Weevils are reared in tubs measuring about 50 cm diameter and 33 cm deep with a 50 L capacity. These containers are readily available in most areas, being widely used as washing bowls. Rearing can be carried out in a greenhouse or outdoors in semi-shade (e.g. under shade trees). Tubs are filled with water and a general fertiliser added (approximately 3 g). Buckets are stocked with 5 to 15 water hyacinth plants, depending on size, and adult weevils are placed on the plants. The number of adults used ranges from one pair per tub to one pair per plant. Adults are allowed to feed, mate and lay eggs on the plants for up to one week, and then removed.

Weevil eggs are extracted from the plant under a dissecting microscope using forceps and placed onto thin layers of water hyacinth tissue. These tissues are then inserted into holes made in fresh plants and the plants are placed in the field within 15 to 20 days. This technique allows accurate recording of the number of eggs released but is tedious and requires skilled labour. There have been no estimates of the number of eggs that survive this process and complete development to adult. Adults for rearing are obtained from a separate culture, maintained in similar tubs, but with eggs allowed to hatch and larvae left to develop through to adults. Adults are harvested by hand three times per week throughout the year, and are stored in plastic jars with water hyacinth leaves until required. A single tub containing nine plants can yield 180 adults per month.

Table 6. Production figures for the mass-rearing techniques used most widely for *Neochetina* spp.

	Pools	Tubs (modified technique–adults collected)
Location	Sepik River, Papua New Guinea	Kisumu, Kenya
Duration of assessment	21 months	21 months
No. containers assessed	5 pools	100 tubs
Insects collected/month	3542	1000
Labour requirements (approx.)	3 workers, 2 days/week (harvesting) = 6 worker days/week = 24 worker days/month	4 workers, 5 x 0.5 days/week (harvesting) 4 workers, 0.5 days/week (plant collection) = 12 worker days/week = 48 worker days/month
Insects /worker/month	148	21
Information source	A. White, pers. comm.	G. Ochiel, pers. comm.

Photo: M. Julien

Tub rearing of *Neochetina* spp.—Kibaha, Tanzania

The tub-rearing technique has been modified in a number of ways.

- Following the removal of adults, infested plants are retained in the tubs until adults start to emerge. These are then collected and released into the field. This method is less labour intensive and permits an accurate record of the number of adults released.

- Following the removal of adults, infested plants are placed directly in the field. This technique requires very little labour input but gives no indication of the number of insects released.

7.4 Comparison of techniques

Both pool rearing and tub rearing have been successful in producing *Neochetina* weevils. The pool-rearing technique has been used in Australia, Papua New Guinea, South Africa, Malawi, Uganda and Malaysia, and the small container technique in Benin, Ghana, Kenya, Tanzania and Thailand. We recommend pool rearing for the production of *Neochetina* spp. for the following reasons:

- Large numbers of insects can be produced at relatively low cost. Workers using the pool-rearing technique have produced averages of 425 adults/pool/month in Makhanga, Malawi; 708 adults/pool/month in the Sepik River, Papua New Guinea; and 1100 adults/pool/month in Brisbane, Australia averaged over a 1–2 year period.

- The numbers of insects released into the field are known with some accuracy.

- Pools are readily available, relatively inexpensive, easily transported and erected, and long-lasting.

- Less labour than for other techniques is needed during rearing and harvesting. As a guide, production figures are shown in Table 6 for pool rearing in Papua New Guinea and for tub rearing using a modified method whereby adults are collected for field release in Kenya. The figures from Kenya were the only ones available to the authors for the tub–rearing technique.

Photo: M. Julien

Tub rearing: adult weevils being collected by hand—Kibaha, Tanzania

Photo: M. Julien

Neochetina weevils being harvested by hand from an established field site for redistribution to new areas

- The process does not involve the transfer of large amounts of plant material, which is costly and risks the spread of other weed species.

- Plants do not need to be regularly collected from the field for use during rearing.

