Sudan University of Science and Technology

College of Graduate Studies

The Biology, Ecology and Control of Mango Leaf Gall Midge *Procontarinia matteiana* (Kieffer & Cecconi) (Diptera:Cecidomyiidae) in North Kordofan, Sudan

بيولوجية، إيكولوجية و مكافحة ذبابة تدرن أوراق المانجو

فى شمال كردفان، السودان

A Thesis Submitted in Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Plant Protection (Entomology)

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Declaration

I, the signing here-under, declare that I'm the sole author of the Ph.D. thesis entitled Biology, Ecology and Control of Mango Leaf Gall Midge Procontarinia matteiana (Kieffer & Cecconi) (Diptera, Cecidomyiidae) in North Kordofan, Sudan

which is an original intellectual work. Willingly, I assign the copy-right of this work to the College of Graduate Studies (CGS), Sudan University of Science & Technology (SUST). Accordingly, SUST has all the rights to publish this work for scientific purposes.

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إقرار

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وهى منتج فكري أصيل . وباختياري أعطى حقوق طبع ونشر هذا العمل لكلية الدراسات العليا جامعه السودان للعلوم والتكنولوجيا ،عليه يحق للجامعه نشر هذا العمل للأغراض العلمية .

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توقيع الدارس :..... التاريخ :.....

Dedication

This thesis is dedicated to:

The soul of my father

The soul of Prof. Dawelbait

A. Abdelwahab

The soul of Prof. Ismail

A. Ismail

My Family

The all true Farmers in my country

Hatim

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In the name of Allah, The beneficent, The merciful. All the praise to his Prophet (peace be upon him).

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ABSTRACT

This study was conducted on mango (*Mangifera indica* L.) to provide information on some aspects of the ecology and biology of mango leaf gall midge (*Procontarinia matteiana* Kieffer and Cecconi) in the Sudan. A total of 97 sites in all mango growing States were surveyed. *P. matteiana* infestation in all the surveyed sites revealed that the insect was widely distributed in 100% infested trees in 11 States, while 3 States were found free of the infestation. The highest mean number of galls/leaf was recorded in West Darfur State while the least one was recorded in Gedarif State.

Procontarinia matteiana adults seem to be very active and its presence coincide with the mango new flush. In El Molbus site, North Kordofan State (Lat: 13 01 08 N, long: 30 14 50 E alt 547 *msl*), two peaks of galls were recorded in late September and late November while in Abu Giebaha (Lat: 11 46 13 N, long: 31 23 19 E alt 679 *msl*) in South Kordofan State three peaks of galls in late July, August and November were recorded.

The study of *P. matteiana* oviposition behavior in the laboratory showed that 79% of the adults emerged during 6 p.m to 6 a.m with 1: 1 sex ratio. The fecundity was 365.13±66.359 eggs and the mean of pre – oviposition, oviposition and post – oviposition periods were 5.8±1.12 hours, 2.7±0.407 days and 11.3±0.98 hours respectively. Life cycle duration of *P.matteiana* under field conditions showed high variation ranged from 1.5 to 8.4 months.

In this study, twelve mango cultivars were field screened for *P. matteiana* natural infestation. All the examined mango cultivars showed

different levels of susceptibility to *P.matteiana* under natural infestation in the field. The combined analysis for the four surveyed sites showed that Al Phonse and Tommy Atkins cultivars showed the highest mean of infested branches (%), infested leaves (%) and number of galls/leaf while the lowest means were recorded in Abu-Samaka Khadra and Abu-Samaka Baida cultivars.

The potentiality of the insecticidal effect of the field application of aqueous extracts of Neem (*Azadirachta indica* (A. Juss)) leaves, Argel (*Solenostemma argel* (Del) Hayne) shoots and Usher (*Calotropis procera* (Ait)) leaves powder to control *P. matteiana* was studied. The aqueous extracts of Neem and Usher leaves and Argel shoot at 200, 300 and 400 g/10 litre of water were evaluated against *P. matteiana* in the field for four flush cycles during two years (2011 and 2012). The aqueous extract of Neem leaves and Hargal shoot powder at their highest concentration (400 g/ 10 Litre of water) gave the lowest mean number of gall/20 new leaves after 10 days of treatment. All tested botanicals increased mango yield, when compared with the untreated control. The results of the combined analysis of the two years showed no significant differences in yield for the two seasons. The aqueous extract of Neem leaves powder at 400g/10 litre resulted in the highest yield of mango fruits (56.15 kg/tree). According to these results, the aqueous neem leaves powder extract at 400g/10 litre is recommended to be used for the control *P. matteiana.*

ملخص الأطروحة

أُجريت هذه الدراسة على المانجو لتوفير معلومات عن بعض أنماط بيئية و حيوية حشرة ذبابة تدرن أوراق المانجو فى السودان.أيضاً تمت غربلة حقلية لإثنى عشرة صنفاً من المانجو ضد الإصابة الطبيعية لذبابة تدرن أوراق المانجو (*Procontarinia matteiana* Kieffer and Cecconi). كما بحثت الدراسة التطبيق الحقلى للمستخلص المائى لمسحوق أوراق نباتى النيم و العشر و المجموع الخضرى لنبات الحرجل لمكافحة ذبابة تدرن أوراق المانجو.

تم مسح مجموع 97موقعاً فى جميع الولايات المنزرعة بالمانجو. أظهرت إصابة ذبابة تدرن أوراق المانجو فى جميع المواقع الممسوحة، أن الحشرة توزعت فى إحدى عشر ولاية بنسبة إصابة 100% فى الأشجار بينما وجدت ثلاث ولايات خالية من الإصابة. أعلى متوسط عدد تدرنات/للورقة سُجل فى ولاية غرب دارفور بينما سُجل أقل متوسط فى ولاية القضارف. الطور البالغ لذبابة تدرن أوراق المانجو يبدو أكثر نشاطاً وإرتباطاً مع الدورة الجديدة لنمو أوراق المانجو. فى موقع الملبس (خط طول 30 14 50شرقاً و خط عرض 13 01 10شمالاً و ارتفاع 540 متر فوق مستوى سطح البحر)، ولاية شمال كردفان سجل أعلى عدد من التدرنات فى أواخر شهر سبتمبر و أواخر شهر نوفمبر. فى موقع أبوجبيهة (خط طول 31 23 19شرقاً و خط عرض 11 46 13شمالاً و ارتفاع 679 متر فوق مستوى سطح البحر)، ولاية جنوب كردفان سجل أعلى عدد من التدرنات فى أواخر يوليو، أغسطس و نوفمبر.

أوضحت دراسة سلوك وضع البيض لذبابة تدرن أوراق المانجو فى المعمل أن 79% من الطور الكامل إنبثقت خلال الفترة من الساعة السادسة مساءاً الى السادسة صباحاً بنسبة جنسية 1:1. كان معدل الخصوبة للأنثى 365.13±66.359 بيضة و متوسط فترة ما قبل الإباضة، الإباضة و ما بعد الإباضة كان 5.8±1.12 ساعة، 2.7±0.407 يوم و 11.3±0.98 ساعة على التوالى. أظهرت فترة دورة حياة ذبابة تدرن أوراق المانجو تبايناً كبيراً تحت ظروف الحقل حيث تراوحت ما بين 1.5 الى 8.4شهراً .

فى هذه الدراسة، تمت غربلة حقلية لإثنى عشرة صنفاً من المانجولمعرفة الإصابة الطبيعية لذبابة تدرن أوراق المانجو (*Procontarinia matteiana* Kieffer and Cecconi) .أظهرت

كل أصناف المانجو المختبرة درجات متفاوتة فى قابليتها للإصابة بذبابة تدرن أوراق المانجو تحت الظروف الطبيعية فى الحقل. أظهر التحليل التجميعى للإصابة لأربع مواقع ممسوحة أن صنفى المانجو الفونس و تومى أتكنز سجلت أعلى متوسط من الفروع المصابة، الأوراق المصابة وعدد التدرنات/الورقة بينما سُجلت أقل متوسطات بواسطة الصنفين أبوسمكة خضراء و أبوسمكة بيضاء.
بحثت الدراسة التطبيق الحقلى للمستخلص المائى لمسحوق أوراق نباتى النيم و العشر و المجموع الخضرى لنبات الحرجل لمكافحة ذبابة تدرن أوراق المانجو.تم تقييم فعالية الأثر القاتل للمستخلص المائى لمسحوق أوراق نباتى النيم و العشر و المجموع الخضرى لنبات الحرجل بمعدلات 200، 300 و 400 جرام/لتر ماء ضد ذبابة تدرن أوراق المانجو فى الحقل لأربع دورات نمو خلال عامين (2001 و 2012). أعطى المستخلص المائى لمسحوق أوراق النيم و المجموع الخضرى للحرجل فى أعلى تركيز (400جم/10 لتر ماء) أقل متوسط عدد تدرنات/ 20 ورقة حديثة بعد عشرة أيام من المعاملة.كل المواد ذات الأصل النباتى المختبرة زادت إنتاجية المانجو عندما قُورنت مع الشاهد غير المعامل.أظهرت نتائج التحليل التجميعى للعامين عدم وجود فروقات معنوية فى إنتاجية المانجو لموسمى الإنتاج. أنتج المستخلص المائى لمسحوق أوراق النيم بمعدل 400 جم/لتر ماء أعلى متوسط إنتاجية لثمار المانجو (56.15 كجم/الشجرة).إعتماداً على هذه النتائج يوصى بإستخدام المستخلص المائى لمسحوق أوراق النيم بمعدل 400 جم/لتر ماء لمكافحة ذبابة تدرن اوراق المانجو.

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CHAPTER ONE

INTRODUTION

Mango *(Mangifera indica* L.) is one of the most important fruit trees grown mainly in the tropical and subtropical countries (Pandey *et al*., 2011). Mango introduced to Sudan early in 20th century (Bacon, 1948). The Sudanese mango occupies about 0.03 million hectare of land distributed in 11 States. The total production reached 0.6 million tons in the year of 2012 (Anon., 2012). The mango cultivars that grown in the Sudan are about 57 (Abdalla and Pehu, 1987; Dawoud, 2008). The Sudanese mangoes are usually exported to some the Middle East countries and Europe, and Saudi Arabia is the main market of Sudanese mangoes (Eltoum, 2009). In 2010 mango contributed by 0.6% of the total agricultural exports of the country (AOAD, 2011). In nutritional aspects, both ripe and unripe mango are rich in several vitamins as well as minerals (Paramanik, 1995). Mango also, contains appreciable quantities of iron, vitamin-C, carotene and soluble sugar. Moreover, it provides alot of energy (as much as 74 kcal/100g edible portion) which is nearly equals the energy values of boiled rice of similar quantity by weight (Hossain, 1989).

The low productivity of mango in Sudan is caused by many constraints that limit production, among which low rainfall comes first, since 90% of the area cultivated depend on rainfall. Also, the poor genetic stocks (seeded mango) grown by farmers, which are characterized by low productivity and late maturity. In addition, pests and diseases cause serious damage to the trees (D. H. Dawood, 2014, pers. Comm.).

More than three hundred pest species have been reported to be infesting mango trees worldwide (Péna and Mohyuddin, 1997). The mango in Sudan is considered the main host plants for several insect pests. The most economically important pests are: the Fruitflies *Ceratitis capitata* (Wied), *Bactrocera invadens* Drew, Tsuruta & White, *Ceratitis cosyra* (Walker) and *Ceratitis quinaria* (Bezzi) and the mango leaf gall midge *Procontarinia matteiana* Kieffer & Cecconi (Dawood, 2008). The damage of these pests leads to a clear reduction in fruits quality and quantity. Ploetz (2003) reported 83 different pathogens caused diseases for mango worldwide. . Almost 5% of them have been found damaging the crop to a considerable extent causing severe losses (Giha, 1996, Elhassan and Ali, 2009, Mardi *et al*., 2009 and Mardi *et al*., 2011).

The mango leaf gall midge *Procontarinia matteiana* Kieffer & Cecconi is one of the most common midges those infests mango crop. It was originated from India (Gupta, 1952). *P. matteiana* was first reported in the Sudan in 2004 at WadMedani, by 2007 it reached all the mango plantations in south Kordofan state (Mardi *et al.*, 2010). It is a monophagous insect its larva is the destructive stage produces wart-like galls on leaves which reduce photosynthesis and cause leaf drop. Young trees can be killed and older trees do not recover normal growth after repeated attacks (Gupta, 1952). Some affected countries are trying to control mango leaf gall midge by using some exotic parasitoids as bio-control agents (Srivastava, 1997). Current mango leaf gall midge control is based on synthetic insecticides. In spite of their

effectiveness, they created many problems, like insect resistance, pollution and toxic side-effect to humans (Joubert *et al.*, 2004).

The use of locally available plants in the control of pests is an age-old technology in many parts of the world. Some plants, namely *Derris*, *Nicotiana* and *Ryania*, were used to combat agricultural pests during the prehistoric era. Used widely until the 1940s, such botanical pesticides have been partially replaced by synthetic pesticides that are easier to procure and longer lasting (Dubey, 2011).

To date, different plant products have been formulated as botanical pesticides for large –scale applications for the eco-friendly management of plant pests and as alternative to synthetic pesticides in crop management. These products are cost-effective and have low toxicity to humans and livestock. Therefore, such products from higher plants may be exploited as the eco-chemical and biorational approach in integrated plant protection programmes (Isman and Akhtar, 2007). Recently in Sudan, many research studies were carried out using extracts of different plants as pesticides (Mardi, 2013).

The sudden invasion and the extensive dispersal of mango leaf gall midge in the Sudan especially in the southern parts have caused great concern to farmers, researchers and the administrators.

Objectives of the present study:

Based on the economic importance of the mango crop and hence the economic importance of the mango leaf gall midge the current study was initiated to study the following objectives:

1- Some aspects of the biology and ecology of the mango leaf gall midge.

2- Susceptibly of the some mango cultivars to the mango leaf gall midge.

3- Organic control of the mango leaf gall midge using some botanicals.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 Mango

2.1.1 The genus *Mangifera*

Mango belongs to the Class Dicotyledonae, Subclass, Archichlamydeae, Order, Sapindales and Family, Anacardiaceae (Fernald, 1950). This family consists of 73 genera and 850 species of which the mango (*Mangifera indica* L.) is the most important (Baily, 1949; Fivaz, 1998)

2.1.2 Botanic characters

2.1.2.1 The tree

The mango is an evergreen tree of the tropics which lives, and fruits over a long period of time. It grows up to 10-40 meters but grafted trees remain shorter less than 9-12 meters (Singh, 1987; Fivaz, 1998). Mango tree is erect, dome-shaped, deep rooted and fast growing. It has a large, wide-spreading canopy of dense green foliage which makes it a popular shade tree and it may survive up to 100 years (Mukherjee and Litz, 2009).

2.1.2.2 Roots

The tap unbranched root provides good anchorage for the tree together with other vertical roots. There is a dense mat of feeding roots too, but altogether the rooting volume is surprisingly small (Paull and Duarte, 2011). Fivaz

(1998) reported that the effective root system of an 18 years old mango tree may be observed at 1.2 m depth with lateral spread as far as 7.5 meter.

2.1.2.3 Leaves

Mango leaves are evergreen, alternate, borne mainly in rosettes at the tips of branches and numerous twigs from which they droop like ribbons on slender petioles (Morton, 1987). Paull and Duarte (2011) reported that, the leaves are spirally arranged and come out in reddish flushes that initially hang straight down. Later they take on a more horizontal position and turn green; they stay on the tree for one to 3 years. The new leaves appearing periodically and irregular on few branches at a time, are yellowish, pink, deep-rose or wine-red, becoming dark-green and glossy above, lighter beneath. The midrib is pale and conspicuous and many horizontal veins are distinct (Fivaz, 1998).

2.1.2.4 Flowers

Mango tree flowers after 5-7 years whereas clonally propagated, grafted trees are generally smaller and can flower after 3-4 years (Dawoud, 2008). Inflorescences primordial of mango are initiated at the apical domes of terminal buds and each inflorescence bears both hermaphrodite and staminate flowers (Fivaz, 1998). Cobley (1956) stated that the mango flowers are reddish, pink, or almost white in colour and are carried on large panicles at the ends of the branches. The inflorescence of mango varies in length from 7.6 or 10.2 cm to 50.8 cm or more and may contain between 200 – 4000 flowers while exceptional inflorescences may carry more

flowers than this. Each tree when fully flowering may carry between 600 – 1000 inflorescences. Fivaz (1998) reported that, less than 1% of flowers result in fruits because of pollination failure and premature fruits drop.

2.1.2.5 Fruits

Fruit set take place after pollination and the fruit reach harvesting stage after 3.5 to 5.5 months depending on the cultivar (Litz, 1994).The mango fruit is a fleshy, drupe, variable in shape (nearly round, oval and ovoid-oblong) and the weighing from 200 to 2000 gram. The fruit colour varies between green, greenish yellow, yellow, red, orange or purple depending on cultivar. The fruit possess a single seed (Fivaz, 1998).

2.1.3 Origin, distribution and spread

Mango is native to Southern Asia especially Indo-Burma region (Mukherjee, 1971; Malo, 1985). It is one of the first fruits to be cultivated by man. It has been grown in India for more than 4000 to 6000 years (Hill, 1952; Snyman, 1998). Mango was commonly grown in East Indies before the early visits of Portuguese who apparently introduced it to West Africa early in 16th century and also into Brazil (Pope, 1929 and Morton, 1987). Mexico acquired mango from West Indies in 19th century and also from Philippines (Popenoe, 1920). By the 1690 mango reached England and grown in green houses (Srivastava, 1998). Early in 16th century mango reached to the rest of the world, reaching America in 18th century (Snyman, 1998). Budded trees of mango were imported in Egypt from Bombay for the first time in 1825. Also, mango was found growing in Lebanon in the middle 18th century, in

Southern Italy 1905 and in Queensland in about 1870 (Burns and Prayag, 1916). Mango has been grown in the Sudan since 1904 (Bacon, 1948). Due to swift and efficient means of transportation, mango found its way to all the tropical and subtropical countries (Snyman, 1998).

2.1.4 Climatic requirement

Mangifera species are mostly distributed below 300 m, but can occur 600-1900 m above the sea level (Lawrence, 1955). Mango thrives well in areas where annual mean temperature ranges between 24 – 27 C^o (Budhwar, 2002). The best climate for mango has rainfall of 750 – 2500 mm in the four summer months (Morton, 1987). Mangoes will grow in areas with an average annual rainfall of less than 300 mm, provided other climatic conditions are favorable. However, unless such low rainfall is supplemented by irrigation, the trees will produce very few fruit. At the other extreme, mangoes will also grow very well in areas with an average annual rainfall of 2500 mm or more (Singh, 1977). The mango tree can grow on a wide range of soil types, providing that they have good drainage with no hard calcareous layer in the subsoil (Morton, 1987). Mostert and Abercrombi (1998) stated that rich, deep, loam or sandy loam, medium textured soil that is not too heavy or wet certainly contributes to maximum growth. For healthy mango orchard the water table in all seasons should be below 180 cm. A pH of 5.5 – 7.5 has been found suitable (Singh, 1960).

2.1.5 Economic importance

The mango is grown in more than 111 tropical and subtropical counties (Snyman, 1998). In 2011, the FAO estimated world production of mango, mangteens and guavas at 39.9 million tones, of which 77.7% is produced in Asia, 10.1% in Africa, 7.6% in North and Central America and 5.6% in South America. The biggest mango, mangteens and guavas producing country is India where planted area totals 2.3 million hectare. The total mango production area in Africa in 2010 was 0.61 million hectare, 4.8% of which was in the Sudan (FAOSTAT, 2011). In Africa, Sudan is the second mango producing county after Nigeria (FAOSTAT, 2013). The approximate Sudanese mango areas are 29416.7 hectare distributed in 11 States which include: South Kordofan, North Kordofan, West Kordofan, Sinnar, Northern, Blue Nile, Gadaref, Gezira, South Darfur, West Darfur and Middle Darfur, Kassala, River Nile and Khartoum. Total yield was estimated about 635,000 tons, most of which in South Kordofan and West Darfur (Anon., 2012). The reported mango cultivars grown in the Sudan are about 57 and they are divided in three groups: true Indian cultivars, Egyptian seedlings cultivars of Indian origin (Zibda, Alphons, Mulgoba and Hindibesinnara) and Sudanese seedlings cultivars of Indian origin (Shendi, Taimour, Nilam, Maboraka, Debsha and Abusamaka) (Abdelalla and Pehu, 1987; Dawood, 2008). The Sudanese mangoes are exported to some Middle Eastern countries, Europe and Saudi Arabia (Eltoum, 2009). Exports of mango reached $0.65 million in 2010 which represent 0.6% of the total agricultural exports (AOAD, 2011).

2.1.6 Nutritional Value

Mango is consumed as fresh mature fruit, green, dried, powder, juice and processed products such as jam (Snyman, 1998). Mango is high in beta-carotene, a precursor of vitamin A and a rich source of vitamin B complex (Barreto *et al.*, 2008). Morton (1987) reported that the food value per 100g of ripe mango flesh contains: Calories, 62.1-63.7, protein 0.36-0.40 g, fat, 0.30-0.53 g, carbohydrates 16.20-17.18, fiber, 0.85-1.06 g, Calcium, 6.1-12.8 mg, phosphors 5.5-17.9 mg, Iron, 0.20-0.63 mg, and Vitamin A (carotene), 0.135-1.872 mg.

2.1.7 Pests and diseases

More than 260 species of insects, 17 species of mites and 26 species of nematodes have been reported to infest mango trees worldwide (Péna and Mohyuddin, 1997). The most economically important pests are: hoppers, mealy bug, gall midges, fruitflies, scale insects, shoot borers, leaf webbers and stone weevil (Veeresh, 1989, Srivastava, 1997 and Péna and Mohyuddin, 1997). In the Sudan, more than 28 species of insects belong to 7 orders were recorded to attack mango. Almost 14% of them have been found damaging the crop to a considerable extent causing severe losses and, therefore, may be termed as major pests of mango (Schumutterer, 1969, Mardi *et al.*, 2010 and Mahmoud *et al.*, 2012). Dawood (2008) stated that the Fruit flies *Ceratitis capitata* (Wied), *Batrocera invadens* Drew, Tsuruta & White, *Ceratitis cosyra* (Walker) and *Ceratitis quinaria* (Bezzi)) and the mango leaf gall midge *Procontarinia matteiana* Kieffer & Cecconi are the most economically important insect pests of Sudanese mangoes.

All parts of the mango plant suffer from several diseases at all stages of its life. Ploetz (2003) reported 3 bacterial, 52 fungal, 25 miscellaneous diseases and 3 pathogenic nematodes on mango throughout the world. In the Sudan, diseases reported on mango includes: malformation (*Fusarium mangiferae* (Britz, Wingfield and Marasas)), anthracnose (*Colletotrichum gloeosporioides* Penz and Sacc), mango die back and gummosis (*Botryodiploidia theobromae* Pat.) and mango die back (*Neofusicoccum mangiferae* (Syd. and P.Syd.) Slippers and Phillips) (Giha, 1996, Elhassan and Ali, 2009, Mardi *et al*., 2009 and Mardi *et al.,* 2011,).

2.2 The family Cecidomyiidae

Cecidomyiidae are a large family of nematocerous Diptera it consists of 6131 species. It is best known as plant gall makers. Included in this family are some of the most destructive pests of grains, fruits, and vegetables as well as important predators of aphids, scale insects and mites. Larvae show a great range of feeding habits, including fungivory, herbivory, and predation on various arthropods (Gagne, 2010). In India, where the highest diversity of mango occurs, about 20 species of midges are reported to infest flowers, leaves and twigs of mango plant (Srivastava, 1997).

2.2.1 Mango leaf gall midge (MLGM)

2.2.1 .1 Taxonomic status:

Order: Diptera

Sudorder: Nematocera

Family: Cecidomyiidae

Genus: Procontarinia

S.N: *Procontarinia matteiana* Kieffer and Cecconi,1906.

2.2.1.2 Distribution

Procontarinia matteiana Kieffer & Cecconi is one of the most common midges that infest mango trees. It was originated from India (Srivastava, 1997). It is also reported in Indonesia, Mauritius, South Africa, Trinidad, Oman, Iran, Pakistan and United Arab Emirates (Urich. 1921, Jhala *et al.*, 1987, Sankaran and Mjeni, 1988, Askari and Radjabi, 2003, Howarth, 2006 and Rehman *et al.*, 2013).

Procontarinia matteiana was first reported in the Sudan in 2004 at WadMedani (M. A. Ahmed, 2010, pers. Comm.). By 2007 it reached all mango plantations in south Kordofan State (Mardi *et al.*, 2010). Satti (2011) stated that *P. matteiana* is one of the alien insect species, believed that it was accidentally introduced to Sudan with the mango seedlings, e.g., cv. Tommy Atkins.

2.2.1 .3 Host plants, Nature of damage and economic importance

Procontarinia matteiana is a monophagous insect attacks the mango tree. Its larvae are the destructive stage (Gupta, 1952). Githure (1999) stated that, presence of galls predominantly on the mango leaves and occasionally on fruits is the most characteristic symptom of Mango gall midge infestation. The galls can be distinguished into two types depending on different mango

cultivars: true galls which appear in forms of small round swelling and Pseudo galls which are tiny indentation on leaves (Githure *et al.*, 1998).In some cases in India, infested leaves suffer deformation and heavily infested shoots have almost no inflorescences resulting in low yields of fruits (Srivastava, 1997). In heavy populations, leaves were found to curl up resulting in dieback of whole branches or crinkled and drop prematurely (Augustyn *et al.*, 2013). *P. matteiana* injury to mango plant can be manifested through reducing of leaf surface area responsible for capturing energy from tree growth and forming fruits (Grové *et al.*, 2002). Galls caused by *P. matteiana* were responsible for increasing in bacterial black spots, *Xanthomonas campestris* pv. *mangiferaeindicae* on mango leaves, also anthracnose, *Colletotrichum gloeosporiodes* have been found to colonize the galls (Van Zyl *et a.l*, 1988).

