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BIOMASS PRODUCTION OF LETTUCE (*Lactuca sativa* L.) UNDER WATER STRESS

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Abstract

This study was conducted to evaluate and determine the effect of water stress (waterlogged and drought) condition on the biomass of lettuce (*Lactuca sativa L.*) under protective structure. Potted lettuce plants were established in 3 weeks from transplanting and immediately subjected to water stress condition within 5 days. Plant height, number of leaves, weight and chlorophyll *b* were significantly influenced by water stress (waterlogged and drought) condition. However, pH, TSS, TA, total carotenoids and chlorophyll *a* was not significantly different among treatments. The result indicates that plants subjected to water stress condition were significantly affected it's physiological and biochemical processes such as changes in biosynthesis of plant pigments especially chlorophyll and carotenoids.

Key words: stress, total soluble solids (TSS), chlorophyll, carotenoids, total acidity, water stress

Introduction

The vegetable industry plays an important role in the economy of the country and nutrition needs of its populace. Vegetables are cultivated on 4.65M hectares with an annual production of 53.5 M tons in South and Southeast Asia. (Srinivasan, 2012). However, recently, the Philippines are only 65% sufficient in vegetable production. Every Filipino consumes only 44 kgs. of vegetables yearly which translates to a yearly demand of 3.8M metric tons for roughly 95M Filipinos. To raise the per capita consumption of every Filipino, vegetable production should be increase per unit area assuring consumers regular supply all-year round in order to be at par with the World Health Organization Standard (Alcala, 2012).

Lettuce (*Lactuca sativa L.*) is the most popular amongst the salad vegetable crops. This crop is a member of the Sunflower or *Compositae* family. Head types do well at low elevations only during the cooler parts of the year. Lettuce cultivars can be selected for their tolerance to the different environmental conditions found throughout the year. Leafy and semi-head lettuces may be grown year-round at many lower elevation sites. Cultivar selection is one of the most important decisions made during the crop production process. Selections of cultivars with disease resistance that are adapted to local growing conditions are significant production factors which need careful planning and consideration. Important quality characteristics for lettuce are size, compactness, sweetness, and succulence. These traits are often correlated with earliness to harvest. Plants which have a delayed harvest due to poor fertility, disease, or environmental factors, often show several disorders such as tip burn or bitterness (Hochmuth, 1990).

Environmental factors are one of the important factors affecting crop production, and that without the control of this factor could limit growth and yield of vegetable crops especially lettuce. Such that adaptation and performance of crops to its growing environment is greatly influenced and therefore should not be taken for granted. These environmental factors are divided into two (2), namely the biotic or biological and abiotic factors. These biotic factors include all life forms existing around the immediate vicinity of the crop, like insects, microorganisms,

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mammals and even weeds. While abiotic factors include the climate, temperature, light and rainfall that would greatly affect the growth performance of crops. Water status of the plant is one of the important factors that determine rate of survival of lettuce plants at the establishment stage. Waterlogging is a severe problem, which affects crop biomass in those areas where the concentration of rain is high. Drought stress on the other hand, results when the plant's water content is reduced enough to interfere with normal plant processes and when water loss from the plant exceeds the ability of the plant's roots to absorb water (Knox, 2005).

This study was conducted to evaluate and determine the effect of water stress condition on the growth and yield performance of lettuce under protective structure.

Materials and Methods

Seedling Production and Transplanting

A sterilized soil mix of garden soil, carbonized rice hull, and vermicast at a ratio of 1:1:1 was prepared and placed in the seedling trays. Lettuce seeds "General" variety was sown directly to the seedling trays at rate of 2 seeds per cell and thinning was done one week after sowing. Polyethylene bags with a size of 3 x 5cm were used and filled of sterilized mixture of garden soil, carbonized rice hull and vermicast at a ratio of 2:1:1. This was prepared before transplanting of the established lettuce seedlings. Lettuce seedlings were transplanted to the prepared growing bags with sterilized medium late in the afternoon to minimize wilting. Starter solution (dissolved fertilizer) was applied to newly transplanted seedlings initiating growth stabilization. One week after transplanting, drenching of Calcium Nitrate (CaNO3) at a rate of 1kg per 50 liters of water was done to give ample supply of nutrients for better growth.

The lettuce plants were placed under a protective structure with UV plastic film roofing materials to protect the plants from rain and direct sunlight.

Experimental Design, Statistical Analysis and Treatments

A Randomized Complete Block Design (RCBD) was used in this study. All treatments were replicated three times and consisted of 5 sample plants in each replication. The treatments were the following:

T_0- Control
T_1- Drought condition
T_2- Waterlogged condition
T_3- Waterlogged-drought condition
T_4- Drought-waterlogged condition

The data gathered were analyzed using the Version 1.0 of the *Statistical Tool for Agricultural research* (STAR) launched by IRRI (International Rice Research Institute). Significant differences were tested using Analysis of Variance (ANOVA). When significant difference existed, treatment means were compared using *Least Significant Difference (LSD).*

Stress Condition

Three weeks after seedling establishment, potted lettuce seedlings were subjected to drought and waterlogged condition. For drought condition, unwatering of lettuce plants was done for five (5) days. For waterlogged condition, lettuce plants were submerged in water at the base of the plants for five (5) days. In drought-waterlogged condition, plants were unwatered for five (5) days and after, immediately subjected to submerged condition, respectively. Potted lettuce plants without stress condition were watered regularly to give comparison with the treated plants.

