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Response to Addition of Lighting Duration and Electrical Induction in Lettuce (*Lactuca sativa* L.) Plant on the Uptake of Nitrogen, Phosphors, Potassium and Yield

Sugiarto Sugiarto[1], Luchis Rubianto[2], Shafira Ghoni Rosyida Shaberina[3]

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ABSTRACT

Background: The impact of excessive use of chemical fertilizers and pesticides causes problems of land degradation, low fertility levels and reduced cation exchange capacity. To increase nutrient uptake and yield of lettuce plants, cultivation techniques using induction and additional lighting are needed. The aim is to increase nutrient absorption and plant yields.

Methods: The research design used a split plot with Factorial Randomized Groups. Factor 1 Lighting duration (P) for 4 and 8 hours per day and Factor 2, induction with DC (Direct Current) current (S). Induction 1 time per day (S_1); The treatment in this study was repeated 4 times. Induction 2 times per day (S_2) and Induction 3 times per day (S_3).

Result: The combination P2S2 showed good results regarding the uptake of Nitrogen (20.1 Kg.Ha^{-1}), Phosphorus (2.71 Kg.Ha^{-1}) and Potassium (67.23 Kg.Ha^{-1}) in plant leaves. The P1S2 treatment showed a leaf area of (1652.19 cm2). The adding 4 hours of light and an induction interval of 2 times per day gave good results on the uptake of Nitrogen, Phosphorus and Potassium in the leaf of lettuce plants.

Key words: Induction, Lighting duration, Nutrient uptake.

INTRODUCTION

It is very possible for lettuce plants to be grown in hydroponic media. To increase productivity, cultivation techniques need to be improved. The technique of adding light and induction is expected to increase the productivity of lettuce plants. Plant productivity can be high if the photosynthesis and nutrient uptake processes run optimally.

Lettuce plants in the photosynthesis process take place well at a wavelength of 435 nm and a peak of 663 nm. Lettuce plants show a positive response if they receive light with a wavelength of 435 nm on the photosynthate grown in hydroponic media. The system of adding LED (Light Emitting Diode) Grow lights in the peak area of 450 nm blue light and 663 nm red light is very good for producing assimilated lettuce plants (Mohamed *et al*., 2021).

During the growth process, plants need nutrients so they can grow and develop well. Lettuce plants absorb nutrients in the form of simple ions and cations. Based on electrochemical properties, complex compounds in soil or hydroponic media have positive and negative ion charges. Chemical compounds in the soil can be broken down if there is a conductor such as water. Technically, decomposition can be accelerated with induction techniques.

The induction technique is one way to help the availability of nutrients in plants. Induction is the provision of a weak electric current to the hydroponic plant media. During the induction process, ionization of the elements in the soil or planting medium occurs (Sugiarto *et al*., 2013a). The induction application is based on electrode theory where the process of releasing anions and cations in the soil will occur. Install electrodes on agricultural land and during the induction process there will be a release of positive and negative ions in the soil. Two electrode poles (anode and cathode) are electrified, which will result in an electrolysis process, namely Anode: $2H_2O–4e^-O_2$ + 4H+ and Cathode: $2H_2O$ +$2e^-H_2$ + $2OH^-$. During the electrocuting process, hydrogen ions are transferred to the cathode and OH^-anode poles (electromigration).

The cultivation system for vegetable crops such as lettuce requires management of the availability of nutrients in sufficient quantities, according to needs and on time. Simple compounds or nutrients must be available and sufficient when plants need them, especially when metabolism takes place, namely photosynthesis. The optimal induction application to decompose complex compounds is 60 minutes in paddy fields or aqueous planting media (Arfarita *et al*., 2020). Improving the quality

[1]Agrotechnology Study Program, Faculty of Agriculture, Islamic University of Malang, 65144, Indonesia.
[2]Industrial Chemical Engineering Study Program, Malang State Polytechnic, 65144, Indonesia.
[3]Bachelor Faculty of Cultural Sciences, Brawijaya University Malang, 65145, Indonesia.

