

How to Cite

Oka, D. N., Sumampouw, H. M., & Adi, N. N. S. (2023). The experiment of stem cutting planting position in increasing sweet potato (*Ipomea batatas L.*) production in horticulture learning. *International Journal of Life Sciences & Earth Sciences*, 6(1), 56-64. <https://doi.org/10.21744/ijle.v6n1.2128>

The Experiment of Stem Cutting Planting Position in Increasing Sweet Potato (*Ipomea batatas L.*) Production in Horticulture Learning

Dewa Nyoman Oka

IKIP Saraswati, Tabanan, Bali, Indonesia

Corresponding author email: dewayomanoka99@gmail.com

Herry Maurits Sumampouw

Universitas Negeri Manado, Minahasa, North Sulawesi, Indonesia

Email: herry.inyo@gmail.com

Ni Nyoman Serma Adi

IKIP Saraswati, Tabanan, Bali, Indonesia

Email: sermaadi26@gmail.com

Abstract---*This study aimed to discuss: (1) the effect of different positions of stem cuttings on sweet potato production; and (2) whether this practical experiment-based approach is effectively implemented in horticulture learning. This experimental research used a completely randomized design. The population was sweet potato plants. The research sample was the tip cuttings of sweet potato plants. The length of the cuttings was 30 cm, measured from the tip of the plant's stem with relatively the same number of segments. The number of treatments was 3: upright P₀ (180°), inclined P₁ (45°) and flat P₂. The number of repetitions was six times, and the number of samples for each treatment was 20 cuttings of the sweet potato stem tips. Thus, the number of sweet potato stem tip cuttings needed in this study is 3 X 6 X 20 cuttings = 360 (three hundred and sixty). Based on the ANOVA test, a significant value of 0,005 was obtained, far smaller than the determined significance level of 0,05. It means there is a significant difference between the weights of sweet potato tubers between treatments. In conclusion, there is a significant difference between the upright/90° and slanted/45° treatment and between the upright/90° and horizontal treatment. Meanwhile, the treatment between slanted/45° and horizontal showed no significant difference. Overall, the best sweet potato production is obtained by planting horizontally with an average tuber weight of 313 grams. It can be concluded that this practical experimental method is very effectively implemented in the horticulture learning process.*

Keywords---*cuttings, horticultural learning, planting position, production.*

Introduction

Sweet potato (*Ipomea batatas L.*) is the main tuber crop produced and consumed mainly by developing countries, with about 90% grown in Asia and less than 5% in Africa and Latin America (Holwerda & Ekanayake, 1991). Sweet potato is a plant that grows well in hot and humid climates, with an optimum temperature of 27°C, humidity of 50-60% and a long exposure of 11-12 hours per day with rainfall of 750-1500 mm per year. Optimal production and growth for suitable sweet potato farming are during the dry season. Botanists and agricultural experts estimate that the origin of the sweet potato or sweet potato plant is New Zealand, Polynesia and Central America. Nikolai Ivanovich Vavilov, a Soviet botanist, confirmed that the primary center of origin of the sweet potato plant was Central America. Sweet potatoes began to spread worldwide, especially in countries with tropical climates in the

16th century. The Spaniards spread sweet potatoes to Asia, especially the Philippines, Japan, and Indonesia (Jayanto, 2009).

Sweet potato stems grow up to 1-5 meters, 3-10 mm in diameter; inside the stems, there is latex. The color of the stems varies; some are green, some are yellow, and some are purple. The color of the leaves is purplish green. This plant's flowers include perfect trumpet-shaped flowers and light purple at the base and the ends. The tubers contain shoots that can grow. Depending on the variety, these tubers are usually formed 20-25 days after planting. The tuber shape is round or oval, with tuber skin varying between white, yellow, purple or orange and light purple. The texture of the meat is soft, and some is watery. The taste is sweet, and some are less sweet. Sweet potato includes a single leaf that grows on the stem. The shape of the leaves varies; some are round, like hands, and some resemble a heart, and some roots grow in the armpits of the leaves, which can grow and become tubers (Sivaci, 2006; Justamante et al., 2017).

