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THE INCIDENCE AND HOST TREES OF THE PINE WOOLLY APHID, *PINEUS PINI* (L.), IN EAST AFRICA

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SUMMARY

Heavy infestation by the pine woolly aphid was first discovered in the estates of the East African Agriculture and Forestry Research Organization (EAAFRO) at Muguga in January, 1969, where it was established on pines.

The taxonomic status of the woolly aphid is briefly reviewed and it is concluded that only one species, *Pineus pini* (L.) (Homoptera: Adelgidae), is present in Kenya.

The history of the introduction of pines is discussed in relation to the occurrence of *P. pini* in East Africa, and it is concluded that the pine woolly aphid was introduced from Australia on pine scions, about six years ago. Subsequent spread has since occurred in all directions from Muguga. Two isolated outbreaks have been reported from seed orchard plots in West Kilimanjaro and in the southern highlands of Sao Hill of Tanzania.

Pineus pini has been reported on 39 species. *Pinus massoniana* Lamb., *P. elliottii* Engelm., *P. contorta* Dougl. ex Loud., and *P. radiata* D. Don were the most favoured hosts; while *P. patula* Schl. and Cham. was less readily attacked. The majority of trees in a stand where the infestation is well established often develop heavy infestations, but a few trees remain untouched. *P. ayacahuite* Ehrenb. and *P. strobus* var. *chiapensis* Martinez. were resistant to attack.

Introduction

The pine woolly aphid, *Pineus pini* (L.) (Homoptera: Adelgidae), was first known as a pest in northern temperature zones of holartica and northern orient (Eastop, personal communication, 1969). The species has been accidentally introduced into tropical and subtropical areas during afforestation programmes with temperate-zone species of pines.

Maskell (1884) reported the species under the name *Kermaphis pini* Koch. var *laevis* from New Zealand on pines. *Pinus sylvestris* L., *P. halepensis* Mill., and *P. radiata* D. Don. were the most favoured hosts. Annand (1928) described a similar species on *P. radiata* in California. Franke-Grossman (1963) also reported the same species on *P. radiata* in Chile. Eastop (1966) recorded *Pineus laevis* from *Pinus radiata*, *P. halepensis*, *P. sylvestris*, and *P. excelsa* Wall, in Australia. According to Eastop (1966), this insect also occurs in New South Wales, Tasmania, New Zealand, Malaya, and perhaps in Pakistan and Utah.

In January, 1968, a *Pineus* sp.? *laevis* Maskell was reported in Rhodesia. During the same year, in November, a *Pineus* sp. was first discovered in Kenya (East Africa) on *P. caribaea* var. *hondurensis* Loock. scions from Australia during quarantine, at the Plant Quarantine Station of the East African Agriculture and Forestry Research Organization (EAAFRO) (Fig. 4 (1)). Two months later, heavy infestation by the pine woolly aphid was found on many species of pines in the estates of EAAFRO, especially in the arboretum and the laboratory Tree Bank. These are the first known occurrences of the genus *Pineus* in Africa south of Sahara.

This study reports the introduction and subsequent distribution of the pest in East Africa and its host range.

Location and Methods

Laboratory and field studies were conducted at Muguga in Kenya. The area lies between latitude 1° 00′ and 1° 18′ south and longitudes 36° 30′ and 36° 43′ East (Fig. 4).

The topography of this area is varied with a general tendency to be more or less broken by shallow valleys. General surveys were carried out in all *Pinus* spp. plantations in Kenya, Tanzania mainland and Uganda.

Four infestation classes—uninfested, light infestation, moderate infestation and heavy infestation—were established according to the distribution and concentration of "wool" on the bark of the trees. The hosts of *P. pini* were recorded during the surveys.

Taxonomic Status

A *Pineus* sp. was first discovered in Kenya in November, 1968, on *Pinus caribaea* var. *hondurensis* Loock. scions from Australia during quarantine, at the Plant Quarantine Station of EAAFRO. Two months later heavy infestation by the pine woolly aphid was found on many species of pines in the estates of EAAFRO, especially in the arboretum and the laboratory Tree Bank.

