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Akash Bhargaw
Agronomist in Ecoponic Agri Tech Kolkata, West Bengal, India

Priyamvada Chauhan
Assistant Professor, Teerthankar Mehaveer University, Moradabad, Uttar Pradesh, India

Corresponding Author:
Akash Bhargaw
Agronomist in Ecoponic Agri Tech Kolkata, West Bengal, India

Photoperiod and light intensity influence on hydroponically grown leaf lettuce

Akash Bhargaw and Priyamvada Chauhan

Abstract
Influence of various light intensities with various photoperiods on metabolism and growth on two variety of lettuce plant were evaluated in this studies. Light emitting diodes (LEDs) were selected as source of light in four different intensity i.e., 200, 230, 260, 290 μmol·m-2·s-1 PPFD, with three different photoperiods (light/dark) 18/6 (1 cycle), 9/3 (2 cycle), and 6/2 (3 cycle) were used in experiment. Maximum plant height and fresh shoot weight was observed in treatment combination of 290-9/3 (light intensity-photoperiod), while longest root and its fresh weight with maximum dry leaf weight were recorded in plants grown under treatment 290-18/6. But maximum dry root weight, maximum number of leafs and largest leaf area were recorded in treatment combination of 290-6/2. By this we can conclude that use of 290 PPFD of light at 6/2 photoperiod is most energy efficient method to grow lettuce using LED light in plant factory.

Keywords: Light emitting diodes (LED), photoperiods, light intensity, fresh weight, dry weight

Introduction

Plants grown in artificial environment condition with artificial light have several potential assistances like maximizing photosynthesis rate, use of higher yield verity, favorable environment condition, less use of natural resources and etc (Kozai *et al*., 1999) [24]. Vertical farming in plant factory is the one of the most advance and protected horticulture practice that currently are used in world. Lettuce of different verity, water cress and escarole have very high market demand mainly due to mixed salads (Carlo *et al*., 2009) [4]. Lettuce is one of the most successfully grown crop in plant factory system. Only in United States 2001 to 2006 [42], lettuce was grown on 121,000 hector per year with market value of 2 billion USD which make it one of the most valuable fresh vegetable in their country (USDA, 2007). Growth of every plants are affected by some basic factor which are nutrient, temperature, humidity, and light (Savvas and Passam, 2002). Growth cycle of plants are affected by many environmental factor out of which one light intensity is considered as important factor (Inada and Yabumoto, 1989) [13]. According to (Hunter and Burritt 2004) [10] growth of lettuce are promoted with increase in light intensity and it is also believe that extra growth promoting agents only work effectively in certain range of light intensity (Li and Kubota, 2009) [26]. So to obtain maximum yield and economic benefit as well as quality products close control environment for production is preferred, in which optimizing light intensity seems important. Previous studies had showed that increase in light intensity has significant positive difference in growth biomass and also increase activity of anti-oxidative enzyme and mild stress in lettuce (Fu *et al*., 2012) [7]. There are three key components of light condition which effect the growth of plants they are light quality, light intensity, and photoperiod (Bhargaw and Chauhan 2020) [1] Light requirement to plants depend highly on plant species, cultivar, different growth stages, environment condition and according to yield and quality of products. So in coming future it is required to focus on detailed studies on light behavior and their effect on physiology on plant to obtain high and qualitative products in a close plant factory or for vertical farming. With the development of light emitting diodes (LED), light efficiency, and their physiological effect on plants had revolutionary changed worldwide. LEDs has the capacity of providing precise light spectrum and close illumination. It is clear that light intensity can positively affect photochemical accumulation (Fe *et al*., 2012) [7] but light quality and there are complex and mixed results are very often reputed (Li and Kubota, 2009) [26]. Change in light spectral trigger different photosynthetic and morphogenetic response that can vary among different plant species. With this photo responses this technology has gained popularity among cultivars to obtain desired yield and specific quality.

