml of hand dish wash liguid deterge(Trade name BEKAS Sine) and shaked well finally turned to white. The sprayer tank was first folly/efail liter of waterand then 10ml prepared white oil a total of 50ml of white oil was added and mixed wealhd used for a single mango tree for this experiment l(ttps:// www. organicgardener.com.au/ blogs/hommedepestremedies retrieved on 01 June 2018/)/verage water requirement used for spray wakefer per tree. Pruning was done for 2 randomly selected mango by removal of undesirable vegetative parts, crowded branches, insemfested and diseased branches, leaves, flowers and other plant parts. Small branches were cut first followed by large brane/he/sall debris was removed to clean the surroundings (Williaetsal.,2009).

Insecticide	Active ingredient	Dosage rate	Mode of application	Source
Gain 20SL	Imidacloprid 20 SL	0.8ml / 1Liter of water	Foliar spray	Chemtrade International
Agro-Thoate 40% EC	Dimethoate 40%(W/V)	0.75 ml / 1Liter of water	Foliar spray	Chemtrade International
White oil extract Pure edi Hand dis	blæil: Tradenam h liquid detergeni	10ml /1 Liter of water e- Sekina trade name BEKAS Si	Foliar spray	Homemade

Table3.2. Dose and formulation of insecticides

3.2.3 Treatments, experimental design and procedures

The mango trease experimental site (\$\$ sosa poly technique college mango favore reused as experimental tree (\$\$ ppendix figure6). Mango trees selected for pruning were treed a during August 115/2018 before the flower induction and right after harves fore spray and spray was taken place during active stage of metogering stage (Williams et al., 2009). Mango trees weresprayed three times with the interval of two weekduring December 1530/2018 and January 15/2018 ter 11:00 hourusing motorized knapsack sprayer and an nureated checkwere maintained for comparisor purposes. In this experiments Dimethoate 40% EC and Imidacloprid 20SL are systemeted as the sprayer and an experiment sprayer and sprayer an

home-made white oil treatmentosere arranged separately as well as in combinationh wit pruning.

The experimental designwas arranged in asimple randomised complete block design (RCBD) with three replication. The treatments were eight three manges treeper treatments were used as three replication in each treatment. A total number of 24 manges treeswere used in this experiment. Uniform size, same age (16 years old age) and cultivar manges trees(Kent) were selected for experimental unit. Drift problemas protected by usingbreaker of a plastic cover of the neigbouring manges trees cathoring spraying. The control was wetted three times with water to avoid moisture difference between treatments. All agronomic practices were kept the same among the treatments during experimental period.

Treatment Code	Treatment Application Rate
(T1)	Imidacloprid 20SL@ImI/5 Liter water
(T2)	Dimethoate 40% E@3.75m/5 Liter water
(T3)	White oil extract @5001 I/5Liter water
(T4)	Pruning
(T5)	Imidacloprid 20SL@ImI/5Liter water+ pruning
(T6)	Dimethoate 40% E@3.75m/5 Liter water + pruning
(T7)	White oil extract @5001 I/5 Liter water+ pruning
(T8)	Untreated Control® 5 Liter water

Table3.3.	Treatmentypes	for the	<i>eperiment</i>
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3.2.4 Data collection for the experiment

Experimental data from the treated and untreated control were collected randomly three from lower, four from middle and three from top of canopy a total of ten sample leaves and 30 sample leaves from each attenent. The mean number of white mango scale population (sum of live nymph and adu) ther 10 leaves before and after the treatments application were taken as the methodology used By ashawbeza Ayale at al., 2014 and Ofgaa Djiratæt al., 2017. Mean number of white mango scale population per 10 leaves prior to treatment application and Mean number of insects from post treatment was used to assess efficacy of the suggested management option.

The averagemango fruit number anglield in Kilo gram per tree pertreatment was determined during March and April at harvestDuring each sampling time marketable quality of the fruits was subjectively assessed judged using a-9 rating scale with 1=unusable, 3=unsalable (poor), 5=fair, 7=goode x 20=

The size, color, firmness surface defects, sigpessift and shrinkage were usessid visual parameters for the rating. Fruits that received a rating of five and above were considered marketable while those rated less than fivere onsidered unmarketable (Mohammeet al., 1999).

3.2.5 Data analysis

Mean number of live nymph and adult of white mango scale per ten leaves per tree per treatment were taken and subjected to analysis. The treatment effect on white mango scale population and moælity were analysed usinggæneral linear model (PROC GLMC) ount data of white mango scale was subjected to square root transformational (dmortality percentages data was subjected to arcsine/angular transformational advector of the varianceHomogeneity of variance of the sample was tested using levene, s test before and after data transformational (Gomez and Gomze 1984andSAS Institute, 2009) The data were reported in the text using the back transformed values.

Percent reduction in white mango scale population over control was worked out after each treatment using Abbott,s (1925) formula of mortality correctio

Where n in T = Population in the treated plot after treatment; n in Co = Population in control after treatment

The treatment effectin average fruit number and yield inid&gramper tree per treament were taken and subjected to analysis by using the methods described by Gomez and Gomez (1984) using a generatihear model (PROC GLM)Whenever the frest was significant, significant means were separated by Fisher,s Least Significant Difference at Star or 1% error level Fortwo groupmeanst-test was used for comparison using PROC TTEST 5% or 1% error level(Gomez and Gomez 1984) and Gomez 1984) Institute, 2009)Microsoft Excel was used for data sunany.

3.2.6 Costbenefit analysis

Costbenefit analysis sing partial budget analysis were subjected to agricultural business (CIMMYT, 1988).

Marginal analysis as used within this context is a procedure for calculating marginal rates of return between treatments, proceeding in a stepwise manner from **actosive** attements to the next highecost treatments and compaing marginal rates of return to acceptable minimum rates of returnThe minimum acceptable rate of return without asking producers what they considered to be a reasonable rate of return, researcheed that experience and empirical evidence suggest that a rate between 50% and 100% seems adequate. If the technology is new and requires learning new skills, then the **dometric** should be used to acceptable. An alternative approach to estimating the minimum rate of return is to double the rate of interest **doge** by the lending institution this context as the experiment wasnew for the of the treatments.

The marginal returnwas computed as the marginal net benefit (he change in net benefits) divided by the marginal cost (i.e. the changesits); coexpressed as a percentage.

DNI MRR€——

The €net benefits• of different meatments were determined by first calculating € gross field benefit• and the €total costs that vary• in switchtinegtmentsThe gross field benefit for eachtreatmentwasobtained by multiplying the €adjust**eid** by the farm gate price. The adjusted yield as represented by a fraction of 0.9 of the average narketable yield which obtained under an experimental coticodi. The farm gate pricesed in the analysis watse price that the producer receives less harvesting and marketing costs price of mango fruits was based on the average farm gate price of fruit between March and April, obtained from personal communication with mango fruit producers around Assosa main market and .Gulit, which were the nearest market to the experimestite. The total costs that vary for eachtreatmentwas computed as the sum of ONLY those costs that were expected to change by using anothetreatment The net benefit for a given treatment as then obtained by subtracting theotal cost from the gross field benefithe dominance analysis welone by sorting the treatmensum on the basis of cosfcom the lowest to the highest, together with their respective net benefithe conclusion of a marginal analysis was also checkersing the concept ofresidual, which was calculated by subtracting the return that farmers require (the minimum rate of return multiplied by the total costs that vary) from the net benefits.

4 RESULTS AND DISCUSSION

4.1 Survey of White Mango Scale

4.1.1 Mango gowers, assessment

White mango scale insect pest introduction periods Table 4.1 illustrates introduction periods of white mango scale in the study areas of Assosa and Bambasi distrives 86% of respondents vere replied that the pest was wn for the area, but only 4% of the respondents replied that they were familiar white pest. The period of introduction in to the study was perceived as spondents of 51.4% replied that the pest had been stayed for about 2 f 5 years in their orchards Respondets of 5.7% and 31.4% were replied that below 2 years and above 5 years respectively respondents of f1.5% had no any evidence about the period of the pest introduction in the sure degreas These implied that the pest was new and introduced at mosty fears and in a few areas motion 5 years even though there was a variation of introduction period in different mango orcha for study results in different mango growing areas also showed that the mango white was al the newly introduced pest.

The studyby Tsegaye Babeget al. (2017) reported that Majority of the respondenin Bench Maji Zone of south west Ethiopiandicated that the pest is new for the locality Tesfaye Hailuet al. (2014) also reported that farmers had never ever seen such defin problem in their mango farm and considered it as new experience for the people of east Wollega.Similarly the studyin East and West WollegadministrativeZonesby Temesgen Fita (2014) reported that majority of the respondents did not know the nacheype of the mentioned insect pest.

Variable	Percent
New pest for the study area	
ð§ Yes	86
ð§ No	14
Introduction period	
ð§ Below 2 years	5.7
ð§ 2 - 5 years	51.4
ð§ Above 5 years	31.4
ð§ Not aware	11.5

Table4.1. White mango scale introduction periods

White mango scalensect pestdamage and identification method Sable 4.2 illustrates growers, perception on white mango scale damage and identification method See study areas of Assosa and Bambasi districtes pondents of 74.3% 51.4% 25.7% 17.1% and 40% were observed that the pestdamage dinango tree Leaes, Fruits, Twigs, Branches and Whole tree parts respectively. Majority of the respondents observed that the aves and fruits were the most plant parts attacked by the neerotest. These result supported by the study result of Haggaget al (2014) who reported that white mango scale insect pestimages mango leaves, branches and fruit, where it causes superficial pink or yellow blem is to develop, making the fruit unmarketable.

Growers, identification methods were perceived respondents of 94.3% and 60% were useds ign and symptom respectively for identifying the pestrom another pest Growers perceived that white, pink, grey, and yellow color as **a tsig** and eaf defoliation, stunting and distortion of fruit, ideback of twigs and branches, premature tf drops and drying of flower as a symptom to of br identification of the pest Majority of respondents of 91.4% and 100% were used white color signand leaf defoliation symptom espectively

Theseresult supported by segaye Babeget al. (2017) in Bench Maji administrative Zone of south west Ethiopiæeported that farmers identified the pest boolors and symptoms observed such as yellowing, defizition, die back and white color Similarly the study in east Wollegaby Tesfaye Hailuet al. (2014) also reported that the discussants of mango growers described the symptoms of the pest infestation on leaves whitish materials, spots and drop down from the tree, attack the sterbasement of the leave, fruit with conveying its original color with varies spot, change color of the leaf after penetrate inside, fix on the root of the tree along by covering of white small fibers and increasingly substantiate inff to poor growth and finally drying out the tree figaa Djirataet al. (2016) study in Central and Eastern Kenyalso revealed that the damages that the respondents believed to have been caused by the pest to mango plantation were spots on fruits wy aplots on leaves, drying and falling off of leaves, and drying of young twigs.

Variable	Percent
DamagedPlant Pa s	
ð§ Leaves	74.3
ð§ Fruits	51.4
ð§ Twigs	25.7
ð§ Branches	17.1
ð§ Whole Tree Parts	40.0
Identification methods	
ð§ Sign	94.3
ð§ Symptom	60.0
Sign	
ð§ White	91.4
ð§ Pink	51.4
ð§ Gray	51.4
ð§ Yellow	25.7
ð§ Not Aware	8.6
Symptom	
ð§ Leaf Defoliation	100.0
ð§ Stunting and Distortionfd Fruit	57.1
ð§ Dieback of twigs and branches	45.7
ð§ Premature fruit drops	22.9
ð§ Drying of Flower	22.9

Table 4.2. Growers, assessme of white mango scale damage and identification methods

Infestation status and variabilityTable 4.3 illustrates white mango scale infestation variability and statuassessment the surveyed arealstifestation variability over time was perceived as anjority of the respondentes 8.6% replied as the infestation had been becoming increased over time. Others respondents 37.1% are feeling that the pest stayed at a maximum infestation status with no differencentifroinitial time of introduction. The incidence and severity f infestation status of white mango scale was perceived as medium to high status. These implies that the pest becoming a serious constraint for mango production of the study areas.

These resultsupported by Tsegaye Babeget al. (2017) reported that arious studies in major mango growing areas of the country (Western Ethiopia and central rift valley) established that white mango scale is becoming the most important limiting factor for mango pioooduct in Ethiopia Studyin western Ethiopia by Ofgaa Djirata and Emana Ge(12015) reported that Infestation of white mango scale on armgo fruits at Different Stages of fruit development studyevealed that white mango scale has become a devastating repastice fruit in western Ethiopia The study inCentral and Eastern Kenyay Ofgaa Djirataet al. (2016) also reported that to be recentage of respondents said that level of the damage showed variations ovtime since first recognized.

The infestation variability within a year was perceived takere was a high fluctuation of mango white scale infestation within a year. The majority of respondent% and 71.4% replied that during April and mayrespectivelythere were a highest infestation for respondent% 4.3% and 48.6% also replied that next peak infestation status were during January and June respectively here implies that the pest has assumed four peak infestation time within a year indicates that the pest reproduced throughout the yearverilapping generation Respondent solution of white mango scale during October, November and Decendibeing which there may be high number of crawlersst instar which is unseen with naked eye airghty mobile within and outside the infested trees whichgint mislead farmers that their mango tfree from scale infestation

These esult in lined withOfgaa Djirata and Emana Ge(122015) report that naturation and ripening of mango fruit begin durintoge first months of rainy season, that is, in March to April and continues for few months, viesvis significant infestation of mago fruits by white mango scale Western EthiopiaAbo-Shanab (2012) reported bat the lowest population density was obseed in the beginning of spring season during the two studies years. However; the current result was not similathe finding byTsegaye Babegeet al. (2017) who reported that najority of respondents replied that gh level of pest preselence was occurred in winter.