Dr. W. R. Richards of the Canadian Entomology Research Institute, Ottawa, has identified specimens from this study as *Pineus laevis* and *P. pini*. According to Dr. Richards, development of *P. laevis* is restricted to *P. radiata* and is characterized by a cephalic shield bearing gland facets in the three groups (Fig. 1), about the same size and arranged in small clusters of two to five glands each. In contrast, the cephalic shield in *P. pini* (Fig. 2), bears distinctly smaller gland facets adjacent to or mixed with larger ones. Unlike *P. laevis*, *P. pini* attacks various pines. Finally Dr. Richards observed that these specimens provided evidence for possible intragradation between *P. laevis* and *P. pini*. He suggested that the species could be called *P. pini* (L.).

This is consistent with the view expressed by Borner and Heinze (1957) who noted that Maskell (1884) had listed the species under the name *P. laevis* Maskell. This argument also conforms with the trend of the taxonomy of *P. pini* in Australia, where it was originally thought that two species *P. pini* (Macquart) and *P. laevis* (Maskell) were present (Eastop 1966). According to Heather (personal communication, 1971) it has now been established that only one species, *P. pini* (L.), is present in Australia, and reports of *P. laevis* are due to early misidentifications.

Many specimens from *P. radiata* examined during this study conformed to either description. A few specimens had a rather intermediate arrangement of gland facets on the cephalic shield. Further variations occurred in the size of the specimens, and somewhat small specimens with smaller wax pores with pleural and mesial pores often present on abdominal segments 1 to 9, have been observed (Fig. 3). Morphologically the latter resemble *Pineus orientalis* (Dreyfus), which has not been reported from East Africa. Moreover, controlled infestations with crawlers from *P. radiata* would preclude any link with *P. orientalis*. Similar variations have been observed on adult progredientes from other *Pinus* spp.

The real problem is to decide whether these morphological differences indicate that different species are involved or whether they are the result of different plant micro-environments affecting the same species. Differences in size perhaps indicate a degree of the suitability of particular pines as a source of nourishment. The occurrence of slightly different specimens from different plants is probably natural, since every parthenogenetic egg gives rise to a parthenogenetic clone of different genetical constitution. A certain degree of morphological variation within a single collection is, therefore, expected.

Simultaneous arrival of two species of *Pineus* in East Africa (Kenya) appears doubtful, particularly in view of the probable origin of the insect from Australia, where only *P. pini* is known to occur. It is, therefore, concluded that only one species, *P. pini* (L.), is present in East Africa and that the variable individuals are merely isolates of the same species.

Introduction and Spread of the Pine Woolly Aphid in East Africa

Following the discovery of the pine woolly aphid, extensive reconnaissance surveys

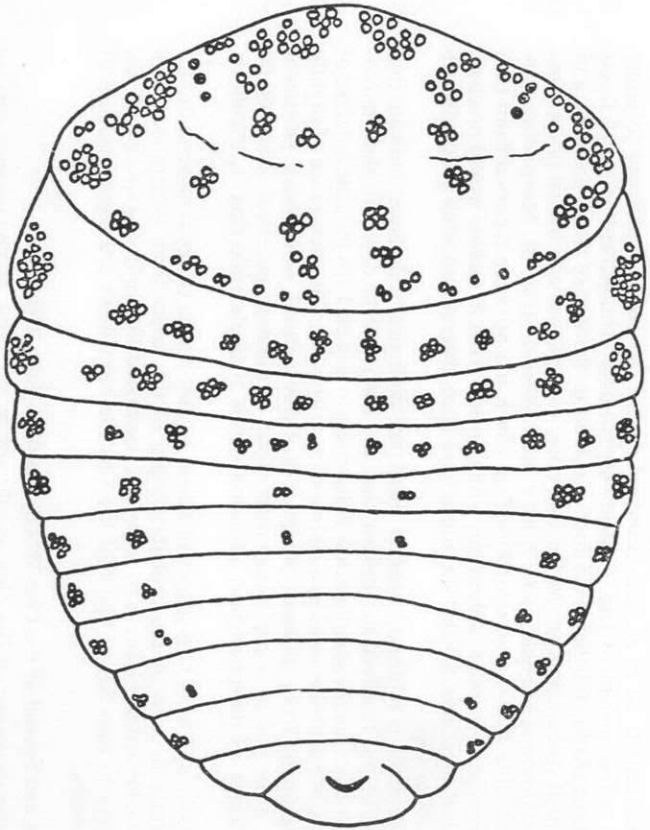


Fig. 1. Dorsal view of adult progrediens, flattened to show gland facets (*Pineus laevis*). Note the near uniform size of wax pores that are arranged in small clusters of two to five, in the three groups of cephalic glands. Clusters of mesial pores absent on abdominal segments 4 to 9. (Pleural pores may be absent on segments 4 to 6 on some specimens.)