Sweet potatoes can be used as a staple food, animal feed ingredients, and industrial raw materials. Besides that, sweet potato is an essential commodity, although it is less popular than other secondary crop commodities. This plant is very familiar to Indonesian people, especially among farmers, because of its various advantages. These advantages are because this plant is very easy to cultivate, not susceptible to disease and pests, is a producer of carbohydrates, the yield of the united land area is relatively high, is short-lived, contains lots of vitamins, and the leaves can be used for vegetables which are rich in vitamin A and iron. In addition, sweet potato tubers contain carbohydrates and high energy, which can restore energy quickly, as well as several substances that are very important for the body, such as vitamins, minerals, fiber and anthocyanins, especially in red and purple types of sweet potatoes which function as antioxidants. Sweet potato leaves contain 4.6% protein, 0.2% lipid, 9.1% carbohydrates, 6.2 mg iron, and 158 mg calcium. Besides that, it also contains anthocyanin and phenolic compounds and is an excellent source of vitamin A and ascorbic acid. Sweet potato tubers have quite a diverse composition. Among them contain 0.8 to 2% protein, 0.2 to 0.4% lipids and 25 to 30% carbohydrates. In addition, tubers also contain lots of vitamins, minerals (calcium and zinc), and some vitamin E (tocopherol) (Zannou et al., 2017).

Sweet potatoes produce more calories than potatoes, namely 113: 75 per hundred grams of material, besides being rich in vitamin A, which is approximately two and a half times the daily menu requirement for adults. When mixed with legumes, ascorbic acid, riboflavin, niacin, phosphorus, iron, and calcium from sweet potatoes can form an ideal food composition to prevent malnutrition. It is further said that sweet potatoes are consumed after simple processing, such as baked, steamed, fried, and others. Sometimes it is processed into syrup, *baozi* or *pao-tsih* (a Chinese bun), and sliced to make chips (Le & Lin, 2019; Alaie, 2020; Nturambirwe & Opara, 2020).

In health, sweet potato is used in pharmacology because it contains certain compounds such as anthocyanins, carotenoids, phenolic compounds, trypsin inhibitory proteins and arabinogalactone compounds. Researchers have reported that sweet potato tuber and leaf extracts protect against cardiovascular disease. The high fiber content in these foods also helps the body to maintain a healthy digestive system (Zannou et al., 2017).

Sweet potato productivity in Indonesia is still low, namely 98.79 kg/ha, while in China, it reaches 208.58 kg/ha and in Japan 247.33 kg/ha. The low productivity of sweet potatoes will hamper the development of the agro-industry (Alimoeso, 2003). Factors that affect the low production of sweet potato tubers include low plant population per unit area, cultivation techniques are rarely carried out, high-intensity land use resulting in loss of soil nutrients carried by crops and soil erosion, the occurrence of major plant pest organisms (*OPT*) attacks, namely pests' holes when the growing season is not suitable (Suharno, 2020).

In increasing sweet potato production, proper cultivation techniques are needed, namely proper propagation techniques, proper planting methods and selection of appropriate varieties because each variety has different production potential. The most appropriate sweet potato plant propagation technique is to use stem cuttings. This is because sweet potato plants do not produce seeds. In addition, the propagation technique through cuttings is a simple and easy way for farmers to apply. It is expected that perfect sweet potato plants will be obtained through this propagation technique, namely plants that already have roots, stems and leaves in a relatively short time (Wudianto, 1998). Several factors influence cuttings' success, namely the cuttings' origin (the cuttings (the position on the mother plant), the length of the cuttings, and the environment (rooting medium, temperature, humidity, light). The length of the cuttings affects the formation of roots and shoots. The longer the cuttings, the greater the carbohydrate content, producing more roots (Ahmad, 2021; Muli & Mwakina, 2016). In addition to these two factors, the position of planting material for cuttings also affects the growth of cuttings (Isa et al., 2015; Suminarti & Novriani, 2017). According to Aziz (1999), stem cuttings planted vertically will produce good growth, while cuttings planted horizontally will produce more shoots.