The infestation variability among farm sites was perceived **ajsrity** of the respondentsf 62.9% were replied that backyard mango tree plantation were highly infested than field mango farm because of the dispersal factors mainly humans **annal**sarmovement accelerate the spread of the pest in addition to other dispersal factorse. result supported by Andrew (2016) suggested that avoiding of staff movement in areas known to be infested with scale insects therwise disinfest clothing and exponent after working in such areas since it enhance infestation.

Variables	Percent
Infestation variabilityover time	
ð§ Increased	48.6
ð§ Decreased	2.9
ð§ Show nodifference	37.1
ð§ Did not know	11.4
Infestation peak months	
ð§ June	48.6
ð§ January	54.3
ð§ April	85.7
ð§ May	71.4
Infestation status	
Incidence	
ð§ High	60
ð§ Medium	40

0

80

20

0

Table 4.3. Infestation status and variability

ð§ Low

ð§ High

ð§ Low

ð§ Medium

Severity

White mango scale infestation impact on margin fyield: Table 4.4 illustrates growers, assessemnet white mango scale infestation on ango fruit yield in the study istricts of Assosa and Bambasi. Mango frut was reduced in guality and guantity after the introduction of this new pestThemeanmango fruit yield beforewhite mango scale infestation waighly significantly higher that the mange scale infestation 4 = 20.06, p < .01). Growers, perceived that there were inimum and reduce the an yield after white mango scale infestation248.3±6.4 than before white mango scale infestation003±21.6 which showed that mean fruit yield reduction suspected ore than 60% due to this pestinfestation

The growers, assessmentapproved that in the study areabefore white mango scale infestation the yield were ranged from 4.5 to 9.6 quintal per a single mangue However growers, discouraged because of the decremented after white mango scale festation in a range of to 3.5 quintals were collected per a single mange Growers, also replied that after mango white scale infestation not ore than 3.5 guintals were collected from a single mango tree even this production was lowequality and easily perishable hese results also supported by the study in the East and West Wollege administrative Zonesby Temesgen Fite2014) who reported that grvey in the infested districts mango yield obtained beforewhite mango scale emergence was significantly higher **aften** white mango scale emergence Mohammed Daw (2012) also reported that farmers esponded that the intervest up to 10 quintal before the occurrence of mango scale had been decreased to 2 to 3 quintal or not at all after the occurrence of mango white scale ges and Harmor (2016) reported that i 2001, losses caused by fruit and from Nayaridue to white mango scale infestation were anged from 50 to 100%.

Yield_condition	Ν	Mean	SD	SE	Min	Max	Cochrant test		
							DF	t Value	Pr > t
YBWMS	35	700.3	127.8	21.5979	450	960	34	-20.06	<.0001
YAWMS	35	248.3	38.0778	6.4363	200	350			

YBWMS=yield before white mango scale infestation; YAWMS=yield after white mango scale infest

White mango scale dispersal mechanism and **Faigeure 4.5** illustrates the **is**persal mechanism and the of white mango scale in the surveyed areas. Wind, birds, insect pest, animal and humannovement, planting material and hers were perceived as dispersal mechanismsMajority of the responden **B4**.3% and 77.1% eplied planting materials and next wind were considered as the main dispersal mechanisms. dispersal rates were varied for different orchards. Majority of responden **tesp**lied as WMS infestation periods had taken a week to a month for dispersing to the neighboring mango tree orchards based on the type of dispersal mechanism

This result supported by messen Fita (2014) reported that initially white mango scalles introduced from Indiato Green Focus Ethiopiated through a variety of ... Alphonsog and farmers witnessed that the pest dispersed among their mango there ugh seedling distribution Tsegaye Babeget al (2017) reported that pest suspected that distributed with planting materials that are hosts to this pest. Similar arguments were made by Gashawbez A yalew et al (2015) who reporte the pest introduction to the country is likely to be with planting materias or fruits that are hosts to hive mangoscale Earlier study by Great head 1990 and 1997 also confirmed that white mangocale can move with the help of external forces like wind, birds and insect pessed yes used by Haggaget al (2014) reported that may the crawler stage can move to new host (adult males can fly but cannot establish a colony), but scale insects can move to new hosts as a result of wind, birds,

and insects. Crawlers are capable of moving distances of tens of kilometres on wind currents to infect clean crops.

Variables	Percent
Dispersal Mechanism	
ð§ Wind	77.1
ð§ Birds	42.9
ð§ Insect pests	25.7
ð§ Planting materials	94.3
ð§ Others	5.7
Dispersal Rate	
ð§ Only One Week	37.1
ð§ Utmost One Month	40
ð§ 1 - 2_Month	14.3
ð§ >2_Month	8.6

Table4.5. White mango scale stipersal mechanism anate

White mango scale host rangeigure4.1 illustrates the host range of WMS in the surveyed areas. Majority of the respondents responded that WMS attacked all mango celtivalty. All respondents didot observe the alternate hosts other than manges The current study result issupported by Tesfaye Hailuet al. (2014) who reported that farmersobservation was taken as the pest is not selective for one or another type of mango varieties. Both improved grafted and local orchards were invariably attacked by the Alest Studyby Ofgaa Djirataet al. (2016) that therespondents reported that all the mango varieties were affected by WMS but some stressed that the damage to Apple mango was more thereio.

However different literaturelescribed that white mango scale have other alternative hosts. Erichsen and Schoeman (1992) reported that white mango scale was found feeding on avocado in South AfricaOthersMalumphy (2014) and Borchsenius (1966) cited in Abo Shanab (2012) also reported that can attack other alternative hosting the insect introduced not more than a decade there may be a probability to expand their feeding habit so it needsgreat attention to inspect and monitor mango trees for scale including other alternate hosts.



Figure 4.1. White mango scale host range

Management practices of white mango scatteble4.6 illustrates managementactices of white mango scale inhe surveyed areals/lajor management/practices that respondents of 82.9% repliedwas cultural practices like pruning/moking, wood ash and site clearing. However 17.1% of the respondente ave the tree withoutiny management measure. The management practices used by most growers, were not successful to the observe to some extent lower the infestation status and otherespondents did not ware of the successfulness of emitigation activities. It was understandable from growers, perception since white mago scale live in the plant and reproduced throughout the year which required continuous monitoring and management. However; it was not adopted such kind of pest control practice for mango trees after plantation establish memot. also unmanageable mango ize contributes for unsuccessful management measures.

These result also supported by messen Fita (2014) and Tesfalyle ilu et al. (2014) reported that mango growers were undertaken cultural control methods like pruning, smoking and site clearing in wolde area. Tsegaye Babeget al. (2017) reported that five farmers undertook control measure like pruning of heavily infested twigs and dense branches to eliminate infestations when infestation **e** an limited parts of the plant.

Variable	Percent
Management Practice	
ð§ Cultural	82.9
ð§ Pesticide	0
ð§ No measure	17.1
Cultural Practice	
ð§ Smoking	62.9
ð§ Ash	54.3
ð§ Pruning	45.7
ð§ Site Clearing	31.4
Management Success	
ð§ Yes	0
ð§ To some extent	28.6
ð§ No	57.1
ð§ Not aware	14.3

Table4.6. Management practices of white mango scale

Extension service for the management of white mango:sEagere 4.7 illustrates the extension service given to growers, for the management of white mango scale in surveyed areas. Aspondent of 91.4% did not get any extension support but they were showed interest to expertise order and medium to very high commitment level to apply the management option which will be given to growe Semilar report in other mango producing areasuch as Tsegaye Babeget al., (2017) reported that most of the farmers in Southwest Ethiopia of Bendal ji Zone were looking for possibilities take intervention measure and the schewed commitment to experts order for any intervention measure. Tesfaye Hailu et al. (2014) also reported that discussant farme highly looking for any external assistance dome management

6	0
Variables	Percent
Extension service	
ð§ Yes	8.6
ð§ No	91.4
Interest of expertise order	
ð§ Yes	100
ð§ No	0
Commitment Level to apply Expertise Order	
ð§ Low	0
ð§ Medium	25.7
ð§ High	54.3
ð§ Very high	20

Table4.7. Extension service for the management of white mango scale

4.1.2 Infestation and amage symptom of white mango scale

The insectpest was obseed infestation of the leaf, fruit, twigs and branches but leaf and fruit were the mostinfested and damagepairts. The flowers observed inimally scattered in the canopy and asily fall dawn Highly infested mangurees canopywere observed whitish appearance and both side of leaf surface ppearance after scraped he scaleshowed yellow color rounding and black lesion at the center of the damaged apd rthe lesion develops to whole leaf the attacked mango trees were showed diebaid the glify om tip of branchesto whole partswere observed progressively dried and inally the mango tree becomeout of production. The infested fruits showed under coverage of the scale and appeared yellow pinkish color aftecraped of the pestIrregular small sized mango fts were observed uring fruiting and harvesting seas and the entire growth of mango trees were observed being attacked by the sectpest. The Appendix figure 2 illustrates image of damage symptoms of white mango scale

These study result support**by** Haggaget al (2014) thatwhite mango scalettacks mango leaves, branches and fruit, where it causes superficial pink or yellow blemishes to develop, making the fruit unmarketable he study in Western Ethiopia bog fgaa Djiratæt al (2015) reported that the heavily infested premature fruits dropping and the mature fruits became small in size with lacking of juice Mango white scale attacked the fruit leaving pinkish blemish on skin of matured and ripe fruits.

These also confirmed by the study results EI-Metwally et al. (2011) and AbeShanab (2012) stated that the damage caused by whitten go Scale includes yellowing of leaves, appearance of conspicuous pink blemishes on mature and ripe fruits, aNdatailset al. (2012) stated that ieback of theplant Infestation in young trees may lead to excessive fall off leaves, retarded growth and death of the whole pTamet.studyin Mango Orchards of Nayarit in Mexicoby Hodges and Harmor(2016) also reported that white mango scale does not cause direct ternal damage to mango fruit but produces chlorotic spots.

4.1.3 Spatial distribution of white mango scale

Abundance of white mango scale/lean±SE of WMS cluster washighly significantly higher at Assos@.59(2.50) ± 4 . 8 5 (0th@n3a)t Bambasi5.07(2.14) ± 0. 4 (0.(0.32) = 3.31, p < .01) (Table 4.8)

Table4.8. White mango scale clustper leaf (pooled data, Assosa and Bambasi)

							Pooledt test			t
Districts	Ν	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
Bambas	135	5.07(2.14)	4.67(1.01)	0.4(0.09)	0	15				

Table 4.9 illustrates mean number of cluste her pooled date for chards were statistically highly significant ($F_{6,252}$ = 395, p < 0.01) different Comparative mean clusters of WMS among orchards were maximally abundant in Amba7128(2.65) in Assosa Districts and lowest mean cluster record in Sonik 59(2.00) in Bambasi districts. Is ignificant difference of mean clusters betwee Amba_8, 6.15(2.39) and Megele_32,6.12(2.39) and also Mender_47,5.30(2.19) and Mender_485.33(2.20). Mean cluster in Amba_86,15(2.39) and Megele_326,12(2.39) were less abundant than Amba_7428(2.65) and Amba_5, 6.82(2.55) and more abundant than Mater_47,5.30(2.19) and Mender_47,5.30(2.20).

a c	,
Kebele	Mean
Amba_14	7.28(2.65)a
Amba_5	6.82(2.55)b
Amba_8	6.15(2.39)c
Megele_32	6.12(2.39)c
Mender_48	5.33(2.20)d
Mender_47	5.30(2.19)d
Sonika	4.59(2.00)e
Mean	5.9(2.3)
SEm	0.11(0.04)
LSD	0.13(0.03)
CV%	5.11(3.20)
Sign.difference	**

Table4.9. Mean number of white mango scale clusters per leaf in the **study**rds (pooled data, Assosa and Bambasi)

Values given in parenthesis are square root to arms d values; Values in each column of the saletter are not significantly different SEm= Standard error of mean; LSD=Least Signific Difference; CV=Coefficient of Variation, * significant at P < 0.05* significant at 0.01

Table 410 illustrates the comparative mean number of WMS cluster of each study district orchardsThesegregatedataof WMS cluster of the study orchardsAssosa 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 orchaeds more abundant in Amba_147.28(2.65) than Amba_5 6.82(2.55) but Amba_5 were more abundant that Amba_8 6.15(2.39) and Megele_326.12(2.39). The mean cluster dWMS insignificant difference betweer Amba_8 6.15(2.39) and Megele_32.6.12(2.39) and Megele_32.6.12(2.39) in abundant Comparative mean cluster at Bambasi district orchavelse insignificantly different between Mender_48.33(2.20) and Mender_475.30(2.19); but both orchards significantly more abundant that the bonika4.58(2.00) orchard

Districts	Kebele	Mean
Assosa	Amba_14	7.28(2.65)a
	Amba_5	6.82(2.55)b
	Amba_8	6.15(2.39)c
	Megele_32	6.12(2.39)c
	Mean	6.6(2.5)
	SEm±	0.15(0.05)
	LSD	0.12(0.03)
	CV%	4.51(3.05)
	Sign.difference	**
Bambasi	Mender_48	5.33(2.20)a
	Mender_47	5.30(2.19)a
	Sonika	4.58(2.00)b
	Mean	5.1(2.1)
	SEm±	0.17(0.06)
	LSD	0.124(0.034)
	CV%	5.87(3.79)
	Sign.difference	**

Table4.10. Mean number of clusters of white mango scale in the study orchards and on leaf surface of Assosa and Bambasi Districts