2.2.1 .4 Developmental Stages

2.2.1 .4 .1The eggs

Eggs of *P. matteiana* are laid as a cluster on the underside or rarely on the upper side of mango young leaves embedded in the soft tissue (Srivastava, 1997 and Askari and Bagheri, 2005). The oviposition sites are marked with a reddish small spots (Githure, 1999). The incubation period of eggs under field conditions in Iran and India lasts for 2.46±0.294 and 3-4 days respectively (Srivastava, 1997 and Askari and Bagheri, 2005).

2.2.1.4 .2The larvae

After hatching, the first instar larvae burrow into the leaves inducing gall formation (Botha and Kotzé, 1987). The number of larvae that are able to enter to the leaf tissue and produce gall is much lower than the number of total laid eggs due to the high mortality of larvae from emergence to entrance to the leaf tissue (Askari and Bagheri, 2005). There is only one larva in each gall completes its lifecycle (Githure, 1999). The mature larva is cylindrical and slightly flattened about 1 mm; yellowish and difficult to detect (Strydom, 2009). The total developmental period takes about two months to almost a complete year in the larvae of the same batch (Gupta, 1952, Srivastava, 1997 and Askari and Bagheri, 2005).

2.2.1.4.3The pupae

The pupa is about 2 mm in length, at first it seen yellow, later the head and thorax turn black (Strydom, 2009). Pupation takes place in the gall the pupal stage takes 8 to 9 days (Srivastava, 1997 and Askari and Bagheri, 2005).

2.2.1.4.4The adult

The adult of *P. matteiana* is about 2 mm long with a grey to yellow body, grey wings covered with small hairs (Strydom, 2009). The adult of gall midge emerge from the gall through an opening in the middle on the underside of the leaf (Askari and Bagheri, 2005). The adult is free living moves about by flying. Harris and Schreiner (1992) reported that, adult of male and female of *P. matteiana*, exhibit different terminalia morphology, which enables differentiation of adult sex. The male terminalia have a long,

robust aedeagus, with sensory pores on distal section; gonocoxite with well developed setose, median basal lobe; hypoproct short. Female terminal cerci broad, relatively short and fused medially. The life span of adult in which the fly has to complete the ovipositoin is about 48 hours (Gupta, 1952 and Srivastava, 1997).The sex ratio is about 1:1 (Askari and Bagheri, 2005).

2.2.1.5 Population dynamics

The population dynamics of *P. matteiana* was studied by some researchers in many countries. Gupta (1952) observed that there are three generations in a year in north India the larval period of the first generation lasts for about 2-12 months. Since there are overlapping broods, the adults emerge and females oviposit in a continuous cycle. In South India and Oman the midge is multivoltine (Sankaran and Mjeni, 1988, Srivastava, 1997, Kaushik *et al.*, 2012). In Mauritius the life cycle occupies about two months and the midge is most common from November to June (Srivastava, 1997). The Mango gall leaf midge has two generations per year. In South Africa, the first generation completes its lifecycle in three months maturing in February and March and second generation completes its lifecycle in six to seven months and the adults appear in September and October (Botha and Kotzé, 1987). High humidity improved the larval and pupal survival capacity and more galls were formed (Grové *et al.*, 2002, Askari and Radjabi, 2003, Mardi *et al.*, 2010).

2.2.1.6 Varietal evaluation

Although levels of susceptibility among the different varieties are varied, *P. matteiana* seem to attack all mango varieties in all infested areas throughout the world. Jhala *et al.,* (1987) observed the average percentage of leaves of three mango varieties damaged by *P. matteiana*. It was observed that the cultivar Alphonso, Kesar and Rajapuri had 47.7, 27.2 and 25.8 infestation, respectively. Rao *et al.,* (1991) did field studies in India and found that the variety Alamur- Baneshan was the most resistant by 7.9% infestation while Panduri, Neeluddin, Olourn and dashehari showed 14.8%, 15.2%, and 17.7% infestation, respectively. It was also found that the cultivar Phirangi-Ladura was highly susceptible with 58.7% infestation. Patel *et al.,* (2011) screened fifteen mango cultivars for their field reaction against *P. matteiana*. They categorized Totapuri as least susceptible cultivar with 9.9% of infested leaves and Alphonso cultivar as the most susceptible one with 52.1% infested leaves. Githure *et al.,* (1998) studied the susceptibility of eleven mango cultivars by quantified leaf area, number of galls per leaf, gall density and gall diameter of each. The cultivars includes: Heidi, Tommy Atkins, Sabre, Zill, Peach, Kensington, Haden, Kent, Keitt, Irwin and sensation to galling by *P. matteiana* .The results showed that sensation was highly resistant whereas psudogalls are found on Kent and Irwin. The remaining cultivars showed some level of susceptibility and Heidi appeared to be most susceptible. Augustyn *et al.,* (2010) proved that certain terpenes such as α-pinene, β-pinene and camphene which emitted by mango flush are associated with the susceptibilities of the cultivars to gall fly infestation.

2.2.1.7 Control Measures:

2.2.1.7.1 Cultural control

Prashad (1968) advocated that the use of resistant varieties, and kept field ground in a state of clean cultivation may reduce the *P. matteiana* infestation. Also, it is advisable to collect and destroy the affected leaves, to prevent the population build up of the pest.

2.2.1.7.2 Natural enemies:

A little is known about the arthropod community associated with different gall- inducing Cecidomyiidae living on species of Anacardiaceae, with except for extremely limited with galls induced *P. matteiana* and *P. mangiferae* (Raman *et al.*, 2009). Whitwell (1993) stated that, information on predatory arthropods associated with gall- inducing Cecidomyiidae is also limited to a few general predators; Formicidae (Hymenoptera) in India sub continent and two general predators; Miridae (Heteroptera) in the Caribbean. Sankaran and Mjeni (1988) reported that, the parasitoids of *P. matteiana* in India include the following hymenopterous: *Chrysonotomia pulcherria* (Kerrich), two undescribed *Chrysonotomia* ssp, two undescribed *Tetrastichus* spp, *Synopes procon* Austin, *Inostemma ocular* Austin, *Trichacoides indicus*, *Ormyrus* sp, *Eupelmus* sp. nr *testaceiventris* (Motsch) *Gastrancistrus* sp and *Aphanogmus* sp. Herting (1978) reported a *Tetrastichus* spp in Mauritius. Kerrich (1970 and 1974) described *C. pulcherrima* from Africa. Biological control using parasitoids was investigated in Oman by introducing and releasing *C. pulcherrima*, C.sp near

pulcherrima, *E.*sp near *testaceiventris, ormyrus* sp and *I. ocular* (Sankaran and Mjeni, 1988).

2.2.1.7.3 Chemical control

A number of products, used singly or in combinations, have been tested for control of *P. matteiana*. Jhala *et al.*, (1990) studied filed efficacy of 8 insecticides against *P. matteiana* and found that the effectiveness of insecticides in descending orders were 0.3% Phosphamidon 0.04% Monocrotophos, 0.03% Dimethoate, 0.05% Quinalphos, 0.04% Malathion, 0.07% Endosulfan, 0.03% Methyl parathion and 0.035 Methyl-O-demeton. Kasi and Rao (1991) tested chemicals against *P. matteiana* and they found that 0.05% Monocrotophos to be most effective followed by 0.05% Dimethoate and 0.05% Phosphamidon. In South Africa Daneel *et al.*, (2000) reported that an excellent control of *P. matteiana* was obtained with Lebaycid (fenthion EC 500g/L @ 100ml/100 Litre of water) and Lannate (methomyl SP 200g/L @ 20ml/100 Litre of water) + Sunspray 7E (medium narrow range mineral oil EC @ 500ml/100 Litre of water) while Azodrin (monocrotophos EC 500g/l @ 50ml/100 Litre of water) was markedly less effective. Products were applied after harvest, coinciding with the first major flush. The same authors stated that, the application of effective insecticides as soon as damage is noticed will reduce the *P. matteiana* population drastically. Surround WP (a non toxic kaolin product) alone and in combination with sulfur and lime sulfur gave an effective control against mango early occurring season pests which include *P. matteiana* (Joubert *et*

al., 2004). Strydom (2009) recommended one spray per season and also he found Lebaycid tend to cause mealy bug repercussions.

2.3 Botanical Insecticides:

The research for new insect pests control strategies, using substances of plant origin (botanicals), has recently attracted several scientists throughout the world. During the last 30 years, intensive and pioneering research on neem and similar products has been established in the Sudan and other parts of the world.

2.3.1. Neem (*Azadirachta indica* (A. Juss))

Neem belongs to the Mahogany family (Meliaceae). It ranks first in the list of 250 potential plant sources for bioinsecticides, mainly because of its very little requirement of water and nutrients (Stoll, 2000). In the Sudan, fruits are usually produced during the period from June to August (Vogt, 1995).

More than 100 compounds have been isolated from the various parts of the neem tree. The most active principal of neem belongs to the group of tetranotriterpenoids, *viz.* azadirachtin (AZ), the principal active ingredient against insects, followed by less biologically active chemicals, such as vilasinine, salanin azadirachtol and meliacarpin (Schumtterer, 1995). The amount of azadirachtin in the neem kernerls is influenced by a number of factors such as humidity, exposure to the sun light, storage, seed drying, pH and method of extraction (Schnieder and Ermel, 1986). Aissaiwi (1999) and Khidir (2001) studied the effect of temperature, pH and photodegradation of

neem extracts. Those authors reported that neem extracts are heat sensitive and the extract components decomposed when exposed to 55° C.

Several authors studied the mode of action of neem extracts on insect pests, diseases and nematodes. Coudriet *et al.,* (1985) and Siddig (1986) reported that neem seed extract (NSE) repelled the whitefly, *B.tabaci* in cotton and potato. Also, lowery and Isman (1993) reported the antifeedant effect of neem oil (N.O) against strawberry aphid *Chaetosiphon fragaefolli* (Cockerell). On the other hand, neem extracts showed inhibition of the growth, reproduction, oviposition and hatchability of homopteran pests (Saxena and Besit, 1982 and Schummtterer, 1990).

The insecticidal effect of neem extracts was weak to moderate, compared with synthetic insecticides. Ermel *et al.,* (1986) found that the insecticides performance (in terms of immediate mortality) of neem products against most insect pests is not as effective (potent) as the synthetic insecticides. The authors stated that, for the equivalent, higher doses are required. The improved extract (mixture of methanolic and aqueous extract sinergized by 0.1% of piperonyl butoxide) gave comparable result with cypermethrin for the control of *Plutella xylostella* .L (Sombatsiri and Temboonkeat, 1986). Rashid *et al.,* (2012) reported that, application of neem oil at 2% and neem water extract at 3% on cotton field reduced the populations of *Bemisia tabaci, Amrasca devastans, Thrips tabaci, Earias insulana, Pectinophora gossypiella* and *Helicoverpa armigera* compared to untreaded control. In Nigeria neem kernel powder mixed with fine -sand at 1:1, was effective in

reducing the symptoms and impact of pink stalk-borer (*Sesamia calamistis*) on sorghum grain yield (Okrikata and Anaso, 2008) .

In Sudan, several workers studied the insecticidal effect of neem extract. Satti (1997) reported that all neem formulations significantly reduced the insect pests in melon, particularly, *B. tabaci* and *A. gossypii*. Moreover, Siddig (1991) concluded that the neem leaf and seed extracts reduced the number of *B. tabaci* and *J. lybica* and increased the marketable potato yield. On the other hand, Elsiddig (1998) studied the effect of different neem preparations on termite *Microtermes thoracalis* (Siost) infesting groundnuts. The author found that all neem treatments (neem leaf powder (NLP), neem seed kernel powder (NSKP), neem seed cake powder (NSCP) and neem seed kernel oil (NSKO)) were effective in preventiving and/or reducing the damaged caused by termites to groundnut up 80 day after germination. The results indicated that neem preparations especially neem seed cake powder (NSCP) may slightly promote the growth of groundnut and increased the yield. Mohamed (2002) recommend the use of neem seed kernel water extract at 40 gm/L of water under field conditions to control *A. gossypii* and powdery mildew fungal disease on Okra during winter season.

In addition to insecticidal effect, NSKE at 5% and N.O at 3% showed superior antifungal effect in controlling the powdery mildew *Erysiphe polygoni*, of black gram, in India and increases grain yield (Rettinassababady *et al*., 2000). In the Sudan, Diab (1998) reported that the Et.OH-extract of neem seed Kernel (NSK) showed an effect comparable to the fungicide Byleton (benomyl) 50% WP in controlling powdery mildew in

cucurbits. Al-Hamzi (2013) found that neem seeds and leaves ethanolic extract at 1:1 v:v reduced the growth of the fungi *Pythium aphanidermatum, Alternaria alternata, Bipolaris sorokiniana, Fusarium oxysporium, Helminthosporium sp. and Thilaeviobsis sp* by 21.74%, 33.2%, 40.27%, 57.26%, 38.56% and 23.40% respectively. In *In vitro* Neem oil extract at 0.5% reduced the growth rate and sporulation of *Penicillium verrucosum* and *P. brevicompactum* (Mossini *et al*., 2009).

In Ghana, 53.3% reduction in *Fusarium moniliforme* incidence on tomato seeds was reduced when treated seeds with water extract of neem seeds at 50% (w/v) (Fuseini, 2010).

2.3.2 Sodom apple (*Calotropis procera* (Ait)), "Usher"

Sodom apple, *Calotropis procera* (Ait) is a member of family Ascelepiadaceae locally known in the Sudan as "Usher" (Braun *et al*., 1991). According to Al-yahya *et al* (1986), *C. procera* contains sterols, triterpenes, tannins, flavonoid oils, coumarins, volatile bases, glucosinolates and anthraquinones. Pant and Chaturvedi (1989) isolated new triterpenes from *C. procera,* which were identified as taraxasteryl acetate. Ahmed (1998), in Sudan, reported that usher Ethanolic extract of leaves flowers and roots contain alkaloids, cardenoloids and tannins.

Studies on usher insecticidal potentialities have received little attention, when compared with neem. These studies were carried out in different countries. Patil *et al.,* (1993) evaluated the insecticidal properties of various plant extracts against *Amsacta moorei* Butler; in Gujarat, India, during the

rainy season. Extracts of *C. procera* gave higher mortality than that of neem within 24hours but after 48 hours, the effect became similar to that of the neem. In Pakistan, Khan and Siddiqui (1994) reported that *C. procera* leaves extracts in benzene, chloroform and methanol showed greater insecticidal activity against the cabbage butterfly, *Pieris brassicae* L. (Sarhad) when compared with whole plant and the garlic rhizome extracts. In the laboratory aqueous extract of *C. procera* leaves and flowers showed significant toxic effect against termite and the flower extract caused more mortality than the leaves extract (Farmanullah, *et al*., 2004).

Meshram (1995) evaluated the potentiality of leaf extracts of 32 medicinal plants against teak skeletonizer, *Eutectona machaeralis* (Walk). The most effective extract, as an antifeedant, was that of *C. procera*, followed by *Datura metel* and *A.indica*.

In the Sudan, Ahmed (1998) reported that Usher leaf, flower and bark extracts showed promising effects against *Henosepilachna elatrii* (Rossi) under laboratory conditions. These effects are found to be antifeedant and/or repellent and growth regulatory effects and the leaf Et.OH-soxhlet- extract was the best one.

Sharma (1983), in India, indicated that the flower- extract alone, and in combination with HCH (BHC) or Malathion, greatly inhibited the rate of increase in *Rhizopertha domimica* (Fab) population in wheat. Ahmed (1993), in the Sudan, reported that the leaf- and flower- powder, aqueous and alcoholic extract decreased the larval rate of feeding and adult emergence of *T.granarium*. Taha *et al.,* (2011) stated that *C. procera* when applied at

100gm powder/tree against immature stages of Green pit scale insect (*Asterolicanium phoenicis* Rao.) on date palm gave good result extended for 8 to 10 weeks after application. Ahmed *et al*., (2006) found that aqueous extract of *C. procera* has a repellent and antifeedent effects against the melon lady bird (*Henosepilachana elaterii* (Rossi)). Mohamed (2002) stated that the soxhlet ethanolic extract of *C. procera* leaf when used under field conditions alone and in combination with Endosufan 50%, reduced the number of White fly (*B.tabaci*) on Okra for 48 hours followed by a rapid increase in population.

Zureen and Khan (1984) tested usher latex at 0.033%, 0.33% and 3.33% (V/V). The three concentrations were highly toxic against the root knot nematode, *Meloidogyne javanica*, and were equivalent to 200-400 ppm of Temik (aldicarb) 10G. Also, the leaves extracts of *C. procera*, *A.indica* and *Ricinus communis*, alone or in paired combination, showed reduction in nematode population, and increased the tomato plant growth (Zaki and Bhatti, 1989). Singh *et al*., (1993) found that the aqueous leaf- extracts (AqLE) of some medicinal plants, including *C. procera* and *A.indica*, resulted in good control of banana fungal diseases. The Okra seeds, when soaked in latex extract of *C. procera* significantly reduced the root knot nematode *Meloidogyne javanica* development. The plant growth increased as a result of increasing the concentration of the extracts and the dipping duration (Wani *et al.*, 1994).

2.3.3. Argel (*Solenostemma argel* (Del) Hayne), "Hargal"

Argel (*Solenostemma argel* (Del) Hayne), or locally called "Hargal" relates to the family Asclepiadaceae. It is an erect perennial under-shrub that reaches up to 1.5 - 2 feet in height with numerous branches carrying opposite decussate leaves. The leaves are lanceolate to oblong-ovate, with acute or sub–acute apex and cuneate base. The leaf petiole is thick (Elkamali and Khalid, 1996). Fruits are solitary follicles, thick, ovoid, lanceolate, acuminate at the apex and they are very hard with dark purple colour. Seeds are turgid, ovoid and they are channel down at one face; they are minutely tuberculate bearing an apical tuft hair (Andrews, 1952 and El Kamali, 1991).

Solenostemma argel is a desert plant, which is of wide spread in Central and North's parts of the Sudan, Egypt, Libya, Chad, Algeria, Saudi Arabia and Palestine. However, Sudan is regarded as the richest source of this plant (Organgi, 1982).

Elkamali, (1991), conducted a phytochemical screening of argel (*Solenostemma argel*) constituents of the leaves, stems and roots at the pre-flowering and flowering stages. Results showed presence of a number of chemical groups (Flavonoides, tannins, sterols, triterpens and saponins) and the major constituents were saponins. Bioactive effects of Hargal plant are mainly attributed to the presence of varieties of bioactive organic substances mainly (teroenes, pergenine ,glycosides, alkaloides , and sterols) (Al-Doghairi *et al.*, 2004). The insecticidal activity of *Solenostemma argel* was investigated by many researchers in many countries. Hag-Eltayeb *et al.*, (2009) reported that argel aqueous extract was effective in control of the

larvae of mosquitoes *Culex spp* and *Anopheles spp* under laboratory conditions. Argel water extract when tested under laboratory conditions against faba bean beetle *Burchidius incarnatus* at 2.5%, 5% and 10% gave 60.1%, 66.7% and 75.8% mortality of the adult insects respectively (Bahkiet and Taha, 2009). In the laboratory, aqueous and organic extracts showed mortality, repellency and anifeedant effects against cow pea beetle *Callosobruchus maculates* (Elkhatim and Abdelbagi, 2014). Sidahmed *et al*., (2009 a) found that aqueous filtrates of Argel plant parts at 10% conc gave 100% mortality of workers and soldiers of the cotton soil termite (*Microtermes thoracalis* Sjost) under laboratory conditions.Also, Sidahmed *et al*., (2009 b) recommended spraying of Argel shoot water filtrate at 1ounce/6liter of water/tree to control white scale insect (*Parlatoria Blanchardii* Targ.) on date palm. Argel application in soil at 100gram powder/tree is recommended as an effective treatment to control the green date palm pit scale insect (*Asterolicanium phoenicis* Rao.) with a positive effect on date palm yield (Eldoush *et al*., 2011). Mardi and Suliman (2014) found that the aqueous extract of Argal shoots at 40g/L of water gave comparable performance to the synthetic insecticide Alpha-cypermethrin 10%. It reduced the population of whitefly and the percentage of tomato yellow leaf curl virus (TYLCV).

Abd El Hady *et al* (1994) reported that three out of four of methanol/ water extraction fractions of arial parts of *Solenostemma argel* gave significant negative inhibition effect on *Aspergillus niger* (Tieghem) which ranged between 5 to 19 mm under laboratory conditions. Also, Sulieman *et al.*,

(2009) reported that aqueous extract of hargal plant reduced the mycelia growth of *A.niger* under laboratory conditions and the effect increased with the increase in concentration. Mardi (2013) recommended the use of Hargal shoot powder at 24 g/ kg seeds as seed dressing against *Aspergillus* crown rot disease on groundnut in the rainfed sector in Sudan. Mardi (2014) found that priming of pearl millet seeds in hargal shoot powder aqueous extract at 30 g/ litre of water for 8 hours, was effective to control downy mildew disease under traditional rain-fed conditions.

CHAPTER THREE
MATERIALS AND METHODS

3.1. Ecological studies:

3.1.1. Geographical distribution:

A survey was conducted on mango new leaves that had emerged in October 2011, to study the geographical distribution of *P. matteiana*. A total of 97 sites were selected randomly from all mango grown States across the country. Three orchards were chosen randomly from each site. Five mango trees were selected at random basis from each orchard. From each tree, ten branches were chosen randomly to calculate the mean infestation percentage. The mean number of galls per leaf was also recorded in 10 randomly selected new leaves from each site. Global point system (GPS) was used for recording sites coordinates. In addition, Geographical Information System (GIS) was used to make distribution map for *P. matteiana* in the country.

3.1.2. Seasonal abundance:

This study was conducted from January 2011 to December 2013, at two sites: El Molbus (Lat: 13 01 08 N, long: 30 14 50 E alt 547 *msl*), North Kordofan State (plate 1) and Abu Giebaha (Lat: 11 46 13 N, long: 31 23 19 E alt 679 *msl*), South Kordofan State, Sudan (plate 2). The study was conducted on the largest Sudanese grown mango cultivar “Kitchiner”. Ten mango trees with new flush were selected randomly every 15 days. From each tree, ten new leaves were picked randomly at about 1.5 m height above the ground. The percentage of infested leaves and the number of galls per leaf were counted.

Plate 1. The study orchard at El Molbus site, North Kordofan State.

Plate 2.The study orchard at Abu Giebaha site, South Kordofan State.

3.2. Biological studies:

3.2.1. Some aspects of *P.matteiana* biology:

Studies were carried out at ElObeid Research Station (ERS) to determine the emergence time of the adult and the sex ratio of *P.matteiana*, during November/ December 2012 under laboratory conditions. The mean temperature and relative humidity were recorded during the studies by using the Max-Min Thermo Hygro & Clock –ISOLAP Germany.

3.2.1.1 Emergence time of the adult.

The insects were reared at an average temperature of 26 ±2 °C during November and 25±3 °C during December with mean relative humidity (R.H) of 42.7% to 49.4% and 42.3% to 51.7% respectively. Infested mango leaves with late pupae were collected from the field and kept in glass Petri - dishes (19 cm in diameter) containing moistened filter paper until the adult emerged.

3.2.1.2 Ovipsition, fecundity and adult longevity

To study the pre-oviposition period, oviposition period, post-oviposition period, fecundity, adult longevity, a newly emerged pair of *P.matteiana* was placed in small cage made of plastic drinking water bottles. The upper and lower parts were removed. The narrower part of the plastic bottle was covered with filter paper and fitted over a kilner jar and kept standing upright. The upper end was covered with muslin cloth to facilitate aeration and was closely tight by a rubber band to prevent insect escape (Plate 3). Tender shoots of mango, *M. indica*, were daily introduced into the cages and kept fresh by dipping the lower end in water contained in kilner jars. Insects were fed aqueous solution of 5 % sugar soaked in a cotton wig and placed on

the filter paper near the tender shoot in the cage. The tender shoots were removed and inspected daily every morning using a microscope (M6C-10/USA). The leaves containing eggs were removed from the tender shoots and transferred to glass Petri dishes (19 cm in diameter) each containing moistened filter paper until eggs count made.

3.2.2.Life cycle:

This study was carried out at El Molbus, North Kordofan State, Sudan (Lat: 13 01 08 N, long: 30 14 50 E alt 547 *msl*) to study the field life cycle of *P. matteiana*. Twenty healthy mango seedlings with newly developed leaves were placed in mango- infested orchard for 24 hours, so the adult could lay eggs on the new leaves of seedlings. The seedlings were placed in a field cages until signs of oviposition appeared on the leaves. Leaves from infested seedlings were tagged in the same cages. The tagged leaves were inspected daily for developmental stages of *P .matteiana*.

Plate 3. Cage for rearing *P. matteiana*.

3.3. Susceptibility studies:

New flushes of mango leaves that had emerged in November 2012 were sampled. The study was conducted at four sites, El Molbus and Errhad, North Kordofan State, Abu Gebiaha, South Kordofan State and Sinnja Sennar State, Sudan. The cultivars studied were Taimour, Dabsha, Abu-Samaka Baida, Abu-Samaka Khadra, Galbaltour, Kitchener, Baladia, Al Phonse, Shendi 1, Zibda Baida, Keitt and Tommy Atkins.

3.3.1. Sampling:

From each site, one orchard was chosen randomly. Ten mature trees from each above cultivar were tagged at random basis to study the following parameters:

3.3.1.1. Infested branches (%).

Ten branches from each tree of each cultivar were inspected randomly for presence and absence of galls on their leaves. The mean percentage of infested branches was calculated for each cultivar.

3.3.1.2. Infested leaves (%).

The mean percentage of mango infested leaves/branch was calculated by ranomomly collected ten infested branches from each tree of each cultivar. The number of leaves with gall or galls was recorded as a percentage.

