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Technical Guidelines for the National Forest Restoration Initiative (NFRI) Part 1: Species Selection, Collection, and Hardening

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Abstract

This guideline outlines collection from the wild, care, and hardening of eleven native trees species in a nursery-like setting. The guideline is intended to produce good quality planting stock for re-planting of reclaimed mined out areas. Species were selected based on morphology, habitat, life history, distribution, ease of collection, and resources required to harden seedlings. The list also contains species such as *Humiria balsamifera (*Tauroniro), *Goupia glabra (*Kabakalli), *Simarouba amara* (Simarupa), *Terminalia amazonica* and *Terminalia dichotoma* (Fukadi), and *Jacaranda copaia* (Futui), with timber value and varying densities. This guideline is expected to be low cost, easy to implement using readily available materials, and requires limited technical skills. A regime for watering, fertilising, pest and disease control, and light acclimatisation is outlined for a three-month hardening period. At the end of three months, seedlings collected from the wild are expected to be hardy.

***Keywords*:** Forest restoration, seed collection, seed hardening, seedling station

1. Project Background

The Low Carbon Development Strategy (LCDS) 2030, recognises the importance of Guyana's forests in the global fight against climate change and simultaneously recognises the forest sector's importance to the local economy. As such, the Government of Guyana intends to "explore options for land reclamation and reforestation of mined areas" (Government of Guyana, 2022). An emerging theme of action is to restore forests and incentivise restoration where deforestation has already taken place.

In 2009, Guyana established a Special Land Use Committee (SLUC) to provide recommendations for managing land use conflicts and issues in the context of degradation from extractive activities. Among the cross-cutting recommendations emanating from the SLUC were specific considerations to ensure enhanced land reclamation. From 2016, this recommendation

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led to the establishment of initial restoration sites across mining districts of Guyana, namely Olive Creek in Region 7, Dakoura Mines in Region 10, and Puruni in Region 7.

The LCDS 2030 further strengthens the commitments for forest restoration with an additional 200,000 hectares as a priority. As a result, in 2023 the Ministry of Natural Resources (MNR), the Guyana Forestry Commission (GFC), and the Guyana Geology and Mines Commission (GGMC) commenced the National Forest Restoration Initiative (NFRI). This initiative represents a coordinated approach to forest restoration, focusing on mined out, degraded, and deforested areas across the country. It focuses on restoration activities using native species and supports community participation and alternative livelihoods for forest-dependent communities. As of 2026, activities implemented by the NFRI are ongoing in Regions 6, 8, and 10.

As the NFRI work continues, it is important to ensure that the methodology, tools and technical approach to restoration are documented, allowing for accountability and replicability across Guyana. It is important that this initiative be easy to implement by a wide range of stakeholders in the interior Regions of Guyana. Through the NFRI, Guyana is committed to combating the negative effects of climate change, supporting local economies, fostering sustainable livelihoods, and adding to the body of scientific knowledge on restoration techniques and practices.

This body of work (Part 1) outlines the restoration works ongoing in Guyana. This includes the technical guidelines for pre-planning, site assessment and land reclamation, and wild harvesting and nursery management for field establishment, along with technical guidelines for outplanting of native tree species on reclaimed sites and early field performance of transplanted tropical forest species wildings on reclaimed bauxite mined lands. The selection, collection, and hardening of native tree species are priorities to achieve the objective of the NFRI. Considerations for species selection include morphology, habitat, life history, distribution, ease of collection, and resources required to collect, care, and harden seedlings. Research is limited on native tree species and their responses to nursery-like settings and survival in degraded mined out sites. As such, institutional knowledge and field observations were used to supplement the preparation of the selection criteria.

