International Journal of Research in Agriculture and Forestry
Volume 2, Issue 8, August 2015, PP 18-24
ISSN 2394-5907 (Print) & ISSN 2394-5915 (Online)

Effects of Plastic Mulch Color on the Total Soluble Solids, Total Sugars and Chlorophyll Content of Lettuce (Lactuca sativa L.)

Edmar N. Franquera[1]

[1]*Tarlac College of Agriculture, Camiling, Tarlac, Philippines*

ABSTRACT

The field study was carried out to determine the effects of plastic mulch color on the total soluble solids, total sugars and chlorophyll content of lettuce. The experiment was laid out according to a split plot design following the randomized complete block design. Two lettuce varieties were evaluated which served as the main treatments and the color of the plastic served as the sub treatments. The colors of the plastic mulch used in the experiment were silver (control), red, orange, yellow and green. Results revealed that Romaine variety had better response in terms of the total soluble solids, total sugars and chlorophyll content. Lettuce grown with red plastic mulch had a higher total soluble solids compared with the other color of plastic mulch. However, lettuce grown with yellow plastic mulch had better total sugars and chlorophyll content compared with the other colors of plastic mulch. It was concluded that the plastic mulch color significantly affected the performance of the lettuce total soluble solids, total sugars and chlorophyll content.

Keywords: chlorophyll, total soluble solids, total sugars, plastic mulch color

INTRODUCTION

Lettuce (Lactuca sativa L.) comes the family Asteraceae. It is one of the most important crops in the world. This crop is synonymous to salad for most people in the world. Lettuce is produced commercially in many countries worldwide and widely grown as vegetable in home gardens (Rubatzky, Yamaguchi, 1997). It is especially important as a commercial crop in the whole world (Lebeda et al., 2007; Mou, 2008). The color of the mulch is a big determinant in the microclimate around the plant. Black, silver and white are the color of plastic mulches predominantly used in vegetable production. Other colors of plastic mulch may affect the growth and development of certain crops. Red, brown, blue and other colored mulch could be a potential material to increased yield of certain vegetables. Growth of lettuce could possibly be affected by the microclimate modification through differences in the spectral balance of each color of the plastic mulch. The difference of the light spectrum that was reflected from the color of the plastic mulch suggests that plants are affected by the little changes in the microenvironment which was induced by the surface mulch color (Yazied and Mady, 2011). The light color that is perceived by the plant can possibly influence the development of the plants including its physiological characteristics. Fatemi *et.al*., (2013) reported that the chlorophyll content of *Cucurbita pepo* was increased when grown with colored polyethylene mulch. The color of the mulch had significant effect on the chlorophyll a, b and carotenoid content. According to Wang *et. al*, (1998) the chlorophyll content of strawberry was highest when grown in fred plastic mulch compared with other colors of plastic mulch. The color of the mulch has been found recently to have a significant effect on the fruit quality. It was found out increased the total soluble solids, total phenolics, flavonols and anthocyanins (Coventry *et al*., 2003). Altering the color of the mulch could also change the chemical compound present in plants such as anthocyanins, total phenolics and total soluble solids (Kasperbauer and Loughrin (2004).Thus, this study was conducted to determine the effects of the colored plastic mulch on the total soluble solids, total sugars and chlorophyll content of lettuce.

METHODOLOGY

Description of the Study Location

The study was conducted at the vegetable experimental station of the University of the Philippines Los Bańos.

Address for correspondence:

edmarfranquera123@gmail.com

Seedling Preparation, Experimental Designs and Treatments

Lettuce seeds were sown in seedling trays with soil media composed of 1 part garden soil, 1 part carbonized rice hull and 1 part compost.One week old lettuce seedlings were pricked to ensure individual seedlings in the trays. This was done for proper growth of the seedlings. The trial was set up using the Split plot design following the Randomized Complete Block Design replicated three times. The following treatments were used in the study; variety (Looseleaf and Romaine), color (silver, red, orange, yellow and green).