Corresponding Author: Sugiarto Sugiarto, Agrotechnology Study Program, Faculty of Agriculture, Islamic University of Malang, 65144, Indonesia. Email: sugiarto@unisma.ac.id

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of lettuce plants as a vegetable with high nutritional value needs to be improved in order to support the fulfillment of vitamins. It is also reported that the application of induction for 60 minutes can improve the quality of onion crops (Sugiarto and Handoko, 2020).

It is hoped that this research can provide input to farmers or practitioners in cultivating vegetable crops using the hydroponic model. Efforts to increase productivity and improve the quality of results can be done by increasing the exposure time and carrying out induction.

MATERIALS AND METHODS

This research was conducted at the agricultural faculty of the Islamic University of Malang, Indonesia and the year of implementation was 2024. Using styrofoam measuring 40×60×30 cm, 15 watt LED (Light Emitting Diode) lamp, Lolin V3 microcontroller, temperature sensor, ac-dc inverter, 5 Volt adapter, digital scale, Total Dissolve Solid meter, pH Meters, Kjeldahl methods, grand rapid lettuce seeds from the Know You Seed brand, rockwool, netpot and AB mix hydroponic nutrients from the Himamix General Vegetable brand. Implementation is 1). Install LED lights at a distance of 50 cm from the plant canopy. 2). Installation of electrical installations for induction of growing media.

Sowing is carried out on rock wall media, until the seeds are 24 days old, then transferred to hydroponic media using the Deep Flow Technique system. This hydroponic system plants without using soil but instead places the plant roots in a 4-6 cm deep nutrient solution with continuous nutrient circulation. Preparation of AB mix Nutrient Solution is adjusted to the recommended dosage. The nutrition used is AB mix brand Himamix. Making the nutrient solution is: taking 5 ml of AB Mix type A solution then adding 990 ml of water and stirring until homogeneous. Once the mixture is even, add 5 ml of AB Mix type B solution and stir evenly.

The additional light treatment was using an LED lamp with a power of 15 watts. The addition of LED lights in treatment P_1 starts at 18.00-22.00. The addition of lights in treatment P_2 starts at 18.00-02.00. The induction application is carried out according to the treatment in each styrofoam tub. Induction is carried out for 30 minutes. Treatment S_1 (1 time) induction starts at 09.00-09.30. S_2 treatment (2 times) induction starts at 09.00-09.30. and will be induced again at 12.00-12.30. S_3 treatment (3 times) induction starts at 09.00-09.30 and is induced again at 12.00-12.30, last induction at 15.00-15.30. The research design used was a split plot with randomized groups consisting of 2 treatment factors. The main plot in this treatment is the addition of light and the subplot is the induction time. The first factor is the addition of the exposure time (P) where P_1 is the addition of the exposure time for 4 hours per day (starts at 18.00 - 22.00). Treatment P_2 is an increase in the length of exposure to 8 hours per day (starts at 18.00-02.00). The second factor is electrical induction with DC (Direct Current) current for 30 minutes. The treatment carried out was induction for 30 minutes carried out once per day. That is induction starts at 09.00-09.30 (S_1). Another treatment is induction for 30 minutes, carried out 2 times per day. Induction to the first starts at 09.00-09.30 and the second at 12.00-12.30 (S_2). The next treatment is induction for 30 minutes carried out 3 times per day. Induction to the first starts at 09.00-09.30 and the second at 12.00-12.30, the last at 15.00-15.30 (S_3). The treatment in this study was repeated 4 times. When carrying out induction, the current coming out of the induction device must be maintained in the range of 11 Volt Amperes. The data analysis used is Analysis of Variance (ANOVA) with a significance level of 5%. If there is a real influence, further tests are carried out using the Duncan Test at a 5% level and regression test.

