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How to Grow Safer Leafy Vegetables in Nethouses and Net Tunnels

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Introduction

Leafy green vegetables are popular around the world and especially in Asia. They are quick-growing crops that are harvested within four to six weeks. Some of the common leafy vegetables are brassicas (pak-choi, mustard, kale), kangkong (water convolvulus), lettuce, spinach, and amaranth. Tender leaves and, in many cases, stems are consumed raw or cooked. These vegetables are valuable sources of vitamins A and C, iron, calcium, folic acid, and dietary fiber.

Cultivation of leafy vegetables is a profitable business for farmers; however, these vegetables are highly perishable and need to be sold in the market within a few hours of harvest. Therefore, these vegetables are usually grown in peri-urban production areas. Daily sales of these vegetables provide valuable cash income to farmers, most of who have small landholdings. In some cases, all members of the farm family are involved in the cultivation and marketing of the vegetables.

In the past, all leafy vegetables were grown in open fields. Insect pest and disease damage levels were moderate and could be effectively controlled with pesticides. The general public was much less concerned of the danger of pesticide contamination of their food and the environment.

But conditions have changed during the past 10 years due to the constant use of pesticides to control pests and diseases. Consumers are becoming more conscious of their personal health and the quality of the environment. Some consumers have started demanding pesticide-free or organically grown vegetables and most are willing to pay higher prices for this produce. Hence, safer methods of pest control have to be found.

Fig. 1. Leafy vegetables growing in nethouse

Whether grown organically or not, all consumers need access to safe vegetables. But this task is not easy. While consumer demand is putting pressure on farmers to spray fewer pesticides, farmers are facing the opposing pressure of spraying more pesticides since pests are becoming more tolerant to the chemicals and more difficult to control.

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Many farmers have responded to these realities by growing leafy vegetables under protective structures, especially large nethouses (Fig. 1). These structures vary in size and the protective materials used to construct them. The most economical and widely used structure is a 2-m-high iron infrastructure with a single door and covered with nylon netting. The netting is usually 16-mesh (hole size 1.6 mm), which allows free flow of air, minimizes build-up of temperature inside the nethouse, and reduces radiation levels by only about 15%. The porous nature of the net helps it to withstand strong winds without much damage.

However, insect damage to vegetables inside these net structures is still common. Sometimes insect damage inside nethouses can be higher than in the open field because some pest insects can pass through 16-mesh nets but many of pests' natural enemies, which roam the open fields, cannot. At the same time, environmental factors such as rain and wind, which help reduce pest damage outside, are less effective inside the nethouses. Therefore, farmers still use chemical pesticides to protect their leafy vegetables inside these nethouses, thereby defeating one of the greatest potential benefits of these structures—producing pesticide-free vegetables.

AVRDC has been working on the management of insect pests of leafy vegetables under net structures. We have designed a suitable nethouse structure and its maintenance procedure. This procedure emphasizes preventing entry of all damaging insects inside these nethouses, thereby reducing the need to use pesticides. In fact, over the past two years, we have cultivated 15 cycles of various leafy vegetables—free of any pesticide use—without loss of yield or quality of the produce.

Choice of land

Choose the highest area of the field for constructing the structure (Fig. 2). This reduces the chances of flooding as well as bringing in insects or pathogens from elsewhere into the nethouse during flooding. Besides damaging and delaying the harvest of the standing crop, flooding can also postpone planting of the next crop. This loss can be substantial considering the high investment needed to construct such structures.

Fig. 2. Choose an elevated, well-drained area for the nethouse.

Flood the land

Once you have selected the land, flood the area on which the nethouse is to be constructed including an extra 2-m-wide border around the perimeter along all four sides (Fig. 3). There should be 15 to 25 cm of water standing continuously for four to seven days. If feasible, puddle the field with suitable farm equipment; this helps to kill insects, some pathogens, and nematodes in the soil.

After flooding, drain the water and allow the soil to dry sufficiently. Do not allow any plant to grow in the flooded area before construction of the nethouse. This will ensure there are no plant-feeding insects or mites in the area.

Fig. 3. Flood the land to kill soil-borne pests

Proper design and construction

Proper design and construction of the nethouse, irrespective of its size and shape, is required to ensure that pests will not enter the structure. There are two critical factors: 1) the choice of mesh size of netting, and 2) design and location of two double doors to the structure.

