Advances in Biological Sciences Research, volume 22
7th International Conference on Biological Science (ICBS 2021)

Effects of Water Availability on Physiological Factors of Cayenne Pepper Plant *Capsicum frutescens* L.

Fiana Lathifah[1], Dwi Umi Siswanti[2,*]

[1,2,*]*Biology Department, Faculty of Biology, Universitas Gadjah Mada, Jl. Teknika Selatan, Yogyakarta Special Region, Indonesia, 55281.*
[*]*Corresponding author. Email:dwiumi@ugm.ac.id*

ABSTRACT
Chili pepper is a vegetable plant that is consumed by many people and has high economic value. Chili peppers contain secondary metabolite compounds, capsaicin which is synthesized in the epidermis cells. Capsaicin acts as a spicy taste in chili peppers, so chili peppers are favored by the public. Environmental factors can affect the growth and content of secondary metabolites in chili pepper plants. Therefore, this study aims to determine the effects of water availability on the wet weight and dry weight of plants, plant height, stem diameter, and the number of leaves, also the productivity of C*apsicum frutescens* L.. plants in the form of capsaicin levels of cayenne pepper fruit. The research was done by growing chili plants and given the treatment of watering interval variations. Data collecting is done by measuring several plant organs when harvesting and analysis of capsaicin levels in chili pepper are done by Thin Layer Chromatography method. Data analyzed with ANOVA and DMRT tests with a significance level of 95% ($\alpha = 0.05$) showed significantly different results. The results showed that the watering interval variations had a significant effect on the yield of cayenne pepper plants aged 96 DAP. This is indicated by a decrease in the diameter of plant stems and an increase in the number of leaves. The more watering intervals, the smaller the diameter of the stem but the more the number of leaves. Low water availability can increase capsaicin levels of C*apsicum frutescens* L. cayenne pepper plants. P3 treatment (watering once every 7 days) shows the highest capsaicin levels compared to control treatment, P1, and P2 which is 1317.63 ng.

Keywords: *Capsaicin, Capsicum frutescens L., Thin layer chromatography, Water stress, Yield.*

1. INTRODUCTION

Chili peppers are a vegetable plant that is widely consumed by the community and has a high economic value. Chili peppers have a lot of nutrients and vitamins, including, protein, fat, kabohidrat, vitamin A, B1, and vitamin C [20]. Chili peppers have several benefits that are complementary to cuisine, appetite enhancers, food preservatives, medicines, as well as used as raw materials for the food industry [37]. Indonesia has several variants of chili commodities including large red chili, curly red chili, as well as chili peppers consisting of green cayenne pepper and red cayenne pepper.

Chili fruit contains capsaicin compounds (spicy flavoring compounds) that are synthesized in epidermis cells, begin to be synthesized about 20 days post-anthesis and accumulate in bags along with the epidermis of chili fruit. Capsaicin is a secondary metabolite of the alkaloid group produced in the septum of chili fruit. Capsaicin content varies depending on variety, season, growth conditions, fruit maturity rate and growing environmental influence [33]. Capsaicin begins to be produced in the early stages of fruit development and will accumulate optimally in the final phase of fruit growth. Accumulation continues until the fruit reaches its maximum length [26]. According to Siswanti research, the most optimal levels of capsaicin were found in the treatment with the highest doses of sludge 36 ml and biofertilizer 10 10L/ha [31]. This suggests that the application of high doses of sludge and biofertilizer in susceptible plant tolerances could increase capsaicin levels of curly chili fruits. Siswanti and Lestari (2019) stated that the application of biofertilizer is necessary for plant commodities because it contains important nutrients N and K that are important in supporting plant growth [30]. Curly red chili plants with the application

of biogas sludge 36 mL + biofertilizer 10 L/ha have the highest plant average high compared to another biogas dosage of sludge and biofertilizer also NPK (control) application. Plants with abundant nutrient availability and biofertilizer and biogas sludge applications have a relatively balanced and rapid vegetative and generative growth rate. Therefore, they can form more secondary metabolites than the chili in the control group. This indicates that plant growth is positively correlated with capsaicin levels of curly red chili fruit.

