Implications and Implementation of Biological Philosophy on Biological Topics: Plant Growth and Development

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Abstract

This article comprehensively discusses growth and development in plants, explaining the differences between these two concepts, as well as their implications in the world of education, especially at the junior high school (SMP), senior high school (SMA) and tertiary education (PT) levels. Growth is explained as an increase in the size and number of cells which is quantitative, while development is a process towards maturity which is qualitative. Growth and development in plants are interrelated and occur continuously. In middle school, students understand the various systems in plant life and the importance of growth and development. In high school, they analyze the relationship between internal and external factors and growth and development processes, and carry out experiments related to external factors in plants. The College provides students with the opportunity to conduct in-depth research on plant growth and development, developing their metacognitive abilities. This article highlights the importance of integrating plant growth and development concepts in educational curricula to create deeper understanding and better quality learning.

Keywords: Biological philosophy, Growth, Development, Plants

1. INTRODUCTION

Human knowledge is born through a systematic process in human brain activity. Each branch of knowledge, which is usually called science, has special characteristics which include the object of study, systematic, universal and objective methods of analysis and verification (Popper, 1959).

The importance of philosophy in the development of science cannot be ignored. The philosophy of knowledge aims to emphasize that knowledge about the world must reflect reality as it is (Russell, 1912). Initially, the term "philosophical" referred to all human knowledge, and the characteristics of philosophy included comprehensive aspects, being the basis for other knowledge, and containing elements of speculation in the discovery of new knowledge.

Science itself is knowledge that is rooted in reality and organized systematically. Philosophy of science overlaps with the history of the development of science, exploring the main foundations in ontology, epistemology, and axiology (Lakatos, 1978). The study of scientific development involves the analysis of visions and paradigm shifts that shape scientific revolutions (Kuhn, 1962).

Biology, whose etymology comes from Greek (bios meaning life and logos meaning science), is the science that studies living organisms and the challenges that influence their survival (Mayr, 1982). In the development of the word, biology is a science that discusses all aspects of life, helps humans understand themselves as living creatures, and solves the problems of everyday life.

Plant growth and development is the main focus in biology. This includes the relationship of living things with their environment and how plants develop (Raven, 2005). Growth involves an irreversible increase in cell size and number and can be measured quantitatively. Development, meanwhile, is a journey towards maturity that is irreversible and more difficult to measure qualitatively.

In the educational context, learning about plant growth and development is taught in a structured manner from elementary school to university. At the college level, courses such as anatomy, morphology, and plant physiology become relevant to understanding this topic. The implementation of philosophy in biology and biology education can help in a deeper understanding of plant growth and development (Dewey, 1916).

In this article, researchers will explain in detail about growth and development in plants, as well as how philosophy has implications and applications in the field of biology and biology education, especially in the context of plant growth and development.

2. METHODOLOGY

The research method applied is a critical analysis approach based on empirical data, facts and relevant theoretical frameworks, with a foundation on a comprehensive literature review from various sources. References taken come from research articles and literature reviews. The research articles used are scientific publications based on empirical research results, while literature review articles are in-depth studies of relevant literature.

The accuracy and validity of the analysis results are supported by relevant theories as well as data and facts found in various reference sources. The references used in this analysis include various peer-reviewed scientific research articles as well as literature review articles that provide an in-depth understanding of the topic being discussed.

Apart from that, the theoretical basis in this research also refers to reference books which comprehensively discuss aspects of plant growth and development. These books provide a solid foundation for further understanding of this topic. References from various books provide diverse and in-depth viewpoints on the topic under investigation.

3. DISCUSSIONS

Growth and development in plants or crops is a continuous process and is closely interrelated (Fosket, 1994; Salisbury & Ross, 1994). A simple definition of growth as an increase in size requires careful use, given that the situation can be confusing (Taiz & Zeiger, 2010). For example, plant cells can increase in size when absorbing water through osmosis, but their size may return to their original size after the water absorption process is complete (Raven, 2005).

This complex process requires us to differentiate between growth and development by referring to relevant literature (Kumar & Sözen, 2018). For example, during cell division of the zygote and early stages of the embryo, there is an increase in the number of cells without an increase in cell size (volume or mass), which can be classified as development, but also involves elements of growth (Poethig, 2013).

