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INTERACTIVE EFFECTS OF LED LIGHTINGS AND NITROGEN ON GROWTH AND PHYSIOLOGICAL PROCESSES OF LETTUCE (Lactuca sativa L.)

NORFADHILLAH BINTI ANUAR

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By

NORFADHILLAH BINTI ANUAR

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

May 2018

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This thesis is dedicated to:
My parents,
My husband,
My siblings,
and
My friends,

For love, support and sacrifices

Abstract of thesis presented to the Senate of University Putra Malaysia in fulfilment of the requirements for the Degree of Master of Science

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May 2018

Chairman : Associate Professor Yahya Bin Awang, PhD
Faculty : Agriculture

Inefficiency of traditional growing lights led the use light-emitting diode (LED), which is characterized as energy efficient, long operating lifetime, low maintenance cost and do not emit excessive radiant heat. Plants growth under varying irradiance regimes have different physiological behaviour thus it respond differently to different levels of nutrient availability. The study reported here was aimed at evaluating the impact of various regimes of LED lights on lettuce (*Lactuca sativa*) grown under different rates and sources of nitrogen.

To evaluate the interaction effects between LED lightings and rate of nitrogen on growth and physiological processes of two varieties of lettuce, an experiment involving five light regimes [L1-red/blue (126 µmol $m^{-2}s^{-1}$), L2-red/blue (170 µmol $m^{-2}s^{-1}$), L3-red/blue/far-red/white (266 µmol $m^{-2}s^{-1}$), L4-red/blue/fluorescent (201 µmol $m^{-2}s^{-1}$) and L5-red/blue/far-red (183 µmol $m^{-2}s^{-1}$)], three additional nitrogen rate (0, 7.5 and 15 g urea L^{-1}) and two lettuce variety (Iceberg and Butterhead) were conducted. Plants grown under L3 with combination spectrums of red, blue, far-red and white with the highest intensity (266 µmol $m^{-2}s^{-1}$) produced the highest yield. Plants under L4 and L3 had higher net photosynthesis compared to those grown under L1, L2, and L5. Leaf of lettuce under L3 contained the lowest nitrogen and potassium percentage. Increasing N rate from 7.5 and 15 g urea L^{-1} did not markedly affect the growth and chlorophyll content of leaves, despite the increase in leaf nitrogen, calcium and magnesium contents in leaves.

The interactive effects of five light regimes (as in earlier experiment), three nitrogen sources (Urea, KNO_3 and $Ca(NO_3)_2$) and two rates (3.45 and 6.9 g N L^{-1}) of nitrogen on butterhead lettuce were examined in the following experiment. Lettuce grown under L3 was the most superior in yield compared to those grown with other lights regimes. The yield of lettuce grown under L3 was 98.03 g plant^{-1}, whereas the lowest yield was belonged to plants grown under L1 (57.51 g plant^{-1}). Plant height, number of leaves and total leaf area were positively correlated to the yield. Nitrate content in leaves was significantly affected by the light regimes with plants grown under L3 and L4 contained the lowest concentration of nitrate. Amongst nitrogen sources tested, use of urea had resulted in heaviest yield with the lowest nitrate content in leaves. Application of urea and KNO_3 had significantly influenced the content of total phenolic and total flavonoid in lettuce. N rate of 6.90 g N L^{-1} generated significantly higher leaf number, yield, total leaf area, leaf nitrogen, nitrate and total phenolic contents in butterhead lettuce compared to those grown under 3.45 g N L^{-1}.

In conclusion, growth and physiological processes of lettuce were found to be significantly affected by the light regimes, nitrogen rate and sources of nitrogen. Within limitation of the current study, it was found that LED light with red, blue, far red and white LEDs (L3, 266 µmol m^{-2}s^{-1}) coupled with urea given at 7.5 g N L^{-1} had produced the highest yield and lowest nitrate content in lettuce.