Material and methods

Plant Culture

Two verity of Leaf lettuce (*Lactuca sativa* L.) Locarno and Romane were used in this trial. Seeds were sown in 156 cell plug trays of oasis cubes and they were kept moist with reverse osmosis water of TDS 25 ± 5. Seeding were grown in growing chamber for 10 days with temperature 20 ℃ ± 2, humidity level of 80 ± 2 with 24 hours light (C1200H3, FC Poibe Co Ltd., Seoul, Korea)., Light emitting diodes were used as source of light in ratio (red: blue: white ₌ 8:1:1) (GT RBW, FC Poibe Co., Ltd., Seoul, Korea) for 15 days ounce seeds are fully germinated and 150 $\mu mol.m^{-2}.s^{-1}$ PPFD was maintained. After 15 days of germination ounce seedling had developed 3-4 true leave they were transplanted at 20cm × 20 cm of density in a close chamber plant factory and they were grown for next 40 days under controls environment. Temperature of close chamber was maintained at 21 ± 1℃ and Humidity of 70 ± 10% was maintained throe out growing phase. Plants were supplied nutrient water of TDS 750 to 780 and Ph. was maintain "between" 6.5 to 5.5 (Sonneveld and Straver, 1994) [40].

Light, photoperiod and regimes

Light emitting diodes (LEDs) were used as source of light for lettuce in mixture ratio 8:1:1 of red, blue, and white (RBW) with (0.5 W per LED chip) placed 20 cm horizontally above the plants in control environment. Four different adjustment of light was made by increasing or by decreasing the light source from the plants to make four different light intensity of (200, 230, 260, and 290 $\mu mol.m^{-2}.s^{-1}$) With the help of digital photometer average PPFD was maintain (LI-250A, LI-COR Inc., Lincoln, NE, USA). Carbon dioxide concentration in close environment was maintain at 500 $\mu mol.mol^{-1}$ during entire life cycle of plants. Three photoperiods were used 18/6 (1 cycle), 9/3 (2 cycle, and 6/2 (3 cycle) (light/dark). 12 different treatments on two lettuce verity are combination of photoperiod and PPFD were expressed as 200- 6/2, 200- 9/3, 200- 18/6, 230- 6/2, 230- 9/3, 230- 18/6, 260- 6/2, 260-9/3, 260-6/2, 290-6/2, 290- 9/3, and 290- 18/6.

Table 1: Spectral characteristic of the mixture of red, blue, and white LEDs.

Photon flux density ($\mu mol.m^{-2}.s^{-1}$ PPFD)					
Light Source	300-400 nm	400-500 nm	500-600 nm	600-700 nm	700-800 nm
RBW= 8:1:1	2.70	24.44	12.15	98.71	1.96

Mixture of RBW lights present in single chips is of 0.5 W per LED chip.

Plant measurements and sampling

Plant growth characteristics, such as root length, plant height, fresh weight of plant, dry weight of plants, leaf area, number of leaf, chlorophyll contain were measured ounce in 5 days during whole life cycle of plant. All the data were collected by labeling the plants and same labeled plant were used to collect data every time to avoid error. To measure leaf area leaf area meter was used (LI-3100, LI-COR Inc., Lincoln, NE, USA). Chlorophyll contain was measured by spectrophotometer (SPAD- 502 Plus, Konica Minolta Sensing Inc., Osaka Japan). Dry weight of samples were measured after drying tissues for 72 hours in drying oven (FO-450M, Jeio Technology CO., Ltd., Seoule, South Korea) at 80 ℃.

Experimental Design and Statistical Analysis

To get better results this experiment was repeated three times with completely randomized design and 15 seedling were used in each treatment of both two verity treatment were randomly mixed between replication to minimize position effect. All the data collected and were analyzed by using SPSS software. The results outcome were subjected to an analysis of variance (ANOVA) and Duncan,s multiple range test.

Results and Discussion

Growth and development of lettuce plant was significantly affected by light intensity and photoperiod as mention in (Table 1). Plant height, fresh weight, dry weight, root length was observe significantly lower in treatment 200-9/3 in compare to other treatment. Minimum dry root weight was observed in treatment 260-18/6. Mitchell *et al*., 1991; Tibbits *et al*., 1983) [31, 41]. Possible reason for this may be due to stress observed shoots and also trend observed of decreasing shoot weight from 200 to 260 $\mu mol.m^{-2}.s^{-1}$ PPFD, but still it can't be Sayed exactly because slight downward trend for root is brought about. It was observed that plants grown under higher light 290 $\mu mol.m^{-}$ had showed better results in compare to other kept under lower light intensity (Knight and Mitchell, 1983a) [19]; It was observed that maximum plant height and fresh shoot weight was recorder in treatment 290-9/3. Maximum dry root weight was observed in treatment 290-6/2 and maximum fresh root weight was observed in 18/6. With this observation we had consulted that higher light intensity with long photoperiod such as 18/6 had greater impact on growth of plant as we had observed that combination resulted in higher fresh and dry weight which as consider as a major factor of growth at inertial stage of plant (vande Vooren *et al*., 1986).