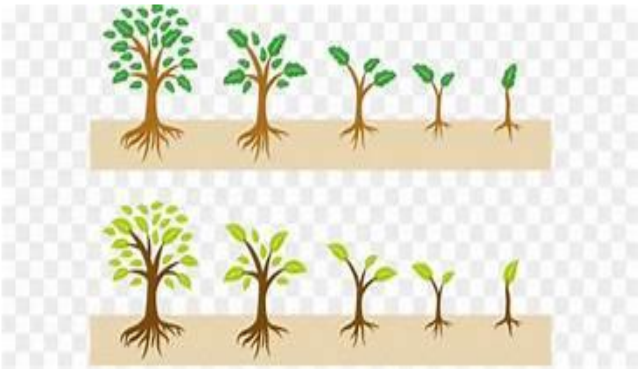


Figure 1: Illustration of plants on plants

To measure the longitudinal growth of plants, a tool called an Auxanometer is used. This tool is equipped with a pulley system and a pointer on a scale arc or needle that can scratch the rotating cylinder (Wareing & Phillips, 1981). The working principle is that as the plant grows, the pulley connected to the thread will move, indicating growth, and this is reflected in the scale needle being moved by the rising weight or the needle on the rotating cylinder which produces additional scratch marks on the cylinder. Growth speed is measured on an increasing time scale.

Plant growth can be positive or negative (Salisbury & Ross, 1994). Positive growth occurs when anabolism exceeds catabolism, resulting in an increase in plant dry weight. For example, primary and secondary growth in plants are examples of positive growth. On the other hand, plant growth can be negative, such as in the germination process (Fosket, 1994). During seed germination, several physical parameters increase, such as cell number, cell size, wet weight, length, volume, and shape complexity. However, dry weight can actually decrease (Raven, 2005).

1. Germination

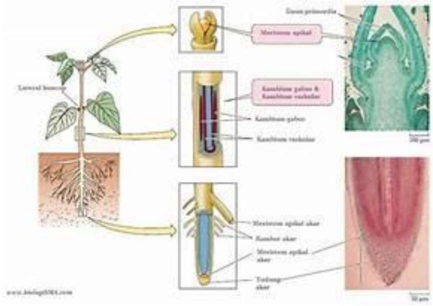
Germination is the initial phase of the development cycle of seed plants, which involves the process of embryo growth which begins after the process of imbibition or water absorption (Bewley & Black, 1994). During this phase, the embryo which was originally in a dormant state undergoes a number of physiological changes which help in its development into an active young plant (Bewley & Black, 1994; Hidayat, 1985).

It is important to understand that growth in plants can be positive or negative depending on the balance between anabolism and catabolism (Salisbury & Ross, 1994). Positive growth occurs when anabolism exceeds catabolism, resulting in an increase in plant dry weight. Examples of positive growth are primary growth and secondary growth in plants (Fosket, 1994). On the other hand, plant growth can be negative, such as in the germination process (Bewley & Black, 1994). During seed germination, various physical parameters increase, including cell number, cell size, wet weight, length, volume, and shape complexity (Raven, 2005).

2. Primary Growth

Primary growth is a growth stage caused by cell division activity in the apical or primary meristem, which results in the elongation of plant roots and stems (Esau, 1977). Apical meristem is meristematic tissue found at the tips of roots and stems of plants, and is characterized by cells that have thin cell walls and are always in the division stage, but have not yet differentiated into specialized cells (Fosket, 1994; Raven, 2005).

Figure 2: Apical meristem tissue structure



Primary meristems originate from promeristems, which in turn develop into various types of tissue, including protoderm (future epidermis), procambium (future transport vessels), and ground meristem (future parenchyma) (Esau, 1977; Salisbury & Ross, 1994). The apical meristem can be divided into three main regions: the division region, the elongation region, and the differentiation region (Taiz & Zeiger, 2010). During the process of apical meristem elongation, the apical bud, which is initially a tip bud, will differentiate into side branches, leaves and flowers (Salisbury & Ross, 1994).

