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The Implementation of Experiments on the Effect of Apical Bud Pruning on the Growth of the Axillary Buds of Tahun Spinach (*Amarantus hybridus L.*) in Horticultural Courses

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ABSTRACT

This study was carried out to enlighten students about the effects of apical bud pruning on the growth of axillary buds, as well as determine if this learning model can be implemented in the learning process for horticulture courses in IKIP Saraswati. A fully randomised design method was used to evaluate the effect of apical bud pruning on the growth of axillary buds in spinach plants. The samples were assigned to the following groups: the first group (J0) served as the control for the experiment while the experimental groups had varying lengths of pruned apical buds (J1- 3cm, J2- 6cm, J3-9cm and J4- 12 cm). Each test was replicated four times to reduce variability in the experimental results. The findings of the study showed that the pruning of apical buds led to an increase in the formation of leaves and the growth of axillary buds. Although the numbers of axillary buds in spinach plants from each treatment group were significantly different, the most notable disparity was observed in J1 plants with an average axillary bud growth of 66. The use of this experiment-based learning approach enhanced the students' ability to use their cognitive, social, psychomotor, and problem-solving skills in the acquisition of knowledge, as well as the analysis and interpretation of data. Based on these findings, it can be concluded that the practical experiment on the effect of apical bud pruning on axillary bud growth should be implemented in the learning process for horticulture courses in IKIP Saraswati. Despite the benefits of the experimental based learning approach, there are certain limitations to its successful implementation in the education system. Some of these include the integration of the experimental learning method to the existing curriculum for horticulture courses, the need to develop new assessment methods in order to evaluate the efficacy of this method, and the insufficient support of teachers and administrators at different tiers of government. This paper also provides recommendations on effective ways to address these challenges and maximize the benefits provided by the experimental based learning methods in the education system.

Keywords: spinach, apical bud, axillary bud, horticultural

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INTRODUCTION

Spinach (*Amarantus Hybridus L.)* is an herbaceous plant that is popularly found in different terrestrial ecosystems. This plant has a long and extensive tap root system that spreads in diverse directions. The highly branched network of the spinach's root system increases the surface area required for the absorption of water and minerals from the soil into the plant during drought conditions. Spinach is an annual plant that can be propagated using seeds during the cool season. Spinach has broad dark green leaves that are succulent, smooth, and fleshy (Ribeiro, Pieterse, & Famba, 2017). The plants grow to reach approximately 5cm to 8cm in height, and 1cm to 1.5cm in width.

Although there are more than 750 species of spinach, the plant can be classified into two major groups: cultivated spinach and wild spinach (Ribeiro et al., 2017). The two main types of wild spinach include spiny spinach (*Amaranthus spinosus L.*) and ground spinach (*Amaranthus blitum L.)* while the major classes of cultivated spinach are the sekul spinach (*Amaranthus tricolour L.)* and tahun spinach (*Amaranthus hybridus L.*). Some of the features of the sekul spinach include red or white green stems, branches, and flowers. The plants with white stems are called white spinach, while those that have red stems are known as red sekul (Ribeiro et al., 2017). On the other hand, the tahun spinach has distinctive leaf characteristics (such as the length and colour of its flowers), which have been used to classify the members of the group into the following species: *Amaranthus hybridus caudatus L.* and *Amaranthus hybridus paniculatus L.*

Spinach is one of the major sources of nutrition to people living in developing countries (Ribeiro et al., 2017). The nutrient composition includes carbohydrates, fat, calcium, protein, phosphorus, vitamin A, iron, vitamin B1, vitamin C, and water (Miano, 2016). The leaves of the plant can be used as a major ingredient for soups, gado-gado, pecel, and other dishes. Spinach is also considered as a good source of protein for vegetarians. Other health benefits of spinach to humans include its use as an active ingredient in traditional medicine, as well as beauty and skincare products (Miano, 2016; Ribeiro et al., 2017). For instance, the roots of the red spinach may be used to treat diarrhea and dysentery, while the flowers and the leaves can cure eczema and asthma. Even to a certain extent, spinach can overcome various types of internal diseases. Moreover, the seeds of the plant can be used in food production processes such as bread making, or the cooking of seed porridge. The extract of spinach seeds can also be used to manufacture drugs to stop excessive blood flows during menstruations and the release vaginal discharge (Miano, 2016).

