

Manual for managing tomato cultivation in Asia Monsoon Plant Factory System (AMPFS)

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1. Introduction

This manual is for tomato cultivation in the Asia Monsoon Plant Factory System (AMPFS), which was created and put into use from 2016 to 2021 as part of a project of the NARO Bio-oriented Technology Research Advancement Institution (R&D matching funds on the field for Knowledge Integration and innovation).

This AMPFS is a greenhouse cultivation system designed for hot and humid regions such as the tropics, and through low node-order pinching and high-density planting, it has produced 30 tons per 10a per annum in Ishigaki city, Okinawa, Japan.

This manual, which summarizes the management methods, is based on the greenhouse and environmental control methods developed from the research conducted at the Tropical Agriculture Research Front of JIRCAS till 2023.



1. Introduction

Asia Monsoon Plant Factory System (AMPFS) has an integrated environmental control system for the cultivation of tomato in tropical and subtropical regions.

Integrative Environmental Control



Cloud server
Environment
control program

Monitoring environment

Inside & outside the GH

- Air temperature
- Humidity
- CO₂ concentration
- Solar radiation



Controlled environment

Temperature control

- Heat insulation film
- Fog cooling system
- Heat pump
- Cooling media

Ventilation

- Ventilation fan
- Circulation fan
- Side window

Others

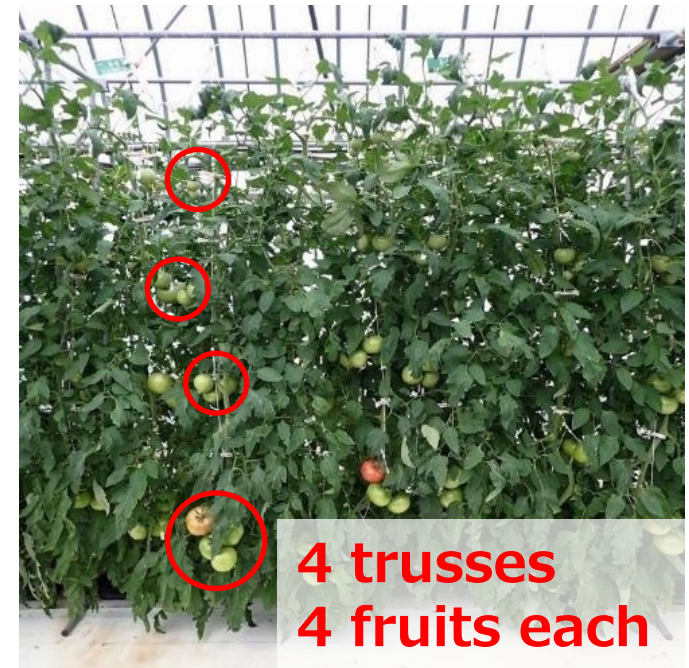
- Light
- UV-B light

1-a Outline of cultivation

Soilless cultivation
Low node-order pinching and high density planting (four trusses per plant)

Plant density : **4.3~5.6 plants/m²**
 Cultivation period: approximately **90-125 days**

Repeated cultivation over a short period of time to allow for all-year-round production.



Tomato cultivation

Table. Example of cultivation schedule

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
①	■		●	●	■	●	●	●					
②		■		●	●	■	●	●	●	●			
③			■		●	●		■		●	●	●	

■ : Transplant, ● : Harvest

1-b Cultivation Management Schedule

Approximately 90 days in summer and 125 days in winter

	Trans plant	Anthesis (1 st – 4 th truss)		Pinc hing	Harvesting begins		End of cultivation
Pruning/training		Every week					
Fruit thinning			One time for each truss				
Fruit-setting hormone		2 times a week					
Chemical spray			1~2 weeks each for prevention				
Harvest							

1-c Precautions: to prevent disease and pest during greenhouse cultivation

To minimize the risk of disease and pest

- 1) Do not leave greenhouse doors open.
 - Cover the outside of the door with an insect net.
 - It is more effective if a net is placed inside the greenhouse to separates the entrance from the plant growing area.
- 2) Change your shoes when entering the greenhouse.
 - Do not enter the greenhouse with the shoes used outside.
- 3) Keep the area around the house clean.
 - Weed well to reduce pests around the greenhouse.



Cover the door with an insect net



Prepare indoor footwears



Sheets for weed control around the greenhouse

2. Preparation of greenhouse before planting

- Preparation of medium

Time: Fill the growing beds with medium approximately one week before transplanting.

<Example>

Medium: Coco peat-based media (45L/bag)

Size of bed: Length 100cm, inside dimension W260 mm, H135 mm

Amount: Approximately 30L/bed

Note: Fill each bed with an even amount of media.

For this purpose, **do not press the media down** after filling.
Discard any media that falls on the floor without filling the beds to prevent disease.



Medium (45L)



Growing bed



Filled medium

2. Preparation of greenhouse before planting

- Place one bag of the growing medium between two cultivation beds.
Fill the two beds with one bag of the medium and then adjust the amount of the medium added in each bed to ensure uniformity of medium amount in each bed.



Growing bed before filling with medium.
The fabric outside of the drainage opening improves drainage.



The greenhouse before filling the medium.
Place one bag between two beds.