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

Table 411 illustrates the comparative mean number of WMS cluster on leaf sufface. mean number of WMS cluster the pooled datavashighly significantly higher on upper leaf surface than lower leaf surfa(te₁₄ = 11.48 p < .01) in all orchards(Appendix figure 3). Mean number of WMS cluster was more abundant on upper leaf surface than lower leaf surface for all the study orchard to be surface surface by the study in Ethiopia in Arjo and Bakeby Ofgaa Djiratæt al. (2018)proved that all developmental stages of mango white scale were found to be more abundant on the upper leaf surfaces. The study by Nabil et al. (2012)and Marwa et al. (2017)recorded that white mango scalpreferred the upper leaf suface compared to the lower one and the upper leaf surface sheaveidr infestation compared with the lower surface

Table4.11. Whitemango scale cluster number on upper and lower leaf surface (pooled data, Assosa and Bambasi)

						_	Cochrant test		
Leaf_surface	Ν	Mean	StdDev	StdErr	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 fowhite mango scale infestation he severity status of the infestion were categorized as zero *de* for less than one clusters formation per leaf $2 \neq M$ inimal for greater than one and ess that two clusters formation per leaf, $\neq 2$ / Moderate for the formation per leaf between the four clusters formation per leaf > 4.5 / Severe for the four clusters formation per leaf between the four clusters formation per leaf > 4.5 / Severe for the four clusters formation per leaf between the four status formation per leaf between the four clusters formation per leaf between the four clusters formation per leaf between the four status formation per leaf b

The WMS severity of infestation status for Zero cluster or free severity statuthefpooled datafrom Assosa and Bambassiudy or chards were statitically highly significant different (F $_{5,45} = 31.7$, p < .01). The comparative mean cluster of WMS zero cluster formation per leaf showed that the severity status were maxiatular mba_5 0.93(1.19) and lowestat Sonika 0.27(0.9) compared with other or chards. The severity statuse insignificantly different between Amba_8, 0.67(1.07) and Megele_320.68(1.09) but both significantly different and less severathan Amba_5 0.93(1.19). Similarly there were insignificant different between Mender_47 0.46(0.97) and Mender_480.51(0.99), but significantly different and more severathan Amba_80.67(1.07) and Megele_320.68(1.09). No zero cluster formationat Amba_14 or chards(Table 412).

The WMS severity of infestation status for one to two cluster formation or minimal severity status of the pooled data from Assosanda Bambasistudy orchards were statisately significant different ($f_{6,24}$ = 3.16,p < .05). The comparative mean WMS cluster greater than one to two cluster formation per leaf were maximumat Amba_8, 1.72(1.49) and Amba_5 1.74(1.49) and lowestseveity status Amba_14 1.22(1.31) compared with other orchards. Comparative minimal severity status betwee formata and Amba_5 was insignificantly different The minimal severity status inedcending order were maximuma_8 and Amba_5 1.74(1.49) and Amba_8, 1.72(1.49);merder_48, 1.64(1.45); Sonika1.58(1.44); Mender_47, 1.4(1.38); Megele_321.28(1.33) and Amba_141.22(1.31) respectively (Table 412).

TheWMS severity of infestation status for two to four cluster formation or moderate severity status of the pooled data for Assosa and Bambæstiudyorchards were statistally highly significant different ($f_{6,42} = 21.08, p < .01$). The comparative mean WMSor two to four clusters formation per leaf showed that the severity status were maxim@ronika 3.58(2.02) and lowest severity status in Mender_4274(1.7) compared with other orchards. Comparative moderate severity status & orfba_8 3.11(1.9) with Amba_14 3.05(1.88) and Megele_32 2.82(1.81) with mender_482.84(1.82) were similar. The moderateseverity status in descending order we&conika3.58(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 412).

The WMS severity of infestation status for four to fize buster formation or sever severity status of the pooled data from Assosa and Bambetsidy orchards were statistically insignificant different (F $_{5, 17}$ = 1.05, ns). All the study orchards had same severity status cluding Megele_32 in which here was severity status corded during the study month (Table 412).

The WMS severity of infestation statutor greater than five cluster mation or very sever severity statue of the pooled data from Assosa and Bambassi yorchards were statisally highly significant different $\mathbb{F}_{6, 141}$ = 168.65,p < .01). The comparative mean WMS cluster for greater than five cluster formation per leaf showed that the severity status were maximum in Amba_14 10.74(3.31) and lowest severity status in Megele, 39252(3.11) and Mender_479.7(3.14) compared with other orands.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 sever severity status in descending order Averba 14 10.74(3.31); Sonika10.25(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 4.12).

			Mean		
Kebele	Free	Minimal	Moderate	Sever	Very Sever
Amba_14	N_r	1.22(1.31) ^d	3.05(1.88 ⁾ °	4.54(2.24)	10.74(3.31°)
Amba_8	0.67(1.07)	1.72(1.49)	3.11(1.9) ⁰	4.75(2.29)ª	9.96(3.18)
Amba_5	0.93(1.19)	1.74(1.49)	3.28(1.95 ^{)b}	4.25(2.18)	10.26(3.31 ^b)
Megele_32	0.68(1.09)	1.28(1.33) ^d	2.82(1.81)	N_r	9.52(3.11)
Mender_47	0.46(0.97)	1.4(1.38 ^{)cd}	2.4(1.7)	4.4(2.21) ^a	9.7(3.14)
Mender_48	0.51(0.99)	1.64(1.45 ^{)b}	2.84(1.82)	4.64(2.27)	9.94(3.19)
Sonika	0.27(0.9)	1.58(1.44 ^{)bc}	3.58(2.02)	4.58(2.25) ^a	10.25(3.25)
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	**

Table4.12. Severity of infestation of white mango scale in the study orchards (pooled data, Assosa and Bambasi districts)

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

The WMS severity of infestation status for Zero clusters or free severity statistics segregated data of Assosa study orchards statistically significant different (F $_{2, 13}$ = 5.45, p < .05). The comparative WMS mean cluster formation per leaf showed that the severity status were maximum in Amb, **a**_.93(1.19) and lowest in Amba_.80.67(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 Amba_14 study orchards (Table 413).

The WMS severity of infestation status for one to two cluster formation or minimal severity status of the segregated data of Assesses study orchards as statistically highly significantly different ($F_{3, 13}$ = 11.32,p < .01). The comparative mean clusters greater than one to two cluster formation per leaf showed that the nimal severity status were maximum (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 cordat Amba_8and Amba_5 and also Amba_14 and Megele_32 vere similar (Table 4.13).

The WMS severity of infestation status for two to four clu**ster** mation or moderate severity status of the segregated data of Assosa study orch**arats** statistically highly significant different ($F_{3, 31} = 21.65, p < .01$). The comparative WMS mean cluster for two to four

cluster formation per leaf showed that theverity status were maximum in Amba_8 3.11(1.89) and Amba_53.28(1.94) and lowest severity status in Megele, 2282(1.81) compared with Amba_143.05(1.88) orchards. Mean cluster records Afmba_8 and Amba_5 was insignificantly different The severity status for moderate severity status in descending order were Amba3528(1.94); Amba_83.11(1.89); Amba_143.05(1.88) and Megele_322.82(1.81) respectively(Table 413).

The WMS severity of infestation status for four to five clusters formation or **sever**erity status of the segregated data of Assosa study orch**ards** statistically insignificant different (F $_{2, 6} = 3.39$, ns). All study orchards had hsignificantly different sever severity status excluding Megele_32h which there was a record of sever severity status (Table 4.13).

The white mango scale severity of infestation status for greater than five clusters formation or very sever severity statusof the segregated data of Assosa study orchands statistically highly significant different ($f_{3,90} = 89.83, p < .01$). The comparative WMS cluster for greater than five clusters formation per leaf showed that the severity status were maximum in Amba_1,410.74(3.31) and lowest severity status in Megele, 9252(3.11) compared with other orchards. The severity status for very sever severity status in descending order were Amba_140.74(3.31); Amba_5 10.26(3.23); Amba_8 9.96(3.18) and Megele_3,29.52(3.11) respectively (Table 413).

. .

			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)	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)	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)	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	**

Table4.13. Severity of white mango scale infestation in orchards of Assosa

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

The white mango side severity of infestation status for Zero clusters or free severity status of these gregated data Bfambasistudy orchardsvasstatistically highly significant different (F $_{2,31}$ = 21.81,p < .01). The comparative WMS mean cluster zero cluster formation per leaf showed that the severity status were maximum in Mender_48(0.99) and Mender_47 0.46(0.97) compared with Sonika 0.27(0.86). Mean cluster of WMS between Mender_47 and Mender_48 orchardsre not significantly different (Table 4.14).

The WMS severity of infestation statoof the segregated data Bfambasistudy orchard for one to twocluster formation or minimal severity statu($F_{2, 11} = 0.84$, ns), for two to four clusters formation or moderate severity stat($F_{2, 11} = 0.79$, n); and for four to five clusters formation or sever severity status($F_{2, 11} = 0.95$, ns) were insignificantly different respectively(Table 4.14).

The WMS severity of infestation status for greater than five clusters formation or vergesever severity status of the segregated data **G** ambasistudy orchards was statistically highly significant different ($f_{2,48}$ = 30.97, p < .01). The comparative WMS clusters for greater than five clusters formation per leaf showed that the severity status were maxim **Somika** 10.25(3.25) and lowest severity status in Mender, **9**.765(3.14) compared with Mender_48 9.94(3.19). The severity status for very segregeverity status in descending order were Sonika Mender_48 and Mender_47 respectively (Table 144).

			Mean		
Kebele	Free	Minimal	Moderate	Sever	Very Sever
Mender_48	0.51(0.99)	1.64(1.45)	2.8(1.82)	4.64(2.27)	9.94(3.19 ⁾
mender_47	0.46(0.97)	1.4(1.38) ^a	2.4(1.7)	4.4(2.21)	9.65(3.14)
Sonika	0.27(0.86) [°]	1.58(1.44 [•])	3.58(2.02)	4.58(2.25)	10.25(3.25)
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	**

Table4.14. Severity of white mango scale infesion in orchards of Bambasi

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

Similar studystudyin the East and West Wollega ZorbeysTemesgen Fite2014), the study in Bench Maji Zone South West Ethiophys Tsegaye Babeget al. (2017) and he study in
Central and Eastern Kenlog Ofgaa Djiratæt al. (2016) reported that the white mango scale infestation recordwas varied spatially among the study site.

4.1.4 Seasonal fluctuation of white mango scale

Seasonal fluctuation of white mangoscaleabundance Mean WMS clusteof pooled data from Assosa and Bambassiuring the study monthwere highly significantly different ($F_{8,252}$ = 6313, p < .01). The mean cluster was eak 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/2018 to April/2019 in descending orders webperil 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 4.15)

Table 4.15. Mean number of clusters of white mango scale during the month of utthe s period (pooled data, Assosa and Bambasi)

Month	Mean
August	5.097(2.4) ^e
September	3.097(1.9)
October	2.097(1.6)
November	1.23(1.3 ⁾
December	0.57(1.01 ⁱ)
January	6.1(2.6) ^d
February	8.1(2.3) ⁵
March	12.1(3.6 ^b
April	15.1(4.0)
Mean	5.9(2.3)
SEm	0.1(0.03)
LSD	0.14(0.035)
CV%	5.11(3.20)
Sign.difference	**

Values given in parenthesis are square root transformed values; Values given in parenthesis are square root transformed values; Values given of the same letter are not significantly different SEm= Standard error of mean; LSD=steaSignificant Difference; CV=Coefficient of Variation, * significant at P < .0,5 ** significant at .0,1 ns=Non_significant

Meanclusterof WMS from the segregate **d** at a of Assosæstudy orchard **s** luring the study months vereshowed highly significantly different (F $_{8, 168}$ = 3230,p < .01). The comparative mean cluster wapeak in April 15.82(4.0) and lowest record during December 86(1.2). The mean clusterof WMS among the study month 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(Table 4.16).

Meanclusterof WMS from the segregated data Bámbasistudy orchardsluring the study months wereshowed highly significantly different (F $_{8,124} = 2575.15$,p < .01). The mean cluster waspeak in April 14.14(3.8) and lowest record during December 19(0.8). The comparative mean cluster bundance mong the study monthis descending orders were April 14.14(3.8), March11.14(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 4.16).

	Mean		
Month	Assosa	Bambasi	
August	5.82(2.5)	4.14(2.2)	
Septembei	3.82(2.1)	2.14(1.6)	
October	2.82(1.8) ^g	1.14(1.3)	
November	1.78(1.5)	0.5(1.0 [†])	
December	0.86(1.2)	0.19(0.8)	
January	6.82(2.7)	5.14(2.4 [¢]	
February	8.82(3.1)	7.14(2.8 [§]	
March	12.82(3.7)	11.14(3.4 ^b)	
April	15.82(4.0)	14.14(3.8)	
Mean	6.6(2.5	5.1(2.1)	
SEm	0.1(0.03)	0.1(0.03)	
LSD	0.19(0.047)	0.1867(0.82)	
CV%	4.51(3.05)	5.87(3.79)	
Sign.difference	**	**	

Table 4.16. Mean number of clusters of white mango scale during the month of the study period in the study districts of Assosa and Bambasi

Values given in parenthesis are square root transformed values; Valluescihumn of the same letter are not significantly different SEm= Standard error of mealsSD=Least Significant Difference; CV=Coefficient of Variation, * significant at P < .0,5 ** significant at .0,1 ns=Non_significant

Interaction effect of study areas and molMlean cluster record during same mo**ath**oss eachorchardshowed a highly significant varation (F $_{48, 252}$ = 4.85,p < .01). the interaction effect sliced by montin decreasing ordeof study periodwas shown a October (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 (Appendix Table).