Field Preparations

The field was plowed and harrowed and plots were made at five square meters per treatment. Plastic mulch were placed in all the plots and secured within the soil. Holes were made where the seedlings were planted. A pressurized sprayer was used to paint the plastic mulch with different colors with the corresponding treatments.

Transplanting and Maintenance of the Trial

Prior to planting, basal application of complete fertilizer (14-14-14) was done. Four week old lettuce seedlings were transplanted with 45 x 20 cm spacing and this was performed late in the afternoon to avoid transplantation shock. Two weeks after transplanting, the lettuce was applied with 5 grams of urea (46-0-0) per plant. Watering was done regularly to ensure proper soil moisture and growth of the plants.

Data Gathered

The total soluble solids, this was determined from the extracted juice of representative leaf samples using a handheld refractometer (Atago N). The leaf chlorophyll content of the species was obtained by collecting one leaf sample of the same sizes with six replications. The samples were put into vial with 10 mL 80% acetone and were kept cool in the dark at 4°C. The absorbance of the extracts were read at wavelengths of 663 nm and 645 nm using UV2100, UVVIS Recording Spectrophotometer (Shimadzu, Japan). Arnon's equation (Arnon 1949). For total sugars, analysis was done using the Phenol sulfuric acid method as described by (Buysse and Merckx, 1993).

Statistical Analysis

Data analysis was performed using the Analysis of Variance (ANOVA) and Least Significant Differences (LSD) of the Statistical Analysis System (SAS 9.1) software.

RESULTS AND DISCUSSIONS

Total Soluble Solids

Total soluble solids or brix is the refractometer reading indicating the percentage dissolved solids contained in the juice being measured and an indication of sugar content.

The two lettuce varieties had a highly significant variation in their total soluble solids which shows that Romaine had higher total soluble solids (5.41%) compared with Looseleaf lettuce (4.59%). According to Crop Services International (2014) the higher the brix reading the better the health and expression of the plant's genetic potential. The significant variation in the total soluble solids of the two lettuce varieties may be a result of their differences in their genetic make-up.

Highly significant variation was observed in total soluble solids content of lettuce within the different colored plastic mulch. The highest value was found in lettuce grown with red plastic mulch (6.04%). This were followed by those grown with yellow, silver and green plastic mulch which were not significantly different from each other having a total soluble solids of 4.91%, 4.84% and 4.84% respectively. The least value was observed within the plants grown with orange plastic mulch with 4.38% (Table 1).

Means in the same column or row followed by a common letter(s) are not significantly different at 5% level by LSD

This means that the color of the mulch had influence the total soluble solids content of the lettuce. Posada *et.al.,*(2011) reported that the total soluble solids measured in strawberry fruits showed a significant variations among the different colored plastic mulch. Those grown with red mulch had

higher total soluble solids compared with the other colored mulch (silver, blue and yellow). The dominant result of red plastic mulch could be attributed to the quality of light that was reflected from the color of the mulch since a certain wavelength of light reflects onto the plants that influenced physiochemical characteristics such as the content in total soluble solids. The different colored plastic mulch reflected different ratios of far red to red (Bradburne *et.al.*,1989; Kasperbauer and Wilkinson, 1995; Kasperbauer, 2000; Antonious and Kasperbauer, 2001; Decoteau, 2007). The red and green plastic mulch was found to have higher ratios of FR/R compared with the other colored plastic mulch. Kasperbaeur *et.al.,(*2001) concluded that FR and the FR and R ratio in light reflected from the red plastic mulch acted through the natural phytochrome system within the growing plants that modifies the gene expression which results to improved phytonutrients, flavor and sweetness. Red and Far red light is captured by phytochrome (Kasperbauer *et.al.*,2001) which triggers a series of chemical modifications including sweetness of fruits. This may be the reason for the higher values of total soluble solids in lettuce grown within the red plastic mulch.