Environmental factors can affect secondary metabolites. Water is an abiotic component that has an important role in plant growth [12, 17, 35]. The response of the plants to the drought is divided into 3 categories namely (tolerance) where plants can tolerate water insecurity or able to survive with low water potential, (escape) where plants complete their life cycle before the occurrence of drought to maintain some of their reproductive processes, and (avoidance) where plants can maintain tissue hydration during drought [18]. Productivity and plant growth will decrease due to the low availability of water [5]. Physiologically plants that grow in inappropriate environments will produce more secondary metabolites. Secondary metabolites are compounds that act as an adaptation response to the environment [25].

Chili peppers are known as a plants that are sensitive to low water availability and excessive water availability [13]. This plant is sensitive to the stress condition at the flowering stage and the development stage of the fruit, where it is considered the most critical stage during the growth of chili plants [19]. Chili is one of the main commodities sold in traditional markets so the demand for chili is relatively high. Based on the Ministry of Trade of the Republic of Indonesia (2019), red chili production in 2016 amounted to 1.04 million tons, in 2017 increased to 1.21 million tons, and in 2019 to 1.12 million tons.But this is not in line with its productivity. In other words, chili production in Indonesia has not been able to meet the needs of national chili peppers. The high demand figures and low productivity figures of chili peppers resulted in soaring chili prices. The low productivity of chili peppers can be caused by several factors, namely environmental factors in the form of drought and low area of agricultural land.

One of the causes of the low production of cayenne pepper is due to environmental factors. This environmental factor can affect the growth of chili plants. Environmental factors can be the area of productive land, the availability of water, light, and also the use of fertilizers. To meet the demand figures of chili peppers and also stabilize the price of chili peppers, it is necessary to research on the availability of water to physiological factors including crop growth results and capsaicin levels of the *Capsicum frutescens* cayenne pepper fruit. So it is expected to be obtained the appropriate water usage efficiency to get a good fruit with high levels of capsaicin. Hopefully, demand and production are stable and the price of chili is cheap, so it does not bother the community.

2. MATERIALS AND METHODS

This research was conducted in December 2020 – May 2021, located in Kulon Progo. Analysis of the capsaicin level of chili fruit was conducted at LPPT Universitas Gadjah Mada.

The tools used are polybag, ruler, cloth meter, trundle, scale, paper envelope, microtube, vortex, GF 254 TLC plate, (*Camag*) Linomat 5 and (*Camag*) TLC Scanner, chamber, and fan. The materials used in this study are cayenne pepper seedlings, water, planting media, fertilizer, methanol, toluene, ethyl acetate, and capsaicin standard solution.

The implementation of this study includes planting cayenne pepper seedlings, watering intervals i.e. control (watering daily), P1 (watering once every 3 days), P2 (watering once every 5 days), and P3 (Watering 7 days once), measurement of growth parameters, and measurement of capsaicin levels of cayenne pepper. The measured growth parameters include the wet and dry weight of the plant, the number of leaves, the height of the plant, and the diameter of the stem. Measurement of capsaicin levels of chili fruit was done by testing thin layer chromatography.The data was analyzed using ANOVA followed by a DMRT test at a confidence level of 95%.

3. RESULTS AND DISCUSSION

Based on Table 1, it is known that the average wet weight of plants decreases as the watering interval increases. The control treatment has the highest wet weight of 61.3419 grams.While the wet weight of the lowest plant in the P3 treatment with watering once every 7 days is 55.8419 grams. The drought caused in loss of water in cells and plant tissues also reduced absorption of CO_2 due to stomata closure [2]. If any of the ingredients for photosynthesis is lacking, photosynthesis stops. If any factor is absent for a long period, a plant will die [32]. Photosynthesis products will be translocated to organs in plants during vegetative and generative growth [28]. As a result the photosynthate translocated to the organs of plants is reduced, so the biomass of plants will decrease.