Table 2: Effect of photoperiod and light intensity on growth and development of Lakorno lettuce in control environment.

Light intensity ($\mu mol.m^{-2}.s^{-1}$ PPFD)	Photoperiod (light/dark)	plant length (cm)	Length of root (cm)	Fresh weight (Gram)		Dry weight (Gram)	
				shoot	root	shoot	root
200	18/6	$15.65^{a} \pm 0.3$	$41.14^{a} \pm 1.2$	$63.94^{a} \pm 2.0$	$9.72^{c} \pm$	$5.22^{ab} \pm$	$0.78^{bcd} \pm$
	9/3	$13.65^{d} \pm 0.3$	$33.68^{ab} \pm 0.8$	$50.96^{a} \pm 1.9$	$9.26^{bc} \pm 0.2$	$2.43^{a} \pm 0.0$	$0.75^{cd} \pm 0.0$
	6/2	$15.45^{d} \pm 0.4$	$35.93^{abc} \pm 0.9$	$63.29^{ab} \pm 3$	$10.94^{ab} \pm 0.4$	$3.9^{ef} \pm 0.0$	$0.8^{c} \pm 0.0$
230	18/6	$17.58^{de} \pm 0.4$	$43.97^{bc} \pm 2.0$	$67.6^{def} \pm 2.2$	$14.49^{bc} \pm 0.9$	$3.86^{de} \pm 0.1$	$0.87^{def} \pm 0.0$
	9/3	$15.66^{d} \pm 0.3$	$41.48^{bc} \pm 1.3$	$64.85^{bc} \pm 1.8$	$13.42^{bcd} \pm 0.4$	$3.28^{cd} \pm 0.1$	$0.91^{e} \pm 0.0$
	6/2	$16.79^{e} \pm 0.4$	$39.33^{cd} \pm 1.3$	$61.11^{ab} \pm 2.8$	$9.7^{bc} \pm 0.2$	$2.74^{ab} \pm 0.0$	$0.83^{ab} \pm 0.0$
260	18/6	$15.23^{c} \pm 0.3$	$40.14^{de} \pm 0.9$	$54.73^{bcd} \pm 2.8$	$9.42^{ab} \pm 0.4$	$3.47^{def} \pm 0.0$	$0.62^{a} \pm 0.0$
	9/3	$16.25^{d} \pm 0.4$	$41.8^{ab} \pm 1.2$	$60.68^{ab} \pm 2.5$	$11.03^{def} \pm 0.7$	$2.74^{f} \pm 0.1$	0.8b ± 0.0
	6/2	$17.42^{e} \pm 0.4$	$41.44^{bc} \pm 2.0$	$66.58^{abc} \pm 3.0$	$17.68^{ef} \pm 0.9$	$2.86^{f} \pm 0.0$	$0.71^{bc} \pm 0.0$
290	18/6	$19.55^{d} \pm 0.5$	$45.83^{ef} \pm 1.2$	$105.66^{bc} \pm 3.8$	$16.8^{de} \pm 0.8$	$4.52^{def} \pm 0.2$	$0.94^{bcd} \pm 0.0$
	9/3	$19.95^{d} \pm 0.5$	$43.13^{abc} \pm 1.9$	$106.48^{ab} \pm 3.9$	$16.91^{e} \pm 0.8$	$5.05^{ab} \pm 0.1$	$0.96^{ab} \pm 0.0$
	6/2	$19.55^{f} \pm 0.4$	$45.14^{a} \pm 2.4$	$100.91^{a} \pm 3.8$	$16.99^{a} \pm 0.9$	$5.73^{de} \pm 0.1$	$1.17^{a} \pm 0.0$

The mean followed by different letters are significantly different at $p < 0.01$ according to tukey LSD for separation of mean

Table 3: Effect of photoperiod and light intensity on growth and development of Romane lettuce in control environment.