The numerous benefits of spinach plants to human health have necessitated the development of effective methods to increase the growth of the axillary buds of the plant (Abunmi & Sakariyawo, 2019). The rise in the growth of a high number of axillary buds results in the formation of more branches of the plant and spinach leaves (Barbier, Dun & Beveridge, 2017). Some researchers have recommended that apical pruning is an effective way to increase the formation of spinach leaves (Adamowski, & Friml, 2015; Anjarsari, Hamdani, Suherman & Nurmala, 2019). This technique has been practiced in different parts of the world by horticulturists. Pruning has been carried out on cucumbers, garden peas, vines, and tea plants to increase fruit production, growth, and yield of plant leaves (Maudu, Mudau & Mariga, 2010; Ding et al., 2015; Fichtner et al., 2017). However, the process must be conducted at specific intervals to obtain the most desired results (Anjarsari et al., 2019). The purpose of pruning may vary in different types of plants (Barbier et al., 2017). For instance, pruning is carried out in vines to increase fruit production, while the process is applied to improve the formation of buds in tea plants (Azizi et al., 2015; Barbier et al., 2015; Anjarsari et al., 2019). This technique has also been used to enhance the formation of leaves in tobacco plants, as well as the height, number of branches, and fertile segments in soybean plants. The pruning of apical buds stimulates the growth of axillary buds (Barbier et al., 2019). Studies have revealed that proper pruning of apical buds may result in a 35% increase in the number of axillary buds that grow to form branches in different plants (Yuan et al., 2015; Francois, Elizabeth & Christine, 2017). The process also triggers the formation of primary and secondary axillary buds and leads to the formation of a high number of leaves (Bennett et al., 2016; Kebrom, 2017). Moreover, the inhibition of the growth of dominant axillary buds (known as apical dominance) can be eliminated by the pruning of apical buds.

Apical dominance can be described as a phenomenon in which the main stem of the plant inhibits the growth of buds and other shoot systems (Barbier, Dun, & Beveridge, 2017). Apical dominance damages the tip of shoots, and inhibits the formation of branches from axillary buds in various plants. This phenomenon is caused by the presence of an inhibitory plant hormone known as Indole Acetic Acid (auxin). The transport of auxin in the stem affects the growth of branches in plants through the regulation of two groups of hormones: cytokinins and strigolactones (Barbier et al., 2017; Xin et al., 2017; Xue et al., 2018). These plant hormones play significant roles in regulating the outgrowth of buds in plants. The signaling mechanisms for the upward transport of cytokinin and strigolactone are regulated by the Branched1/Teosinte Branched1 (BRC1/TB1) transcription factors (Yang & Jiao, 2016; van Rongen et al., 2019). Although the outgrowth of buds is inhibited by the lack of specialized carrier proteins that transport auxin into plant buds, the high demands of growing shoots for sugars may also contribute to the presence of strong apical dominance in plants (Barbier et al., 2017). Barbier et al. (2017) explained that sugar molecules may act as a stimulus that inhibits the outgrowth of axillary buds. Over the years, it was discovered that the removal of shoot tips gradually results in a decrease in the concentration of auxin in the stem. This process also triggers the translocation of sugars to other parts of the plant, and the growth of axillary buds. The occurrence of a complete life cycle in pruned plants that exhibit strong apical dominance depends on the successful growth of axillary buds to form branches (Barbier et al., 2017; Xin et al., 2017; Xue et al., 2018). On the other hand, plants that display weak forms of apical dominance respond differently to such shoot treatments because they already have the ability to form branches (Adamowski, & Friml, 2015; Anjarsari, Hamdani, Suherman & Nurmala, 2019). Nonetheless, researchers have documented that the removal of shoot tips is an effective way to promote the growth of axillary buds and formation of more leaves in a plant (Adamowski, & Friml, 2015; Barbier et al., 2017; Anjarsari, Hamdani, Suherman & Nurmala, 2019). This technique has been used to improve the features of trees, as well as maximize the ability of plants to absorb water and nutrients from the soil.