Keywords: Light emitting diode (LED), lettuce, nitrogen, nitrate, urea, total phenolic content, total flavonoids content.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

KESAN INTERAKTIF LAMPU LED DAN NITROGEN PADA PERTUMBUHAN DAN PROSES FISIOLOGI KE ATAS SAYUR SALAD (*Lactuca sativa* L.)

Oleh

NORFADHILLAH BINTI ANUAR

Mei 2018

Pengerusi : Profesor Madya Yahya Bin Awang, PhD
Fakulti : Pertanian

Ketidakcekapan lampu tradisional telah membawa kepada penggunaan diod pemancar cahaya (LED), yang mempunyai ciri sebagai tenaga yang cekap, jangka hayat operasi yang lama, kos penyelenggaraan yang rendah dan tidak memancarkan haba yang berlebihan. Pertumbuhan tumbuhan di bawah rejim lampu yang berlainan memberikan respon fisiologi yang berbeza, dengan itu ia memberikan tindak balas berbeza terhadap tahap ketersediaan nutrient. Kajian ini bertujuan untuk menilai impak rejim lampu LED pada salad (*Lactuca sativa* L.) yang tumbuh di bawah kadar dan sumber nitrogen yang berbeza.

Untuk menilai kesan interaksi antara cahaya LED dan kadar nitrogen pada pertumbuhan dan proses fisiologi terhadap dua jenis salad, eksperimen yang melibatkan lima rejim cahaya [L1-merah / biru (126 µmol $m^{-2}s^{-1}$), L2-merah / biru (170 µmol $m^{-2}s^{-1}$), L3-merah / biru / 'far-red' / putih (266 µmol $m^{-2}s^{-1}$), L4-merah / biru / pendarfluor (201 µmol $m^{-2}s^{-1}$) dan L5-merah / biru / merah-merah (183 µmol $m^{-2}s^{-1}$)], tiga kadar nitrogen (0, 7.5 dan 15 g urea L^{-1}) dan dua jenis salad (Iceberg and Butterhead). Tumbuhan yang ditanam di bawah L3 dengan spektrum gabungan merah, biru, merah dan putih dengan intensiti tertinggi (266 µmol $m^{-2}s^{-1}$) menghasilkan hasil tertinggi. Tumbuhan di bawah L4 dan L3 mempunyai fotosintesis yang lebih tinggi berbanding dengan yang ditanam di bawah L1, L2, dan L5. Daun salad di bawah L3 mengandungi peratusan nitrogen dan kalium terendah. Kadar N meningkat daripada 7.5 dan 15 g urea L^{-1} tidak menjejaskan pertumbuhan dan kandungan klorofil daun, walaupun peningkatan kandungan nitrogen daun, kalsium dan magnesium daun.

Kesan interaktif lima rejim cahaya (seperti dalam eksperimen terdahulu), tiga sumber nitrogen (Urea, KNO_3 dan Ca $(NO_3)_2$) dan dua kadar (3.45 dan 6.9 g N L^{-1}) nitrogen

pada salad butterhead dikaji di dalam eksperimen. Salad yang ditanam di bawah L3 mempunyai hasil yang paling unggul berbanding dengan yang dibawah dengan rejim lampu lain. Hasil salad yang ditanam di bawah L3 adalah 98.03 g, sedangkan hasil terendah adalah salad yang ditanam di bawah L1 (57.51 g). Ketinggian tumbuhan, jumlah daun dan jumlah luas daun berkorelasi positif kepada hasil. Kandungan nitrat dalam daun telah terjejas dengan ketara oleh rejim cahaya dimana salad yang ditanam di bawah lampu L3 dan L4 mengandungi kepekatan nitrat yang paling rendah. Di antara sumber nitrogen yang diuji, penggunaan urea telah menghasilkan hasil paling berat dengan kandungan nitrat paling rendah dalam daun. Penggunaan urea dan KNO_3 telah mempengaruhi kandungan fenolik dan flavonoid dalam salad. Kadar N pada 6.90 g N L^{-1} telah menghasilkan jumlah daun, hasil, jumlah keluasan daun, kandungan nitrogen dalam daun, nitrat dan jumlah kandungan fenolik yang tinggi di dalam salad butterhead berbanding dengan yang tumbuh di bawah 3.45 g N L^{-1}.