Light intensity ($\mu mol.m^{-2}.s^{-1}$ PPFD)	Photoperiod (light/dark)	plant length (cm)	Length of root (cm)	Fresh weight (Gram)		Dry weight (Gram)	
				shoot	root	shoot	Root
200	18/6	$20.25^{bc} \pm 1.1$	$49.21^{abc} \pm 1.1$	$88.91^{bc} \pm 3.8$	$13.12^{c} \pm 0.4$	$7.01^{bc} \pm 0.2$	$1.05^{b} \pm 0.0$
	9\3	$17.1^{abc} \pm 0.8$	$40.31^{a} \pm 2.1$	$70.34^{cd} \pm 3.2$	$11.86^{b} \pm 0.2$	$3.33^{a} \pm 0.1$	$1.01^{cd} \pm 0.0$
	6\2	$20.1^{a} \pm 0.9$	$43.11^{ab} \pm 2.2$	$87.6^{ef} \pm 3.8$	$14.31^{ab} \pm 0.2$	$5.26^{cd} \pm 0.2$	$1.08^{abc} \pm 0.0$
230	18/6	$22.85^{cd} \pm 1.2$	$52.11^{abc} \pm 1.5$	$92.64^{ab} \pm 3.5$	$19.25^{cde} \pm 0.4$	$5.11^{cde} \pm 0.1$	$1.17^{e} \pm 0.0$
	9\3	$20.24^{de} \pm 0.7$	$49.77^{f} \pm 2.0$	$91.79^{a} \pm 2.9$	$18.1^{cd} \pm 0.3$	$4.42^{a} \pm 0.0$	$1.22^{d} \pm 0.0$
	6\2	$20.9^{ef} \pm 0.8$	$47.2^{def} \pm 2.1$	$84.55^{ab} \pm 2.8$	$13.58^{b} \pm 0.2$	$3.69^{bc} \pm 0.1$	$1.12^{de} \pm 0.0$
260	18/6	$19.79^{bcd} \pm 0.9$	$48.16^{ef} \pm 1.8$	$77.62^{cd} \pm 3.6$	$13.18^{a} \pm 0.6$	$4.52^{b} \pm 0.2$	$0.83^{cde} \pm 0.0$
	9\3	$20.8^{a} \pm 0.6$	$50.02^{e} \pm 2.0$	$83.91^{bc} \pm 2.6$	$13.98^{bc} \pm 0.2$	$3.69^{c} \pm 0.0$	$1.08^{cd} \pm 0.0$
	6\2	$22.2^{abc} \pm 1.0$	$49.72^{de} \pm 1.9$	$91.2^{c} \pm 3.2$	$23.54^{abc} \pm 1.2$	$3.76^{ab} \pm 0.2$	$0.95^{abc} \pm 0.0$
290	18/6	$25.41^{bcd} \pm 1.1$	$54.9^{bcd} \pm 2.2$	$143.92^{a} \pm 4.6$	$23.11^{bc} \pm 1.3$	$6.01^{bc} \pm 0.3$	$1.26^{cd} \pm 0.0$
	9\3	$25.93^{de} \pm 0.8$	$51.75^{cd} \pm 3.0$	$147.07^{b} \pm 4.7$	$23.67^{ab} \pm 1.4$	$6.81^{cd} \pm 0.3$	$1.29^{c} \pm 0.0$
	6\2	$25.66^{f} \pm 0.3$	$54.12^{abc} \pm 2.8$	$140.27^{bc} \pm 3.9$	$13.7^{cd} \pm 0.5$	$7.77^{ab} \pm 0.2$	$1.57^{bc} \pm 0.0$

The mean followed by different letters are significantly different at $p< 0.01$ according to tukey LSD for separation of mean