Horticulture courses is an elective course in the Biology Education study program, Faculty of Mathematics and Natural Science Education, IKIP Saraswati. One of the achievements of horticulture learning is that students can understand, plan, implement, evaluate, and communicate basic horticultural concepts and principles and apply basic

horticultural knowledge in cultivating horticultural crops and making gardens. IKIP Saraswati, as an educational institution, needs to improve the quality of its graduates from year to year. To improve the quality of graduates, the quality of the learning process must also be continuously improved. Horticultural learning should be delivered by emphasizing students' involvement in an active learning process and training students to think critically and objectively (Oka et al., 2019). So, what they have experienced will become a new experience, so they will be more interested in learning. A teaching and learning process can be meaningful and valuable if it can create learning situations that stimulate learning activities and provide information on student results and awards for achievements (Rusman, 2017).

Horticulture is one of the introductory elective courses for students because horticulture is related to everyday life or real life. For example, in the future they want to farm sweet potatoes or see farmers experiencing problems in increasing sweet potato production, they can provide solutions and have skills in solving problems faced by farmers. The authors apply the experimental method to improve the quality of the horticulture learning process. All students taking horticulture courses are involved in the experimental process from the beginning to the end. With the hope of (1) increasing their motivation and activity in the learning process; (2) helping students to understand that the acquisition of knowledge is a continuous process; (3) using their cognitive, psychomotor, and problem-solving skills to identify problems, develop, and test the efficacy of the solutions they provide as a group; (4) foster collaboration between students and provide opportunities for students to exchange ideas, and acquire important leadership, communication, and coordination skills. Experiments are also able to foster student curiosity. However, they can also foster their rational and scientific way of thinking so that the experiment results can be accepted as a scientific product while the steps in its implementation as a scientific process (Peña-Claros et al., 2002; Zheng et al., 2016).

From the description above, the focus of discussion in this study is twofold, namely (1) the effect of different positions on planting cuttings on sweet potato production; and (2) whether the implementation of this practical experiment-based approach can increase student activity in the learning process, improve cognitive, affective, psychomotor skills, and encourage collaboration between students so that there are opportunities for students to exchange ideas, acquire important leadership, communication, and coordination skills.

Method

This type of research was experimental, using a completely randomized design. The population in this study was sweet potato plants. The research sample was the tip cuttings of sweet potato plants. Cuttings were taken from healthy trees in the morning because the water content was still high. The length of the cuttings was 30 cm, measured from the tip of the plant's stem with the same number of relative segments and cut with a sharp knife. To reduce evaporation, the leaves of the cuttings were pruned, and only three were left at the ends. Cuttings were stored for five days in a shady and humid place. The number of treatments was 3: P⁰ (180°), inclined P1 (45°) and flat P2. The number of repetitions was six times, and the number of samples for each treatment was 20 cuttings of the sweet potato stem tips. Thus, the number of sweet potato stem tip cuttings needed in this study was 3 X 6 X 20 cuttings = 360 (three hundred and sixty). The research was conducted in an open place, namely in paddy fields. As a place for planting stem cuttings before planting, the medium was processed with a hoe and then harrowed until loose. Then make six bunds with dimensions: 30 cm high, 300 cm long, and 80 cm wide. The distance between the bunds was 75 cm. Each bund was planted with 60 cuttings of plant stems grouped into three groups. The first group, P⁰, with 20 cuttings in an upright position/90°, P1, with 20 cuttings in an inclined position/45°, and P2, were planted with 20 cuttings in a flat position. P⁰, P1 and P2 are placed randomly on each bund.

The data obtained from the fresh weight of sweet potato tubers were tested for normality and homogeneity. The normality test was performed using the *Kolmogorov-Smirnov* and *Shapiro-Wilk* statistics. At the same time, the homogeneity test was carried out with the *Levene* test. The significance level (α) is set at 0.05. The normality and homogeneity test criteria used were if the significance number (sig.) is more significant than the significance level (α). The statistical number was insignificant, meaning the sample data comes from a normally distributed population. Vice versa. If the requirements for normality and homogeneity have been met, then a parametric analysis with the analysis of variance (ANOVA) test was carried out. If there is a significant difference, it is necessary to carry out further tests to find out which treatment groups are significantly different. Further tests were carried out with the least significant difference (LSD) test. The horticultural learning process data were collected using observation sheets and formative tests.

Results

The data were collected by harvesting sweet potatoes after 137 days of age. Sweet potatoes that have been harvested are weighed per tree to calculate the wet weight. Before weighing, the sweet potato tubers are cleaned by cutting off the remnants of the stems or roots. The average fresh weight of sweet potato tubers in each treatment is presented in Table 1.