This in-depth understanding of primary growth is an important aspect in plant biology and agriculture, and much research has been carried out to reveal the molecular mechanisms and regulation of apical meristem growth (Taiz & Zeiger, 2010; Poethig, 2013). In addition, this knowledge has practical implications in efforts to develop plants that are more productive and resistant to environmental stress (Kumar & Sözen, 2018).

3. Secondary Growth

Secondary growth is a growth stage that is triggered by cell division activity in the lateral meristem, which results in an increase in the diameter or thickness of plant roots and stems (Chaffey et al., 2002). This lateral meristem allows plant organs to develop laterally or sideways (Chaffey et al., 2002). Two important types of lateral meristem are cambium and cork cambium (phellogen) (Chaffey et al., 2002).

The cambium plays a role in the growth of plant diameter by forming the phloem layer which points outwards and the formation of the xylem layer which points inward (Scherp et al., 2001). Meanwhile, cork cambium, or phellogen, produces a protective layer known as periderm, or cork (Liese & Köhl, 2015). The development of the periderm layer is important in protecting and isolating stems and roots from the external environment (Liese & Köhl, 2015).

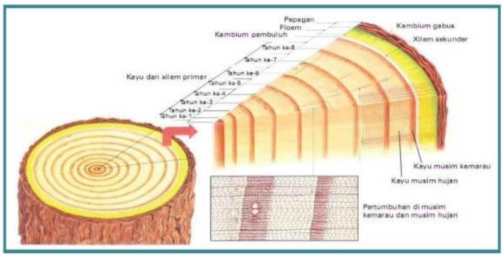


Figure3: Appearance of year rings on the stem

This understanding of secondary growth has implications in plant breeding and wood production, as well as in understanding how plants adapt to changing environmental conditions (Fahn & Werker, 1972; Chaffey et al., 2002; Liese & Köhl, 2015). Recent studies have also revealed complex molecular roles in this secondary growth regulation (Hussey et al., 2013; Suer et al., 2011).

4. Plant Development

Development in the context of plant biology is a process that involves cell differentiation, organogenesis, and the formation of new individuals that are more mature qualitatively (Rastogi, 2012). This development is a change that cannot be measured in numbers and lasts throughout the life of a living creature, not limited by age (Knox, 2014).

One significant example of development in plants is the flowering process in the angiosperm plant group (Taiz & Zeiger, 2010). The important stages in the flowering process of angiosperm plants can be divided into six stages as follows:

a. Flower Induction (Evocation): At this stage, the meristem tissue undergoes transformation into reproductive meristem tissue (Bowman et al., 2012).
b. Flower Initiation: This process involves the morphological change of the vegetative bud into the reproductive bud form (Coen & Meyerowitz, 1991).
c. Towards Blooming Flower: This stage includes the differentiation of flower components, such as megasporogenesis and microsporogenesis, as well as the maturation of male and female reproductive organs (Rastogi, 2012).
d. Flowers Bloom (Anthesis): At this stage, flower opening occurs, often coinciding with the maturity of the male and female reproductive organs (Taiz & Zeiger, 2010).
e. Pollination and Fertilization: This process involves the pollination of the female reproductive organs by the male reproductive organs, resulting in the formation of immature fruit (Simpson & Johnson, 2001).
f. Fruit and Seed Ripening Development: This stage begins with the enlargement of the ovaries and involves the development of the endosperm (food reserves) as well as embryo development (Knox, 2014).

A deeper understanding of these developmental processes has a significant impact on agriculture, plant reproduction, and the study of plant biology as a whole (Mauseth, 2003; Rastogi, 2012; Simpson & Johnson, 2001).

5. Factors that Influence Growth and Development in Plants

The process of plant growth and development is strongly influenced by internal and external factors, which interact with each other with high complexity so that it is difficult to determine which factor is more dominant (Taiz & Zeiger, 2010).

Internal factors:

a. Intracellular Factors: These internal factors are related to genetics and the potential for plant growth and development (Taiz & Zeiger, 2010). Genes in plants play an important role in regulating these processes (Moore et al., 1995).

b. Intercellular Factors (Plant Hormones): Plant hormones are chemical compounds produced in small amounts by plants and influence their growth and development (Moore et al., 1995). Important groups of plant hormones include auxins, gibberellins, cytokinins, abscisic acid, calin, traumatic acid, and ethylene gas (Taiz & Zeiger, 2010). Each hormone has a special role in regulating the growth and development of plant cells.