Many studies have indicated that apical dominance is caused by a hormone called auxin, which can be found in the meristematic region, particularly the apical buds of plants (Kebrom, & Mullet, 2015; Li et al., 2016; Xin et al., 2017; Leyser, 2018; Anjarsari et al., 2019). The transport of auxin in the lower part of the stem results in the accumulation of the hormone in the armpit leaves, thereby inhibiting the formation of axillary buds. It also affects the growth of axillary buds in plants (Mathan, Bhattacharya, & Ranjan, 2016). The bicipital theory of auxin transport explains that the transport of this hormone from the axillary bud to the main stem initiates the growth and development of buds (Muller et al., 2015). During this process, a high amount of auxin may accumulate in the lateral buds of plants that exhibit strong apical dominance (Pernisova et al., 2016; Xie et al., 2018; Qiu et al., 2019). Consequently, this affects the transport of the hormone to the stem, as well as the growth of axillary buds (Muller, Larsson, Spichal & Sundberg, 2017). The effects of a high concentration of auxin in such plants can be reduced by decapitation treatment. This process results in a rise in cytokine levels in the stem and axillary buds of the plant, thereby resulting in the formation of branches with many leaves (Muller et al., 2015; Nguyen & Neil, 2015; Qiu et al., 2019). A study carried out by Qiu et al. (2019) indicated that the outgrowth and dormancy of axillary buds are coordinated by auxin and cytokinin in the plant. The authors discovered that high auxin levels were present in dormant buds, while an increase in cytokinin activity was observed in non-dormant buds. The application of decapitation treatment on dormant buds resulted in a decrease in the concentration of auxin in the lateral buds and the development of axillary buds. Moreover, the study indicated that the levels of both hormones must be equilibrated in the plant to accelerate the growth and development of axillary buds.

Horticulture courses have been included in the biology program at IKIP Saraswati to improve the basic knowledge of students about horticultural practices, as well as enhance the application of horticultural techniques in farming and gardening. These courses are expected to help students use the various principles, concepts, and procedures of horticulture studies in the discovery, analysis, and development of solutions to the challenges associated with the incorporation of science and technology to existing practices in this field of study. In this regard, efforts have been made to enable students to identify the important factors that influence the success of the horticulture business. In this regard, education experts have proposed the adoption of active learning practices to trigger the process of critical thinking and processing in students (Deslauriers et al., 2019). This technique will also improve the research, analytical, and problem-solving skills of learners.

A major challenge that affects the learning of students is the lack of motivation to develop critical reasoning skills (Arliantya, Febriana, & Diniaty, 2017). This may be attributed to the inefficacy of the traditional teaching methods used in different institutions. In this regard, it is important to develop learning approaches that will improve the cognitive, affective, and psychomotor skills of students. Learning activities in the classroom are not enough to enhance these attributes in learners because the information provided by the teacher is solely based on the theories documented in the reading materials (Deslauriers et al., 2019). As a result, students are not actively involved in the learning process. An effective learning process must be oriented to the independent development of students' knowledge.

