Roles of Plant Tissue Culture on Agricultural Productivity

By Dwi Hapsoro

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Introduction

As human population grows, its need for food increases. It was estimated that by the year of 2050, human population would be 9.1 billion, which is about 34% higher than the world's population now (Salokhe, 2016). Therefore, increasing agricultural production has become never-ending effort to catch up the population growth to sufficiently meet its demand.

Rising agricultural production could be achieved by intensification and extensification. Intensification is carried out mainly by increasing the technological level, or by employing more modern one, while extensification is done mainly by increasing land area. For a large company, the two strategies are often executed simultaneously, in order to meet increasing product demand. Plant tissue culture technology has been very advantegous for supporting both intensification and extensification.

This paper aims to put forwad roles plant tissue culture for supporting agricultural productivity.

Plant Tissue Culture and Its Role on Agricultural Productivity

Plant tissue culture could be defined as aseptically culturing in vitro small parts of plants (protoplast, cell, tissue, organ) on a spesific medium containing a complete mineral nutrients and plant growth regulators under controlled environmental condition in order that the plant parts grow, proliferate and develop into complete plants or just grow and proliferate for special purpose. Based on the definition, the end goal is not always complete plants, but it could be other forms, for example proliferating calli, roots, or shoots. Based on the definition, plant tissue culture has five important characteristics i.e in vitro, aseptic, complete mineral nutrients, plant growth regulators, and controlled environmental conditions.

In relation to agricultural productivity, plant tissue culture has been applied for (1) rapid clonal propagation of plants with novel characters, (2) production of disease-free plants, (3) seed germination, especially for orchids, (4) embryo rescue, (5) induction of desirable, heritable trait through somaclonal variation, (6) production of homozigous, pure lines of plants for hybrid variety production, and (7) providing facility for mutation breeding and plant genetic engineering. Basically plant tissue culture could be applied for rapid clonal propagation and for facilitating plant breeding, both being supportive for plant productivity.

Rapid clonal propagation by tissue culture for supporting productivity. Planting materials are vital to productivity. They should be genetically, physiologically, and physically superior. The plants being mass propagated are always those considered to have novel, heritable characters. Environmental condition of plant tissue culture system, which is aseptic and supplied with optimal amount of nutrients, enables the production of planting materials which are physiologically and pysically superior and free of disease, especially caused by pathogenic bacteria and fungi. Virus-free planting materials could also be produced, i.e. by culturing a very small part of meristem tips.

Plant tissue culture has been used to clonally mass propagate various species of plants for commercial purpose and for community development. Plant tissue culture has been applied to propagate many herbaceous plants and floricultural plants. This technology has long been used to propagate banana of Cavendish type. It is almost impossible to use suckers as planting materials for growing banana in a large area (on the scale of thousand plants) because one mother plant could only produce more or less five suckers with variable sizes. This means they have variable ontogenetic ages, which could most likely result in variable harvesting time.

Recently, some oil palm plantation companies have been using plant tissue culture to clonally mass-propagate superior mother plants to produce a large number of planting materials. Traditionally, the planting materials are hybrid seeds from hybridization of progenitors *dura*

type and *picifera* type. The hybrid planting materials, which are called *tenera* (D x P) type, are of high variability genetically, which in turn will result in variable productivity. If the superior *tenera* (D x P) type is selected, and clonally mass-propagated, superior uniform planting meterials will be produced and productivity will increase. It was reported that productivity of oil palm using clonal tenera plants was 30% higher than that using (D x P) seeds (Ng et al., 2003). Similar results were also reported by Alwee et al.(2010), when comparing productivity of oil palm plants derived from clonal propagation and those derived from (D x P) seeds.

Tissue culture-facilitated plant breeding for supporting productivity. The use of plant tissue culture for facilitating plant breeding includes embryo rescue, production of homozigous, pure lines of plants for hybrid variety production; induction of desirable, heritable trait through somaclonal variation; mutation breeding and plant genetic engineering.