DMRT advanced test on wet weight cayenne pepper plant with watering interval showed that each treatment does not show any real different results. This indicates that the growth of chili plants does not require enough water. Research Putra *et al*. mentions that the average water needs of cayenne pepper plants from the vegetative and generative phase from the beginning of planting up to 75 DAP with planting media in the form of rice fields

Table 1. Average wet weigh, dry weight, height, diameter, number of leaves, and capsaicin content of cayenne pepper plants by interval Watering at 96 DAP

Treatments	Wet weight (gram)	Dry weight (gram)	Height chilipepper plant(cm)	Diameter stem (cm)	Number of leaves chili pepper plant (sheet)	Capsaicin Content of chili pepper (ng)
Control	61,3419±4,000^{a}	11,6144±0,832^{a}	87,000± 7,0^{b}	0,6150±0,015^{c}	137,000±7.000^{a}	708,04±191,58^{a}
P1	58,8419±2,291^{a}	11,1855±0,402^{a}	70,000± 5,0^{a}	0,5000±0,010^{b}	180,000±30,000^{b}	887,24±70,89^{ab}
P2	57,3419±3,279^{a}	12,3539±0,253^{a}	93,500± 3,5^{b}	0,5333±0,035^{b}	223,333±2,207^{c}	1133,85±275,85^{ab}
P3	55,8419±0,500^{a}	11,2012±1,874^{a}	91,000 ± 3,0^{b}	0,4533±0,015^{a}	240,333±0,577^{c}	1317,63±414,05^{b}

Notes : The number followed by the same letter in the column the same shows results that are not significantly different in at 95% ($\alpha \leq 0.05$)

60% and manure 40% is 22.06 ml per day [23]. The watering interval variations have no real effect on the growth of chili plants. Chili plants can still grow with low water availability. Chili plants with daily watering as a control show the highest value.But the value is no different than other treatments.

P2 watering treatment shows the highest dry weight (12,3539 g). This is possible because the total volume of water in the planting media by giving a watering interval of 5 days is the volume of water that suits the needs of chili plants so that the use of water for the process in plants is more efficient. Chili plants are particularly vulnerable to excess and lack of water due to their shallow rooting system [34]. DMRT advanced test showed that the influence of water availability has no real effect on the dry weight of plants. This may occur because chili plants are drought-resistant plants or have special mechanisms to deal with the drought. The drought-tolerant chili pepper was able to preserve water so the negative consequences such a decrease in photosynthetic activities, decelerate plant growth and development, and eventually decrease yield did not happen [26].

Overall the value of dry weight decreased in line with the decrease in watering. The measurement results showed that the P1 treatment showed the lowest dry weight of 11,1855 grams. In the treatment, it is suspected that the availability of water in the planting media is too low and unable to fulfill the water needs of plants, as a result of which the growth and development of chili plants are inhibited. Low water availability can cause a decrease in turgor pressure in plant cells, resulting in a decrease in the cell's ability to lengthen and enlarge cells. Water plays an important role in all metabolic processes in plants, water deficiency results in a decrease in plant biomass [16]. The results of the DMRT advanced test showed that the dry weight of the plant did not show any noticeable different results with all treatments. So it can be known that the influence of water availability has no real effect on the dry weight of plants. Research Sato *et al*. shows that Thai chili peppers respond to drought by reducing stomata conduction [29].

Based on the results of the study it is known that the average height of plants shows significantly different results between control and P1. P1 treatment with watering once every 3 days shows results with the lowest plant height of 70 cm and is significantly different from the control. Watering once every 3 days results in significantly lower results than other controls and treatments. This happens because the volume of water in the planting medium is very low, so the water needs in plants are not fulfilled and the metabolic process running is not optimal. Chili plants are particularly susceptible to excess and lack of water during the growth period, excess and lack of water will result in a decrease in the process of photosynthesis in plants [13]. Watering interval variations showed different influences on P1 with control, P2, and P3 treatments. P1 treatment with watering once every 3 days affects the height of the plant that increases the height of chili plants. While other treatments do not affect the height of plants.

The control treatment indicates the highest diameter stem (0.615 cm), this happens because the volume of water contained in the planting medium is relatively high. So that the process of water absorption by the roots can be optimal. The high water content in plants will result in the process of food synthesis and cell division can be optimal, this will affect the development of plant stem diameter. P3 treatment with watering once every 7 days shows the lowest stem diameter result. The more watering intervals, the lower the water content in the planting medium. As a result the absorption of water by the roots of plants is progressively reduced. Low absorption of water by plants affects the development of plant stem diameter, namely cell division in plant stems is reduced and photosynthate translocated to plant organs will also be reduced.