Select size 32-mesh (32 holes per inch or hole size 0.8 mm), uniformly weaved, durable quality, nylon netting. Make sure the holes are uniformly 0.8 mm wide. The use of net of any lower mesh, for example, 16-mesh (hole size 1.6 mm), is not advisable because the larger gaps in the netting allow several species of insects to enter the nethouse (Fig. 4). These pests include diamondback moth (*Plutella xylostella*), striped flea beetle (*Phyllotreta striolata*), leaf miners, and aphids. The former two species are serious pests of crucifers while the latter two pest groups attack a wide variety of vegetables.

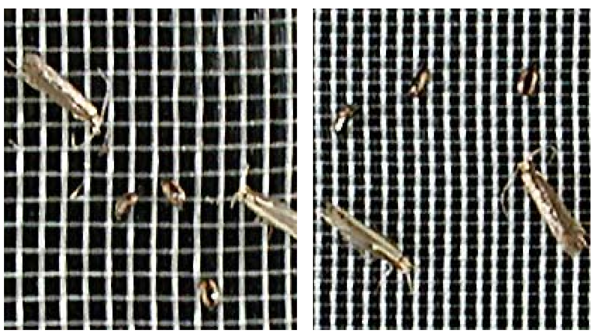

Fig. 4. Diamondback moths (long insects) and striped flea beetles (globular insects) can penetrate through 16-mesh (left), but not 32-mesh (right) netting

Finer mesh nets with smaller size holes, such as 40- or 64-mesh, are available in the market and can be used. However, air does not flow readily through these nets and temperatures inside these nethouses rise to harmful levels. The transmission of sunlight is also reduced measurably due to blockage of holes by dust particles blown by the wind. This problem is much less with size 32-mesh.

Good quality, uniformly woven, size 32-mesh netting does not allow diamondback moth or striped flea beetle to pass through. It will allow a few aphids and thrips to penetrate but their numbers are miniscule and will not damage leafy vegetables harvested within four to six weeks.

The other critical matter in the design of the nethouse is the number and location of doors. The doors are easy entry points for pest insects to get inside nethouses. Most nethouses have only one door. This allows easy entry of insects when a farmer opens the door or gaps develop between the door panel and soil surface. We have come across many instances of these doors being kept halfway or fully open while farmers are operating inside.

A double door with two sliding panels is adequate, but the arrangement of two double doors at right angles to each other is best (Figs. 5, 6). The larger double door (Panels 1 and 2) is used only at planting and harvesting to enable farm equipment in and out of the structure. When entering or leaving, only one door should be opened at a time. When not in use, these doors should be shut promptly to prevent insects entering the structure. We suggest that after planting, Panel 1 should be shut tight or even locked shut until harvest. This will prevent opening of this door (accidentally or otherwise) and minimize entry of insects. The smaller double door (Panels 3 and 4) is erected at a right angle to the larger double door and should be used for entering the structure for daily opera-

Fig. 5. Two sliding double doors are recommended

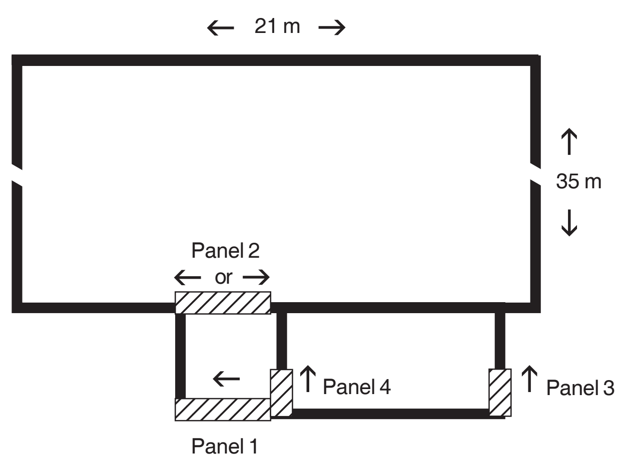

Fig. 6. Diagram of nethouse opening; arrows indicate directions that doors (indicated by slanted boxes) slide

tions. Here also, while entering or leaving the nethouse only one door is to be opened at a time and shut promptly when not in use. If necessary, the walkway between Panels 3 and 4 can be shortened to 2 m but not less.

