STRAWBERRY PRODUCTION THROUGH TISSUE CULTURE

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MESSAGE

Benguet State University continues to pursue its commitment of providing extension services that are research results aligned with quality education and sustainable development practices. This year's University Foundation theme "Creating Milestones toward Global Engagements: BSU @102" makes this knowledge product (KP) timely and relevant. It concretizes important steps to bring to fruition our vision of delivering quality education and client satisfaction that promotes sustainable development.

Through this technology guide, BSU has upscaled research-based initiatives and technologies thru handy materials for use by varied audiences - from farmers, to homemakers, to fieldworkers and extensionists. By circulating this knowledge product, the development of a critical mass of farmers who adopt and champion BSU technologies will be facilitated effectively and support sustainable development and continuing innovations from the field. It is our fervent hope that in the long run, this knowledge will contribute in improving quality of life and increasing income of our communities and clients.

I congratulate the Office of Extension Services' team for producing this knowledge product which is a testimony of BSU's prolific knowledge generation and continuing commitment to serve its communities. This should encourage other knowledge holders to work on translating their knowledge to tangible KPs.

Mabuhay tayong lahat!

FELICIANO G. CALORA JR.
President
Benguet State University
27 September 2018

MESSAGE

The Research and Extension (R&E) sector's goal explicitly highlights the generation of "relevant and gender sensitive research and extension programs for institutional development, sustainable communities, climate resilience, industry innovation and partnerships." To do this, there is a need to disseminate research results in different platforms for BSU- R&E outputs to reach the widest audience possible. The knowledge products produced by the Office of the Extension Services is a step towards addressing the different client needs in this increasingly competitive and changing world. With many years of extension work, there is also an increasing recognition to capacitate Extension Service Providers aside from directly working with clients, and one way is to produce knowledge products (KPs) tailored to answer this emerging need of the sector. Many of the knowledge products developed therefore are for these Extension Service Providers. Specifically, this technology guide on strawberry production through tissue culture which puts together long research work outputs as well as actual experiences, aims to facilitate the work of the University research and extension.

It is hoped that this KP will be utilized and will serve its purpose which is a handy guide for extension workers, and also the bigger public such as strawberry growers and interested farmers in the region and in the neighboring provinces with similar environmental condition. The technology guide is a concrete manifestation of technologies generated in the academe and translated into a language that can be used by the popular sector.

I congratulate the Extension sector for coming up with various knowledge products which is a timely response to the very fast changing and challenging prospects of the times. Being the lead University in the region, it is but proper that we also lead in this kind of engagements, while working for excellence and innovation for client satisfaction.

CARLITO P. LAUREAN
Vice - President for Research and Extension
Benguet State University
27 September 2018

MESSAGE

In the journey of extension work, we gain knowledge through our exposure to different fieldwork experiences and interaction with our development partners. In the process, we generate knowledge and build on it – thereby making each one of us "knowledge holders" and is magnified in the collective knowledge of our University. One way of retaining and ensuring intergenerational transfer of knowledge is through knowledge products. Knowledge Products or KPs, in the context of knowledge management, aim at transferring knowledges to identified users. What makes a KP unique is that it is a "call to action" by its intended users, enabling application of the knowledge easy and handy. This is the purpose of the technology guide developed by the Horticulture Research and Training Institute.

What comes with this exercise is the "communication and persuasion" package, a task taken by the Office of Extension Services (OES). In the process of doing these tasks, admittedly, the OES had several realizations: the urgency of tapping knowledge holders (who are retiring), the need to maximize resources which required a multidisciplinary lens and in the process, the need to refine some "extension processes" necessary for extension operation to adopt to the "changing times." It was a difficult task, but in this way, we have innovated the generation of knowledge for our intended specific audiences.

In this age where knowledge-based economy is increasingly becoming important, we believe that knowledge generation, transmission and application is facilitated through the culture of sharing. Through this techno-guide, we hope to contribute to the circulation of technology and innovation menu while innovating further on knowledge and technologies.

RUTH S. BATANI
Director, Office of Extension Services
Benguet State University
27 September 2018

ACKNOWLEDGMENTS

I would like to thank the Office of Extension Services (OES) for encouraging me to write a technology guide on strawberry production through tissue culture. I am also thankful to the OES team for considering my expertise. To the Horticulture Research and Training Institute (HORTI), thank you for encouraging me to publish this established technology. My deep gratitude is also due to the farmers who continue to use this technology for their fruit production.

Sincere acknowledgment is given to my former research leaders Dr. Julia A. Solimen, project leader, Sergio T. Gayao, and my co-researcher Lorelie R. Ollayan on the CHED-funded project to disseminate or commercialize tissue cultured-strawberry. To all of the HORTI and Extension staff thank you for the ready support and assistance in the preparation of this knowledge product.

Above all, thanks to the Almighty for providing me the strength to write this technology guide.

PREFACE

Strawberries have been in the Cordillera highlands since the early 20th century. This was the time when the Americans became the next colonizers after the Spaniards and made efforts to "modernize" agriculture by introducing temperate vegetables including strawberries. The cultivation of strawberries was well accepted by both farmers and consumers. Hence, the venture flourished specially in the munipality of La Trinidad, Benguet, where it was declared as its One Town Product (OTOP) .

With the increasing demand of this small fruit, efforts have been made by private and public sectors to improve the yield as well as the system of strawberry production. The initiatives of Benguet State University in the strawberry industry are focused on research under variety evaluation and improvement, cropping systems and production innovations, as well as value addition.

Several materials have been published for this crop. However, this technology guide is unique in the sense that it features tissue culture technology to give attention to the strawberry production concerns of the farmers. This technology may be one of the solutions to increase production, deliver sustained demands, as well as help farmers increase their profit.