3.3.1.3. Number of galls/leaf:

Hundred infested leaves were collected randomly, ten from each tree of each cultivar. The number of galls on each leaf was counted for the four sites.

3.3.1.4. Gall diameter (mm):

Ten leaves from each tree of each tested cultivars were collected randomly. Ten galls per leaf were randomly selected from each leaf and the gall

diameter (mm) measured using an ocular micrometer on a M6C-10 microscope. The mean gall diameter for each cultivar was then calculated.

3.3.1.5. Gall density (gall/sq.cm):

For the gall density, the same samples mentioned above were used. Four counts were made for each leaf. The mean gall density for each cultivar was then calculated.

3.3.1.6. Leaf area (cm^2):

Again the same sample mentioned above were used for calculating the leaf surface area. The surface area of each leaf was measured using a LiCor LI 3100 area meter (cm^2). Mean leaf-surface areas were then calculated for each cultivar.

3.3.2. Statistical analysis:

Data of percentage infested branches and infested leaves were transformed to arcsine, while number of galls/leaf, galls density, gall diameter and leaf surface area data was transformed to $\sqrt{x+0.5}$. All data were subjected to Analysis of Variance (ANOVA). Duncan's Multiple Range Test (DMRT) was used for means separation. Analysis was done for each site and combined data was also calculated. Mstat-C statistical package was used to analyze the data.

3.4. Botanicals for control mango leaf gall midge:

This experiment was conducted for two years 2011-2012 at El Molbus area (Lat: 13 01 08 N, long: 30 14 50 E alt 547 m) North Kordofan State, Sudan (Plate 4). The soil of the experimental site is sandy where the sandy fraction amounts to more than 42%. The total annual rainfall of the experimental site for 2011 and 2012 were 423 mm and 382 mm, respectively. Mango trees

were irrigated by rains and supplementary irrigation was done every 21 days through the dry season. The orchard chosen to perform the study was grown by 10 years old mango cultivar (Kitchener) with spacing of 12 meters and 10 meters between and within trees rows, respectively. Five rows, each containing 10 mango trees were chosen randomly. Each row represents a block (Replication). The experiment was arranged in a completely randomized block (CRB) design.

3.4.1. Preparation of the botanical extracts:

Hargal shoot parts (crop of 2010) were bought from the local market and ground by electric mill to very fine powder and kept at room temperature in a plastic container until to be use. For preparation of the extract, the fine powder was weighed to rates as follows 200, 300 and 400 grams. Each one was mixed with 10 litres of tap water and left for 24 hours in plastic container under room conditions. Then, each mixture was filtered by muslin cloth and was ready for spraying mango trees. Fresh mature leaves of usher and neem plants were collected from the farm of ElObeid Research Station, and left to dry for one week at room temperature. For preparation of leaves powder water extract of each plant, the above mentioned procedure with the same rates was used. A solution of 1% Gum Arabic was added to each treatment as sticky material.

3.4.2. Application:

A knapsack sprayer (SEMCO 14PM/ Japan) was used to apply the following treatments:

1- Usher leaves powder aqueous extract at 200g/10 litre.

2- Usher leaves powder aqueous extract at 300g/10 litre.
3- Usher leaves powder aqueous extract at 400g/10 litre.
4- Hargal Shoots powder aqueous extract at 200g/10 litre.
5- Hargal Shoots powder aqueous extract at 300g/10 litre.
6- Hargal Shoots powder aqueous extract at 400g/10 litre.
7- Neem leaves powder aqueous at 200g/10 litre.
8- Neem leaves powder aqueous at 300g/10 litre.
9- Neem leaves powder aqueous at 400g/10 litre.
10- Control treated with water.

Throughout the study, the experiment received twelve sprays three for each mango flush cycle. Treatments were applied after harvest, coinciding with the first major flush.

3.4.3. Counts and statistical analysis:

Twenty new leaves were randomly selected from each tree. The mean number of galls per tree was recorded after 10 days of each spray. Yield (Kg/tree) was taken each season. Data was transformed to $\sqrt{x+0.5}$ when needed and subjected to analysis of variance (ANOVA). Duncan's Multiple Range Test (DMRT) was used for means separation. For the yield, analysis was done for each season and combined data. Mstat-C statistical package was used to analyze the data.

Plate 4. The study orchard for botanicals application at El Molbus site, North Kordofan State.

CHAPTER FOUR
RESULTS

4.1. Ecological studies:

4.1.1. Geographical distribution:

The mango leaf gall midge *P. matteiana* infestation in all surveyed sites revealed that the insect is widely distributed with 100% infested trees in 84 sites in 10 States. The rest of the surveyed sites were free of the infestation (Table 1).

The geographical distribution map of *P. matteiana* is shown in figure 1. The results of the survey showed that South Kordofan, North Kordofan, West Kordofan, Sennar, Blue Nile, South Darfur and West Darfur States showed 100% mean number of infested branches per mango tree, while the lowest infestation was recorded in Gezira State. Of the 13 surveyed States, five had means above 300 galls per mango leaf, namely South Kordofan, West Kordofan, Sennar, South Darfur and West Darfur States. Also, six of the other infested States had mean number of galls per leaf ranged between 97 and 261. In Gedarif State 97 galls per leaf was the lowest mean (Table 1 and Fig 1).

4.1.2. Seasonal abundance:

Throughout the period of the study From January, 2011 up to December, 2012, in ElMolbus site, appearance of *P. matteiana* galls on mango new leaves in the field coinsided with the start of the rainy season in mid July each year. The infestation increased and reached its peak in late September. A second peak was observed in late November (Fig 2 and Appendix A).Also

during the period of the study in AbuGebaiha site, the incidence of galls on new leaves was observed in few numbers in first June, when the rain started in south Kordofan State. Three peaks of *P. matteiana* galls were recorded in the late of July, August and November (Fig 3 and Appendix A).

Table 1. Surveyed sites, mean infestation percentage of trees and branches and the mean number of gall/leaf in the mango commercial mango orchards, Sudan, 2011.

State	No. of surveyed sites	Mean(%) infested trees/site	Mean (%) infested branches/tree	Mean number. of gall/ leaf
South Kordofan	22	100	100	362
North Kordofan	7	100	100	261
West Kordofan	4	100	100	317
Sennar	6	100	100	359
Blue Nile	30	100	100	256
Kassala	3	100	68	122
Gedarif	3	100	54	97
Gezira	3	100	52	112
South Darfur	3	100	100	364
West Darfur	3	100	100	372
Khartoum	4	0.0	0.0	0.0
River Nile	4	0.0	0.0	0.0
Northern	5	0.0	0.0	0.0
Total	97	1000	752	2622
Mean	-	76.9	57.8	201.7

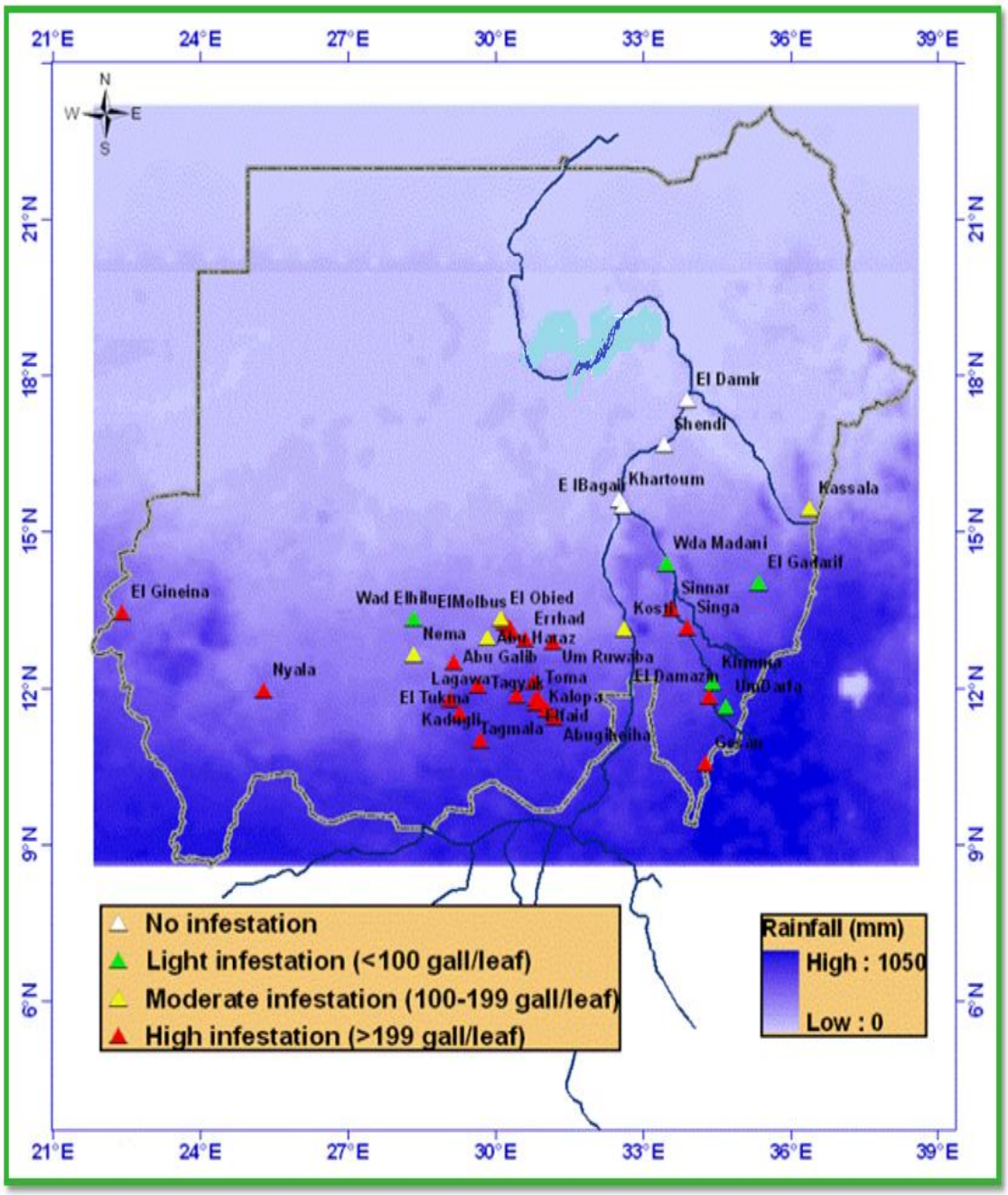

Fig 1. Map show some surveyed sites and levels of infestation by *P.matteiana* across mango growing areas in the Sudan.

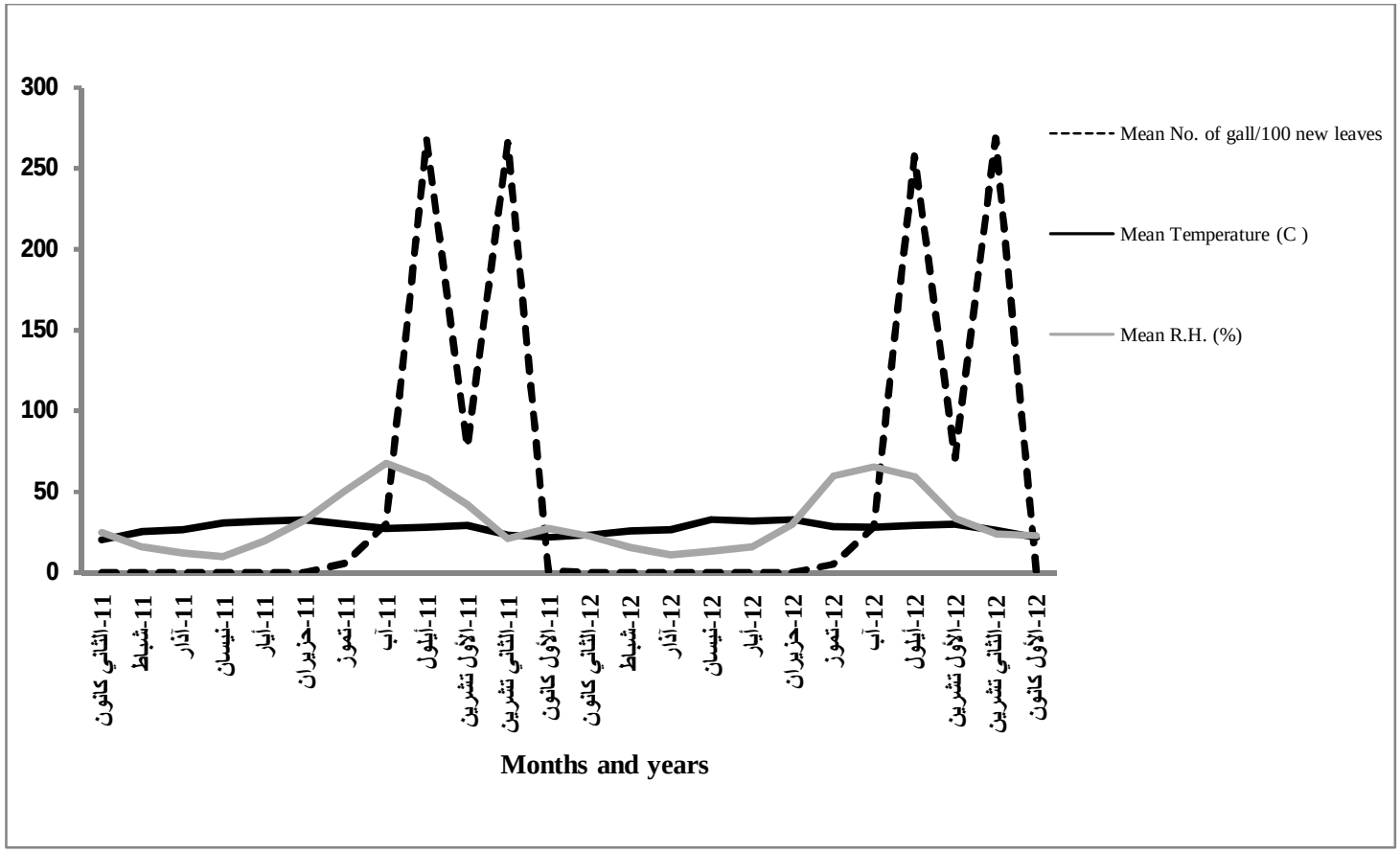

Fig 2. Seasonal abundance of *P.matteiana* galls on new mango leaves in relation to the mean temperature and relative humidity (ElMolbus, North Kordofan, Jan, 2011 - Dec, 2012).

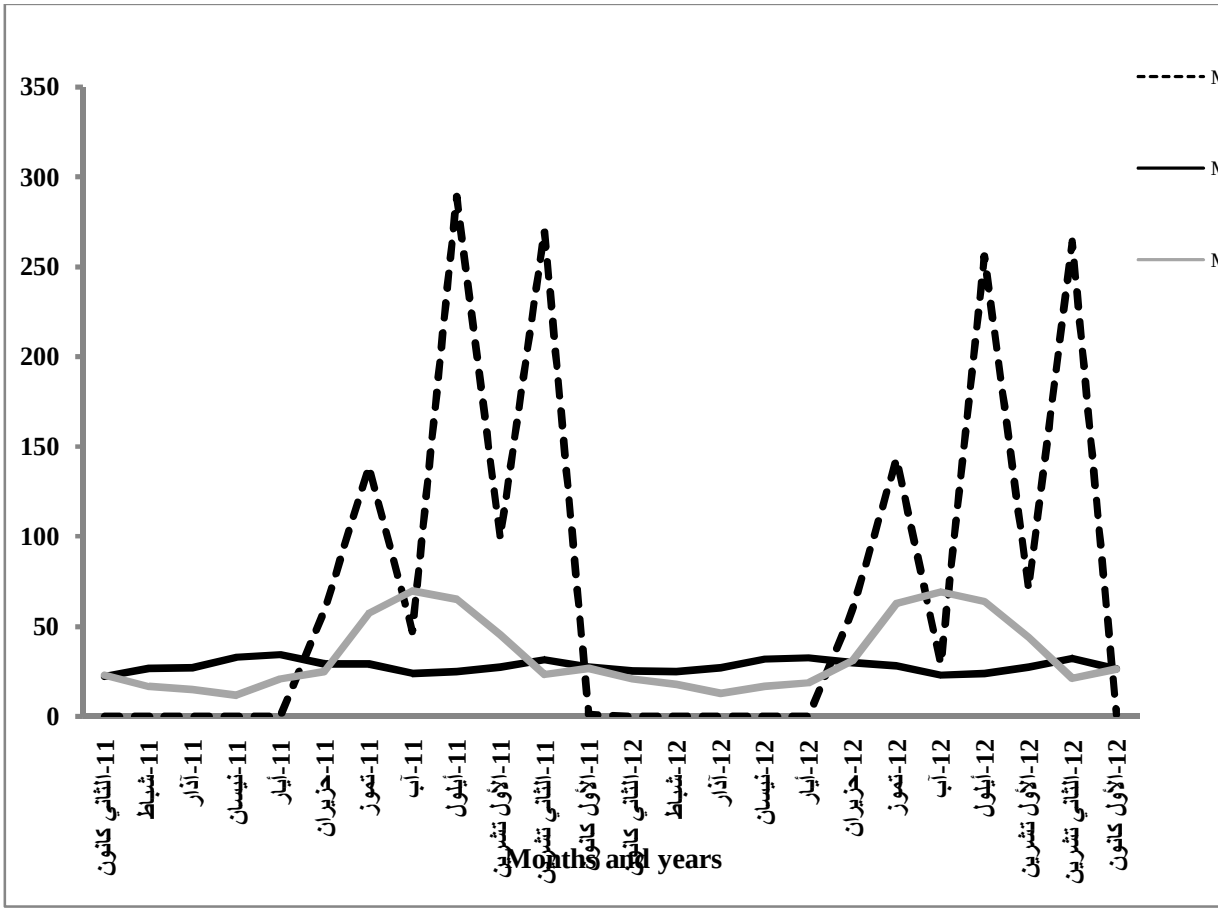

Fig 3. Seasonal abundance of *P.matteiana* galls on new mango leaves in relation to the mean temp
(AbuGebaiha, South Kordofan, Jan, 2011 - Dec, 2012).

4.2. Biological studies:

4.2.1. Some aspects of the biology of *P. matteiana*:

4.2.1.1. Life cycle

4.2.1.1.1. The egg stage

Under laboratory conditions at an average temperature of 26±2 ^{o}C and 42.7% to 49.4% R.H., eggs are laid as a cluster on the underside rarely on the upper side, of mango young leaves and lie embedded in the soft tissue. The oviposition sites are marked with a reddish small spots. The mean duration of the eggs was 2.36±0.339 days.

4.2.1.1.2. The larval stage

After hatching under field conditions, the larvae penetrated the leaves and started forming the galls. The new developed galls were light green, increased in size and gradually became hard and concave at oviposition site. The average duration of larvae ranged from 35.41 to 242.44 days (plate 5 and 6).

4.2.1.1.2. The pupal stage

The pupa is yellow, turning darker as it develops. It is about 2 mm in length. Pupation took place within the gall. Under field conditions the duration of the pupal stage was 8.62±0.4.6 days (plat 7).

4.2.1.2.4. The adult stage:

Adults emerge at about dawn and became active in the early morning, dusk and night (plate 8 and 9). Under laboratory conditions at an average temperature of 26±2 ^{o}C and 42.7% to 49.4% R.H, the percentage of adult emergence was 79% and 21% at 6 p.m to 6 a.m. and 6 a.m. to 6 p.m. respectively (Appendix A). The Sex

ratio was 1: 1. The mean of pre – oviposition, oviposition and post – oviposition periods were 5.8±1.12 hours, 2.7±0.407 days and 11.3±0.98 hours respectively (Table 2). The longevity of the adult ranged from 2 to 4 days, with an average of 2.0±0.000 and 3.7±0.407 days for male and female, respectively (Table 2). The fecundity varied from 175– 483 eggs per female with mean of 365.13±66.359 eggs (Table 3).

The mean duration of the life cycle was 46.203±0.27 days when eggs were laid in mid of August and 53.755±0.00 days when laid in 1st October. The mean duration of the life cycle, when eggs are laid in late November, was 253.60±0.20 days (Table 4).

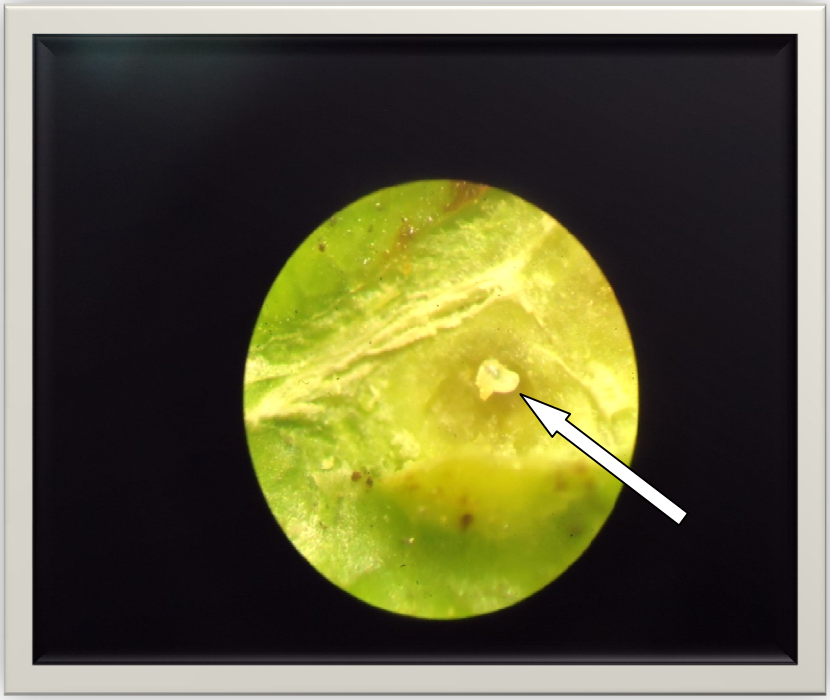

Plate 5. 1st larva of *P. matteiana* in agall

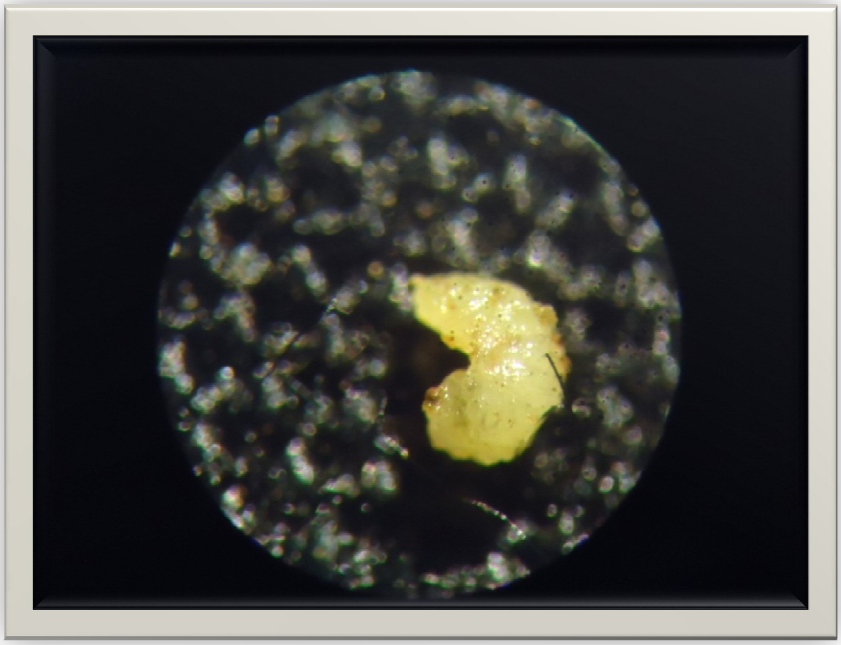

Plate 6. Mature larvae out of gall

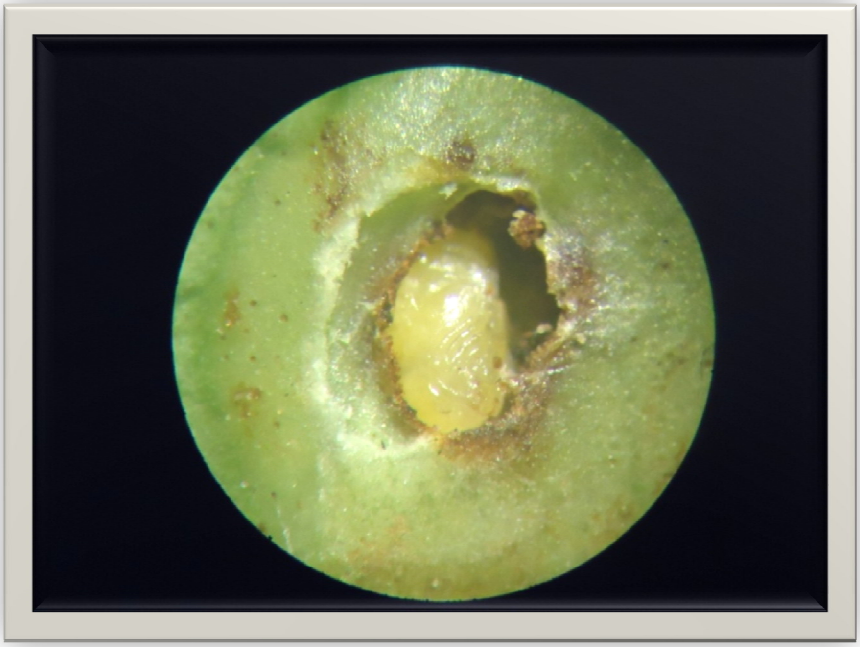

Plate 7. The pupation within the gall

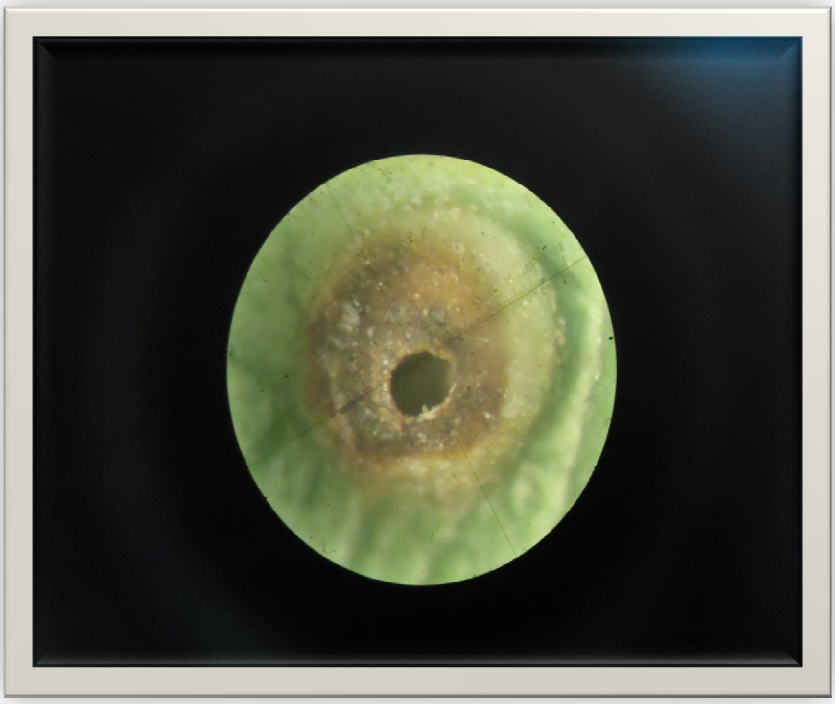

Plate 8. Exit hole of *P. matteiana* adult.