Table 1
The average wet weight of sweet potato tubers (grams) in each treatment

Repetition	Treatment			Number
	P ₀	P ₁	P ₂	
I	250	308	395	953
II	245	300	353	898
III	241	300	303	844
IV	212	255	272	739
V	250	260	285	795
VI	210	245	270	725
Total	1408	1668	1878	4954
Average	234,67	278	313	

Based on Table 1 above, the average production of fresh-weight sweet potato tubers in each treatment can be described as shown in Figure 1.

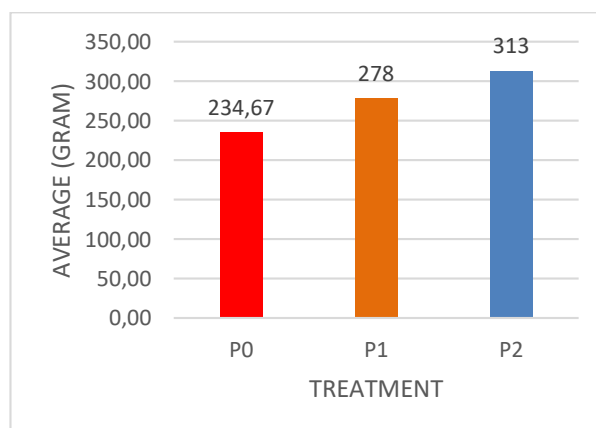


Figure 1. The average fresh weight production of sweet potato tubers in each treatment

Normality test

Before the ANOVA test is carried out, a prerequisite test is first carried out, namely the normality test. After calculating with SPSS, the normality test data is obtained, as shown in Table 2.

Table 2
The summary of the normality test

	Treatment	Kolmogorov-Smirnov ^a		
		Statistics	df	Sig.
Tuber weight	Upright	.300	6	.099
	Slant	.287	6	.133
	Horizontal	.245	6	.200*

Based on the data distribution normality test, it is found that all data obtained a significance value (sig.) above the specified significance level of 0.05. Thus, it can be said that the data is normally distributed.

Homogeneity test

After calculating with SPSS, the homogeneity test data is obtained, as shown in Table 3.

Table 3
The summary of the homogeneity test

Levene Statistics	df1	df2	Sig.
4.446	2	15	.030

Based on the homogeneity test, a significance value (sig.) of 0.030 is obtained, which is smaller than the predetermined significance level of 0.05; thus, the data is not homogeneous.

ANOVA test

The following data summary is obtained based on the ANOVA test that has been carried out with the help of SPSS.

Table 4
The summary of ANOVA test results

	Sum of squares	df	Mean square	F	Sig.
Between Groups	18477.778	2	9238.889	7.578	.005
Within Groups	18287.333	15	1219.156		
Total	36765.111	17			

Based on the ANOVA test that has been carried out, a significance value of 0.005 is obtained, which is much smaller than the predetermined significance level of 0.05. Thus, there is a significant difference in the weight of sweet potato tubers between treatments. Further tests are carried out to see which treatment has a significant difference. Assuming the data is not homogeneous, a further test is carried out with the Games-Howell test. The test results look like in Table 5 below.

Table 5
The summary of further test results

(I) treatment	(J) treatment	Mean Difference			95% Confidence interval	
		(I-J)	Std. Error	Sig.	Lower bound	Upper bound
Upright/90 ⁰	Slant/45 ⁰	-43.333*	13.601	.028	-81.48	-5.18
	Horizontal	-78.333*	21.968	.025	-144.70	-11.97
Slant/45 ⁰	Upright/90 ⁰	43.333*	13.601	.028	5.18	81.48
	Horizontal	-35.000	23.486	.347	-102.58	32.58
Horizontal	Upright/90 ⁰	78.333*	21.968	.025	11.97	144.70
	Slant/45 ⁰	35.000	23.486	.347	-32.58	102.58

*. The mean difference is significant at the 0.05 level.

Further tests show a significant difference between the upright/90⁰ and slanted/45⁰ treatments and between the upright/90⁰ and horizontal treatments. Meanwhile, the treatment between slanted/45⁰ and horizontal showed no significant difference. Overall, the best sweet potato yields are obtained by horizontal planting with an average tuber weight of 313 grams.