DARWIN A. BASQUIAL
Director , Horticulture Research and Training Institute
Benguet State University
27 September 2018

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INTRODUCTION

General Characteristics of Strawberries

Strawberries are perennial, stoloniferous herbs that spread via stolons or "runners". The leaf has three leaflets, and arise from the "crown" (a reduced stem in the center of the plant). Leaflets are ovate or broadly oval, obtuse, dentate or coarsely serrate. The runners produce "daughter" plants at every other node, particularly in summer, these take roots when they touch the ground and become independent plants.

Flowers are white, about 1 inch across, with 25-30 yellow stamens and 50-500 pistils on a raised, yellow, conical receptacle. Borne on a dichasial cyme, the center-most terminal flower opens first and is the largest. It also produces the largest fruit. Subordinate flowers are smaller, have fewer pistils, and produce smaller fruit. Flowering occurs over several weeks, and plants may have ripe fruits, developing fruits, and flowers all at once.

Most cultivars are self-pollinated and therefore do not need cross pollination for fruit set. However, bee activity is beneficial in transferring pollen to stigmas in an individual flower. A few hundred pollination events must take place to produce a well-formed berry.

The strawberry is an accessory fruit, since the edible portion is non-ovarian in origin (it is largely swollen receptacle tissue). The true fruits which contain the seed of the strawberry are achenes, which are similar to tiny sunflower seeds.

The achenes are the numerous, tiny, ellipsoid specks that cover the fruit surface. They are essential to fruit development because they produce growth regulators that enhance growth of the underlying fleshy tissue. Areas on the fruit surface devoid of functional achenes do not grow, causing irregularly shaped fruits. Ultimate fruit size and shape is therefore heavily dependent on achene set, hence pollination. Fruiting begins after a year of planting, and continues for more than three years. However, the size and quality declines after the first year. Its fruits mature rapidly and ripening occurs in 20 to 50 days after pollination.

Contribution to Diet

Strawberries have higher Vitamin C than many citrus fruits. Below is the nutritional composition (per 100 gram edible portion).

	Strawberry
Water (%)	90
Calories	37
Protein (%)	1.4
Fat (%)	0.7
Carbohydrates (%)	8
Crude fiber (%)	1.5
	% of US Recommended Dietary Allowance
Vitamin A	1.2
Thiamin, B1	2.1
Riboflavin, B2	4.4
Niacin	3.3
Vitamin C	131
Calcium	2.6
Phosphorus	2.6
Iron	10
Sodium	< 1
Potassium	3.5

About Plant Tissue Culture

Plant tissue culture refers to the growing and multiplication of cells, tissues and organs on defined solid or liquid media under aseptic and controlled environment. Meanwhile, tissue culture technology is the ability of a single cell to develop into a whole organism. Tissue culture supports the growth and/or development of isolated plant cells, tissues or organs on an artificial, nutritive medium. Plant tissues are maintained on the culture medium for a specified period of time and may be transferred to fresh medium periodically, or to a different medium to alter the path of development.

Plant tissue culture technology is being widely used for large-scale plant multiplication. The commercial technology is primarily based on micropropagation, in which rapid proliferation is achieved from tiny stem cuttings, axillary buds, and to a limited extent from somatic embryos, cell clumps in suspension cultures and bioreactors. Plant tissue culture was first practiced in the university on 2005.

PRINCIPLES OF PLANT TISSUE CULTURE

Tissue culture is one of the technologies that can be used to improve the productivity of planting materials through enhanced availability of identified planting stocks with desired traits. It can produce true-to-type selected genotypes using in-vitro culture propagation technique. This technique provides a rapid reliable system for the propagation of large number of genetically-uniform disease, free-plantlets.

Advantages of Plant Tissue Culture Technology

1. Eliminates of viruses from infected plants
2. Produces true-to-type planting materials
3. Rapid multiplication of clones
4. Multiplication maybe carried out anytime of the year in a laboratory
5. Produces disease-free plants
6. Vegetative propagation of difficult to propagate species
7. Produces quality fruits and higher productivity
8. Regenerate planting materials
9. Large number of plantlets can be produced using a small portion of the plants and small space in the laboratory

Disadvantages of Plant Tissue Culture Technology

1. Mass propagation cannot be done with all crops to date
2. Regeneration is often not possible, especially with adult woody plant material
3. It may not get uniform growth of original plant, thus, cannot be used for floriculture crop production where uniformity is critical
4. Equipment used are usually expensive
5. Technicians with good knowledge and experience are needed




STAGES IN MICROPROPAGATION

Tissue culture is a term that is used to refer to the growth of plants or plant parts in sterile culture. Micropropagation is a method of propagating plants that uses very small parts of plants that are grown in sterile culture.

Stage 1: Establishment Stage

During this stage, the explant is cultured in a suitable culture medium, and different techniques are used for tissue activation and multiplication. Any part of the plant can be used in the micropropagation.

The different techniques used are described below.

A. Vegetative Portions

1. Meristem culture

Meristem tip culture is used successfully to remove viruses, bacteria, and fungi from plants. In a majority of cases, heat therapy is combined with meristem tip culture in order to produce the greatest number of plants that are "virus-free". A few words of caution are required, particularly in the terminology.

The term meristem, shoot tip, meristem tip are often interchanged. Here, the term shoot is used to refer to an apical tip ranging from 1-3 cm. The meristem is strictly the meristematic dome without any primordial leaves. The term meristem tip will be used to denote the

meristem together with one to two primordial leaves and measuring between 0.1 - 0.5 cm in height.

Why virus eradication works

Several hypotheses exist to explain why heat therapy and meristem tip culture, when used together, are effective in eradicating viruses. These can include the following: 1) virus distribution is uneven in a plant and is much less in a meristem; and 2) viruses cannot travel quickly enough through plasmodesmata to keep up with actively growing tip.