Increasing photoperiod had been always a better option for lettuce cultivar to obtain higher yield (Koontz and Mitchell, 1986) [22]. Increase in dry weight and better growth rate of lettuce (Knight and Mitchell, 1983b) [20] under light source of LEDs. Leaf length was highest recoded in 290-9/3 and minimum in treatment 200/6. If we observe table number 1 than we can conclude that plants under higher light intensity had resulted in better growth at both shot and longer photoperiods. Plants at lower light intensity 230 or 260 $\mu mol.m^{-2}.s^{-1}$ PPFD with shorter photoperiods 9/3 and 6/2 (light/ dark) resulted in slight reduction in growth rate but chlorophyll content were higher. No change in chlorophyll contain is a different aspect which need to be investigated further at anatomical structure change at the leaf level of the plant. Blue and red lights are readily absorb by plants, so absorbance of light is high and reflection is relatively low in these ranges of spectrum (Kim *et al*., 2004; Klein, 1992; Smith, 1993) [16, 18, 39]. Peak blue and red light emission coincide closely with the absorption peaks of chlorophyll a and b, and wavelengths are of maximum photosynthetic efficiency reported by (McCree, 1972) [29]. According to (Amasino, 1996) [3] cryptochrome and phytochrome photo-receptors, which promote the expression of genes that change the fate of shoot apical meristem from vegetative growth to reproductive development. Among all light mixture (red, blue, and white) red light spectrum has maximum photon flux as mention on (Table 1). According to Mor *et al*. (1980) [32] most effective light in transport of assimilates to shoot tips is red and it also promote shoot sink activity by increasing the unloading process. Blue and Red light have greater impact on plant growth because they are the major source of energy or photosynthetic CO_2 assimilation in plants. Studies showed that combined blue and red LED light were proved to be an effective light source for many plant species including lettuce in a control environment (Dougher and Bugbee, 2001; Hanyu and Shoji; 2000; Kim *et al*., 2004., Lian *et al*., 2001) [5, 9, 16, 28]. Many studies had been conducted on lettuce to check various environmental factor like temperature, light quality spectral, intensity and duration are most important factor affecting plant growth and development (Inada and Yabumoto, 1989) [13]. Many researcher had reported that high light intensity usually promote the growth of lettuce (Pavlou *et al*., 2007) [34]. Apart from growth many more character of lettuce also get affected positively from high light intensity (Knight and Mitchell, 1983a; Mitchell *et al*; 1991; Tibbits *et al*; 1983) [19, 31, 41]. Knight and Mitchell, 1983a, 1988 [19, 21] reported earlier that high energy light result in increase in dry weight and plant growth of lettuce in growing chamber. But resent studies had also shown that growth is still effective under light intensity high as 889-932 $\mu mol.m^{-2}.s^{-1}$ PPFD (Knight and Mitchell, 1983a, 1983b) [19, 20]. But some of the studies had reported that saturation point of lettuce is between 500-520 $\mu mol.m^{-2}.s^{-1}$ PPFD (Li and Gong, 2002).

The highest chlorophyll value (SPAD) was observed in plant treated with light intensity 260-18/6 and lowest in the treatment of 200-9/1. The value of chlorophyll (SPAD) did change significantly in all treatment. Photoperiod can be easily control in totally control environment using artificial lights. High PPF and lengthening the photoperiod have been resulted in better gain in weight if plants therefore affording a means of reducing the length of production cycle.

Table 4: Effect of photoperiod and light intensity on growth and development of Lakorno lettuce in control environment.