An effective way to improve learning outcomes in students is the application of an experiment based learning model (Harr, Eichler & Renkl, 2015; Thanida, Jintawat, and Aungtinee, 2019). This process of learning involves the use of concrete experience, collaborative activities, reflection, and interpretation to foster the acquisition of knowledge, as well as the development of cognitive, affective, and psychomotor skills in students (Thanida, Jintawat, and Aungtinee, 2019). Experiment based learning facilitates the development of new ideas and concepts by students. This model can be used to improve learning outcomes in science because it provides the diverse conditions that enhance the thinking and creativity of learners. Moreover, experiment-based learning gives students the opportunity to construct their concepts in their cognitive structure, and apply the knowledge they have acquired in their everyday lives (Harr, Eichler & Renkl, 2015; Thanida, Jintawat, and Aungtinee, 2019). In view of this, a study was carried out using experimental-based learning methods to improve the acquisition of knowledge, as well as the cognitive and problem-solving skills of students. The purpose of this research was to enlighten learners about the effects of apical bud pruning on the growth of axillary buds, as well as determine if this experimental model can be implemented in the learning process for horticulture courses in IKIP Saraswati.

METHOD

Research approach

The fully randomized design method was used to evaluate the effect of apical bud pruning on the growth of axillary buds in spinach plants. This experimental approach involved the random classification of normal and pruned buds into five different treatment groups, a control group, and four test groups.

Cultivation of spinach plant

Fourteen-day old spinach seedlings obtained from prepared seeds were planted into different seedbeds for 7 days. The seedlings were then transferred to various experimental pots. Each pot contained only one spinach seedling.

The pruning of apical buds

The 21-days-old spinach seedlings were grouped into five different groups. The first treatment group (J0) served as a control for this experiment. It comprised seedlings with intact apical buds. The remaining treatment groups and the varying lengths of the apical buds of spinach seedlings that were cut off include the following: J1- 3cm, J2- 6cm, J3-9cm, and J4- 12 cm. Each test was replicated four times to reduce variability in the experimental results. The total number of axillary buds observed after the pruning of the apical buds was recorded at 7 days interval until the plant was 41 days old.

Data analysis

The data obtained in this study were analyzed to determine the significance of the findings generated in this research. The statistical methods used include the normality test and homogeneity test. The Kolmogorov-Smirnov and Shapiro-Wilk tests were used to determine the normality of the data, while the Levene test was used to investigate the heterogeneity of the data. The significance level (α) for this experiment was set at 0.05. The criteria used to draw conclusions about the normality and homogeneity of the data include the following: if the probability value (p) is greater than the significance level (α), the numbers are not significant (accept the null-hypothesis). However, if the probability value (p) is less than the significance level (α), the numbers are not significant (reject the null-hypothesis). The former criterion indicates that the sample data were obtained from normally distributed populations, while the latter depicts that the data were not obtained from a population that follows a Gaussian distribution. The experimental data that fulfills all the requirements of the normality and homogeneity tests will be subjected to the one-way ANOVA test. If the result of this analysis indicates that there was a significant difference between the data observed in each experimental group, the Least Significance Difference (LSD) test will be carried out to determine the groups that are statistically different from each other. The learning outcomes of students using the experimental-based learning method was also evaluated using formative assessments.

RESULT

A total number of 1,013 spinach seedlings were randomly assigned into five different groups (Table 1). The calculated values of axillary buds observed in each replicate of the 41-days old spinach plants are shown in Table 1 and Figure 1.

Table 1. The total number of axillary bud growths in each treatment

REPLICATE (N)	Treatment				
	J0	J1	J2	J3	J4
	(Control)	(3 cm)	(6 cm)	(9 cm)	(12 cm)
I	32	58	53	52	47
II	39	60	48	55	51
III	51	74	59	48	35
IV	41	72	40	53	45
Total	163	264	200	208	178
Average	40.75	66	50	52	44.5