2. Preparation of greenhouse before planting

- Irrigate the growing medium

Purpose:

Wash away unwanted material to homogenize the chemical properties of the medium.

Note:

Check the quality of water used for irrigation. The water used can be tap water, rainwater, well water, or other water used for cultivation.

Work procedure:

Water the entire surface of the medium using a watering can. Water until it drains out from under the bed to moisten the entire bed. This should be done 2-3 times before planting.

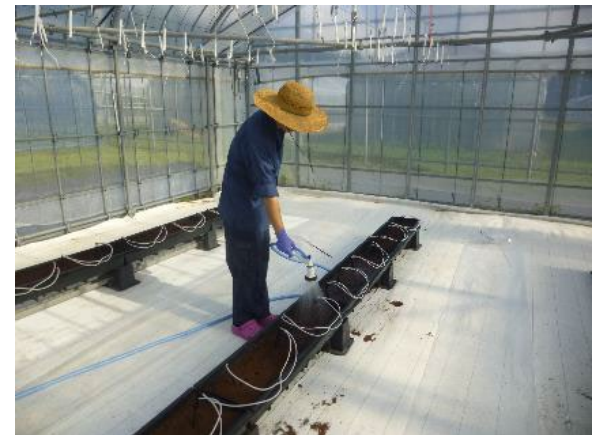


Photo of work in progress

2. Preparation of greenhouse before planting

- Limiting concentrations (ppm) of each ion in the water used for the culture solution and appropriate EC and pH.

Ion	ppm	Ion	ppm
NO ₃ -N	60	Fe	10
P	30	Mn	1
K	80	Zn	1
Ca	80	B	0.7
Mg	40	Na	80
		Cl	200
EC: less than 0.3dS/m		pH: 5~8	

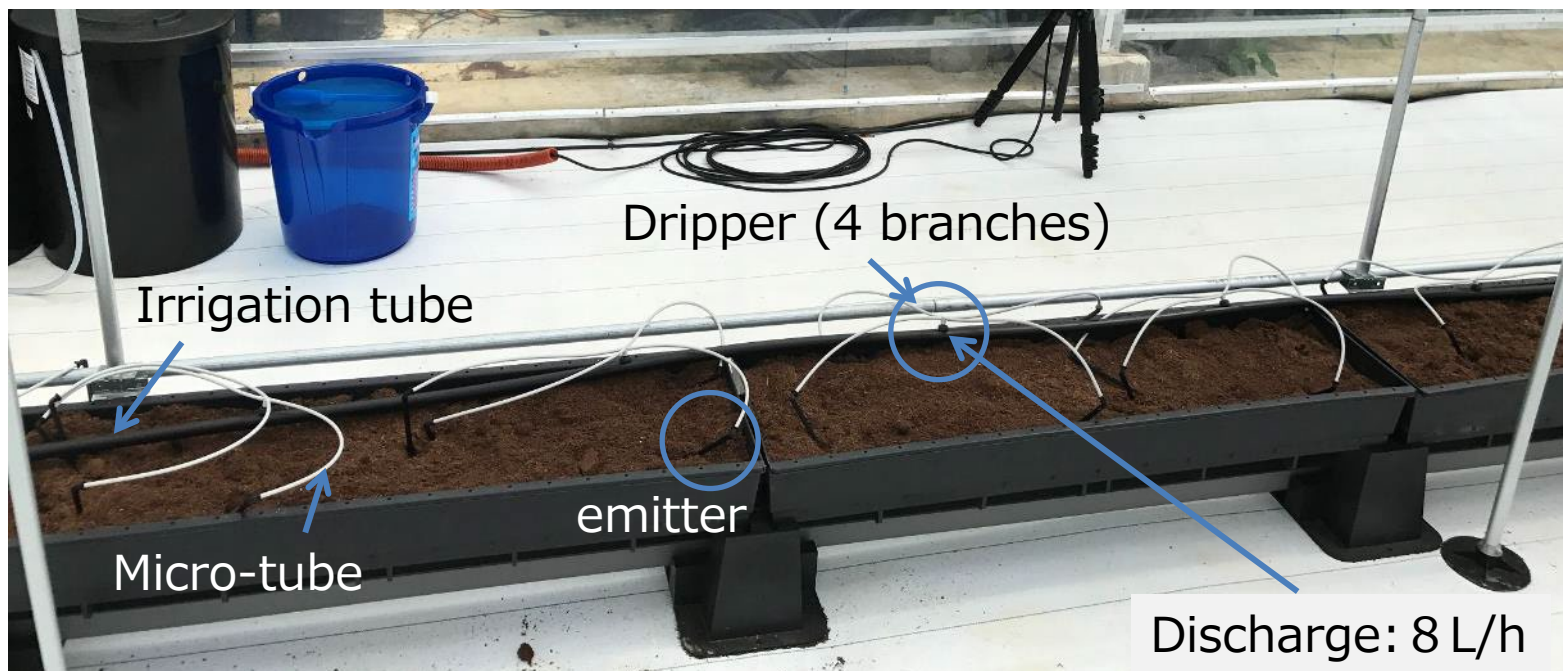
Source: Japan Greenhouse Horticulture Association and Hydroponic Society of Japan. All about Hydroponics. Seibundo Shinkosha Publishing Co., Ltd., 2012

2. Preparation of greenhouse before planting

Preparation of irrigation tube

Time: Before planting (preferably before filling the medium)

Work: Attach irrigation tubes to the cultivation beds and install an irrigation emitter for each plant.