The results of observations regarding activities show that students are very active, both when designing experiments, making observations during experiments, and discussing experimental results. The evaluation of the learning outcomes of students who have taken part in the experiment showed that: (1) practical experiments provide real-life ambiguity and complexity that help students redefine their theoretical understanding of various concepts; (2) the experiment allows students to develop their cognitive, psychomotor, and affective skills; (3) experiments foster collaboration between students and provide opportunities for students to exchange ideas, and acquire important leadership, communication, and coordination skills.

Discussion

Based on the ANOVA test in Table 4, it can be seen that the calculated F value is 7.578 with a significance of 0.005, which is much smaller than the predetermined significance level of 0.05. It means that, in general, there is a significant difference between the weight of sweet potato tubers based on treatments. To see which treatment is significantly different, further tests are carried out. Further test results showed a significant difference between the treatment of planting upright cuttings/90⁰ and planting slanted cuttings/45⁰ and between the treatment of planting upright cuttings/90⁰ and planting horizontal cuttings. Meanwhile, the treatment between planting slanted cuttings/45⁰ and planting horizontal cuttings showed no significant difference. The best results for sweet potatoes are obtained by planting horizontal cuttings with an average tuber weight of 313 grams, this difference in production is due to the influence of hormones. Hormones or growth regulators in plants are non-nutrient organic compounds, which in small amounts, can support, inhibit and change plant physiological processes. There are three hormones plants need in their growth process: Auxins, Gibberellins, and Cytokinins. If a plant lacks one of these hormones, its growth will be disrupted. Hormones can stimulate the accelerated release of roots, multiplication of roots and root nodes, stimulate the growth process utilizing cell division, increase the size of cells and cell tissues, stimulate the release of flowers and fruit simultaneously, stimulate the healing process from picking wounds or bite wounds from pests and diseases, stimulate the enlargement of rhizomes and tubers with extra fast and extra-large (Manurung et al., 2018).

The role of auxins and cytokinins in growth was demonstrated by Nagarathna et al. (2010), in a study of *Helianthus annuus*. At the beginning of the study, auxin and cytokinin concentrations were measured at all axillary nodes to determine the translocation of each of these hormones. Based on the study results, auxin concentrations will decrease in axillary nodes far from shoots, whereas cytokinin concentrations will increase in axillary nodes far from shoots. Nagarathna decapitated the apical bud of *H. annuus*. The study's results stated that the lowest axillary nodes showed rapid growth compared to the other axillary nodes above because of the low auxin and high cytokinin concentrations in the lower axillary nodes. It shows that a balanced ratio between the hormones auxin and cytokinin is needed to stimulate shoot growth (Iráizoz et al., 2003; Paoli et al., 2022).

On horizontally planted cuttings, the auxin spreads evenly, resulting in more root and shoot growth. It is in line with Aziz (1999), which stated that cuttings planted horizontally would produce more shoots. The number of shoots produced will increase the number of leaves so that the carbohydrates produced through photosynthesis will increase. This increase in photosynthesis results will positively affect the weight gain of sweet potato tubers. On the other hand, an even distribution of auxin on cuttings planted horizontally will also promote better root growth. Good adventitious root growth will cause tubers to develop well because adventitious roots will develop into tubers. It aligns with Putri (2017), which states that the tuber development stage begins when adventitious roots grow and develop into tubers. The direction of tuber growth in sweet potato plants aged two days after planting (days after planting) was initially horizontal, 7 (days later), the direction of tuber growth was positive geotropism; and 30 days later, the direction of tuber growth occurred randomly with *plagiotropic* and positive geotropism growing directions. Tuber length and diameter development began when tubers began to form at 30 days and continued to increase in tuber length and diameter. Good root and shoot growth on cuttings planted horizontally causes higher production than those planted obliquely (45⁰) and upright (90⁰).