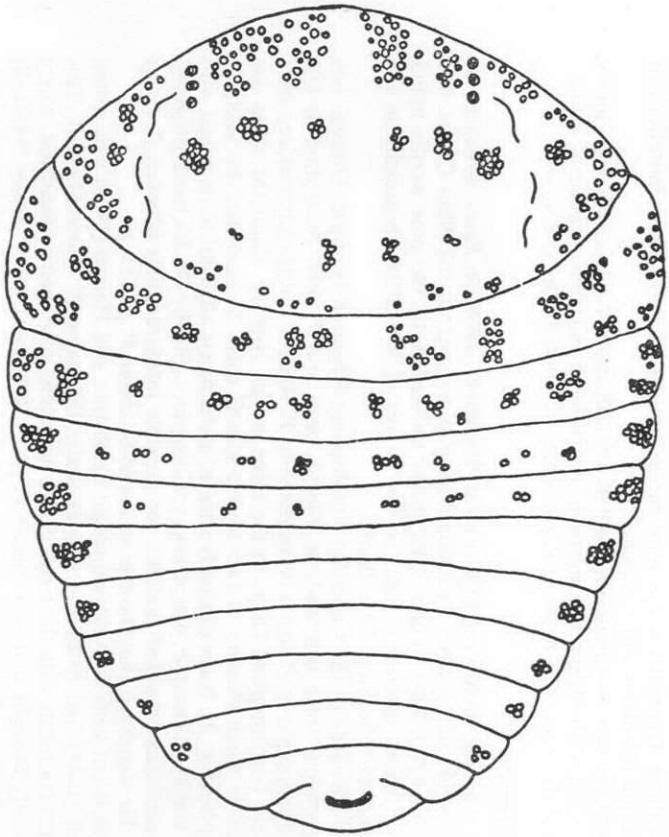


Fig. 2. Dorsal view of adult progrediens, flattened to show gland facets (*P. pini*). Note the cephalic shield with small wax pores adjacent to or mixed with larger ones. Clusters of mesial and pleural pores absent on abdominal segments 3 to 9.

of individual trees. This practice was later discouraged, when scaling ladders were introduced for climbing tall trees. This enabled a closer and more accurate examination of all branches which had not been possible in stands supporting tall trees. Identification of attack was based on the presence of white "wool" mats on the bark.

About 41 species of pines have been introduced into East Africa. All species except *Pinus patula*, *P. radiata*, and *P. caribaea* var. *hondurensis* have been introduced as seeds. Many *P. radiata* selected strains referred to as ACTS, and one batch of *P. caribaea* var. *hondurensis* have been imported from Canberra, Australia, since 1957, while a few *P. patula* clones have been introduced from Rhodesia. According to the quarantine regulations, the introduced plant materials are held in quarantine at the Plant Quarantine Station in EAAFRO.