3. Transplantation

• **Work procedure**

- ① Hand irrigate to moisten the growing medium.
- ② Dig holes to plant seedlings in the medium.
- ③ Put 1-2 g of pesticide containing “Dinotefuran” in each hole and mix it with the surrounding medium.
- ④ Carry the tomato seedlings to the greenhouse.
- ⑤ Put the seedlings into the planting hole and cover the medium to prevent the seedlings from falling over.

• **Management after planting**

- ⑥ Hand irrigate all the tomato seedlings planted.
- ⑦ Place drip irrigation emitters at the base of each plant.

• **Notes**

Do not keep seedlings under direct sunlight or high temperatures for a long period. Tomato seedlings should be planted as soon as possible after they are carried from the nursery.

If this is not possible, create a shaded area (using shade curtains, etc.) in the greenhouse and temporarily keep the seedlings there.

* Planting should be done before the seedlings wilt because they wilt over time.

3. Transplantation

① Hand irrigate to moisten the growing medium.

Irrigating the medium just enough to moisten it slightly in the morning on the planting day is sufficient.



3. Transplantation

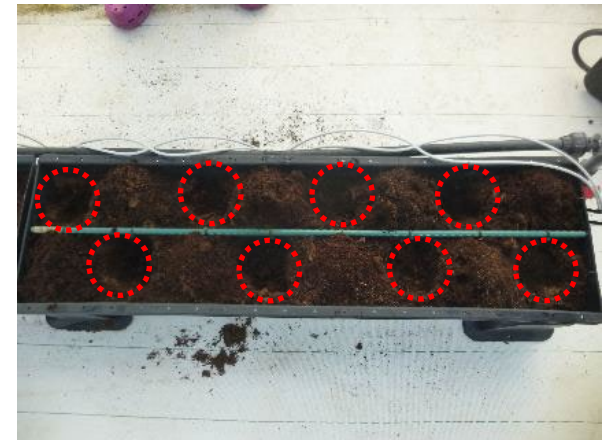
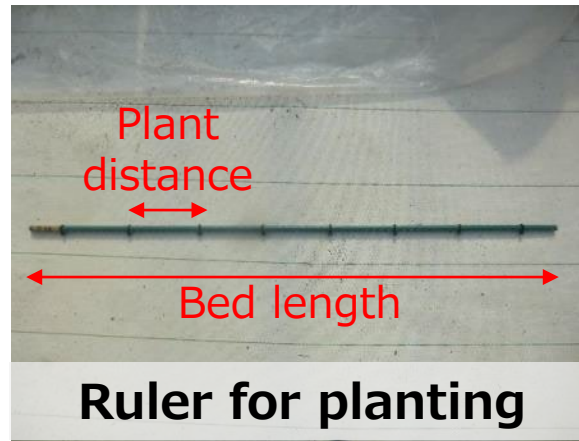
② Dig holes to plant seedlings in the medium.

Hole size: Approximately 7-8 cm to fill the root pot of the seedlings

Hole distance: 12.5 cm spacing (8 holes per meter). It is more efficient to use a "ruler for planting" at this time.



Holes in the medium



Completed

3. Transplantation

③ Put 1-2 g of pesticide containing “Dinotefuran” into each hole and mix it with the surrounding medium.

* The use of pesticides should be according to the pesticide use standards for the growing area.



Pesticide



Putting pesticides in the hole.



Pesticide is in the hole



Mix pesticide with surrounding medium.



Completion of planting

3. Transplantation

- ④ Carry the tomato seedlings to the greenhouse.
(The place where seedlings are kept in a greenhouse should be shaded in advance.)

Tomato seedlings



From the above

From the side



Bottom irrigation

Transport the seedlings to the greenhouse.
Do not leave the seedlings outside the greenhouse to reduce the risk of insect infestation.



Plant height is approximately 30 cm with 6-7 true leaves.

10cm

Fill a large container to hold the cell trays with water and immerse only the cell tray media in the water.