Light intensity ($\mu mol.m^{-2}.s^{-1}$ PPFD)	Photoperiod (light/dark)	Leaf Length (cm)	Leaf Width (cm)	Leaf (cm^2/ plant)	No. of leaves	Chlorophyll (SPAD)
200	18/6	$11.28^{bc} \pm 0.2$	$13.15^{c} \pm 0.3$	$1{,}042^{de} \pm 20$	$11.01^{b} \pm 0.5$	$20.02^{d} \pm 0.3$
	9\3	$12.11^{cd} \pm 0.4$	$13.27^{cd} \pm 0.2$	$830^{cd} \pm 15$	$12.5^{d} \pm 0.2$	$18.35^{ab} \pm 0.4$
	6\2	$13.06^{cd} \pm 0.2$	$14.09^{a} \pm 0.3$	$909^{c} \pm 13$	$12.5^{cd} \pm 0.4$	$18.69^{de} \pm 0.4$
230	18/6	$12.69^{de} \pm 0.4$	$14.75^{b} \pm 0.2$	$925^{de} \pm 20$	$11.3^{de} \pm 0.3$	$19.59^{f} \pm 0.4$
	9\3	$12.06^{def} \pm 0.3$	$14.49^{bc} \pm 0.4$	$1{,}007^{abc} \pm 31$	$12.4^{d} \pm 0.4$	$21.38^{abc} \pm 0.2$
	6\2	$11.84^{c} \pm 0.4$	$14.64^{c} \pm 0.2$	$692^{de} \pm 21$	$12.8^{def} \pm 0.4$	$21.44^{cd} \pm 0.4$
260	18/6	$11.76^{cde} \pm 0.3$	$13.71^{d} \pm 0.3$	$1{,}015^{ef} \pm 34$	$13.3^{d} \pm 0.2$	$21.68^{de} \pm 0.2$
	9\3	$12.49^{de} \pm 0.2$	$14.71^{bc} \pm 0.4$	$818^{a} \pm 25$	$12.9^{de} \pm 0.5$	$18.81^{ab} \pm 0.4$
	6\2	$12.59^{a} \pm 0.2$	$14.04^{de} \pm 0.2$	$1{,}162^{ab} \pm 29$	$12.8^{ab} \pm 0.4$	$20.3^{de} \pm 0.2$
290	18/6	$14.41^{ab} \pm 0.4$	$16.45^{ef} \pm 0.4$	$1{,}476^{def} \pm 4.1$	$15.0^{f} \pm 0.4$	$19.03^{ab} \pm 0.3$
	9\3	$14.45^{b} \pm 0.4$	$16.00^{f} \pm 0.3$	$1{,}223^{de} \pm 32$	$14.6^{d} \pm 0.3$	$20.11^{de} \pm 0.4$
	6\2	$14.13^{cd} \pm 0.3$	$17.06^{de} \pm 0.3$	$1{,}557^{d} \pm 28$	$15.9^{cd} \pm 0.2$	$20.8^{d} \pm 0.4$

The mean followed by different letters are significantly different at $p< 0.01$ according to tukey LSD for separation of mean

Table 5: Effect of photoperiod and light intensity on growth and development of Romane lettuce in control environment.

Light intensity ($\mu mol.m^{-2}.s^{-1}$ PPFD)	Photoperiod (light/dark)	Leaf Length (cm)	Leaf Width (cm)	Leaf (cm^2/ plant)	No. of leaves	Chlorophyll (SPAD)
200	18/6	$13.53^{bc} \pm 0.3$	$15.12^{e} \pm 0.3$	$1354^{f} \pm 41$	$12.11^{de} \pm 0.2$	$24.02^{bc} \pm 1.1$
	9\3	$14.53^{cd} \pm 0.5$	$15.26^{de} \pm 0.2$	$1079^{e} \pm 32$	$13.75^{ab} \pm 0.4$	$22.02^{abc} \pm 0.9$
]	6\2	$15.67^{de} \pm 0.3$	$16.2^{cd} \pm 0.2$	$1182^{de} \pm 34$	$13.75^{bcd} \pm 0.4$	$22.43^{ab} \pm 0.8$
230	18/6	$15.22^{e} \pm 0.2$	$16.96^{b} \pm 0.3$	$1202^{bcd} \pm 29$	$12.43^{ab} \pm 0.2$	$23.51^{bc} \pm 1.2$
	9\3	$14.47^{de} \pm 0.4$	$16.66^{bcd} \pm 0.3$	$1310^{def} \pm 28$	$13.64^{ab} \pm 0.2$	$25.66^{ab} \pm 1.3$
	6\2	$14.2^{a} \pm 0.4$	$16.83^{abc} \pm 0.4$	$900^{a} \pm 24$	$14.08^{ab} \pm 0.4$	$25.73^{bc} \pm 0.9$
260	18/6	$14.11^{c} \pm 0.4$	$15.76^{bc} \pm 0.2$	$1319^{b} \pm 21$	$14.63^{abc} \pm 0.3$	$26.02^{a} \pm 0.9$
	9\3	$14.98^{de} \pm 0.3$	$16.91^{a} \pm 0.2$	$1063^{cd} \pm 31$	$14.19^{cde} \pm 0.2$	$22.57^{bc} \pm 1.1$
	6\2	$15.1^{bc} \pm 0.3$	$16.14^{c} \pm 0.3$	$1511^{bc} \pm 21$	$14.08^{d} \pm 0.2$	$24.36^{abc} \pm 1.0$
290	18/6	$17.29^{b} \pm 0.4$	$18.91^{bc} \pm 0.2$	$1919^{de} \pm 49$	$16.5^{de} \pm 0.3$	$22.84^{bc} \pm 0.9$
	9\3	$17.34^{bc} \pm 0.5$	$18.4^{ab} \pm 0.2$	$1590^{cd} \pm 51$	$16.06^{abc} \pm 0.4$	$24.^{13ab} \pm 0.8$
	6\2	$16.95^{a} \pm 0.5$	$19.61^{bc} \pm 0.1$	$2024^{bcd} \pm 61$	$17.49^{c} \pm 1.1$	$24.96^{bcd} \pm 0.7$