Fluctuation of white mango scale cluster across orchards during study periodse 4.2 showed that the abundance work fite mango scale meahuster during the studyeriod across orchards showed apid decrease from August to October and during November and December were stayed low and being undetectable. The clusters were started progressive increase from January to February and rapid increase to peak from March to April.

Figure 4.2. Fluctuation of white mango scable ster across orchards during study periods Seasonal fluctuation of severity status of white mango scale infestation whitemango scale severity of infestation status if the pooled data from Assosa and Bambasi study orchards during the study month for Zero cluster or free severity status were statistically highly significantly different ($F_{2, 45} = 43.89 \text{ p} < .01$). Mean WMS clustefor zero cluster formation per leafwas maximum in Octobe 0.65(1.07) and November 0.57(1.02) and lowest in December 0.44(0.954). The severity status durin October and November were insignificantly different both significantly higher severity status than December cluster formation were notecord during the study months of August, September, January, February March and April (Table 4.17).

The white mango scale severity of infestation statute pooled data from Assosa and Bambasi study orchardsuring the study monst for one to twoclustes or minimal severity

status were sta**tis**ally significant different (F $_{3, 24}$ = 3.15, p < .05). Mean WMS clustefor one to twocluster formation per leaf were significantly different duringSeptember 1.65(1.46), November 1.61(1.5) and October 1.52(1.42) but significantly higher than December 1.22(1.31). One to twoclusters formation were not ecorded during the study months of August, January, February, March and Appeible 4.17).

The white mango scale severity of infestation statutes pooled data from Assosa and Bambasi study orchardsuring the study monst for two to fourclustes or moderates everity status were statistically ighly significant different ($F_{3, 42} = 37.99 \text{ p} < .01$). Mean WMS cluster for two to four clustes formation per leaf showed that the severity status were maximum during August 3.65(2.04) and lowest during November 2.5(1.74). The severity status was insignificantly different between September 8.06(1.88) and October 2.9(1.85). Two to four clustes formation were notecord during the study months of ecember of April (Table 4.17).

The white mango scale severity of infestation stables he pooled data from Assosa and Bambasi study orchards uring the study month for four to five clustes or sevee severity status were statistically significant different ($f_{2, 17} = 2.19$, ns). The meanWMS cluster formation were similar among August 4.52(2.24), September 4.46(2.22) and January 4.7(2.3). Formation of four to five clusters was not recorded during the study months of October, November, December 176 April (Table 4.17).

The whitemango scale severity of infestation statutisthe pooled data from Assosa and Bambasi study orcharddsuring the study month or greater than fivelustes or very sever severity status were status status insignificantly different ($F_{4, 141} = 4241$, p < .01). Mean WMS cluster for greater than five luster formation per leaf showed that the severity status were maximum during April 15.1(3.95) and lowest during August 5.9(2.5). The severity status indescending or derivere April 15.1(3.95), March 12.1(3.6), February 8.1(2.93), January 6.4(2.62) and Augus 5.9(2.5) respectively. No greater than five uster formation or very sever severity status ererecord edduring the study months **G** teptember, October, November and December (Table 417).

			Mean		
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) [»]	N_r	N_r
November	0.57(1.021)*	1.61(1.5)ª	2.5(1.74)°	N_r	N_r
December	0.44(0.954) [»]	1.22(1.31) [»]	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)°
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	**

Table4.17. Severity of infestation of white mango scale during the month of the study period (pooled data, Assosa and Bambasi districts)

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

The WMS severity of infestation status of the segregated data Assesses archards during the study month for Zero cluster or free severity status were **istatis** to significantly different (F_{2,13}=7.63, p < 0.05). Mean WMS cluster for zero cluster formation per leaf sheed with the severity status of Dctober 0.9(1.18) November 0.9(1.18), December 0.7(1.09) were insignificant difference The zero cluster formation were negtor deduring the study months of August and September algorithmatical and uary to April (Table 4.18).

The WMS severity of infestation statue of the segregated data Assesses chardsduring the study month forone to two buster or minimal severity status were statistically highly significantly different ($F_{2, 13} = 8.25$, p < .01). Mean WMS clustefor one to two clubers formation per leaf showed that the severity status were maximum October 1.75(1.5) and November .61(1.45) and insignificantly different severity status between October and November but significantly highethan December .22(1.31). One to two busters formation were not recorded uring the study months of August and September, Janua Apprild (Table 4.18).

The WMS severity of infestation statuos the segregated data Assessorchardsduring the study monthfor two to four cluster or moderate verity status were statistically ghly

significanty different ($F_{2,31} = 53.77$, p < .01). Mean WMS clustefor two to four cluster formation per leaf showed that the severity tasts were maximum in September 47(1.99) and lowest in Novemb@.53(1.74). The severity status inedcending order were September 3.47(1.99), October2.93(1.85) and November2.53(1.74) respectively. Two to four cluster formations were notrecordedduring the study months of August an Decemberto April (Table4.18).

The WMS severity of infestation statudes the segregated data Assesses conchards during the study month for four to five clusters or severes everity status were statisfield insignificantly different (F 2, 6 = 0.8, ns). Formation of four to five cluster evere not recorded during the study months of October to December defined February o April (Table 4.18).

The WMS severity of infestation statudes the segregated data Astisosa or chardsduring the study monthfor greater than five clusters or very sever severity **state** restatistically highly significantly different ($F_{4,90}$ = 3390.21 p < .01). Mean WMS cluster for greater than five cluster formation per leaf showed that the severity status were maximum April 15.82(4.0) and lowest during August 5.93(2.54). The severity status in descending order were 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 greater than five cluster formation or very sever severity status were severity status were severity status were severity status in descending order were 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 greater than five cluster formation or very sever severity status were seve

		Mean				
District	Month	Free	Minimal	Moderate	Sevee	Very Sever
Assosa	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(131)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(0018)	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)
	Sian.difference	*	**	**	ns	**

Table4.18. Severity of white mango scale infestation during the study month in Assosa and Bambasi districts

Values given in parenthesis are square root transform**eds**; all alues in each column of the sa letter are not significantly different; SEm= Standard error of mean; LSD=Least Signi Difference; CV=Coefficient of Variation; * significant at P < .05 ** significant at .01, ns=Non_significant]_r=Not RecordedNumber of white mango scale cluster

The WMS severity of infestation status the segregated data Bámbasi orchards uring the study month Zero cluster or free severity status were statistic to the statistic of the study significant different ($F_{2, 31} = 37.87$, p < .01). Mean WMS clustefor zero cluster formation per leaf showed that the severity status were immain during Octobe 0.65(1.07) and lowest during December 0.19(0.82) compared with November 5(0.99). The severity status in descending order were October, November, and December respectively. The zero cluster formation were not occurred during the study months of August, September, and Jaou Appyil (Table 4.19).

The WMS severity of infestation status the segregated data Béambasi orchards uring the study month for one to two clusters or minimal severity status were statilist insignificant different ($E_{2, 11} = 1.67$, ns). The severity status of September 1.65(1.46), October 1.47(1.39) and November 1.47(1.39) were insignificantly different One to two cluster formation were not occurred during the study months of August Decemberto April (Table 4.19).

The WMS severity of infestation status the segregated data Bámbasi orchards uring the study month for two to four clusters or moderate verity status were statistical highly significant different ($F_{2, 11} = 14.9$, p < .01). Mean WMS cluster for two to four cluster formation per leaf showed that the severity status were maximum August 3.65(2.04) and lowest during Septembe 2.47(1.72) and October 2.47(1.72) Two to four cluster formation were not occurred during the study month store formation April (Table 4.9).

The WMS severity of infestation status the segregated data Bambasi orchards uring the study month for four to five clusters or sever severity status were tatistically insignificant different ($r_{2, 11} = 1.72$, ns). Mean WMS cluster for four to five cluster formation per lea were insignificantly different between August 4.47(2.23), September 4.47(2.23) and January 4.65(2.27). Formation of four to five cluster were not occurred during the study months @ctoberto December an Elebruary to April (Table 4.19).

The WMS severity of infestation status the segregated data Béambasi orchards uring the study montifior greater than five clusters or very severe verity status were statisally highly significant different ($F_{3,48}$ = 1750, p < .01). Mean WMS cluster for greater than five cluster formation per leaf showed that the severity status were maximum April 14.14(2.44) and lowest during January 5.47(2.44). The severity status in descending order were April 14.14(2.44), March 11.14(3.41), February 7.14(2.76) and January 5.47(2.44) respectively. No greater than five clust formation or very sever severity status were recorded during the study months of August December (Table .19).

				Mean		
District	Month	Free	Minimal	Moderate	Sever	Very Sever
Bambasi	August	N_r	N_r	3.65(2.04)a	4.47(2.23) ^a	N_r
	September	N_r	1.65(1.46)	2.47(1.72)b	4.47(2.23) ^a	N_r
	October	0.65(1.07)a	1.47(1.39)	2.47(1.72)b	N_r	N_r
	November	0.5(0.99)b	1.47(1.39)	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	**

Table4.19. Severity of white mango scale infestation during the study month in Assdsa Bambasidistricts

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

The seasonalwhite mango scale abundance and severity status variation also supported by different studyesults such as: The study by Ofgaa Djirata at al (2018) revealed that the white mango ale population fluctuation showed significance variation among the study month segaye Babeget al (2017) also reported that white mango scale infestation variation among the study districts and season reported that white mango scale infestation variation fluctuations of mango white scale, some of these are study waig and Fayza (2009) who stated that. tuberculauishad three peaks of seasonal abundance o mango trees in Egypt. Similar Abo-Shanab (2012) recorded four annual peaks of seasonal abundance for the mango scale mango trees in Egypt.

4.1.5 Spatial and season distribution map of white mango scale

Spatial distribution map of white mango scaffigure 4.3 illustrates the spatial distribution of WMS in the study site of Assosa and Banadisi districts. The spatial distribution the reference of the experimental size, Assosa Town, Assosa Poly Technique leget was

ranged from 5.003 km to 33.922 km air distance. Table 20 illustrates WMS distribution of average air distance it in orchards and rom experimental site the study districts

		MeanAir Distance	MeanAir Distance From
Study Districts	Kebele	Within Orchards(Km)	Experiment Stie (Km)
Assosa	Amba 14	4.292	9.296
	Amba 5	4.099	8.151
	Amba 8	2.386	5.946
	Megele 32	1.845	5.424
Bambasi	Menider 47	3.885	23.610
	Menider 48	3.785	26.280
	Sonika	4.239	33.922

Table4.20. Sp	atial distribution	on of white n	nango scale
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Figure 4.3. Spatial distribution map of white mango scale

Seasonal distribution map of white mango scatting ure 4.4 illustrates seasona WMS distribution map indicates that severity status varied during the study monith the study orchards WMS severity of infestationni the study month of August (Moderate to ry severe), September (Minimal to Moderate), October (Free toodle rate), NovembeF (ee to Minimal except in Amba_14 Moderate), ecember (Free to Minimal), anuary (Moderate to Very severe), and February to April (evy severe) severity status were recorded in the study orchards.

Figure 4.4. Seasonal distribution map of white mango scale

4.1.6 Factors contributing for infestation of white mango scale

Correlatons of white mango scalewith meteorological dataln Assosa orchardenean clusterabundancewas more strongly negatively related redative humidity ($_{178}$ = -0.532, p < .01) than to rain fall(r $_{178}$ = -0.277, p < .01). These finding indicated the teancluster abundances ome how more varied brelative humidity than rain fall. In Bmabasiorchards of Bambasi also mean cluster bundance strongly negatively related reginfall (r $_{133}$ = -0.380, p < .01). In both Assosa and Bambasi orchards mean cluster strongly positively related to the temperature r($_{178}$ = 0.898, p < 0.01) and (r $_{133}$ = 0.838, p < .01) respectively (Table 2.1, Appendix Table and 8.

Table 4.21. Correlations of white mango scale **de**rsabundance per leaf with rain fall, temperature and relative humidity in Assosa and Bambasi orchards

		Rain Fall	Temperature	Humidity
Assosa	r ₁₇₈	-0.277	0.898	-0.532
	р	0.0002	<.0001	<0.0001
Bambasi	r ₁₇₈	-0.380	0.838	-
	р	<.0001	<.0001	-

RF=rain fall (cm);Max $T^{0}(^{0}c)$ = maximum temperature in degree Celsi **Ms** in $T^{0}(^{0}c)$ = minimum temperature in degree Celsius, RH=relative humidity

Progressive change of white mango scale with RainTfethpratureand Relative humidity: Figure 45 illustrates the impact of ain fall and temperature onean cluster abundance per leaf at Bambasidistrict. Maximum cluster abundance 4.1 per leaf was recorded at the maximum temperaturerecords of the studyperiod during April, 2019 at maximum temperature 5.64°c and minimum temperature 0.84°c and rain fall 39.2mm Mean duster abundance per leaf wasserved becreasing while there was a domued and high rain fall from Augusta rain fall record of 263mmto Decembea minimumrain fall record of 5.2mm during which a minimum0.19 cluster abundance per leaf was recorded

Figure 4.6 illustrates the impact of rain fall, temperature and relationeidity on mean cluster abundance per leaf in Assolute an cluster abundance per leaf was decreased from August to December coincides with lowering orfelative humidity. Building up of cluster abundance coincides with a startup of relative humidity and rain fall increstmenting from March.Maximumclusterabundance/5.8per leaf was recorded at the maximum perature records of the studyperiod April, 2019 at maximum temperature/2.9 ⁰c, minimum

temperature17.8 ^oc and optimumrain fall 42mm andrelative humidity 32%. Cluster abundance per leaf was observed decreasing while there was a continued and high rain fall during Augusta rain fall record of 218.9mm to December 1.5mm inimum rain fall record during which a minimum cluster abundance 0.86 was recorded

These study result also supported by different literature such as: **Djfgeta** et al (2018) reported that **te**perature variation affect the white mango scale populations, each populations were recorded in the months with maximum monthly temperatures of 35 and 31°C at Arjo and Bako of western Ethiopia, respectively x **te**emely low population level below 10 mm avege monthlyrain fall (highly affected by drought) and in contrary heavy and continued rain fall decreases the population during the first months of rainy seasore, that in March to April and continues for few months, **-** wis is significant infestation of mango fruits by white mango scale, in Western Ethiopia below ver; this result contradicted with the earlier finding of Labuschagnet al. (1995) that white mango scale allow tolerance to high temperature, and as a result its population declined in temperatures above 30°C.