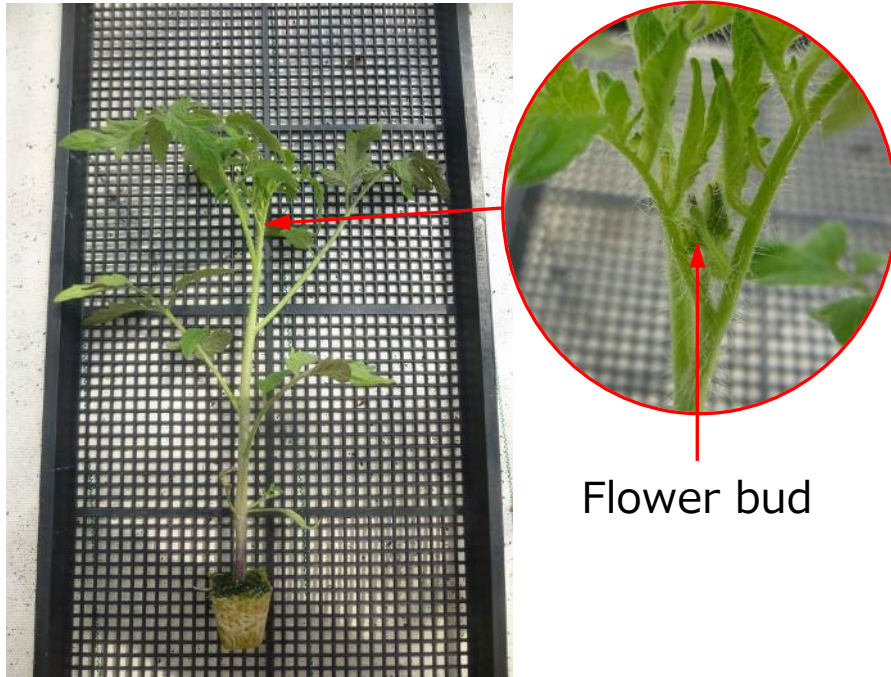
(to prevent wilting and to make it easier to pull out the seedlings from the cell trays)

Amount of water: The entire media should be submerged in water.

Time: Until no bubbles come out of the medium.

3. Transplantation

Good seedlings



Flower bud

The overall appearance is stout and the leaves are not broken.
The first flower bud can be seen.

Bad seedlings



Stem is divided into three parts.



Thin stem and seedling is small.



The stem is thin and floppy. The leaf is broken.

3. Transplantation

- ⑤ Put the seedlings into the planting hole and cover the seedling with enough medium to prevent the seedlings from falling over.

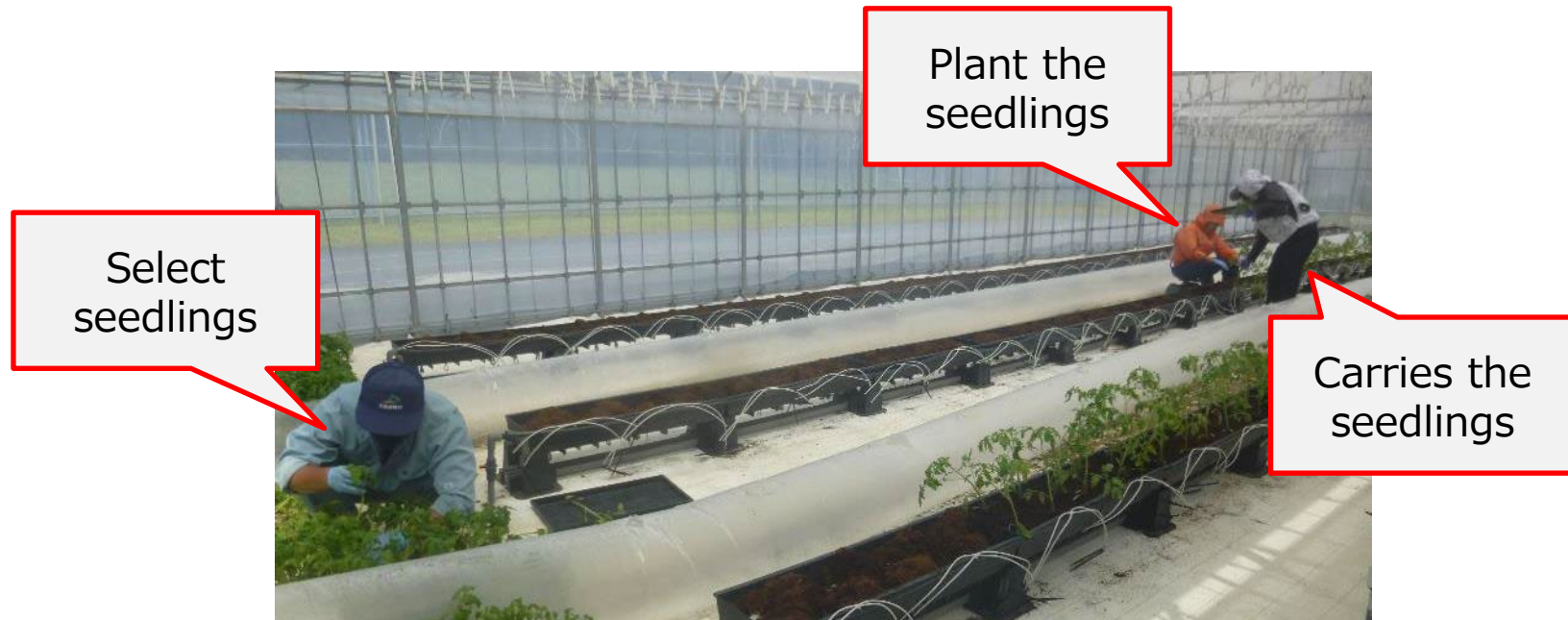


Place the root part of the seedling in the planting hole and cover it lightly with medium such that the seedling does not fall over.
(No need to push hard from above)

3. Transplantation

Distribution of work:

Transplantation can be done efficiently if several people share the work. For example, one person selects good seedlings from cell trays, another person carries the seedlings, and another person plants the seedlings, and so on.