Plate 9. The adult (free stage) of *P. matteiana*

Table 2: Oviposition and longevity of the adult *P. matteiana* (Temperature 26±2 ^{o}C & R.H 42.7% - 49% during Nov/Dec 2012).

Cage no. (Caged pairs)	Pre-oviposition period (hours)	Oviposition period (days)	Post - oviposition period (hours)	Female longevity (days)	Male longevity (days)
1	5	3	10	4	2
2	6	3	9	4	2
3	5	2	9	3	2
4	6	3	11	4	2
5	8	3	11	4	2
6	4	2	10	3	2
7	5	3	12	4	2
8	8	3	11	4	2
9	5	3	10	4	2
10	6	3	12	4	2
11	5	2	10	3	2
12	4	3	10	4	2
13	8	3	11	4	2
14	7	2	12	3	2
15	5	3	11	4	2
Total	87	41	170	56	30
Mean ± SE	5.8±1.12	2.7±0.407	11.3±0.98	3.7±0.407	2.0±0.000

Table 3: Rate of egg production and fecundity of the female of *P.matteiana*

(Temperature 26 ±2 ^{o}C and R.H 42.7% to 49.4% during Nov/Dec 2012)

Female no.	Days after adult emergence					Total number of eggs
	No. of eggs laid per female					
	1	2	3	4	5	
1	52	160	61	49	**D**	322
2	72	205	69	64	**D**	410
3	8	127	40	**D**	**-**	175
4	20	140	73	42	**D**	275
5	17	201	85	42	**D**	345
6	18	200	51	**D**	**-**	269
7	23	217	76	50	**D**	366
8	72	221	81	23	**D**	397
9	63	207	79	52	**D**	401
10	54	256	71	51	**D**	432
11	56	211	124	**D**	**-**	391
12	84	257	97	35	**D**	473
13	82	303	80	16	**D**	481
14	96	329	58	**D**	**-**	483
15	27	175	45	10	**D**	257
Total						5477
Mean						365.13±66.359

D = Death of the female

Table 4. Duration of *P. matteiana* life cycle and its relation to date of eggs laying under field conditions in El Molbus, North Kordofan State, Sudan.

Date of eggs laying	No. of eggs observed	Mean duration (egg-adult) ±SE (days)
15th August	1000	46.203±0.27
1st October	1000	53.755±0.00
26th November	1000	253.60±0.20

4.3 Formation of galls and symptoms of damage by mango leaf gall midge:

The female gallfly oviposited on flush leaves, larvae (maggots) emerge from the eggs and tunnel into the leaf tissue. After 2-3 days the galls appeared as green spots on the new brownish mango leaves. The gall diameter ranged between 0.9 - 1.2 mm (plate 10). After 7-12 days the formation of the galls is completed it seemed like a wart (plate 11). The infestation started as nearly invisible galls on newly brownish mango leaves (plate 12). In the dark green mature leaves galls were round and swelling (plate 13). Heavily infested leaves showed curly symptom (plate 14). After 4-6 months the galls covered with dust (plate 15). Mango orchards infested by *P. matteiana* showed heavy pre-mature shedding of leaves (plate 16). The young infested mango trees were killed and the older trees did not recover the normal growth (shedding and die-back symptoms) (plate 17 and 18). Also, *P. matteiana* galling increased the infection by *C. gloeosporiodes*, the casual agent of anthracnose disease on mango leaves (plate 19).

Plate 10. New gall of *P. matteina*.

Plate 11. A completely developed gall (true gall)

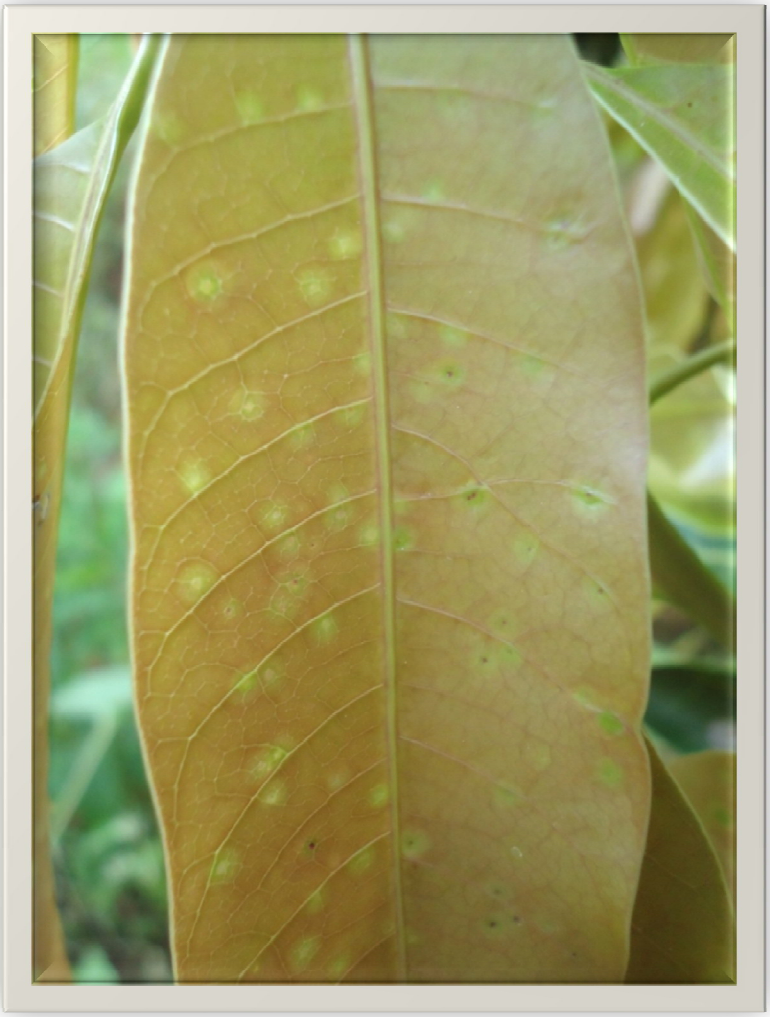

Plate 12. A new leaf of mango showing the new galls of *P. matteina*

Plate 13. Mature mango leaves showing the high density of *P. matteina* galls

Plate 14. Mature mango leaves showing heavy galling and curling symptoms.

Plate 15. Old galls covered with dust

Plate 16. Pre-mature shedding of mango leaves is a common symptom of *P. matteina*.

Plate 17. Death of mango seedling (Al Phonse cultivar) due to *P. matteina* infestation.

Plate 18. A mango tree (Al Phonse cultivar) showing leaves Shedding and dieback symptoms due to *P. matteina* infestation.

Plate 19. Anthracnose disease on mango leaf associated with *P. matteina* galls.

4.4. Susceptibility studies:

4.4.1. Symptoms of galling

All tested cultivars in the four mango-growing sites (ElMolbus, Errhad, AbuGebaiha and sinnja) showed true galls symptom (small round swellings on leaves).

4.4.2. Percentage of infested branches

All tested 12 mango cultivars, at the four surveyed sites showed variations in the mean percentage of infested branches. At ElMolbus and Errhad sites, the mean percentage of infested branches ranged between 16% to 99% and 11% to 99% respectively. At both sites Abu-Samaka Khadra and Abu-Samaka Baida cultivars showed the lowest mean percentage of infested branches while Al Phonse and Tommy Atkins cultivars had the highest mean percentage of infested branches (Table 5, 6 and Appendix B). Complete infested branches were noticed in Kitchener, Baladia, Al Phonse and Tommy Atkins cultivars at Abu Gebaiha site (Table 7 and Appendix B). Abu-Samaka Khadra and Abu-Samaka Baida cultivars showed the lowest mean percentage of infested branches in the same site. Sinnja site showed mean percentage of infested branches ranged between 16% to 100%. In this site, the highest mean percentage of infested branches was found in Baladia, Al Phonse and Tommy Atkins cultivars and the lowest mean of the same damage was recorded in Abu-Samaka Khadra and Abu-Samaka Baida cultivars (Table 8 and Appendix B). The results of the combined analysis of the four sites showed that Al Phonse and Tommy Atkins cultivars recorded the highest mean percentage of infested branches while the lowest damaged branches were shown by Abu-Samaka Khadra and Abu-Samaka Baida cultivars (Fig 3 and Appendix E).

4.4.3. Percentage of infested leaves

The tested mango cultivars were different in their interaction to *P. matteiana* in the field. All tested sites, showed similar trend for infested leaves percentage. Al Phonse and Tommy Atkins cultivars gave the highest mean percentage of infested leaves while the lowest mean of infestation was shown by Abu-Samaka Khadra and Abu-Samaka Baida cultivars (Table 6, Fig 4 and Appendix B and E).

4.4.4. Number of galls/leaf

The mean number of galls per leaf differed significantly among the cultivars at the four sites. At ElMolbus site, Abu-Samaka Khadra and Abu-Samaka Baida cultivars gave a significantly lowest mean number of galls per leaf compared to other cultivars while the Kitchener, Al Phonse and Tommy Atkins gave the highest mean number of galls per leaf. The mango cultivars Abu-Samaka Khadra, Abu-Samaka Baida and Galbaltour showed the lowest mean number of galls per leaf at Errhad site while the highest number of gall per leaf was recorded in Kitchener, Al Phonse and Tommy Atkins cultivars. At AbuGebaiha site the lowest mean number of gall per leaf was reported by Abu-Samaka Baida cultivar while the highest number of galls per leaf was found in Kitchener, Al Phonse and Tommy Atkins cultivars. At Sinnja site the cultivars Debsha, Abu-Samaka Khadra, Abu-Samaka Baida and Galbaltour showed the lowest mean number of gall per leaf while the highest number of gall per leaf was shown by Kitchener, Al Phonse and Tommy Atkins cultivars (Table 7 and Appendix B). The combined analysis of the four tested sites showed that the Kitchener, Al Phonse and Tommy Atkins cultivars had the highest mean number of galls compared to the other cultivars while Abu-Samaka Khadra

and Abu-Samaka Baida cultivars had the lowest mean number of galls per leaf (Fig 5 and Appendix E).

4.4.5. Gall density

The four tested sites showed significant differences among the tested cultivars in mean gall density/cm^2.At ElMolbus and Sinnja sites, Taimour, Debsha, Abu-Samaka Khadra, Abu-Samaka Baida and Galbaltour cultivars gave a significantly lowest mean gall density/cm^2 compared to the other cultivars while Kitchener and Al Phonse had the highest mean gall density/cm^2. Abu-Samaka Baida cultivar had the lowest mean gall density/cm^2 at Errhad site while Tommy Atkins cultivar showed the highest mean gall density/cm^2 (Table 6 and Appendix B). At Abu Gebaiha site the cultivars Taimour, Debsha, Abu-Samaka Baida and Galbaltour reflected the lowest mean gall density/cm^2 while the highest mean gall density/cm^2 was recorded by Tommy Atkins o cultivars. It appears that in four sites Abu-Samaka Khadra and Abu-Samaka Baida had the lowest mean gall density/cm^2 while Al Phonse and Tommy Atkins cultivars had the highest mean gall density/cm^2 (Fig 6 and Appendix E).

4.4.6. Gall diameter

The mean gall diameter differed among cultivars at the four tested sites. At ElMolbus site Debsha cultivar showed the highest mean gall diameter among all tested mango cultivars. The lowest mean gall diameter at the same site was recorded by Abu-Samaka Baida cultivar. Also, Abu-Samaka Baida cultivar gave the lowest mean gall diameter in Errhad and Sinnja site while Debsha and Tommy Atkins cultivars showed the highest mean diameter. Similar results were noticed at Abu Gebaiha site and Al Phonse cultivar did not differe significantly from Debsha and Tommy Atkins cultivars (Table 9 and Appendix B). Across the four sites,

Debsha cultivar showed the highest mean gall diameter while the lowest value was recorded in Abu-Samaka Baida cultivar (Fig 7 and Appendix E).

4.4.7. Leaf area (cm^2)

The mean leaf area is shown in tables from 5 to 8. There are significant differences among the tested mango cultivars at the four sites. Baladia cultivar had a significantly largest mean leaf area compared to the other cultivars at ElMolbus, Abu Gebaiha and Sinnja sites while Debsha cultivar had the smallest mean leaf area at the same sites. At Errhad site, Baladia cultivar had a significantly larger mean leaf area compared to the other tested cultivars (Table 6 and Appendix B). Across the four sites, Baladia cultivar recorded a significant larger mean leaf area while the lower mean leaf area was found in Debsha Cultivar (Fig 8 and Appendix E).

Table 5. Mean infested branches percentage for twelve mango cultivars attacked by *P.matteiana* at four sites under field conditions in the Sudan.

Mango cultivar	Mean infested branches in 4 sites (%)			
	ElMolbus	Errhad	AbuGebaiha	Sinnja
Taimour	33 (34.60) e	36 (36.71) e	42 (40.35) d	37 (37.16) e
Debsha	32 (33.52) e	28 (31.16) ef	28 (30.81) ef	31 (32.64) e
Abu-Samaka Khadra	17 (23.48) f	13 (21.54) g	20 (25.55) f	18 (24.64) f
Abu-Samaka Baida	16 (22.76) f	11 (19.91) g	18 (24.43) f	16 (22.86) f
Galbaltour	29 (31.96) e	19 (25.39) fg	33 (35.31) de	31 (33.63) e
Kitchener	70 (57.04) c	66 (54.51) c	100 (90.00) a	73 (58.84) b
Baladia	94 (79.97) b	92 (78.34) b	100 (90.00) a	97 (85.50) a
Al Phonse	94 (86.31) a	99 (88.16) a	100 (90.00) a	99 (88.16) a
Shendi 1	70 (56.98) c	65 (53.90) c	(57.04) b	62 (52.09) c
Zibda Baida	47 (43.38) d	47 (43.38) d	70 (49.31) c	48 (44.12) d
Keitt	63 (52.86) c	59 (50.31) c	56 (48.69) c	62 (52.20) c
Tommy Atkins	99 (88.16) a	99 (88.16) a	100 (90.00) a	100 (90.00) a
SE±	2.180	2.124	2.175	2.293
C.V (%)	13.54	13.63	12.29	13.99

-Means with the same letter in the same column are not significantly different ($P< 0.05$) according to DMRT.

-Means in the parenthesis are transformed to arcsine.

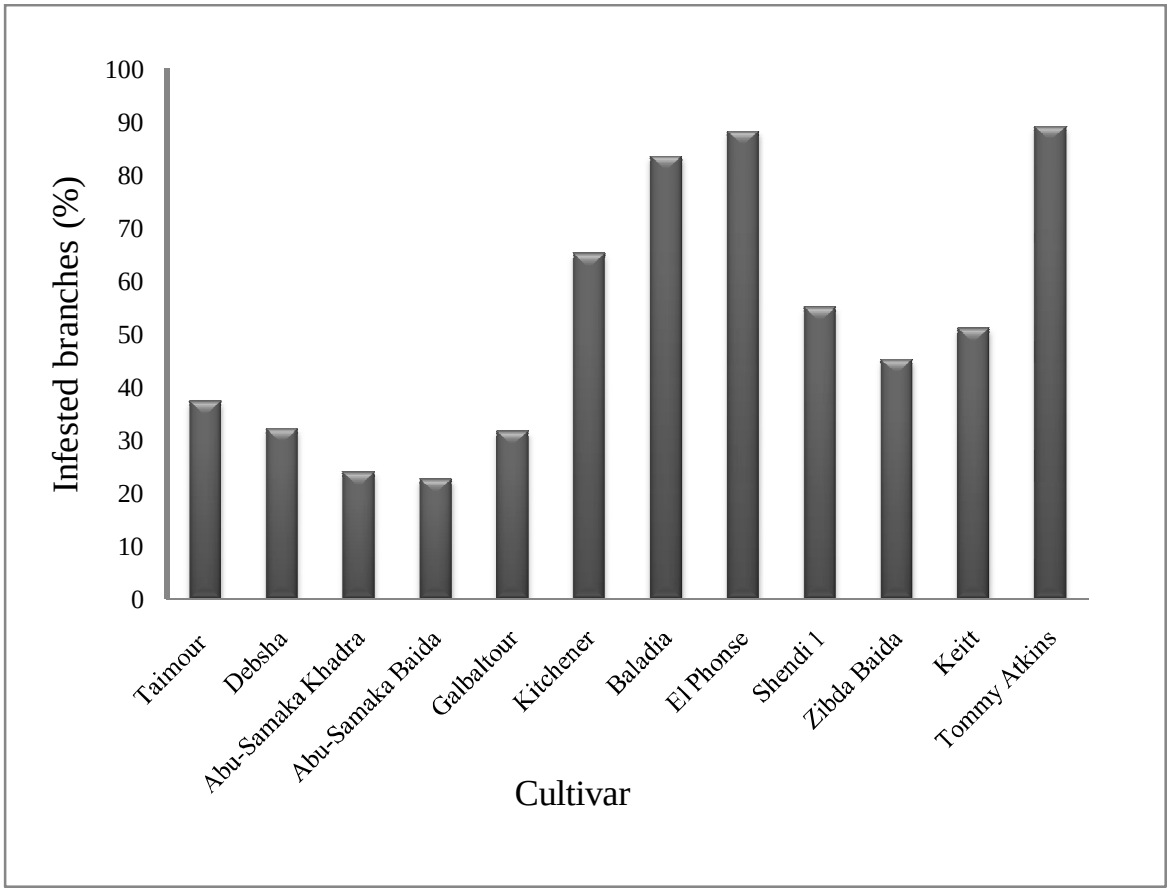

Fig 4. Mean percentage of infested branches for twelve mango cultivars attacked by *P. matteiana* under field conditions in the Sudan (mean of four sites).

Table 6. Mean infested leaves percentage for twelve mango cultivars attacked by *P.matteiana* at four sites under field conditions in the Sudan.

Mango cultivar	Mean infested leaves in 4 sites (%)			
	ElMolbus	Errhad	AbuGebaiha	Sinnja
Taimour	38 (38.00) d	35 (36.16) e	40 (39.18) e	34 (36.74) d
Debsha	42 (40.37) d	41 (39.78) de	42 (40.91) e	43 (40.94) d
Abu-Samaka Khadra	23 (28.14) e	20 (26.27) f	25 (29.40) f	19 (28.80) e
Abu-Samaka Baida	23 (28.14) e	20 (26.06) f	23 (27.99) f	20 (28.17) e
Galbaltour	38 (37.31) d	35 (36.22) e	41 (39.58) e	40 (39.15) d
Kitchener	84 (69.12) bc	80(63.88) c	85 (70.89) bc	83 (68.38) bc
Baladia	89 (74.14) b	87 (70.46) b	93 (77.10) b	89 (76.35) b
Al Phonse	99 (88.20) a	99 (88.16) a	100 (90.00) a	99 (88.16) a
Shendi 1	80 (63.88) c	82 (66.48) bc	94 (62.92) d	82 (67.72) c
Zibda Baida	45 (42.11) d	45 (42.17) d	44 (41.54) e	45 (42.11) d
Keitt	83 (68.38) bc	83 (66.32) bc	81 (68.23) cd	83 (68.53) bc
Tommy Atkins	100 (90.00) a	100 (90.00) a	100 (90.00) a	100 (90.00) a
SE±	2.384	1.996	2.619	2.814
C.V (%)	13.55	10.86	14.66	15.82

-Means with the same letter in the same column are not significantly different ($P< 0.05$) according to DMRT

-Means in the parenthesis are transformed to arcsine.

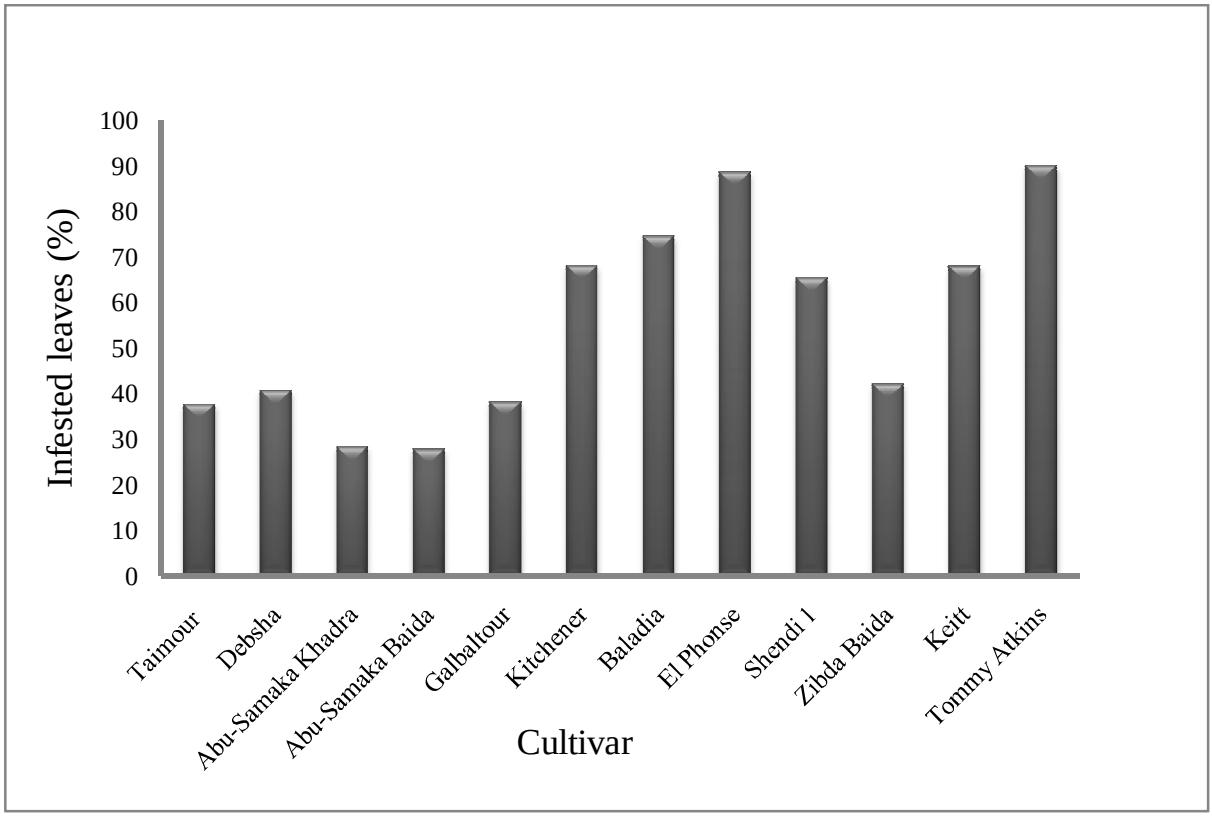

Fig 5. Mean of infested leaves percentage for twelve mango cultivars attacked by *P. matteiana* under field conditions in the Sudan (mean of four sites).

Table 7. Mean number of galls/leaf for twelve mango cultivars attacked by *P.matteiana* at four sites under field conditions in the Sudan.

Mango cultivar	No. of galls per leaf in 4 sites			
	ElMolbus	Errhad	AbuGebaiha	Sinnja
Taimour	33.3 (5.420) de	33.3 (5.500) e	35.1 (5.790) d	35.6 (5.750) d
Debsha	14.1 (3.535) ef	16.1 (3.830) ef	16.0 (3.920) e	14.5 (3.640) e
Abu-Samaka Khadra	6.4 (2.355) f	6.4 (2.220) f	7.7 (2.710) ef	7.4 (2.530) e
Abu-Samaka Baida	4.8 (2.090) f	5.3 (2.120) f	3.1 (1.800) f	4.2 (2.070) e
Galbaltour	12.0 (4.327) ef	11.9 (2.910) f	13.8 (3.680) e	12.7 (3.490) e
Kitchener	261.4 (15.94) a	279.3 (16.19) a	276.7 (16.32) a	273.3 (16.42) a
Baladia	57.1 (7.101) d	69.9 (16.19) d	64.3 (7.990) c	65.5 (8.080) c
Al Phonse	269.3 (16.22) a	287.9 (16.92) a	308.7 (17.50) a	293.7 (17.00) a
Shendi 1	138.1 (11.45) b	129.9 (11.25) bc	126.9 (11.08) b	119.5 (11.36) b
Zibda Baida	95.5 (9.280) c	96.9 (9.490) cd	99.6 (9.572) bc	101.1 (9.590) bc
Keitt	153.4 (12.22) b	153.4 (12.22) b	119.3 (10.71) b	123.2 (10.80) b
Tommy Atkins	276.3 (16.57) a	276.3 (16.58) a	298.8 (17.21) a	279.7 (16.41) a
SE±	0.7342	0.6310	0.5634	0.6581
C.V (%)	26.16	22.29	19.74	23.31

Means with the same letter in the same column are not significantly different ($P< 0.05$) according to DMRT

Means in the parenthesis are transformed to $\sqrt{x+0.5}$.