DMRT advanced test results average diameter of chili plant stems showed that variations between watering intervals P1, P2, and P3 showed real different results to control. So it is known that the availability of water affects the diameter of cayenne pepper plant stem age 96 DAP that is the diameter of the stem is decreasing along with the increasing watering interval.The presentation of the size of the diameter of the stem occurs due to the secondary growth of plants, namely due to the activity of xylem and phloem. Xylem is formed inwards and phloem is formed outwards. Research by Aikmelisa and Waluyo

shows that plants with large stem diameters have large amounts of xylem and phloem as well [1].

The highest number of leaves is found in the P3 treatment. This can happen because in P3 treatment plants have leaves with a relatively narrow area but the number is quite large. Then the least number of leaves is found in the control treatment, which should be in the control treatment of water availability is relatively large so that the number of leaves is the most. But based on the observations, the leaves on the control treatment plant have a relatively large leaf area but the number of leaves is relatively small.The low water availability in the vegetative phase will affect the development of leaves i.e. the leaves will be smaller in size. The condition aims to reduce light [24]. The control treatment has an average number of leaves of at least 137 sheets. Based on the morphological observations of leaves, the size of leaves in plants with this control treatment is relatively larger. In the control treatment, the water content in the planting medium is more than in the other treatments. It shows that water need for metabolism is sufficient, so that plants don't need to give a response for adaptation to drought conditions. The growth of leaves in control treatment is more focused on the size of the leaves, which is relatively wide, but the number of leaves is relatively small. As a result, the increase in the number of leaves in the control treatment is not as much as the increasing number of leaves in P1, P2, and P3.

Based on a statistical analysis of the DMRT advanced test on the increase in the number of leaves of cayenne pepper plants by giving variations in watering intervals showed that the watering intervals had a real influence on the number of leaves. Control treatment differs significantly with P1, P2, and P3. While P1 differs significantly also with P2 and P3. DMRT advanced test showed that the watering intervals affect the number of leaves of chili plants, that is the number of leaves increased along with the watering intervals treatments.

The highest level of capsaicin is in chili fruit with P3 treatment with watering once every 7 days which is 1317.63 ng. P3 treatment is assumed to be a condition with an extreme environment that is drought. The water content in the planting media is quite low. So the results of this P3 treatment are by the hypothesis that low water availability can increase capsaicin levels. Increased production of secondary metabolites is an effort to defend plants as well as an effort of plants to respond and adjust drought insecurity by changing cellular metabolism to form various defense mechanisms.

Low water availability can increase capsaicin levels in cayenne pepper [21]. Increased production of secondary metabolites is an effort to defend plants as well as an effort of plants to respond and adjust drought insecurity by changing cellular metabolism to form various defense mechanisms [9, 10]. Plant survival in stressful conditions depends on the plant's ability to transmit signals that can further form a variety of physiological and chemical changes. In severe water stress conditions can result in oxidative stress due to the formation of reactive oxygen species (ROS) [4]. In-plant cell chloroplasts, protection against oxidative damage is carried out by enzymatic and non-enzymatic antioxidants. Therefore the concentration of antioxidants can increase in water stress conditions. It may also increase the concentration of secondary metabolites in plant tissues [7, 38].

The control treatment (708.04 ng) produced the lowest capsaicin levels. In the watering control, the condition indicates the need for water by plants can be fulfilled. Therefore, the plant does not make defense efforts to sustain its life. So the production of secondary metabolites of capsaicin is not very high. DMRT advanced test showed that the treatment of watering interval variations gave a noticeable difference in control of P3. Watering interval once every 7 days (P3) has a noticeable effect on the capsaicin content of cayenne pepper fruit. More and more watering intervals show drought insecurity is increasing, as a result of cayenne pepper plants adapting in response to drought suffices by forming secondary metabolites in the form of capsaicin.

Based on the research conducted, can be obtained conclusions that the variations in watering interval P1 (watering once every 3 days), P2 (watering 5 days once), P3 (watering 7 days once) has a significant effect on the yield of cayenne pepper plants aged 96 DAP. This is indicated by a decrease in the diameter of plant stems and an increase in the number of leaves. The more watering intervals, the smaller the diameter of the stem but the more the number of leaves. Low water availability can increase capsaicin levels of C*apsicum frutescens* L. cayenne pepper plants. P3 treatment (watering once every 7 days) shows the highest capsaicin levels compared to control treatment, P1, and P2 which is 1317.63 ng.