4. Management after planting

⑥ Hand irrigate all the tomato seedlings planted.

* Apply water to the base of the plant so as not to wet the leaves. An irrigation amount of approximately 1 L per cultivation bed is sufficient.



Irrigate to the base of the plant.



Irrigate close to the medium to avoid wetting the leaves.

After planting, the entire bed is moistened via hand irrigation to allow water spread to the roots throughout the bed. Hand irrigate once a day for approximately one week after planting. Irrigation may be canceled if the medium is moist due to deep clouds or rain. You can switch to automatic irrigation when new white roots are visible on the surface of the medium 4 to 5 days after planting.

4. Management after planting

- ⑦ Place drip irrigation emitters at the base of each plant.



Install drip irrigation emitters at the base of the plant



Ready for automatic irrigation

5-a Training

Purpose: Support the plant to grow vertically

When to perform the work:

Start when the transition to automatic irrigation is complete.

(start 4-5 days to 1 week after planting. Plant height is approximately 40 cm)

Train approximately once a week until the main stems are pinched.



Support the plant body with 1 piece of string and 3-4 clips per plant.



5-a Training

Preparation

Attach the string at a height of 1.8 to 2.0 m above the cultivation beds so that there is one string per plant until the start of the train.



Attach the string above the beds

5-a Training



Add the clip at the base of the leaf below the uppermost flower truss.

Work procedure:

- 1) Put on clean gloves, place the clips for training in the basket and hang it on your waist.
- 2) Clip the bottom of the stem at the base of the leaves below one of the flower trusses. Insert the string in the center of the clip and support the stem with the loop. As the plants grow, use new clips to support the stems when they grow longer and become droopy.

5-a Training



Train the stem that has grown laterally and drooped.

Work procedure:

- 1) Put on clean gloves, place the clips for training in the basket and hang it on your waist.
- 2) Clip the bottom of the stem at the base of the leaves below one of the flower trusses. Insert the string in the center of the clip and support the stem with the loop. As the plants grow, use new clips to support the stems when they grow longer and become droopy.

5-b Lateral bud removal

Purpose:

Remove the "lateral buds" from the base of the leaves to allow nutrients concentrate on the main stems. This helps to improve the quality of the stems, leaves, flowers, and fruit. It also enhances plant ventilation and reduces the risk of disease.

Tools required:

- Gloves, scissors, and ethanol (for disinfection)
- Baskets and plastic bags (to hold removed buds)

When to perform the work:

Lateral bud removal should begin approximately one week after planting (after the training starts) and be performed once a week until the main stem is pinched. After pinching, it is advisable to continuously remove the bud as needed while monitoring the condition of the plants. It is more efficient to do this during training.

5-b Lateral bud removal

Work procedure:

1) Put clean gloves on your hands and disinfect the scissors with ethanol to prevent disease transmission to plants. Cover the basket with a plastic bag to hold the removed buds.

2) Observe each plant and remove any buds from the base when they are found. Tiny buds should be plucked by hand, and large shoots should be removed with scissors so that the wounds on the plant will be small and dry quickly. Minimizing the size of the wound on the plant body reduces the risk of disease infection.

Notes:

- ✓ The lower part of the plant should be checked, because side shoots may reappear from the area where the buds were once removed.
- ✓ Special attention should be paid to the area near the growing point, because it is difficult to distinguish the main stem from the side shoots. Usually, the main stem is the one with flower buds.
- ✓ Some shoots may also develop from within the flower trusses, which should be removed.
- ✓ Side shoots grow faster when temperatures are high. Additionally, side shoots tend to increase after the main stem is pinched.

5-b Lateral bud removal

Preparation before work

Ethanol in spray bottle

Work with clean hands. Gloves should be used.

Disinfect scissors with ethanol before working.

Change shoes when entering the greenhouse.

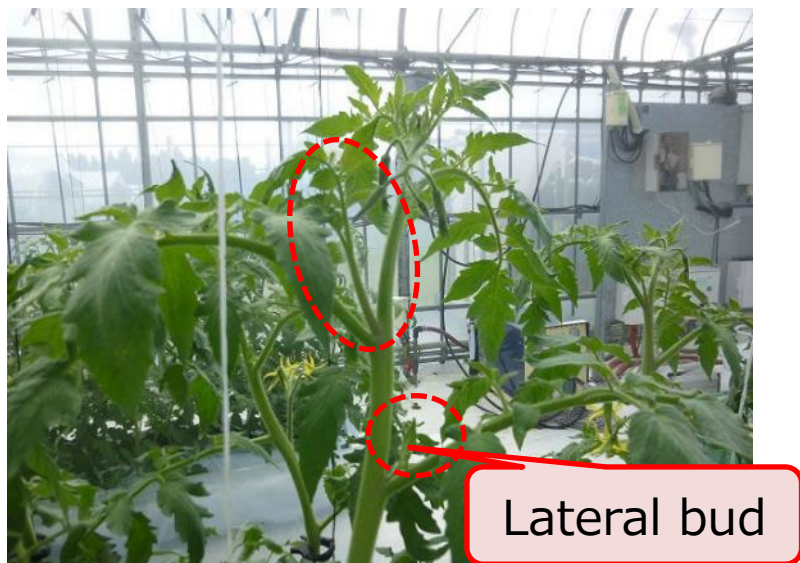


Work

Collect removed side shoots in a plastic bag in a basket.



