Pest and Disease Problems of Native Tree Seedlings in Northern Thailand: Some Examples

The results of a six month survey at the FORRU Nursery, Doi Suthep-Pui National Park, Chiang Mai, Thailand

By: Tim Rayden
The Forest Restoration Research Unit

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Tim Rayden, Forest Restoration Research Unit, Chiang Mai University, Chiang Mai, Thailand.

FORRU is identifying 'framework' tree species for the restoration of northern Thailand's upper watershed forests. Since 1994, research at FORRU has focussed on collecting seeds of native species, and testing germination and growth rate in nursery conditions. However, the current emphasis is on improving nursery technology and increasing the production of high quality seedlings for planting. Large productivity step-downs occur at germination and potting stages, but losses to pests and diseases are also significant. It has been noted that the incidence of phytophagous insect outbreaks has increased with the age of the nursery, and that certain seedling species have encountered recurring problems with disease. Little information is currently available on the scale of these problems, or the types of disease that are present. This survey has highlighted areas for concern, with a view to developing elementary and cost effective management strategies. Some such strategies are suggested. With further monitoring of the prevalent pests and diseases, together with a more detailed assessment of the recommended treatments, it will be possible to make well informed decisions about seedling production targets and the overall suitability of certain tree species for forest restoration schemes.

Contents:

Section 1. Introduction:

The majority of native trees in northern Thailand's upper watershed forests have never been raised as seedlings in nursery conditions. In the search for tree species best suited for accelerating natural regeneration of upland forests, FORRU has tested the germination and growth rates of a large number of tree seedlings. However, to identify the best trees for reforestation schemes it is important to assess all aspects of the nursery production process. Selection criteria should include the susceptibility of seedlings to diseases and pests. Although losses due to pests and diseases are at present fairly limited, the incidence of insect outbreaks has increased with the age of the nursery (S Elliott pers comm), and it has been noted that certain species have recurring problems, while others remain relatively healthy.

1.1 Seedling health and production in the nursery

FORRU has been monitoring the health of seedlings planted in the field for three years. Health-scoring is useful to show the decline or recovery of seedlings after planting, and general observations have highlighted a few disease symptoms that have recurred on certain species. However, the standard health score monitoring is not specific enough to provide useful information about the majority of seedling afflictions. What is more, death of seedlings after planting tends to be due to abiotic factors (seedlings poorly planted or with damaged roots or stems, trampling, cutting, drought etc). It is rare that planted seedlings under-perform due to damage sustained before planting; i.e. from pests and pathogens in the nursery.
This is largely because seedlings are graded in the nursery before planting, and this ensures the vast majority that make it to the planting stage are free from serious pest or pathogen damage.

Planted seedlings represent the tip of the iceberg in terms of nursery production work. Large step-downs in productivity occur at both germination and potting-up stages (germination percentages are highly variable and could be anywhere between 84.6% for *Bishofia javanica*, to 14% for *Heynea trijuga*). With grading prior to planting, the overall percentage of seedlings surviving to be planted in the field drops still further. Analysis of the production data available for species contained in this report shows an average of approximately 36% of potted seedlings never make it to planting (C. Kurak pers. comm.). This data includes loss from pest and diseases as an unseen factor, and there is, as yet no information on the scale of losses that can be expected from this alone.

1.2 Pest and disease problems in the nursery

Pest problems are best discussed separately from disease problems although they do have similarities, and often arise in combination.

Insect pests
I have used the term 'Pests' to refer to insects only, because no problems caused by non-insect organisms such as nematodes have yet been detected in the nursery. Insect pests can damage their host plant in a number of ways.
The most common and obvious of these is defoliation through leaf eating, which is characteristic of the larvae of Lepidoptera, the butterflies and moths (caterpillars). Defoliation, or damage to the leaves of a plant by a Lepidopteran larva should only cause a minor depression in growth rate, but may open wounds that can become infected by opportunistic

pathogens (especially bacteria)[1]. Heavy leaf predation, when caterpillar densities become unusually high, will stress the root system and lead to the depletion of stored food resources.
Sap-sucking insects can cause a variety of symptoms on plants depending on where they prefer to feed. Commonly they will produce wrinkled or distorted leaves and may assist the direct transfer of viruses and bacteria between individual seedlings. Aphids and scale insects (Hemiptera), and Thrips (Thysanoptera) are common examples of such pests.
The larval stages of some Lepidopterans and Coleopterans are leaf miners. Such larvae feed beneath the cuticle of the leaf, on the softer mesophyll cells. They generate serpentine patterns or blotches on the leaf. Examples of these can be seen on the leaves of *Gmelina arborea* (serpentine mines), and *Erythrina stricta* (blotch mines), although neither of these insect pests is discussed further here.
Gall forming insects (like the Cecidomyiidae seen in *Bischofia javanica*) can be responsible for stem and leaf deformations, and considerable structural weakening of the seedling. The larvae, which live inside the galls, have a vested interest in keeping the plant alive, (most produce plant growth inducing chemicals in order to enhance plant growth in some way). However when the insect matures and leaves the confines of the plant, the galls are no longer under the protective influence of the larva and become vulnerable to opportunistic infectious pathogens.

Most phytophagous insects show a high degree of specificity to a single host plant species. (The specificity of enterophagous insects is generally believed to be higher still.) Bernays and Chapman [2] studied the feeding preferences of insects in the British Isles and extrapolated their data to make predictions about host specificity on a global scale. They found approximately 75% of British insects to be mono or oligophagous (i.e. feeding on a single species or small group of related species.) Their estimation was that, on a global scale, this figure was likely to be around 80%. Tropical ecosystems are known to have a larger number of available ecological niches due to the relative stability of their climates over geological time [3]. What is more, the niches tend to be 'narrower', due to the intensity of competition and predation in highly biodiverse communities. The greater amount of interspecific competition, in such environments is thought to lead to a higher degree of niche specialisation, and this has been demonstrated for some phytophagous Coleoptera and Lepidoptera in tropical forest ecosystems [4]. Therefore, in Doi Suthep-Pui National Park we can expect a very high level of insect-host specificity.

Bacterial and Fungal pathogens
Bacteria are ubiquitous in the natural environment, and the majority are not harmful to either plants of animals. However, pathogenic varieties will damage plants, usually by infecting through wounds, then multiplying rapidly within the host tissue [5].
Aggressive fungal pathogens are usually dispersed as wind-born spores, although many are carried by water. As a result they are also widely dispersed in the natural environment. They generally possess the ability to infect *healthy* hosts by penetrating the cuticle or growing in through open stomates [6].
Both fungal and bacterial pathogens become systemically dispersed throughout the host very quickly. As a result they tend to kill the host outright, as opposed to causing temporary damage like most insect pests. For this reason they represent a much more serious problem to nursery production should they emerge on any significant scale. This report contains three examples of pathogen infections: see *Balakata baccatum* (Bacterial blight), *Morus macroura* (Rust fungus), and *Melia toosendan*.

1.3 Overview and aims:

This survey has attempted to highlight areas of concern, where pests and pathogens are seriously damaging the nursery stock. Some elementary strategies for management of disease problems have been suggested, although proper testing of these strategies has not yet been carried out. At present it is difficult to recommend long term management plans, due to the unpredictable nature of pest and disease outbreaks, and the lack of information on seasonality and life cycles of pest organisms (see section 3). It is hoped, that with careful monitoring of these problems in the future, it will become possible to predict future incidences of disease or pest damage and develop effective and efficient control strategies.

Section 2. Survey of pests and diseases: listed by seedling species:

2.1 *Balakata baccatum*

During the 1999 growing season, *B. baccatum* (Euphorbiaceae) seedlings suffered considerable damage from both pest and pathogen attack. This member of the Euphorbiaceae family is an emerging framework species that has perforemed well since its first planting in June and could prove extremely valuable in reforestation schemes if nursery problems can be overcome.

Problems:

1. Symptoms commonly seen include necrosis of the mid vein of young leaves due to leaf minors, and the rolled-leaf pupariums of Gracillariid moths. These effects however, are not thought of as serious and no recommendations are made here.

2. Far more serious is the defoliation of *B. baccatum* by the caterpillar larvae of a Noctuid moth (shown in Figure 2.1.1). The youngest instars are entirely yellow, but the older caterpillars have black heads and develop a pronounced black dorsal stripe.
The larvae grow rapidly and pupate relatively fast, (1 to 2 weeks) enabling several life cycles to be present simultaneously on a single batch of seedlings. The caterpillars were found on young un-potted seedlings, but also on every other batch of B. baccatum seedlings in the nursery. This, together with the fact that eggs are laid on the same host species, would indicate a high level of host specificity for this pest.

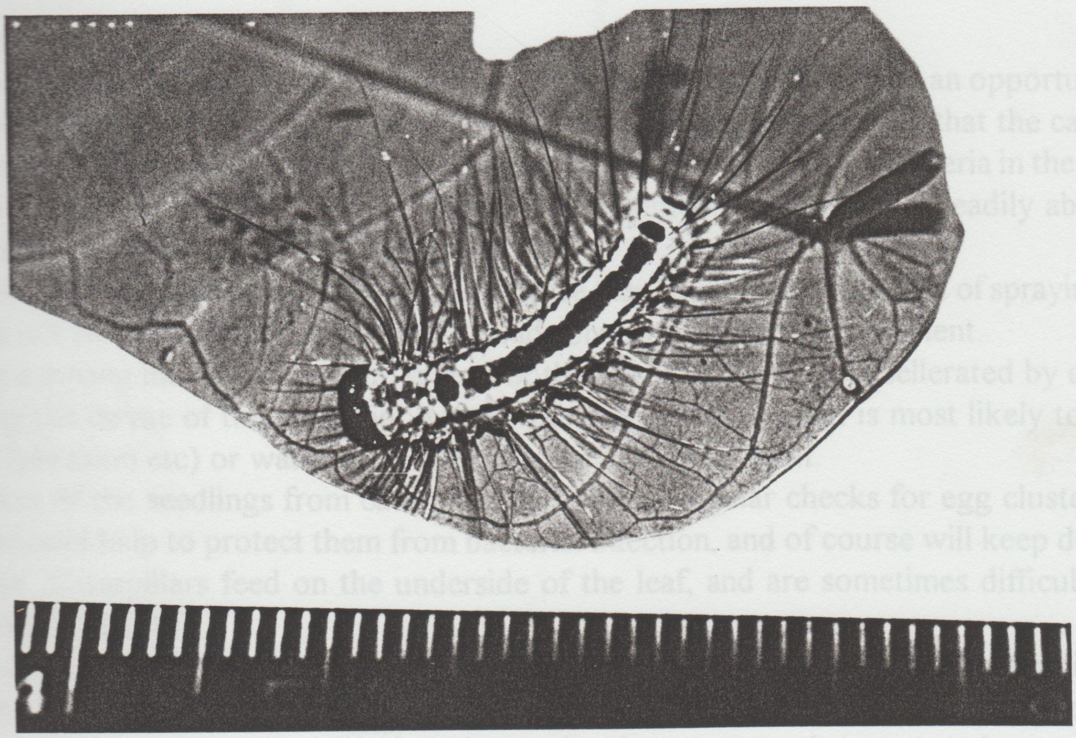

Figure 2.1.1 Noctuid Caterpillar on a leaf of *B. baccatum*

3. More damaging still, was the effect of a bacterial blight disease (thought to be a Psuedomonad or Xanthomomad) towards the end of the 1999 rainy season. In the vast majority of cases, infection resulted in rapid death of the seedling, with a minority showing a slow decline. But the action of this pathogen caused the loss of an entire batch of 1-year-old seedlings in December 1999.
The first visible symtoms are black lesions on the petioles or upper stem. Affected leaves will quickly yellow and abscise, as the plant attempts to isolate the diseased area. However, the lesions will spread down the seedling, gradually enveloping the stem, which takes on a blackened and sooty appearence.