2. Aim

In response to the overall objective of the national initiative to implement a coordinated approach to forest restoration using mainly native tree species in mined out, degraded, and deforested areas in Guyana, this guideline addresses the components needed to ensure that good quality planting material is available for re-planting reclaimed mining sites. The guideline considers:

1. The development and management of seedling station near restoration activities**.** For successful implementation of these restoration activities, accompanying infrastructure is required near selected sites. Establishment and management of these field seedling stations increase job and training opportunities for communities and youths while providing good quality planting stock for restoration efforts;
2. The collection of seedlings from healthy populations in forests neighbouring or similar to forest type pre-mining;
3. The hardening of seedlings in seedling stations to become acclimatised to the harsh conditions of the planting site; and

4. The management and maintenance of seedling stations to reduce cost and produce good quality seedlings.

3. Technical Guidelines

These guidelines were developed in 2023 for implementation of the first pilot plot of the NFRI in Dakoura, Region 10, and are expected to be implemented for all other pilot sites under this initiative. The guidelines are intended to function as a field based, low input guide for seedling collection and hardening. It uses readily available materials with limited technological input in a minimally controlled environment, and is intended for use by stakeholders in the extractive industries and other parties that wish to undertake reclamation and restoration activities. Table 1 provides the materials and equipment that may be used.

Table 1

Materials and Equipment List

Materials	Small Tools
Dried chicken manure	Shovel
Sand	Spade
Forest topsoil	Garden trowel
Plant bags	Secateurs
Clay	Hand sprayers
10.50.10 fertiliser	Buckets
30.10.10 fertiliser	Wheelbarrow
Sevin powder (carbaryl)	Measuring cups
Neem oil	
Detergent/soap	
Isopropyl alcohol	
Gloves	
Eye goggles	
Visibility vests	
Long boots	
Face mask	

3.1 Seedling Station: Site Selection, Layout, and Management

Seedling stations are established using the following criteria:

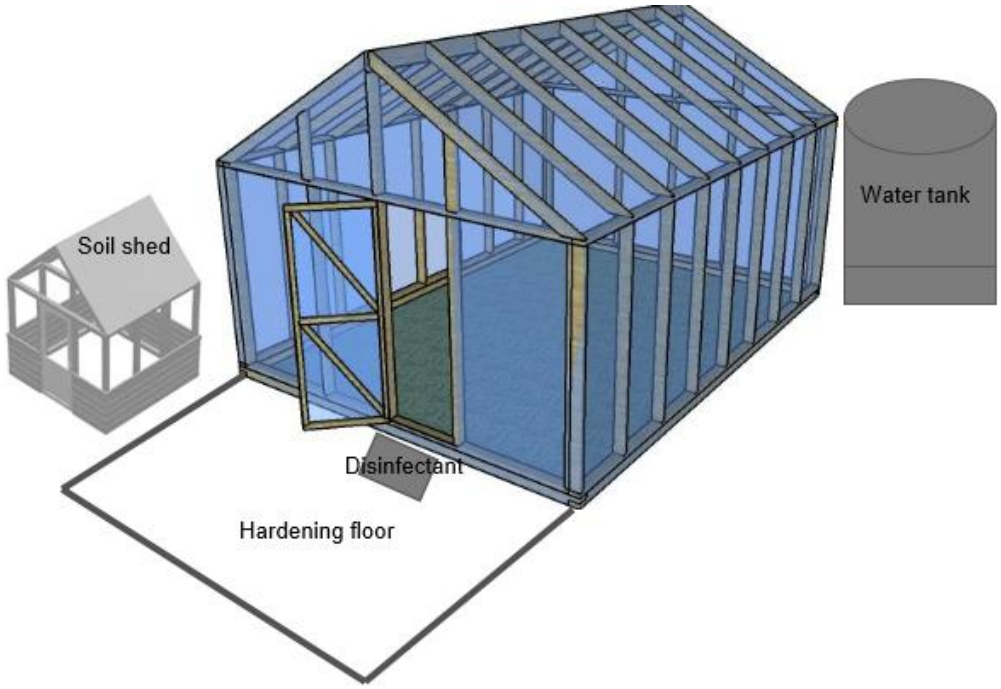
1. The seedling station should be built on lands under the management of GFC, GGMC, or the MNR.
2. The seedling station should be close to communities and selected restoration sites for easy vehicular access.
3. There must be direct sunlight.
4. Access to water and healthy seedling stock are vital.

The rafters for the seedling station roof should be metal and 75% covered with a single ply of agriculture 50% shade mesh. The station should be enclosed using shade mesh to allow air flow while keeping out insects and pests. The concrete hardening floor should have direct sunlight and

easy access for vehicles. A covered soil shed and elevated water tank should accompany the infrastructure for the seedling station (Figure 1).