7.5 Field harvesting

Mass rearing of insects is often labour intensive and requires special facilities. To overcome these problems, *Neochetina* spp. can be harvested from natural infestations for wider distribution. The process is convenient, cost effective, and ensures insects are well adapted to field situations. However, at least two years may be required to enable populations to build up at a site before field harvesting can commence. Adult weevils can be hand picked from plants in the field, or the plants themselves can be collected for redistribution. Although the latter method is rapid and ensures that all stages of the insect are included in the shipment, large numbers of plants are required to ensure sufficient insects are present. This can amount to a considerable mass of plant material. Infested plant material requires protection from extreme heat during transportation to the release sites. Care should be taken to ensure that other weed species are not spread to new locations with the collected water hyacinth.

7.6 Storage and transportation

Adult insects can be stored and transported in small containers that have air holes or gauze covers for ventilation. It is very important to prevent overheating of the containers, so direct sunlight must be avoided at all times.

The method of transport depends on the distance insects will travel and the time for which they will be in storage.

- For transfers of short duration, containers should be stocked with clean, fresh water hyacinth leaves. Containers of approximately 11 cm diameter, 11 cm depth, and a capacity of 800 mL will hold 200–250 adults. If held for more than two days adults should be transferred to clean containers with fresh leaves. Failure to regularly replace the leaves and transfer to new containers will result in reduced fecundity, poor health, disease and death of the weevils.

- To transfer between countries, plant material may be replaced by clean, damp (not wet) rag. This should be placed loosely in the container to allow free movement of the adults. Lids should be taped to prevent accidental opening during transit. Adults can

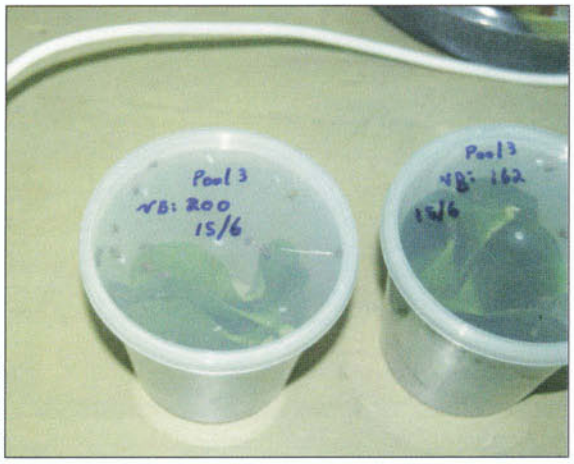


Photo: A. White

Insects can be stored and transported in small containers with leaf material

be stored for no longer than 3 days under these conditions. Containers should be loosely packed in a strong, sealed box that will protect the insects from heat. The box should be clearly marked 'LIVING INSECTS' and 'PROTECT FROM HEAT'. Import permits should accompany the package and the recipient should be advised of the package transport number, the flight number and arrival details.

- If necessary, storage can be prolonged by holding the adults at 12–15°C. At these cooler temperatures, activity, including egg laying, is reduced, and up to 100 adults can be stored in small containers for 1–2 months. Insects should be checked every week and transferred to clean containers with fresh leaves when necessary.

Adults should be released into the field as soon as possible after collecting, maximising the opportunity for oviposition on plants in the field rather than in the container, where the eggs are wasted.

7.7 Field releasing

When releasing weevils onto field infestations a number of factors should be considered.

- Releases should be made away from critical locations where herbicidal or physical controls may occur. Such control measures may prevent establishment or affect populations of control agents.

- Establishment is more likely if the plants are in good condition and the weed mat is stable and unlikely to be flushed downstream. Releases are likely to be more effective in slow-moving water bodies or in protected sections of a river system, such as coves, inlets or small lakes, than in fast-flowing rivers, where severe and/or repeated flooding flushes out the weed. In catchments, weevils should be released at source infestations as high up the system as possible.

- In an extensive infestation, release of large numbers of insects into a number of well distributed sites is recommended.

Photo: M. Julien

Releasing *Neochetina* adults at Madang, Papua New Guinea

Neochetina spp. do not disperse rapidly, so multiple releases ensure that large areas are brought under control more rapidly.