Below are plants in which virus eradication is commonly used.

garlic	pineapple
dahlia	cymbidium orchid
carnation	strawberry
hyacinth	sweet potato
lily	apple
cassava	banana
narcissus	perlagonium (geranium)
gooseberry	raspberry
sugarcane	potato
grape	ginger

2. Shoot tip

This refers to the structure consisting of the shoot apical meristem plus one to several primordial leaves usually measuring from 0-10 mm in length, in insistences included in the structure can measure up to several centimeters in length.

3. Leaf disc

This is the circular piece cut from the lamina of leaf. The cutting is through a metallic or glass tube having sharp edge. Leaf lamina is cut after surface sterilization of leaf when it is to be used to initiate the callus culture from leaves.

4. Single node

This is the stem with one to four nodes, which include the shoot tip and single node planted vertically in the medium.

B. Reproductive Portions

Anthers, pollen, ovules, embryo, seed, and spores.

Considerations

a. Part of plant used – shoots or flushes, nodal segments, seeds, roots, young leaves, flowers, young fruits, etc.

b. Disinfestations or surface sterilization – one must clean plant tissues of all contaminating microorganisms.

c. Medium - must contain all components necessary to nourish explant

i. Inorganic elements
Macroelements - N, P, K, Ca, Mg
Microelements - B, Co, Cu, Mn, I, Fe, Zn

ii. Organic source - carbon source - are needed since plants do not seem to photosynthesize well in culture.

iii. Vitamins: Thiamine, Myoinisitol, B vitamins, folic acid, biotin, glycine (essential)

iv. Growth regulators:

cytokinins - induced shoot bud formation
Auxins - induce root formation
GA, ABA rarely used

v. Complex organic source – natural orange juice, coconut milk, bananas, tomatoes

vi. Agar

vii. Sugar/Sucrose

d. Environmental conditions

Light - light intensity, photoperiod, and quality

Temperature - there are usually high and low cutoffs. In some cases, a specific temperature is needed but of all environmental conditions, specific temperatures are generally not required beyond the all-purpose 25°C.

Stage 2: Multiplication

This refers to the propagules to be multiplied by shoot, embryos, meristematic, nodules, and leafy callus. During this stage, the amount and kinds of hormones to be used are critical. Often the concentration of hormone determines the morphology of propagules.

Methods of Multiplication

1. Axillary shoot formation

This refers to the axillary meristem located in the axil of a leaf and giving rise to an axillary bud, shoot tips and meristems. These already have organization of shoot and can use lower amounts of hormones than other structures where shoot morphology is not present.

2. Adventitious shoot formation

a. callus – organogenesis - most structures other than shoots usually must go through callus first. Get dedifferentiation and then redifferentiation. The process is similar to that with root primordia formation.

b. This pertains to organ formation directly without callus. For example are the African violet, peperomia plants, etc.

3. Callus embryogenesis

This is the callus in first stage. Callus then is placed in liquid culture. Through callus and liquid culture using 2, 4-D, NAA, embryos

is formed. Shoot formation may occur through organogenesis or embryogenesis from the callus produced from the explant.

Stage 3: Rooting Stage/ Pre-treatment for Soil Transfer

In this stage, there are selected plants forced for root formation, which can be achieved by modifying the media and/or concentration of growth regulators. The concentration of cytokinins and sugars are reduced and concentration of auxins and light intensity in the laboratory is increased to enhance root formation.

The following are the consideration of cultures when transfering to rooting stage:

- needs root formation and adjustment to greenhouse conditions;
- for root initiation growth, regulators are important;
- Naphthaline Acetic Acid used for herbaceous plants;
- Indole Butyric Acid for woody plants;
- reduce sugar to encourage autotrophic growth;
- Reduce or increase light duration depending on the needs of a specific plant. Lessen or tottally shut off light for 1 week for root formation; and
- 10,000 lux of light to adapt it to higher light intensities in greenhouse or field.

Stage 4: Acclimatization/Hardening

Plants grown in tissue culture are usually established in a culture media maintained in a sterile environment with high humidity. A light cycle is used to promote growth in ex-plants, they only photosynthesize at approximately 10% of normal photosynthetic capacity.

- Most of the nutrients they receive come from the plant growth media. Therefore, ex-plants need to learn to survive in a non-sterile environment with lower humidity and higher light levels and shift from relying on media nutrients and learn to photosynthesize to provide their own food source.

- To initiate the plantlets to be independent as fast as possible and not allowing them to wilt after transplanting.

- Do not transplant plantlets if the weather is hot, or very dry. Timing of planting in the greenhouse must be early in the morning or late afternoon hours, for the plantlet to adjust in the environment and to avoid wilting.

- After 3-5 days, check a few of the plantlets for signs of new leaves and root tips. As soon as there are new shoots produced, remove the polyethylene cover. Generally, remove the coverings at night, even at the first day, to keep the air fresh and reduce disease.

- Never use automatic mist at night, it encourages disease, slows growth and creates leaves with no effective cuticle.

- Plantlets may be transferred to container kept in mist chambers where relative humidity must be maintained.

- Once new growth is seen, the plants may be slowly transferred to outside forh increased light intensity.

The following are the steps on the acclimatization of rooted plantlets inside the greenhouse.

1. Once plantlets are well rooted, they must be acclimatized to the green house environment.

2. Tissue-cultured plants are acclimatized to glasshouse conditions by leaving them for seven or 14 days having a higher survival rate.

3. In - vitro rooted plants are removed from the culture vessel and the agar is washed away completely to remove a potential source of contamination.

4. Plantlets are transplanted into a standard rooting or soil mixture in small pots or trays in a more or less conventional manner.

5. Plantlets should be protected from covering polyethylene transparent plastic to maintain the relative humidity. Several days may be required for new functional roots and shoots to form before removing the plastic cover.