The mean followed by different letters are significantly different at $p < 0.01$ according to tukey LSD for separation of mean

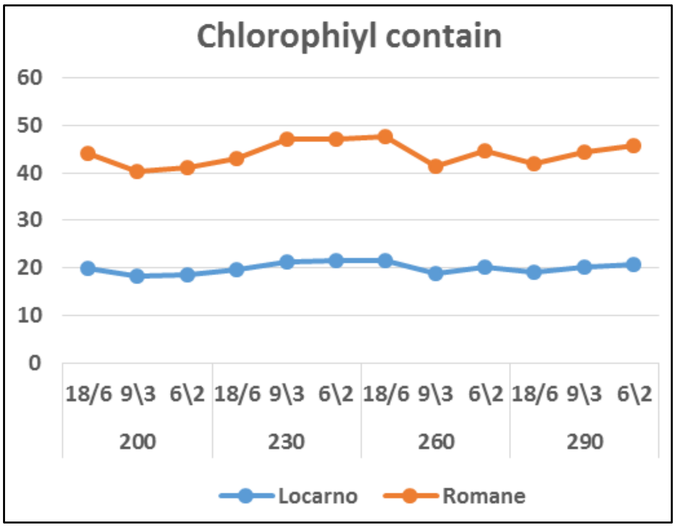

Fig 1: Chlorophyll fluorescence as affected by light intensity and Photoperiod of lettuce.

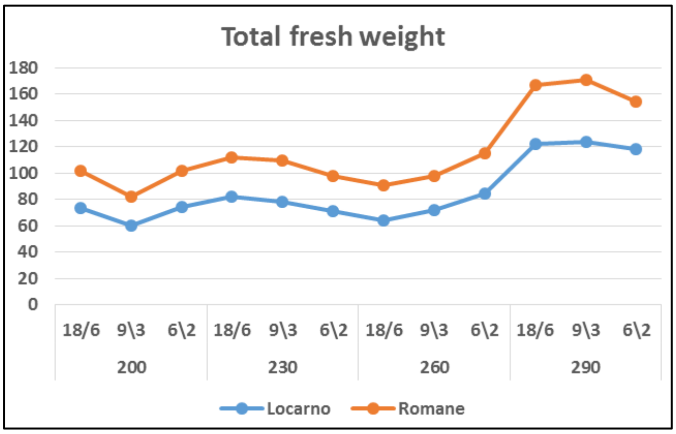

Fig 2: Higher light intensity effect the total fresh weight of lettuce.

Conclusion

If we conclude this study than we came to a result that plants under treatment 290 ($\mu mol.m^{-2}.s^{-1}$ PPFD) with 6/2 (light/dark) photoperiod had better growth. But if consider results obtain at lower light intensity than treatment 230 ($\mu mol.m^{-2}.s^{-1}$ PPFD with photoperiod of 18/6 and 9/3 (light/ dark) had best results. Even results achieve by this combination provide good growth but still lower than high light intensity combination. In treatment 290-6/2 and 230-18/6 more growth was observed of shoot and dry root weight which are the factor affecting growth and transplanting and harvest. This experiment had showed that lettuce show high growth rate in high light intensity with shoter photoperiod. Hence this can help to obtain goal to produce better quality lettuce.

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