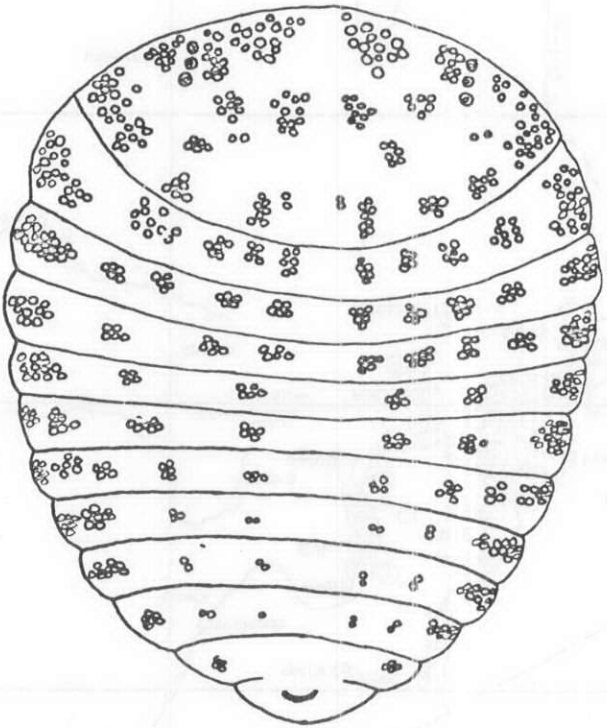
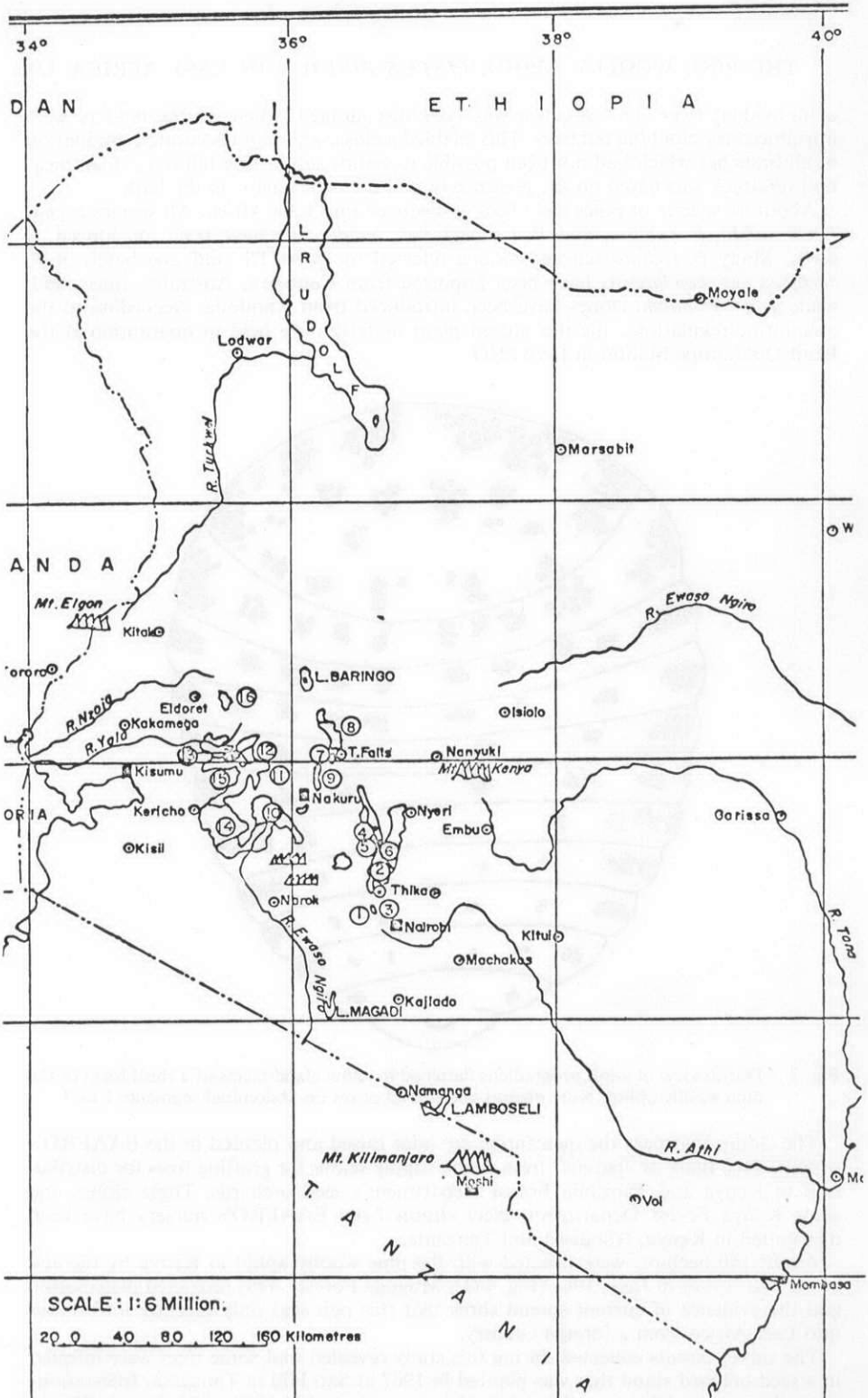


Fig. 3. Dorsal view of adult progrediens flattened to show gland facets of a third form of the pine woolly aphid. Note pleural and mesial pores on abdominal segments 1 to 7.