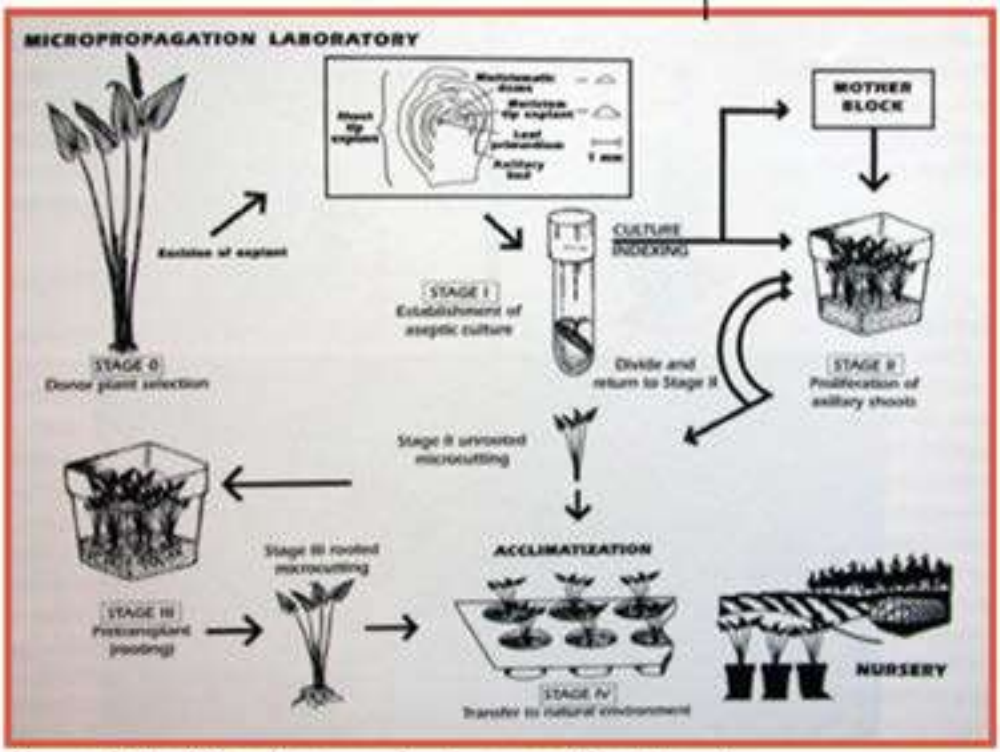

Figure 1. The different stages of micropopagation laboratory

Figure 2. The ideal greenhouse condition for strawberry production

THE POTENTIALS OF TISSUE-CULTURED STRAWBERRIES

Why produce strawberry through tissue culture

Tissue-cultured runners result in quality planting materials with productivity and lower in price comparable to imported ones. Old planting materials can regenerate and produce quality planting materials through tissue culture. It can produce true-to-type selected genotypes using in-vitro culture propagation technique. This technique provides a rapid and reliable system for the propagation of large number of genetically-uniform, disease-free plantlets.

What strawberry varieties are available

The different varieties of strawberry are the following: 'Festival', 'Winter Dawn', 'Early Bright', 'Whitney', 'Sweet Charlie' (California, Argentina, Washington, Texas, Israel), 'Sweet Charlie' (*Fragaria x ananasa duch.*), a short day cultivar that is early fruiting, sweet flavor and resistant to anthracnose caused by *Colletetrichum acutatum* is recommended by the farmers. However, strawberry variety 'San Andreas' is day - neutral strawberry variety also known as the "everbearing strawberry variety". It has the ability to initiate flower buds regardless of daylength, within certain temperature parameters. It allows fruit production to continue throughout the entire growing season. Fruit production is highest during the summer. This variety was introduced in La Trinidad, Benguet in 1993 and is still adaptable and popular to date despite the presence of new varieties introduced later in 2005.

How strawberries are produced

One runner tip of strawberry using meristem technique can produce a maximum of 2,000 plantlets after culturing for 8-10 months in the laboratory. This technique is mainly used to regenerate and rapidly produce clean quality and true-to-type planting materials and also to eliminate virus diseases. A plantlet can grow into a mother plant that can produce an average of 150 runners.

The micropropagation on strawberry is shown in the diagram below.

Figure 3. Cycle on the micropropagation of strawberry from establishment to runner production

Pre-culture Preparations

Step 1

1. Prepare the mother stock solution of the different component of macro and micro-elements, iron source, vitamins and growth regulators.

2. Withdraw the desired concentration from the stock solution then add with 4% sugar and distilled water to a desired volume.

3. Dissolve the sugar then adjust the pH according to the desired needs of the plantlets.

4. Heat the media and add 0.6% of agar under continuous stirring until the agar is dissolved and the media has become clear.

5. Dispense into culture vessels with a volume of 30-40 ml.

6. Sterilize the culture media under a temperature of 120oC for 20-30 minutes or depending on the volume dispensed on the culture vessels.

7. After the media has cooled down and solidified, they are ready for inoculation.

Step 2: Collection and sterilization

1. Runner tips are explants used as planting materials for micropropagation inside the laboratory.

2. Runner tips are collected from the mother plant of strawberry from the field or in the nursery. These are then washed with detergent soap and rinsed with running water.

3. They are then soaked in distilled water with detergent soap for 15 minutes with the addition of two to three drops of a commercial surfactant then rinsed three times with distilled water.

4. Sterilize with 100% sodium hypochlorite (chlorox) for 30

minutes with surfactant then rinse three times with sterilized distilled water.

5. Explants are then ready for excision under the binocular microscope inside the laminar flow.

Stage 1: Culture Initiation/ Establishment Stage

Initiation and inoculation of explants

Meristem and shoot tip are the techniques used for the explants establishment.

a. **Shoot tip** - the base of the runner tips are cut off and outer leaves are removed.

b. **Meristem technique** - two to three leaf primodia are left along with the meristem and these are inoculated in a Boxus (1974) medium with the addition of 1mg/l benzyl adenine (BA) and 1 mg/l Gibberellic acid (GA3) having 40g/l of sucrose. Add 0.6% of agar to solidify the medium.