Embryo rescue could be conducted by tissue culture by culturing the embryos, unless otherwise they will undergo abortion. The embryos being rescued are usually resulted from hybridization of distantly related plants. For example, rice varieties called NERICAs (New Rices for Africa) are derived from hybridization between *Oryza glaberrima*, an African species, and *Oryza sativa*, an Asian species. *Oryza glaberrima* are local variety which is well adapted to local agroclimate conditon (Africa) but has low productivity (yield of about 1 ton per hectar), while *Oryza sativa* is not adapted to African agroclimate condition but shows relatively high productivity (yield of about 5 tons per hectar). The resulting NERICAs show characteristics of the African and Asian rice varieties. The characteristics of Africal rice varieties include tolerant to drought stress, poor nutrient condition and mineral toxicity, and local pest and disease; grow well on upland condition, and perform early vigorous growth. The characteristics of Asian rice varieties include producing more erect leaves and full panicles of grain and showing earlier harvesting time i.e 90-100 days after planting, which is 30-50 days earlier than local varieties. The NERICAs has higher yield (around 4 tons per hectar) compared to the African varieties (approximately 1 ton per hectar).

Plant tissue culture can be applied for producing homozigous, pure lines of plants for hybrid variety production. This is done by culturing haploid cells such as those from anthers and pollen grains of plants derived from the hybridization of two or more progenitors with desired characters, allowing them to proliferate as calli, which expectedly consist of haploid cells. Chromosome doubling could occur spontaneously or by applying a chromosome-doubling agence such as colchicines, causing the cells in the calli to become diploid. Each individual diploid cells are by theory completely homozygous, meaning that the genes at each locus are homozygous. The calli are then regenerated into population of plants which were then selected for novel characters. The selected plants could be propagated to become varieties or become parental lines for producing hybrid varieties. One example of producing homozygous plant of rice using plant tissue culture were reported by Dewi and Purwoko (2016).

Plant tissue culture could be used to induce somaclonal variations. Somaclonal variations could be defined as genetic variations in somatic cells resulted from in vitro culture of plants (tissue culture of plants). Inducing somaclonal variations could be used as a means to produce new varieties with desired characters. Somaclonal variations usually result from induction and proliferation of callus in a tissue culture system. The rapid induction and proliferation of callus may lead to changes in genes which in turn cause changes in heritable characters. In a breeding program for certain novel characters, the proliferating calli are subjected to a selection pressure which is related to the desired characters. In this case, the proliferating calli are cultured on the media containing selection pressure materials, and the survived cells are then selected and regenerated into plants. Some researchers used polyethylene glycol (PEG) as a selection pressure to obtain plants with drought tolerance. Some also used sodium chloride as a selection pressure material to obtain plants with both tolerance to drought and high salinity stress. The selection pressure materials could also be those to mimic biotic stresses. For example, some researchers used toxins as a selection pressure material to produce plant varieties with tolerance to patogens that release the toxins.

Plant tissue culture could facilitate mutation breeding and plant genetic engineering. In this case, certain concentration (LD_{50}) of mutagenic chemical agence such

as EMS (ethyl methanesulfonate) could be put into culture of proliferating callus or shoots. The lethal dosage (LD_{50}) of EMS should be determined an experiment. The survived callus or shoots are then regenerated into plants and the plants are selected for desired characters. The mutagenic agence could be physical, such as gamma ray. As with the chemical mutagenic agence, LD_{50} of physical mutagenic agence should be determined before being applied (Hapsoro et al., 2018)

Basically, plant tissue culture is not theoretical requirement for plant genetic engineering. However, almost all genetic engineering practices has used plant tissue culture system. Plant genetic engineering is a biotechnology to modify character (s) of a plant by directly inserting a gene (s) of interest into its genome. What it means by "directly" is that the sexual hybridization does not occur. The process of gene insertion uses plant tissue culture system, usually in the form of callus culture and shoot culture.

Conclusion and future prospects

Roles of plant tissue culture for supporting agricultural productivity are on the area of rapid clonal propagation and facilitating plant breeding. Rapid clonal propagation is intended mainly to provide high quality planting materials, in term of genetics, physiology, and physical appearance. Facilitating plant breeding is done by induction of genetic variability due to somaclonal variations, mutation breeding, and genetic engineering. In practice, the application of plant tissue culture technology find limitations especially in many developing contries such as Indonesia. The technology is still considered expensive. Therefore, low-cost plant tissue culture operation should be formulated. Since each plant species need special "recepie", it is necessary in the future to find more general recepie by deciphering mechanism of plant regeneration in vitro. Research in molecular biology and plant physiology on regeneration aspects of plant tissue culture will expectedly solve the problem.

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