Figure 4.5. Progressive change of fean cluster/lea/with Rain fall and Tempraturaet Bambasi



Figure 4.6. Progressive change on fean cluster/lea/with Rain fall, Temprature and Relative humidity at Assosa

Effect of mango orchard characteristics to white mango scale severity of tattes tation: Table 4.22 Illustrates white mango scale severity status variability with variation of surveyed mango orchards, characteristics during the storehold August/2018 to April/2019.

White mango scale insect pest infestation status significantly variedifferent age category of mango trees 2(95 (2) =7.48 p < .05). Mango orchards in age less than 10 years old age group were at 51% lower risk of minimal to moderate severity status compared to greater than 20 years old age mango trees group (OR: 90549;CI: 0.290.817). This implied that mango trees ages a factor for infestation varability the study orchards. Old age mango trees were observed more likely at riskito mangement which become suitable for the reproduction of the pest and used for source of infestation stilled yresult of Seid Hussen and Zeru Yime2(013) also revealed that according to the oldness of three age mostfarmers did not give attention to mango trees plantation.

White mango scale insect pest infestation status significantly varied for different height category of mango tree($x^2.95$ (3) = 11.8, p < .05). Mango orchards in short height group were at 60% lower risk of minimal to modter severity status compared to very long height mango trees group (OR: 0.40; 95% CI: 902239). This implied that very long height mango trees were observed more likely at risk of minimal to medium severity status. Since unmanageable sized ango trees ignificantly contribute forwhite mango scale festation. This result by riesbach 2003 reported that all trees present a harvesting problem and create difficulties during spraying and pruning.

White mango scale insect pest infestationatus significantly varied for difference anopy volume category of mango tree($X^2.95$ (3) = 8.18, p < .05). Mango orchards in crowded canopy group were at 2.079 times more at risk of minimal to moderate severity status compared to uncrowded canopy ango tees group (OR: 2.0295% CI: 1.2483.465). This implied that uncrowded canopy volume which sun light easily penetrate to inner canopy and also free air movement made lower infestation of white mango straige result supported by Bally (2006) who reported that well managed orchard trees require regular annual pruning to maintain appen canopy of manageable size what the six and sunlight to penetrate, which reduces pests and disebases and Mishra (2007) reported that trapping is an important cultral operation for obtaining quality yield from the fruiting travelsich reduces incidence of pests and disease occurs due to high relative hurstdidy by Sharma

et al. (2001) also suggessil thatregular canopymanagementhecessary for mango yield improvement.

White mango scale insect pest infestation status significantly varied for diffetenting pattern or spacingof mango orchard (X².95 (1) = 5.62, p < .01). Mango orchards in not recommended planting pattern group were at 75% more likely keep finisinimal to moderate severity status compared to recommended planting pattern mango trees group (OR: % 75): 95102 2.774). This implied that mango trees planted with recommended planting space which is used regularly 10m X 10m as general guidet be study districts were beerved less likely at risk of minimal to moderate severity status. This study result ported by Seid Hussen and Zeru Yimer (2013), Olaniyan(2004), Khanet al (2015), Sharmæt al (2001) and Griesba (2003) who reported that since mango trees grow in to large specimen need appropriate spatigring ensity planting show a progressive decline in crop yielder 14/15 years, due to overcrowding afreopies, which results in the production of fewer fruits which are apt to deerly colored and infected withests Also Andrew (2016) suggested there plant space ideal environments for scale insects to develop and increases the ease of teletion

White mango scale insect pest infestation status significantly variethtery cropping condition of mango orchard $(X^2.95 (1) = 7.37, p < .01)$. Mango orchards in not intercropped group were at 44% lower risk of minimal to moderate severity statums pared to intercropped mango trees group (OR: 0.56; 95% CI:-0.8731). This implied that mango trees intercropped with other plants were highly at riskwohite mango scale. The intercropped plants might be used to harbor the persent infestation status significantly varied for difference of infestation status categories group were at 52% lower risk of minimal to moderate severity status compared mango trees group (OR: 0.48; 95% CI: 0.269302). This also implied that mango trees infested by weed more likely attacked by hite mango scale omparatively high infestation status. These results ported by Andrew (2016) who suggested that for scale management removing crop debris and disinfest the growing area and free of weeds since scale may survive for weeks on crop debris and in egg masses that have fallen off plants.

	-	Odds Ratio Estimates				
Effoct		Point Ectimate	95% Confiden	Wald		
Moderate vs Free	Intercept	Estimate	Connuen		<.0001	
Minimal vs Free	Intercept				<.0001	
Age					0.0237	
10_20Years vs>20 Year:		0.7	0.433	1.137	0.9792	
<10 Years>20 Years		0.49	0.29	0.817	0.0212	
Moderate vs Free	Intercept				<.0001	
Minimal vs Free	Intercept				<.0001	
Height					0.0081	
Long vs Very Long		0.73	0.428	1.238	0.2899	
Medium vs Very Long		0.45	0.254	0.809	0.1388	
Short vs Very Long		0.4	0.22	0.739	0.0476	
Moderate vs Free	Intercept				<.0001	
Minimal vs Free	Intercept				<.0001	
Canopy					0.0167	
CD vs Un_CD		2.08	1.248	3.465	0.0074	
L-CD vs Un_CD		1.37	0.803	2.334	0.8174	
Moderate vs Free	Intercept				<.0001	
Minimal vs Free	Intercept				<.0001	
Intercropping					0.0066	
No vs Yes		0.561	0.37	0.851	0.002	
Moderate vs Free	Intercept				<.0001	
Minimal vs Free	Intercept				<.0001	
Planting pattern					0.0177	
N_R vs R		1.75	1.102	2.774	0.0177	
Moderate vs Free	Intercept				<.0001	
Minimal vs Free	Intercept				<.0001	
Weed					0.0167	
High vs Medium		0.66	0.405	1.07	0.8174	
Low vs Medium		0.48	0.289	0.802	0.0266	

Table 4.22 Effect of mango orchard characteristics to white mango scale severity status

N_R= Not recommended, R= Recommended CD=CrowdedCDn=uncrowdedL_CD=less crowded

4.2 Field Experiment

4.2.1 Effects oftreatmentson white mango scalesopulation

The pretreatment observation on white mango scalespopulation 333.33(18.23) to 370(19.22) per ten leaves per træn hich was statistically insignificant (F_{7, 14} = 2 44, n), which indicated uniform distribution of the pest among different teatments. The observations were recorded on WMS population with 14th day, s interval of post first, post second and post this prayapplication (Table 4.23).

The data reveled that after first stray mearWMS population ranged from 141.(33.88)to 407(20.16)per ten leaves per tree in different treatmenterhighly significantly different (F _{7, 14} = 2 44, p < .01). The lowestWMS population were observed inimidacloprid 20SL+pruning treatment141.33(11.88) compared to other treatmentEne comparative WMS population among treatments againstWMS at fourteenthday after first spraying found indescending orderwere untreated Control407(20.16), Pruning285.33(16.86) White oil 267.67(16.35), Dimethoate40% EC 261.33(16.14) Imidacloprid20SL 252.67(15.84), White oil extract + pruning 251(15.8), Dimethoate 40% EC+ pruning 222.67(14.89) and Imidacloprid 20SL+pruning 141.33(11.88) respectively. All the treatments were significantly different from untreated controlWhite oil extract + pruning 251(15.84) which were found to be at par with each othe/He is and Dimethoate40% EC 261.3(216.14) which were found to be at par with each othe/Table4.23).

The data revealed that aftesecond spray the mean WMS population ranged from 89.33(9.44) to 447.67(21.14) per ten leaves per tree in different treatment wheightly significantly different ($F_{7, 14}$ = 68.62,p < 0.01). The lowest WMS population was observed in Imidacloprid 20SL + pruning treatment 89.33(9.44) compared to other treatment wheight comparative WMS population among treatments fourteenth day after second spraying found in descending order were Control 447.67(21.14), Pruning 234(15.24), White oil extract 224(14.93), Dimethoate 40% EC 184.33(13.52), Imidacloprid 20SL 163(12.63), White oil extract + pruning 161.33(12.58), Dimethoate 40% EC + Pruning 138.67(11.68) and Imidacloprid 20SL + pruning 89.33(9.44) respectively. All the treatments were significantly different from untreated control Pruning 234(15.24) and White oil extract 224(14.93) which were found to be at par with each other idacloprid 20SL 163(12.63).

andWhite oil extract + Pruning 61.33(12.58) which were found to be **p**ar with each other (Table 4.23).

The data revealed that afterird spraymeanWMS population ranged from 24(4.87) to 492.67(22.18) per ten leaves per tree in different treatment weight significantly different (F 7, 14 = 90.81, p < .01). The lowestWMS populationwere observed in initial cloprid 20 SL + Pruning treatment 24(4.87) compared to other treatment the comparative WMS population among treatments fourteenth day after third spraying found indescending orderwere Control 492.67(22.18), Pruning 187.33(13.52), White oil extract 165.67(12.77), Dimethoate 40% EC 92(9.44), Imidacloprid 20 SL 74(8.46), White oil extract + pruning 78.67(8.74), Dimethoate 40% EC + pruning 66.33(8.013) and Imidacloprid 20 SL + pruning 24(4.87) respectively All the treatments were significantly different from untreated control. Pruning 187.33(13.52) and White oil 165.67(12.77) which were found to be at par with each other. Dimethoate 40% EC 92(9.44), Imidacloprid 20 SL 74(8.46) and White oil extract + Pruning 78.67(8.74) which were found to be at par with each other. Dimethoate 40% EC 92(9.44), Imidacloprid 20 SL 74(8.46) and White oil extract + Pruning 78.67(8.74) which were found to be at par with each other. Dimethoate 40% EC 92(9.44), Imidacloprid 20 SL 74(8.46) and White oil extract + Pruning 78.67(8.74) which were found to be at par with each other. Dimethoate 40% EC 92(9.44), Imidacloprid 20 SL 74(8.46) and White oil extract + Pruning 78.67(8.74) which were found to be at par with each other. Dimethoate 40% EC 92(9.44), Imidacloprid 20 SL 74(8.46) and White oil extract + Pruning 78.67(8.74) which were found to be at par with each other. Dimethoate 40% EC 92(9.44), Imidacloprid 20 SL 74(8.46) and White oil extract + Pruning 78.67(8.74) which were found to be at par with each other. Dimethoate 40% EC 92(9.44), Imidacloprid 20 SL 74(8.46) and White oil extract + Pruning 78.67(8.74) which were found to be at par with each other. Dimethoate 40% EC 92(9.44), Imidacloprid 20 SL 74(8.46) and White oil extract + Pruning 78.67(8.74) which were found to be at par with

The mean of the three spradata revealed that three an WMS population ranged from 85(9.21) to 449.33(21.18) per ten leaves per tree in different treatment wheighly significantly different ($r_{7,14} = 98.63 \text{ p} < .01$). The lowestWMS populationwere observed in Imidacloprid 20SL + Pruning treatment85(9.21) compared to other treatment85he comparative white mango scales population on gtreatments against white mango scale found in descending order were Control 449.33(21.8), Pruning 235.67(15.28) White oil 219.33(14.78), Dimethoate 40% EC 179.33(13.34), Imidacloprid 20SL 163.33(12.69), White oil extract + Pruning 163.67(12.72), Dimethoate 40% EC + Pruning 142.67(11.89) and Imidacloprid 20SL + Pruning 85(9.21) respectively. All the treatments were significantly different from untreated control Pruning 235.67(15.28) and White oil extract 219.33(14.78) which were found to be at par with each other indacloprid 20SL 163.33(12.69) and White oil extract + Pruning 163.67(12.72) which were found to be at par with each other indacloprid 20SL 163.33(12.69) and White oil extract + Pruning 163.67(12.72) which were found to be at par with each other indacloprid 20SL 163.33(12.69) and White oil extract + Pruning 163.67(12.72) which were found to be at par with each other indacloprid 20SL 163.33(12.69) and White oil extract + Pruning 163.67(12.72) which were found to be at par with each other indacloprid 20SL 163.33(12.69) and White oil extract + Pruning 163.67(12.72) which were found to be at par with each other indacloprid 20SL 163.33(12.69) and White oil extract + Pruning 163.67(12.72) which were found to be at par with each other indacloprid 20SL 163.33(12.69) and White oil extract + Pruning 163.67(12.72) which were found to be at par with each other indacloprid 20SL 163.33(12.69) and White oil extract + Pruning 163.67(12.72) which were found to be at par with each other indacloprid 20SL 163.33(12.69) and White oil extract + Pruning 163.67(12.72) which were found to be at par with each other indacloprid 20SL 163.33(12.69)