These doors should be erected at the side of the nethouse opposite the direction of the wind encountered during most of the year.

Crop selection

Although market demand determines what vegetables to grow inside the net structures, rotating crops from different plant families is highly recommended (Fig. 7). This is especially true when cultivating crucifers such as kale, pak-choi, and mustard. Cultivation of these crucifers season after season leads to poor crop growth and low yield due to accumulation of undesirable crucifer root exudates in the soil. Growing of non-crucifers such as kangkong, lettuce, amaranth, or spinach should follow growing of crucifer species.

Crop rotation will reduce accumulation of undesirable chemicals in soil and lets one grow healthy vegetables continuously season after season. If market demand requires a farmer to grow crucifers continuously, we suggest that the nethouse be divided into two halves; one half is planted to crucifer and the other to non-crucifer in each crop cycle. During succeeding crop cycles, one should rotate the crop and plant non-crucifer over the half of the land that was planted to crucifer in the immediate preceding season, and vice versa.

Fig. 7. Crop rotation is recommended to minimize insect and pest damage; rotate crucifers such as Chinese cabbage (top) and pak-choi (bottom) with non-crucifers, for example, lettuce (right) and vegetable amaranth (left)

Insect pest and disease management

When we followed the above steps, we prevented damage to all tested leafy vegetables (pak-choi, kale, amaranth, lettuce, spinach, kangkong) by all insect pests, except occasional infestation of common armyworm (*Spodoptera litura)*. This insect is a big moth and cannot enter through 32-mesh netting. However, the female moths of this pest lay eggs in small batches on the top of the net (Fig. 8) and tiny larvae hatching from these eggs drop through the holes over the crop inside the nethouse. This starts a new infestation.

This insect, however, can be controlled by application of biological pesticide based on *Bacillus thuringiensis*. In some countries, a virus-based bio-pesticide, specifically designed to kill the larvae of this pest, is available. It is essential to observe the crop frequently and spray bio-pesticides only when insect damage is prevalent. Chemical pesticide should only be used when absolutely necessary. We discourage the use of chemical pesticides due to the unnecessary risk of toxic pesticide residues on the vegetables.

Occasionally, if the gaps between door panels and the main frame of the nethouse are not tightly shut, adults of striped flea beetle can enter the nethouse and damage the crop. For this purpose Panel 1, which is the major barrier for the entry of this pest, should always be closed tight, making sure there are no gaps between the door panel and the land or frame of the nethouse and door panel.

We rarely face disease problems. This we attribute to our strict use of crop rotation. Damping-off caused by *Pythium* or other fungi may infect

Fig. 8. Common armyworm eggs laid on netting may hatch (left) and drop inside nethouses onto plants (right)

young plants inside, especially during the hot-wet season. Damage by these soil-borne diseases occurs in small patches. We recommend prompt uprooting and destruction of the infected young seedlings. Such soil-borne diseases, in general, can be controlled by sowing fungicide-treated seeds, using healthy seedlings, using raised beds to improve soil drainage, and promptly removing all plant debris after harvest. For fungicide use, identify the diseases correctly, check local recommendations, and follow instructions on the label.

For a healthier crop environment and reduced pest and disease problems, we suggest flooding of the soil followed by puddling for one to two weeks, at least once every two years. This can be done with minimum loss of earnings during the peak vegetable supply season, such as winter when vegetable prices are low. In areas where paddy rice is grown widely, we suggest growing of paddy rice for one season in the nethouse area every two years.

Some farmers stagger their plantings of leafy vegetables of the same species inside nethouses. Under such conditions, vegetables of various growth stages are always present inside the same nethouse. This is a risky practice because, if indeed insects are inside the nethouse, they will move readily from older to younger plants, which tend to be more vulnerable to pest damage.

We suggest that if staggered plantings are to be practiced, farmers should inspect the nethouse frequently and plug the holes promptly to make sure no insect enters inside. If feasible, plant only one or two crops of equal duration in order to break the cycle of pests between crops.