5-b Lateral bud removal



Before removing



After removing



Remove small shoots by hand



Remove big shoots using scissors

5-b Lateral bud removal

Lateral bud are developing from the flower truss



Main stem and side shoot have almost the same thickness near the growing point.



Leave
(main stem as
flower truss appear)

Remove
(side shoot)

5-c Fruit setting treatment using hormone spray

Purpose:

Spraying tomato flowers with a hormone will encourage fruit set. Natural pollination and pollination by bees (bumblebees) are common. Moreover, fruits do not often set in high-temperature environments where the temperature exceeds 30°C; therefore, to prevent the flowers from blooming without producing fruit, a hormone agent (Tomato-tone) is sprayed on the flowers.

Tools required:

- Gloves, ethanol (for disinfection)
- Hormonal agents (Tomato-tone), Gibberelins, food colorant

When to perform the work:

Spray twice a week after flowering
(do not spray the same flower twice).



5-c Fruit setting treatment using hormone spray

Work procedure:

- ① Dilute Tomato-tone 100 times (check the instructions for use), color the solution with food colorant, and fill a spray bottle. Coloring the solution makes it easier to identify the flowers that have been sprayed.
- ② Wear clean gloves when working in a greenhouse.
- ③ Walk around the greenhouse and pull the spray lever 1-2 times to spray any blooming flowers that have not yet been sprayed with the hormone.

Note:

- ✓ You can determine whether the flowers have been hormone-treated by checking whether they have been colored.
- ✓ Do not spray when the flowers are in the bud, but spray slightly as soon as they begin to flower.
- ✓ When spraying, use your hand to protect the growing points and treated flowers, because spraying these areas may cause deformities.
- ✓ Hormones can be stored for approximately four weeks after dilution (check the instructions for use), but they may get moldy in hot and humid environments. If you notice anything unusual in the diluted solution, discard it immediately and use a new diluted solution.
- ✓ Gibberellin may be added (10 ppm dilution) to prevent puffy fruits.

5-c Fruit setting treatment using hormone spray

Spraying



When spraying, use your hand to protect the growing points and treated flowers, as spraying these areas may cause deformities.

5-c Fruit setting treatment using hormone spray



Use your hand to guard the growing points and treated flowers while spraying to avoid getting hormone agents on these points.

It is better to guard the flowers by putting your hand on the thicker part of the flower truss near the stem, because touching the area near the flower may cause the flower to fall off.

5-d Fruit thinning

Purpose:

Fruit thinning helps to adjust the number of tomatoes on a single truss to the proper number so that right-size tomatoes can be harvested for the intended purpose. It also help to maintain proper growth balance of the tree.

Tools required:

- Gloves, scissors, and ethanol (for disinfection)
- Baskets and plastic bags (to hold removed fruits)

When to perform the work:

Fruit thinning should be performed when the largest fruit in each flower truss exceeds the size of a ping pong ball (approximately 4 cm in diameter). Perform this action once for every flower truss.

5-d Fruit thinning

Work procedure:

- 1) Put clean gloves on your hands and disinfect the scissors with ethanol to prevent disease transmission to plants. Cover the basket with a plastic bag to hold the removed buds.
- 2) Observe each plant individually and cut out the other fruits, leaving four in good conditions (or the desired number)

Note:

Fruits that are considered suitable should meet the following criteria:

- (1) they must be round in shape (similar to a typical tomato),
- (2) they should be larger than the other fruits in the truss,
- (3) they must be free from blossom end rot (BER), that is, there should be no black spots at the bottom of the fruit.



5-d Fruit thinning

Two small fruits
to be picked.



Before thinning (6 fruits)



After thinning (4 fruits)

5-d Fruit thinning



Cut from the base of the unwanted part as much as possible.



The fourth fruit is relatively small. Wait until it is a little larger before picking it.



It is difficult to decide which fruits to pick when the number of fruit is large. Leave four fruits that better meet the criteria of a good tomato fruit.

5-d Fruit thinning



The underside of the fruits is also checked for BER.



If it is difficult to see the fruit from below, feel it by hand.

5-e Fruit truss support

Purpose:

As the fruits enlarge, the weight of the fruits may cause the fruit stalk to break off. If the fruit stalk breaks, water and nutrients may not reach the fruits; hence, there is need to support the fruit stalk to prevent it from breaking.

Tools required:

- Gloves, ethanol (for disinfection)
- Hooks for supporting fruit trusses
- Baskets and plastic bags (to keep the hooks)

When to perform the work:

After fruit thinning, the fruit stalk should be supported when the truss of all the fruits has grown so large that the fruit stalks are at risk of breaking off.

Work procedure:

- 1) Put on clean gloves, place the hooks for support in the basket, and hang the basket on your waist.
- 2) Observe each plant individually, and when the fruit trusses is observed to need support, attach the hooks to hang the trusses from the training string to support the trusses.

5-e Fruit truss support

Notes:

Attach the device to support the fruit truss around the center of gravity (the center of the four fruits). If the device is attached near the main stem, the tip of the truss will likely break.