Meanwhile, in the treatment of planting slanted cuttings with a slope of 45⁰, the tuber production was lower because the auxin synthesized in the apical shoots would be transported *basipetally* to the lower parts of the stem, eventually accumulating at the growing point under the apical shoots and in the roots, thereby hindering the growth of shoots and roots. Accumulation of auxin at the point of growth and roots will result in the initiation of the formation of more shoots and stunted roots. Inhibition of root formation will reduce the number of tubers produced because sweet potato tubers are formed from adventitious roots. In treating planting slanted cuttings with an upright position of 90⁰, the tuber production is lower than the horizontal treatment, and the degree of inclination is 45⁰. Because the amount of auxin synthesized in apical shoots will be transported *basipetally*, more of it accumulates in the roots. Accumulation of auxin with higher concentrations in the roots will hinder the initiation of root formation. The more hindered the formation of roots will further reduce the number of tubers produced (Suriani & Darmadi, 2019).

The results of observations regarding the activities of students during the experiment are very active, both when designing the experiment, making observations during the experiment, and discussing the experimental data. The experiment can increase students' activity, motivation and involvement in the learning process. It is in line with Rusman (2017), who states that a teaching and learning process can be meaningful and valuable if it can create learning situations that stimulate learning activities, provide information on student results and provide rewards for achievements achieved. Biology learning should be delivered by emphasizing the involvement of students in an

active learning process and training students to think critically and objectively (Bakti et al., 2013). So, the students' experience will become a new experience, so they will be increasingly interested in learning (Suryani et al., 2019).

Practical experiments provide real-life ambiguity and complexity that help students redefine their theoretical understanding of various concepts. It follows the statement (Sujarittham et al., 2019), which states that students must be involved in collaborative learning to develop their problem-solving skills and an effective way to apply the knowledge gained in real-life situations. The experiment-based learning model is integral to teaching and learning activities in horticulture courses because it allows educators to clarify concepts discussed in class through direct examples and enhance students' intellectual abilities through direct observation. It also enables students to understand and choose theories that support mapping practical problems, developing problem-solving skills, and applying acquired knowledge in different situations.

The experiments allow students to develop cognitive, psychomotor, and affective skills. As we know, one of the problems faced by our world of education is that the learning process is still weak; students are not encouraged to develop their thinking skills, while teachers still apply traditional teaching methods, which are oriented towards the cognitive measurement of students only. Meanwhile, in the constructivist learning paradigm, learning must measure three aspects: cognitive, affective, and psychomotor. To achieve these three aspects, more than learning activities in class are needed to apply the lecture method because teachers can only provide material. Theoretically, the students are not actively involved in learning, and even students need help to apply the material directly in the form of observations or experiments. This principle causes a paradigm shift in the educational process from the teaching paradigm to the learning paradigm. The teaching paradigm that focuses more on the role of educators in transforming knowledge for their students shifts to a learning paradigm that gives more roles to students to develop their potential and creativity (Oka, 2016). A critical review of this study reveals several benefits of using an experimental learning approach, such as student motivation, in-depth understanding of various concepts, increased problem-solving, critical reasoning, and inquiry skills in students, as well as higher academic achievement.

The experiments foster student collaboration and provide opportunities to exchange ideas and acquire important leadership, communication, and coordination skills. It is in line with the research results of Clobert et al. (2018), and (Sujarittham et al., 2019), which show that experimental-based horticulture learning can improve students' abilities to organize, communicate, and interpret the results obtained from direct observation. Most importantly, these experiments motivate students to develop curiosity, equip students with the skills necessary to conduct experiments and encourage the acquisition and development of basic biology concepts, social skills, and scientific attitudes.

Based on this, experiment-based learning is an effective learning strategy that aligns with the principles of the constructivism paradigm (Azis, 2019). This model allows students to organize knowledge from practical experience, collaborative activities, reflection, and interpretation of data. Experimental implementation can provide opportunities to help students develop logical thinking skills. It also stimulates the active involvement of students in formulating situations to solve problems, critical analysis of existing problems and facts, and the discovery and application of concepts and principles used in horticulture.

Conclusion

There is a significant difference between the treatment of planting upright cuttings/90⁰ and planting slanted cuttings/45⁰ and between the treatment of planting upright cuttings/90⁰ and planting horizontal cuttings. Meanwhile, the treatment between planting slanted cuttings/45⁰ and planting horizontal cuttings showed no significant difference. Where the best sweet potato yields are obtained by planting horizontal cuttings with an average tuber weight of 313 grams, this practical experimental method is very effectively implemented in horticulture learning.