Figure 2.1.2 Early stages of bacterial blight on *B. baccatum* seedling

Suggestions:
Bacteria usually rely on physical wounding of the host to provide them with an opportunity to infect. Most bacteria that cause foliar diseases are not soil borne [2] so it is likely that the causative agent of blight on B. baccatum is usually present on the leaves. The ubiquity of bacteria in the environment, and their ability to multiply rapidly in favourable conditions mean they are readily able to colonise wound sites and spread within the host.
Furthermore, bacterial diseases are untreatable once they have taken hold (short of spraying antibiotics, which is not recommended) so control depends on good nursery management.
There is a strong indication that the spread of the blight was greatly accellerated by damage to the leaves by the larvae of the Noctuiid, but transfer from plant to plant is most likely to be via direct contact (abrasion etc) or water run-off, not by the caterpillar itself.
Protection of the seedlings from caterpillar damage, by regular checks for egg clusters and young larvae, should help to protect them from bacterial infection, and of course will keep defoliation to a minimum. Caterpillars feed on the underside of the leaf, and are sometimes difficult to spot, but should be picked off.
If bacterial infection does occur, the seedlings showing symptoms *and* those surrounding (touching) the infected seedlings should be quarintined. Surrounding seedlings should be removed even if they show no visible symtoms. A close visual inspection for symptoms is not enough to certify seedlings disease free. Of 25 seedlings that passed a visual inspection and were isolated, 23 had developped symptoms within a month, and 6 these had died.
Infected seedlings should **not** be pruned. If symptoms are showing, the bacteria will already be systemic within the seedling. Cutting away the visibly affected portion will not remove the pathogen.

Furthermore, the bacteria is readily transferrable by pruning. A stem cut provides the ideal wound site for infection. Sterile pruning (where the sheres are sterilized with alcohol between cuts) is sometimes reccomended for bacterial infections [7] but will not "cure" an infected seedling. Therefore pruning should be avoided when a bacterial infection such as this is suspected. "Clean" seedlings isolated following a careful visual inspection should be left for 1 month to allow the development of any symptoms before sterile pruning is to be undertaken.

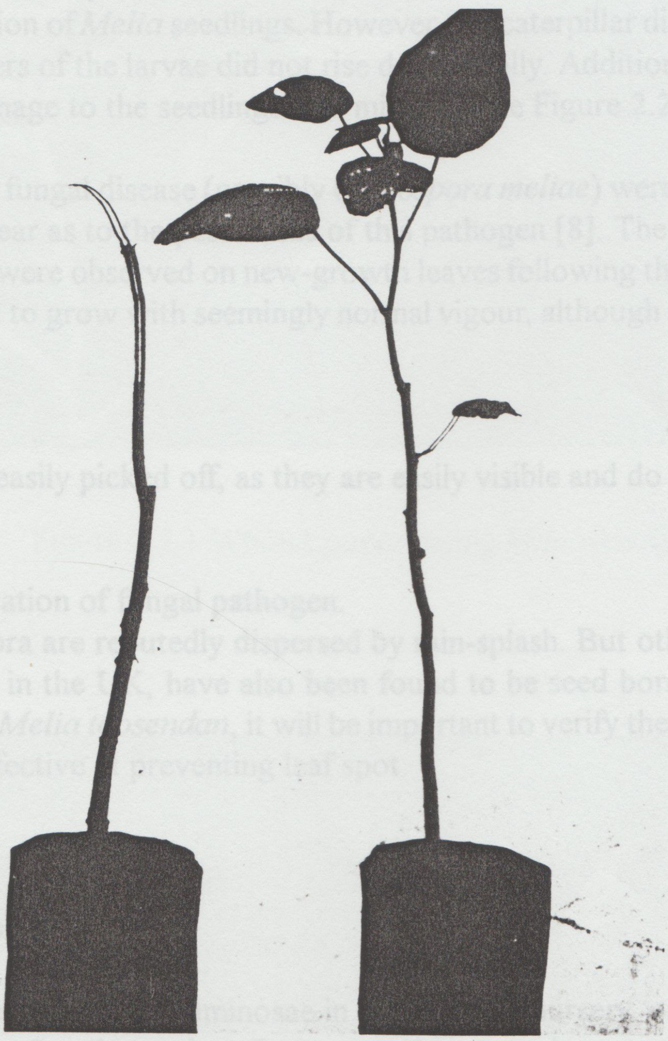

Figure 2.1.3 Late stage of blight on *B. baccatum*

Further Research:
Response of Noctuiid caterpillars to insecticides eg *Bt*.
Laboratory classification of bacteria and host specificity tesing using wound innoculations on different species.

2.2 *Melia toosendan*

M. toosendan is a very fast growing pioneer species and has shown good rates of recovery from both nursery afflictions recorded. It has a tendency to drop leaves quickly when under stress, or when foliage is attacted by a pathogen, but new shoots are quick to re-emerge.

Problems:

1. Defoliation by white loopers (Geometridae). An outbreak of these caterpillars in October resulted in extensive defoliation of *Melia* seedlings. However, the caterpillar did not appear to enter a second lifecycle, and numbers of the larvae did not rise dramatically. Additionally, leaf regrowth was rapid, meaning overall damage to the seedlings was minimal (see Figure 2.2.1) .

2. Symptoms of this fungal disease (possibly *Cercospora meliae*) were first seen in November 1999. At present it is unclear as to the pest status of this pathogen [8]. The seedling undergoes rapid leaf drop, but leaf spots were observed on new-growth leaves following the shedding of infected foliage. Seedlings continued to grow with seemingly normal vigour, although over the longer term they may show decline.

Suggestions:

Caterpillars can be easily picked off, as they are easily visible and do not sting!

Further Research:

Laboratory classification of fungal pathogen.

Spores of Cercospora are reputedly dispersed by rain-splash. But other leaf spot diseases, notably that on Sugar Beet in the UK, have also been found to be seed borne [9]. If leaf spot becomes a serious problem on *Melia toosendan*, it will be important to verify the means of spread. Disinfection of seeds, may be effective at preventing leaf spot.

2.3 *Dalbergia rimosa*

There are many seedlings of Leguminosae in the FORRU nursery, on account of the excellent soil conservation value of such species. *D. rimosa* however, is not widely planted at present. It is frequently found colonising deforested areas by natural means (pers. comm. JF Maxwell).

Problems:

Asside from a variety of minor insect damage symptoms, this species suffered from a single major outbreak of Arctiidae caterpillars in 1999. One batch of 60 seedlings was completely defoliated during this infestation in August, and recovery of the leaves was not rapid.

The Arctiid larvae showed pronounced social behaviour, webbing leaves together with silk and feeding in armies of upto 50 individuals (Figure 2.3.1). Furthermore, the larvae appeared to be relatively long lived and slow growing (as compared to the other Arctiid pest found on *Beilschmedia sp*), subsequently appearing on a wide range of other host plants in the nursery. If the true host range covers the other species of Leguminosae and Ficus on which older caterpillars of this species were found, this species may well become a serious nursery pest.