			Mean		
Treatment	PrT	PFS	PSS	PTS	MS
Control	370(19.22)	407(20.16) ^a	447.67(21.14) ^a	492.67(22.18)	449.33(21.18)*
Pruning	348.33(18.64)	285.33(16.86 ⁾	234(15.24 ⁾	187.33(13.52) ⁹	235.67(15.28 ⁾
White oil extract	355(18.84)	267.67(16.35 [%]	224(14.93 ⁾	165.67(12.77) ⁹	219.33(14.78 ⁾
Dimethoate	333.33(18.23)	261.33(16.14 [%]	184.33(13.52)	92(9.44) ^c	179.33(13.34)
Imidacloprid	340(18.41)	252.67(15.84) [°]	163(12.63) ^{5d}	74(8.46) ^c	163.3 3 (12.69) ^{5d}
White oil + pruning	358.33(18.9)	251(15.8) ^c	161.33(12.58) ^{°d}	78.67(8.74) ^c	163.67(12.72) ^{cd}
Dimethoate+ puning	351.67(18.72)	222.67(14.89) ^d	138.67(11.68) ⁹	66.33(8.013) rd	142.67(11.89) ^d
Imidacloprid + pruning	353.33(18.78)	141.33(11.88)	89.33(9.44)°	24(4.87) ^d	85(9.21) ^e
Mean	351.3(18.7)	261.1(15.99)	205.3(13.9)	147.6(10.99)	204.8(13.89)
SEm	4.4(0.11)	5.8(0.17)	6.8(0.25)	9.2(0.34)	6.4(0.21)
LSD	21.8(059)	28.7(0.85)	33.46(1.27)	45.44(1.68)	31.77(1.064)
CV%	3.53(1.79)	6.28(3.044)	9.31(5.199)	17.58(8.72)	8.86(4.37)
Sign.difference	ns	**	**	**	**

Table4.23. Mean number of white mango scaleshie experimental mango orchards

Values given in parenthesis are user root transformed value/alues in each column of the same letter are not significantly diffedent; Standard error of mean LSD=Least Significant Difference CV=Coefficient of Variation, * significant at P < .05 ** significant at .01, ns=Non_significant; PrT=Pre_Treatment/WMS count/10 leaves, PFS=Post First Spray WMS count/10 leaves, PSS=Post Second Spray WMS count/10 leaves, PTS Spray WMS count/10 leaves, MS=mean WMS count/10 leaves after all spray

4.2.2 Effects oftreatmentson white mango scalesortality

The WMS mortality percentages ver control was worked out after each treatment using Abbott,s (1925) formula of mortality correction T(able 4.24)

The mortality percentage f WMS fourteen_days after the first application was highly significantly different among treatments ($F_{7, 14} = 136$, p < .01). The highest mortality percentage was beserved inlmidacloprid20SL+ pruning treatment 65(53.73) compared to other treatments. The comparative mortality percentage among treatments in descending order were lmidacloprid 20SL + pruning 65(53.73), Dimethoate 40%Ec + pruning 45.33(42.27), White oil extarct+ pruning 38.67(38.42), Imidacloprid 20SL 38.33(38.18), Dimethoate 40%EC36(36.9), White oil 34(35.5), Pruning 30.33(33.3) and Control 0(0.33) respectively. All the treatments were significantly different from untreated control. Dimethoate 40%EC+ pruning 45.33(42.27) and White oil extracc+ pruning 38.67(38.42) which was found to be at par with each oth Dimethoate 40%EC 36(36.9) and White oil extract 34(35.5) which werefound to be at par with each other.

The mortality percentage f WMS fourteen_days after the second applicationere highly significantly different among treatment $F_{7, 14} = 167$, p < .01). The highest mortality percentage was beserved in midacloprid 20 SL + pruning treatment 80(63.44) compared to other treatments. The comparative mortality percentage among treatments in descending order werd midacloprid 20 SL + pruning 80(63.44), Dimethoat e40% EC+ pruning 69(56.3), Imidacloprid 20 SL 64(53.1), White oil extract + pruning 64(53.3), Dimethoat e40% EC 59(50.2), White oil extract 50(45.0), Pruning 47.67(43.7) and Control 0(0.33) respectively. All the treatments were significantly different from untreated control dacloprid 20 SL 64(53.1) and White oil extract + pruning 64(53.3) which were found to be at par with each other. White oil extract 50(45.0) and Pruning 47.67(43.7) which were found to be at par with each other.

The mortality percentage f WMS fourteen_days after the third application religning significantly different among treatment ($F_{7, 14} = 168.1$, p < .01). The highest mortality percentage was been with indicoloprid 20SL + pruning treatment (77.12) compared to other treatments. The comparative mortality percentage among treatments in descendin order were midacloprid 20SL + pruning (77.12), Dimethoat (69.1), Imidacloprid 20SL 85.33 (67.7), White oil + pruning 84.67 (67.1), Dimethoat 40% EC

81.67(64.9), White oil extract 66(54.5), Pruning 62.33(52.4) and Control 0(0.33) respectively. All the treatments were significantly different from untreated control. Dimethoate40%EC+ pruning87(69.1),Imidacloprid20SL85.33(67.7),White oil extract+ pruning84.67(67.1) andDimethoate40%EC81.67(64.9) which were found to be at par wit each otherWhite oil extract66(54.5) andPruning62.33(52.4) which were found to be at par with each other.

Mortality percentage of WMS showed a progressive increase from first spray to third spray application for all treatments compared to untreatendarol. The progressive increase of mortality percentage of each treatmelinteidacloprid20SL+ pruning Dimethoate40%EC + pruning Imidacloprid20SL, White oil extract + pruning Dimethoate40%EC, White oil extractandPruningwere65 to 95, 45.33to 87, 38.33to 85.33, 38.67to 84.67, 36 to 81.67, 34 to 66 and 30.33to 62.33respectively

	Mean					
	first spray mortality	second spray mortalit	third spray			
Treatment	%	%	mortality %			
Imidacloprid + Pruning	65(53.7 3) ª	80(63.44) ^a	95(77.1 2 ª			
Dimethoate+ Pruning	45.33(42.27) ^b	69(56.3) ^b	87(69.1) ^b			
Imidacloprid	38.33(38.18)°	64(53.1) ^{bc}	85.33 (67.7) ^b			
White oil +Pruning	38.67 (38.4 2) ^b	64(53.3) ^{bc}	84.67 (67.1) ^b			
Dimethoate	36 (36.9) ^{cd}	59(50.2)°	81.67 (64.9) ^b			
White oil	34(35.5) ^{cd}	50(45.0) ^d	66(54.5)°			
Pruning	30.33(33.3) ^d	47.67 (43.7) ^d	62.33 (52.4)°			
Control	0(0.33) ^e	0(0.33) ^e	0(0.33) ^d			
Mean	35.97(34.8)	54.22 (45.7)	70.3(56.6)			
SEm	1.3(0.8)	1.5(0.9)	1.9(1.14)			
LSD	6.49(3.97)	7.34(4.5)	9.24(5.6)			
CV%	10.31(6.5)	7.73(5.7)	7.51(5.7)			
Sign.difference	**	**	**			

Table4.24. Mortality percentage of white mango scales in response of treatments in the experimental mango orchards

Values given in parenthesis **are**gular transformed value values in each column of the sar letter are no significantly different; $SE_{m\pm}$ = Standard error of mean SD=Least Significant Difference; CV=Coefficient of Variation, * significant at P < .05 ** significant at .01 ns=Non_significant

4.2.3 Effects oftreatmentson mango fruitnumber and/ield (kg/tree)

The mean marketable fruit number ranged from 43.33 to 262 per tree in different treatments were highly significantly different (7, 14 = 23.68 p < .01). The lowestmarketable fruit number was untreated contr(43.33) compared to other treatment (5) he comparative

marketable fruit numbeamong treatments found in descending order **wreid**acloprid 20SL+pruning(262), Dimethoate40%EC+pruning(170.67), Imidacloprid20SL(145.33), White oil extract + pruning (142.33), Dimethoate40%EC(137.33), White oil extract (115.67), Pruning(112), untreated contro(H3.33) respectivelyImidacloprid20SL(145.33), White oil extract + pruning(142.33) and Dimethoate40%EC(137.33) which were found to be at par with each othew/hite oil extract(115.67) and Pruning(112) which were found to be at par with each othew/hite 4.25).

The meanunmarketable fruit number ranged from 6.33 to 176.67 per tree in different treatments werehighly significantly different ($F_{7, 14} = 6.46$, p < .01). The lowest unmarketable fruit number washidacloprid 20SL + pruning treated 83.33 compared to other treatments The comparative marketable fruit number among treatments found in descending order werentreated contro (176.67, Pruning (154.67, White oil extract (147), White oil extract + pruning (144.67, Dimethoate40%EC (132.67, Dimethoate 40%EG+pruning (130), Imidacloprid 20SL (122.33, and Imidacloprid20SL+pruning (83.33) respectively. Pruning (154.67, White oil extract (147) and White oil extract + pruning (144.67, White oil extract (147) and White oil extract + pruning (144.67, White oil extract (147) and White oil extract + pruning (144.67, Dimethoate40%EC (132.67, Dimethoate40%EC (132.67, Dimethoate40%EC (132.67, Dimethoate40%EC + pruning (130) and Imidacloprid20SL (122.33) which were found to be at par with each oth interval with each oth interval to be at par with each oth interval to beach oth interval to be at par with each oth int

The mean total fruit number ranged from 45.33 to 220 per tree in different treatments were significantly different ($r_{7, 14}$ = 3.66, p < 0.05). The lowest total fruit number was intreated control 220 compared to other treatments he comparative total fruit number among treatments found in descending order were daclopid 20SL + pruning (345.33), Dimethoate 40% EC + pruning (300.67), White oil extract + pruning (287), Dimethoate 40% EC(270), Imidacloprid 20SL (267.67), Pruning (266.67), White oil extract(262.67) and untreated control (220) respectively. Dimethoate 40% EC (270), Imidacloprid 20SL (267.67), Pruning (266.67) which were found to be at par with each othe (Table 4.25).

The meanmarketable fruit yield ranged from 0.83 to 65.5 per tree in different treatments were significantly **id**ferent ($F_{7, 14} = 23.68 \text{ p} < .01$). The lowestmarketable fruit yield was untreated contro (10.83) compared to other treatments comparative narketable fruit yield among treatments found in descending order **weid** acloprid 20SL + pruning (65.5), Dimethoate 40%EC + prunir (**g**2.67), Imidacloprid20SL(36.33), White oil extract

+ pruning (35.58), Dimethoate40%EC(34.33), White oil (28.92), Pruning(28), untreated control(10.83) respectivelylmidacloprid20SL(36.33), White oilextract + pruning(35.58) and Dimethoate40%EC(34.33) which were found to be at par with each other white oil extract(28.92) and Pruning(28) which were found to be at par with each other (Tabl25).

The meanumarketable fruit yield ranged fro 200.83 to 44.17 per treen different treatments were significantly **if**ferent (F_{7,14}= 6.46, p < 0.01). The lowest umarketable fruit yield was Imidacloprid 20SL+ pruning treated (20.83) compared to other treatments comparative unmarketable ruit yield among treatments fund in descending order we metreated control (44.17), Pruning (38.67), White oil extract (36.75), White oil extract+ pruning (36.17), Dimethoate 40% EC (33.17), Dimethoate 40% EC peruning (32.5), Imidacloprid 20SL (30.58), and Imidacloprid 20SL + pruning (20.83) respectively. Pruning (38.67), White oil extract (36.75) and White oil extract+ pruning (36.17) which were found to be at par with each other. Dimethoate 40% EC (33.17), Dimethoate 40% EC + pruning (32.5) and Imidacloprid 20SL (30.58) which werefound to be at par with each other. Dimethoate 40% EC (33.17), Dimethoate 40% EC + pruning (32.5).

The average total fruit yield ranged from 55 to 86.33 per tree in different treatment sere significantly different ($F_{7, 14} = 3.66$, p < 0.05). The lowest total fruit yield was untreated control 55 compared to other treatments The comparative total fruit yield among treatments found in descending order were idacloprid 20SL + pruning (86.33), Dimethoate 40% EC + pruning (75.17), White oil extract + pruning (71.75), Dimethoate 40% EC (67.5), Imidacloprid 20SL (66.92), Pruning (66.67), White oil extract (65.67) and untreated control (55) respectively. Dimethoate 40% EC (67.5), Imidacloprid 20SL (66.92), Pruning (66.67) and White oilextract (65.67) which were found to be at par with each ot (Teable 4.25).

	Fruit me	ean (Numben/er tree)		Fruit Yield mean(kg/tree)		
Treatment	Marketable	Unmarketabe	Total	Marketable	Unmarketable	Total
Imidacloprid + Pruning	262a	83.33c	345.33a	65.5a	20.83c	86.33a
Dimethoate+ Pruning	170.67b	130b	300.67ab	42.67b	32.5b	75.17ab
Imidacloprid	145.33bc	122.33b	267.67bc	36.33bc	30.58b	66.92bc
White oil + Pruning	142.33bc	144.67ab	287b	35.58bc	36.17ab	71.75b
Dimethoate	137.33bc	132.67b	270bc	34.33bc	33.17b	67.5bc
White oil	115.67c	147ab	262.67bc	28.92c	36.75ab	65.67bc
Pruning	112c	154.67ab	266.67bc	28c	38.67ab	66.67bc
Control	43.33d	176.67a	220c	10.83d	44.17a	55c
Mean	141.1	136.4	277.5	35.3	34.1	69.4
SEm	7.8	6.6	11.5	1.9	1.9	2.7
LSD	38.41	32.54	56.91	9.6	8.13	14.23
CV%	15.54	13.62	11.71	15.54	13.62	11.71
Sign.difference	**	**	*	**	**	*

Table4.25. Mean number of mango fruind yieldper tree in response of treatments in experimental mango orchards

Values in each column of the same letter are not significantly difference V=Coefficient of Variation, * significant at P < .05** significant at .01, ns=Non_significant

Generallytreatments against white mango scale population found in descending order we Pruningat par withWhite oil extract> Dimethoate40% EC> Imidacloprid 20SLat par with White oil extract + Pruning Dimethoate40% EC+ Pruning> Imidacloprid 20SL + Pruning respectively. Treatmentsagainst mortality percentage found in descendinger were Imidacloprid 20SL + pruning Dimethoate 40%EC + pruningmidacloprid 20SL White oil + pruningandDimethoate40% ECat par with each other White oil extractat par with Pruning respectivelyFruit numberand yieldamong treatments found intescending order were Imidacloprid 20SL + pruning > Dimethoate 40%EC + pruning/bite oil extract+ pruning > Dimethoate40%EC Imidacloprid20SL, Pruning, White oilextract at par with each otherespectively.