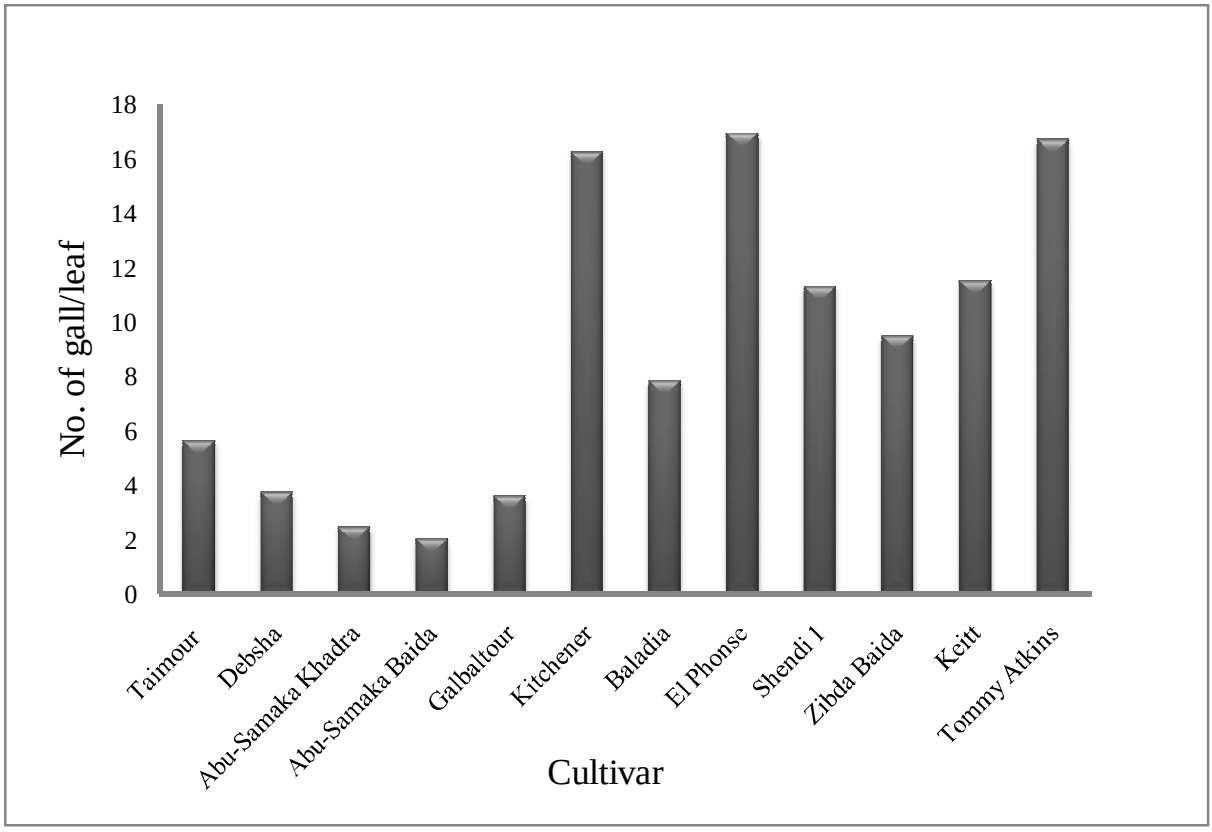

Fig 6.Mean number of gall per leaf for twelve mango cultivars mean of four sites under field conditions in the Sudan.

Table 8. Mean gall density/cm^2 for twelve mango cultivars attacked by *P.matteiana* at four sites under field conditions in the Sudan.

Mango cultivar	Mean gall density in 4 sites			
	ElMolbus	Errhad	AbuGebaiha	Sinnja
Taimour	1.1 (1.200) c	1.4 (1.340) d	1.1 (1.190) e	1.0 (1.160) c
Debsha	0.6 (1.000) c	0.8 (1.090) de	0.9 (1.120) e	0.8 (1.100) c
Abu-Samaka Khadra	0.7 (1.030) c	1.1 (1.220) d	1.4 (1.360) de	0.7 (1.020) c
Abu-Samaka Baida	0.3 (0.8400) c	0.4 (0.800) e	0.9 (1.130) e	0.5 (0.9400) c
Galbaltour	0.5 (0.9500) c	0.9 (1.120) de	0.9 (1.120) e	1.0 (1.180) c
Kitchener	3.2 (1.890) b	3.3 (1.930) c	3.5 (1.980) b	3.6 (2.010) b
Baladia	2.7 (1.710) b	2.8 (1.770) c	2.3 (1.610) cd	3.1 (1.940) b
Al Phonse	5.3 (2.350) a	5.3 (2.350) ab	4.6 (2.190) ab	5.2 (2.320) a
Shendi 1	3.0 (1.830) b	3.7 (2.040) bc	3.5 (1.980) b	3.8 (2.050) b
Zibda Baida	2.7 (1.680) b	2.9 (1.740) c	3.1 (1.830) bc	3.1 (1.870) b
Keitt	3.2 (1.890) b	3.3 (1.940) c	3.5 (1.960) b	3.6 (2.010) b
Tommy Atkins	5.0 (2.281) a	6.0 (2.501) a	5.4 (2.450) a	5.8 (2.460) a
SE±	0.1196	0.1109	0.1162	0.08888
C.V (%)	24.30	21.23	22.11	16.86

Means with the same letter in the same column are not significantly different ($P< 0.05$) according to DMRT

Means in the parenthesis are transformed to $\sqrt{x+0.5}$.

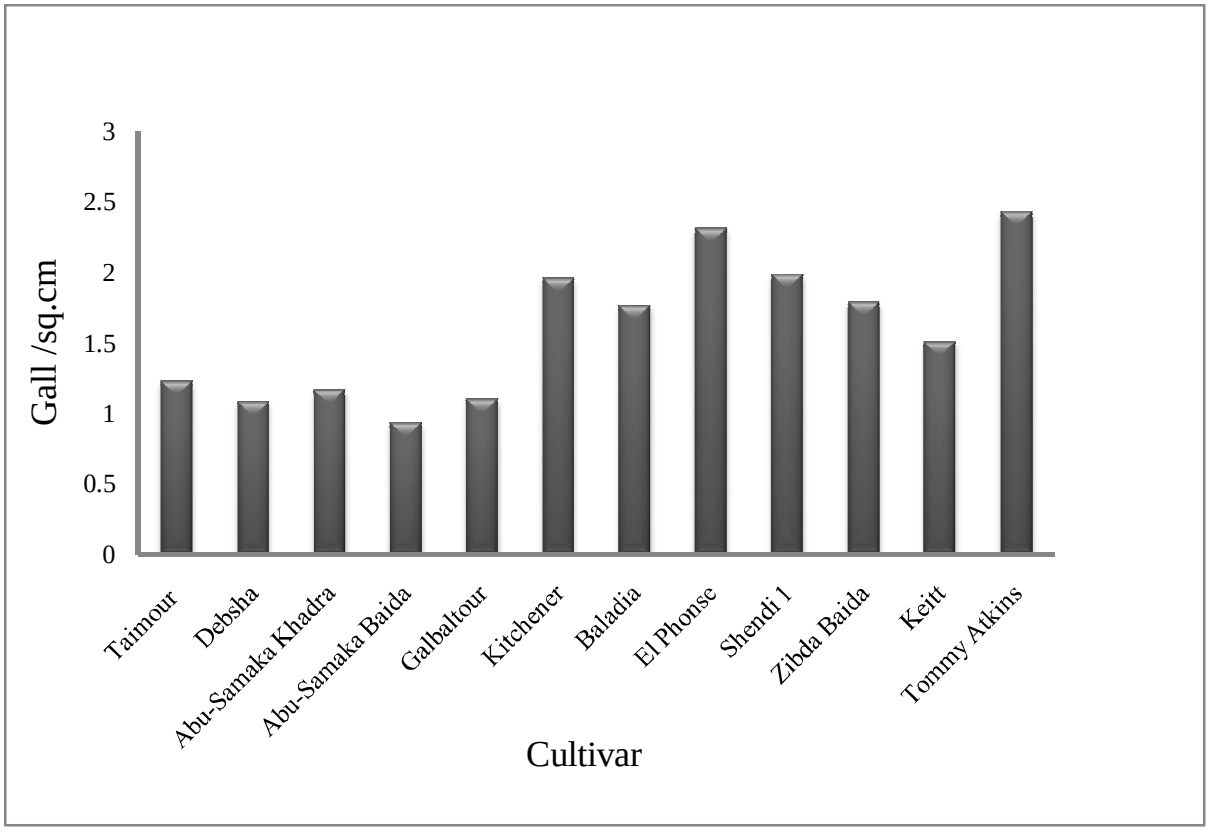

Fig 7.Mean gall density (galls/cm^2) for twelve mango cultivars mean of four sites under field conditions in the Sudan.

Table 9. Mean gall diameter (mm) for twelve mango cultivars attacked by *P.matteiana* at four sites under field conditions in the Sudan.

Mango cultivar	Mean gall diameter in 4 sites			
	ElMolbus	Errhad	AbuGebaiha	Sinnja
Taimour	3.200 bcde	3.140 de	3.090 c	3.050 def
Debsha	4.490 a	4.330 a	4.480 a	4.150 a
Abu-Samaka Khadra	2.500 ef	2.460 f	2.420 d	2.590 ef
Abu-Samaka Baida	2.000 f	1.810 g	1.720 e	1.870 g
Galbaltour	3.460 bcd	3.420 cde	3.910 b	3.210 de
Kitchener	3.240 bcde	3.670 bcd	3.700 b	3.360 cd
Baladia	3.870 abc	3.730 bc	3.740 b	3.883 abc
Al Phonse	3.620 bcd	4.000 ab	4.570 a	4.050 ab
Shendi 1	3.290 bcd	3.640 bcd	3.772b	3.450 bcd
Zibda Baida	2.880 de	3.060 e	2.960 c	2.930 def
Keitt	3.140 cde	3.260 cde	2.920 c	2.540 f
Tommy Atkins	3.960 ab	4.240 a	4.540 a	4.342 a
SE±	0.2462	0.1723	0.1510	0.2135
C.V (%)	23.56	16.03	13.70	20.55

Means with the same letter in the same column are not significantly different ($P< 0.05$) according to DMRT.

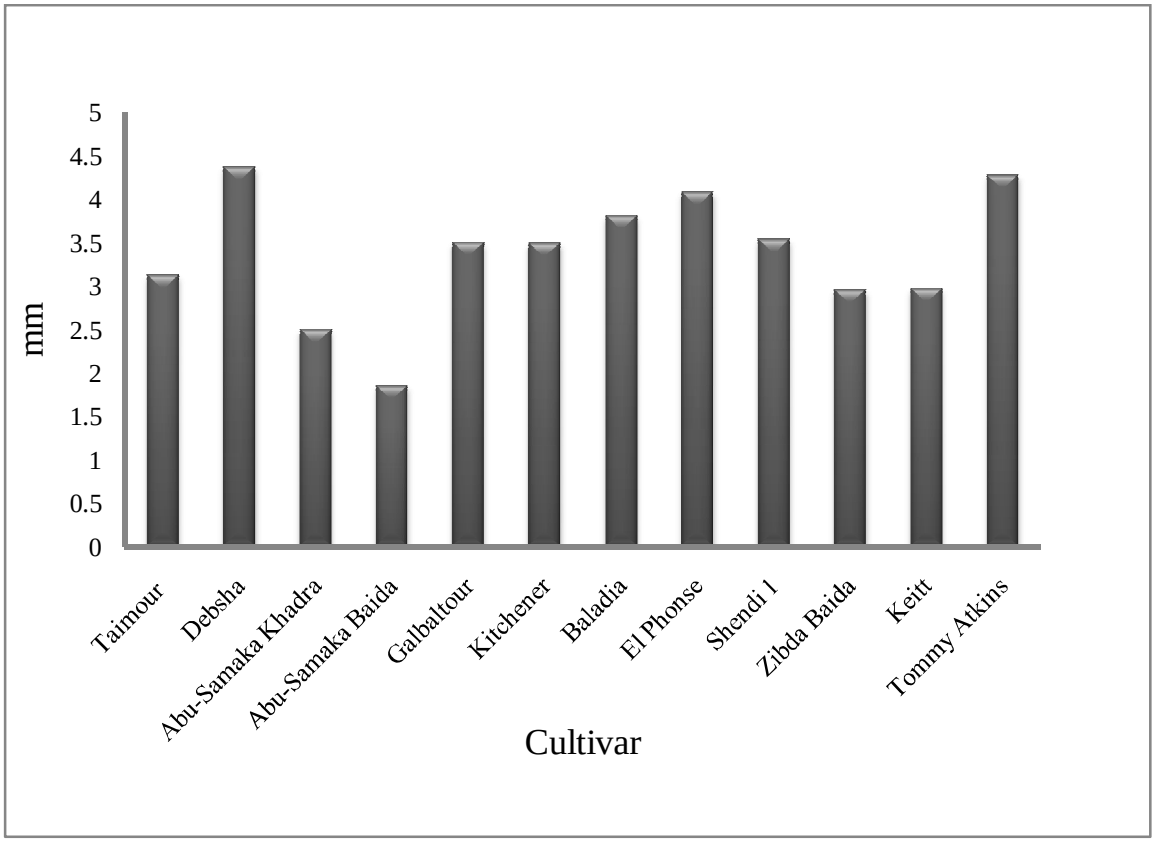

Fig 8. Mean of gall diameter for twelve mango cultivars mean of four sites under field conditions in the Sudan.

Table 10. Mean Leaf area (cm^2) for twelve mango cultivars attacked by *P.matteiana* at four sites under field conditions in the Sudan.

Mango cultivar	Mean leaf area			
	ElMolbus	Errhad	AbuGebaiha	Sinnja
Taimour	94.20 bc	91.70 b	94.10 abc	94.10 abc
Debsha	89.40 c	90.20 b	89.30 c	89.40 c
Abu-Samaka Khadra	95.90 abc	95.60 ab	95.90 abc	95.90 abc
Abu-Samaka Baida	92.00 bc	93.90 b	92.00 bc	92.00 bc
Galbaltour	98.00 abc	98.30 ab	98.00 abc	98.10 abc
Kitchener	98.60 ab	98.00 ab	98.60 ab	98.50 ab
Baladia	102.7 a	102.6 a	102.6 a	102.6 a
Al Phonse	90.30 bc	90.20 b	90.40 bc	90.40 bc
Shendi 1	92.30 bc	93.70 b	92.20 bc	92.30 bc
Zibda Baida	98.00 abc	97.70 ab	97.38 abc	97.40 abc
Keitt	9050 bc	92.00 b	90.60 bc	90.60 bc
Tommy Atkins	93.90 bc	93.90 b	93.90 bc	93.90 bc
SE±	2.674	2.625	2.691	2.676
C.V (%)	8.93	8.76	8.99	8.94

Means with the same letter in the same column are not significantly different ($P< 0.05$) according to DMRT

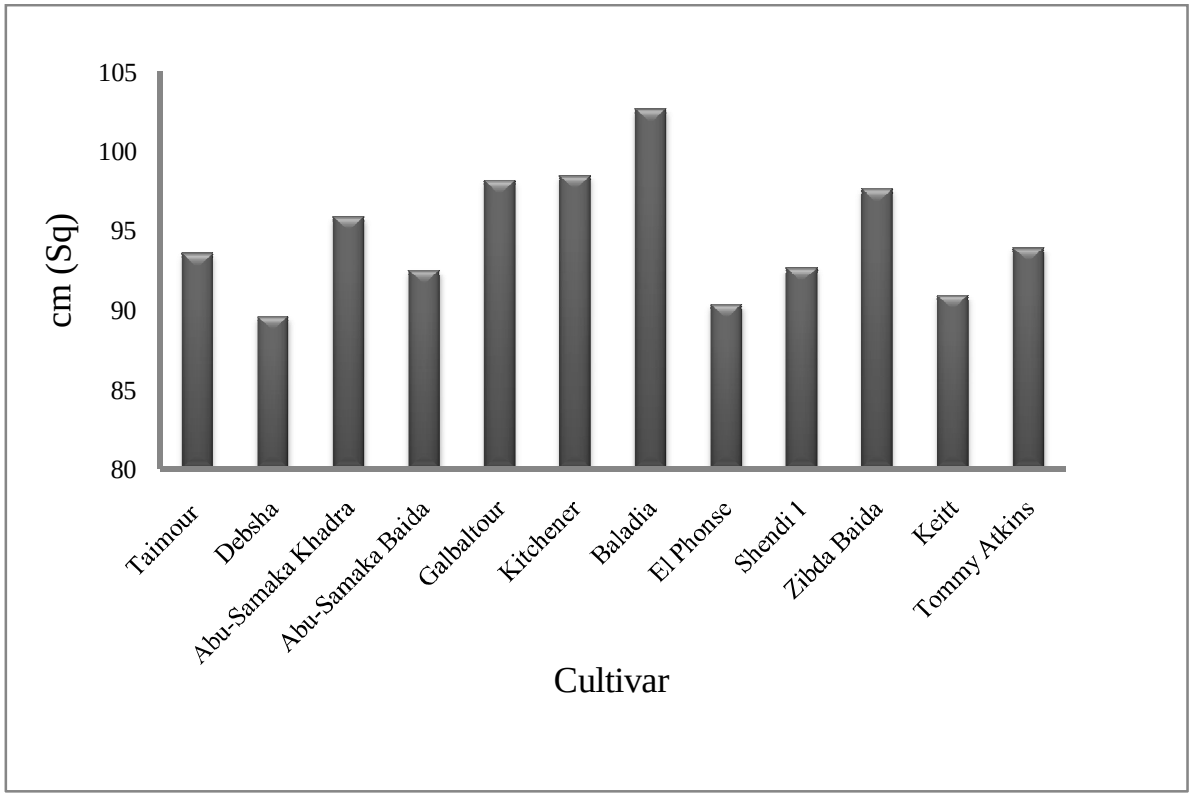

Fig 9.Mean leaf area (cm^2) for twelve mango cultivars mean of four sites under field conditions in the Sudan.

4.4.8 A preliminary classification of the susceptibility of some mango cultivars grown in the Sudan to galling by *Procontarinia matteiana*.

Table 11 present a premlimiary classification of some Sudanese mango cultivars into categories of susceptibility. The categorization was based on measures of infested leaves percent, number of gall/leaf, gall density and gall diameter. Of the all tested mango cultivars, Tommy Atkins and AlPhonse were the most susceptible. Although gall diameter was big for these cultivars, infested leaves percent, number of gall/leaf and gall density were extremely high. Abu-Samaka Khadra and Abu-Samaka Baida appanetly the least susceptible, with small gall diameter and lowest infested leaves percent, number of gall/leaf and gall density. The remaining eight cultivars differed to some extent between sites. Kitchener cultivar may be considerd seconed most susceptible with high number of gall/leaf and gall density. Taimour, Debsha, Galbaltour, Baladia, Shendi 1, Zibda Baida and Keitt mango cultivars showed no consistency in ranking for neither the number of gall/leaf nor the gall density.

Table 11. A preliminary classification of the susceptibility of some mango cultivars grown in the Sudan to galling by *P. matteiana*.

Cultivar	Classification	Description of susceptibility
Taimour	Susceptible	Variable
Debsha	Susceptible	Variable
Abu-Samaka Khadra	Susceptible	Low
Abu-Samaka Baida	Susceptible	Low
Galbaltour	Susceptible	Variable
Kitchener	Susceptible	Variable
Baladia	Susceptible	Variable
Al Phonse	Susceptible	High
Shendi 1	Susceptible	Variable
Zibda Baida	Susceptible	Variable
Keitt	Susceptible	Variable
Tommy Atkins	Susceptible	High

4.5. Application of botanical extracts for the control of mango leaf gall midge *Procontarinia matteiana.*

4.5.1. Control experiment in the year 2011:

In the first year (2011), the experiment received six sprays of all tested concentrations of aqueous extracts of hargal shoot, usher and neem leaves powder at 10 days interval.

4.5.1.1 Application of botanical extracts at the 1st flush mango trees (July-August, 2011).

For the first flush, the first spray applied when the pre- spray counts of galls ranged from 10.20 to 12.40 galls/20 new leaves. Mango leaf gall midge appeared in early July. The general performance of the treatments indicated their effectiveness in controlling *P. matteiana* compared with the untreated control as shown in (Table 12 and Appendix F).

4.5.1.2. Application of botanical extracts at the 2nd flush mango trees (October, 2011).

In this 2nd flush also three sprays were applied and similar results were noticed, as indicated in tables 13 and Appendix F.

4.5.2. Control experiments in the year 2012.

In the second year (2012) also, six sprays were applied to control *P. matteiana* on mango trees.

4.5.2.1. Application of botanical extracts at the 1st flush mango trees (July-August, 2012).

In the first flush, all tested concentrations reduced the mean number of gall/20 new leaves compared to the control (Table 14 Appendix F).

4.5.2.2. Application of botanical extracts at the 2nd flush mango trees (October, 2012).

For the second flush, the same trend of results was noticed as in the all previous flushes (Table 15 Appendix F).

Throughout the study, aqueous extract of hargal shoot and neem leaves powders at their highest concentration (400 g/ 10 Litre of water) gave the lowest mean number of gall/20 new leaves. The aqueous extract of usher leaves powder at highest tested concentration recorded higher mean number of galls compared with the highest concentrations of aqueous extracts of hargal shoot and neem leaves powder.

4.5.3. Effect of the treatments on mango fruit yield:

Yield of mango fruits (kg/tree) was determined during the season 2011 and 2012. All tested botanicals supported yields higher than the control.

In season 2011, aqueous extract of neem leaves powder at 400g/10 litre resulted in the highest yield (55.02 kg/tree), followed by aqueous extract of hargal shoot powder at 400g/10 L (44.58 kg/tree) and aqueous extract neem leaves powder at 300g/10L (43.20 kg/tree), aqueous extract usher leaves powder at 400g/10 L (38.98 kg/tree), aqueous extract of neem leaves powder at 200g/10 litre (31.78 kg/tree), aqueous extract of hargal shoot powder at 300g/10 L (27.98 kg/tree) and aqueous extract of hargal shoot powder at 200g/10 L (24.08 kg/tree) respectively, which were significantly better than the lower doses of aqueous extract usher leaves powder at 200 and 300 g/ 10 L (15.12 and 18.76 kg/tree). For the 2012

season, the same trend was noticed for mango yield (kg/tree) as in the previous season. The results of the combined analysis of the two seasons showed no significant differences in yield for the two seasons. The aqueous extract of neem leaves powder at 400g/10 litre resulted in the highest yield of mango fruits (56.15 kg/tree) (Table 16 Appendix F).

Table 12. Effect of aqueous extracts of Hargal shoot, Usher leaves and Neem leaves powder on mango leaf gall midge; 1st flush, July-August, 2011.

Treatment	Concs (g/10 L of water)	Mean No. of galls/20 leaves					
		Spray number					
		1st spray		2nd spray		3rd spray	
		Pre- spray count	Count 10 days after spray	Pre- spray count	Count 10 days after spray	Pre- spray count	Count 10 days after spray
Hargal shoot powder	200	10.80 a	26.4 (5.14) c	26.4 (5.14) c	17.4 (4.22) d	17.4 (4.22) d	17.4 (4.02) c
Hargal shoot powder	300	11.20 a	19.6 (4.45) d	19.6 (4.45) d	12.4 (3.80) d	12.4 (3.80) d	14.4 (3.84) c
Hargal shoot powder	400	12.40 a	7.8 (2.62) f	7.8 (2.62) f	3.0 (1.88) f	3.0 (1.88) f	1.6 (1.44) e
Usher Leaves powder	200	11.60 a	33.4 (5.86) b	33.4 (5.86) b	28.8 (5.38) b	28.8 (5.38) b	20.0 (4.50) b
Usher Leaves powder	300	11.00 a	24 (4.90) cd	24 (4.90) cd	22.0 (4.70) c	22.0 (4.70) c	18.8 (4.38) b
Usher Leaves powder	400	11.80 a	8.0 (2.88) f	8.0 (2.88) f	7.2 (2.66) e	7.2 (2.66) e	4.8 (2.26) c
Neem Leaves powder	200	10.80 a	20.8 (4.58) d	20.8 (4.58) d	16.4 (4.08) d	16.4 (4.08) d	13.2 (3.68) d
Neem Leaves powder	300	10.40 a	14.6 (3.84) e	14.6 (3.84) e	8.4 (2.98) e	8.4 (2.98) e	6.2 (2.54) e
Neem Leaves powder	400	10.20 a	7.8 (2.66) f	7.8 (2.66) f	2.4 (1.70) f	2.4 (1.70) f	1.4 (1.36) e
Untreated control	-	11.20 a	60.4 (7.76) a	60.4 (7.76) a	36.4 (6.04) a	36.4 (6.04) a	24.2 (4.92) a
C.V (%)	-	30.53	8.09	8.09	8.01	8.01	7.84
SE±	-	1.521	0.1619	0.1619	0.1342	0.1342	0.1158

-Means with the same letter in the same column are not significantly different (P< 0.05) according to DMRT

-Means in parenthesis are transformed to $\sqrt{x+0.5}$.