ACKNOWLEDGMENT

Thanks are conveyed to the Faculty of Biology, especially Drs. Sudjino, MS as Supervisor Lecturer who always patiently provide guidance, for the contribution of ideas, discussion of reasoning is very constructive.

REFERENCES

[1] R. Aikmelisa, dan B. Waluyo, Keragaman Berkas Pembuluh Xilem-Floem dalam Hubungannya dengan Komponen Hasil dan Hasil pada Galur-Galur Jarak Kepyar (*Ricinus communis* L.) Colchicine Treatment 5, Jurnal Produksi Tanaman, vol. 7(5), 2019, pp. 904-911.

[2] M. Aslanpour, H.D. Baneh, A. Tehranifar, dan M. Shoor, Effect of water stress on growth traits of roots

and shoots (fresh and dry weights, and amount of water) of the white seedless grape, International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies, vol. 10(2), 2019, pp. 169-181.

[3] Bosland, W. Paul, and E. J. Votava, Peppers: Vegetable And Spice, J. Votava, 2012. DOI:https://doi.org/10.1079/9781845938253.0000

[4] C. de Carvalho, M. H. Drought, Stress and reactive oxygen species, Plant Signaling & Behavior, vol. 3(3), 2008, pp. 156–165. DOI:10.4161/psb.3.3.5536

[5] C. Felania, Pengaruh ketersediaan air terhadap pertumbuhan kacang hijau (*Phaceolus radiatus),* Seminar Nasional Pendidikan Biologi, 2017. pp:131-38.

[6] Gupta, N., H. Ram, dan B. Kumar, Mechanism of Zinc absorption in plants: uptake, transport, translocation and accumulation, Reviews in Environmental Science and Bio/Technology, vol. 15 (2016), 2016, pp. 89-109. DOI: https://doi.org/10.1007/s11157-016-9390-1

[7] M. Hasanuzzaman, M.H.M. Bhuyan, F. Zulfiqar, A. Raza, S.M. Mohsin, J.A. Mahmud, and V. Fotopoulos, Reactive oxygen species and antioxidant defense in plants under abiotic stress: revisiting the crucial role of a universal defense regulator, Antioxidants, vol. 9(8), 2020, pp. 681. DOI:https://doi.org/10.3390/antiox9080681

[8] P. Huang, L. de-Bashan, T. Crocker, J.W. Kloepper, dan Y. Bashan, Evidence that fresh weight measurement is imprecise for reporting the effect of plant growth-promoting (rhizome) bacteria on growth promotion of crop plants, Biology and Fertility of Soils, vol. 53(2), 2017, pp. 199-208. DOI:10.1007/s00374-016-1160-2

[9] T. Isah, Stress and defense responses in plant secondary metabolites production, Biological research, 2019, pp. 52. DOI: https://doi.org/10.1186/s40659-019-0246-3

[10] D. Kapoor, S. Bhardwaj, M. Landi, A. Sharma, M. Ramakrishnan, dan A. Sharma, The impact of drought in plant metabolism: how to exploit tolerance mechanisms to increase crop production, Applied Sciences, vol. 10(16), 2020, pp. 5692.DOI:https://doi.org/10.3390/app10165692

[11] Kementrian Perdagangan Republik Indonesia. Analisis Perkembangan Harga Bahan Pangan Pokok di Pasar Domestik dan Internasional. Pusat Pengkajian Perdagangan Dalam Negeri. 2019, pp: 19.

[12] Kramer , J. Paul, dan J. S. Boyer, Water Relations of Plants and Soils, Academic Press, United States, 1995, pp:4-5

[13] R.A. Laise, M. Ahmad, dan L. Tangge, Respon Pertumbuhan Tanaman Cabai (*Capsicum frutescens* L.) Terhadap Cekaman Air Untuk Pemanfaatannya Sebagai Media Pembelajaran, e-JIP BIOL., vol. 5(1), 2017, pp. 109-118.