Kesimpulannya, pertumbuhan dan proses fisiologi salad didapati dipengaruhi oleh rejim cahaya, kadar nitrogen dan sumber nitrogen. Dalam batasan kajian semasa, didapati cahaya LED dengan gabungan merah, biru, ‘far-red’ dan putih LED (L3, 266 µmol $m^{-2}s^{-1}$) ditambah dengan urea yang diberikan pada 7.5 N g L^{-1} telah menghasilkan hasil tertinggi dan kandungan nitrat terendah dalam salad.

Kata kunci: Diod pemancar cahaya (LED), salad, nitrogen, nitrat, urea, kandungan fenolik, kandungan flavonoid.

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Signature:	______________________
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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
$CA(NO_3)_2$	Calcium nitrate
CO_2	Carbon dioxide
cm	Centimetre
DAT	Day after transplant
DNA	Deoxyribosenucleic acid
ETP	Economic Transformation Programme
FAO	Food Agriculture Organization
DOA	Department of Agriculture
GAE	Gallic acid equivalent
g	Gram
g Urea L^{-1}	Gram urea per liter
HPS	High pressure sodium
H_2O_2	Hydrogen peroxide
H_2SO_4	Sulphuric acid
IAA	Indole acetic acid
kg	Kilogram
KNO_3	Potassium nitrate
K+	Potassium ion
LED	Light-emitting diode
MeOH	Methanol
mmol m^{-2} s^{-1}	Millimol per meter square per second
NADH	Nicotineamide adenine dinucleotide
NADPH	Nicotineamide adenine dinucleotide phosphate hydrogen

NaOH	Sodium hydroxide
Na_2CO_3	Sodium carbonate
NO^{-3}	Nitrate
nm	Nanometer
PAR	Photosynthetically active radiation
Pn	Photosynthesis rate
PS I	Photosystem I
PS II	Photosystem II
QA	Electron acceptor
RuBisCO	Ribulose-1,5-bisphosphate carboxylase/oxygenase
RH	Relative humidity
RNA	Ribonucleic acid
TFC	Total flavonoid content
TPC	Total phenolic content
UV	Ultraviolet
v/v	Volume per volume
$\mu mol\ m^{-2}\ s^{-1}$	Micromole per meter square per second

CHAPTER 1

INTRODUCTION

Light is energy that radiated by a light source in electromagnetic wave. In photobiological study, light is very crucial to the plants for photosynthesis process. Natural light emitted energy from various range of wavelength as a broad spectrum. Some narrow spectrum such as blue and red play roles as the basis of absorption spectra for the development of growth and physiology of the plants. Study regarding on light quality or spectrum is quite complex, compared to study conducted based on light intensity or photoperiod.

Indoor farming normally involves cultivation of high value and fast growing crops with high harvest index in closed and control environment of growth chamber. The benefits of indoor farming are able to avoid the uncertainty of weather, avoid pest mortality, provide pollution security to consumer and offer sustainability for consistent production of produces. This practice is perhaps able to develop year-round and rapid production practice for fresh, high quality, pesticide-free produces and economically feasible crops that is produced close to the final retail market (Lin et al., 2013). However indoor farming is extremely dependent on environment conditions, fertilizer formulation and light source.

Indoor farming require artificial lightings, which had been implemented in horticultural industry since decades ago as a replacement of natural light. Various types of artificial lightings had become as a source of light to the plants for example fluorescent lamp, metal halide, high pressure sodium (HPS) and incandescent lamp. These kinds of lamps emitted broad spectrum of wavelength. Other than red and blue, it may became such a waste as the other wavelength does not give crucial benefit or impact to the plants performance, if have, might be very little. Low energy efficiency yet high electrical power consumption had increase in production cost. Beside, this type of lamps contain filaments that must be periodically replaced. An adverse effect of high heat emission from these traditional lamps cause thermal injury if place close to the plant surface (Singh et al., 2015).This characteristics of lamps is contrast with the electrical efficiency of light- emitting diode (LED) (Barta et al., 1992).