Table 13. Effect of aqueous extracts of Hargal shoot, Usher leaves and Neem leaves powder on mango le

October, 2011.

Treatment	Concs (g/10 L of water)	Mean No. of galls/20 leaves				
		Spray number				
		1st spray		2nd spray		
		Pre- spray count	Count 10 days after spray	Pre- spray count	Count 10 days after spray	Pre- co
Hargal shoot powder	200	37.60 a	75.4 (8.68) d	75.4 (8.68) d	37.0 (6.10) b	37.0 (6
Hargal shoot powder	300	36.80 a	31.4 (5.48) e	31.4 (5.48) e	31.4 (5.66) b	31.4 (5
Hargal shoot powder	400	38.00 a	11.6 (3.46) fg	11.6 (3.46) fg	11.0 (3.36) e	11.0 (3
Usher Leaves powder	200	36.60 a	95.2 (9.80) b	95.2 (9.80) b	37.0 (5.98) b	37.0 (5
Usher Leaves powder	300	38.40 a	84.8 (9.24) c	84.8 (9.24) c	33.8 (5.83) b	33.8 (5
Usher Leaves powder	400	39.20 a	15.2 (3.90) f	15.2 (3.90) f	17.2 (4.18) d	17.2 (4
Neem Leaves powder	200	42.40 a	80.6 (8.98) cd	80.6 (8.98) cd	33.8 (5.84) b	33.8 (5
Neem Leaves powder	300	41.60 a	30.6 (5.24) e	30.6 (5.24) e	26.4 (5.14) c	26.4 (5
Neem Leaves powder	400	40.00 a	9.6 (3.16) g	9.6 (3.16) g	8.8 (3.08) e	8.8 (3.0
Untreated control	-	42.80 a	116.2 (10.76) a	116.2 (10.76) a	84.8 (9.24) a	84.8 (9
C.V (%)	-	19.31	5.69	5.69	6.87	6.87
SE±	-	3.400	0.1749	0.1749	0.1673	0.1673

-Means with the same letter in the same column are not significantly different (P< 0.05) according to DMRT

-Means in parenthesis are transformed to $\sqrt{x+0.5}$.

Table 14. Effect of aqueous extracts of Hargal shoot, Usher leaves and Neem leaves powder on mango leaf gall
2012.

Treatment	Concs (g/10 L of water)	Mean No. of galls/20 leaves				
		Spray number				
		1st spray		2nd spray		
		Pre- spray count	Count 10 days after spray	Pre- spray count	Count 10 days after spray	Pre- co
Hargal shoot powder	200	8.20 a	27.8 (5.28) c	27.8 (5.28) c	24.0 (4.90) c	24.0 (4.
Hargal shoot powder	300	10.00 a	26.6 (5.16) c	26.6 (5.16) c	20.6 (4.56) d	20.6 (4.
Hargal shoot powder	400	10.20 a	6.6 (2.62) f	6.6 (2.62) f	3.0 (1.88) g	3.0 (1.8
Usher Leaves powder	200	9.80 a	31.2 (5.64) b	31.2 (5.64) b	28.6 (5.36) b	28.6 (5.
Usher Leaves powder	300	9.20 a	28.6 (5.36) bc	28.6 (5.36) bc	24.2 (4.92) c	24.2 (4.
Usher Leaves powder	400	8.60 a	10.2 (3.26) e	10.2 (3.26) e	8.2 (2.94) f	8.2 (2.9
Neem Leaves powder	200	9.00 a	22.6 (4.76) d	22.6 (4.76) d	19.4 (4.44) de	19.4 (4.
Neem Leaves powder	300	9.60 a	21.8 (4.78) d	21.8 (4.78) d	17.8 (4.22) e	17.8 (4.
Neem Leaves powder	400	10.00 a	6.4 (2.58) f	6.4 (2.58) f	2.2 (1.64) g	2.2 (1.6
Untreated control	-	9.40 a	54.6 (7.40) a	54.6 (7.40) a	46.0 (6.80) a	46.0 (6.
C.V (%)	-	29.76	5.57	5.57	5.45	5.45
SE±	-	1.251	0.1131	0.1168	0.1010	0.1010

-Means with the same letter in the same column are not significantly different (P< 0.05) according to DMRT

-Means in parenthesis are transformed to $\sqrt{x+0.5}$.

Table 15. Effect of aqueous extracts of Hargal shoot, Usher leaves and Neem leaves powder on mango le

October, 2012.

Treatment	Concs (g/10 L of water)	Mean No. of galls/20 leaves				
		Spray number				
		1st spray		2nd spray		
		Pre- spray count	Count 10 days after spray	Pre- spray count	Count 10 days after spray	Pre- s cou
Hargal shoot powder	200	28.00 a	38.4 (6.20) bc	38.4 (6.20) bc	36.6 (6.08) c	36.6 (6.
Hargal shoot powder	300	30.00 a	30.2 (5.52) cd	30.2 (5.52) cd	26.6 (5.16) d	26.6 (5.
Hargal shoot powder	400	30.80 a	8.8 (3.04) f	8.8 (3.04) f	8.8 (3.02) g	8.8 (3.0
Usher Leaves powder	200	28.40 a	43.2 (6.60) b	43.2 (6.60) b	41.8 (6.48) b	41.8 (6.
Usher Leaves powder	300	33.00 a	39.0 (6.08) bc	39.0 (6.08) bc	36.8 (6.10) c	36.8 (6.
Usher Leaves powder	400	35.00 a	12.6 (3.60) f	12.6 (3.60) f	17.8 (3.40) f	17.8 (3.
Neem Leaves powder	200	35.40 a	29.6 (4.86) de	29.6 (4.86) de	28.4 (5.34) d	28.4 (5.
Neem Leaves powder	300	32.00 a	21.8 (4.68) e	21.8 (4.68) e	21.0 (4.60) e	21.0 (4.
Neem Leaves powder	400	33.00 a	7.8 (2.86) f	7.8 (2.86) f	8.2 (2.96) g	8.2 (2.9
Untreated control	-	35.00 a	115.2 (10.92) a	115.2 (10.92) a	87.2 (9.36) a	87.2 (9.
C.V (%)	-	25.73	10.19	10.19	4.90	4.90
SE±	-	3.692	0.2470	0.2470	0.1149	0.1149

-Means with the same letter in the same column are not significantly different (P< 0.05) according to DMRT

-Means in parenthesis are transformed to $\sqrt{x+0.5}$.

Table 16. The effect of hargl shoot, usher leaves and neem leaves powder aqueous extract on mango yield (Kg/Tree).

Treatment	Concs (g/10 L of water)	Year		Combined
		2011	2012	
Hargal shoot powder	200	24.08 f	25.68 f	24.88 g
Hargal shoot powder	300	27.98 e	29.98 e	28.98 f
Hargal shoot powder	400	44.58 b	45.88 b	45.23 b
Usher Leaves powder	200	15.12 h	17.06 h	16.09 i
Usher Leaves powder	300	18.76 g	20.56 g	19.66 h
Usher Leaves powder	400	38.98 c	40.82 c	39.90 d
Neem Leaves powder	200	31.78 d	33.56 d	32.67 e
Neem Leaves powder	300	43.20 b	43.80 bc	43.50 c
Neem Leaves powder	400	55.02 a	57.28 a	56.15 a
Untreated control		15.96 gh	16.12 h	16.04 I
C.V (%)	-	8.55	7.30	8.12
SE±	-	0.8531	0.7634	0.5867

-Means with the same letter in the same column are not significantly different (P< 0.05) according to DMRT.

CHAPTER FIVE

DISCUSSION

5.1. The mango leaf gall midge *P. matteiana*

In the Sudan, *P. matteiana* was recently reported in the Gezira, North and South Kordofan States (Mardi *et al.*, 2010). Results of the current study showed wide spread of *P. matteiana* in (76.9%) of the mango growing areas, covering ten states. In the northern parts of the country, where the annual rainfalls are less than 200 mm, the mango cultivations were found to be free of infestation. In this study, gall flies actively in the field coincide with the new flush of mango leaves. The larvae of *P. matteiana* are observed to have confined themselves in galls on leaves. Pupation took place in the same galls. The same observations have also been reported by Gupta (1952), Botha and Kotzé (1987) and Askari and Bagheri (2005). In this study, *P. matteiana* life cycle under field conditions showed high variation ranged from 1.5 to 8.4 months. This variation may be attributed to the date of eggs laying and its relation to the relative humidity. This finding agreed with Botha and Kotzé (1987), who reported that variation in life cycle period ranged from 3 to 7 months in South Africa. In north India, Gupta (1952) observed three generations in the year, the larval period of the first generation lasts for about 2-12 months. Since there are overlapping broods, the adults emergence and oviposition are a continuous activity. During the present study at ElMolbus, North Kordofan State, annually, two peaks of galls per new mango leaves were observed in late September and late November. This result is in line with Grové *et al* (2002) who found that the gall flies are very active during November to April with two peaks in February and April in South Africa. This result is also similar to observations of Kaushik *et al.*, (2012) who observed two generations in India; in April and September. In AbuGabaiha, South Kordofan State three peaks of galls per new mango leaves were recorded in July, September and November of the year. This

result agrees with Gupta (1952) who reported three generations per year in north India. This study showed that the galls formation was enhanced with high humidity. So, the larval and pupal survival capacity was improved. Similar results were reported by Grové *et al.,* (2002) ; Askari and Bagheri (2005) and Mardi *et al.,* (2010). In this work some aspects of *P. matteiana* were studied under laboratory conditions. During this work eggs are laid as a cluster on the underside, rarely on the upper, side of mango young leaves and lie embedded in the soft tissue. Same observations wewe forwarded by Askari and Bagheri (2005). With respect to the sex ratio of *P. matteiana*, it was found to be 1:1 in this work, which is similar to finding of Askari and Bagheri (2005) who reported same sex ratio for *P. matteiana* in Iran.

5.2. Susceptbility of some Sudanese mango cultivars for *P. matteiana* infestation.

Regarding the mango cultivars responses to attack by *P. matteiana*. All tested mango cultivars had fully developed galls (true galls) on their leaves and hence were susceptible with different levels. From the results on the mean infested leaves percentage, Al Phonse and Tommy Atkins were found to be the most susceptible cultivars irrespective of the different localities whereas Abu-Samaka Khadra and Abu-Samaka Baida were the least susceptible. The rest of cultivars showed moderate susceptibility with slight variability between them in the four sites. Similar studies were done in India and South Africa by Jhala *et. al.* (1987), Rao *et al* (1991), Githure *et al* (1998) and Patel *et al.,* (2011) were consistent with these findings though the cultivars used in India and South Africa were not the same as those in Sudan expect Al Phonse and Tommy Atkins cultivars. Significant differences in levels of susceptibility to *P. matteiana* between cultivars of mangoes were observed in the studies by all above mentioned authors. However, in these four studies, only Githure *et al.,* (1998) mentioned the damage made of the non

developed galls (pseudogalls). In this study, Al Phonse and Tommy Atkins were found to be the most susceptible cultivars across all the sites. This finding agreed with the results reported by Jhala *et al.,* (1987), Githure *et al* (1998) and Patel *et al.,* (2011) in India and in South Africa. The mean number of gall per leaf results showed that Kitchener, Al Phonse and Tommy Atkins cultivars showed the highest susceptibility while Abu-Samaka Khadra and Abu-Samaka Baida were the least susceptible ones. The mean number of gall per leaf were substantially higher in this study than those reported on mango leaves in two sites in South Africa where means ranged between 42.65 to 229.85 galls per leaf (Githure *et al.,*1998). The gall densities per leaf recorded in the present study were lower than those recorded on fifteen cultivars in India, where mean number of gall per square centimeter range is 7.17-91.58 (Patel *et al.,* 2011). In South Africa, Githure *et al.,* (1998) recorded the mean number of gall/cm^2 ranged between 0.8-4.1, which is approximately the same means in this study. The present study showed 2-10 times mean number of gall/cm^2 higher than those recorded on 23 mango cultivars in India, where mean number of gall/cm^2 ranged from 0.287-0.549 (Sathiyanandam *et al.,*1973). In the present study, there was a significant difference in mean gall diameter among tested cultivars. This finding agreed with the results of Githure *et al.,* (1998) who found variations in gall diameter among mango cultivars in South Africa. The mean diameter of galls did not appear to be influenced by the mean number of galls per leaf. This was the case in the observed variations such as Al Phonse and Tommy Atkins cultivar which were heavily infested but had larger galls than the other cultivars. Abu-Samaka Khadra and Abu-Samaka Baida which were least infested had smaller galls than other cultivars. Other cultivars showed variable gall sizes that did not seem to have any relationship with the number of galls. From the results of leaf area, the tested mango cultivars showed variations in mean leaf area. No relationship was noticed between the mean leaf area and mean number of gall

per leaf, mean gall density and mean gall diameter. This finding dose not agree with the data presented by Githure *et al.*, (1998) who reported that leaf area seemed to have a positive effect on gall diameter. The same author attributed this effect to two factors. First, differences in climate between the sites may influence the plant growth rate, water content, nutrient availability and chemical substances (secondary metabolites). These plant attributes are known to affect oviposition preference, and larval performance and survival. Second, different management practices between sites such as fertilizer application, irrigation and general crop husbandry may have resulted in higher levels of infestation of some cultivars. Results obtained from all above studies showed that levels of susceptibility appear to be related to cultivar differences based on their genetic differences. Genetic traits interact with environmental factors and therefore varying environmental factors such as nutrient supply, have been shown to affect the level of attack in gall-forming herbivores (Horner and Warren, 1992). Sathiyanandam *et al.*, (1973) also found that the most susceptible cultivar "Peter" had a higher amino acid content, less sugars and less fibre content, whereas the resistant cultivar "Chandrakaran" had less amino acids, high sugar content and high fibre content. Augustyn *et al.*, (2010) in South Africa found that Tommy Atkins, Heidi and Zill the most susceptible cultivars were emitting terpenes more than the least susceptible ones.

5.3. Efficacy of some botanical extracts for control of *P. matteiana*

Screening of botanical extracts, especially neem, for the control of insect pests under field conditions was done by several researchers in different countries (Saxena and Besit, 1982; Schumtterer, 1995; Satti, 1997; Rashid *et al.*, 2012). Extracts of neem tree parts showed a good performance in controlling some insect pests of mango such as: fruit flies, mango leafhoppers, mango tip borer and mango

shoot caterpillar (Bissdorf, 2005). The results of the present study showed that aqueous extract of neem leaves powder has potential for control of *P. matteiana* on mango trees. Reductions in number of galls on mango leaves after neem treatment are the result of mortality of eggs and the first larval instar and adult female repellency. Antifeedant effect, insecticidal effect by contact and repellency effect of neem may cause the mortality of eggs and the first larvae and repellency of adult female, respectively. This result agreed with Ermel *et al.*, (1986), Siddig (1986), Lowery and Isman (1993) and Naumann and Rankin (1999) who reported the antifeedant effect and insecticidal effect of neem extracts against some insect pests. It was observed from the results presented that aqueous extract of hargal shoot and neem leaves powder at 400g/10 litre gave similar and non statistical significant difference the mean of gall /leaves. So, the galls reduction obtained by aqueous extract of hargal shoot powder may be attributed to the systemic insecticidal effect of hargal. This result is similar to the result obtained by Elkhatim (2005) and Eldoush *et al.,* (2011) who reported the systemic insecticidal effect of hargal on some insect pests of Lodgepole pine, Okra and Date palm. The performance of aqueous extract of usher leaves powder, when tested at 200, 300 and 400g/10 litre was less potent against *P. matteiana* when compared with the same concentrations of aqueous extract of neem leaves powder. Similar results were reported by Mohamed (2002) who stated that ethanolic extract of *C. procera* leaf when used under field conditions alone reduced the number of White fly (*B. tabaci*) on Okra for 48 hours followed by a rapid increase in population. Also, Patil *et al.*, (1993) stated that extracts of *C. procera* gave higher mortality of *A. moorei* than that of neem within 24 hours but after 48 hours, the effect became similar to that of the neem. The quick decreasing in uhser extract potency could be a result of environmental effects viz. temperature, photodecomposition (UV-light), oxidation, ect. This finding disagreed with Taha *et al.,* (2011) who stated that application of

C. procera at 100gm powder/tree controlled immature stages of Green pit scale insect (*A. phoenicis*) on date palm for 8 to 10 weeks. In this study, most of the effect of usher on *P. matteiana* adult female and first larvae may be attribuated to antifeedant and repellency properties. This is on line with several researchers such as: Sharma (1983), Meshram (1995), Ahmed (1998), Mohamed (2002) and Ahmed *et al.*, (2006). The combined analysis of mango fruits yield (Kg/tree) showed an increase after treatment with the all tested botanicals compared with the control. The yield in aqueous extract of hargal shoot and neem leaves powder treatments was significantly increased. This was attributed to the control of *P. matteiana*. Moreover, the aqueous extract of neem leaves powder at highest concentration (400g/10 litre of water) showed highest mean yield (56.15 kg/tree) when compared with the same concentration of aqueous extract of hargal shoot powder. Similar results were obtained by Siddig (1991) and Elsiddig (1998) when applied some neem formulations to control some insect pests on potato and groundnut.

Conclusions and Recommendations:

According to the findings of the present work the followings results can be concluded:

1- It seems that, *P. matteiana* is widely distributed in most mango growing areas in Sudan.

2- The duration of the life cycle showed high variations under field conditions.

3- *P. matteiana* has two peaks of galls n mang in North Kordofan during late September and late November. South Kordofan recorded three peaks of galls abundant during the late of July, August and November.

4- The screening of mango cultivars against *P. matteiana* indicated that all tested cultivars from the four mango-growing sites were susceptible with different levels. Based on infested leaves percent, number of gall per leaf and gall density/cm^2 Alphonse and Tommy Atkins cultivars showed high susceptibility while low susceptibility was recorded by Abusamaka Khadra and Abusamaka Baida cultivars. This finding needs intensive research on genetic and chemical constituents of the two cultivars, in addition to their acceptance by the consumers.

5- The aqueous extract of neem leaves powder and hargal shoot powder at 400g/10 litre is highly effective in controlling *P. matteiana*. Neem leaves aqueous extract resulted in the highest yield of mango fruits and hence it recommended for the control *P. matteiana*, as it is cheap, effective and easy to prepare.

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Appendixes

Appendix A

Table 1. Monthly number of gall/10 leaves for mango trees attacked by mango leaf gall midge during January to December, 2011 at ElMolbus, North Kordofan State Sudan.

Month	Replication (tree)									
	Number of gall/10 leaves									
	1	2	3	4	5	6	7	8	9	10
11 January	0	0	0	0	0	0	0	0	0	0
11 February	0	0	0	0	0	0	0	0	0	0
11 March	0	0	0	0	0	0	0	0	0	0
10 April	0	0	0	0	0	0	0	0	0	0
10 May	0	0	0	0	0	0	0	0	0	0
10 June	0	0	0	0	0	0	0	0	0	0
10 July	6	4	6	5	5	7	4	4	4	5
10 August	30	21	26	34	39	31	28	22	30	39
10 September	268	254	298	304	260	296	308	295	198	199
10 October	78	82	76	79	85	88	91	65	60	76
10 November	266	256	319	312	298	276	221	234	234	244
10 December	1	0	1	2	2	1	0	2	1	0

Table 2. Monthly number of gall/10 leaves for mango trees attacked by mango leaf gall midge during January to December, 2012 at ElMolbus, North Kordofan State Sudan.

Month	Replication (tree)									
	Number of gall/10 leaves									
	1	2	3	4	5	6	7	8	9	10
11 January	0	0	0	0	0	0	0	0	0	0
11 February	0	0	0	0	0	0	0	0	0	0
11 March	0	0	0	0	0	0	0	0	0	0
10 April	0	0	0	0	0	0	0	0	0	0
10 May	0	0	0	0	0	0	0	0	0	0
10 June	0	0	0	0	0	0	0	0	0	0
10 July	5	7	5	6	6	4	4	4	4	5
10 August	28	22	35	25	21	27	23	31	36	32
10 September	258	301	290	265	193	195	234	195	310	339
10 October	71	91	86	68	61	73	54	62	69	75
10 November	269	321	298	285	281	254	221	236	311	214
10 December	1	0	1	0	2	0	1	2	2	1

Table 3. Monthly number of gall/10 leaves for mango trees attacked by mango leaf gall midge during January to December, 2011 at Abu Gabiaha, South Kordofan State Sudan.

Month	Replication (tree)									
	Number of gall/10 leaves									
	1	2	3	4	5	6	7	8	9	10
11 January	0	0	0	0	0	0	0	0	0	0
11 February	0	0	0	0	0	0	0	0	0	0
11 March	0	0	0	0	0	0	0	0	0	0
10 April	0	0	0	0	0	0	0	0	0	0
10 May	0	0	0	0	0	0	0	0	0	0
10 June	59	51	46	51	56	64	59	65	70	69
10 July	139	136	141	160	147	153	132	134	123	125
10 August	47	42	51	42	51	49	48	49	45	46
10 September	289	299	286	292	283	276	281	285	298	301
10 October	99	98	152	89	95	97	98	101	150	111
10 November	262	289	273	265	269	275	273	261	270	263
10 December	2	0	0	1	1	1	1	1	1	2

Table 4. Monthly number of gall/10 leaves for mango trees attacked by mango leaf gall midge during January to December, 2012 at Abu Gabiaha, South Kordofan State Sudan.

Month	Replication (tree)									
	Number of gall/10 leaves									
	1	2	3	4	5	6	7	8	9	10
11 January	0	0	0	0	0	0	0	0	0	0
11 February	0	0	0	0	0	0	0	0	0	0
11 March	0	0	0	0	0	0	0	0	0	0
10 April	0	0	0	0	0	0	0	0	0	0
10 May	0	0	0	0	0	0	0	0	0	0
10 June	59	57	61	65	63	64	52	58	60	51
10 July	143	145	155	156	139	137	141	145	130	139
10 August	29	29	25	28	32	32	25	26	30	34
10 September	256	265	242	256	259	245	256	259	241	281
10 October	71	68	69	73	76	75	63	68	76	71
10 November	264	268	261	272	258	267	255	251	270	274
10 December	1	2	0	0	0	0	2	2	2	1

Table 5. Monthly mean temperature and relative from January to December, 2011 and 2012 at ElMolbus, North Kordofan and Abu Gabiaha site States, Sudan.