As the fruits grows larger and heavier, this (the fruit stalk) breaks off.



Hang the fruit truss with a hook and a training string to support the fruit stalks so they do not break.



5-e Fruit truss support



5-f Top pinching

Purpose:

After the fourth flower truss emerges, the main stem is cut off to allow nutrients go into the fruits.

Tools required:

- Gloves, scissors, and ethanol (for disinfection)
- Baskets and plastic bags (to hold removed stems)

When to perform the work:

When two leaves have developed on the fourth flower truss in all the plants.

Work procedure:

- 1) Put clean gloves on your hands and disinfect the scissors with ethanol to prevent disease transmission to plants. Cover the basket with a plastic bag to hold the removed buds.
- 2) Cut the main stem of tomatoes, leaving the two leaves above the fourth fruit truss.

Note:

Check the number of flower trusses and cut the main stem. If there are any loose stems, you will have to repeat the process; thus, be sure to do it for all the plants.

5-g Chemical control

Purpose:

Prevention of disease and pest outbreaks, and prevention of the spread when outbreaks occur.

Tools required:

- Power sprayer or manual sprayer
- Protective clothing (long sleeves, long pants, mask, goggles, and gloves)
- Agrochemical to spray

When to perform the work:

For prevention, spray once a week from the beginning of training till harvest. Spray each time a disease or pest infestation occurs.

Work procedure:

- 1) Wear protective clothing, wash the sprayer, and prepare (dilute and/or mix) the agrochemicals.
- 2) Spray evenly on all plants.

5-g Chemical control

Notes:

- ✓ When selecting agrochemicals to be sprayed, comply with the standards established for each region.
- ✓ When spraying agrochemicals, be sure to check the guideline for the chemical (dilution rate, time of use, chemicals that can be mixed, etc.)
- ✓ To avoid health hazards, do not spray chemicals for long period (control chemical application time).

To reduce chemical application

- ❑ Ensure doors and nets are closed to prevent insects from entering the greenhouse.
- ❑ Change your shoes in the greenhouse and thoroughly disinfect your work gloves and scissors to keep pests out of the greenhouse.
- ❑ Ensure early detection of diseased plants and pests for chemical spraying before pests spread in the greenhouse.

5-g Chemical control



Change into protective clothing



Activate the sprayer for each chemical.



Put the chemical into the tank and dilute it with water.



Clean the used utensils immediately. 47

5-g Chemical control



Move to the greenhouse.



Change shoes when entering the greenhouse.



Spray evenly up and down so that the chemical reaches the underside of all leaves.

5-g Chemical control



Spray evenly up and down so that the chemical reaches the underside of all leaves.

5-g Chemical control

Notes:

Clean the tank before spraying another chemical.



Clean the tank with water.



Spray nozzles and hoses should also be cleaned with water.

5-g Chemical control

Chemical usage records (Transplant: May 5, End of cultivation: Sep. 25, area: 150m²)

Date	Chemical	Formulation ^z	Active ingredient and content	Target pest	Amount	Dilution ratio	No. used / Maximum No. ^y	Harvest ^x	Pest outbreak
Jul 4	Chlorothalonil pesticide (ダコニール1000)	WP	TPN40%	Corynespora target spot	100L	1000	1/4	Day before	No pest
Jul 11	Kaligreen	SP	Potassium bicarbonate 80%	Powdery mildew	100L	800	Unlimited	Day before	No pest
Jul 19	Kaligreen	SP	Potassium bicarbonate 80%	Powdery mildew	100L	800	Unlimited	Day before	No pest
Jul 25	Diethofencarb fungicide (ゲッター)	WP	Diethofencarb 12.5%, Thiophanate-methyl 52.5%	Leaf mold	100L	1000	1/6	Day before	No pest
Aug 4	Isopyrazam fungicide (ネクスターフロアブル)	WP	Isopyrazam 18.7%	Leaf mold	100L	1000	1/3	Day before	No pest
Aug 15	Chlorothalonil pesticide (ダコニール1000)	WP	TPN40%	Corynespora target spot	100L	1000	2/4	Day before	No pest
Aug 18	Spinetoram insecticide (DIANA®, ディアナSC)	WP	Spinetoram 11.7%	Armyworm	100L	2500	1/2	Day before	Armyworm
Aug 22	Kaligreen	SP	Potassium bicarbonate 80%	Powdery mildew	100L	800	Unlimited	Day before	No pest
Aug 30	Diethofencarb fungicide (ゲッター)	WP	Diethofencarb 12.5%, Thiophanate-methyl 52.5%	Leaf mold	100L	1000	2/6	Day before	No pest
Sep 5	Chlorothalonil pesticide (ダコニール1000)	WP	TPN40%	Corynespora target spot	100L	1000	3/4	Day before	No pest
Sep 12	Kaligreen	SP	Potassium bicarbonate 80%	Powdery mildew	100L	800	Unlimited	Day before	No pest
Sep 19	Spiracle-blocking insecticides (フーモン)	EC	Polyglycerol esters of fatty acid 82.5%	Powdery mildew	100L	1000	unlimited	Day before	No pest

^z: WP: wettable powder, SP: water soluble powder, EC: emulsifiable concentrate

^y: Number of times the chemical has been used to date/the maximum number of times it can be used

^x: Number of days the chemical can be used before harvest.