External Factors:

a. Nutrients: The availability of nutrients such as nitrogen, phosphorus, and potassium affects plant growth (Marschner, 2012). Adequate nutrition is important for healthy growth and development.
b. Light: The intensity, duration and spectrum of light received by plants greatly influences the photosynthesis and growth processes (Smith, 2000).
c. Temperature: Environmental temperature influences the rate of chemical reactions in plants and can affect growth (Hänninen, 2016).
d. Humidity: Air and soil moisture levels also play a role in plant growth (Passioura, 2006).
e. Aeration: Soil aeration and air circulation around plants influence root absorption and root growth (Colmer & Voesenek, 2009).

A deep understanding of these factors is important in agricultural management, optimal plant growth, and plant adaptation to environmental changes (Kramer & Boyer, 1995; Taiz & Zeiger, 2010).

6. Implications and Implementation of Growth and Development in Plants in Biology and Biology Education

The study of growth and development in plants has important implications in various aspects of human life, especially in the context of agriculture and food production. This knowledge is the basis for developing efficient and sustainable agricultural methods (Sadava et al., 2013). Apart from that, this topic also plays a vital role in education, especially in biology learning at various levels of education (Dahler, 2011).

The importance of understanding growth and development in plants has had a positive impact in various fields, including modern agriculture (Sadava et al., 2013). Apart from that, this material is also applied in formal education, especially at middle and high school levels, as well as in universities in biology-related study programs (Dahler, 2011). The learning process at various levels of education has different goals, according to the level of cognitive development and abilities of students.

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At Middle School Level:

At the Junior High School (SMP) level, material on plant growth and development is usually presented in class VIII odd semester with basic competencies (KD) which include an understanding of various systems in plant life and analysis of the importance of growth and development in plants (Ministry of Education and Culture of the Republic Indonesia, 2017). At this level, learning still includes three dimensions of knowledge: factual, conceptual, and procedural which are associated with cognitive abilities such as classifying (C3).

At High School Level:

At the Senior High School (SMA) level, material on growth and development in plants is usually presented in class which influences plant growth and development (Ministry of Education and Culture of the Republic of Indonesia, 2017). Students at the high school level are expected to be able to explain the concept of growth and development in plants, understand the characteristics of growth and development, and analyze the factors that influence growth and development (Dahler, 2011). The learning process still includes three dimensions of knowledge and cognitive abilities up to the analyzing level (C4).

At the College Level:

At the Higher Education (PT) level, students are expected to develop higher metacognitive abilities (Anderson & Krathwohl, 2001). The material on plant growth and development at this level includes aspects of understanding concepts in depth and the ability to carry out independent research. Students are required to carry out research that comes from solving problems, drawing conclusions, and analyzing data independently. At this level, cognitive abilities reach the creating level (C6) (Dahler, 2011).

The use of this material at various levels of education shows that understanding the growth and development of plants is an important aspect in the educational curriculum. Apart from that, creative and innovative learning methods can also increase students' understanding of this material. Creating connections between this material and everyday life can also facilitate understanding and reduce misconceptions (Zubaidah, 2018).

Thus, a good understanding of growth and development in plants is not only important for science but also for developing the potential of students in biology and agriculture, as well as for increasing awareness of the importance of the natural environment and sustainable agriculture.

4. CONCLUSIONS

Based on the description of the material above, it can be concluded that growth and development in plants are two interrelated processes, where growth includes quantitative increases such as size and number of cells, while development is related to qualitative changes towards maturity. This process occurs continuously in plant life. Education also plays an important role in conveying growth and development material at various levels, from junior high school to university. At the junior high school level, students are taught about systems in plant life and the importance of plant growth and development. At the high school level, they analyze the relationship between internal and external factors and the growth and development processes of living things and conduct experiments related to external factors on plants. Furthermore, in higher education, students are given the opportunity to conduct research on plant growth and development, developing their metacognitive abilities in a more complex way. This conclusion reflects the importance of understanding and integrating the concept of plant growth and development in the educational curriculum to create a deeper understanding and better quality of learning.

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