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Impact of Dry Weather on Infestation Rate of Aphids (Homoptera: Aphididae: Adelgidae) on Highland Conifers in Azad Jammu and Kashmir

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Abstract.- An unusual high infestation of Aphids and Adelgids has been a big challenge for the last 5-10 years in Himalayan highland conifers. The highest attack rate has been observed during the early winter from mid of November and continues until the end of January. The principle aim of the study conducted was to identify the aphid pest species and to find out the factors that contribute in the severe infestation of aphids/adelgids during dry winter and the species variation from six natural forests sites. The interaction between aphids and their host trees were thoroughly studied and there was no apparent indication of genetic variation among the conifer trees. Uniform attack rate was seen on the trees those were under severe water stress. The pine trees from same study site were not attacked at all or less attacked was due to the severity of physiological drought. Soil moisture around the affected and non-affected trees was estimated and there was a significant difference between the availability of gravimetric soil moisture between the attacked (0-25%) and non-attacked trees (50-75%). The most of the startling affect of the damage occurred on terminal portions of upper stems of those trees severely affected by the water stress and true firs that brought by the family Adelegidae. None of the natural enemy of pest was found on a single study site during the peak infestation period of early winter.

Key words: Aphids, Adelgids, conifers, field capacity, holocyclic and anholocyclic, generation, physiological drought, permanent wilting point, sap flow, residual water.

INTRODUCTION

The hill pine is a second most popular timber produced in Kashmir has been affected by severe infestation of aphid species since last two decades. Numerous insect pest, that affect the growth of pine trees and reduced tree production but their infestation rate was never been so high like conifer aphids today. The crown foliage of affected trees is unable to acquire the sufficient sap flow as a result the tree enters into lethal physiological drought (Deorksen and Mitchell, 1985). This soft-bodied insect usually occurs on new shoots, in the crown, and close to the terminal buds (Blackman and Eastop, 2000). The major loss was reported only defoliation and delay in growth with the attack of other insect species (Nichols, 1987). The damage caused by aphids on conifer trees ranges from a subtle immeasurable amount to the possible death of the whole mature tree through a change in its anatomical and physiological conditions (Carter and Nichols, 1985). Apart from the huge old forest trees the silviculture area has also been affected which is manageable through the spraying operations of broad spectrum chemical pesticides. In the same ecological zones of the pine another adelgid species, *Pterochloroides persicae,* commonly called Peach Trunk Aphid (PTA) is a serious pest of many pomes and stone fruits acquiring the resistance against many groups of pesticides (Ateyyat and Abu-Darwish *et al*., 2009). When the walk ways under pine forest and peach orchards are seen covered with a thick layer of honey dew. This situation is welcomed by the bee keepers who recognized it a good source of forest honey and bring colonies to the affected areas for benefit (Kidd, 1988). The trees affected by scarcity of water unable to acquire sufficient sap flow, so the tree sometimes enters into a lethal physiological drought and declined spiral (Major, 1990).

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Since the year of independence of Azad Kashmir the management of natural forest was focused and the re-forestation practices were also intensified but due to the sudden outbreak of aphids/adelgids pests and diseases affect the developmental process and the results are less progressive.

The present study was aimed to make an inference on the factors that contribute to the emergence of the aphid pests and to synthesize the management strategies may be applicable.

MATERIALS AND METHODS

The study was conducted during the year 2009 in upland pine forests of two District of Azad Jammu and Kashmir. The first phase of the study was the geophysical survey of the pest occupation zones, their host plant preference and their accurate identification.

This study was framed in a template of three parameters:

1. Survey of the study sites for recording the pest emergence and development during the year from January to December.
2. The rate of infestation in association with environmental variables.
3. Species diversity in various natural geographical zones.