Figure 1

Rendering of the Recommended Layout of a Seedling Station



Note. Not drawn to scale. Rendering by the authors.

Seedling stations are enclosed, with 75% covered by shade mesh and 25% by zinc. A hardening floor and a soil shed are also available. Concrete work benches are erected for potting, up-potting, and daily activities, while metal tables with metal mesh are available to house seedlings.

1) Seedling stations are usually set up in forested or semi-forested areas. The surroundings must be kept clean of debris and bushes to reduce the occurrence and severity of insect attacks.
2) Surroundings must be sprayed with Sevin powder (carbaryl) solution based on the established timeline to keep insects out of the station.
3) Leaf fall must be removed from the roof.
4) Concrete floors should be pressure washed and kept free of obstacles.
5) Fertilisers, chemicals, and other materials should be kept away from water and in properly labelled storage containers.
6) A weekly seedling register of treatments administered, mortality, and other observations must be kept (Table 2).
7) New seedlings entering the station must be properly sorted and recorded.
8) Seedlings are sorted by species and amount of time spent in the seedling station.
9) During hardening, monthly visits are done to assess status of seedling station and number of hardened seedlings available for planting.

Table 2
Seedling Station Weekly Report

Date (D/M/Y)	Name of Officer/ CRW (Printed)	Number of plants alive (by spp.)	Number of plants morbid (dying) (by spp.)	Number of plants dead (by spp.)	Reasons for death (send pictures where possible)	Treatment(s) added during reporting period (e.g. fertilizer, pesticide, other)	Date treatment administ-ered	Request/ remarks
		Awati						
		Baromalli						
		Bloodwood						
		Fukadi						
		Futui						
		Kabukalli						
		Kaditiri						
		Simarupa						
		Soft Wallaba						
		Tauroniro						
		Trysil						

3.2 Seedling Collection

Seedlings of the recommended species were collected from healthy natural forests surrounding the restoration sites. The aim is to re-introduce species that would have been present in the naturally occurring forest before mining activities occurred. Eleven (11) species were selected based on their ecology, distribution, and perceived responsiveness to the conditions of mined out areas (Table 3) and are recommended for use in reforestation initiatives across Guyana.

Three main criteria were considered in the selection of the eleven species for restoration activities. Firstly, these species tolerate harsh conditions common in mined-out, degraded areas. The selected species are known for surviving in disturbed environments with high light exposure and poor soils, typical of pioneer or early successional species (Elliott et al., 2013; FAO, 1989; Parrotta & Knowles, 2001). Secondly, the distribution and availability of seedlings in large quantities are key considerations. The species must be prolific and easily identifiable at the seedling stage, with sufficient natural regeneration to allow sustainable collection (FAO, 1989). Finally, the cost of collection and hardening is important for producing large quantities of planting material efficiently. Traits such as root structure, accessibility, and abundance influence operational feasibility (Elliott et al., 2013; FAO, 1989).

The successful implementation of restoration activities depends not only on the careful selection and collection of suitable species, but also on the proper handling and management of seedlings after collection. Observing appropriate techniques for seedling collection and potting, followed by care and hardening at the seedling stations, are vital to produce high-quality planting material.

Table 3
Native Tree Species Collected for Restoration Efforts

Image	Vernacular Name	Scientific Name & IUCN ranking	Family	*Characteristics
	Awati	*Maprounea guianensis* Aubl. (IUCN LC)	Euphorbiaceae	Established seedlings are drought tolerant. Evergreen shrub in savannah or medium-sized tree in forests.
	Baromalli	*Catostemma commune* Sandwith *C. fragrans* Benth. *(Sand baromalli)* (IUCN NE)	Malvaceae	*C. fragrans* better suited for white sands. Species are known to grow well in secondary but shaded forests. Density 0.59 g/cm³ (FPDMC, 2016).
	Bloodwood	*Vismia macrophylla* Kunth. (IUCN LC) *V. guianensis* (Aubl.) DC. (IUCN LC) (syn. *V. guianensis*) *V. laxiflora* Rchb. Fil. (IUCN NE)	Hypericaceae	Understory tree in secondary forests, also in primary forests and savannahs. Well noted in degraded sandy areas.
	Fukadi	*Terminalia amazonica* (J.F.Gmel) Exell *Terminalia dichotoma* E.Mey. (IUCN NE)	Combretaceae	Tree grows up to 20-35m tall, buttressed base. Moderately dense branch rounded or flattened. Found in Wallaba and mixed forests. Density 0.84 g/cm³ (FPDMC, 2016).
	Futui	*Jacaranda copaia* (Aubl.) D.Don (IUCN LC)	Bignoniaceae	Prefers a sunny position and is fast-growing in open areas. In a sunny location with well-drained, slightly sandy, and acidic soil can grow up to 3m annually in height in its native tropical environments. Density 0.43 g/cm³ (FPDMC, 2016).
	Kaditiri	*Tachigali guianensis (Benth.) Zarucchi & Herend.* *Tachigali micropetala (Ducke) Zarucchi & Pipoly (IUCN NE)*	Fabaceae	Nitrogen-fixing, semi-deciduous trees, flat to rounded spreading crown, and seedlings of these fast-growing species often found in forest gaps.