RESULTS AND DISCUSSION

The results of the analysis of nitrogen uptake on the leaves of lettuce plants showed that the treatment with additional light for 4 hours per day was better than the addition of 8 hours. The treatment of adding LED light illumination for 4 hours per day on lettuce plants using the Deep Flow Technique hydroponic cultivation system showed that it was able to increase the amount of nitrogen uptake as much as 5 kg per hectare for each additional 1 hours 35 minutes. Meanwhile, adding 8 hours of light per day showed that it took longer, namely 2 hours 38 minutes, to increase the amount of nitrogen uptake as much as 5 kg per hectare (Graph 1).

The growth of lettuce plants is influenced by nutrients such as nitrogen, phosphorus and potassium. The presence of these elements is very important in the formation of leaf chlorophyll. The photosynthate produced during the metabolic process requires light. The addition of light with LED lights is expected to increase photosynthate yield and nutrient uptake in plants. The photosynthesis rate of lettuce plants will produce good photosynthesis as the LED light intensity increases (Miao *et al*., 2023). Application using light can improve the biological and morphological parameters of flower and vegetable plants (Arkam *et al*., 2017). The function of nitrogen not only increases photosynthetic efficiency but also promotes cell differentiation (Liu *et al*., 2018). The nitrogen uptake shown by lettuce plants with additional LED lighting for 4 hours per day showed a higher uptake value (20.1 $kg.Ha^{-1}$) compared to the addition of 8 hours of light (11.25 $kg.Ha^{-1}$).

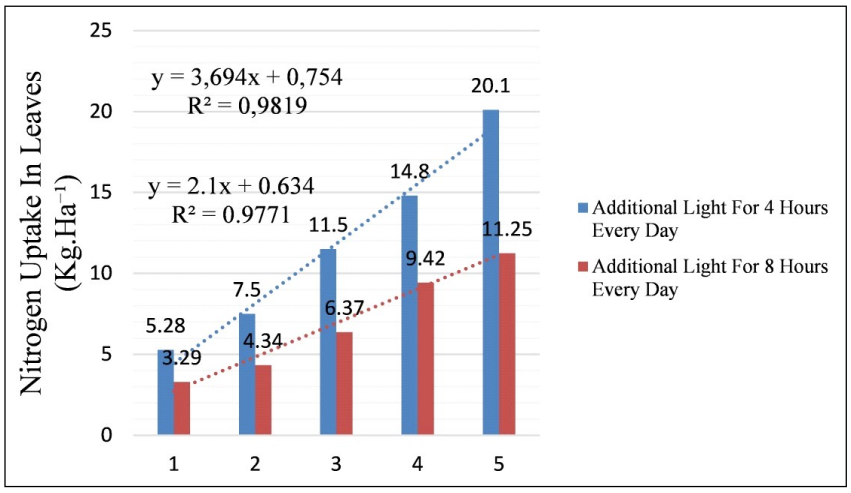
Lettuce plants need a wavelength range of 400-700 nm to carry out photosynthesis. Photosynthesis can run optimally at a wavelength of 660 nm. This situation really helps the metabolic process in producing photosynthesis. The growth of lettuce plants during photosynthesis runs well in blue and red light with a ratio of (1.25±0.1). A wavelength of 450 nm of blue light with a peak of 663 red light has a ratio of (1.25±0.1) at high intensity (270±20 μmol $m^{-2}s^{-1}$) (Mohamed *et al.,* 2021).

The application of electrical induction for 30 minutes twice a day on the planting medium can help with the availability of nutrients. Electrical induction can decompose complex compounds into simpler compounds that are available to plants. Application of electrical induction twice a day with a duration of 30 minutes can help break down complex compounds into ions and cations that are available for plants (Sugiarto and Handoko, 2020).