Stratified random sampling was employed for each site of the study area. Accessible tree height was chosen for sampling. The number of sampling units per site was same. Samples were taken with a sharp pruning scissor from the spurs 2cm. long with natural thickness. Samples from the barks were taken by swiftly removing the sample area and were put in to the disposable aphid collection cups and after a manual count of aphids they were preserved for identification. Life cycles were studied in labortory and insectary of the Department of Entomology, Faculty of Agriculture, Rawalakot, Azad Kashmir. Temperature was recorded by using the clinical thermometer, minimum-maximum thermometer and hygrothermograph to minimize the errors. The analytical methods used in the study were computer based statistical packages.

Study sites

Six study sites were located from District Poonch and Bagh after an initial survey of the infested conifer forests of both the Districts. The variation in plantation area between high land and low laying foot hill was kept in consideration. The natural conifer zone starts from the 4500ft. to 6500ft. altitude from sea level. During initial survey benchmark points were marked like Banjonsa (5500ft) was the fixed point in District Poonch and Pine forest of Dhirkot (5300ft) was the 2nd bench mark point for District Bagh. To examine the soil from variable series of shallow mountains and semi hard rocks the soil samples were taken to assess the water shortage. The low laying areas below terrain soils were mostly sandy loam and deep clay can support moisture requirement of pine during long dry spell. There were four standard used for measuring the soil moisture level. In addition to the other methods tensiometers and electrical resistance blocks were also used to figure out the moisture status according to those four standards.

Measurement of soil moisture under the attacked and un-attacked trees

To determine the amount of stored moisture the gravimeteric soil moisture meter was used. The soil sampling tools were a soil probe, auger or a post-hole digger, sealable container, a cooler, soil sampling tool, paper plates and a scale.
Soil sample were taken at a minimum of three sample locations under the infested and uninfested trees. Sample locations were chosen which are representative of the entire field. The Sampling of the small areas of low spots or ridges that do not represent the majority of the field was avoided. The samples were taken in 2 feet (preferable 3 feet) in one-foot increments with each foot kept separately.

Measuring the temperature range of common natural enemies

The most common predators of the conifer aphids are Conccinellids, Syrphid flies and lace wings which remain active from March to October above 10ºC but the rapid population increase starts in the beginning of November. There were no more predators or parasitoids seen on conifer trees below 10ºC. One of the most commonly found coccinellid species; *Coccinella septempunctata* was taken from the study sites and tested for its prey searching activity at various temperature levels.

RESULTS

Life cycle of pine aphids

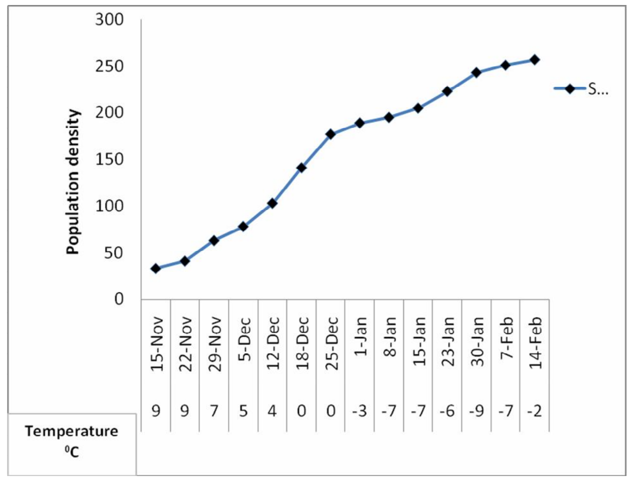
The life cycle study of both the pine aphids was very complex having holocyclic and anholocyclic generations. The taxonomic status of the species is described as the holocyclic (cyclical parthenogenesis, reproducing by means of sexual in autumn and by parthenogenesis for the rest of the year) and anholocyclic (reproducing only by parthenogenesis) was kept in consideration. They are regarded as the same species if they are found elsewhere on similar hosts, or as a geographical race or sub-species. The average number of nymphs and adults on terminal nodes of pine were 86.5/cm^2 (Fig. 1) in the month of November and there was no significant variation in pest density on various locations of infested trees.