[14] R. Lemoine, S. la Camera, R. Atanassova, F. Dédaldéchamp, T. Allario, N. Pourtau, dan M. Durand, Source-to-sink transport of sugar and regulation by environmental factors, Frontiers in plant science, vol. 4 (272), 2013. DOI: 10.3389/fpls.2013.00272

[15] Ludewig dan F. UI, Role of metabolite transporters in source-sink carbon allocation, Frontiers in Plant Science. 2013. DOI: 10.3389/fpls.2013.00231

[16] H. Manurung, W. Kustiawan, dan I.W. Kusuma, Pengaruh Cekaman Kekeringan terhadap Pertumbuhan dan Kadar Flavonoid Total Tumbuhan Tabat Barito (*Ficus deltoidea* Jack), Jurnal Hortikultura Indonesia, vol. 10(1), 2019, pp. 55-62. DOI : http://dx.doi.org/10.29244/jhi.10.1.55-62

[17] N.D. Marsha, N. Aini, dan T. Sumarni, Pengaruh Frekuensi Dan Volume Pemberian Air Pada Pertumbuhan Tanaman Crotalaria Mucronata Desv, Jurnal Produksi Tanaman, vol. 2(8), 2015, pp.673-678.

[18] L.P. Manavalan, dan H.T. Nguyen, Drought tolerance in crops: Physiology to genomics, Plant Stress Physiology, 2017. pp. 1-23. DOI:https://doi.org/10.1079/9781780647296.0001

[19] G.O. Okunlola, O.A. Olatunji, R.O. Akinwale, A. Tariq, dan A.A. Adelusi, Physiological response of the three most cultivated pepper species (*Capsicum* spp.) in Africa to drought stress imposed at three stages of growth and development, Scientia Horticulturae, vol. 224, 2017, pp.198-205. DOI: http://dx.doi.org/10.29244/jhi.10.1.55-62

[20] Piay, S. Sisca, A. Tyasdjaja, Y. Ermawati, dan F.R.P. Hantoro, Budidaya dan Pascapanen Cabai Merah (*Capsicum annuum* L.), BPTP, Jawa Tengah, 2010. pp: 1. DOI: https://doi.org/10.1016/j.scienta.2017.06.020

[21] Phimchan, Paongpetch, S. Techawongstien, S. Chanthai, dan P. Bosland, Impact of Drought Stress on the Accumulation of Capsaicinoids in Capsicum Cultivars with Different Initial Capsaicinoid Levels, Hort Science: a publication of the American Society for Horticultural Science, vol. 47(9), 2012, pp.1204-1209. DOI:10.21273/HORTSCI.47.9.1204

[22] H. Poorter, P.B. Reich, K.J. Niklas, dan J. Oleksyn. Biomass allocation to leaves, stems and roots: Meta-analyses of interspecific variation and environmental control, New Phytologist, vol. 193(1), 2011, pp.30-50. DOI:10.1111/j.1469-8137.2011.03952.x

[23] I.M.S.A. Putra, I.W. Tika, dan I.B.P. Gunadnya, Kebutuhan Air Tanaman pada Budidaya Cabai Rawit (*Capsicum Frutescens* L.) dengan Sistem Polybag yang Menggunakan Berbagai Tingkat Kandungan Organik Tanah, Jurnal BETA (Biosistem dan Teknik Pertanian), v*ol.* 7(2), 2019, pp. 302-309. DOI :https://doi.org/10.24843/JBETA.2019.v07.i02.p11

[24] A. Pratiwi, dan S. Sugianto, The Effect of Water Stress on Growth and Capsaicin Content of Cayenne Pepper (*Capcisum frutences* L.), J.Appl. Environ. Biol. Sci., vol. 7(6), 2017, pp.76-80.

[25] D.S. Rini, B. Budiarjo, I. Gunawan, R.H. Agung, dan R. Munazar, Mekanisme Respon Tanaman Terhadap Cekaman Kekeringan, Berita biologi, vol. 19(3B), 2020, pp. 373-384. DOI:https://doi.org/10.14203/beritabiologi.v19i3B.4025

[26] N. Ruiz-Lau, F. Medina-Lara, Y. Minero-García, E. Zamudio-Moreno, A. Guzmán-Antonio, I. Echevarría-Machado, dan M. Martínez-Estévez, Water Deficit Affects the Accumulation of Capsaicinoids in Fruits of *Capsicum chinense* Jacq., Hort Science, vol. 46(3), 2011, pp.487-492. DOI: https://doi.org/10.21273/HORTSCI.46.3.487

[27] U.L. Sahitya, M.S.R. Krishna, P. Suneetha, Integrated approaches to study thedrought tolerance mechanism in hot pepper (*Capsicum annuum* L.). Physiol. Mol. Biol. Plants, vol. 25, 2019, pp. 637–647.