The combination of adding LED lights and electrical induction (P_1S_2) showed an increase in leaf area variables (Table 1). This is because plants aged 17 days already have the ability to adapt to their growing environment. This is supported by the temperature conditions in the growing room, namely 15-18°C in the morning and 25-28°C in the afternoon. This situation will help the process of storing photosynthate results to be allocated to the broad organs of the plant leaves. The increase in fresh weight of lectuce plants is caused by environmental support such as solar radiation, humidity, temperature and microorganism activity (Gheshm and Brown, 2020). Crunchy and Deangelia lettuce cultivars showed an increase in photosynthate yield as LED light intensity increased (Miao *et al*., 2023).

Induction of 30 minutes per day is still not optimal in stimulating plant vegetative growth (Sugiarto and Handoko, 2020). This is because 30 minutes of induction does not produce sufficient perfect ionization. Good induction for food and vegetable plants should be carried out for 60 minutes (Sugiarto *et al.,* 2013a; Sugiarto *et al*., 2013b). For nutrient absorption, lettuce plants require Emultion Concentration (EC) ranging from 1.5-2.5 dS/m or equivalent (750-1250 ppm). A nutrient solution whose concentration is too high will affect the absorption capacity of plant roots (Mohamed *et al*., 2021). Lettuce plants are a type of vegetable that is easy to grow in hydroponic media. Therefore, this research was carried out on hydroponic media to study nutrient uptake using electrical induction. The results of this research show that the absorption of nitrogen, phosphorus and potassium elements is very good.

The induction process forces the ionized solution through the cathode. The release of positive and negative ions in the nutrient solution will be absorbed by the lettuce plant roots. Based on the analysis results (Graph 2), induction at intervals of 3 times a day is less effective when applied to lettuce plants using the Deep Flow Technique hydroponic systems. Lettuce plants during the growth process require the availability of sufficient nutrients, at the right time and in the right concentration so that they can be absorbed effectively and efficiently. Hydroponic growing



Graph 1: Nitrogen uptake in lettuce plant leaves treated with additional exposure time.

Table 1: Area of leaves each plant on lettuce plants with additional duration of lighting and electrical induction.

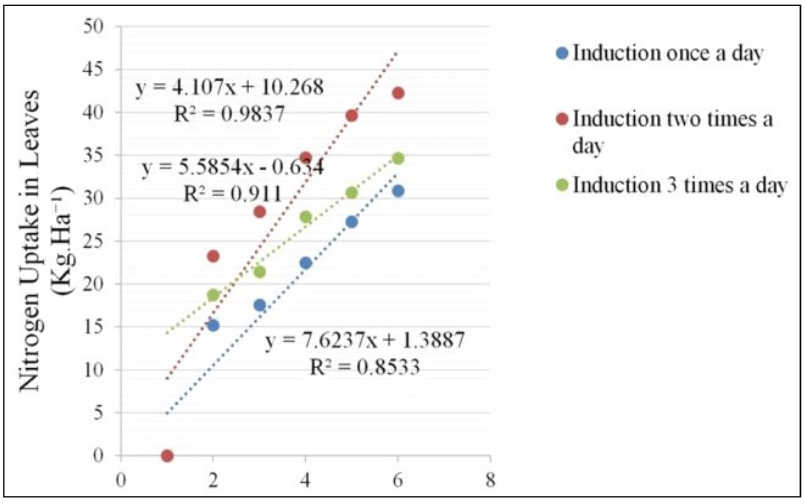
Treatment		Area of leaves each plant (cm²)			
		14	17	23	26
P_1	S_1	65.90 cd	118.93 a	405.42 a	1307.54 c
	S_2	65.65 c	146.15 b	560.34 c	1652.19 e
	S_3	74.13 d	118.14 a	466.95 b	1111.80 b
P_2	S_1	49.06 a	164.38 c	493.43 bc	1426.53 d
	S_2	60.64 b	166.44 c	529.71 c	1407.71 d
	S_3	44.75 a	115.55 a	390.45 a	798.21 a
Duncan 5%		s	s	s	s

Note: Numbers accompanied by the same letter in the column indicate that they are not significantly different at the Duncan test level of 5%, s- significant, P- Additional Duration of Lighting, $S_{1,2,3}$-induction per day.