Month	2011				2012			
	ElMolbus site		Abu Gabiaha site		ElMolbus site		Abu Gabiaha site	
	T	R.H	T	R.H	T	R.H	T	R.H
January	20.1	24.7	22.2	23	23.1	22.2	25.3	21
February	25.4	15.6	26.8	17	25.8	15.3	25	18
March	26.4	12	27.1	15	26.4	10.9	27.1	13
April	30.4	9.8	32.9	12	32.8	13.3	32	17
May	31.7	19.5	34.4	21	31.7	15.8	32.5	19
June	32.4	32.3	29	25	32.7	29.7	30	31
July	29.7	50.5	29.1	57.2	28.2	59.6	28	63
August	27.2	67.5	24.1	69.8	27.8	65.3	23	69.5
September	28.1	58.3	25.1	65.4	29	59.5	24.1	63.9
October	29.2	41.9	27.4	45.6	29.9	33.4	27.5	44.3
November	23.1	20.9	31.5	23.5	25.9	23.8	32.2	21.4
December	21.6	27.2	27.3	27	21.7	22.6	26.4	26.7

Table 6. Time of *P.matteiana* adult emergence

Time	Replication (100 pupae)					Total	Mean
	1	2	3	4	5		
6 p.m - 6 a.m	73	77	82	83	80	395	79
6 a.m - 6 p.m	27	23	18	17	20	105	21

Appendix B

Table 1. Percentage of infested branches for twelve mango cultivars attacked by *P.matteiana* at ElMolbus, North Kordofan State, Sudan

Mango cultivar	Replication (10 branches/tree)									
	1	2	3	4	5	6	7	8	9	10
Taimour	50	40	30	20	20	20	30	40	40	40
Debsha	50	50	10	10	10	40	40	30	30	50
Abu-Samaka Khadra	20	20	10	10	10	30	20	20	20	10
Abu-Samaka Baida	10	10	10	20	30	10	20	20	20	10
Galbaltour	20	30	30	30	40	20	40	20	40	20
Kitchener	80	80	60	70	60	70	80	80	60	60
Baladia	100	100	80	100	100	90	90	90	90	100
Al Phonse	100	100	100	100	100	100	100	90	90	100
Shendi 1	80	80	70	70	60	60	60	70	80	70
Zibda Baida	80	50	40	40	50	40	50	40	40	40
Keitt	80	80	70	60	50	50	60	60	70	50
Tommy Atkins	100	100	100	100	100	100	100	90	100	100

Table 2. Percentage of infested branches for twelve mango cultivars attacked by *P.matteiana* at Errhad, North Kordofan State, Sudan

Mango cultivar	Replication (10 branches/tree)									
	1	2	3	4	5	6	7	8	9	10
Taimour	50	50	30	20	30	30	40	40	40	30
Debsha	50	10	20	10	20	20	20	50	40	40
Abu-Samaka Khadra	20	10	10	30	10	10	10	10	20	10
Abu-Samaka Baida	10	10	10	10	10	30	10	10	10	10
Galbaltour	20	20	20	20	20	40	20	10	10	10
Kitchener	80	80	80	80	60	70	60	60	60	70
Baladia	100	100	100	100	100	80	90	90	100	80
Al Phonse	100	100	100	100	100	90	100	100	100	100
Shendi 1	80	60	80	60	60	60	60	60	60	80
Zibda Baida	80	40	80	40	50	50	40	40	40	40
Keitt	80	50	80	50	60	60	60	60	60	60
Tommy Atkins	100	100	100	100	100	100	100	100	100	90

Table 3. Percentage of infested branches for twelve mango cultivars attacked by *P.matteiana* at AbuGabaiha, South Kordofan State, Sudan

Mango cultivar	Replication (10 branches/tree)									
	1	2	3	4	5	6	7	8	9	10
Taimour	80	80	60	20	30	30	30	30	30	30
Debsha	60	60	50	10	10	10	20	20	20	20
Abu-Samaka Khadra	40	40	30	30	10	10	10	10	10	10
Abu-Samaka Baida	10	40	10	30	20	10	20	20	10	10
Galbaltour	20	50	50	40	20	20	20	50	40	30
Kitchener	100	100	100	100	100	100	100	100	100	100
Baladia	100	100	100	100	100	100	100	100	100	1001
Al Phonse	100	100	100	100	100	100	100	100	100	100
Shendi 1	80	60	60	60	70	70	60	80	80	80
Zibda Baida	80	70	70	40	40	60	70	50	50	40
Keitt	80	80	50	50	50	50	50	50	50	50
Tommy Atkins	100	100	100	100	100	100	100	100	100	100

Table 4. Percentage of infested branches for twelve mango cultivars attacked by *P.matteiana* at Sinnja, Sennar State, Sudan

Mango cultivar	Replication (10 branches/tree)									
	1	2	3	4	5	6	7	8	9	10
Taimour	50	50	40	20	40	40	40	50	20	20
Debsha	50	10	10	10	40	40	40	50	50	10
Abu-Samaka Khadra	20	20	20	30	10	20	10	30	10	10
Abu-Samaka Baida	10	10	30	30	30	10	10	10	10	10
Galbaltour	20	20	20	40	40	40	40	30	30	30
Kitchener	80	80	30	70	60	70	70	70	70	80
Baladia	100	100	90	80	100	100	100	100	100	100
Al Phonse	100	100	100	90	100	100	100	100	100	100
Shendi 1	80	60	60	60	50	60	70	60	50	70
Zibda Baida	80	40	40	40	80	40	40	40	40	40
Keitt	80	80	50	60	50	50	70	70	60	50
Tommy Atkins	100	100	100	100	100	100	100	100	100	100

Table 5. Percentage of infested leaves for twelve mango cultivars attacked by *P.matteiana* at ElMolbus, North Kordofan State, Sudan

Mango cultivar	Replication (10 infested branches/tree)									
	1	2	3	4	5	6	7	8	9	10
Taimour	30	40	40	50	40	40	40	40	30	30
Debsha	30	50	50	50	50	40	40	40	40	30
Abu-Samaka Khadra	20	20	20	40	40	10	10	30	20	20
Abu-Samaka Baida	20	30	20	10	20	20	40	40	10	20
Galbaltour	30	40	50	50	40	30	40	40	30	30
Kitchener	90	90	80	80	80	100	70	70	100	80
Baladia	90	90	100	100	90	100	90	70	70	90
Al Phonse	100	100	100	100	100	100	100	100	100	90
Shendi 1	90	90	80	80	70	90	70	70	80	80
Zibda Baida	50	50	50	50	40	50	40	40	40	40
Keitt	90	100	80	80	70	100	70	70	100	80
Tommy Atkins	100	100	100	100	100	100	100	100	100	100

Table 6. Percentage of infested leaves for twelve mango cultivars attacked by *P.matteiana* at Errhad, North Kordofan State, Sudan

Mango cultivar	Replication (10 infested branches/tree)									
	1	2	3	4	5	6	7	8	9	10
Taimour	40	40	40	40	30	30	40	40	30	20
Debsha	40	40	40	50	40	40	40	50	40	30
Abu-Samaka Khadra	20	20	20	30	30	10	10	20	20	20
Abu-Samaka Baida	20	20	20	10	10	20	40	30	10	20
Galbaltour	30	40	40	40	40	30	40	30	30	30
Kitchener	80	90	80	80	70	80	70	70	90	90
Baladia	90	90	90	100	90	90	90	70	70	90
Al Phonse	100	100	100	100	100	100	100	100	100	90
Shendi 1	90	100	80	70	70	90	80	70	90	80
Zibda Baida	40	50	40	50	50	50	40	40	50	40
Keitt	90	90	90	70	70	70	90	90	90	80
Tommy Atkins	100	100	100	100	100	100	100	100	100	100

Table 7. Percentage of infested leaves for twelve mango cultivars attacked by *P.matteiana* at AbuGabaih, South Kordofan State, Sudan

Mango cultivar	Replication (10 infested branches/tree)									
	1	2	3	4	5	6	7	8	9	10
Taimour	30	40	40	50	40	30	40	40	50	40
Debsha	50	50	50	30	50	40	40	50	30	30
Abu-Samaka Khadra	10	20	20	30	40	40	10	40	20	20
Abu-Samaka Baida	10	30	10	10	20	40	40	30	20	20
Galbaltour	20	50	50	50	40	50	40	40	20	50
Kitchener	100	70	80	70	80	100	80	80	100	90
Baladia	100	100	100	90	90	90	90	90	90	90
Al Phonse	100	100	100	100	100	100	100	100	100	100
Shendi 1	90	80	70	80	70	90	70	70	70	70
Zibda Baida	40	50	40	50	40	50	40	50	40	40
Keitt	100	90	70	70	70	100	70	70	100	70
Tommy Atkins	100	100	100	100	100	100	100	100	100	100

Table 8. Percentage of infested leaves for twelve mango cultivars attacked by *P.matteiana* at Sinnja, Sennar State, Sudan

Mango cultivar	Replication (10 infested branches/tree)									
	1	2	3	4	5	6	7	8	9	10
Taimour	30	30	40	50	40	40	40	40	20	30
Debsha	30	50	40	50	50	40	40	40	40	50
Abu-Samaka Khadra	20	10	20	40	40	20	10	30	20	30
Abu-Samaka Baida	20	30	20	10	10	20	30	40	30	20
Galbaltour	30	40	50	40	40	30	40	50	30	50
Kitchener	90	100	80	80	70	70	80	70	100	90
Baladia	70	90	100	100	90	100	100	70	70	100
Al Phonse	100	100	100	100	100	100	100	100	100	90
Shendi 1	90	90	70	80	70	100	100	70	70	80
Zibda Baida	40	50	40	50	40	50	50	40	40	50
Keitt	70	90	100	80	70	90	70	70	90	100
Tommy Atkins	100	100	100	100	100	100	100	100	100	100

Table 9. Number of galls/leaf for twelve mango cultivars attacked by *P.matteiana* at ElMolbus, North Kordofan State, Sudan

Mango cultivar	Replication (10 infested leaves/tree)									
	1	2	3	4	5	6	7	8	9	10
Taimour	9	49	32	5	48	56	6	18	45	65
Debsha	34	5	8	25	27	16	13	3	1	9
Abu-Samaka Khadra	3	1	1	1	13	3	14	3	4	21
Abu-Samaka Baida	1	1	1	8	7	2	2	3	12	9
Galbaltour	12	26	5	12	28	14	2	7	6	8
Kitchener	207	91	312	325	280	266	314	392	173	254
Baladia	52	118	33	63	68	80	55	45	30	27
Al Phonse	231	88	263	359	230	255	326	280	330	331
Shendi 1	93	185	106	221	255	165	104	98	71	83
Zibda Baida	55	79	14	19	88	142	144	98	123	193
Keitt	169	187	211	154	94	72	91	207	166	183
Tommy Atkins	256	198	223	347	245	265	326	262	329	312

Table 10. Number of galls/leaf for twelve mango cultivars attacked by *P.matteiana* at Errhad, North Kordofan State, Sudan

Mango cultivar	Replication (10 infested leaves/tree)									
	1	2	3	4	5	6	7	8	9	10
Taimour	15	61	12	12	34	36	69	7	33	57
Debsha	12	5	8	17	33	21	9	36	18	2
Abu-Samaka Khadra	1	1	11	1	1	2	1	3	24	19
Abu-Samaka Baida	7	1	6	1	1	4	1	1	19	12
Galbaltour	9	31	2	19	22	2	4	14	2	14
Kitchener	93	198	209	312	356	346	299	349	254	377
Baladia	23	82	120	45	77	93	63	43	41	112
Al Phonse	254	297	289	341	356	312	235	223	301	271
Shendi 1	108	79	89	221	98	102	95	166	187	154
Zibda Baida	142	198	133	68	98	114	36	93	19	68
Keitt	169	187	211	154	94	72	91	207	166	183
Tommy Atkins	256	198	223	347	245	265	326	262	329	312

Table 11. Number of galls/leaf for twelve mango cultivars attacked by *P.matteiana* at AbuGabaiha, South Kordofan State, Sudan

Mango cultivar	Replication (10 infested leaves/tree)									
	1	2	3	4	5	6	7	8	9	10
Taimour	18	55	30	17	33	70	20	18	40	50
Debsha	5	9	28	10	28	14	19	8	19	20
Abu-Samaka Khadra	2	7	4	5	15	6	9	4	5	20
Abu-Samaka Baida	2	3	8	5	8	1	1	1	1	1
Galbaltour	9	20	17	23	7	19	19	7	8	9
Kitchener	200	320	400	299	201	245	389	219	300	194
Baladia	41	72	54	64	59	60	80	42	78	93
Al Phonse	300	244	200	322	260	297	320	355	402	387
Shendi 1	209	119	100	120	74	225	80	77	165	100
Zibda Baida	41	143	35	144	6	173	43	100	200	50
Keitt	135	160	114	23	89	171	102	120	137	142
Tommy Atkins	388	241	319	289	356	301	380	288	193	233

Table 12. Number of galls/leaf for twelve mango cultivars attacked by *P.matteiana* at Sinnja, Sennar State, Sudan

Mango cultivar	Replication (10 infested leaves/tree)									
	1	2	3	4	5	6	7	8	9	10
Taimour	51	49	18	38	41	62	9	24	7	57
Debsha	10	20	11	27	16	2	10	15	2	32
Abu-Samaka Khadra	12	3	2	8	23	1	7	2	2	12
Abu-Samaka Baida	5	2	3	8	5	1	7	2	2	12
Galbaltour	10	18	11	20	3	8	19	22	4	12
Kitchener	187	292	312	190	300	221	299	397	328	207
Baladia	67	98	58	51	68	75	65	58	48	67
Al Phonse	245	120	310	322	290	314	290	324	335	387
Shendi 1	189	177	123	257	41	187	114	109	132	42
Zibda Baida	33	198	56	23	78	167	174	79	145	68
Keitt	73	200	87	38	94	168	91	78	200	203
Tommy Atkins	238	227	300	356	317	227	387	185	300	230

Table 13. Gall density (gall/cm^2) for twelve mango cultivars attacked by *P.matteiana* at ElMolbus, North Kordofan State, Sudan

Mango cultivar	Replication (100 galls/tree)									
	1	2	3	4	5	6	7	8	9	10
Taimour	0	1	2	1	1	1	2	0	0	3
Debsha	1	0	0	1	1	1	1	0	0	1
Abu-Samaka Khadra	0	0	2	2	1	1	1	0	0	0
Abu-Samaka Baida	0	0	0	0	0	1	0	0	0	2
Galbaltour	1	1	0	1	1	0	0	1	0	0
Kitchener	2	4	2	4	2	2	4	2	5	5
Baladia	3	3	2	2	3	2	3	0	4	3
Al Phonse	4	5	6	3	5	8	7	7	6	2
Shendi 1	1	4	4	2	5	3	5	2	2	2
Zibda Baida	0	0	3	3	3	0	5	4	5	4
Keitt	4	4	3	1	5	3	5	2	3	2
Tommy Atkins	4	4	5	5	7	7	7	4	3	3

Table 14. Gall density (gall/cm^2) for twelve mango cultivars attacked by *P.matteiana* at Errhad, North Kordofan State, Sudan

Mango cultivar	Replication (100 galls/tree)									
	1	2	3	4	5	6	7	8	9	10
Taimour	1	1	2	0	1	1	2	1	2	3
Debsha	1	1	1	1	0	1	1	0	0	2
Abu-Samaka Khadra	1	0	2	1	1	2	1	2	0	1
Abu-Samaka Baida	1	0	0	0	0	1	0	1	1	0
Galbaltour	2	1	2	1	1	0	0	2	0	0
Kitchener	4	1	3	3	3	3	3	5	4	4
Baladia	2	5	3	4	2	3	0	4	2	3
Al Phonse	6	3	5	4	2	6	8	6	5	8
Shendi 1	3	3	3	3	4	4	3	5	4	5
Zibda Baida	2	0	0	3	2	3	4	5	5	5
Keitt	3	2	3	2	4	4	4	3	4	4
Tommy Atkins	4	8	5	7	6	3	6	8	7	6

Table 15. Gall density (gall/cm^2) for twelve mango cultivars attacked by *P.matteiana* at AbuGabaiha, South Kordofan State, Sudan

Mango cultivar	Replication (100 galls/tree)									
	1	2	3	4	5	6	7	8	9	10
Taimour	2	0	3	2	1	2	0	0	0	1
Debsha	0	0	0	2	1	1	1	2	2	0
Abu-Samaka Khadra	1	1	1	2	2	1	1	2	2	1
Abu-Samaka Baida	0	1	0	0	1	1	1	1	2	2
Galbaltour	2	0	0	2	2	0	1	1	1	0
Kitchener	4	4	3	4	5	2	2	3	4	4
Baladia	0	4	3	2	4	1	4	1	2	2
Al Phonse	5	2	2	8	5	3	7	2	6	6
Shendi 1	3	3	3	3	2	5	5	2	5	4
Zibda Baida	2	0	5	4	2	2	4	4	4	4
Keitt	2	3	3	5	2	4	4	3	4	4
Tommy Atkins	8	4	7	5	2	7	7	4	7	7

Table 16. Gall density (gall/cm^2) for twelve mango cultivars attacked by *P.matteiana* at Sinnja, Sennar State, Sudan.

Mango cultivar	Replication (100 galls/tree)									
	1	2	3	4	5	6	7	8	9	10
Taimour	0	0	0	2	2	2	2	1	1	0
Debsha	1	1	1	0	1	0	1	1	1	1
Abu-Samaka Khadra	0	0	0	2	2	0	1	2	0	0
Abu-Samaka Baida	0	0	0	1	0	1	0	1	0	2
Galbaltour	1	2	1	1	0	2	0	1	1	1
Kitchener	4	4	3	5	3	2	4	3	4	4
Baladia	2	3	4	2	2	3	3	4	4	4
Al Phonse	5	5	4	4	3	7	7	7	6	4
Shendi 1	2	3	4	5	6	4	5	3	3	3
Zibda Baida	1	3	2	2	4	4	4	4	4	3
Keitt	2	3	4	4	4	4	4	5	3	3
Tommy Atkins	3	5	5	7	5	6	7	7	6	7

Table 17. Gall diameter (mm) for twelve mango cultivars attacked by *P.matteiana* at ElMolbus, North Kordofan State, Sudan.

Mango cultivar	Replication (10 infested leaves/tree)									
	1	2	3	4	5	6	7	8	9	10
Taimour	2.2	3.5	3.5	4	3.7	3	3.1	3	3	3
Debsha	5	5.5	5.2	4	3	6.5	7.2	5	1.5	2
Abu-Samaka Khadra	2	3	2.1	2.8	2.1	2.2	2.3	2.7	3	2.8
Abu-Samaka Baida	1.5	2.2	2.2	1.5	2.6	2	1.5	2	2	2.5
Galbaltour	4	3.3	3.9	3.4	4	3.5	2.6	4	2.9	3
Kitchener	4	4	3.9	3.8	4	3.2	2.5	2.5	2.4	2.1
Baladia	3.9	4.5	2.5	4	4	3.8	3.5	4.2	4	4.3
Al Phonse	3.2	3.5	1	4	4	5	4	3.5	4.5	3.5
Shendi 1	3.2	3.9	3.4	3.5	3.5	3.9	2	3.2	3.4	2.9
Zibda Baida	3.1	3.1	3.2	2.9	2.8	3.1	3.2	2.8	2.4	2.2
Keitt	3	2.9	2.8	3.5	3.8	3.7	2.5	2.9	2.4	3.9
Tommy Atkins	3.2	3.1	4	4	3.9	4.2	4.2	4.9	4.2	3.9

Table 18. Gall diameter (mm) for twelve mango cultivars attacked by *P.matteiana* at Errhad, North Kordofan State, Sudan.

Mango cultivar	Replication (10 infested leaves/tree)									
	1	2	3	4	5	6	7	8	9	10
Taimour	3	2.2	3.2	3.9	3.9	3	3.2	3	3	3
Debsha	4	4.9	4.9	4.1	4	4.2	4	5.4	4.5	3.3
Abu-Samaka Khadra	2.2	3.1	2	2	2	2.4	3	2.7	2.8	2.4
Abu-Samaka Baida	2	2	2	2.4	1.5	1.5	1.5	1.7	1.7	1.8
Galbaltour	3.9	4	4	4	2.8	3.7	2.8	4.1	2.9	4
Kitchener	3.9	3.9	3.9	4	3.9	3.8	3.2	3.4	3.4	3.4
Baladia	4	3.9	3.2	3.9	4.1	4	3.7	4.1	3.9	4.2
Al Phonse	4	5	5	2.2	2.2	4	4.2	3.9	4.9	2.9
Shendi 1	3.1	4	4	3.9	4	4	3.5	3.7	4	3.1
Zibda Baida	3	3	3.6	3	2.9	2.9	3.4	2.9	3.2	2.9
Keitt	2.8	3.1	3.2	2.8	2.9	4	2.9	3	2.8	4
Tommy Atkins	5	4.7	3.9	3.9	4	3.3	4.8	3.9	4.7	4.2

Table 19. Gall diameter (mm) for twelve mango cultivars attacked by *P.matteiana* at AbuGabaiha, South Kordofan State, Sudan.

Mango cultivar	Replication (10 infested leaves/tree)									
	1	2	3	4	5	6	7	8	9	10
Taimour	3.1	2.3	3.4	3.7	2.2	3.1	3.4	2.9	3.9	2.9
Debsha	4.1	5	4.9	4.2	3.9	5	4.5	4.9	4.9	3.4
Abu-Samaka Khadra	2.1	3.2	3	2.2	3	2	2	2.1	2.1	2.5
Abu-Samaka Baida	2.1	2.3	1.7	2.1	2	2	1.1	1.2	1.3	1.4
Galbaltour	3.7	4.1	3.9	3.9	3.9	3.7	4	4	4	3.9
Kitchener	3.8	4	4	4.1	2.9	3.9	3.7	3.8	3.7	3.1
Baladia	4.1	3.9	3.7	3.1	3.9	3.4	4.2	3.6	3.9	3.7
Al Phonse	2.9	4.9	4.7	3.7	4.2	5	5	5.2	6.1	4
Shendi 1	3.9	3.1	4.2	3.1	3.7	3.9	4	4	3.9	3.9
Zibda Baida	2.8	2.8	3.1	2.5	3	3	3	3.1	3.1	3.2
Keitt	4	3.4	2.5	3	3	3.1	2.5	2.6	3	2.1
Tommy Atkins	4	4.9	5	5	5	4	4.6	4.9	4	4

Table 20. Gall diameter (mm) for twelve mango cultivars attacked by *P.matteiana* at Sinnja, Sennar State, Sudan

Mango cultivar	Replication (10 infested leaves/tree)									
	1	2	3	4	5	6	7	8	9	10
Taimour	3.1	2.4	2.1	3.9	2.9	3.5	3.7	2.9	3.1	2.9
Debsha	4.1	3.9	4.7	4.5	3.7	4.7	3	4.1	3.8	5
Abu-Samaka Khadra	2.1	2.9	2.1	2.4	3	3.1	2.4	2.8	3	2.1
Abu-Samaka Baida	1.7	2.1	3	1.4	1.9	2	1.1	2	1.5	2
Galbaltour	3.5	3.9	2	4.8	2	2	2.1	3.9	3.9	4
Kitchener	4	4	3.2	3.4	4	2.5	3.4	3.4	3.9	2.2
Baladia	3.4	4	4	4.1	3.5	3.7	3.9	4	4.1	4.1
Al Phonse	5	4.9	3.1	3.7	4.9	5	4.1	4.1	2.7	3
Shendi 1	4	3	3.4	4	3.7	2.1	4	3.9	2.4	4
Zibda Baida	3.1	2.6	2.9	3.2	2.9	2.5	3.1	3	3	3
Keitt	2.7	4	2.2	2.1	3.1	4	2	2	2.1	2.1
Tommy Atkins	4.9	4.7	5	3.4	3.8	3.9	5	3.9	4.5	4.3

Table 21. Leaf area (cm^2) for twelve mango cultivars attacked by *P.matteiana* at ElMolbus, North Kordofan State, Sudan

Mango cultivar	Replication (10 leaves/tree)									
	1	2	3	4	5	6	7	8	9	10
Taimour	86	107	79	112	94	103	110	102	66	83
Debsha	100	88	110	92	78	92	79	76	102	77
Abu-Samaka Khadra	98	94	100	101	102	86	94	79	105	100
Abu-Samaka Baida	101	92	85	82	99	86	97	86	99	93
Galbaltour	97	106	113	94	95	92	85	111	102	85
Kitchener	100	104	104	101	98	95	95	92	98	99
Baladia	93	109	118	93	105	89	115	101	106	98
Al Phonse	95	90	103	97	78	94	79	78	95	94
Shendi 1	101	93	100	86	87	92	101	91	87	85
Zibda Baida	96	103	94	93	103	105	105	93	98	93
Keitt	100	99	94	86	89	88	83	83	84	99
Tommy Atkins	94	94	94	94	93	94	94	95	93	94

Table 22. Leaf area (cm^2) for twelve mango cultivars attacked by *P.matteiana* at Errhad, North Kordofan State, Sudan

Mango cultivar	Replication (10 leaves/tree)									
	1	2	3	4	5	6	7	8	9	10
Taimour	87	107	79	111	94	103	110	102	66	83
Debsha	100	88	110	92	78	92	79	76	102	77
Abu-Samaka Khadra	98	94	100	101	102	86	94	79	105	100
Abu-Samaka Baida	101	92	85	82	99	86	97	86	99	93
Galbaltour	97	106	113	94	95	92	85	80	102	85
Kitchener	100	104	104	101	98	95	95	92	93	99
Baladia	93	109	118	93	105	89	115	101	105	98
Al Phonse	95	90	103	97	78	94	79	79	95	94
Shendi 1	101	93	100	86	86	92	101	91	87	85
Zibda Baida	96	103	94	93	103	105	105	93	89	93
Keitt	100	99	94	86	89	88	84	83	84	99
Tommy Atkins	94	94	94	94	93	94	94	95	93	94

Table 23. Leaf area (cm^2) for twelve mango cultivars attacked by *P.matteiana* at AbuGabaiha, South Kordofan State, Sudan

Mango cultivar	Replication (10 leaves/tree)									
	1	2	3	4	5	6	7	8	9	10
Taimour	86	107	79	111	94	103	110	102	66	83
Debsha	100	87	110	92	78	92	79	76	102	77
Abu-Samaka Khadra	98	94	100	101	102	86	94	79	105	100
Abu-Samaka Baida	101	92	85	82	99	86	97	86	99	93
Galbaltour	97	106	113	94	95	92	85	111	102	85
Kitchener	100	104	104	101	98	95	95	92	98	99
Baladia	93	109	118	92	105	89	115	101	106	98
Al Phonse	95	90	103	97	78	94	79	79	95	94
Shendi 1	101	93	100	86	87	92	101	91	87	84
Zibda Baida	96	103	94	93	103	105	105	93	89	93
Keitt	100	99	94	86	89	88	84	83	84	99
Tommy Atkins	94	94	94	94	93	94	94	95	93	94

Table 24. Leaf area (cm^2) for twelve mango cultivars attacked by *P.matteiana* at Sinnja, Sennar State, Sudan

Mango cultivar	Replication (10 leaves/tree)									
	1	2	3	4	5	6	7	8	9	10
Taimour	86	107	79	111	94	103	110	102	66	83
Debsha	100	88	110	92	78	92	79	76	102	77
Abu-Samaka Khadra	98	94	100	101	102	86	94	79	105	100
Abu-Samaka Baida	101	92	85	82	99	86	97	86	99	93
Galbaltour	97	106	113	94	95	92	85	111	102	86
Kitchener	100	104	104	101	98	94	95	92	98	99
Baladia	93	109	118	93	105	89	114	101	106	98
Al Phonse	95	90	103	97	78	94	79	79	95	94
Shendi 1	101	93	100	86	87	92	101	91	87	85
Zibda Baida	96	103	94	93	103	105	105	93	89	93
Keitt	100	99	94	86	899	88	84	83	84	99
Tommy Atkins	94	94	94	94	93	94	94	95	93	94

Appendix C

Table 1. Effect of aqueous extract of hargal shoot, usher leaves and neem leaves powder on mango leaf gall midge; 1st flush July- August, 2011. (Pre-count).

Treatment	Replication (Tree)					
	Number of gall/20 leaves					
	Concs (g/10 L of water)	1	2	3	4	5
Hargal shoot powder	200	9	11	12	12	10
Hargal shoot powder	300	10	9	9	8	20
Hargal shoot powder	400	17	8	9	9	19
Usher Leaves powder	200	12	14	8	9	15
Usher Leaves powder	300	12	9	15	8	11
Usher Leaves powder	400	9	14	9	10	17
Neem Leaves powder	200	12	9	17	8	8
Neem Leaves powder	300	12	14	9	9	8
Neem Leaves powder	400	11	9	9	14	8
Untreated control	-	14	12	11	11	8

Table 2. Effect of aqueous extract of hargal shoot, usher leaves and neem leaves powder on mango leaf gall midge; 1st flush July- August, 2011. (First spray).