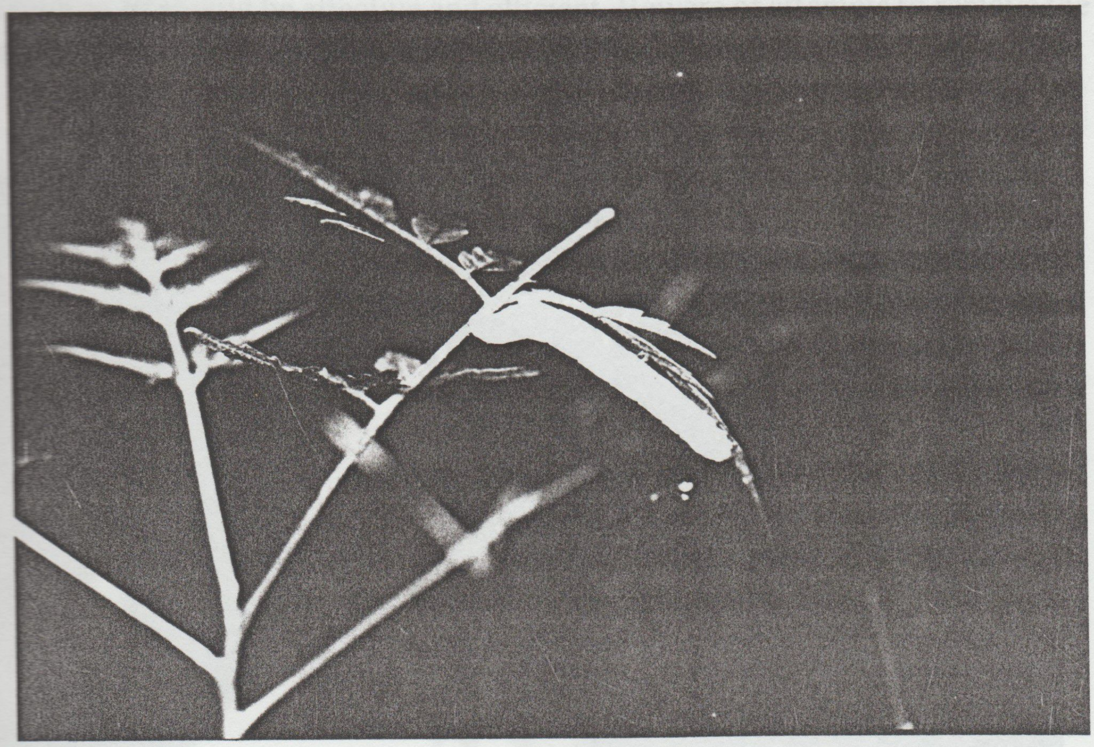

Figure 2.2.1 White Looper eating *M.toosendan*

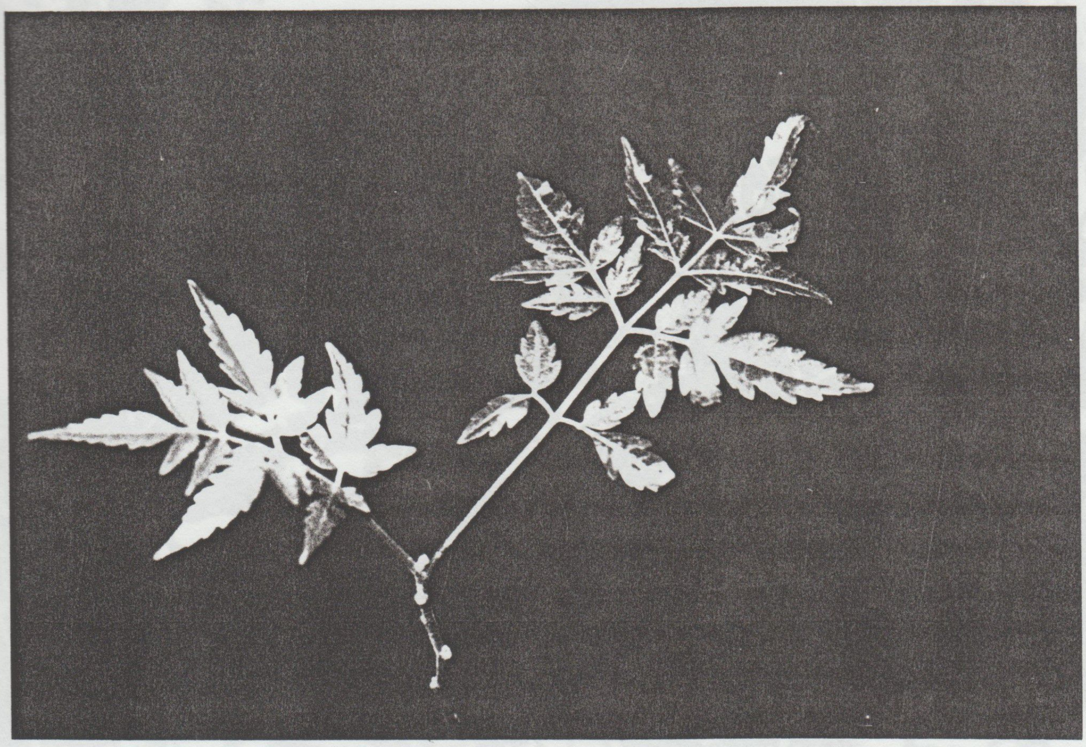

Figure 2.2.2 Leaf spot on *M. toosendan*

Suggestions:

The action of this caterpillar is not difficult to spot, as the webbing of leaves gives them a silvery-gray colour (Figure 2.3.2). As the caterpillars tend to group together in families, control with an insecticide such as *Bt* should be effective and efficient. Beware of attempts to remove the caterpillars by hand, as they drop from the leaves and disperse rapidly when disturbed.

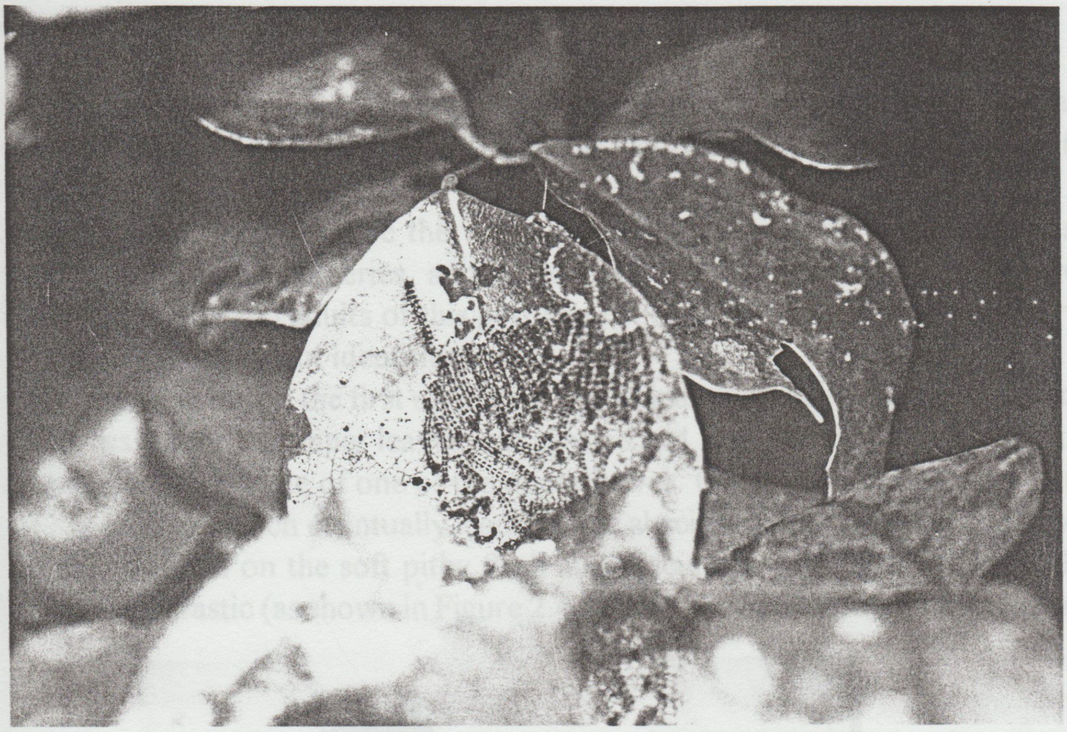

Figure 2.3.1 Arctiid larvae feeding on *D. rimosa*

Figure 2.3.2 Defoliated seedlings of *D. rimosa* following Arctiid infestation

2.4 *Gmelina arborea*

This is a favoured framework species, but has suffered considerably from damage both in the nursery and in the field. The seedlings planted at Ban Maesa Mai in 1998 suffered heavily from defoliation by a Coleopteran pest [10], reputedly the Yemane Leaf Beetle *Calopepla leyana*. But in addition some limited evidence was also seen of the action of the longhorn beetle (*Glena indiana*) which is a notorious stem borer of this species. The longhorn beetle forced the Royal Forest Department to abandon Gmelina arborea as a plantation species in Thailand [11].

In the nursery, *G. arborea* plays host to large communities of tiny leaf minor moths, which despite their numbers are not a damaging pest species. The only serious pest so far identified on this species is a stem borer.
It is tempting to assume the pest to be the well known longhorn beetle, but this pest species has never before been reported in nurseries, and instead only attacks trees more than 1 year old (C. Hutachareon pers. comm.). No adults of this pest were sucessfully raised during the survey, so it is currently not possible to carry out identification.
During attack by the stem borer, the first or second pair of leaves may first be seen to wilt slightly, as if under water stress. Later the upper leaves will abscice and the stem begin to die back. The adult insect lays an egg into the petiole of one of the upper leaves. Once hatched, the larva eats away the inner tissue of the petiole, which eventually leads to leaf abscision, but only after the larva procedes down into the stem to feed on the soft pithy flesh and vascular tissue. In most cases, the result of stem borer damage are drastic (as shown in Figure 2.4.1) but occasioally the stem remains superficially healthy.

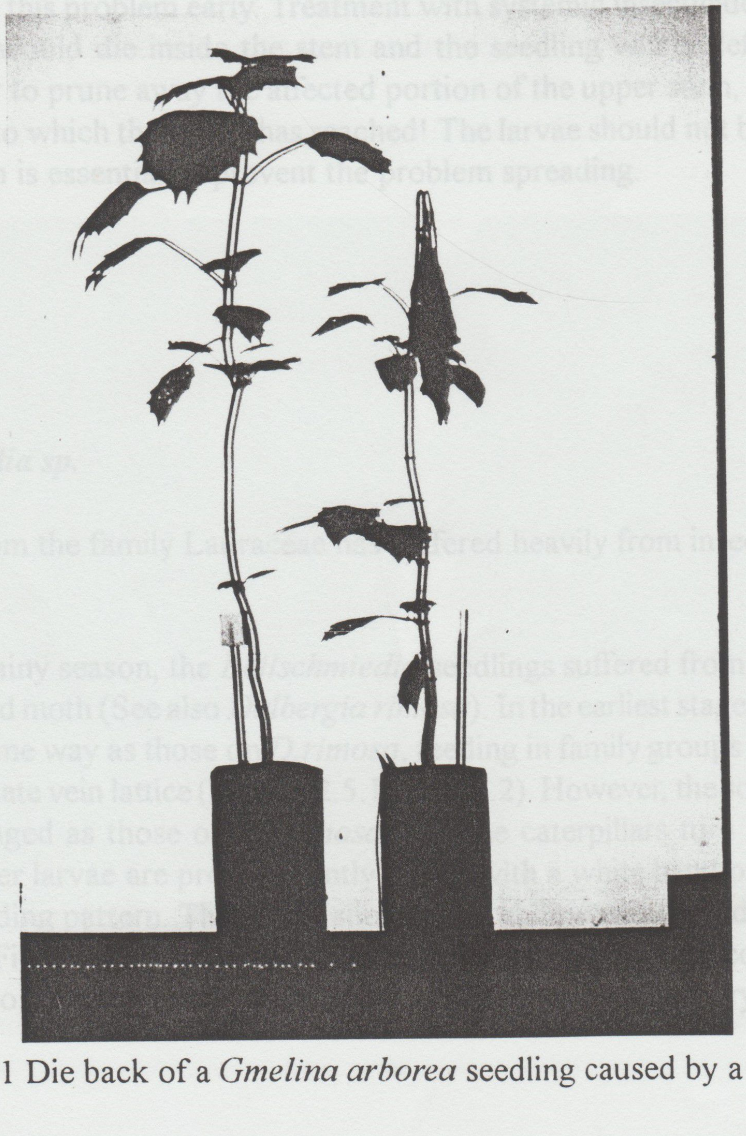

Figure 2.4.1 Die back of a *Gmelina arborea* seedling caused by a stem borer

Suggestions:
It is strongly suspected that the adult form of the stem boring insect feeds on the *Gmelina* foliage prior to depositing an egg in the seedling. This pattern of leaf eating was closely associated with the emergence of the stem borer problem, and it is thought to be that of the adult pest.