The eggs of the aphid species overwinter on the base of the needles and bark of the pine tree. The over wintering eggs hatched in the Laboratory at 16±1ºC in the month of March and at the same time some colonies were found guarded by the ants in open field conditions. During same period of time viviparous production was seen by both species. The clusters of Adelgids were recorded during winter feeding but after winter no sign of Adelgids attack was there. Any alternate host nearby forest area was not observed by an Adelgids attack. So the life cycle and general count of regeneration was very complex. Generally, they produce several generations during summer but the severe infestation was only seen on pine trees in the month of November. As these pests change their hosts and the morphological appearance very quickly, so in a thick forest only indicator of aphid attack is a layer of sticky honey dew on the surface of the soils or tops of the grasses and bushes around the pine tree.

The pest calendar

Conifer aphids do not have the secondary host. They are usually found in the twigs and the branches but may occur in trunks and the roots as well. During the peak of their infestation aphids always produce lot of honey dew which attracts the ants and yellow jackets.

The infestation results the needles being twisted and matted together with copious amount of honey dew and wax. The Important natural enemies like lady birds, lacewings and syrphid flies start hibernating during the fall and the pests have no resistance to grow more colonies. Pest calendar showing the peak population seasons during the year (Fig. 1).



Pest Calendar of Aphids/Adelgids

Infestation very high	**No symptoms of attack**	**Infestation rate moderate**	**Infestation very high**
Jan. – Feb.	March – July	Aug. – Oct.	Nov. – Dec.

Fig. 1. The highest attack rate during early fall and continues increasing in winter months. During summer the population growth remains under certain limits.

Feeding habits of the aphids and adelgids

Generally the feeding habits of all aphid species seen more or less the same, that is the insertion of the stylet in the host plant tissues except the adelgids which produce very high amount of honey dew. The sticky sugary material (honey dew) attracts the ants and black fungus sooty mold. The distribution of aphids and adelgids colonies was uneven. No specific part of the plant was chosen by any of the species. There was an indiscriminate attack on the twigs spurs and the stems. No signs of sooty mold black fungus were seen during the winter attack and the gall formation on attacked trees was not common. Generally the apparent plant health was indicating the overall development loss in comparison with normal uninfested pine trees. There was no species variation found from the difference of study sites.

Effect of water stress on population indication

There was a great tendency of population iniciation in the water stressed plants when tested in the silviculture nursery on two years old plants. The survival of the aldelegids was possible at very low temperature around freezing (Table I). In silviculture plants the attack was seen on more than two years old plants. The water stress plants are nutritionally modified and all kinds of sucking insects usually thrived on such plants rather than non-treated. Generally there is Synergistic interaction between the host plants and their pests and the natural enemies (Yang *et al*., 2007).

Table I.- The population indication of conifer aphids in silviculture plants manipulated of water stress verses the normal watering at 8 temperature levels during the whole year.

Temperature range	No of samples	Av. density indication range (Watered)	Density indication range (Unwatered)
32/27	5	1-3	1 -9
28/24	5	1-5	1 -6
20/16	5	1-3	1-10
15/12	5	1-2	1-24
12/9	5	1-7	1-29
7/3	5	1 -3	1-37
3/0	5	1-5	1-35
0/-2	5	0-0	1-19

When soil gets too dry the transpiration drops because the water is becoming increasingly bound to the soil particles by suction. Below the wilting points trees were no longer able to extant water. At this point they stop transpiring and make praline of available starch for their survival. This praline is a life saving nutritional fluid plant use to overcome stress and this is best time for the aphids to get readily available food from stressed tree. That's why the tree with less physiological drought (0.1-0.35) (Table II) were not severely attacked or even not attacked at all. The moisture contents from the attacked tree were showing the level of residual water and around some of the tree the level at high tension from the hard rocks and the areas highly exposed to the sun.