The clones that pass the quarantine are later raised and planted in the EAAFRO's nursery Tree Bank as "parent" trees which supply scions for grafting trees for distribution to Kenya and Tanzania Forest Department's seed orchards. These clones and some Kenya Forest Department select strains from EAAFRO's nursery have been distributed in Kenya, Rhodesia and Tanzania.

About 140 hectares were infested with the pine woolly aphid in Kenya by the end of the first survey in June, 1969 (Fig. 4 (1), Muguga Forest). This restricted distribution and the evidence of current spread show that this pest was only recently introduced into East Africa from a foreign country.

The survey results collected during this study revealed that some trees were infested in a seed orchard stand that was planted in 1967 at Sao Hill in Tanzania. Infestations


34°
36°
38°
40°
ETHIOPIA
LUDOLF
Moyale
Lodwar
Marsabit
R. Turkwel
Mt. Elgon
Kitale
L.BARINGO
Eldoret
Kakamega
R. Nzoia
R. Yala
T.Falls
Nanyuki
Mt. Kenya
Kisumu
Nakuru
Kericho
Nyeri
Embu
Garissa
Kisii
Thika
Narok
Nairobi
Kitui
Machakos
R. Ewaso Ngiro
L.MAGADI
Kajiado
Namanga
L.AMBOSELI
Mt. Kilimanjaro
Moshi
R. Athi
R. Tana
Voi
Mombasa
TANZANIA
SCALE : 1: 6 Million.
20 0 40 80 120 160 Kilometres

and at West Kilimanjaro in Tanzania. The pest has not been reported from Uganda, as might be expected, because Uganda does not participate in the seed orchard planting programme. The only clones that were exported to Rhodesia in 1964 were found clean at the time the pest was discovered there in 1968 (Barnes, personal communication, 1969).

Results of surveys show that the pine woolly aphid was concentrated in Muguga area, especially in EAAFRO's estate. The infestation in Sao Hill suggests that the pest was probably distributed with the planting stock from EAAFRO's nursery. It is, therefore, likely that the pine woolly aphid was present in EAAFRO between mid 1966, when these clones were grafted, and March, 1967 when they were distributed to Tanzania.

All orchards that were planted before this date were uninfested. Two importations remain strong suspects; *P. radiata* from Australia, and *P. patula* from Rhodesia, that arrived here in 1964 and were released to EAAFRO's nursery in 1965. The *P. patula* from Rhodesia were found with mild attack and could not have been the carriers of the original infestation. It is, therefore, probable that the pine woolly aphid was accidentally introduced with the importation of *P. radiata* from Australia in 1964. The distribution of the pest with seedlings from Muguga to seed orchard plots in Sao Hill, West Kilimanjaro, and two plots in Muguga supports this view.

Well established infestations were found in Muguga especially in EAAFRO's estate, where up to 20 per cent mortality occurred in some plots. This was probably the centre of the outbreak. Cases of die-back were widespread, particularly in the arboretum. Regular surveys revealed that the pest was moving outward in all directions, especially northward into Uplands (3), North Kinangop (4), South Kinangop (5), Ol Bolossat (7) and Marmanent (8) Forests (Fig. 4). Westward advance was checked by the lack of pines about 5 km away from EAAFRO. The rate of advance north and westward until October, 1971 averaged about 5 km per six months.

Once the northern advance reached Kinangop and Ol Bolossat forests (Fig. 4, (4), (5) and (7)) the movement to the west became very rapid and averaged 15 to 35 km in 6 months. The pest probably reached Nakuru area from the Aberdares through Dundori and Bahati forests (Fig. 4 (9)) about December, 1972. Three to six months later, the insect had extended to Njoro, Molo, Londiani (Fig. 4 (10)), and Maji Mazuri forests (Fig. 4 (12)). *Pinus halepensis* was consistently the first to become attacked and provided a useful indicator species for spotting the limits of the leading edge of the front.

It is likely that movement to the west had earlier been impeded by the lack of pines in the lower section of the Rift. The eastward thrust progressed at a moderate pace of about 3 km in about six months until it reached the limits of pines east of Nairobi. The advance to the northwest progressed at the rate of about 4 to 6 km in about six months until it converged with the westward advance that originated from Bahati forest (Fig. 4 (9)).