Figure 2.4.2 Leaf damage to *G. arborea* by adult of stem borer

Vigilance for this type of symptom and for signs of wilting or leaf abscision should enable nursery staff to deal with this problem early. Treatment with systemic insecticide is not recommended in this case. The larva would die inside the stem and the seedling will be left with structural weakness. Instead it is safer to prune away the affected portion of the upper stem, ensuring that the stem is cut below the point to which the larvae has reached! The larvae should not be allowed to reach maturity, so prompt action is essential to prevent the problem spreading.

2.5 *Beilschmiedia sp.*

This species, from the family Lauraceae has suffered heavily from insect pests in the nursery.

Problems
1. Early in the rainy season, the *Beilschmiedia* seedlings suffered from an infestation of caterpillars of another Arctiid moth (See also *Dalbergia rimosa*). In the earliest stages of growth, these caterpillars behave in the same way as those on *D.rimosa*, feeding in family groups and skeletonising the foliage down to an intricate vein lattice (Figures 2.5.1 and 2.5.2). However, the social stage of these caterpillars is not so prolonged as those on *D. rimosa*, and the caterpillars turn to individual foraging much sooner. The older larvae are predominantly black, with a white band on the thorax. They also have a distinctive feeding pattern. The larvae showed the ability to eat a wide range of species within the Lauraceae and Ficus families, but it is unclear if these other species could act as primary hosts for this species. If so, this caterpillar could become a more serious nursery pest in the future.

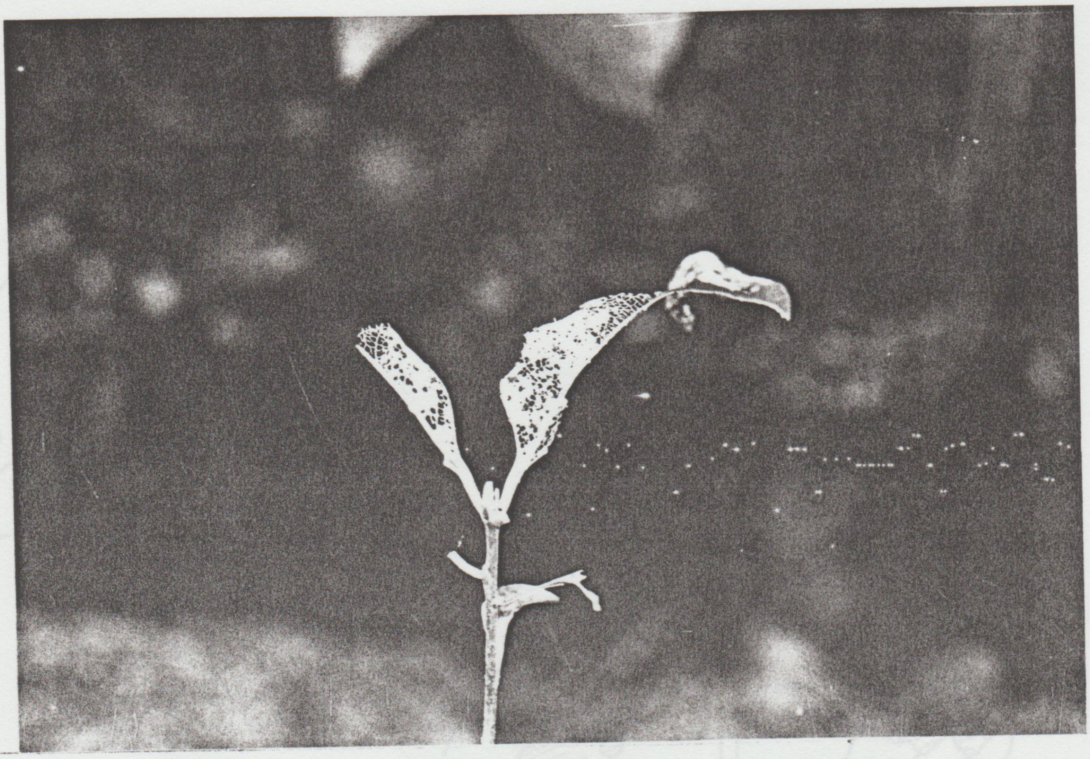

Figure 2.5.1a Leaf damage to *Bielscmiedia sp* by young Arctiid caterpillars

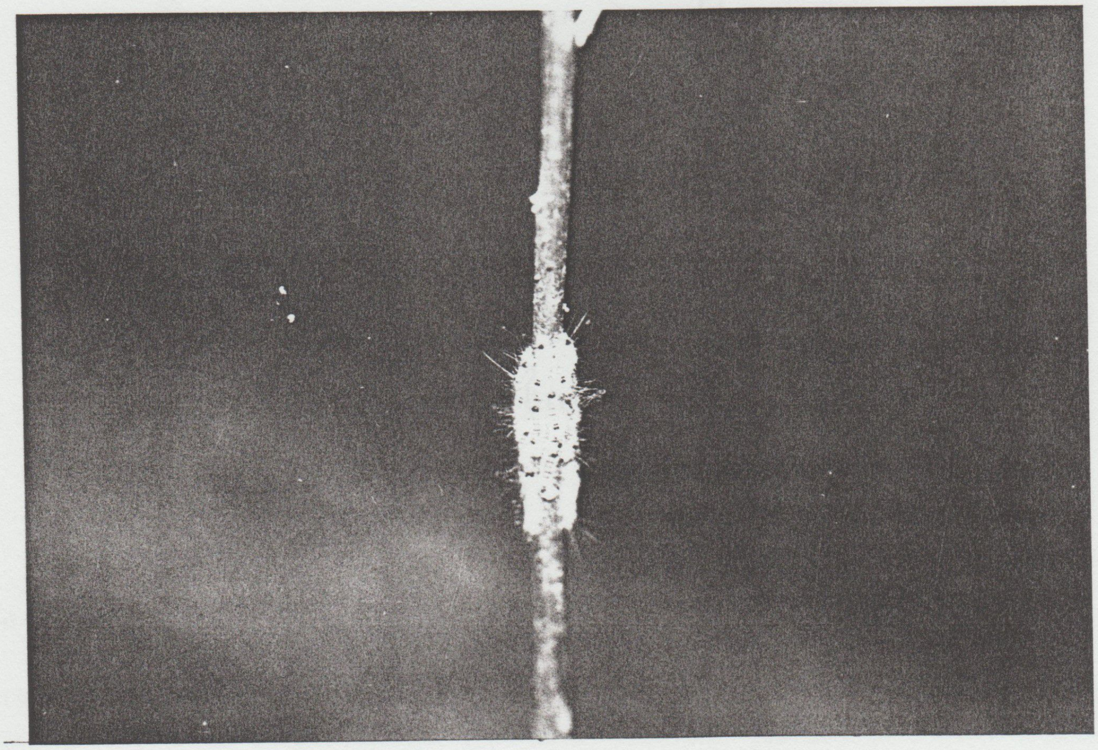

Figure 2.5.1b A family of young Arctiid caterpillars on *Bielscmiedia sp*

...es upto 10cm about 50 times their body length, although it is unclear if this is to facilitate ...ation of a new host plant, or a means of moving out of the leaf in order to pupate in the soil.) ... case, treatment with a systemic insecticide (e.g. Furadan) is recommended.

...er Research:

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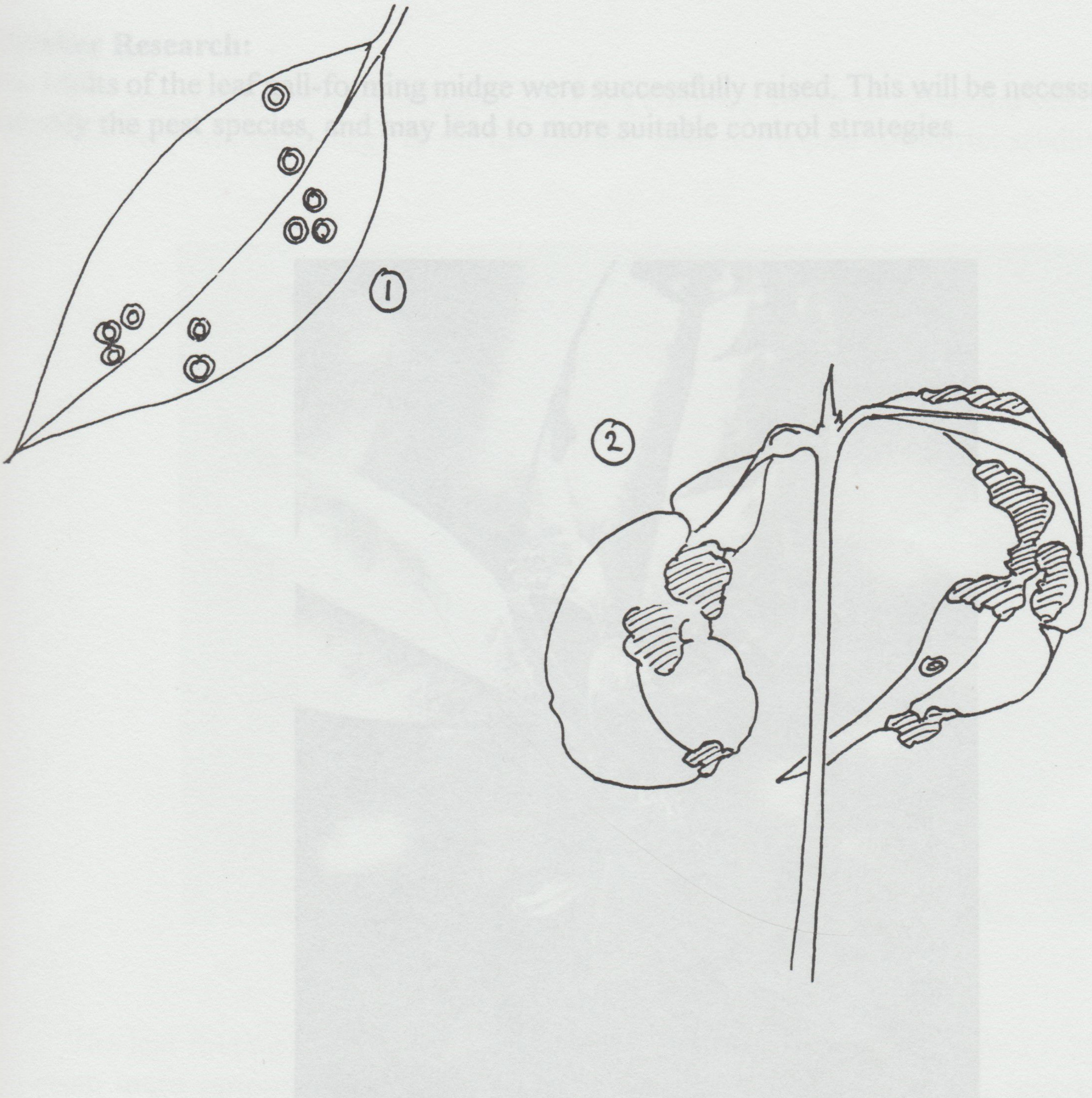

Leaf lesions + leaf distortion from endophagous fly larvae on Bielschmedia sp 122

Figure 2.5.3 Sap-sucking insect damage on *Bielschmiedia sp*

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... *Erythrina subumbrans*

...is is a very fast growing legume with many good framework species characteristics, including a ...idly spreading crown of dense foliage. However, seedlings planted at Ban Maesa Mai, have ...ffered damage from a stem borer. The trunk may become so weakened that it will colapse. Three ...-year-old trees were lost during light winds in November. Heartwood in the trunk had beeneaten

Control of the leaf gall larvae is, however, more difficult. Their large numbers, and long, overlapping life cycles mean that treatments like pruning will be ineffective. Any new shoots emerging will be quickly re-colonised. (The larvae also show an astonishing ability to jump, projecting themselves distances upto 10cm about 50 times their body length, although it is unclear if this is to facilitate colonisation of a new host plant, or a means of moving out of the leaf in order to pupate in the soil.) In this case, treatment with a systemic insecticide (e.g. Furadan) is recommended.