Light-emitting diode (LED) lightings had been implemented in various industry, including horticultural industry since two decades ago. Innovation of LEDs had brought an attention to researchers in investigating the influence of LEDs as sole lighting system or supplementary lights in photobiological studies. One of the unique characteristics of LED is having specific wavelength of lights, that initiate the intention of researchers to conduct studies concerning the response of horticultural crops affected by specificity of wavelength impose. A little different in wavelength of light spectrum, let’s say blue spectrum at wavelength of 450 and 470 nm may possibly give different results on the morphological growth, physiological responses and quality of crops. Radiation of varies of wavelength stimulate different physiological effects on plants (Samuoliene et al., 2013). Other than that, LED is sustainable light source that is high in energy efficiency, which its electrical power consumption is lower. This can be attributed to reduction of production cost, thus bring more profit to the growers. Even though, at first the capital and operating cost is high, but then this utilization of LEDs technology give a profitable return in the long run. As LEDs have the ability to produce high luminous flux with low radiant heat output (Singh et al., 2015), so this light can be placed closed without the risk of thermal injury to the plants. LEDs is built with semiconductor diode which is safer to operate as it do not made with glass envelope, plus do not contain mercury, and does not build with filament which need to be periodically replaced.

The growth of indoor cultivated plants not only depending on the light irradiation, but also on adequate supply of nutrient for the growth and development of plants. One of the element that is needed the most by the plants is nitrogen. It is an essential macroelement that is vital for the morphological growth and physiological process in plants. It enhance the vegetative growth of plants by improve the plant height, increasing the leaves number of plants, increase the expansion of diameter and else. Besides, it plays roles in physiological approach such as responsible for chlorophyll synthesis, which it relate to the process of gases exchange in plants such as photosynthesis, chlorophyll fluorescence, transpiration rate, stomatal conductance and others. According to Teixeira et al. (2011), nitrogen stimulate the formation of photosynthetic pigments by increase the quantity of stroma and thylakoid proteins in leaves. Other than that, nitrogen also acts as a significant constituent for the synthesizing of amino acids and protein. Salisbury and Ross, (1992) testified that nitrogen works as a key component of metabolites involving amino acids, proteins, purines, pyrimidines, chlorophylls, enzymes as well as co-enzymes.

The hypothesis that want to be pointed out in this study is plants grown under different light intensity and spectrum may produce different growth rate and quality. Addition of nitrogen may help to increase the vegetable growth of plants and at the same time alter their constituents. It is known that light intensity affects the nitrogen content in plant, however not much is understood regarding the interaction between specific wavelength of light and nitrogen in plant. In view of the scenario, the objectives of this research are

1) To determine the effects of varying regimes of LED lights and rate of nitrogen on vegetative growth, yield and gas exchange of lettuce
2) To determine the interaction of LED lights and different sources of nitrogen on growth, yield and selected phytochemicals of butterhead lettuce.

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BIODATA OF STUDENT

Norfadhillah binti Anuar was born in Kemaman, Terengganu on 29th December 1991. She was the second child from six siblings. She received her primary education at Sekolah Kebangsaan Seri Kemaman (1998-2003); secondary education at Mara Junior Science College Kota Putra, Besut Terengganu (2004-2006) and Mara Junior Science College Tun Ghafar Baba, Jasin, Melaka (2007-2008). Then, she furthered her study at Pahang Matriculation College in 2009. A year later, she continued her study at Universiti Putra Malaysia (UPM), Serdang Selangor and received Bachelor of Horticultural Science in 2014. After graduated, she decided to pursue in Masters of Science in Horticulture under supervision of Associate Professor Dr. Yahya Awang.

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