References

- Ahmad, F. (2021). Pengaruh Panjang Stek Terhadap Pertumbuhan Dan Hasil Tanaman Ubi Jalar (*Ipomoea batatas* L.). *Cendekia Eksakta*, 5(2).
- Alaie, S. A. (2020). Knowledge and learning in the horticultural innovation system: A case of Kashmir valley of India. *International Journal of Innovation Studies*, 4(4), 116-133. <https://doi.org/10.1016/j.ijis.2020.06.002>
- Alimoeso, S. (2003). Jangan Sepelekan OPT Bila Menginginkan Hasil dan Mutu Ubi jalar meningkat. *Bullein Pangan*, 1(02).
- Azis, T. N. (2019). Strategi pembelajaran era digital. In *The Annual Conference on Islamic Education and Social Science* (Vol. 1, No. 2, pp. 308-318).

- Aziz, S. A. (1999). Studi pembiakan vegetatif bambu betung (*Dendrocalamus asper* Schult. F.) Backer X. Heyne) dan bambu ampel hijau (*Bambusa vulgaris* Schard) dengan menggunakan stek buruh dan kultur in-vitro.
- Bakti, E. M. S., Suparmi, S., & Sunarno, W. (2013). Pembelajaran biologi melalui metode eksperimen dengan laboratorium riil dan laboratorium virtuil ditinjau dari kemampuan berfikir kritis dan gaya belajar siswa. *Inkuiri*, 2(03).
- Clobert, J., Chanzy, A., Le Galliard, J. F., Chabbi, A., Greiveldinger, L., Caquet, T., ... & Saint-André, L. (2018). How to integrate experimental research approaches in ecological and environmental studies: AnaEE France as an example. *Frontiers in Ecology and Evolution*, 43.
- Holwerda, H. T., & Ekanayake, I. J. (1991). Establishment of sweet potato stem cuttings as influenced by size, depth of planting, water stress, hormones and herbicide residues for two genotypes. *Scientia horticultrae*, 48(3-4), 193-203. [https://doi.org/10.1016/0304-4238\(91\)90127-K](https://doi.org/10.1016/0304-4238(91)90127-K)
- Iráizoz, B., Rapún, M., & Zabaleta, I. (2003). Assessing the technical efficiency of horticultural production in Navarra, Spain. *Agricultural Systems*, 78(3), 387-403. [https://doi.org/10.1016/S0308-521X\(03\)00039-8](https://doi.org/10.1016/S0308-521X(03)00039-8)
- Isa, M., Setiadi, H., & Putri, L. A. P. (2015). Pengaruh jumlah ruas dan sudut tanam terhadap pertumbuhan dan produksi beberapa varietas ubi jalar (*Ipomoea Batatas* L.) Lamb. *Agroekoteknologi*, 4(1), 1945-1952.
- Jayanto, A. D. (2009). *UbijalarKetela rambat (Ipomoea batatas)*. Jakarta: Kantor Deputi Menegristek Bidang Pendayagunaan dan Pemasyarakatan Ilmu Pengetahuan dan Teknologi.
- Justamante, M. S., Ibañez, S., Villanova, J., & Pérez-Pérez, J. M. (2017). Vegetative propagation of argan tree (*Argania spinosa* (L.) Skeels) using in vitro germinated seeds and stem cuttings. *Scientia Horticulturae*, 225, 81-87. <https://doi.org/10.1016/j.scienta.2017.06.066>
- Le, T. T., & Lin, C. Y. (2019). Deep learning for noninvasive classification of clustered horticultural crops—A case for banana fruit tiers. *Postharvest Biology and Technology*, 156, 110922. <https://doi.org/10.1016/j.postharvbio.2019.05.023>
- Manurung, B., Zahrah, S., & Zulkifli. (2018). Pemberian hormax dan npk mutiara 16: 16: 16 pada tanaman ubi jalar (*Ipomoea batatas* L.). *Dinamika Pertanian*, 34(2), 139-150.
- Muli, M. B., & Mwakina, D. (2016). Effect of variety and size of stem cutting on flesh root yield and yield components of sweet potato. *Journal of Agricultural Science and Technology*, 6, 175-179.