Further Research:
No adults of the leaf gall-forming midge were successfully raised. This will be necessary to correctly identify the pest species, and may lead to more suitable control strategies.

Figure 2.5.3 Sap-sucking insect damage on *Bielscmeidia sp*

2.6 *Erythrina subumbrans*

This is a very fast growing legume with many good framework species characteristics, including a rapidly spreading crown of dense foliage. However, seedlings planted at Ban Maesa Mai, have suffered damage from a stem borer. The trunk may become so weakened that it will colapse. Three two-year-old trees were lost during light winds in November. Heartwood in the trunk had beeneaten away, and the trees were not able to support themselves. However, in the field the action of this agent may be beneficial. The loss of the upper part of the trunk forces the tree to produce new low branches, which creates more shade.

One example of a stem-boring caterpillar was seen in the nursery, but it is not thought likely to be the same pest.

Problems:

1. The grasshopper shown in Figure 2.6.1 is a common visitor to *Erythrina* seedlings. But this pest causes very limited damage to the foliage, and does not appear to restrict seedling growth.

Figure 2.6.1 Grasshopper on *E. subumbrans*

2. The leaf folding caterpillar (Lepidoptera, Pyralidae) shown in Figures 2.6.2a & b represents a much more serious pest of *E. subumbrans* seedlings. There were two severe outbreaks of this caterpillar during the survey period, and it was not seen on any other seedling species in the nursery. The first outbreak was around the 16th September, and the second at the beginning of November. During the first outbreak, defoliation of the seedlings reached approximately 30% of the leaf area of each seedling. The seedlings were pruned following the infestation in a misguided attempt to remove affected foliage and any edgg clusters that could have given rise to a second outbreak. This attempt failed, and during the second outbreak defoliation reached 100%. The vastly increased damage during the second outbreak was due to the greater numbers of larvae present (at the peak of the infestation there were 2-3 caterpillars per seedling on each of the 550 seedlings in the batch). In the absence of effective control, the rate of larval population growth was extremely fast.

3. Immediately following the second outbreak of leaf folding caterpillars on this seedling species, another serious problem was identified. The die-back of seedlings, shown first as a failure to re-sprout following defoliation, is thought to be due to the overstressing of the root system. Losses in December 1999 totaled nearly 40% of the E. subumbrans seedlings that had been potted in April of the same year. The above ground symptoms are shown in Figure 2.6.3.

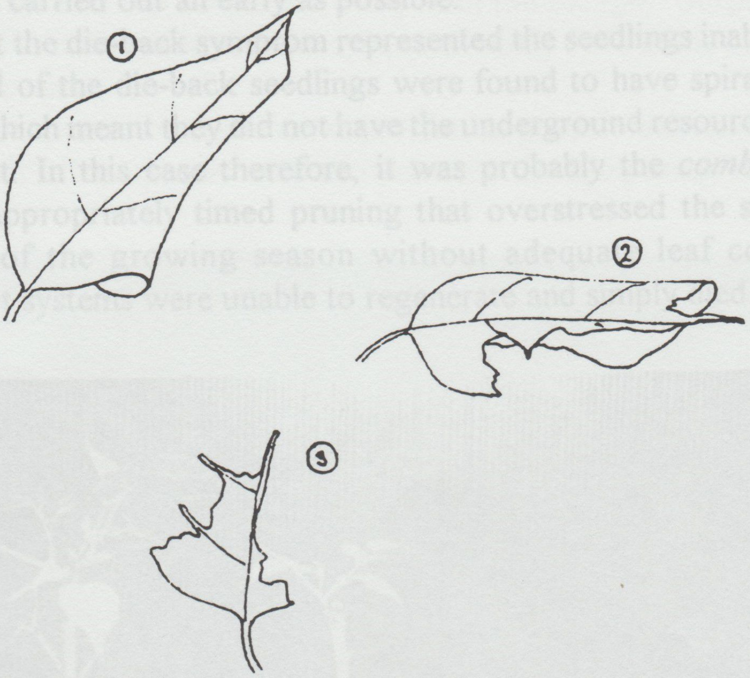

Figure 2.6.2a Stages of leaf damage to *E. subumbrans*

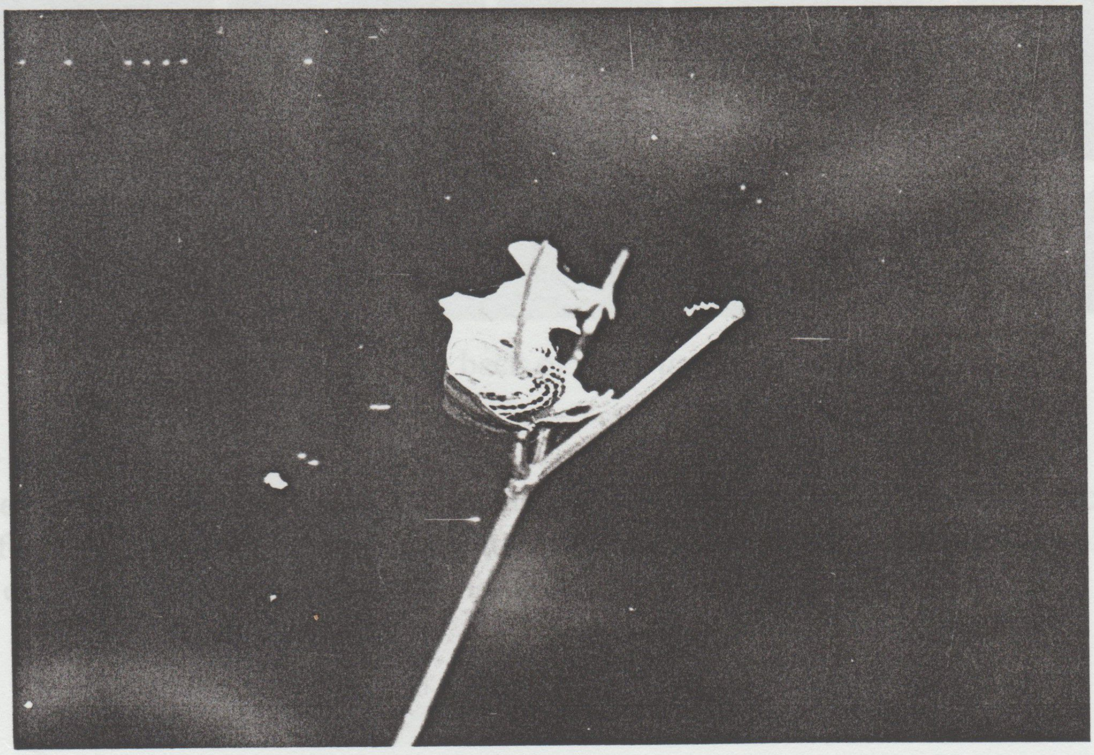

Figure 2.6.2b Leaf folding caterpillar on *E. subumbrans*

Suggestions:
Control of leaf folding caterpillars should be attempted using an insecticide such as *Bt.* This should be done as soon as the insects are first seen. It is also possible to pick off folded leaves containing caterpillars, but the rapid life cycle of the pest (c. 10 days from larva to adult) means that any control attempted should be carried out an early as possible.
It is highly likely that the die-back symptom represented the seedlings inability to deal with repeated defoliations. Several of the die-back seedlings were found to have spiralling or otherwise poorly developped roots, which meant they did not have the underground resources to cope with the loss of photosynthetic input. In this case therefore, it was probably the *combination* of the caterpillar infestations *and* inappropriately timed pruning that overstressed the seedlings. Having spent a significant period of the growing season without adequate leaf cover, the seedlings with underdeveloped root systems were unable to regenerate and simply died.

Figure 2.6.3 Die back of *E.subumbrans* seedlings

Further Research
Subsequent re-emergence of the caterpillars should be monitorred closely to develop good information on the life/breeding cycle of the pest. If outbreaks can be predicted at certain times of the year, the chances of effective control are greatly increased.

2.7 *Heynea trijuga*

This fast growing member of the Meliaceae performs well in the nursery and the planting sites (it has a survival rate of 100% from the1998 plantings). However, it has shown susceptibility to a number of minor pest problems.

1. The leaf wrinkle shown in Figure 2.7.1 is thought to be caused by a virus. In severe cases, all the leaves of the seedling will show severe distortion, but the youngest leaves usually show the worst symptoms. Sterile pruning of the infected upper parts of the seedling appeared to remove the infection. The re-growth shoots showed no signs of leaf wrinkling, indicating the infection may not be present systemically in the plant and can be pruned away with the foliage. Surprisingly however, normal pruning was not so effective at removing the symptoms. Only 50% of the un-steirle pruned seedlings re-grew without symptoms.

This problem does not appear to be serious at present, as growth restriction of affected seedlings is minimal, and the plant often appears able to overcome the symptoms, maintain some uninfected foliage.