Postharvest care

Immediately after harvest, the land should be cleared of all plant debris. This will reduce carryover of pests and diseases to subsequent crops. Clean the net if it is soiled. We use pressurized water to clean the net. The net is to be cleaned from inside (Fig. 9). This will reduce accumulation of water inside the nethouse and enable planting of crops without delay. Such cleaning removes dust and insect eggs from the net and increases transmission of sunlight.

Compost or other manures can be applied at this time. However, make sure the manure is fully decomposed and free of pests, especially grubs. The manure should be finely ground and passed through 8-mesh sieve.

Fig. 9. Clean the net from the inside of the nethouse

Summary of key points for nethouses

- Choose an elevated and well-drained area for construction of nethouse.
- Flood the area so that 15 to 25 cm of water stands continuously for four to seven days.
- Drain the field, allow the soil to dry, and construct the nethouse without delay.
- Use 32-mesh nylon netting that is uniformly weaved and of durable quality.
- A double door with two sliding panels is adequate, but an arrangement of two double doors at right angles to each other is best.
- Keep the nethouse tightly sealed at all times.
- Rotate crops chosen from different plant families to reduce pest and disease problems.
- Monitor crops closely and use pesticides only when absolutely necessary. Follow local recommendations and safety instructions carefully.
- After harvest, clean soil of all debris.
- Maintain the cleanliness and integrity of the netting.

Constructing and managing net tunnels

Farmers who cannot afford the high initial costs in construction of nethouses can grow safer vegetables under temporary net tunnels. These tunnels are constructed and maintained with the same care as for nethouses. The location of tunnels needs to be shifted from season to season to minimize damage by soil-borne pests such as striped flea beetle.

Step 1: Choose an elevated, well-drained area.

Step 2: Flood the area with 15 to 25 cm of standing water for four to seven days. Allow the soil to dry.

Step 3: Rototill the land and prepare 1.5-m-wide raised beds (Fig. 10). If desired, apply basal fertilizers and finely chopped, well-decomposed compost and mix evenly with the topsoil of the beds. Level the top uniformly and sow seeds. If growing crucifers, rotate with non-crucifers.

Fig. 10. Prepare raised beds for sowing

Step 4: Erect inverted, "U" shaped, 2-m-wide and 1-m-high iron or aluminum bars over each bed (Fig. 11). Maintain a distance of 1 m between two adjacent bars within the row. The thickness of bar will depend on the length of the plot but a 1-cm-diameter bar placed at intervals of 1 m down the row will be adequate for any length of the bed. We suggest bed lengths of 10–15 m for convenience of operations such as weeding.

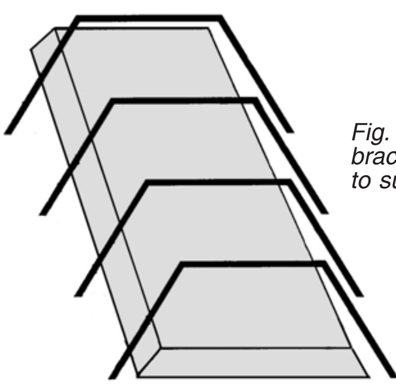

Fig. 11. Place metal brackets over beds to support netting

Step 5: Place 32-mesh nylon net over the bar from one end of the row to the other. Pull the net tightly over the bars from all four sides and bury 10–15 cm of net edging in the soil (Fig. 12). Make sure there are no gaps between the soil and the net. These gaps allow insects to get in.

Step 6: Initially irrigate the beds from over the net using a low water pressure sprinkler. After the crop has been established, water can be applied in the furrows. Water will seep from furrows into the planted area by capillary action.

Step 7: If weeds become problematic, remove the net and uproot weeds quickly. Close the net again promptly to avoid insects entering the planting. At this stage fertilizers can be applied, however, it should be done as quickly as possible. If you have planted several beds, open only one bed at a time.

Step 8: At harvest time, open only one bed at a time and harvest the crop quickly. Remove all plant debris. If the beds are usable, seeds or seedlings of a second crop can be planted and the beds covered with the net promptly. If the beds are deformed, the whole area will need to be rototilled and worked into new beds and the cycle repeated all over again.

Step 9: After harvest, the net should be cleaned of plant and soil debris before using again. ⌘

Fig. 12. Place netting over metal brackets (top) and tuck edges into the soil (bottom)