Stage 2: Multiplication of Adventitious Buds/Proliferation Stage

a. The adventitious buds induced from the meristematic tissue can be subdivided into smaller pieces.

b. Transfer them into fresh multiplication medium.

c. Cultures are maintained in a medium (Boxus medium, 1974), which contains mineral nutrients, 4% sugar, 0.6% agar and growth regulators such as 1 ppm BA and 1 ppm GA3.

d. The number of subcultures should be limited to six or seven, in order to reduce the incidence of off-types arising through somaclonal variation.

Stage 3: Elongation/Rooting Stage

a. Elongation and rooting of adventitious buds can be accomplished by transferring to a rooting semi-solid medium containing 1 ppm Indole butyric acid (IBA) and activated charcoal.

b. Plantlets are maintained in the medium for rooting for three to four weeks.

c. When plantlets have produced enough roots, these are ready to be transferred outside of the laboratory for it to adapt to the ambient environment.

d. Different stages of cultures are inoculated and maintained in a growth chamber with a temperature of 14°C -24°C with 16 hours light and 8 hours dark for rapid growth.

e. One runner tip can produce 2,000 plantlets of eight months inside the laboratory.

Stage 4: Acclimatization/Hardening Stage

a. To acclimatize/harden the plantlets, leave the bottled plantlets in side the greenhouse for 3-5 days before removing them from the bottle.

b. Remove the plantlets from the culture bottle and wash with tap water to remove the gelling agent.

c. Plantlets are soaked with recommended dosage of fungicide solution for five minutes then transplanted into a soil growing medium.

Soil media proportion

a. To promote rapid rooting of plantlets/runners, the soil medium on the pan shall consist of 50% mountain sand, 25% alnus compost, and 25% burnt rice hull ash.

b. This soil mixture has good drainage and aeration, which is conducive for rooting and is more advantageous than the ordinary garden soil.

c. Before planting to the growing media, drench with recommended dosage of fungicide solution to avoid fungal infection.

STRAWBERRY RUNNER PRODUCTION THROUGH TISSUE CULTURE

A. Establishment of the mother plant for runner production

Tissue-cultured seedlings of strawberry are used as mother plants for runner production. These are planted in the field or in the greenhouse by adding compost and rice hull to the soil to improve aeration and soil fertility. The planting distance is 1m x 1m. Runners produced must be potted for higher percentage of recovery when planted in the field for fruit production.

B. Cultural management practices for strawberry runner production

1. Land preparation

Prepare the land intended for runner production. Plot the area into 1.25 m x 10 m measurement and level it. Broadcast compost and mix with soil at a rate of 2-4 kg/sq.m.

Figure 5. Land preparation for runner production

2. Planting

After mixing the fertilizer, plant the mother plant at the center of the plot at a distance of 50 cm.

3. Low tunneling construction

Runner production planted on the field needs protection such as low tunnel. The plants are protected from heavy rains and winds by transparent polyethylene plastic cover supported with bamboo strip or steel bars. The cover should be rolled in both sides when there is no rain for faster runner multiplication and cover when there is heavy rain.

Figure 6. Tunneling of Strawbbery production

4. Water management

After planting the tissue-cultured mother plant, irrigate twice a week to enhance growth and development.

Newly-planted mother plant should be irrigated twice a week. Continue watering every three days to enhance the growth and development for higher yield of runner production.

Figure 7. Watering of strawberry runner production using a sprinkle

5. Fertilizer application

Apply nitrogen fertilizer at a rate of 1 kg and dissolve it with 1 L water. Drench the dissolved fertilizer with 100 ml per plant. Application should be done every 15 days after transplanting.

6. Crop protection management

During runner production, the sucking pests such as two-spotted spider mites, aphids and thrips may attack the plant. To prevent damage from pests, spray with the recommended dose of pesticide.

Good agricultural practices like field sanitation, weeding, rouging and burying or burning of leaves infected with diseases can also help minimize pests.

7. Pre-harvesting of runners

Potting of runners should be done when the runner tips begin to creep. Potted runners should be separated from the mother plant two to three weeks after potting.

On the other hand, potted runners should be allowed to creep and establish on the plots to encourage all daughter plants to develop.

Figure 8. Potting of strawberry runner production.

8. Harvesting of runners

Potted runners are harvested or detached from the mother two to three weeks after potting. The individual runners are dug and then trimmed before planting.

Figure 9. Farmers are uprooting strawberry runner production for their planting materials.

CULTURAL MANAGEMENT FOR STRAWBERRY PRODUCTION

1. Land preparation

This will start from cleaning the area of weeds, debris and other obstacles so that the plots can be dug or plowed. The plots are then prepared with a distance one m x 10 m. The plots will be applied with processed chicken manure (PCM) at one can per plot and mix thoroughly to the soil and mulched with black polyethylene plastic sheet. Holes are made on the plastic mulch with a distance of 30 cm x 30 cm between hills and rows.

2. Planting

The runners produced are uprooted and transplanted in the prepared plots covered by the plastic mulch.

3. Water management

Plants are irrigated twice a week. There are several methods of irrigating a farm or garden.

a. Flooding is one method of irrigating the garden when there is flowing supply.

b. Use of watering can is the most common method used by the farmers to irrigate their garden.

Irrigation is very important because this will enhance the growth and development of strawberries that will result to higher yield.

4. Fertilizer management

The organic fertilizer applied during the land preparation is not enough to provide the nutrient elements needed by the plants for growth, development and the production of berries for six to seven months. There should be enough stored nutrient in the soil from previous application. Supplemental application during the growth is needed for strawberry requires high amounts of macro and micro elements.