Table1. *Total soluble solids (% Brix) of leaf lettuce grown with different colored plastic mulch*

MULCH COLOR	VARIETY		MEAN
	Looseleaf Lettuce	Romaine Lettuce	
Silver	4.30[b]	5.39[b]	4.84[b]
Red	5.48[a]	6.60[a]	6.04[a]
Orange	4.25[b]	4.51[c]	4.38[c]
Yellow	4.36[b]	5.46[b]	4.91[b]
Green	4.58[b]	5.10[b]	4.84[b]
Mean	4.59[b]	5.41[a]	

In strawberry, the proportion of red and far red light radiation reflected by the red mulch contributes to the improved fruit quality and sweetness due to the activity of saccharose phosphate synthase (Kasperbauer *et.al.*,2001). However, they pointed out that the activity of this enzyme is not determined by phytochrome in all plants. In corn but not in soybeans or sugar beans, Vassey (1988) found the involvement of phytochrome in the activity of saccharose phosphate synthase. In tobacco, another enzyme (fructose 1-6 bisphosphatase) was reported to be mediated and regulated by phytochrome (Lee and Hann, 2002; cited by Posada *et.al.*, 2011). These phytochrome regulated enzymes could also be related to the improved sweetness of the plants which could explain the improved sweetness and higher total soluble solids or bix found in lettuce grown with red plastic mulch. Posada *et.al.*, (2011) pointed out that the positive effects of red mulch could be due to the increased absorption of red and far red light by the phytochrome. Another factor which could affect the brix levels or total soluble solids in vegetables is the environmental conditions such as light and temperature. Exposure of various environmental conditions such as light, temperature and moisture and their combinations could influence the amount of soluble solids (mostly sugars) in marketable leaves, fruits, tubers and roots of vegetables. These environmental factors interacts to set a rate of sugar production affecting the sweetness of the vegetables and fruits (Kleinhenz and Bumgarner, 2012). This may explain also the reason for the significant differences on the amount of total soluble solids of lettuce grown within the different colored plastic mulch since the color of the mulch could modify the plant microenvironment affecting its growth and development (Tarara, 2000; Kasperbauer *et.al.*,1987).

Differences in the interaction effect between the varieties and colored plastic mulch were observed to be highly significant. Romaine grown with red plastic mulch had the highest value of 6.60%. In Looseleaf, a higher value was also noted when grown with red plastic mulch (5.48%). The least value was observed in Looseleaf grown with orange plastic mulch (4.25%).

Total Sugars (% of Glucose)

The two lettuce varieties had highly significant differences in terms of total sugars (% of glucose). Romaine had higher total sugars (0.60) while Looseleaf had (0.40).

Highly significant differences were evident in the total sugars from lettuce grown with different colored plastic mulch. Those grown with yellow plastic mulch gave the highest with 0.72. This was followed by those grown with red and silver plastic mulch with 0.55 and 0.44 respectively. A lower value was found within green and orange plastic mulch with 0.40 and 0.38 (Table 2).

Table2. *Total sugars (% glucose) of leaf lettuce grown with different colored plastic mulch*

MULCH COLOR	VARIETY		MEAN
	Looseleaf Lettuce	Romaine Lettuce	
Silver	0.33[b]	0.55[b]	0.44[c]
Red	0.53[a]	0.58[b]	0.55[b]
Orange	0.33[b]	0.44[d]	0.38[d]
Yellow	0.52[a]	0.93[a]	0.72[a]
Green	0.30[b]	0.50[c]	0.40[d]
Mean	0.405[b]	0.602[a]	

Means in the same column or row followed by a common letter(s) are not significantly different at 5% level by LSD

The differences in the total sugars in lettuce grown with different colored plastic mulch could be due to the differences in the spectral quality of light reflected on the leaves of the plants which affects the photosynthate partitioning and sugar accumulation in lettuce leaves. It should be noted that different colors reflect different patterns of light such in the case of color mulch which could modify the amount of total sugars present in the leaves. Concentrations of sugars in plant leaves were altered by the ratio of FR/R recieved by the leaves (Antonoius et.al., 1996). This alteration could also contribute to the differences in total sugars present in lettuce leaves as affected by the colored plastic mulch because different color of the mulch had different ratios of FR/R. The result of present study was in contradictory to the reports conducted by Wang et. al.,(1998) quoted by Yazied and Mady (2012) which indicated that strawberries grown in red plastic mulch had highest total sugars compared with the other colored plastic mulch.