Table II.- Shows four standard water contents that are routinely measured and used, which are described according to texture of the soils. The attack plants were marked with high tension (*) sign indicating severe shortage of water.

Name	Notation	Suction pressure (J/kg or kPa)	Typical water content (vol/vol)	Description
Saturated water content	θ_s	0	0.2–0.5	Fully saturated water, equivalent to effective porosity
Field capacity	θ_{fc}	−33	0.1–0.35	Soil moisture after 2–3 days after a rain or irrigation
Permanent wilting point	θ_{pwp} or θ_{wp}	−1500	0.01–0.25	Minimum soil moisture at which a plant wilts
Residual water content	θ_r	$-\infty$	0.001–0.1*	Remaining water at high tension

Compatibility of natural enemies with pest occurrence

The survival range of maximum and minimum temperature for *Coccinella septempunctata* was measured with its prey searching and handling activities (Table III). The lowest range starts from 10ºC and maximum temperature at which they maintain their survival. The maximum limit of their full activities was below 40ºC. One of the factors for very high increase in conifer aphids was the non-availability of natural enemies. There was no compatibility of the population growth of the pests and their predators. The colonies of conifer aphids were started increasing at the temperature when the natural enemies were disappearing from the sites. In addition to that the prey consumption by *Coccinella septempunctata* at 25ºC (Table III) was the maximum which indicates the specificity of narrow temperature range.

Table III.- The search rate (a´) Handling time (Th) and (R^2) of *Coccinella septempunctata* (Adult) calculated for different temperatures under which they were fed on seven different food regimes (prey density).

Temp. (°C)	Instantaneous search rate (´a)	Prey handling time (T_h)	R^2	Max. no attacked
12	0.414	0.228	0.94	11c
15	0.540	0.197	0.97	19.0c
20	0.780	0.155	0.98	24b
25	0.975	0.105	0.98	45a
30	0.303	0.209	0.98	23b
35	0.489	0.536	0.9	13c

DISCUSSION

The presence of pine aphids have never been noticed in natural forests of Azad Kashmir before the year 2001. The current levels of aphid infestation in the pine plantation areas are a big continuing economic threat to the state. Besides causing the annual losses of valuable timbers in both natural forests and established plantations, the attack of aphids also have several important indirect effects like set back in the expanding plantation programme. Taking into account the timber losses due to insect attack no such study has been carried out in Kashmir so far.

The results of some studies from African countries showing the impact of pine aphid on wood production but the climatic conditions of these countries are not very similar to the mountains of Himalayan base. In Kenya, (Mailu *et al.*, 1978) showed that 6% mortality of the plantations of medium-aged. Later, Odera (1974) also reported that 20% mortality occurred in some study plots in the centre of the aphid outbreak in 1968. Madoffe and Austara (1990) reviewed the losses from studies conducted in Tanzania, that the shoots and stems of seedlings of *Pinus patula* lost 20.9 % of their dry weight after 24 weeks.

In comparison with population studies by Lottyniemi (1979) from Zambia and later on by Katerere (1984) from Zimbabwe two peaks of aphids were seen each year which are more or less in accordance with results of the present studies. The climatic conditions of Himalayan foothills and those of African peaks may not match but the tendency of attack seems to be similar and correlated with the weather dryness. However, the origin of pests in Europe and North America are reported by Carter and Maslen (1982). The first record of the pine needle aphid came from Zambia, Zimbabwe and South Africa in late 1970's and 80's by Loyttyniemi (1979), Odendaal (1980) and Merchant (1981) but the pest species have also subsequently spreaded to Malawi and Tanzania (Carter and Maslen, 1982; Evans, 1982).

Earlier, Furuta and Takai (1983) from Japan reported the attack of grey pine aphid, *Schizolachnus pineti* (F.) which reduced the growth of Scots pine to a similar extent. It indicates that the pest is cosmopolitan except the species variations.