In Sao Hill in Tanzania, once the pest had become established, subsequent spread was much faster than in Muguga area because the pines occur in large uniform stands. At the end of March, 1973, the infestation had covered about 2,900 hectares in Kenya and about 1,700 hectares in Tanzania.

The outward spread is likely to continue steadily in all directions. At present there are no obvious permanent barriers to further expansion throughout the entire range of pines in East Africa and elsewhere. Thus every favourable habitat supporting susceptible species of pines will become infested.

Dispersal of the Pine Woolly Aphid

Obtaining direct evidence of population movements of the kind secured by aircraft observation or long distance marking-and-recapture would create a lot of problems in the study of a small insect such as the pine woolly aphid. Indirect evidence has been

the winged forms, whose ability to reproduce remains doubtful, are encountered in low numbers (Odera, in press), the flightless crawlers and possibly the eggs must disperse passively between hosts. The other stages are sessile and although they may be dislodged from the host plant they were found incapable of re-establishing themselves once they drop to the ground.

That aphids and other light-bodied insects may be carried long distances by the wind has been known for some time. According to Brown (1958), and Rabkin and Lejeune (1954) the larvae of adelgids and scale insects, being small and flattened, are aerodynamically unstable and are thus capable of a dispersal range of 402 m to 4.8 km. Johnson (1969) observed that many insects are delivered by air currents directly into habitats or into places near by as if they were inert particles. The most unequivocal evidence of population movement of the pine woolly aphid is provided by the appearance of fresh infestations in areas that were previously clean of the insect.

The importance of wind in the dispersal of the aphid was further demonstrated by using plastic sheets 30 × 30 cm that were previously coated with "Tanglefoot". Crawlers were recovered on the sticky traps at different intervals, extending up to 60 m away from the nearest infested tree. The biggest catch was recorded on traps that were facing east and lying west of the infested stand.

The direction of the prevailing winds must, therefore, be taken into account to interpret the probability of wind action in the dispersal of the pine woolly aphid. The surface wind at the central point of introduction at Muguga is mainly easterly, varying between north and south at different times of the year. The northerly components are prominent from October to April, while the southerly winds occur between May and September. These two periods constitute the north-east and south-east monsoon seasons respectively (Ramsay, 1966).

Very little backing was recorded during the north-east monsoon months, between October and April. By contrast, the westerly winds were prominent during the south-east monsoon season, especially during May and June. All months show a degree of daily shift from the north-east before midnight to the south-east. This feature was particularly pronounced during the south-east monsoon season.

These wind patterns have undoubtedly contributed to the fast and extensive spread of the insect to areas north-west of the central point of introduction. It was also noted that the rate of advance was fastest to areas west of EAAFRO until the insect reached the limits of the occurrence of pines on the eastern flank of the Rift. This is further consistent with the rapid spread west of foci established in the course of the advance of the infestation, and the subsequent rapid rate of advance to areas west of Nakuru. The apparently moderate rate of movement eastward can be explained by the less prevalent upwinds.

Survey results had indicated that the distribution of the infestations appeared to be patchy throughout the occurrence of the pine woolly aphid. Many stands had remained clean within the infested areas. The rate of spread also appeared to be faster along the depressions and drainage lines than across the depressions. This was probably due to the influence of topography on the flow of the prevailing winds. Wegorek (1969, quoted by Johnson, 1969) reported that flying Colorado beetles, *Leptinotarsa decemlineata* (Say), were deposited immediately after having passed a belt of forest and that they accumulated where contours of the ground interrupted the flow of air.

Dispersal of eggs and crawlers may also be aided by the movement of insects, birds, animals, humans, especially field workers, vehicles and equipment on which they may fall. Crawlers and batches of eggs held in masses of waxy threads have been removed from clothing of field workers.

The movement of infested nursery stock is probably the greatest factor contributing to the spread of the insect to distant points. All evidence at hand seems to show, beyond reasonable doubt, that the original infestation in East Africa resulted from importation of pine scions.

mills and homesteads for use as firewood or building purposes may also effect regional spread of the insect. Observations recorded in the present study show that the insects remained alive for about 90 days in logs exposed to sunshine, and for up to 175 days when the logs were kept in a shaded site.