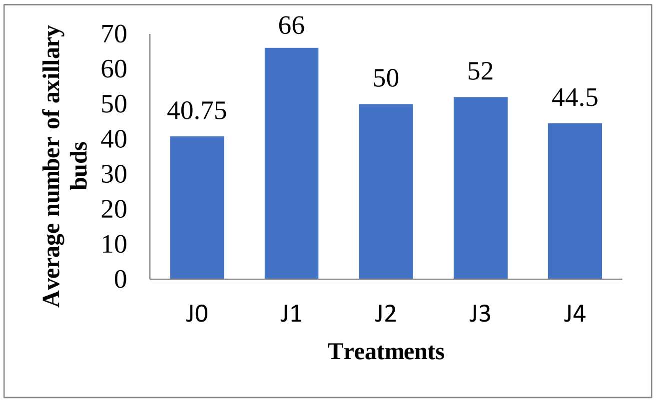

Figure 1. The average number of axillary bud growths in each treatment

Normality and Homogeneity tests

The results of the Shapiro-Wilk test are shown in Table 2. This figure indicates that the probability values for each treatment group (J0- 0.971, J1- 0.844, J2-0.994, J3-0.953, and J4- 0.923) is greater than 0.05. This indicates that the data were collected from a population that follows a Gaussian distribution.

Table 2. Normality test results

	Shapiro-Wilk Test		
	Statistic	**df**	**p**
J0	.971	4	.845
J1	.844	4	.207
J2	.994	4	.979
J3	.953	4	.734
J4	.923	4	.556

KEYS: df- degree of freedom
p- probability values

The result of the Levene test is shown in Table 3. This figure indicates that the probability value for the treatment groups, 0.379, is greater than 0.05. This depicts that the data were derived from a normally distributed population. Based on this finding, it can be inferred that the variability of the data obtained in this study is homogenous.

Table 3. Homogeneity test results

Levene Test			
Statistic	**df1**	**df2**	**p**
1.132	4	15	.379

KEYS: df1- the first degree of freedom
df2- the second degree of freedom
p- probability value

Based on the results of the normality and homogeneity tests, an ANOVA test was carried out to determine if there are significant differences between each treatment group. The results of the analysis are shown in Table 4.

Table 4. Results of the one-way ANOVA test

	Sum of Squares	df	Mean Square	F	p
Between Groups	1494.800	4	373.700	7.537	.002
Within Groups	743.750	15	49.583		
Total	2238.550	19			

KEYS: df- degree of freedom
p- probability value

Table 4 shows that the p-value, when F is 7.537 is 0.002. This is less than the predetermined significant value (0.05). In this regard, it can be inferred that there is a significant difference between the numbers of axillary bud growths in each treatment.

Based on the result of the one-way ANOVA test, the Least Significance Difference (LSD) test was carried out to determine the treatment groups that are significantly different from each other (Table 5). Table 5 shows that five pairs of treatment groups (highlighted in yellow) were significantly different from each other. These include J1 and J0, J1 and J2, J1 and J3, J1 and J4, as well as J0 and J3. The most notable disparity was observed between J0 (the control group) and J1 (treatment group subjected to 3 cm apical bud pruning). These findings indicate that the most distinct number of axillary bud growth was recorded in J1.

Table 5. Results of the Least Significance Difference (LSD) test

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
J0	J1	-25.250*	4.979	.000	-35.86	-14.64
	J2	-9.250	4.979	.083	-19.86	1.36
	J3	-11.250*	4.979	.039	-21.86	-.64
	J4	-3.750	4.979	.463	-14.36	6.86
J1	J0	25.250*	4.979	.000	14.64	35.86
	J2	16.000*	4.979	.006	5.39	26.61
	J3	14.000*	4.979	.013	3.39	24.61
	J4	21.500*	4.979	.001	10.89	32.11
J2	J0	9.250	4.979	.083	-1.36	19.86
	J1	-16.000*	4.979	.006	-26.61	-5.39
	J3	-2.000	4.979	.694	-12.61	8.61
	J3	5.500	4.979	.287	-5.11	16.11
J3	J0	11.250*	4.979	.039	.64	21.86
	J1	-14.000*	4.979	.013	-24.61	-3.39
	J2	2.000	4.979	.694	-8.61	12.61
	J4	7.500	4.979	.153	-3.11	18.11
J4	J0	3.750	4.979	.463	-6.86	14.36
	J1	-21.500*	4.979	.001	-32.11	-10.89
	J2	-5.500	4.979	.287	-16.11	5.11
	J3	-7.500	4.979	.153	-18.11	3.11