Management of white mango scale using pitug results in lined with Cunningham (1989) who reported post-harvest pruning is an effective control measure and also helps the penetration of chemical sprays through the tree can be preserved to be a the transmission of transmission of transmission of the transmission of transmission of

Management of white scale using bute oil extract efficacy in lined with Tesfaye Hailuet al. (2014) reported that white oil is recommended for control of white mango scale. Also Mark et al. (2019) reported that cale insects are suffocated by oils and dried out by insecticidal soaps. Insecticidal soaps disrupt the waxy cuticle or €skin• of the insect, which eventually causes the insect to dry out or desiccate and Pdesannath 2(016) supports to use such type dotanical control due to iodegradable nature, systemicity after application, capacity to alter the behaviour of target pests and favourable safety.profile

Managementof white scale using Imidacloprid 20SL efficacy in lined wittlegde and Nidagundi, 2009and Patil et al. (2009) reported that midacloprid is a new class of

insecticide and its potency against sucking insect is well reported in different countries of the world Some studies show that imidacloprid gives an outstanding resultstaga sucking insects (Kencharaddai and Balikai, 2012 and Joshi and Sharma, I2069). comparatively safer than other conventional insecticides and once it is applied, the action continued for a longer period. On the other hand, attrieon of imidacloprid persisted at least up to day 10 which raises the possibility that once it enters into the plant system, the imidacloprid remains comparatively for a longer period of time (Retbson al., 2007 and Shet al., 2011). Thesestudy result also supports as this imidacloprid is comparatively less toxicity to human and environment.

Control of white scale using imethoate40%EC efficacy supported by warinathanet al. (2010) who reported that dimethoate was effective in reindgruthe effect of sucking insect pest. Earlier study by Howard (1989) showed that Dimethoate 40%EC was our second trol of white mango scale. Diethoate is organo phosphate class which is now in modern crop protection is not recommended due to Itazardos natureto water, soil, environment and human health compared with eonicotinoides we type insecticides like imidacloprid.

Control of white mango scale using white oil extrainctidacloprid 20SL and dimethoate 40%EC integrating with pruning increases tefficacy which in lined with Cunningham (1989) and Andrew (2016) reported post harvest pruning is an effective control measure which helps the penetration of chemical sprays through the tree canopy.

4.2.4 Costbenefit analysis

Partial budget analysis for with mango scale management experimentable 4.26 illustrates the partial budget analysis for treatments ETB18/Kg was used as farm gate price. Adjusted yield total costs that vargend net benefit was done for each treatment

Table4.26. Partial budgeanalysis forwhite mango scale management experiment

_	Treatments							
ltem	Control	Pruning	White oil extract	Dimethoate 40%EC	White oil extract + pruning	Imidacloprid 20SL	Dimethoate 40%EC + pruning	Imidacloprid 20SL + pruning
Average yield (kg/tree)	10.83	28	28.92	34.33	35.58	36.33	42.67	65.5
Adjusted yield (kg/tree)	9.747	25.2	26.028	30.897	32.022	32.697	38.403	58.95
Gross field benefits (ETB/tree)	175.446	453.6	468.504	556.146	576.396	588.546	691.254	1061.1
cost of insecticide (ETB/tree)	0	0	0	3.94	0	9.36	3.94	9.36
cost of white oil (ETB/tree)	0	0	10.3		10.3	0	0	0
Cost of labor to apply insecticide (ETB/tre	0	0	0	90	0	90	90	90
Cost of sprayer rental (ETB/tree)	0	0	40	60	40	60	60	60
Cost of labor to apply white oil (ETB/tree)	0	0	30	0	30	0	0	0
Cost of labor for pruning (ETB/tree)	0	75	0	0	75	0	75	75
Total costs that vary (ETB/tree)	0	75	80.3	153.94	155.3	159.36	228.94	234.36
Net benefits (ETB/tree)	175.446	378.6	388.204	402.206	421.096	429.186	462.314	826.74

Dominance analysis for white mango scale management experimeters 427 illustrates Dominance analysis between reatments In moving from the lowest to the highesthere were no dominated treatments betained which costs more than there evious. Therefore all treatments were taken in to MRR analysis.

		Total costs		
		that vary	Net benefits	
	Treatment	(ETB/tree)	(ETB/tree)	Dominancy
-	Untreated Contro	0	175.446	
	Pruning	75	378.6	No
	White oil extract	80.3	388.204	No
	Dimethoate40% EC	153.94	402.206	No
	White oil extract+ pruning	155.3	421.096	No
	Imidacloprid20SL	159.36	429.186	No
	Dimethoate40% EC+ pruning	228.94	462.314	No
	Imidacloprid20SL+ pruning	234.36	826.74	No

Table4.27. Dominance analysis white mango scale management experiment

Marginal analysisfor white mango scale management experimeable 4.28 illustrates calculating the MRR between reatments The MRR by switching from untreated control to pruning treatment was 2707.8%, well above the minimum Hence, a270.87% MRR in switching fromuntreated contrdb pruning treatmentimplied that for eachETB invested in the new teatment the producer can expect to recover the 1EinBested plus an additional return of 2.7087ETB. Therefore pruning was certainly a worthwhile alternative to the untreated control. By switching from pruning to white oil treatment the marginal rate of return was 181.21%, also well above the minimutence, a181.21% MRRin switching from pruningto white oil treatmentmplied that for eachETB invested in the new determination of t the producer can expect to recover the 1ETinByested plus an additional return of 1.8121ETB, and therefore white oil was certainly a worthwhile alternative to pruning management optio By switching from white oil to Dimethoatte % ECtreatment the MRR was 19.014%, and below the minimul mence, at 9.014% MRR in switching from pruning to white oil treatmentmplied that for eachETB invested in the new datment the producer can expect recover the 1ET Browsted plus an additional return of 0.19014ETB which was less than white oil treatment. Therefore Dimethorate Ectreatment had been eliminated

from consideration. But the MRR between Dimethorale/ECtreatment and white oil + pruning was 1388.97% and above the minimum rate of return which seems profitable. However the MRR by switching from white oil to white oil + pruning was 43.86%, below the minimum. Hence, a43.86% MRRin switching from white oil to white oil + pruning implied that for eachETB invested in the new datment the producer can expect to recover the 1ETBinvested plus an additional return of 0.4386ETB which was less than white oil treatment. Therefore white oil + pruning had been eliminated from consideration. By switching from white oil + pruning to Imidacloprid 20SL treatment the MRR was 199.26%, well above the minimum, which seems profitable however the MRR by switching from white oil to Imidacloprid 20SL treatment was 51.85%, below the minimulance, a51.85% MRR in switching from white oil to Imidacloprid 20SL treatment in plied that for each ETB invested in the new datment the producer can expect to recover the 1ET Bested plus an additional return of 0.5185ETB which was less than white oil treatment. To here f Imidacloprid 20SL treatment had been eliminated from consideration. By switching from Imidacloprid 20SL treatment to Dimetho##@%EC+ pruning the MRR was 47.61%, below the minimum and also by switching from white oil to Dimethot EC+ pruning the MRR was 49.85, below the minimum lence, a49.85% MRRin switching from white oil to Dimethoate40%EC+ pruning treatmentimplied that for eachETB invested in the new treatment the producer can expect to recover the 1EinBested plus an additional retu of 0.4985ETB which was less than white oil treatment. There Doine ethoate 40% EC+ pruning treatment had been eliminated from consideration. By switching from Dimethoat 40%ECe + pruning to Imidacloprid 20SL+ pruning treatment the MRR was 6723.72%, well above the minimum which seems unrealistic since which was seen from not profitable treatment. But by switching from white oil to Imidacloprid 20SL + pruning treatment the MRR was 284.65%, also well above the minimumence, a284.65%, MRRin switching from white oil to Imidacloprid 20SL+ pruning treatmembplies that for eacETB invested in the new teatment the producer can expect to recover the 1 Ein Bested plus an additional return of 2.8465ETB which was greater than white oil treatment. Therefinded loprid 20SL + pruning treatment was certainly a worthwhile alternative to all management option. Therefore white oil and pruning should be considered as second and third alternative to producers.

Researchers should continue to experiment white a minipipe and Imidacloprid 20SL + pruning treatment which seems to be a promising alternative to producers white mango scale

management. Dimethoa40%EC white oil + pruning, Imidacloprid 20SL, and Dimethoate 40%EC+ pruning treatments gave higher yield attatistically significant different from pruning and white oil treatment but their costs were such that they did not provide an acceptable rate of return. However Imidacloprid 20SL + pruning treatment costs higher compared with all other treatment but gave her yield and acceptable rate of return. Table4.28. Marginal analysisor white mango scale management experiment

Treatment	Total costs that vary (ETB/	tree Net benefits (ETE	B/tree <u>Ma</u>	rginal rate of re	tun(MRR)%
Untreated Control	0	175.446			
			270.87%		
Pruning	75	378.6			
			181.21%		1
White oil extract	80.3	388.204			
			19.01		
Dimethoate40% EC	153.94	402.206			
			1388.9		
White oil extract+ pruning	155.3	421.096		43.9	
			199.26		
Imidealaprid2081	150.26	100 196		510	
Initiaciophi203L	159.50	429.100	17 61	51.9	
			47.01		
Dimethoate40% EC+ pruning	228.94	462.314			49.8
			6723.7		
Imidacloprid20SL + pruning	234.36	826.74			284.6

Residual analysis four hite mango scale management experimetable 4.29 illustrates the computation of residual outfeatments. The treatments were arranged in order from lowest to highest total costs that vary. Since producers will be interested in the treatment with the highest residual. The treatment with highest residual was Imidacloprid 20SL + pruning treatment and the second and third highest residual were white oil and pruning respectively which was the same conclusion reached in the previous MRR analysis.

	1 2		3	4	
-	Total costs	Net	Return required	Residual	
	that vary	benefits	[100%*(1)]	[(2)-(3)]	
Treatment	(ETB/tree)	(ETB/tree)	ETB/tree	ETB/tree	
Untreated Control	0	175.446	0	175.446	
Pruning	75	378.6	75	303.6	
White oil extract	80.3	388.204	80.3	307.904	
Dimethoate0% EC	153.94	402.206	153.94	248.266	
White oil extract+ pruning	155.3	421.096	155.3	265.796	
Imidacloprid20SL	159.36	429.186	159.36	269.826	
Dimethoate0% EC+ pruning	228.94	462.314	228.94	233.374	
Imidacloprid20SL+ pruning	234.36	826.74	234.36	592.38	

Table 4.29. Residual aalysis for white mango scale management experiment

<u>a</u>/The firstMaximum residuab/The secondMaximum residuab/The thirdMaximum residual

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Mango growers, perceived that white mango scale insect pest infestation varied from medium to high incidence and severity status which attack all mango cultivar and made the trees whitish colour canopy cover, leaf defoliation, stunting artdrttign of fruits, dieback of twigs and branches premature fruit drop and drying of flower and results a significant yield reduction. Growers, believed that the pest mainly dispersed through planting materials and as well its management was difficult witteir unmanageable mango size nature and majority of mango trees were grown in the backyards farms made difficulty for insecticide spraying and cultural management due to this they eager to expertise solutiess the growers, used proper management/donite mango scale the infestation become serious.

White mango scale insect pest infestation was varied spatially and seasonally based on mango orchards management, rain fall, temperature and relative humidity. It was higher at Assosa than at Bambasi oactds and more abundant on upper leaf than on lower leaf. 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 mark to peak during April. Temperature influence the infestation positively and a maximum record during maximum temperature of the study month during April. High and continued rain fall and relative humidity influence infestation negatively; however optimum rain fall and relative humidity enhance infestation managed mango tree orchards condition wasntributed for infestation enhancement

Experiment against white mango scale infested mango trees **Inside** cloprid 20 SL + pruning treatment weathe most effective than others treatment be cost benefit analysis of the management option used for this experiment against white mango scale insect pest was revealed that midacloprid 20 SL + pruning treatment provide a promising alternative to producers against white mango scale ectpest. Since Imidacloprid 20 SL is ecologically safe insecticide compared Doimethoate 40%EC; therefore ist more preferable for white mango scale insect pest management. Management of white mango scale using integrate management approach as used in this experiment is effective to reduce the infestation contribute for mango fruit yield improvement in quality and quantity.