Treatment	Replication (Tree)					
	Number of gall/20 leaves					
	Concs (g/10 L of water)	1	2	3	4	5
Hargal shoot powder	200	18	18	15	17	19
Hargal shoot powder	300	12	14	14	15	17
Hargal shoot powder	400	2	2	1	1	2
Usher Leaves powder	200	21	23	19	18	19
Usher Leaves powder	300	18	18	19	19	20
Usher Leaves powder	400	5	6	4	5	4
Neem Leaves powder	200	12	13	15	14	12
Neem Leaves powder	300	7	6	6	5	7
Neem Leaves powder	400	1	1	2	1	2
Untreated control	-	26	21	19	24	31

Table 3. Effect of aqueous extract of hargal shoot, usher leaves and neem leaves powder on mango leaf gall midge; 1st flush July- August, 2011. (Second spray).

Treatment	Replication (Tree)					
	Number of gall/20 leaves					
	Concs (g/10 L of water)	1	2	3	4	5
Hargal shoot powder	200	18	18	15	17	19
Hargal shoot powder	300	12	14	14	15	17
Hargal shoot powder	400	3	3	4	2	3
Usher Leaves powder	200	27	29	28	31	29
Usher Leaves powder	300	21	25	19	24	21
Usher Leaves powder	400	9	9	6	7	5
Neem Leaves powder	200	15	15	18	19	15
Neem Leaves powder	300	9	8	9	8	8
Neem Leaves powder	400	1	3	3	3	2
Untreated control	-	46	36	39	32	29

Table 4. Effect of aqueous extract of hargal shoot, usher leaves and neem leaves powder on mango leaf gall midge; 1st flush July- August, 2011. (Third spray).

Treatment	Replication (Tree)					
	Number of gall/20 leaves					
	Concs (g/10 L of water)	1	2	3	4	5
Hargal shoot powder	200	26	26	27	21	32
Hargal shoot powder	300	19	18	21	21	19
Hargal shoot powder	400	7	9	7	9	7
Usher Leaves powder	200	35	34	32	27	39
Usher Leaves powder	300	28	27	25	21	19
Usher Leaves powder	400	10	9	6	9	6
Neem Leaves powder	200	19	21	23	19	22
Neem Leaves powder	300	12	15	15	16	15
Neem Leaves powder	400	7	9	9	6	7
Untreated control	-	52	56	66	72	56

Table 5. Effect of aqueous extract of hargal shoot, usher leaves and neem leaves powder on mango leaf gall midge; 2nd flush October, 2011 (Pre-count).

Treatment	Replication (Tree)					
	Number of gall/20 leaves					
	Concs (g/10 L of water)	1	2	3	4	5
Hargal shoot powder	200	45	41	42	31	26
Hargal shoot powder	300	21	43	45	29	46
Hargal shoot powder	400	39	43	43	31	34
Usher Leaves powder	200	42	36	34	29	42
Usher Leaves powder	300	39	41	35	42	35
Usher Leaves powder	400	41	43	42	41	29
Neem Leaves powder	200	41	42	45	43	41
Neem Leaves powder	300	46	41	38	51	32
Neem Leaves powder	400	41	32	45	63	24
Untreated control	-	45	46	39	41	43

Table 6. Effect of aqueous extract of hargal shoot, usher leaves and neem leaves powder on mango leaf gall midge; 2nd flush October, 2011 (First spray).

Treatment	Replication (Tree)					
	Number of gall/20 leaves					
	Concs (g/10 L of water)	1	2	3	4	5
Hargal shoot powder	200	31	29	28	31	26
Hargal shoot powder	300	23	31	32	20	25
Hargal shoot powder	400	8	8	7	6	6
Usher Leaves powder	200	32	36	32	27	31
Usher Leaves powder	300	31	20	25	28	35
Usher Leaves powder	400	10	12	14	15	12
Neem Leaves powder	200	34	23	26	28	31
Neem Leaves powder	300	23	25	25	23	26
Neem Leaves powder	400	7	7	5	8	5
Untreated control	-	64	68	71	56	67

Table 7. Effect of aqueous extract of hargal shoot, usher leaves and neem leaves powder on mango leaf gall midge; 2nd flush October, 2011 (Second spray).

Treatment	Replication (Tree)					
	Number of gall/20 leaves					
	Concs (g/10 L of water)	1	2	3	4	5
Hargal shoot powder	200	42	42	32	37	32
Hargal shoot powder	300	26	35	39	26	31
Hargal shoot powder	400	10	12	15	9	9
Usher Leaves powder	200	42	39	37	32	35
Usher Leaves powder	300	37	23	38	36	35
Usher Leaves powder	400	16	18	17	19	16
Neem Leaves powder	200	37	38	35	28	31
Neem Leaves powder	300	21	26	27	29	29
Neem Leaves powder	400	9	9	8	10	8
Untreated control	-	88	91	81	86	78

Table 8. Effect of aqueous extract of hargal shoot, usher leaves and neem leaves powder on mango leaf gall midge; 2nd flush October, 2011 (Third spray).

Treatment	Replication (Tree)					
	Number of gall/20 leaves					
	Concs (g/10 L of water)	1	2	3	4	5
Hargal shoot powder	200	70	77	62	70	98
Hargal shoot powder	300	26	35	39	26	31
Hargal shoot powder	400	9	13	17	10	9
Usher Leaves powder	200	91	95	96	93	101
Usher Leaves powder	300	88	81	87	82	86
Usher Leaves powder	400	12	14	17	17	16
Neem Leaves powder	200	66	88	87	81	81
Neem Leaves powder	300	23	27	25	39	39
Neem Leaves powder	400	9	10	10	9	10
Untreated control	-	107	109	120	132	113

Table 9. Effect of aqueous extract of hargal shoot, usher leaves and neem leaves powder on mango leaf gall midge; 1st flush July- August, 2012. (Pre-count).

Treatment	Replication (Tree)					
	Number of gall/20 leaves					
	Concs (g/10 L of water)	1	2	3	4	5
Hargal shoot powder	200	7	8	5	9	12
Hargal shoot powder	300	11	9	15	9	6
Hargal shoot powder	400	9	8	10	14	10
Usher Leaves powder	200	8	9	12	11	9
Usher Leaves powder	300	11	9	12	8	6
Usher Leaves powder	400	5	9	14	8	7
Neem Leaves powder	200	15	9	4	8	9
Neem Leaves powder	300	5	11	14	9	9
Neem Leaves powder	400	9	7	12	12	10
Untreated control	-	12	9	8	11	7

Table 10. Effect of aqueous extract of hargal shoot, usher leaves and neem leaves powder on mango leaf gall midge; 1st flush July- August, 2012. (First spray).

Treatment	Replication (Tree)					
	Number of gall/20 leaves					
	Concs (g/10 L of water)	1	2	3	4	5
Hargal shoot powder	200	18	17	17	15	15
Hargal shoot powder	300	15	14	15	17	18
Hargal shoot powder	400	2	1	1	1	3
Usher Leaves powder	200	18	20	18	18	17
Usher Leaves powder	300	17	18	15	17	17
Usher Leaves powder	400	4	4	3	2	2
Neem Leaves powder	200	16	18	18	17	18
Neem Leaves powder	300	16	12	21	13	14
Neem Leaves powder	400	1	1	2	1	2
Untreated control	-	26	21	19	19	21

Table 11. Effect of aqueous extract of hargal shoot, usher leaves and neem leaves powder on mango leaf gall midge; 1st flush July- August, 2012. (Second spray).

Treatment	Replication (Tree)					
	Number of gall/20 leaves					
	Concs (g/10 L of water)	1	2	3	4	5
Hargal shoot powder	200	22	25	23	23	27
Hargal shoot powder	300	20	19	19	24	21
Hargal shoot powder	400	3	2	3	4	3
Usher Leaves powder	200	23	27	29	31	33
Usher Leaves powder	300	22	24	28	24	23
Usher Leaves powder	400	7	8	9	9	8
Neem Leaves powder	200	18	20	20	20	19
Neem Leaves powder	300	15	23	17	15	19
Neem Leaves powder	400	1	2	3	2	3
Untreated control	-	46	49	42	45	48

Table 12. Effect of aqueous extract of hargal shoot, usher leaves and neem leaves powder on mango leaf gall midge; 1st flush July- August, 2012. (Third spray).

Treatment	Replication (Tree)					
	Number of gall/20 leaves					
	Concs (g/10 L of water)	1	2	3	4	5
Hargal shoot powder	200	24	28	29	29	29
Hargal shoot powder	300	22	27	29	28	27
Hargal shoot powder	400	6	7	7	6	7
Usher Leaves powder	200	25	29	33	35	34
Usher Leaves powder	300	26	28	31	29	29
Usher Leaves powder	400	10	11	12	9	9
Neem Leaves powder	200	22	22	23	23	23
Neem Leaves powder	300	19	25	25	19	21
Neem Leaves powder	400	7	6	6	5	8
Untreated control	-	58	62	51	53	49

Table 13. Effect of aqueous extract of hargal shoot, usher leaves and neem leaves powder on mango leaf gall midge; 2nd flush October, 2012 (Pre-count).

Treatment	Replication (Tree)					
	Number of gall/20 leaves					
	Concs (g/10 L of water)	1	2	3	4	5
Hargal shoot powder	200	23	29	31	31	26
Hargal shoot powder	300	31	27	31	25	36
Hargal shoot powder	400	33	29	22	46	24
Usher Leaves powder	200	24	25	41	28	24
Usher Leaves powder	300	24	41	29	32	39
Usher Leaves powder	400	41	29	25	59	21
Neem Leaves powder	200	29	41	32	37	38
Neem Leaves powder	300	45	29	29	36	21
Neem Leaves powder	400	23	32	45	41	24
Untreated control	-	42	31	39	29	35

Table 14. Effect of aqueous extract of hargal shoot, usher leaves and neem leaves powder on mango leaf gall midge; 2nd flush October, 2012 (First spray).

Treatment	Replication (Tree)					
	Number of gall/20 leaves					
	Concs (g/10 L of water)	1	2	3	4	5
Hargal shoot powder	200	29	29	28	27	26
Hargal shoot powder	300	20	25	31	20	22
Hargal shoot powder	400	7	6	5	5	6
Usher Leaves powder	200	32	31	30	28	28
Usher Leaves powder	300	25	20	20	23	23
Usher Leaves powder	400	11	9	11	10	9
Neem Leaves powder	200	32	22	23	28	25
Neem Leaves powder	300	19	17	14	18	19
Neem Leaves powder	400	5	7	5	4	4
Untreated control	-	77	72	71	53	52

Table 15. Effect of aqueous extract of hargal shoot, usher leaves and neem leaves powder on mango leaf gall midge; 2nd flush October, 2012 (Second spray).

Treatment	Replication (Tree)					
	Number of gall/20 leaves					
	Concs (g/10 L of water)	1	2	3	4	5
Hargal shoot powder	200	35	39	41	39	29
Hargal shoot powder	300	25	25	29	28	26
Hargal shoot powder	400	8	7	9	10	10
Usher Leaves powder	200	39	41	42	45	42
Usher Leaves powder	300	32	39	37	39	37
Usher Leaves powder	400	12	12	12	10	13
Neem Leaves powder	200	35	25	24	29	29
Neem Leaves powder	300	21	21	21	23	19
Neem Leaves powder	400	9	8	9	8	7
Untreated control	-	85	92	85	87	87

Table 16. Effect of aqueous extract of hargal shoot, usher leaves and neem leaves powder on mango leaf gall midge; 2nd flush October, 2012 (Third spray).

Treatment	Replication (Tree)					
	Number of gall/20 leaves					
	Concs (g/10 L of water)	1	2	3	4	5
Hargal shoot powder	200	37	39	45	42	29
Hargal shoot powder	300	27	29	28	32	35
Hargal shoot powder	400	9	7	9	9	10
Usher Leaves powder	200	42	43	43	46	42
Usher Leaves powder	300	35	39	41	41	39
Usher Leaves powder	400	12	14	16	9	12
Neem Leaves powder	200	32	23	31	28	34
Neem Leaves powder	300	21	19	18	25	26
Neem Leaves powder	400	8	7	8	9	7
Untreated control	-	112	123	142	102	97

Table 17. The effect of hargl shoot, usher leaves and neem leaves powder aqueous extract on mango yield (Kg/Tree) 2011.

Treatment	Concs (g/10 L of water)	Replication				
		1	2	3	4	5
Hargal shoot powder	200	25.3	21.9	25.0	25	23.2
Hargal shoot powder	300	25.1	26.6	32	30.2	26
Hargal shoot powder	400	48.5	44	44.2	41.9	44.3
Usher Leaves powder	200	22.0	10.5	11.7	15.2	16.7
Usher Leaves powder	300	19.2	18.6	18.0	17.9	20.1
Usher Leaves powder	400	42.3	33.1	39.7	40.5	39.3
Neem Leaves powder	200	32.5	29.5	31.7	32.5	32.7
Neem Leaves powder	300	40.9	41.2	49.1	42.9	41.9
Neem Leaves powder	400	53.1	54.4	51.9	57	58.7
Untreated control	-	15.9	15.4	20.4	14.9	13.2

Table 18. The effect of hargl shoot, usher leaves and neem leaves powder aqueous extract on mango yield (Kg/Tree) 2012.

Treatment	Concs (g/10 L of water)	Replication (tree)				
		1	2	3	4	5
Hargal shoot powder	200	25.2	27.3	23.9	27.0	25
Hargal shoot powder	300	29	31.2	29.1	28.6	32
Hargal shoot powder	400	47.2	42.6	44.9	49.5	45.2
Usher Leaves powder	200	12.2	14.9	20.0	18.7	19.5
Usher Leaves powder	300	19.3	21.9	21.1	20.8	19.7
Usher Leaves powder	400	42.5	40.1	40.3	39.9	41.3
Neem Leaves powder	200	32	37.1	34.5	31.2	33.0
Neem Leaves powder	300	46.4	42.9	43.7	45.1	40.9
Neem Leaves powder	400	56.7	61.3	59	56.3	53.1
Untreated control	-	10.1	15.8	18.1	19.2	17.4

Appendix D

Susceptibility of some mango cultivars to Mango Leaf Gall Midge

Table 1. ANOVA for infested branch% in ElMolbus site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	1063.741	118.193	2.4863
Mango cultivars	11	60923.709	5538.519	116.5068
Error	99	4706.277	47.538	
Total	119	66693.727		

Table 2. ANOVA for Infested leaves% in ElMolbus site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	827.280	91.920	1.6167
Mango cultivars	11	55708.278	5064.389	89.0711
Error	99	5628.925	56.858	
Total	119	62164.482		

Table 3. ANOVA for Number of galls in ElMolbus site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	46.397	5.155	0.9564
Mango cultivars	11	3339.060	303.551	56.3157
Error	99	533.626	5.390	
Total	119	3919.084		

Table 4. ANOVA for gall density in ElMolbus site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	2.041	0.227	1.5894
Mango cultivars	11	30.857	2.805	19.6595
Error	99	14.126	0.143	
Total	119	47.025		

Table 5. ANOVA for Gall diameter in ElMolbus site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	5.840	0.649	1.0710
Mango cultivars	11	48.501	4.409	7.2768
Error	99	59.987	0.606	
Total	119	114.328		

Table 6. ANOVA for leaf area in ElMolbus site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	8.596	0.955	1.3361
Mango cultivars	11	18.143	1.649	2.3072
Error	99	70.774	0.715	
Total	119	97.513		

Table 7. ANOVA for Infested branch% in Errhad site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	960.359	106.707	2.3656
Mango cultivars	11	66413.649	6037.604	133.8510
Error	99	4465.583	45.107	
Total	119	71839.591		

Table 8. ANOVA for Infested leaves% in Errhad site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	404.364	44.929	1.2900
Mango cultivars	11	56637.034	5148.821	147.8263
Error	99	3448.191	34.830	
Total	119	60489.588		

Table 9. ANOVA for of galls in Errhad site

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	28.791	3.199	0.8036
Mango cultivars	11	3575.631	325.057	81.6606
Error	99	394.078	3.981	
Total	119	3998.500		

Table 10. ANOVA for gall density in Errhad site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	1.839	0.204	1.6593
Mango cultivars	11	31.492	2.863	23.2452
Error	99	12.193	0.123	
Total	119	45.524		

Table 11. ANOVA for Gall diameter in Errhad site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	1.777	0.197	0.6659
Mango cultivars	11	57.847	5.259	17.7353
Error	99	29.355	0.297	
Total	119	88.979		

Table 12. ANOVA for leaf sickness in Errhad site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	0.010	0.001	1.5647
Mango cultivars	11	0.133	0.012	17.3242
Error	99	0.069	0.001	
Total	119	0.212		

Table 13. ANOVA for leaf area in Errhad site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	9.165	1.018	1.4774
Mango cultivars	11	15.498	1.409	2.0440
Error	99	68.237	0.689	
Total	119	92.900		

Table 14. ANOVA for Infested branch% in Abu Gebaiha site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	1980.568	220.063	4.6523
Mango cultivars	11	79549.021	7231.729	152.8854
Error	99	4682.862	47.302	
Total	119	86212.451		

Table 15. ANOVA for Infested leaves% in Abu Gebaiha site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	971.565	107.952	1.5739
Mango cultivars	11	56547.521	5140.684	74.9500
Error	99	6790.231	68.588	
Total	119	64309.318		

Table 16. ANOVA for No. of galls in Abu Gebaiha site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	28.342	3.149	0.9923
Mango cultivars	11	3576.439	325.131	102.4465
Error	99	314.193	3.174	
Total	119	3918.974		

Table 17. ANOVA for gall density in Abu Gebaiha site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	2.048	0.228	1.6890
Mango cultivars	11	24.062	2.187	16.2362
Error	99	13.338	0.135	
Total	119	39.448		

Table 18. ANOVA for Gall diameter in Abu Gebaiha site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	2.651	0.295	1.2925
Mango cultivars	11	86.548	7.868	34.5289
Error	99	22.559	0.228	
Total	119	111.758		

Table 19. ANOVA for leaf sickness in Abu Gebaiha site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	0.007	0.001	2.5273
Mango cultivars	11	0.137	0.012	41.0422
Error	99	0.030	0.000	
Total	119	0.174		

Table 20. ANOVA for leaf area in Abu Gebaiha site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	8.481	0.942	1.3021
Mango cultivars	11	17.596	1.600	2.2106
Error	99	71.641	0.724	
Total	119	97.718		

Table 21. ANOVA for Infested branch% sinnja site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	819.380	91.042	1.7319
Mango cultivars	11	65119.880	5919.989	112.6142
Error	99	5204.310	52.569	
Total	119	71143.570		

Table 22. ANOVA for Infested leaves% in Sinnja site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	652.945	72.549	0.9165
Mango cultivars	11	56400.686	5127.335	64.7715
Error	99	7836.874	79.160	
Total	119	64890.505		

Table 22. ANOVA for No.of galls in Sinnja site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	15.128	1.681	0.3881
Mango cultivars	11	3434.622	312.238	72.0896
Error	99	428.794	4.331	
Total	119	3878.543		

Table 23. ANOVA for gall density in Sinnja site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	1.425	0.158	1.9941
Mango cultivars	11	33.156	3.014	37.9516
Error	99	7.863	0.079	
Total	119	42.444		

Table 24. ANOVA for Gall diameter in Sinnja site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	2.003	0.223	0.4885
Mango cultivars	11	60.683	5.517	12.1081
Error	99	45.106	0.456	
Total	119	107.792		

Table 25. ANOVA for leaf sickness in Sinnja site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	0.061	0.007	1.3721
Mango cultivars	11	0.151	0.014	2.7794
Error	99	0.490	0.005	
Total	119	0.702		

Table 26. ANOVA for leaf area in Sinnja site.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	8.470	0.941	1.3146
Mango cultivars	11	17.446	1.586	2.2154
Error	99	70.872	0.716	
Total	119	96.788		

Appendix E

Table 27. ANOVA for Infested branch% (Combined analysis).

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	3181.002	353.445	7.2218
Sites (A)	3	2905.145	968.382	19.7867
Mango cultivars (B)	11	264083.470	24007.588	490.5406
AB	33	7922.788	240.084	4.9056
Error	423	20702.078	48.941	
Total	479	298794.484		

Table 28. ANOVA for Infested leaves% (Combined analysis).

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	1300.963	144.551	2.4207
Sites (A)	3	334.874	111.625	1.8693
Mango cultivars (B)	11	224660.803	20423.709	342.0202
AB	33	632.716	19.173	0.3211
Error	423	25259.411	59.715	
Total	479	252188.767		

Table 29. ANOVA for No. of galls (Combined analysis).

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	54.538	6.060	1.4776
Sites (A)	3	1.348	0.449	0.1096
Mango cultivars (B)	11	13869.298	1260.845	307.4326
AB	33	56.454	1.711	0.4171
Error	423	1734.811	4.101	
Total	479	15716.450		

Table 30. ANOVA for gall density (Combined analysis).

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	2.854	0.317	2.5781
Sites (A)	3	1.059	0.353	2.8717
Mango cultivars (B)	11	116.880	10.625	86.4004
AB	33	2.687	0.081	0.6621
Error	423	52.020	0.123	
Total	479	175.500		

Table 31. ANOVA for Gall diameter (Combined analysis).

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	5.476	0.608	1.5714
Sites (A)	3	3.053	1.018	2.6283
Mango cultivars (B)	11	239.964	21.815	56.3349
AB	33	13.615	0.413	1.0654
Error	423	163.801	0.387	
Total	479	425.910		

Table 32. ANOVA for leaf area (Combined analysis).

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	9	24.923	2.769	4.0211
Sites (A)	3	0.041	0.014	0.0200
Mango cultivars (B)	11	67.580	6.144	8.9208
AB	33	1.103	0.033	0.0485
Error	423	291.313	0.689	
Total	479	384.960		

Appendix F

Botenical for Mango Leaf Gall Midge

Table 1. ANOVA for No.of galls/tree 1st spray 1st flush 2011 (pre-count).

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	4	39.920	9.980	0.8627
Botanicals	9	19.620	2.180	0.1884
Error	36	416.480	11.569	
Total	49	476.020		

Table 1. ANOVA for No.of galls/tree 1st spray 1st flush 2011

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	4	0.319	0.080	0.6088
Botanicals	9	115.129	12.792	97.7075
Error	36	4.713	0.131	
Total	49	120.161		

Table 3. ANOVA for No.of galls/tree 2nd spray 1st flush 2011

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	4	0.133	0.033	0.3685
Botanicals	9	93.109	10.345	114.8357
Error	36	3.243	0.090	
Total	49	96.485		

Table 4. ANOVA for No.of galls/tree 3rd spray 1st flush 2011

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	4	0.433	0.108	1.6253
Botanicals	9	75.336	8.371	125.6232
Error	36	2.399	0.067	
Total	49	78.168		

Table 5. ANOVA for No.of galls/tree 1st spray 2nd flush 2011(pre count)

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	4	224.080	56.020	0.9691
Botanicals	9	256.580	28.509	0.4932
Error	36	2081.120	57.809	
Total	49	2561.780		

Table 6. ANOVA for No.of galls/tree 1st spray 2nd flush 2011

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	4	1.438	0.360	2.3505
Botanicals	9	379.321	42.147	275.5693
Error	36	5.506	0.153	
Total	49	386.265		

Table 7. ANOVA for No.of galls/tree 2nd spray 2nd flush 2011

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	4	0.363	0.091	0.6492
Botanicals	9	136.466	15.163	108.5388
Error	36	5.029	0.140	
Total	49	141.858		

Table 8. ANOVA for No.of galls/tree 3rd spray 2nd flush 2011

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	4	0.156	0.039	0.3293
Botanicals	9	116.789	12.977	109.5863
Error	36	4.263	0.118	
Total	49	121.208		

Table 9. ANOVA for No.of galls/tree 1st spray 1st flush 2012 (pre-count)

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	4	29.000	7.250	0.9262
Botanicals	9	19.200	2.133	0.2725
Error	36	281.800	7.828	
Total	49	330.000		

Table 10. ANOVA for No.of galls/tree 1st spray 1st flush 2012

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	4	0.677	0.169	2.4828
Botanicals	9	100.295	11.144	163.4271
Error	36	2.455	0.068	
Total	49	103.427		

Table 12. ANOVA for No.of galls/tree 2nd spray 1st flush 2012

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	4	0.651	0.163	3.1632
Botanicals	9	14.068	12.674	246.2612
Error	36	1.853	0.051	
Total	49	116.572		

Table 13. ANOVA for No.of galls/tree 3rd spray 1st flush 2012

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	4	0.233	0.058	0.9130
Botanicals	9	75.747	8.416	131.8031
Error	36	2.299	0.064	
Total	49	78.279		

Table 14. ANOVA for No.of galls/tree 3rd spray 1st flush 2012

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	4	2.419	0.605	1.9850
Botanicals	9	234.639	26.071	85.5660
Error	36	10.969	0.305	
Total	49	248.027		

Table 15. ANOVA for No.of galls/tree 1st spray 2nd flush 2012 (pre-count)

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	4	304.680	76.170	1.1177
Botanicals	9	335.680	37.298	0.5473
Error	36	2453.320	68.148	
Total	49	3093.680		

Table 16. ANOVA for No.of galls/tree 1st spray 2nd flush 2012

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	4	0.147	0.037	0.5521
Botanicals	9	168.022	18.669	280.8320
Error	36	2.393	0.066	
Total	49	170.562		

Table 17. ANOVA for No.of galls/tree 2nd spray 2nd flush 2012

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	4	0.925	0.231	2.1634
Botanicals	9	126.357	14.040	131.3753
Error	36	3.847	0.107	
Total	49	131.129		

Table 18. ANOVA for on mango yield (Kg/Tree) 2011.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	4	56.447	14.112	1.9391
Botanicals	9	8283.624	920.403	126.4710
Error	36	261.993	7.278	
Total	49	8602.064		

Table 19. ANOVA for on mango yield (Kg/Tree) 2012.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Replication	4	18.089	4.522	0.7760
Botanicals	9	8449.692	938.855	161.1039
Error	36	201.795	5.828	
Total	49	8677.576		