*- The mean difference is significant at the 0.05 level

Evaluation of Learning Outcomes in Students

A formative assessment was carried out to evaluate the learning outcomes of the students who participated in this experiment. The results showed that:

1. The experience acquired by the learners during the process of active experimentation increased their level of motivation and engagement in the learning process.
2. The practical experiment provided real-life ambiguities and complexities that helped students to redefine their theoretical understandings of different concepts.
3. This experiment helped learners to understand that the acquisition of knowledge is a continuous process that depends on their proper use of scientific methods, active engagement, and deductive and inductive reasoning skills.
4. This learning approach enabled learners to use their cognitive, psychomotor, and problem-solving skills to identify issues, develop, and test the efficacy of the solutions they provided as a group.
5. This learning approach fostered collaboration between students and provided opportunities for learners to brainstorm, and acquire important leadership, communication, and coordination skills.

DISCUSSION

The results of the ANOVA ad LSD tests indicated that there was a significant difference between the numbers of axillary buds observed in the spinach plants subjected to different pruning treatments. The growth of axillary buds in spinach plants that were pruned on their apical buds was higher than those that were not pruned in this region (Wang, Smith, & Li, 2018). The findings of this experiment may be attributed to the production of auxin in the meristematic region of the spinach (Anjarsari, Hamdani, Suherman, & Nurmala, 2019; Qiu et al., 2019). The transport of auxin to the lower portion of the stem may have resulted in the accumulation of this plant hormone in the armpit leaves of the plant, thereby inhibiting the formation of axillary buds (Qiu et al., 2019). The growth of axillary buds in plants subjected to apical pruning suggests that this treatment reduced the occurrence of apical dominance in the spinach plants (Rameau et al., 2015; Procko et al., 2016). This may be due to the transport of auxin from the armpit leaves to the main stem (Shu, Liu, Xie, & He, 2016; Smehilova et al., 2016; Tarancon et al., 2016). In this regard, it can be inferred that the decrease in the accumulation of the hormone-stimulated the growth of axillary buds (Robert et al., 2015; Shi et al., 2016). The findings in this study are in accordance with the reports of Anjarsari, Hamdani, Suherman, and Nurmala (2019), and Qiu et al. (2019). These authors documented that the pruning of apical buds stimulates the growth of dormant axillary buds and the development of leaves and branches from the primary and secondary axillary buds of the plant.

Furthermore, the findings obtained from this experiment showed that there were significant differences between the following pairs of treatment: J1 and J0, J1 and J2, J1 and J3, J1 and J4, as well as J0 and J3. The most notable disparity was observed between J0 (the control group) and J1 (treatment group subjected to 3 cm apical bud pruning). The result of this study also indicated that the greatest axillary bud growth was recorded in J1, with an average number of 66 buds. The findings generated in this study are in consonance with the report of Qiu et al. (2019), which documented that the outgrowth and dormancy of axillary buds are coordinated by the presence of auxin and cytokinin in the plant.