Image	Vernacular Name	Scientific Name & IUCN ranking	Family	*Characteristics
	Simarupa	*Simarouba amara* Aubl. (IUCN LC)	Simaroubaceae	Fast growing, shade-tolerant. Large evergreen/semi-deciduous, fast-growing tree, growing up to 45m tall. Density 0.41 g/cm³ (FPDMC, 2016).
	Soft Wallaba	*Eperua falcate* Aubl. (IUCN LC)	Fabaceae	Species with medium growth rate and a variety of habitats. Grows best in deep, rich moist soil in full sun or bright shade. A legume species that can enrich soil through nitrogen-fixing symbiosis with anaerobic bacteria. Moderately drought tolerant. Density 0.92 g/cm³ (FPDMC, 2016).
	Tauroniro	*Humiria balsamifera* (Aubl.) A.St.-Hil. (IUCN LC)	Humiriaceae	Seedlings are drought tolerant. Evergreen to semi-deciduous large tree with heavy rounded crown. Density 0.95 g/cm³ (FPDMC, 2016).
	Trysil	*Pentaclethra macroloba* (Willd.) Kuntze (IUCN LC)	Fabaceae	Pioneer species recommended for reforestation within its native range. Fast growing and successful in full sunlight or light shade. A legume species that can enrich soil through nitrogen-fixing symbiosis with anaerobic bacteria. Drought-tolerant.

Note. *Species characteristics and ecological roles are based on regional silvicultural knowledge and supported by tropical forest restoration literature (Elliott et al., 2003, 2013; FAO, 1989; Parrotta & Knowles, 2001). Ecology and morphology descriptions are based on Polak (1992).

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3.3 Seedling Care

Successful restoration activities depend on the quality of seedlings collected and hardened at the seedling stations. Quality is assessed visually: seedlings must have good colour, no damage to the plant form, and be at least 30cm tall for most species (Figure 2).

Figure 2

GFC Officers Collect Seedlings From Healthy Natural Forests Near Restoration Sites

Source: FRMD, 2023

The following list provides detailed guidelines for appropriate seedling care:

1) Seedlings should be collected during the cool hours of the mornings and afternoons.

2) Seedlings that are free of disease and pests with little to no physical irregularities should be selected for collection.

3) All selected species have tap root systems that penetrate loose sandy soils well. Precautions must be taken to keep roots intact during removal and moist during transportation.

4) A digging implement is used to dig around the seedling. Care is taken to ensure that most of the lateral and primary roots are collected without damage.

5) When the collection point is accessible, the seedlings are placed in bags with soil from the area. For cases where access is limited, multiple seedlings are collected and placed in

buckets and tubs with a soil slurry: a mixture of water and soil that has a semi-liquid texture.

6) Seedlings should be potted the same day of collection or left in a soil slurry in a shaded area for no more than two days.