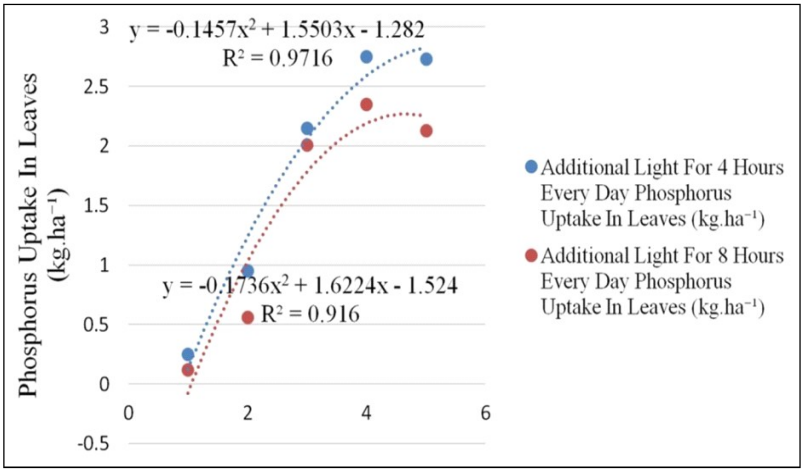
media that is electrically induced for 30 minutes per day means that lettuce plants show the ability to increase nitrogen absorption by 5 kg per hectare with an additional time of 1,22 minutes. The application of electric induction intervals 2 times per day with a duration of 30 minutes requires an additional 0.89 minutes of time to increase. The application of electrical induction intervals 3 times per day with an induction duration of 30 minutes requires an additional 0.66 minutes (Graph 2) Implementation of induction for 60 minutes in plant media can help provide nutrients for plants (Arfarita *et al*., 2020).

The effect of increasing the length of light on the uptake of the element Phosphorus in the leaves of lettuce plants is shown in Graph 3. Lettuce plants show an increase in the uptake of the element Phosphorus, where the addition of 4 hours of light is proven to be better compared to 8 hours per day. The results of the analysis of the uptake of phosphorus elements show that the treatment of adding 15 watt LED light for 4 hours per day shows that for each additional 3 hours 42 minutes can increase the uptake of phosphorus elements by 0.5 kg per hectare. The addition of LED lights for 8 hours per day requires an additional 3 hours 28 minutes. Meanwhile, the electrical induction treatment on hydroponic media which is carried out once a day for 30 minutes requires an additional 0.13 minutes. Application of electrical induction for 30 minutes, carried out twice per day, requires an additional time of 0.15 minutes. Meanwhile, 30 minutes of electrical induction carried out 3 times per day requires an additional 0.23 minutes to produce 0.5 Kg per hectare (Graph 4).

The addition of 4 hours of exposure showed better phosphorus absorption results compared to 8 hours. An additional 4 hours with a 15 watt LED lamp, when the sun has just set, still has a hot (warm) effect on the environment, so that plants can still utilize the thermal heat for metabolism. The addition of light after sunset will increase the amount of thermal heat that plants can use to carry out metabolism (periodic photos). As for the addition of 8 hours, the growing environmental conditions are relatively close to the minimum temperature and maximum humidity. Plants that have experienced saturation in absorbing light will also have an impact on their ability to absorb elements such as



Graph 2: Nitrogen uptake in lettuce plant leaves during the induction interval treatment.