Strawberry plants are applied with the following fertilizer:

a. Complete fertilizer (T16) is applied at a rate of 20 bags/ ha during flowering stage and every after harvesting.

b. Add chicken manure at 100 sacks/ha and should have been soaked in the water for seven days during vegetative and flowering stage.

c. Mixed fertilizers are drenched equally to the plot for every two weeks with a rate of urea 50 kg/ha and 50 kg of complete fertilizer (T16).

5. Crop protection and management

Strawberry plants are sprayed with recommended dose of insecticide to control pests once a week during the vegetative stage.

PEST AND DISEASE MANAGEMENT

Common Pests of Strawberries

1. Two-spotted spider mites and thrips

These are the most serious pests infesting the strawberry plant. When the pest start sucking the strawberry leaves, the plant will become stunted and will not produce good berries. Also, the thrips are minute insects sucking the sap of the leaves and they usually stay on the base of the petals and sepals during the flowering stage.

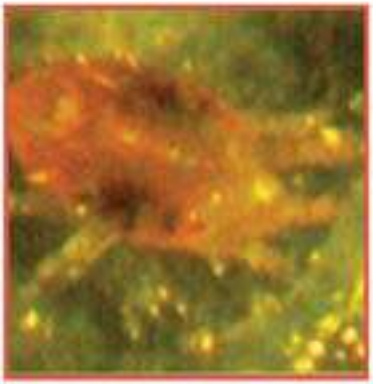

Figure 10. Two spotted spider mites sucking the leaves of the strawberry

Control measures

To control the two-spotted mites, spray insecticide. To control the thrips, aphids, white flies and other sucking insects, spray thiametoxam (actara). Follow instructions and recommended rate on the labels of the said chemicals.

Aside from spraying, predators should be released in the field when there are five two- spotted spider mites per leaf of the strawberry plant.

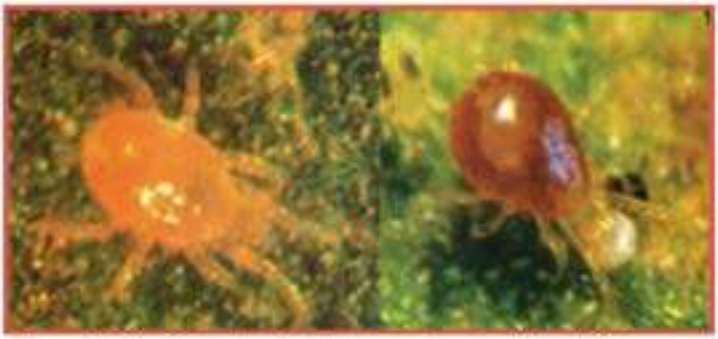

Figure 11. Predator mites (a)deutonymph stage (b) adult stage that can help to control the two spotted spider mites attacking strawberry

2. White Grubs (Babali)

These are larvae of June beetle. The larva eats the crown and the roots beneath the soil surface resulting to the death of the plant.

Figure 12. White grubs are larvae that eats the strawberry root

Control measures

The white grubs can be controlled by digging the base of the strawberry plant that are wilting or drying. Look for the white grubs and crush their heads. Aside from digging, spray molluscicide. Follow instructions and recommended rate on the labels of the said chemicals.

3. Fruit flies

Fruit flies are observed to lay their eggs into the ripe berries making it soft and if people are not aware, they eat the maggots inside the berries.

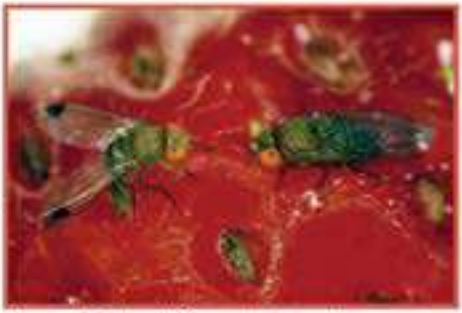

Figure 13. Fruit flies- a destructive pest attacking the strawberry fruits

Control measure

Trap the fruit flies and other insects by hanging a sticky yellow trap along the strawberry plants.

Figure 14. Use yellow sticky trap to content flying insect pests attacking the strawberry plants.

4. Slugs

Fruits of the strawberry plant are eaten by slugs and they make holes on the fruits.

Figure 15. Slugs destroys the fruits

Control measures

Bull frog eat the slugs and this can help to control them.Another is trap the slugs by burying the cans in the soil up to the rim and pour with as bait.

Aside from trapping, broadcast molluscicide to control them and follow the instruction and the recommended rate.

Figure 16. Bull frog can also help control pests attacking strawberries

5. Cutworm

Young leaves of the strawberry are eaten by cutworms and they make holes on the leaves.

Figure 17. Young leaves of the tissue cultured strawberry damaged by cutworms

Control measures

The cutworms can be controlled by spraying Spodoptera Litura Nucleo Polyhedrovirus (SlNPV). The most effective rate of SlNPV larvae is 60 SlNPV and dilute it with 16 liters of water. Spraying of larvae cut SlNPV must be done with three days interval to control the insect pest.

Aside from SlNPV, spray insecticide to control cutworms. Follow instructions and recommended rate on the labels of the said chemicals.

Aside from SlNPV, spray insecticide to control cutworms. Follow instructions and recommended rate on the labels of the said chemicals.

Common Diseases of Strawberries

Apply these basic control measures to prevent the common diseases of strawberries.

- Improve soil drainage.
- Avoid planting in known infected areas.
- Plant quality runners that are free from pests and diseases.
- Apply soil fumigants before planting.
- Clean farm machinery.
- Avoid over-watering.

- Good agricultural practices can be implemented to prevent crop loss. Among these are field sanitation to prevent the occurrence of pest and diseases in the garden. Diseased plants parts like leaves, and flower stacks infested with diseases should be removed and buried deep or burnt.