Data Collection

The study gathered the following data: plant height (cm), number of leaves, and weight of plants. Homogenization of plants samples was done for the laboratory analysis of the parameters that include plant pH, total acidity (TA), total soluble solids (TSS), chlorophyll a & b (UV-VIS spectrophotometry technique), total carotenoids and stomata density.

Results and Discussion

General observation

Uniform growth of potted lettuce plants was evident until before subjection to water stress condition. When plants subjected to stress condition, wilting, reduction in growth, yellowing of leaves was clearly visible. However, plants were able to subsist/resist waterlogged condition while plants subjected to drought condition showed wilting and some plants weren't able to survive. After 10 days of treatment, plants were harvested and brought to the laboratory room for gathering the necessary data or analysis.

Horticultural Characteristics

Table 1 shows the plant height, number of leaves, and weight of plants. Horticultural parameters show significant difference among treatments. Furthermore, lettuce plants subjected to water stress condition significantly reduces its plant height, number of leaves and weight of plants. The results affirmed the study of Ines Eichholz1 et. al., 2014 reported that to water stress. Biomass production under drought conditions was reduced significantly in 'Struwelpeter', 'Trianon' lettuce variety.Furthermore, Carotenoid and chlorophyll contents in 'Teodore' lettuce variety decreased in both water extremes, while total phenols accumulated under limited water availability.

Moreover, as cited by Ines Eichholzl et. al, 2014, the plants response to water stress conditions is accompanied by a variety of physiological and biochemical changes at cellular and whole-organism levels, thus making it a complex phenomenon (Shao et al., 2009). Drought stress disturbs water relation of plant and reduces leaf size, stem extension and root proliferation (Farooq et al., 2009; Shao et al., 2009).

Basically the results denotes that plants that experience water stress condition reduces its growth, number of leaves and weight of the plants which probably due to disruption of physiological and biochemical process of plants specifically the assimilation of photosynthates of the plants.

Table1. Horticultural characteristics of lettuce as affected the water stress condition

Treatments	Plant height (cm)	Number of leaves	Weight of Plants (g)
T_0 – Control	205.33a	13.87a	60.79a
T_1 – Drought	174.22b	10.90b	31.10b
T_2 – Waterlogged	174.93b	9.85bc	21.24bc
T_3 – Waterlogged-Drought	160.72bc	8.75c	16.22cd
T_4 – Drought-waterlogged	136.12c	9.20c	8.80d
CV (%)	7.77	7.10	16.69

Means with the same letter are not significantly different.

Physico-Chemical Properties

The quality of lettuce depends on the nutrients absorbed by the root system; the optimum quality of the produce can be obtained only at the right stage of maturity. At that stage, commodity has accumulated the chemical components and food reserve necessary for the attainment of desirable physico-chemical, sensory properties and for long shelf life. Other maturity indicators utilized the chemical composition of the commodity, such the level of starch, oil, total soluble solids (TSS), titratable acids (TA) and TSS:TA ration.

Table 2 shows the physico-chemical properties of lettuce plants as affected by water stress condition and has comparable effect among treatments. However, plants subjected to drought-waterlogged condition obtained the lowest amount of chlorophyll *b*. Many studies confirmed the impact of water stress in plant compounds as cited by Inez Eixhholzl et.al, 2014

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reported the carotenoids of the study of Sabale and Kale, 2010; Loggini et al., 1999; Moran et al., 1994), phenolic compounds (Sabale and Kale, 2010; Sánchez-Rodríguez and Rubio-Wilhelmi, 2010; Alexieva et al., 2001), and dietary fibers (hemicellulose, cellulose and lignin) (Tobisa et al., 1997; Okuyama et al., 1995; Von Wilpert, 1991). While carotenoids and phenolic compounds act as protective plant compounds in plant defense mechanisms (Treutter, 2010), hemicellulose, cellulose, pectin and lignin function as essential compounds for plant cell wall metabolism thus, results to reduction of plant growth and textural stability.