The peak of aphid population from all the study sites was in the early winter season due to the unusual long dry spell. It was a definite effect of bearing physiological drought by pine trees. There was clear indication of the difference of population density on the trees bearing less water stress and those of badly effected by water deficiency. In concurrent with Larsson (1985) about the relationship between the seasonal changes and distribution of aphids, *Cinara pini* on Scots Pine, the results of the present study are showing a coincidence of strong relationship between the underlying biotic and a-biotic factors. An imbalance of major plant nutrients, especially nitrogen and potassium ratios, can significantly alter both the quality and quantity of available amino-acids and hence influence the growth rate of aphids (Kidd *et al.*, 1990)

There is an evidence of species susceptibility, as Zwolinski (1989) reported that a wide range of pine species were attacked by the pine woolly aphids but there seems a great variation in the susceptibility to attack between the aphid species (Odera, 1974) of the main industrial species, *Pinus kesiya*, *Pinus elliottii*, and *Pinus radiata s*eem to be highly to moderately susceptible while *Pinus patula and Pinus taeda* are only slightly susceptible to attack the mature plantation trees.

The difference of infestation rate between siliviculture plants was very significant when tested under stress verses normal conditions of routinely watered plants. Water stress brings about an amino-acid imbalance that favors aphid development but is then detrimental to the trees. Previous studies show the nutritionally modified conditions of the host plant can be brought about by an aphid of the same or even another species. A simple example being a delay in bud burst in trees following heavy aphid attacks was put forward by Larsson (1985) and Major (1990) during the previous growing seasons. Chlorosis of *Picea* caused by the green spruce aphid, *Elatorium abietinum* improves the growth rate of the subsequent aphid generation by providing a better quality food source (Fisher, 1987). *Eulachnus agilis* favours senescing pine needles; its growth rate has been shown to increase when feeding on the same needles as *Schizolachnus pineti* (Kidd *et al.,* 1985). Similarly in clustered aggregations of *Schizolachnus pineti* or *Cinara pini,* there is a temporary increase in amino acids concentration to 47% at their feeding sites, which results in a 31% increase in nymphal growth rates (Kidd *et al.,* 1990).

The lower temperature range for the survival of conifer aphids goes down to the level of zero but the survial of most of natural enemies (Frazer and Mcgregor, 1982) is rare at this level. This is one of the key factors contribute in high population rate of both species.

Observation on the life stage of *Cinara* species indicates that both winged and wingless female (apterous and allate) are present during the growing season (April-September) and nymphs are produced by parthenogenesis. Both the sexes (allate and apterous females) are present during October and November and females produced eggs. This kind of studies on reproductive biology was carried out in Jordan by Mustafa (1987) and 8-9 generations were reported. On similar pattern a study was also conducted later by Salom (2009) on Pine Bark Adelgid in Virginia, America interpreted the relationship between the physiological drought and the feeding response of the aphids/adelgids in pine forest zones are nearly in accordance with present results in certain aspects particularly the survival of the adelgids at minus 10°C. On the other hand, the moisture status of the soil is a critical factor influencing pest infestation. There are no such examples of regular existence of the pest in each winter. Long dry spell in winter can cause the physiological drought which will be the obvious cause of the infestation. The relationship between the soil moisture and infestation rate was not yet studied. This study was based on four standards of determining the moisture contents used according to the texture of the soil (Kachanoski *et al*., 1992). In addition to the other manual methods tensiometers and electrical resistance blocks were also used to figure out the moisture status according to those four standards.

CONCLUSIONS

Physiological drought caused the nutritionally modified conditions in the host plant trees which attract the aphid pests. The infestation rate increased during winter because of unusual long dry spell. The trees bearing more stress were more thrived by the pests whereas those with fewer droughts were less infested even in small silviculture plants. An imbalance of major plant nutrients, especially nitrogen and potassium ratios can significantly alter both the quality and quantity of available amino-acids and hence influence the growth rate of aphids. Further studies are needed on the imbalance of major plant nutrients due to the short and long drought period.

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