- The number of insects to be released depends on the size of the infestation and the number of adults available. Although successful establishment will result from releases of low numbers of insects, the greater the numbers released, the more rapid will be any impact on the weed. Normally, releases comprise 250 to 1000 adults

- Adults can be tipped from containers directly into the infestation, either from a boat or from the waters edge. In one instance in Thailand, adults were reportedly dropped from a low-flying plane over an isolated infestation and established.

Photo: M. Julien

Releasing *Neochetina* adults from a boat—Sepik River, Papua New Guinea

- Records should be kept of the estimated number and stages of insects released.

An example of a consignment sheet to accompany each shipment of insects being released is shown in Box 3.

Box 3. Consignment sheet — biological control of water hyacinth

CONSIGNMENT SHEET

Insect sp:. ..... Date consigned: .....

Life stage: ..... Date released: .....

Number of insects dispatched: .....

Recipient: .....

Carrier: .....

Released by: .....

Condition of insects/material on arrival:

Any evidence of

- insect mortality? .....
- deterioration of plant material? .....
- over-heating during/after shipment .....

Other comments: .....

.....

.....

Number of insects released: .....

Details of release site: .....

Site name: .....

Type (dam, lake, stream etc): .....

Location .....

Estimated size: .....

Water hyacinth cover (%): .....

Other insect agents present: .....

Other comments: .....

.....

.....

(On reverse, please sketch site to show point of release.)

Please return this form to:

..... (Contact person and address)

.....

Chapter 8
Post-release Management

8.1 Evaluation

Monitoring the establishment, spread and impact of a control agent is a very important stage in a biological control program. It provides information on the effectiveness of an agent in establishing and reducing the weed problem, and allows assessments to be made of the potential effectiveness of the agent if introduced to other regions. In addition, observations on the interactions between agent and host, and between different agents, provides important biological information and allows an evaluation of alternative or complementary management techniques if the level of control achieved is less than that desired.

As part of any biological control release on water hyacinth the following information should be recorded:

- whether the agent established following release in a particular area;
- the rate of natural spread of the agent;
- the time taken for the agent to reach a damaging population; and
- the progressive impact on the weed infestation and the eventual level of control achieved.

The success of the *Neochetina* spp. weevils in establishing and the level of control achieved will vary according to the following factors:

- Nutrient levels and temperature of the water body;
- occurrence and degree of flooding;
- number of insects released; and
- amount of disruption to the system by chemical and/or physical control measures.

Neochetina spp. should be monitored after release, at a number of different scales.

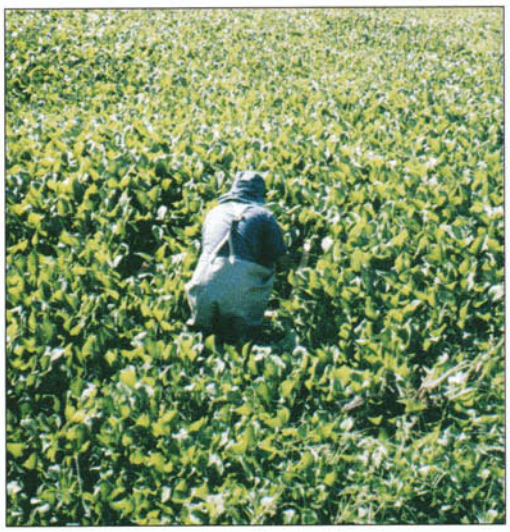


Photo: A. Wright

Placement of the quadrat during monitoring in Kenya

Quadrat monitoring

Quadrat monitoring from a boat or by wading into the infestation allows assessment of establishment, changes in weevil abundance, and impact on the weed population. Monitoring at different distances from the original release sites gives an indication of dispersal of the agents. Monitoring is recommended at one to three-monthly intervals following initial release. In a monitoring system developed by CSIRO scientists in Australia, a series of six randomly located quadrats is sampled and 10 plants are removed from each for close assessment (additional plants should be taken from next to the quadrat if there are less than 10 within the quadrat). The remaining plants and ramets within the quadrat are then counted. In locating the quadrats it is important to place them within the mat rather than on the edge to avoid irregular results due to an edge effect. An example of a monitoring sheet is shown in Box 4.