5.2 Recommendations

From the study recommendation are made for the management of white management agricultural extension service and researchers. Agricultural Extension service should focus to regular inspection and monitoring of white mango scale insect pest since white mango scale insect pest reproduce throughout mango tree growing yelawuld soe interested to give attention for awareness creation to growers, about this pest reproduction nature for the sake of effective management. Develop a strong domestic guarantine among regions and within regions since this pest has persed phoretida; it can be dispersed through planting materials, animals and others. Since the unmanaged huge sized and old age mango trees used as white mango scale infestation source, so it is important to replace such type of mango trees through grafting to manabee size and also focusing to plantation of short height mango varieties. Focus to integrated pest management approach since management of white mango scale using a combination of different cultural and IPM (integrated pest management) compatible insectide as used in this experiment can combat white mango scale insect pest effectively. Researchers also should give attention to investigate resistance varieties of mango trees and further screening of IPM compatible insecticide for the sakevioling to growers, sustainable management approach of white mango scales for the improvement of mango fruit yield in quality and quantity.
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APPENDIX

Appendix Table1. Questionnaires used for mango growers, perception A. Environments (locality)

Region_____Zone_____stri**@**s_____

Location ______North _____East _____Altitudes

- B. Name of Farmers______ State or private farm_____
 - What is your Educational level? 0=no education 1=primary 2=secondary 3=institution 4=university
 - How many mango tree in your mango orchards do you have Age ______
 - 3. What are the major problem of your mango tree? (1) Insect (2) Diseases (3) Not aware
 - 4. If the answer for Q3 is insect, what type of insect?
 - 5. Is there any local name given to this pest?Y(ds) (2) No
 - 6. If the answer is ... Yes, for Q5 what is the name?
 - 7. Is this pest new to your mango tree? (1) Yes (2) No
 - When the period of time since white mango scale has been known in the survey area? (1)
 Below 5 years (2) 510 years (3) not aware
 - 9. What was the extent of incidence in your respective?
 - (1) High (2) Medium (3) Low
 - 10. What was the extent of severity in your respective?
 - (1) High (2) Medium (3) low
 - 11. Which parts of the plants attacked by the pest?
 - 12. By which ways youdentify the pest? 1. Color/sign 2. Symptom
 - 13. What is the color/sign you used for identification?
 - 14. What type of symptom you used for identification?
 - 15. How the pest distribute / spread?
 - 16. How long take to spread to your neighborhood farms (weekt/ms)?_____
 - 17. In which season the hite mango scale insect pest become serious?
 - 18. On which farm site you observed the pest infestation were serious?
 - (1) Field farm (2)Backyard (3) No difference (4) Not aware
 - Did you have observation whether the pest wfeected the local varieties and exogenous ones equally or not? (1) Yes (2) No
 - 20. If they answer, no, please ask them the reason why?
 - 21. Did you observe other than mango tree which is attacked by MWS? (1) Yes (2) No
 - 22. If ... Yes, for Q2 ask what type of Ipnt?_____
 - 23. What was the pest prevalence level variation over time?
 - (1) Increasing (2) Decreasing (3) Show no differer about aware

- 24. What type of management practice you attempt to control white mango scale?
 - (1) Cultural (2) Pesticide (3) No measure
- 25. If Q24 pesticides were used as one type of control measure, what type of pesticide used?
- 26. If Q24 cultural practices were used as one type of control measure, what type of cultural practices used?
- 27. Did the management option you used was successful?
 - (1) Yes (2) To some extent (3) No (4) Not aware
- 28. What was the average mango production collected from a tree before this pest in k/g?
- 29. What was the average mango production collected from a tree aftpeshis k/g?____
- 30. Did you get extension service for the managementation managementation and scale?(1) Yes (2) No
- 31. If the Q30...No, do you have interest to take intervention from experts of defes (2) No
- 32. What is your level of commitment? (Low (2) medium(3) high (4) very high
- 33. Please ask if any other comment concerning the pest

Appendix Table2. White mango scale infestation survey data collection format

-					
Orchards /mango farm field/growen name					
Number of Mangoree per observed orchard					
Varity	Improved	Indigenous	Unkr	nown	
Age of mango tree					
Growth stage of mango tree					
Mango tree heigh		_		-	
Location	Latitude	Longitude	Alti	tude	
Planting Methods					
Cropping system					
Pesticideused					
Weed density					
Fertilizationused					
Mango trees canopy densi	Uncrowded				
	Less crowdec				
	Crowded				
	Very crowded				
Mango white scale clusters/le					
Measure severity of infestatio	Free				
-	Minimal				
	Moderate				
	Severe				
	Very Severe				

Appendix Table3. White mango scaledentification key

WMS	Description	Source
Female	Opaque white armor is circular, flat, thin and ofter	Hamon, 2016
	wrinkled.	Tagaki, 2010;
	Exuviae is near the margin, and is yellowibe bown,	Ben-Dov, 2012
	with a median black ridge, forming a dark distinct	
	median line	
Male	Armors are small, white, sides nearly parallel and	
	distinctly tricarinate	
Crawler	Crawlers are deep bright brick red	

Districts	kebele	Aug	Sept	Oct	Nov	Dece	Janu	Febru	Mar	Apr
Assosa	Amba_14	6.8	4.8	3.8	2.7	1.2	7.8	9.8	13.8	16.8
		6.3	4.3	3.3	2.3	1.1	7.3	9.3	13.3	16.3
		6.6	4.6	3.6	2.7	1.2	7.6	9.6	13.6	16.6
		6.6	4.6	3.6	2.6	1.5	7.6	9.6	13.6	16.6
-		6.4	4.4	3.4	2.5	1.1	7.4	9.4	13.4	16.4
	Amba_5	6.4	4.4	3.4	2.4	1.2	7.4	9.4	13.4	16.4
		5.8	3.8	2.8	1.8	0.8	6.8	8.8	12.8	15.8
		6.1	4.1	3.1	2	1	7.1	9.1	13.1	16.1
		6	4	3	1.9	1	7	9	13	16
-		6	4	3	1.8	0.9	7	9	13	16
	Amba_8	4.9	2.9	1.9	0.9	0.4	5.9	7.9	11.9	14.9
		4.6	2.6	1.6	0.8	0.3	5.6	7.6	11.6	14.6
		5.8	3.8	2.8	1.8	0.8	6.8	8.8	12.8	15.8
		5.8	3.8	2.8	1.7	0.8	6.8	8.8	12.8	15.8
-		5.6	3.6	2.6	1.6	0.7	6.6	8.6	12.6	15.6
	Megele_32	5.5	3.5	2.5	1.5	0.7	6.5	8.5	12.5	15.5
		5.4	3.4	2.4	1.3	0.7	6.4	8.4	12.4	15.4
		5.4	3.4	2.4	1.2	0.6	6.4	8.4	12.4	15.4
		5.2	3.2	2.2	1.1	0.6	6.2	8.2	12.2	15.2
		5.1	3.1	2.1	1	0.5	6.1	8.1	12.1	15.1
Bambasi	Mender_47	4.6	2.6	1.6	0.8	0.3	5.6	7.6	11.6	14.6
		4.5	2.5	1.5	0.7	0.3	5.5	7.5	11.5	14.5
		4.4	2.4	1.4	0.7	0.2	5.4	7.4	11.4	14.4
		4.3	2.3	1.3	0.6	0.2	5.3	7.3	11.3	14.3
_		4.2	2.2	1.2	0.6	0.2	5.2	7.2	11.2	14.2
	Mender_48	4.1	2.1	1.1	0.5	0.2	5.1	7.1	11.1	14.1
		4.1	2.1	1.1	0.5	0.2	5.1	7.1	11.1	14.1
		4	2	1	0.3	0.1	5	7	11	14
		5	3	2	1	0.5	6	8	12	15
_		5	3	2	0.9	0.4	6	8	12	15
	Sonika	3.8	1.8	0.8	0.3	0.1	4.8	6.8	10.8	13.8
		3.7	1.7	0.7	0.2	0	4.7	6.7	10.7	13.7
		3.6	1.6	0.6	0.1	0	4.6	6.6	10.6	13.6
		3.5	1.5	0.5	0.2	0.1	4.5	6.5	10.5	13.5
		3.3	1.3	0.3	0.1	0	4.3	6.3	10.3	13.3

AppendixTable4. Monthly average number of white mango scale per leaf

AppendixTable5. Coordinates and elevations of the of survey areas

Woreda name	Kebele	ORCHARD CODE	Latitude	Longitude	Altitude(m)
Assosa	AMBA 14	AK1OR1	10.00701	34.61298	1497
		AK1OR2	10.01646	34.60047	1492
		AK1OR3	9.98912	34.606	1454
		AK1OR4	10.022	34.58699	1475
		AK1OR5	9.99621	34.59629	1480
	AMBA 5	AK2OR1	10.12734	34.60467	1602
		AK2OR2	10.11447	34.60608	1570
		AK2OR3	10.09401	34.59006	1587
		AK2OR4	10.08645	34.57551	1610
		AK2OR5	10.11862	34.59488	1579
	AMBA 8	AK3OR1	10.11835	34.54211	1536
		AK3OR2	10.1057	34.54414	1528
		AK3OR3	10.09086	34.55095	1547
		AK3OR4	10.11086	34.53231	1544
		AK3OR5	10.09138	34.55858	1525
	MEGELE 32	AK4OR1	10.03276	34.52379	1527
		AK4OR2	10.01432	34.52702	1512
		AK4OR3	10.02275	34.51743	1523
		AK4OR4	10.02553	34.52647	1486
		AK4OR5	10.00628	34.53121	1507
Bambasi	Menider 47	BK1OR1	9.89977	34.64738	1450
		BK1OR2	9.88696	34.66182	1457
		BK1OR3	9.8753	34.67765	1442
		BK1OR4	9.86269	34.68318	1457
		BK1OR5	9.86922	34.6505	1457
	Menider 48	BK2OR1	9.89372	34.67865	1447
		BK2OR2	9.88775	34.69193	1453
		BK2OR3	9.86499	34.70295	1453
		BK2OR4	9.85146	34.70106	1451
		BK2OR5	9.85869	34.69024	1463
	Sonika	BK3OR1	9.7852	34.67419	1460
		BK3OR2	9.77894	34.68704	1464
		BK3OR3	9.77061	34.70776	1469
		BK3OR4	9.79433	34.70705	1475
		BK3OR5	9.81785	34.69107	1460

RegionNameBenishanguGumuz, Code06 ZoneNameAssosa

	Least Squares Meansquare 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		
Augusť kebele	6	1.45	0.24	42.91	<.0001		
December* kebele	6	1.24	0.21	36.67	<.0001		
Februay* kebele	6	0.93	0.16	27.64	<.0001		
Januayy*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		
Octobe*kebele	6	3.36	0.56	99.51	<.0001		
Septenber* kebele	6	2.31	0.38	68.4	<.0001		

Appendix Table6. Interaction of month*kebeleeffectsliced by month for white mango scale across orchards during study periods

Appendix Table7. Simple Statistics of Correlation coefficient among WMS cluster, RF, T and RH at Assosa and Bambasi orchards

The CORR Procedure								
Districts=Asso	sa							
4 Variables:	cluster, RF	, T, RH						
Variable	N	Mean	Std Dev	Sum	Minimum	Maximum		
cluster	180	6.59333	4.84754	1187	0.3	16.8		
RF	180	7.38244	9.17447	1329	0	21.89		
T ⁰	180	22.43889	1.67312	4039	20.4	25.35		
RH	180	43.62	19.27809	7852	19.16	72.67		
Districts=Bam	bas							
3 Variables:	cluster, RF	, T, R						
cluster	135	5.07407	4.67005	685	0	15		
RF	135	8.65556	10.00501	1169	0	26.3		
T ⁰	135	25.16056	2.1971	3397	22.1	28.48		

Appendix Table8. Meteorological data of districtor August 2018 to April 2019

		Asso	osa		Bambasi		
Month	RF(cm)	Max T ⁰ (⁰ c)	Min T ⁰ (⁰ c)	RH	RF(cm)	Max T ⁰ (⁰ c)	Min T ⁰ (⁰ c)
August	21.89	29.1	13.3	72.67	26.3	26.5	17.7
September	21.55	25.8	15.8	67	24.36	28.07	18.16
October	16.71	25.7	15.1	66.03	13.38	28.8	18.62
November	1.78	28.1	14.5	47.33	9.42	28.71	18
December	0.15	29.4	14.6	36.5	0.52	30.9	18.2
January	0	31.5	13.9	25.19	0	33.4	19.29
February	0.14	31.4	15.3	25.9	0	33.4	19.7
March	0	32.8	16.9	19.16	0	35.18	21.78
April	4.222	32.9	17.8	32.8	3.92	35.64	20.84

RF=rain fall in cm, Max T⁰ (⁰c)= maximum temperature Min T⁰ (⁰c)= minimum temperature RH=relative humidity Data Source:National Meteorology Agency Benshangul Gumuz Reg Meteorological Service Center

(a) to (e) mango growers, photo were taken from Amba_14; (f) to (h) mango growers, phot were taken from megele_32

Appendix Figure1. Mango growers, assessment

Appendix Figure2. Damage symptom of white mango scale

Appendix Figure. Infestation of white mango scalen upper and lower leaf surface

AppendixFigure4. Severity status of white mango scale

Appendix 55. Experimeental materials

Appendix Figure6. Treatments and spraying acties

BIOGRAPHICAL SKETCH

The author,Bizuayehu Jemaneh Woldesenbeets born inDecember 5,1984 in Oromia National Regional StateArsi administrative zon Sire districts Ethiopia. He attended his elementaryschoolat Haile Abamesa(1990-1995). He also attended his secdary education andjunior educationat SireSeniorSecondary School (SSSB) m 1996-2001. He took the Ethiopian School Leaving Certificatex Emination (ESLCE) in 2001. In 2001, de joined Mekelle University and graduated with Bachelof Science Degree inDry Land crop Sciencein July, 2005 In September 2005, he was employed in Ministry of griculture at Benshangul Gumuz Region Homoshaworeda and servedhere as Crop Production and Protection Expert (20052012). He joined the Benshangul Gumuz Region Plant Health Clinic in 2012 and served there adirector. He joined MSc in Plant Protection Graduate Program Bahirdar University in 2017 majoring in Plant protection