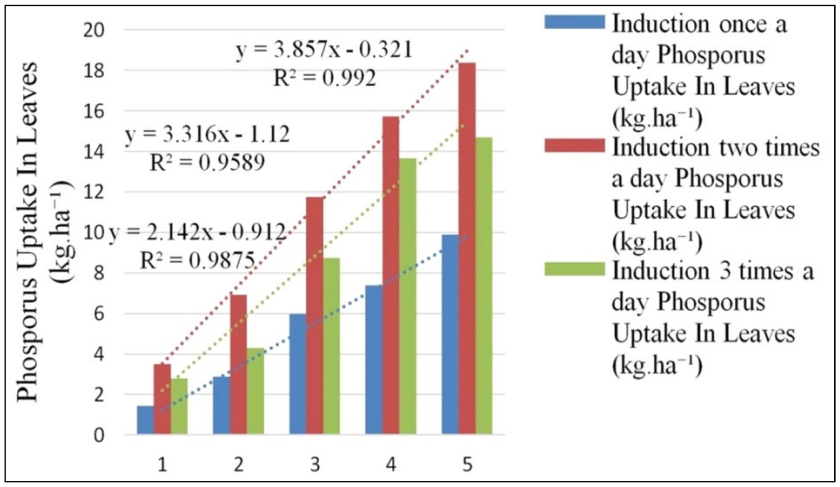
Graph 3: Uptake of the phosphorus in lettuce plant leaves treated with additional exposure time.

phosphorus. The decrease in light absorption is related to the role of phosphores in photosynthetic activities. Low absorption of phosphorus often results in low photosynthetic activity so that the photosynthate yield is also relatively low (Kume *et al*., 2018).

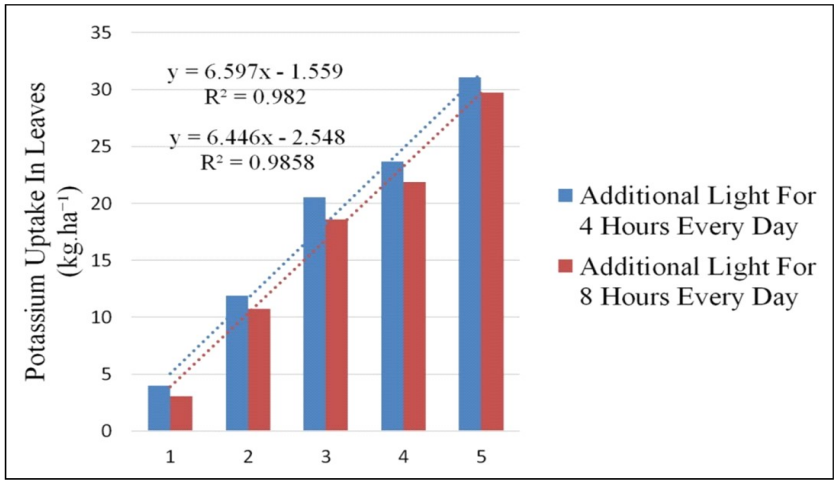
Induction treatment at intervals of 2 times a day showed that the results of plant uptake of the Phosphorus element (18.34 kg.ha^{-1}) were relatively better when compared to induction once per day and 3 times a day (9.83 kg.ha^{-1}). Planting media that was given induction treatment at intervals of 3 times a day did not show optimal results. This is possible because during application intervals 3 times a day, the growing environmental conditions in the green house are already relatively hot. Lettuce plants adapt when there is more daylight, as the effect of transpiration is quite high. This situation will affect the amount of phosphorus uptake in the leaves of lettuce plants. Lettuce plants in their growth and development really need the element Phosphorus. Phosphorus is an important macro nutrient that plants must obtain. The role of the phosphorus element is for plant metabolism, adenosine triphosphate (ATP), nicotinamide adenine dinucleotide phosphate hydrogen (NADPH), nucleic acids, phospholipids, each of which has a function in growth, signal transduction, photosynthesis and plant yield (Hong *et al*., 2023).