Site planimetry

Planimetry techniques enable measurement of the changes in the size of a weed infestation over time. They involve measuring the area of an irregular plane surface, e.g. the area of a water hyacinth mat or a water body. This can be done using a special instrument, a planimeter, or can be estimated using graph paper. When using graph paper, an outline of the water body and/or infestation is drawn on a sheet of graph paper and the number of squares occurring within that outline are counted. Initially the outline and size of a water body are determined from aerial photographs or satellite images. This outline is replicated for each sampling occasion. The portion of the water body covered with water hyacinth is mapped on each occasion, preferably by two or more independent assessors, and the percentage weed cover is determined using a planimeter or by counting the squares on graph paper. The data can be presented as a percentage cover by water hyacinth or can be converted to actual cover in square metres or kilometres.

Assessments can be made from an elevated position on the ground, or preferably from aerial surveys. Ground surveys will be effective only on water bodies which are relatively small and easily accessible, while aerial surveys allow coverage of water bodies which are larger or more widely distributed within a catchment. Surveys conducted six monthly or annually provide an indication of the effectiveness of the control program. The results should be combined with monitoring of the abundance and impact of released agents to link any reduction in weed biomass to the activity of control agents. Examples of mapping diagrams and the information which can be derived from them are shown in Box 5.

Satellite imagery has been tested in Uganda using SPOT images and spectral analysis, in conjunction with ground assessments, to delineate water hyacinth (Neuville et al. 1995). Large infestations on lagoons of the Sepik River flood plain could be observed on LANDSAT images in natural colour, but no measurements or comparisons over time were made. Satellite images have not yet been used as part of a practical monitoring technique.

Box 4. Monitoring sheet — biological control of water hyacinth

MONITORING SHEET

Site: ..... Date: .....

Name of collector: .....

Site characteristics: Water hyacinth cover (%): .....

Open water (%): .....

Water temp. (°C): .....

General comments (including photo details): .....

Quadrat samples (0.5 x 0.5 m, randomly located, avoiding edges)

Sample no.: ..... of 6 No. of plants: ..... per quadrat No. of ramets: ..... per quadrat

Take 10 plants from this quadrat or immediately nearby if there are not 10 in the quadrat and record the following. Repeat this for Sample 2, Sample 3, etc.

Plant No.	No. of N.b.	No. of N.e.	Second youngest leaf				Comments
			Leaf length (mm)	Total feeding scars	Leaf area (cm^2)	Wet weight (gm)	
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

Definitions

Plant — Single plant including all attached stolons and daughter plants ie a number of clones joined by stolons.

Ramet — An individual clone ie, the mother plant and each daughter plant counted separately.

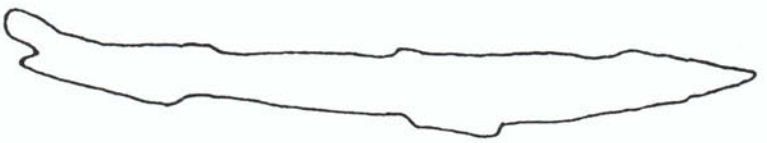
Leaf length — Measured from the tip of the lamina to the base of the petiole.

Box 5. Process of planimetry monitoring for assessing the impact of a biological control agent. An outline of the lake surface, obtained from an aerial photograph (A), is used to chart the change in weed cover during three-monthly surveys following the release of the agent (B). This information can be used to generate tables (C) and figures (D) summarising the impact of the control agent on the weed infestation. The example given is for information collected for *Cyrtobagous salviniae* Calder and Sands (Coleoptera: Curculionidae) released on *Salvinia molesta* D.S. Mitchell in northern Australia (Julien and Storrs, unpublished data).

A.

Location: Jabiluka Billabong

Area: 0.116 km^2



B.