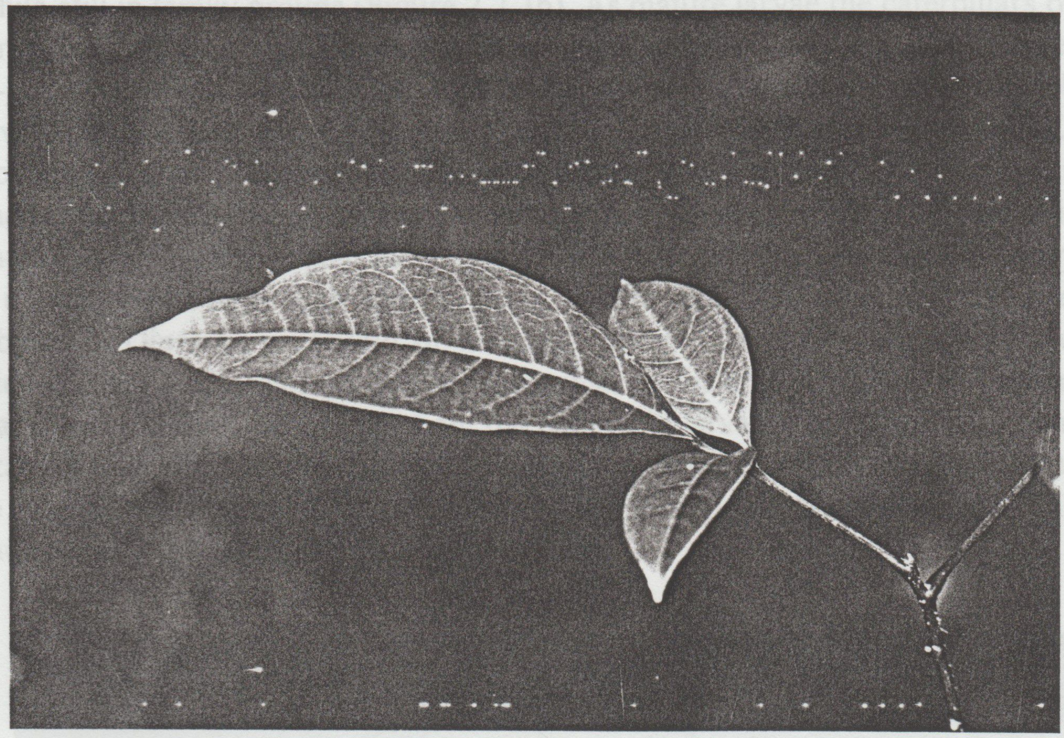

Figure 2.7.1a Healthy leaf of *H. trijuga*

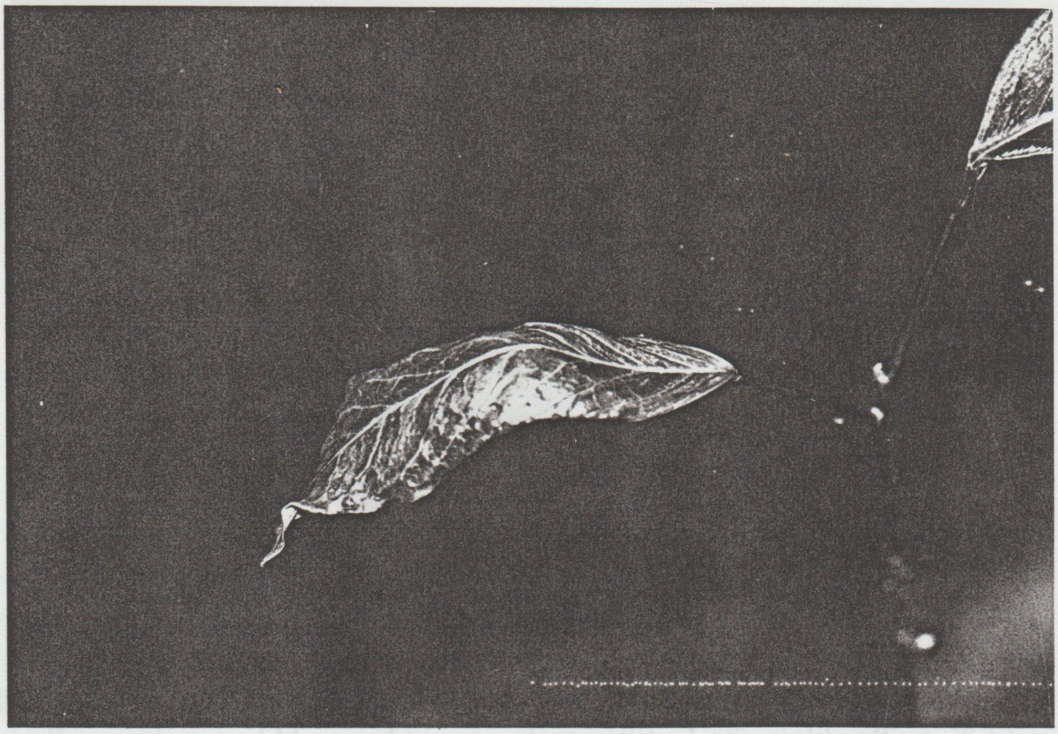

Figure 2.7.1b Wrinkled leaf of *H. trijuga*

2. Another minor problem is damage to young shoots due to the action of a stem-boring fly. The first visible symptom is the wilting of new leaves, but closer inspection of the shoots will show a slightly bulging stem, and often a mass of white excreta squeezed out from a tiny hole near the base of the leaf blade. The shoot will eventually collapse and abcise.
The pest is a small fly possibly an Agromyzid [14], whose larvae probably never reach sizes where they are likely to damage the main stem of the seedling. When the feeding stage is over, the larvae crawl out of the shoot and pupate in the soil.

3. Defoliation by the larvae of two species of Noctuid moth, reached quite high levels in late September and October. One of these, shown in Figure 2.7.3a, shows a characteristic feeding pattern in the first instar, while still in family groups (Figure 2.7.3b). As mature larvae the caterpillars of both species trim entire leaves off at the petiole, thus accounting for large leaf area losses. However the speed of shoot re-growth means that defoliation by either pest has not yet caused a severe problem. Feeding tests showed that while the yellow Noctuid (Figure 2.7.3a) showed some liking for *M. toosendan*, it would not eat leaves of *Aphanamixis polystachya* (both Meliaceae) and would not eat leaves of any Leguminous species, *Beilschmedia sp* or *Castanopsis accuminatissima*. This would indicate a high level of host specificity. If the caterpillars a can be effectively controlled on their primary host species, they are unlikely to be large scale nursery pests. Furthermore, this caterpillar has been particularly susceptible to a Dipteran parasitoid of the well-known Tachinid family. These are non-specific parasitoids of many Lepidoperans, whose larvae wait on the host plant leaf, and are ingested by the caterpillar during feeding. After ingestion, the parasitoid larvae grow at a phenomenal rate, (some species taking only four days to entirely consume the caterpillar from the inside) but only emerge form the caterpillar on pupation (pers. comm H. Benzinger). This parasitoid may well be helping to reduce numbers of the caterpillar pest in the nursery.

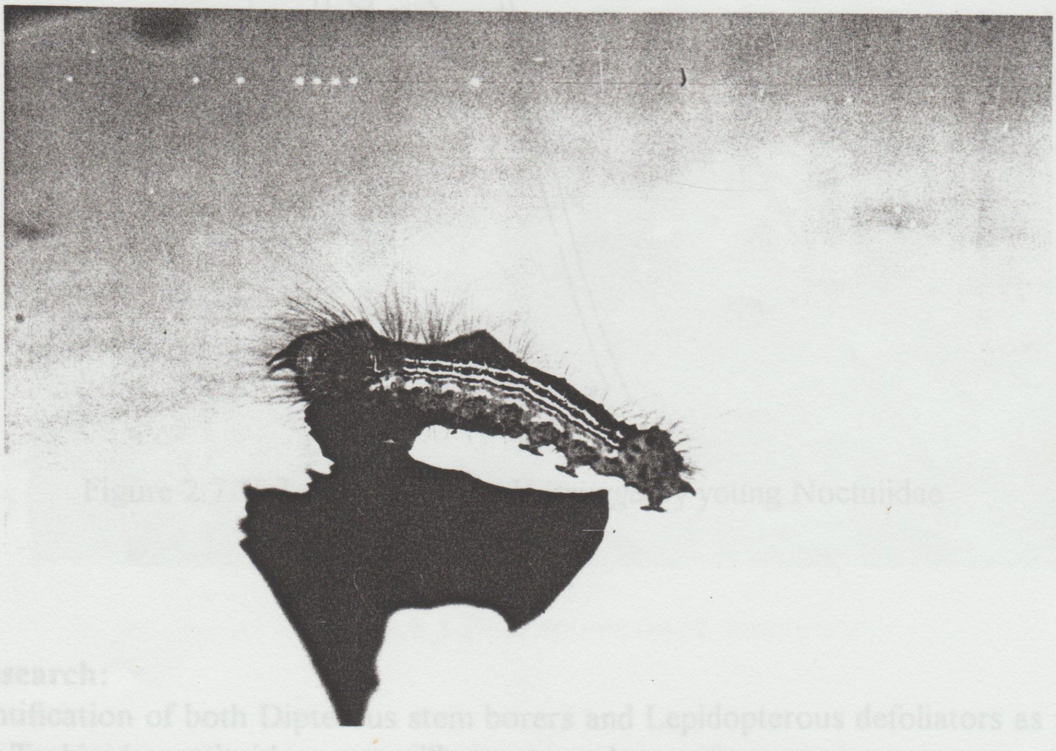

Figure 2.7.3a Noctuid caterpillar on *Heynea trijuga*

Suggestions:
Clearly sterile pruning could be used to cure plants of the leaf wrinkle effect, if it becomes a serious problem.

Control of the stem-borer could be achieved using a systemic insecticide such as Furadan but is not recommended unless the problem worsens considerably in future seasons.
Yellow Noctuid caterpillars show a characteristic feeding pattern while in the first instar. The leaves are skeletonised as shown in Figure 2.7.3b while the caterpillars are still gathered in family groups. If seedlings showing this type of damage can be spotted at this early stage, it should be possible to 'weed out' entire family groups of the caterpillars before they spread individually. Care should be taken when removing these insects as their spines will cause irritation of the skin. Nevertheless, even as mature larvae they can easily be picked off from the host plant with tools or gloves.