Potassium is an enzyme activator in protein synthesis, sugar transport, nitrogen and carbon metabolism and photosynthesis processes. Potassium has an important role in increasing plant quality and yield. The treatment of adding 15 watt LED light for 4 hours per day on hydroponic media planted with lettuce showed that every 0.76 hour additional time could increase the uptake of potassium by 5 kg per hectare. Meanwhile, adding 8 hours of light per day requires 0.77 hours to increase potassium uptake by 5 kg per hectare (Graph 5). The research results show that white light combined with 663 nm red light and 435 nm blue light can increase growth and essential oil conten (Shiren Jalal Mohamed, 2024).

The results of the analysis of potassium uptake in lettuce plants grown in hydropnic media and subjected to electrical induction for 30 minutes at intervals of 1 time per



Graph 4: Phosphorus nutrient uptake in lettuce plant leaves against induction interval treatment.



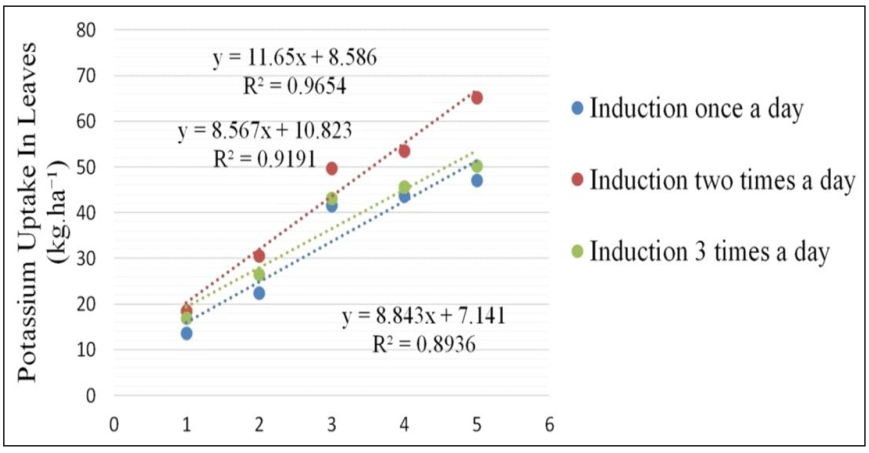
Graph 5: Uptake of potassium elements in lettuce plant leaves with increasing exposure time.

day show that to increase the absorption capacity of lettuce plants for potassium, an additional 0.86 hours is needed to increase 10 kg per hectare. Meanwhile, the application of electrical induction twice per day for 30 minutes requires an additional 1.17 hours to increase potassium uptake by 10 kg per hectare. The application of electrical induction for 30 minutes at intervals of 3 times per day requires an additional 1.13 hours to increase potassium uptake by 10 kg per hectare (Graph 6).

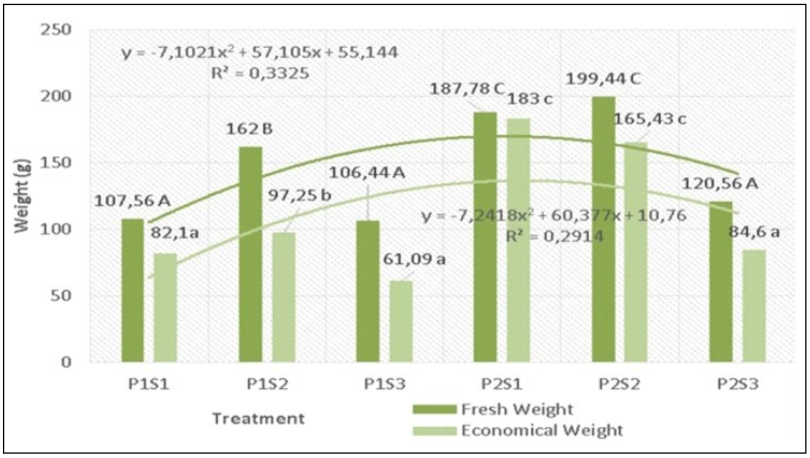
The potassium element is needed in large quantities because it has a very important role in metabolic activities both in cells and improving the quality of plant products, including fruit that tastes sweeter, tastes better and increases weight. Potassium is essential for cell growth, controlling ATPase in the plasma membrane, triggering cell wall loosening and hydrolase activation. Potassium also plays an active role in strong mobility in plants, regulates cell osmotic pressure, balances cations and anions in the cytoplasm (Lilan *et al*. 2023).