- Fruits infected with fungus should not just be left in the canals or in the field. The fungus will remain in the soil even for many years and then spread to other plants by means of wind, rain, insects, and human beings.

Soil-Borne Root Diseases

1. Fusarium wilt

This is a soil-borne disease that can cause crop loss under warm condition. It spread through infected runners, irrigation water and farm machinery. It enters through roots and affects the water-conducting tissues in the crown. Development is favored by warm to hot growing conditions and when plants are under stress.

Figure 18. Crown and roots of strawberry infected with fusarium wilt

Symptoms

It is fast acting as strawberry plants can suddenly wilt and die. This disease affects the outer leaves first; they become yellow and eventually take on a scorched appearance. Younger leaves stay healthy longer during cooler conditions.

2. Crown rot

Crown rot is considered to be a major disease under suitable conditions. It is caused by several soil-borne fungi. This rot can cause heavy plant loss in a short period of time. Fungi are spread by infected runners, water (irrigation or rain) and farm machinery. Crown rot development is favored by warm, wet conditions and waterlogged soil.

Figure 19. Crown rot disease of strawberry caused by fungus

Symptoms

This disease produces some wilting of leaves and eventual collapse of the plant. It can affect the roots which may turn black indicating rotting.

3. Black root rot

This causes root injury or generally weakened plants. The following factors are associated with its appearance: soil borne fungi, nematodes, drought, winter injury, excessive fertilizer application, or excessive soil moisture.

Figure 20. Black root rot disease of strawberry caused by fungus

Symptoms

Plants may wilt, appear stunted, or die outright. The leaves may turn purplish with red petioles. By the second growing season, the main or perennial roots of a healthy strawberry plant become woody. They have a dark brown or black outer covering and the inside is usually

lighter colored. A plant affected by black root rot will have brown or black (inactive) feeder roots or none at all. The outer root covering will die and pull off easily. The white core of the main roots may turn black in patches or along the entire length of the root.

Fruit Rot Diseases

1. Gray Mold

This disease is caused by the fungus, *Botrytis cinerea*, which overwinters on plant debris on the ground. Rainy or humid periods favor disease development.

Figure 21. Fruit of strawberry attacked with gray mold caused by fungus

Symptoms

At the beginning of bloom, the fungus attacks the blossoms and causes a blossom blight leading to considerable crop loss. Fungus spores form on the blighted blossoms and infection spreads to both green developing fruit and ripening fruit. The disease first appears on fruit as small, water-soaked areas which are soon covered with gray, fuzzy-spore masses.

Control measures

- Organic agriculture practitioners have difficult in controlling diseases due to limited control agents. *Trichoderma spp.* which is carried by honey bee during their foraging on strawberry flowers is observed to reduce grey mold infection.
- Serenade bio-fungicide containing strain of dried *Bacillus subullis* can also be used not only for leaf blight but also for grey mold.
- Good practices that can implement field sanitation to prevent the occurrence of pest and diseases in the garden. Diseased plants parts like

leaves, and flower stacks infested with diseases should be removed and buried deep or burned.

- Fruits infected with fungus should not be left in the canals or in the field because the fungus will remain in the soil even for many years and then spread to other plants by means of wind, rain, insects, and human beings.

- Spray fungicide when it begins to bloom. Continue at seven to 10 days interval up to the harvest time. Follow the instruction and the recommended rate in using the fungicide.

2. Black spot

This is considered a major strawberry disease that can cause serious crop loss. It mostly affects fruit, but can also affect runners, stalks and crown. It is favored by warm, humid and wet conditions.

Figure 22. Black spot disease of strawberry caused by fungus

Symptoms

This disease produces a round, firm, dark brown, sunken spot on ripening fruit. A white fungal growth can also develop on the fruit. Black spot is spread from infected plants and fruit by rain splash, overhead irrigation and on the hands of fruit pickers.

Control measures

- Plant quality runners that are free from pest and diseases.
- Apply protective fungicides when conditions favor the disease.
- Avoid using overhead irrigation.
- Fruits are cooled.

3. Stem end rot

This disease is caused by the fungus *Dendrophoma obscurans*. This disease causes rot at the stem end of the strawberry fruit.

Figure 23. Stem end rot disease of strawberry fruit caused by fungus

Symptoms

The fungus attacks the new leaves and causes the primary infection. Later, when fruit has formed, the calyx (fruit cap) becomes infected and instead of remaining green and healthy, turns brown. The fungus enters the fruit through the infected calyx, causing it to rot. The fruits may rot when harvested. The infected leaf and stem will also rot.

4. Leather rot

The disease is caused by the fungus *Phytophthora cactorum*. Leather rot has been observed as serious limiting factor in the cultivation of strawberry. The disease affects both the fruit quality and quantity.

Figure 24. Leather rot disease of strawberry fruit caused by fungus

Symptoms

Ripening fruit clusters that are touching the ground in standing water after prolonged warm rains suddenly (one – two days) turn gray-brown and become mushy. The fruit stems often rot. The disease progresses rapidly and a rotten smell pervades the field. After a few days, infected berries start to dry out and become leathery. If infected berries are cut longitudinally, the vascular system of the fruit is darkened and shows up as dark streaks radiating from the fruit core outward.

Control measures

- Select planting site with good drainage and air circulation.
- Plant should be exposed to direct sunlight. Plant rows with the direction of the prevailing wind to promote faster drying of foliage and fruits.
- Mulching must be done to keep berries off on the soil is a very useful cultural control.
- Spray recommended rate of fungicide to control the diseases.

5. Rhizopus rot

This is a disease caused by fungus *Rhizopus stolonifer*. It is a fruit rot disease that mainly affects ripe fruit late in the season. It is considered to be a common postharvest disease. It can be spread by wind, overripe fruit left on the plant and crop trash in the soil. Fruit skin needs to be injured for infection. Development is favored by hot, humid conditions.