At the beginning of the study, the levels of both hormones in the axillary nodes were determined to monitor its translocation to the stem of the plant. The result of the measurement revealed that there was a decrease in the concentration of auxin in the axillary nodes that were far from the tip of the apical buds while there was an increase in cytokine levels in this region (Sun et al., 2016; Truskina & Vernoux, 2018). As a result, there was rapid growth in the lower part of the axillary nodes compared to the upper area of the spinach. This observation may be due to the high levels of cytokine in the lower axillary nodes, which stimulated the occurrence of the mitotic division, and differentiation of cells in meristematic tissue, as well as the growth of axillary buds and formation of leaves (Waldie & Leyser, 2018; Wang & Jiao, 2018; Wang et al., 2019; van Rongen, Bennett, Ticchiarelli & Leyser, 2019). These findings suggest that there must be equilibrium between the ratios of auxin and cytokine to stimulate axillary bud growth in spinach plants. The result of this experiment is in agreement with the report of Qiu et al. (2019), which emphasized that decapitation treatment can increase the level of cytokines in the axillary buds and the main stem of plants. Based on the data obtained from this study, it can be inferred that the optimum equilibrium of the ratio of auxin and cytokinin was attained in the plant subjected to an apical bud pruning of 3cm away from the stem (J1). This is based on the fact that the spinach in this category had the highest number of axillary bud growth.

In the past decade, a major problem in the education system has been the poor efficacy of traditional learning methods (Darling-Hammond et al., 2019). Although this teaching technique is designed to measure the cognitive performance of students, it does not encourage students to develop critical reasoning and problem-solving attributes. The learning constructivism paradigm facilitates the measurement of cognitive, affective, and psychomotor skills in learners. However, these core competencies cannot be enhanced using learning activities in the classroom because students are expected to rely on the theoretical information provided by the teacher about the topic (Yadav, 2015; Darling-Hammond et al., 2019). As a result, the learners may not be able to apply the theoretical knowledge acquired in practical experiments (Oka, 2016; Thanida, Jintawat, and Aungtinee, 2019). This phenomenon has led to a paradigm shift in the education system in which the role of educators in conveying knowledge to students has been replaced with the active involvement of students in the development of their potential and creativity.

The academic potential and creativity of learners can be enhanced by observing, questioning, associating, experimenting, and networking. In this regard, educators must design a learning process that prioritizes the personal experience of learners through the aforementioned processes. Moreover, students must engage in collaborative learning to develop their problem-solving skills, as well as effective ways to apply the acquired knowledge in real-life situations (Yadav, 2017; Thanida, Jintawat, and Aungtinee, 2019). This experiment was an integral aspect of the learning activity. It improved the learning outcomes of the topics taught and increased the basic knowledge of students about the concepts discussed in the classroom (Harr, Eichler & Renkl, 2015; Darling-Hammond et al., 2019). This experimental model also provided learners with the skills required to apply the knowledge they have acquired in gardening and the cultivation of horticultural plants.

The outcome of this study showed that experiment-based horticultural learning can be used to improve a student's ability to organise, communicate, and interpret the results obtained from direct observations. Most importantly, this experiment motivated learners to develop curiosity, equipped students with the skills required to carry out experiments, and fostered the acquisition and development of basic biological concepts, social skills, and scientific attitudes. These findings are in consonance with the report of the study conducted by Clobert et al. (2018), and Thanida, Jintawat, and Aungtinee (2019), which documented that the use of experimental based learning is an effective way to improve cognitive and psychomotor skills in students. In view of this, it can be inferred that experimental-based learning is an effective learning strategy that is in line with the principles of constructivism paradigm (Yadav, 2017; Clobert et al., 2018; Darling-Hammond et al., 2019). This model enabled students to organise knowledge from practical experience, collaborative activities, reflection, and interpretation of data. The conduction of the experiment may provide opportunities that will help learners to develop logical thinking skills (Oka, 2016; Yadav, 2017; Clobert et al., 2018). It also stimulated the active involvement of students in the formulation of situations to solve problems, critical analysis of the problems, and existing facts, as well as the discovery and application of the concepts and principles used in horticulture.