6 Harvest

Tools required:

- Gloves, scissors, and ethanol (for disinfection)
- Baskets

When to perform the work:

At AMPFS, ripe fruit that had turned red or near the head are harvested three times a week (Monday, Wednesday, and Friday mornings). Depending on the sales channel and distribution system, the fruit may be harvested in a green; hence, harvesting should be done according to actual conditions.

Work procedure:

- 1) Put clean gloves on your hands and disinfect the scissors with ethanol to prevent disease transmission to plants.
- 2) Check each plant one by one and harvest the fruit when it is time to harvest.



6 Harvest

Note:

- ✓ The ripe fruit can be harvested by hand, but the stem on the fruit head should be removed with scissors (If stems are left on the fruits, they may damage other fruit in the harvest box).
- ✓ Some fruits are behind the leaves; hence, look carefully and harvest them.
- ✓ When harvesting is performed by more than one person, use a color chart or similar tool to standardize the criteria for the fruit to be harvested.

Use scissors to cut this part of the stem short.



6 Harvest



Wear gloves and disinfect scissors with ethanol.



Work with a basket on your waist.



Harvested fruits are carried out together in containers.



Wash used utensils with water and keep them properly.

7 After the end of a cultivation cycle

Purpose:

Clean the greenhouse after the end of a cultivation cycle in preparation for the next round of cultivation.

Tools required:

- Chemicals for disinfecting materials

When to perform the work:

After the end of the cultivation cycle. If there is enough time for the next cultivation, it is recommended to stop irrigation few days after the end of the cultivation cycle to allow the medium to dry out for easy removal.

Work procedure:

- 1) Remove the plants and medium from the greenhouse and dispose them.
- 2) Collect materials such as strings, clips, irrigation emitters, etc. from the greenhouse, disinfect them, and store them in a warehouse.
- 3) Clean the greenhouse and disinfect the growing containers and other items that could not be moved from the greenhouse using a sprayer.

Note:

Check the instructions for use when disinfectant solution is used.

7 After the end of a cultivation cycle

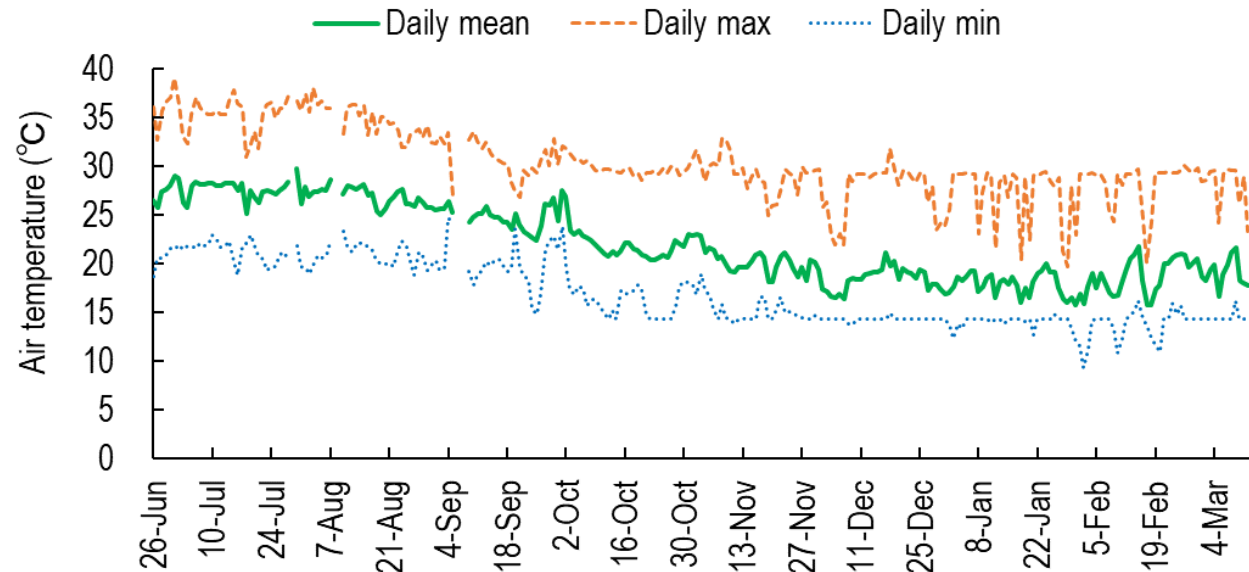
Disinfection of cultivation materials

Fill large bucket with disinfectant solution and immerse each tool inside. Plastic products are held above the containers to prevent them from floating.



8 Reference data

(Greenhouse air temperature and tomato yield in Ishigaki Island)



Yield of tomato

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Kg/plant	Kg/m ²
Cul.1	■	■	●	●							1.7	7.2
Cul.2		■	■	●	●						1.6	6.8
Cul.3			■	■	●	●					1.9	8.1
Cul.4				■	■	●	●				2.4	10.2
Cul.5					■	■	●	●	●		2.8	11.9

(Nakayama *et al.* 2021, Hort. J.)



www.jircas.go.jp