Induction treatment at intervals of 2 times a day showed that the results of plant uptake of the potassium element were significantly different when compared with induction once per day and 3 times a day. Planting media that is induced at intervals of 3 times a day does not show optimal results. This makes it possible for plants to be more likely to adapt, namely to compensate for excessive transpiration. This situation will affect the amount of potassium absorbed in the leaves of the lettuce plant. The potassium content in each plant is not the same and the relationship between potassium and nitrogen in metabolism is antagonistic (Coskun *et al*. 2016).

The combination of increasing the length of light and induction shows a real influence on the total fresh weight variable of lettuce plants, as presented in Graph 7. The combination of increasing the length of light for 8 hours per day with induction once results in fresh plant weight (187.78 g) and twice per day (199.44 g), showed no significant difference. However, the fresh weight of plants produced in treatments P_2S_1, P_2S_2 was better when compared to P_2S_3 showing a significant difference (120.56 g). This situation is caused by plant metabolism starting to decline during the day from 11.00 - 15.30. Plants do a lot of evapotranspiration so they look wilted. This situation is due to the temperature in the greenhouse increasing, so that the induction application given 3 times a day is not effective.



Graph 6: Uptake of potassium elements in lettuce plant leaves during induction interval treatment.



Graph 7: Fresh weight and economic weight of lettuce with additional exposure time and induction.

When lettuce plants undergo transpiration, they can adapt to their environment, relatively plants do not absorb many nutrients. The temperature in the greenhouse plays a very important role in the process of photosynthesis and growth of lettuce plants. The role of light intensity and temperature is very large in the photosynthesis process. Lettuce plants in carrying out metabolic activities require a certain amount of light intensity and an optimal temperature range, so that the photosynthate produced can be high. The photosynthesis process will run well and can increase nutrient uptake and plant yields if the light received is 100% (Setyaningrum *et al*., 2020). The light range for photosynthesis and yield of lettuce plants is 350-500 $\mu mol \cdot m^{-2} \cdot s^{-1}$ with temperatures ranging from 15°C. Light intensity of 350-600 $\mu mol \cdot m^{-2} \cdot s^{-1}$ preferably a moderate temperature of 23°C. The light intensity is 500 - 600 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and is good for strong lettuce plants at 30°C (Zhou *et al*., 2022).

The combination of treatments P_2S_1 (183.00 g) and P_2S_2 (165.43 g) showed better economic weight compared to the other treatments. The addition of light can minimize stem growth and plant etiolation. The number of induction intervals has been proven to influence plant growth and development. This is due to the availability of the right nutrients when needed for planting. Lettuce plants carry out the process of photosynthesis, needing an adequate supply of nutrients, in order to increase high photosynthesis yields (Lestari *et al*., 2019).

CONCLUSION

Efforts to increase the quantity and quality of lettuce production can be done using the Deep Flow Technique hydroponic system. The implementation is good if combined with the addition of LED lights for 4 hours per day and the application of electric induction for 30 minutes twice a day.

ACKNOWLEDGEMENT

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Recommendations

Further investigation is needed. Research can be carried out using a hydroponic system or in the field with the addition of light for 4 hours per day and the application of electric induction lasting 60 minutes once per day.

Conflict of interest

We respectfully wish to convey there is an error in one of the authors' names in our article. After we ran through it together one more time, we discovered an error in the writing: The name Luchis Rubianto was incorrectly written as Lucis Rubianto. As authors, we acknowledge that this error was purely an oversight and not intentional. We provide this statement for the official record.

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