The spread of the pine woolly aphid is finally determined by the number that become established following dispersal. The successful establishment of air-borne larvae or those that are transported on animals and other agencies depends on their longevity and ability to find a susceptible pine. It is suggested that while a few air-borne crawlers may land directly on their host trees, the majority land on plants unsuitable for food, or on bare ground. A few of the latter probably reach the host plants by crawling about. Observations reported elsewhere show that the crawlers may remian mobile for one to five days before settling at a feeding site. Starved crawlers remained alive for six to seven days in the insectary. These factors, and the tremendous crawling capacity of the crawlers, would enable some stray crawlers to locate the host plants by crawling.

Host Trees

The list of host trees of the pine woolly aphid was compiled during the survey, especially in EAAFRO's arboretum, the research and trial plots at Muguga and the arboretum at Uplands Forest Station. About 39 species of pines are recorded as furnishing food for the pine woolly aphid in East Africa. Development is restricted to pines and no alternate (primary) host is known in East Africa. Hosts of all sizes are attacked.

Both New World and Old World species were heavily infested. Of the Old World pines, *Pinus gerardiana*, *P. roxburghii*, *P. canariensis*, *P. massoniana*, *P. thunbergii*, and *P. yunnanensis* were readily attacked. The insect population increased rapidly resulting in heavy infestation over a short period. *P. muricata*, *P. radiata*, *P. elliotii*, *P. douglasiana*, *P. hartwegii*, *P. montezumae*, and *P. caribaea* were also very susceptible among the New World species. *P. merkusii*, *P. virginiana*, *P. contorta*, *P. echinata*, *P. michoacana*, *P. patula*, *P. rudis*, *P. tenufolia*, and *P. teocote* constitute a middle group which developed the infestation at a moderate rate. *P. ponderosa*, *P. sabiniana*, *P. clausa*, *P. taeda*, *P. engelmannii*, *P. leiophylla*, *P. pseudostrobus*, *P. cubensis*, *P. occidentalis*, and *P. oocarpa* were often among the last species to be infested. By contrast, *P. ayacahuite*, a Mexican New World species and *P. strobus* var. *chiapensis*, a tropical New World species, have remained clean in areas where the infestation was well established. It is likely that these species are not susceptible to attack by pine woolly aphid.

Borner and Heinze (1957) reported *Pineus pini* from *Pinus sylvestris*, *P. montana* and *P. halepensis* in Germany. Maskell (1884) lists the species under *Pineus laevis* Maskell from New Zealand on *P. sylvestris*, *P. halepensis*, and *P. radiata* imported there. According to Heather (personal communication, 1971) *P. pini* attacks all species of pines such as *Pinus radiata*, *P. taeda*, *P. elliottii*, *P. caribaea* and other species in Australia.

Barnes (personal communication, 1971) observed that nearly all species of pines in the research station, near Penhalonga in Rhodesia, have been attacked. *Pinus halepensis*, *P. khasya*, *P. rudis*, *P. serotina* Michx., and *P. taeda* were heavily infested and had varying degrees of die-back. Mild attacks were reported on *P. clausa*, *P. caribaea*, *P. densiflora* Sieb. and Zucc., *P. douglasiana*, *P. echinata*, *P. durangensis* Martinez, *P. elliottii*, *P. engelmannii*, *P. glaba* Walter, *P. hartwegii*, *P. lutea* Blanco, *P. montezumae*, *P. patula*, *P. pseudostrobus*, *P. pugens* Lamb. ex Michx., *P. roxburghii*, *P. rudis*, *P. tenufolia* Benth., and *P. virginiana*.

Infestation often occurred in patches within individual stands, and trees under heavy, moderate or light status coexisted with individual trees which were not infested. Certain clones, of nearly all susceptible species, not necessarily suppressed or healthy trees, may be heavily attacked, whereas some of their neighbours are only mildly infested or uninfested. This observation suggests that some varieties or clones may be resistant to the pine woolly aphid attack. The nature of immunity or resistance to attack suggested by these observations is not clear. Whether any of these cases represent

firs to the balsam woolly aphid may be related to site, and certain resistant firs become heavily attacked, and severely damaged when moved to lower elevations.

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