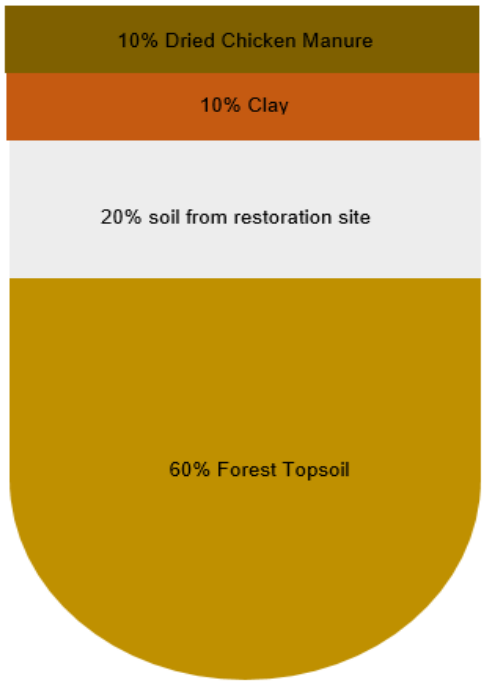
7) The soil mixture for potting is intended to mimic the sandy well-drained soil the seedlings were collected from, along with additions to prepare the seedlings for the restoration site conditions. Generally, sands and sandy loams have a bulk density of 1.3 to 1.7 g/cm³ (Brown & Wherrett, 2026), and this mixture is expected to fall within this range. The proportions were developed from trial and error and based on field observations. The proportions are kept simple, with readily available components for easy replication.

8) The soil mixture used for seedling potting (Figure 3) should ideally consist of:
   - 60% - Forest topsoil similar to collection site;
   - 10% - Chicken manure that is sufficiently dried and without odour;
   - 10% - Clay for binding; and
   - 20% - White sand to mimic soil that will be transplanted.

   Chicken manure may be sourced from poultry farmers after it is hot composted for three months. It is further dried on tarp on concrete surface, in direct sunlight for 3 to 5 days. Only odourless, dried, dark, and crumbly chicken manure is introduced to soil mixture for biosafety reasons.

Figure 3

Composition of Soil Mixture for Seedling Potting



9) Seedlings should be potted in appropriately sized seedling bags. Bags should be approximately one and a half times the size of the root/rootball. If the bags are too large, the Seedling Station Attendant will have a difficult time controlling the moisture content, and the seedling may rot or dry out.

10) Potting mixture should be damp while potting and consistent with the proportions previously outlined.

11) A layer of soil is added to the bottom of the bag, then the seedling is placed in an upright position without bending or contorting the natural shape of the root. In cases where the root system is laterally or horizontally longer than can practically be placed in a plant bag, the root is wrapped circularly to fit into the available space. This should not damage the root system and will allow the root ball to grow tightly bound.

12) Stems should not be buried. Soil coverage should stop at the natural upper limit of the root.

13) The entire root system is then covered; no roots should be left exposed. If roots become exposed during watering, soil must be added. Mulch is not recommended at this stage since it will be difficult to efficiently gauge soil saturation to inform watering regime.

14) Watering moderately, twice daily for the first two weeks is recommended. Watering regimes significantly influence seedling survival and establishment success (McLaren & McDonald, 2003). However, it is necessary to use your fingers to test the moisture in the bags before watering. When soil is squeezed in the palm, it should not fall apart or exude water; it should hold together loosely.

15) Examination of all seedlings for disease, insects, rot, and mortality (Table 4) must be done and recorded weekly.

16) Any seedling with insects, fungus, or signs of disease must be separated from the others immediately upon observation.

17) Two weeks after collection, seedlings should be moved gradually from the shaded area to a semi-shaded area; then within two months they should be moved to the full sun hardening floor.

18) As seedlings are exposed to increasing sunlight, watering frequency should also be reduced. It is important to record various species responses to this regime, in order to develop species-specific procedures for hardening.

19) Seedlings are considered hardened after three months in the seedling station and the transition from shaded to full sunlight is completed.