- Nagarathna, TK, Shadakshari, YG, Jagadish, KS, & Sanjay, MT (2010). Interactions of auxin and cytokinins in regulating axillary bud formation in sunflower (*Helianthus annuus* L.). *Helia*, 33 (52), 85-94.
- Nturambirwe, J. F. I., & Opara, U. L. (2020). Machine learning applications to non-destructive defect detection in horticultural products. *Biosystems engineering*, 189, 60-83. <https://doi.org/10.1016/j.biosystemseng.2019.11.011>
- Oka, D. N. (2016). Education Implementations of Experiments Ingreen Mustard (*Brassica Juncea* 1) Production with Cow Urine For Horticulture Learning Application. *Journal of Science Education*, 17(1), 39-42.
- Oka, D. N., Sumampouw, H. M., & Putu Aryana, I. B. (2019). 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. *Systematic Reviews in Pharmacy*, 10(1), 247-256.
- Paoli, R., Feofilovs, M., Kamenders, A., & Romagnoli, F. (2022). Peat production for horticultural use in the Latvian context: Sustainability assessment through LCA modeling. *Journal of Cleaner Production*, 378, 134559. <https://doi.org/10.1016/j.jclepro.2022.134559>
- Peña-Claros, M., Boot, R. G., Dorado-Lora, J., & Zonta, A. (2002). Enrichment planting of *Bertholletia excelsa* in secondary forest in the Bolivian Amazon: effect of cutting line width on survival, growth and crown traits. *Forest ecology and management*, 161(1-3), 159-168. [https://doi.org/10.1016/S0378-1127\(01\)00491-1](https://doi.org/10.1016/S0378-1127(01)00491-1)
- Putri, I. D. P. (2017). Tahap perkembangan umbi ubi jalar. *Simki-Techsin*, 1(1), 1-5.
- Rusman, M. P. (2017). *Belajar & Pembelajaran: Berorientasi Standar Proses Pendidikan*. Prenada Media.
- Sivaci, A. (2006). Seasonal changes of total carbohydrate contents in three varieties of apple (*Malus sylvestris* Miller) stem cuttings. *Scientia Horticulturae*, 109(3), 234-237. <https://doi.org/10.1016/j.scienta.2006.04.012>
- Suharno, S. (2020). Pengaruh jenis pupuk organik terhadap produksi (berat umbi) ubi jalar (*Ipomea batatas* L) clon madu. *Jurnal Ilmu-Ilmu Pertanian*, 3(1), 6.
- Sujarittham, T., Tanamatayarat, J., & Kittiravechote, A. (2019). Investigating the Students' Experimental Design Ability toward Guided Inquiry Based Learning in the Physics Laboratory Course. *Turkish Online Journal of Educational Technology-TOJET*, 18(1), 63-69.
- Suminarti, N. E., & Novriani, R. (2017). Pengaruh defoliasi dan posisi penanaman stek batang pada pertumbuhan dan hasil tanaman ubi jalar (*Ipomoea batatas* L.) Lam. Var. Sari. *Jurnal Biodjati*, 2(1), 21-29.
- Suriani, N. L., & Darmadi, A. A. K. (2019). Utilization of biotechnology staters to improve quality and production of clove plant (*syzygium aromaticum* l). *International Journal of Life Sciences & Earth Sciences*, 2(1), 38-43. <https://doi.org/10.31295/ijle.v2n1.92>

- Suryani, N., Setiawan, A., & Putra, A. (2019). Media pembelajaran inovatif dan pengembangannya.
- Wudianto, R. (1998). Membuat Stek, Cangkok dan Okulasi, Jakarta. *Penebar Swadaya*.
- Zannou, A., Gbaguidi, M., & Ahoussi-Dahouenon, E. (2017). Synthesis of research on sweet potato (*Ipomoea batatas*) with a view to its valorization: A review. *International Journal of Chemical Science*, *1*(2), 84-89.
- Zheng, Y., Zhang, Y., & Wu, J. (2016). Yield and quality of *Moringa oleifera* under different planting densities and cutting heights in southwest China. *Industrial Crops and Products*, *91*, 88-96.
<https://doi.org/10.1016/j.indcrop.2016.06.032>