Figure 25. Rhizopus rot disease of strawberry fruit caused by fungus

Symptoms

Affected fruit are soft, watery and become covered with grey, white fungal growth with black spore bodies. Juice also leaks from the affected fruit.

Control measures

- Remove overripe fruit in the field.
- Burn or bury waste fruit from around the packing shed.
- Cool fruit as soon as possible after harvest and keep at 0–5°C.

- Avoid packing overripe fruit.
- Use refrigerated transport.

Leaf Diseases

1. Leaf scorch

Figure 26. Leaf Scorch disease of strawberry caused by fungus

This fungus (*Diplocarpon earliana*) causes leaf scorch and can live through the cold weather in old, infected strawberry leaves. Spores are easily spread by splashing rain or by mechanical means, such as by machinery or people passing through an infected planting. It is common on older leaves and at the end of the season, but can also affect leaf stalks, fruits stacks, flowers and fruit.

Symptoms

This disease produces small purple spots that first appear on the older leaves and gradually enlarge, joining other spots and finally producing large dead patches giving the leaves a scorched appearance. Spots of the leaves may appear at any time during the growing season. Affected leaf margins may curl up. This disease is favored by warm, wet growing conditions and is spread by rain splash, overhead irrigation and wind. As the spots age, black pimple-like fruiting bodies of the fungus are produced in the center of each spot. Spots may rapidly become so numerous that the entire leaf dries up and looks scorched" as though by fire. Spots may also occur on petioles, stolons and fruit stalks.

Control measures

- Avoid overhead irrigation, if possible.
- Remove and burn older infected leaves after fruit bearing.
- Spray recommended rate of fungicide to control the leaf scorch.
- Practice crop rotation.

2. Leaf blight

Leaf Blight is caused by *Dendrophoma obscurans*, the fungus which also causes stem end rot. It is considered a minor disease of strawberries. It affects mostly mature leaves, but can cause soft rot on ripe fruit.

Figure 27. Leaf blight disease of strawberry leaf caused by fungus

Symptoms

Leaves are roughly circular, purplish spots, 1/8 to 1/4 inch in diameter. Large round spots develop on leaves with three distinct color zones. Spots can form a V-shaped area limited by veins that extend to the edge of the leaves.

3. Leaf spot

The disease is caused by the fungus *Mycosphaerella fragariae*. The fungus overwinters on old, infected, strawberry leaves. It is considered a major disease under suitable conditions. It is mostly a leaf disease, but can attack both leaf and fruit stalks and also fruit. Severe infection can kill the leaf. The spores are spread by wind,

Figure 28. Leaf spot disease of strawberry leaf caused by fungus

rain splash and overhead irrigation.

Symptoms

The symptom on the fruit is dark brown, sunken spot up to 3 mm wide. Leaf spot is favored by wet, cooler conditions and is more severe in low lying or shaded areas. The spores are spread by wind, rain splash and overhead irrigation.

4. Powdery mildew

Powdery mildew is caused by fungus *Sphaerotheca macularis*. It is considered a moderate disease that can affect fruit, leaves and flowers. It is favored by warm, dry conditions followed by moisture on leaves from overnight dew or rainfall. Spores can be spread by wind and can over-winter in trash from the previous and current crops.

Figure 29. Leaf spot disease of strawberry leaf caused by fungus

Symptoms

This disease produces white patches of web-like growth that develop on both the lower and upper leaf surface. The edges of the leaves may curl upwards. Immature fruit may fail to ripen, become hard, crack and turn a reddish color with raised seeds. It appears as a grayish-white coating on the undersides of leaves late in red or purple in color. Leaf function is impaired but symptoms develop so late in the season that plant vigor is seldom affected.

Non-Disease Fruit Problems

1. Sunburn

The fruit surface loses its red color and takes on a scalded appearance. It is caused by fruit long period exposure to hot, dry conditions in the field. It is more common when plants are water-stressed on clear, sunny days following a period of overcast weather.

Figure 30. Powdery mildew disease of strawberry leaves and fruits caused by fungus

Crop management

- Maintain adequate soil moisture.
- Provide good leaf canopy.

2. Frogmouth

The end of the fruit splits, and fruit is hollow. It is caused by rapid changes in field temperature.

Figure 31. Strawberry fruit exposed to hot which causes the burning effect of fruits

Crop management

- Use less susceptible varieties. Weed and removed the old leaves after harvesting. Weeding should be done to avoid competing nutrients with the strawberry plants.

Harvesting

Berries are harvested when the surface (skin) turns about 75% reddish for distant market, but for immediate fresh consumption, it should be at full ripe stage. Harvesting is done every two to three days. The common practice of the farmers in harvesting strawberries is early in the morning. The disadvantage of this practice is that the cells of the berries are turgid and easily bruised. Besides, the leaves and berries are still wet with morning dews. It is best to harvest the berries at the later part of the day.

In harvesting berries, the "tender loving care" concept should be applied if possible, one-touch harvesting should be practiced.

After harvesting, fruitless flower stalks and the old leaves should be removed or pruned to lessen overcrowding within the canopy of the plants to improve the development of berries.

Do not allow the strawberry plant to produce too many fruits at once during the early bearing stage because the strawberry plant transfer its nutrition to the fruits and the strawberry plant itself gets weaker and weaker. The plant will stop producing new leaves and the flowers will become small.

The best practice to handle the harvested berries is to detach the berries from the plant and pack right away in the field with specific weight containers to protect the berries.

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Milagros R. Dumaslan was born and raised in Pinili, Ilocos Norte. She completed her degree in Agricultural Education major in Agronomy at Mariano Marcos State University in 1981. She pursued her master's degree in Horticulture at Benguet State University where she graduated in 2006.

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