Table 4
Common Seedling Issues and Recommended Actions

Observations	Likely cause	Susceptible spp.	Treatment/ Recommended actions
Eaten leaves, naked stems	Caterpillar, drugger-ants, grasshopper	Awati is more commonly affected by ants Tauroniro, simarupa, and Kaditiri are susceptible to all.	It is best to physically remove and destroy caterpillars and grasshoppers. Then spray susceptible species with an anti-feedant e.g. neem oil (Bond et al., 2012). For ants, a mixture of Sevin powder and water must be sprayed around the seedling station and inside the building. 2.5 to 5 tablespoons per litre of water is recommended (Bond et al., 2016; DIY Pest Control Experts, 2026). Continue treatments until insects are no longer observed, in addition to routine treatments.
Leaf margin necrosis, curling and drying leaves	Lack of water, root rot, excessive heat	All	Assess soil moisture content, soil should clump together when squeezed in the palm of the hand, if moisture is exuded move to sunnier location and reduce water, if soil falls apart and remains loose-increase water. Move seedlings into shadier areas. If this results in no improvement, that check for root rot. Remove rotted portion with clippers and repot in new soil. Always discard soil from diseased plants.
Blotches on leaf	Fungi and other pathogens	All	Remove and destroyed affected leaves, stems, or entire seedling depending on extent of damage. Space seedlings out.
Wilting, rotting of apical meristem	Mealy bug, too much moisture, root fungus	Baromalli: mealy bugs	In most cases the effects of mealy bug are not seen until the seedling is wilting, as such the underside of Baromalli leaves must be routinely checked. Use rubbing alcohol to wipe off leaves and stems affected by mealy bug, keep them away from other seedling until they are bug free. It is advised to repot seedlings in fresh soil after examining the roots and removing rot for seedlings with rotted meristems. Use a sanitised pruner and clip off rotted stem after re-potting. Simarupa and Fukadi seedlings should survive this treatment. Finally check that plant bag is draining properly and reduce watering. It was observed that Fukadi seedlings grow branches with a wide spread, and often begin to wilt when clustered. Ensure there is space for good air flow and light.
Yellowing leaves	Watering issues, nutrients deficiencies, limited light	All Note: Kabukalli and Kaditiri have leaves that are naturally yellow green in colour.	Seedlings respond to over- and under-watering with yellowing leaves. Assess watering regime and soil moisture content. Ensure seedling is not crowded and has access to direct sunlight. If none of the above actions result in improvement, treat seedling with nitrogen fertiliser and Epsom salt.

20) A regime for the application of fertiliser and insecticide must be established (Table 5). Neem oil is a naturally occurring pesticide and can be used in conjunction with Sevin (carbaryl) powder. Chemicals banned or controlled by the Guyana Pesticide and Toxic Chemical Control Board are not utilised.

Table 5

Recommended Fertiliser and Pest Control Regime

Timeline for treatments (Weeks)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Root development fertiliser (High in P) 10.50.10 (NPK)		X		X		X						
Foliage development fertiliser (High in N) 30.10.10 (NPK)								X		X		X
Neem oil anti-feedant	X			X			X			X		
Sevin insect powder		X			X			X			X	

Note. This table outlines the routine regime to be used when pests and diseases are observed. The recommendations from Table 4 (Common Seedling Issues and Recommended Actions) should also be implemented to address pests and diseases.

3.4. Chemical Handling and Safety

When using chemical pesticide or cleaning agents, the following must be considered (Blatchford, 1979):

1. **Personal Protective Equipment**
   Appropriate protective clothing as stipulated on chemical labels must be worn when handling and applying chemicals. These include at minimum, gloves, goggles, masks, and waterproof work boots; all exposed skin must be covered. Personal protective equipment (PPE) must be kept clean and in good working order.

2. **Preparation and Application**
   All manufacturer leaflets and labels should be kept for reference. Mixing and application dosage should be implemented based on manufacturer instructions. Knapsacks or hand sprayers must be used for application; care should be taken to prevent spray drifting to non-target areas. Implement the 12-hour re-entry interval after application of carbaryl and all other inputs for seedling stations. Wash all equipment used before storage.

3. **Storage and Disposal**
   All chemicals must be stored in a cool, dark, concrete workspace at the back of the seedling station, and must always remain locked. Safety Data Sheets (SDS) should be available for all stored chemicals. Containers should be double washed, flattened, and disposed of with the other seedling station garbage.

4. **Emergency Measure**
   Signs indicating the presence and use of chemicals should be clearly visible. If a chemical contacts skin or eyes, flush with cool water for 15 minutes. For accidental ingestion or inhalation, persons should move away from the chemical and immediately contact emergency services.

Care should always be taken to choose less hazardous options such as neem oil. In most cases neem oil is used, unless the infestation is large and the quantities of neem oil are not available. All inputs applied should be registered for use by the Guyana Pesticide and Toxic Chemical Control Board.

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