The experiment-based learning model was an integral part of the teaching and learning activities in the horticultural course because it enabled the educator to clarify the concepts that were discussed in the classroom through direct examples and improve the intellectual skills of students via direct observation. It also allowed learners to understand and select the theories that support the mapping of problem experiments, the development of problem-solving skills, and the application of the knowledge acquired in different situations. Most importantly, the experiment design fostered different scientific attitudes in the students. Some of these include the development of the hypothesis, the presentation of data, analysis, and interpretation of scientific findings, and the development of strong conclusions that are based on the outcomes of a research study. The results of this study suggest that the experiment based learning approach can be used to increase the learning outcomes of students and improve the efficacy of teaching methods used by educators. These findings are in agreement with various studies on the use of this approach to enhance learning outcomes in students (Oka, 2016; Clobert et al., 2018; Darling-Hammond et al., 2019). A critical review of these studies revealed that some of the benefits of using this learning approach include the motivation of students, the development of in-depth comprehension of different concepts, enhancement of problem-solving, critical reasoning, and inquiry skills in learners, as well as higher academic achievements (Oka, 2016; Yadav, 2017; Clobert et al., 2018; Darling-Hammond et al., 2019). Although this model offers various benefits to learners, teachers, and the education system, there are certain limitations to its successful integration into the existing curriculum for horticulture courses (Darling-Hammond et al., 2019). Other drawbacks include the development of new assessment methods to evaluate the efficacy of this method of learning and the insufficient support of teachers and administrators at the state, district, and school level. In this regard, educators must develop strategies to address this issue to fully enjoy the advantages of using this learning approach (Darling-Hammond et al., 2019). In view of this, strategies have been developed to broaden the application of this learning approach in the education system. Some of these strategies focus on the provision of adequate support to educators, as well as the review and modification of the existing curriculum for horticulture courses.

CONCLUSION

This study showed that the pruning of apical buds results in an increase in the formation of leaves and the growth of axillary buds. Although there was a significant difference between the numbers of axillary buds in spinach plants subjected to different treatments, the most notable disparity was observed in J1 plants with apical buds that were pruned 3 cm away from the stem. The use of this experiment based approach enhances the learners' ability to organise, communicate, and interpret the results obtained from direct observations. It also motivated the students to enhance their cognitive, social, psychomotor, and problem-solving skills, redefine their theoretical understandings of different concepts, apply deductive and inductive reasoning skills, and foster collaboration between students. Based on these findings, it can be concluded that practical experiments on the effect of apical bud pruning on axillary bud growth should be implemented in the learning process for horticulture courses in IKIP Saraswati.

RECOMMENDATIONS

The impact of experiment-based learning methods on students can be maximized by adopting the following practices: the experimental design should be based on the learning outcomes for the course, the development of an instant feedback system after the conduction of practical experiments, the use of quizzes to evaluate the impact of the experimental approach, and the drafting of pre-test questions evaluate the level of knowledge acquired by the learner. The report and findings of the students must be assessed to modify or optimize the principles designed for the course. The benefits of the experiment based approach can be maximized by organizing training sessions that will enlighten educators about the importance of active learning and effective ways to incorporate this learning process into the existing curriculum for horticulture courses. The principles for the design and integration of experimental-based learning methods should be based on the prior knowledge of the student, the enhancement of the ability of learners to organize and use conceptual knowledge in real-life situations, and the understanding of how students learn and manage their learning process.

Experimental-based methods of learning should build on and increase the student's basic knowledge and prior experiences. This approach will enable learners to retain information about new concepts and develop the skills required to apply the knowledge they have obtained. Educators should consider using challenging activities to achieve the goals mentioned above and introduce new experiences that encourage the active involvement of students in their learning process. The approach must also be designed to enhance the strategic learning and metacognitive capacity of students. This will enable learners to take responsibility for their learning and apply the skills acquired in diverse contexts. In this regard, the design of the practical experiments should provide opportunities for the setting of goals, self-direction, and planning by students. Educators must carry out formative assessments and provide regular feedback to learners to evaluate the efficacy of the new teaching strategy and learning outcomes of students.

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