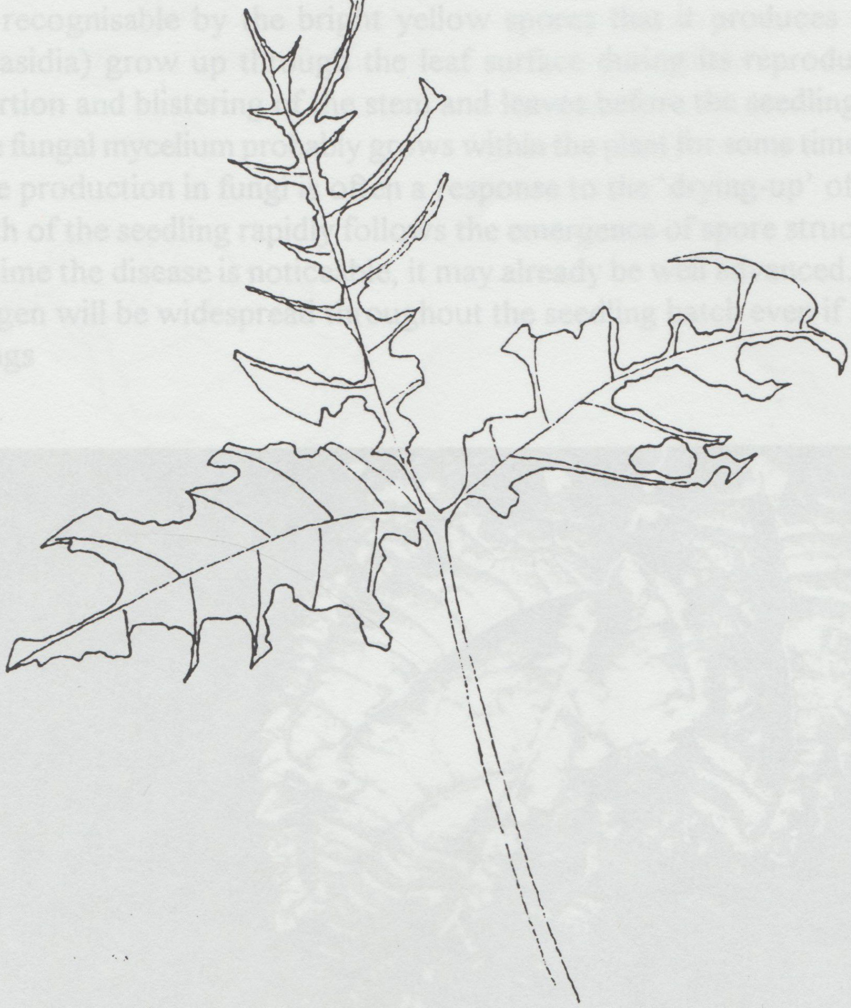

Figure 2.7.3b Leaf damage to *H. trijuga* by young Noctuiidae

Further Research:
Species identification of both Dipterous stem borers and Lepidopterous defoliators as well as the effect of the Tachinid parasitoid on caterpillar pest numbers.
Further study of the leaf wrinkle disease to establish modes of infection and spread would be useful information for the development of a control strategy. Proof that it is a viral agent would be difficult without electron microscopy, but satisfying Koch's Postulates that leaf wrinkle is caused by an infectious particle (and not a genetic aberration in the plant) should be straight forward.

2.8 *Morus macroura*

This is a common upland tree that is a potential framework species, although not yet in widespread use by FORRU. It is a member of the Moraceae family.

Problems:

Only one disease problem was observed with this species, but unfortunately it killed the entire 1999 seedling batch. The disease is a Rust fungus (order Basidiomycotina, family Uridinales) that is, like most rusts, an obligate necrotrophic parasite. This means it can only grow on the tissue of the host plant, (and is therefore highly adapted to it) and that in growing, it necessarily kills its host. It is immediately recognisable by the bright yellow spores that it produces when the spore forming structures (basidia) grow up through the leaf surface during its reproductive phase. This causes growth distortion and blistering of the stem and leaves before the seedling withers and dies. However, the fungal mycelium probably grows within the plant for some time before spore production. Indeed, spore production in fungi is often a response to the 'drying-up' of a food resource, and the fact that death of the seedling rapidly follows the emergence of spore structures would support this. Thus by the time the disease is noticeable, it may already be well advanced. It is highly likely that the fungal pathogen will be widespread throughout the seedling batch even if spores are visible on only a few seedlings

Figure 2.8.1 Rust spores on *M. macroura*

Suggestions:

Fungal diseases are difficult to control without resorting to large-scale applications of preventative chemicals, or expensive modern systemic fungicides. Neither of these strategies is recommended. Furthermore rust spores are dispersed by wind, and restricting the spread of such a disease is not easy. The only viable strategy for managing as destructive a fungal pest as this will be to maximise the genetic variation within any given seedlot of this species (See section 3).

2.9 *Bischofia javanica*

Although a valuable framework species, this member of the family Euphorbiaceae has encountered several pest and disease problems in the nursery and the field. Seedling batches of *B. javanica* sustained substantial losses during the rainy season of 1999, it is highly likely that no *B. javanica* seedlings will be planted in 2000.

Problems:

1. The Hemipterous sap sucking insect reported on *Beilschmiedia sp* (Section 2.5) has also been seen on *B.javanica*. The symptoms generated are almost identical, with young leaves being preferred.

2. The leaf curl shown in Figure 2.9.2 is rarely seen in the nursery, but very common on seedlings in the field plots from 1998 and 1999. The causative agent is still unknown, but could be a species of sap-sucking mite or a plant virus. The damage is not fatal to the seedling, but does appear to exert a mild restriction on growth.

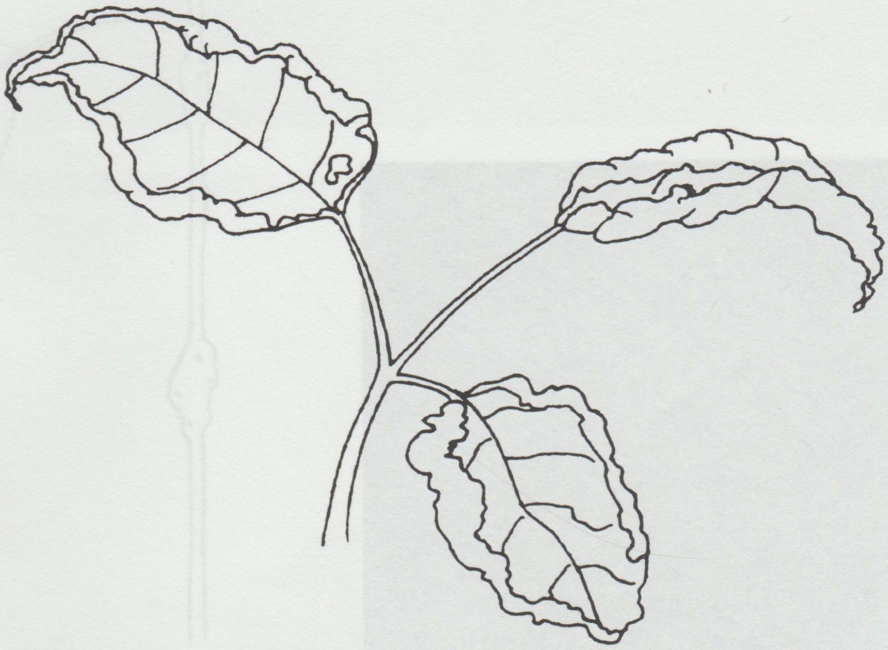

Figure 2.9.2 Leaf curl on *B. javanica*

3. The stem galls shown in Figure 2.9.3a were first recorded on *B.javanica* seedlings at the end of July 1999. At that stage it was noted that 13% of the seedlings had at least one gall in the stem. Over the course of the rainy season, the gall-forming larvae (thought to be a midge of the family Cecidomyiidae) passed through three life-cycles each of which was approximately 3-4 weeks. By the end of October, 100% of the seedlings had been affected, most with several galls in the stem and leaf petioles. Galls had caused severe distortion of the stems and caused the seedlings to become unbalanced and top heavy. Once the galls had been vacated by the larval occupants, many became infected by opportunistic pathogens (particularly soft-rotting bacteria). The stems of many seedlings rotted and many simply collapsed or broke (Figure 2.9.3b). Overall losses reached approximately 30% when seedlings failed to re-sprout during November.

4. During November, and immediately following the worst effects of the gall forming insects, *Bischofia javanica* seedlings that were attempting to re-sprout, were attacked by caterpillars of an unknown family. This striking black and red caterpillar (Figure 2.9.4) is the larva of a day flying moth. The

infestation occured quite suddenly. The young larvae produce a skeletonised leaf damage pattern (Figure 2.9.4a), but the older ones will trim the leaves completely. Some were even seen feeding on the stem tissue due to the shortage of available foliage. The suppressive effect of the caterpillars on the re-growth of new foliage, had, at time of writing accounted for a further loss of seedlings. Only 44% were still surviving, none of which will be fit for planting in 2000.