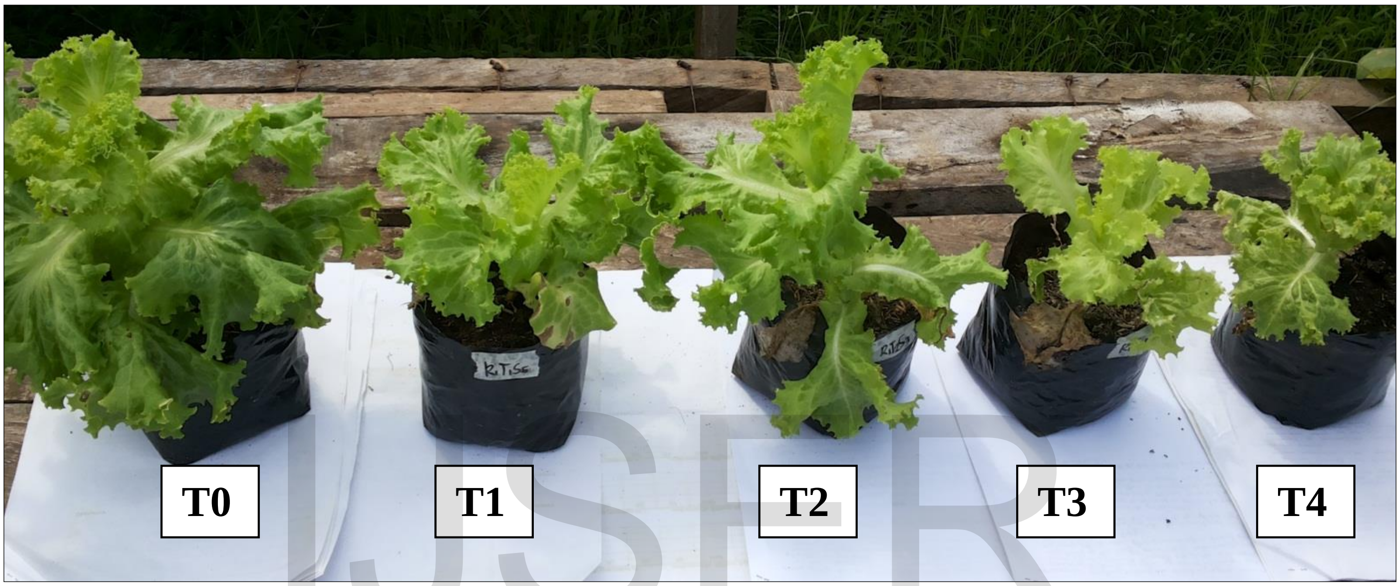

Fig.1. Lettuce plants after subjected to water stress (waterlogged and drought) condition

A

B

Fig.2. (A) lettuce plants subjected to waterlogged condition on its 1st day. (B) Lettuce plants waterlogged in 3 days.

Table 2. Physico-chemical properties of lettuce as affected by water stress condition

Treatments	Chlorophyll A	Chlorophyll B	Total Carotenoids	pH	TSS	TA
T_0 – Control	11.14	4. 28ab	5.56	6.02	5.67	0.26
T_1 – Drought	12.73	4.65a	6.70	6.02	5.73	0.26
T_2 – Waterlogged	9.46	3.57bc	5.96	6.11	5.27	0.23
T_3 – Waterlogged-Drought	10.42	3.99ab	5.72	6.08	5.13	0.22
T_4 – Drought-waterlogged	7.44	2.85c	4.37	6.29	6.60	0.28
CV (%)	18.84	12.92	14.66	2.55	12.93	32.59

Means with the same letter are not significantly different.

Furthermore, the study results of the study validate the findings of Inez Eixhholzl et.al, 2014, reported that carotenoid and chlorophyll contents did not differ between water-deficit and waterlogged plants. Nonetheless, drought-waterlogged condition exhibited significant lower in chlorophyll *b* content than other treatments. Also cited, that drought conditions caused a change in the biosynthesis of plant pigments especially of chlorophylls and carotenoids (Farooq et al., 2008; Anjum et al., 2003). It is also known that photosynthesis of higher plants is reduced with decreasing leaf water potential (Reddy et al., 2004; Zlatev and Yordanov, 2004; Van Holsteijn et al., 1977) and associated with low contents of chlorophyll pigments (Mafakheri et al., 2010; Arunyanark et al., 2008).

Effects of Drought stress and waterlogged condition

Roots in waterlogged soils frequently die from anoxia (oxygen deficiency).Crop growth and yield basically affected with severe waterlogging problem due to high concentration of rain. The main cause of damage under water logging is oxygen deficiency showing wilting of plants even in enclosed excess of water. This is due to oxygen deficiency in water logging soil. Water logging causes a condition of hypoxia (low oxygen concentrations) because of the low solubility of oxygen in water. Plants under drought and water logging stresses can also cause the accumulation ethylene and rotting of roots and bacterial anaerobic photosynthesis declination, stomatal closure resulted to decrease in metabolism. Plants tolerant to water logging stress in respiration, biomass production and exhibit certain adaptation.

Conclusion

The study revealed that plant subjected to water stress (waterlogging and drought) has significant effect on the growth and yield performance of lettuce plants. Moreover, plants undergo water stress significantly reduces it growth, number of leaves, weight as well as physico-chemical constituent such as chlorophyll and carotenoids. Generally, water stress alters the physiological and biochemical process of the plants. This study allows to develop and improve the cultural and management of the crop.

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