[28] V.Y. Saputri, R.N. Sholichah, L. Solichah, M.A. Najah, dan M. Su'udi, Translokasi Asimilat Pada Anggrek Akar, Jurnal Penelitian Sains, vol. 22(1), 2020, pp. 1-8. DOI:https://doi.org/10.1016/j.envexpbot.2005.10.002

[29] S. Sato, S. Moreshet, M. Takagaki, Y. Shinohara, dan T. Ito, Effects of drought stress on sap flow, stomatal conductance, and leaf water potential of pepper cultivars (*Capsicum annuum* L.), Japanese Journal of Tropical Agriculture, vol. 47(2), 2003, pp.61-69.

[30] D.U. Siswanti, dan M.F. Lestari, Growth Rate and Capsaicin Level of Curly Red Chili (*Capsicum annum* L.) on Biofertilizer and Biogas Sludge Application, Jurnal Biodjati, vol. 4(1), 2019, pp. 126-137. DOI: 10.15575/biodjati.v4i1.4216

[31] D.U. Siswanti, dan N.H.P. Utaminingsih, Capsaicin Level and Anatomy Response of Curly Red Chili (*Capsicum annuum* L.) to Bio Fertilizer and Sludge Biogas Application, International Conference on Science and Technology, UIN Alauddin Makasar 2-3 May, 2019. DOI: http://dx.doi.org/10.4108/eai.2-5-2019.2284700

[32] State University, Extension Service, O., State University. Extension, W., of Idaho. Extension, U., States. Dept. of Agriculture, U., Burt, L., Wolfley, B., & Northwest Cooperative Extension, P., Plant and Growth Development, Oregon State University, Extension Service, 2021.

[33] Jr. C. Stewart, B.C. Kang, K. Liu, M. Mazourek, S.L. Moore, E.Y. Yoo, B.D. Kim, I. Paran, and M.M. Jahn, The Pun1 Gene for Pungency In Pepper Encoding a Putative Acyltransferase, The Plant Journal, vol. 42, 2005, pp. 675-688. DOI: https://doi.org/10.26554/jps.v22i1.553

[34] D.R. Supriadi, A.D. Susila, dan E. Sulistyono, Penetapan Kebutuhan air tanaman cabai merah (*Capsicum annuum* L.) dan cabai rawit (*Capsicum frutescens* L.), Jurnal Hortikultura Indonesia, vol. 9(1), 2018, pp. 38-46. DOI:https://doi.org/10.29244/jhi.9.1.38-46

[35] S.A. Susanti, and E.S. Fuskhah, Pertumbuhan dan Nisbah Kesetaraan Lahan (NKL) Koro Pedang(*Canavalia Ensiformis*) Dalam Tumpangsari dengan Jagung (*Zea Mays*), Agromedia, vol. 32(2), 2014, pp. 38-44. DOI: https://doi.org/10.47728/ag.v32i2.92

[36] Y. Wahyuni, A.R. Ballester, E. Sudarmonowati, R.J. Bino, dan A.G. Bovy, Secondary Metabolites of Capsicum Species and Their Importance in the Human Diet, Journal of Natural Products, vol. 76(4), 2013, pp. 783–793. DOI:10.1021/np300898z

[37] Zamora, A. G, E. S. Campos, R.P. Morales, C. V.Vázquez, M. A. G. Robles, J. D.L. Martínez, dan J. L. G. Hernández, Measurement of Capsaicinoids in Chiltepin Hot Pepper: A Comparison Study between Spectrophotometric Method and High Performance Liquid Chromatography, Analysis Journal of Chemistry, vol. 2015, 2014, pp.1-10. DOI:https://doi.org/10.1155/2015/709150

[38] S.M.A. Zobayed, F. Afreen, dan T. Kozai, Phytochemical and physiological changes in the leaves of St. John's wort plants under a water stress condition, Environmental and Experimental Botany, vol. 59(2), 2007, pp.109-116.