Figure 2.9.3a Stem galls on *B. javanica*

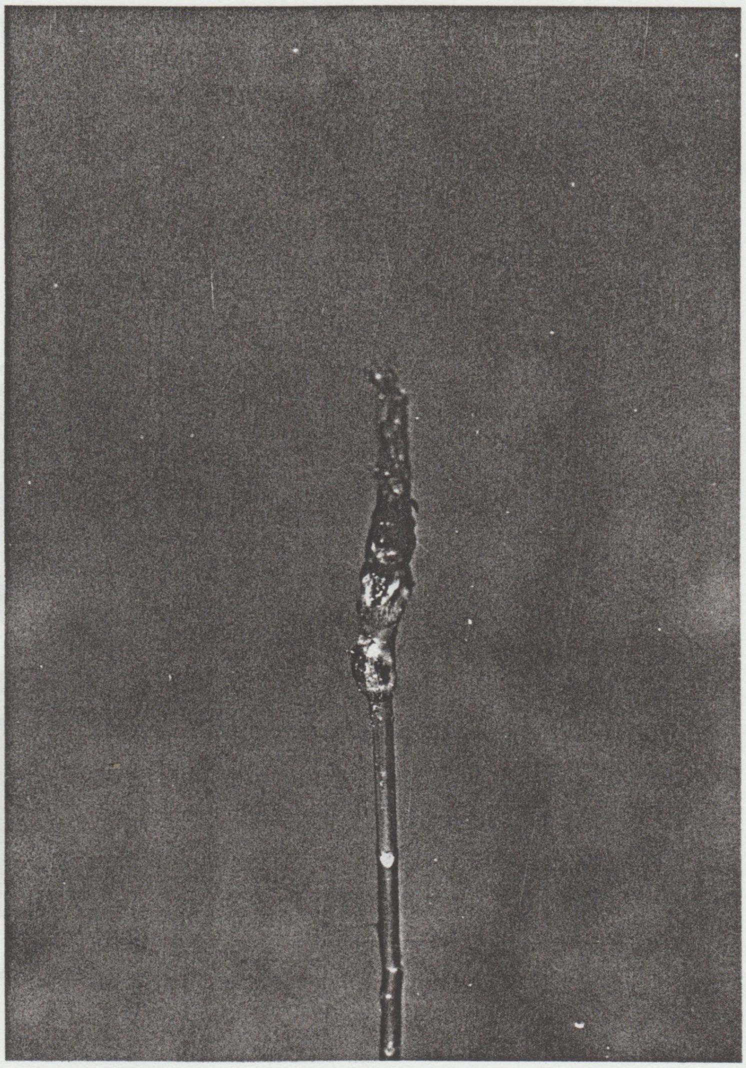

Figure 2.9.3b Stem rotting following gall infestation of *B. javanica*

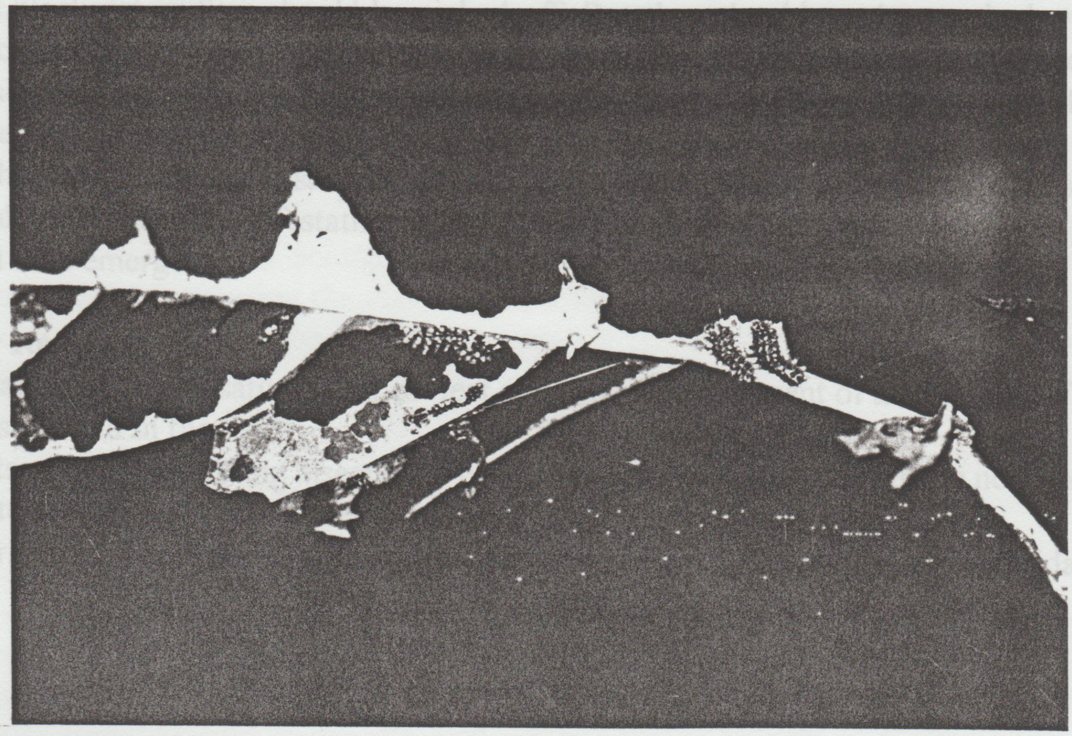

Figure 2.9.4a Young caterpillar larvae skeletonising *B. javanica* leaf

Figure 2.9.4b Mature larvae on *B. javanica*

Suggestions:

Damage to the seedlings from sap sucking or leaf curl seems, at present to be limited. The large host range of the Hemipterous bug is interesting, and could be useful information if disease transmission is suspected, but it does not pose a substantive threat to B.javanica. No suggestions are made for the management of this pest.

Red and black caterpillars should be picked off. But they should not be touched without gloves. They secrete drops of venom from their red spines when disturbed. This can severely irritate the skin. They can be picked off using tweezers, and spraying with detergent should be tried as recommended by [7].

Enterophageous pathogens, such as gall forming insects, are controlable by the use of systemic insecticides like Furadan. Infestations should be preventable if affected stem tissue is pruned before the adult flies emerge.

Further Research

Identification of the causative agent of 'leaf curl' and an assessment of the severity of symptoms on seedlings planted in the field.

No adults of the gall forming insect have been successfully raised. This will be necessary in order to identify to the genus or species level.

Comparrison of chemical and pruning treatments to combat gall forming Cecidomyiidae (see section 3.3).

Section 3. Discussion

3.1 Pest problems and biodiversity issues:

It is worth stating here that "pest" is an entirely anthropocentric concept. Pests are by definition, organisms that hamper man's agronomic activities, and therefore a "pest" does not exist in the natural environment. Furthermore the degree to which agricultural activities distort natural ecological relationships correlates closely with the severity of pest outbreaks. Increasing the carrying capacity of an individual niche (e.g. by growing a single crop) creates the conditions necessary for the development of a pest problem. It is the 'scorched earth' policy of large-scale monoculture cropping that leads inexorably to an ever-intensifying spiral of pesticide use [15].

Logically therefore, nursery operations (just like agricultural activities) should utilise, as far as is possible, then variability present in the natural environment. Reversing any trend away from this biodiversity, should remove much of the threat posed by pests and pathogens.

Nevertheless, it is not sufficient to look only at crop (or in this case seedling) *species* diversity. In the forest, every tree is a small part of an ecological community comprising organisms from all kingdoms. The kind of diversity that breeds true ecological stability involves birds, insects, fungi and bacteria in addition to a mix of plant species. Every potential insect 'pest' has a natural enemy that ensures it remains only a potential pest. Every pathogen is engaged in a continuous struggle with resistant host varieties in order to survive. Only by removing these natural contraints does man create a pest species.

3.2 Integrated pest management (IPM):

Since the 'Green Revolution' there has been a general shift of emphasis from the philosophy of pest *control by eradication* to that of pest *management*. Central to this emerging and ecologically sound doctrine, is the idea of a basal level, or 'economic threshold' beneath which a pest should not be tackled. This reduces the overall amount of pesticide use by the farmer, and encourages the close monitoring of pest damage to ensure pesticides are used only at the most appropriate time. What is more, by keeping a basal level of the pest organism present in the crop, the farmer is providing a food resource for the pest's natural enemies, which should keep the pest population in check automatically, and prevent the frequent recurrence of infestations. Integrated management schemes make use of information on pest life-cycles and seasonality, the lifecycles of natural enemies and the possibility that there are alternative hosts for the pest organism (in the case of pathogenic diseases, knowledge of resistant host varieties is also crucial). The idea is to maximise the potential of all available control techniques by using them in parallel. Cultural techniques that reduce the likelyhood of pest problems arising are also involved, although the rapidly expanding organic farming movement views the cultural techniques as the first step, and any application of (natural) pesticides a last resort.

The success of IPM schemes [16], [17] demonstrates the importance of detailed knowledge of pest organisms. Attempting to eradicate a pest for the short-term goal of seedling production in any given year is ill advised. Doing so gives no opportunity to study the ecological relationships between pest and host, which will reap long-term rewards in terms of sustainable pest management.

3.3 Review of major problems:

The four major nursery problems identified in this report are bacterial blight on *Balakata baccatum*, stem gall infestations on *Bischofia javanica*, the leaf folding caterpillars on *Erythrina subumbrans* and the rust fungus on *Morus macroura*. As mentioned in the text, treatment of the infectious diseases will be extremely difficult and control will depend on good nursery management. It is likely that the insect causing *Bischofia* stem galls can be effectively controlled.

Once a disease like a rust fungus has taken hold in the nursery, quickly disposing of the affected seedlings may be the only management option. It is often the case that pathogenic fungi, and especially biotrophs, are so closely involved with their host plant, that doses of systemic fungicide sufficient to kill the pathogen will also damage the plant [18]. Management of this pest will be dependent on prevention rather than cure.

Given that the disease is so destructive, and that both fungus and host must co-exist in the natural forest, it is almost certain that different trees will exhibit differing degrees of susceptibility to the pathogen. Indeed, so subtle and complex are the host pathogen interactions in these cases that the fungus tends to be adapted to individual genotypes within a species. (This is the basis for most crop resistance breeding schemes.)

It is therefore necessary to assess the susceptibility of seedlings from genetically diverse seed-lots. Seeds should be collected from several mother trees, and background levels of susceptibility should be tested (i.e. any batches that develop symptoms naturally). Following this, an innoculation protocol should be devised, that allows the introduction of a known quantity of spores into seedlings from each seed-lot, and the measuring of any symptoms that develop. It should be possible to identify trees showing more and less resistance to this pathogen and efforts can then be made to avoid cultivation of those trees that appear most susceptible.

The bacterial blight disease of *Balakata baccatum* (section 2.1) is less likely to be host genotype specific. Bacteria are simple organisms, and do not possess the specialised infection structures of most plant pathogenic fungi. They tend therefore to infect the plant via ready-made wounds, and are much more dependent on opportunity than adaption. It is possible that this blight disease could become a problem on other, unrelated species in the nursery. Innoculation tests on different species should be carried out to determine the risk of cross contamination.

Like rust fungi, control of this pathogen will depend on vigilance and damage limitation alone, as there is no convenient chemical remedy. It is essential that nursery staff can recognise the symptoms of this or similar diseases, and are able to control the spread of the pathogen by 'cultural' means (section 2.1). This means the use of quarantines and the avoidance of pruning.

Controlling the damage to *Bischofia javanica* seedlings (section 2.9) from gall forming insects will probably depend on the combined use of systemic insecticide (e.g. Furadan) and appropriately timed pruning. It will be necessary to monitor the natural development of symptoms on a control seedling batch, and to test different treatments in parallel.

If insecticide is to be used, defining the minimum effective dose is necessary for both economic and environmental reasons. In addition, the *timing* of application will need to be optimised. A single application (in granular form) to each seedling at the potting stage would be the most convenient treatment, but the effective life-span of the chemical may make this inappropriate. Nevertheless, treating the seedlings both before and after the development of symptoms should be tested. Pre-emergence treatment is good as it should completely prevent the development of symptoms, but it may be wasteful of chemicals. Post emergence treating is more efficient as long as the pest is effectively killed and the seedling is not damaged by the pest beforehand.

A comparison of chemical use with a pruning treatment should also be carried out. If the immature larvae can be removed quickly by cutting away affected stem tissue, it may be possible to prevent the spread of the problem without resorting to an insecticide. For pruning to be effective, some knowledge of the life cycle stage of the pest will be essential.

The Pyralid leaf folding caterpillar (Lepidoptera, Pyraustinae) seen on seedlings of *Erythrina subumbrans* during September October and November of 1999, is the most damaging of all the phytophagous insects found during the survey. The combination of its host specificity with its rapid life-cycle and population growth make it a potentially serious pest. As recommended in the text (section 2.6), control of this insect with an insecticide like *Bt* should be attempted, but as for *Bishofia*, careful experimentation to determine the optimum time for treatment and the minimum effective dose should be carried out.

It is highly likely that defoliation pressure from this caterpillar pest was directly responsible for the subsequent loss of seedlings from die-back. This shows that although most phytophagous insect pests do not themselves kill the plant, defoliation pressure, in combination with other factors like poor seedling health (or over pruning) can lea

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THE END