The combined effect of the varieties and the color of the mulch exhibited highly significant variations in terms of the total sugars. Results showed that Romaine grown with yellow mulch had the highest total sugars (0.93). However, in Looseleaf, highest total sugars was observed in lettuce when grown with red plastic mulch (0.53). The lowest value was recorded in Looseleaf grown with green plastic mulch (0.30).

Chlorophyll – a

The concentration of chlorophyll a was significantly higher in Romaine (8.00 µg/mL) compared with Looseleaf (6.10 µg/mL).

The highest amount of chlorophyll a was obtained within the yellow plastic mulch with (7.92 µg/mL). However, this was not significantly different with red plastic mulch (7.77 µg/mL). Lettuce grown with the green plastic mulch followed (7.13 µg/mL). Silver (6.42 µg/mL) and orange (6.02 µg/mL) plastic mulch did not differ significantly and the lettuce grown within those color of mulch had the least values of chlorophyll a concentration (Table 3).

Table3. *Chlorophyll a concentration (µg/mL) of leaf lettuce grown with different colored plastic mulch in Vegetable Crop Division experimental station UPLB*

MULCH COLOR	VARIETY		MEAN
	Looseleaf Lettuce	Romaine Lettuce	
Silver	5.30[b]	7.55[c]	6.42[c]
Red	7.03[a]	8.51[b]	7.77[a]
Orange	5.95[ab]	6.09[d]	6.02[c]
Yellow	6.45[a]	9.39[a]	7.92[a]
Green	5.79[ab]	8.47[b]	7.13[b]
Mean	6.10[b]	8.00[a]	

Means in the same column or row followed by a common letter(s) are not significantly different at 5% level by LSD

The result indicates that the color of the mulch had influenced the concentration of chlorophyll a in lettuce (Panchal *et.al.*, 2001; Yazied and Mady, 2012). The differences in the concentration of

chlorophyll a could be due to the spectral distribution of light reflected from the color of the mulch. Red plastic mulch produced higher concentrations of chlorophyll a compared with the other colored mulch (George *et.al.*, 2011). Similarly in strawberry plants, the chlorophyll content was higher in red plastic mulch as compared to the other colored plastic mulch (Wang *et.al.*,1998). However this has not been the case in the present study since those grown with the yellow plastic mulch had higher chlorophyll a concentration as compared with the other colored plastic mulch. The reason might be due to the differences in the quality and quantity of light transmitted absorbed and reflected from the color of the mulch which in turn might affect the plant growth and development including its quality (Wang *et.al.*,1998).

Chlorophyll – b

Differences on the concentration of chlorophyll b between the varieties were highly significant. Romaine had higher chlorophyll b concentration with 10.74 µg/mL compared to Looseleaf with 6.44 µg/mL . The differences in the chlorophyll concentrations between the two varieties could be attributed to their differeneces in their genetic make up.

The different colored plastic mulch significantly affected the chlorophyll b concentration of lettuce. Among the different colored plastic mulch, lettuce grown with yellow plastic mulch (11.53 µg/mL) was the highest but was not significantly different with those grown with red plastic mulch (9.60 µg/mL). This was followed by green, orange and silver with 8.96, 7.34 and 5.53 µg/mL which are not significantly different. Light quality and spectral change of solar radiation could affect or change the concentration of chlorophyll b (Van et.al.,nd; Zhong Xi *et.al.*, 1999) thus, this could be the reason for the differences in the chlorophyll b concentations of the lettuce plants. Red light induces a higher chlorophyll b concentrations in cucumber (Zhong Xi *et.al.*, 1999) and this could be the possible reason for the higher concentrations of chlorophyll b in red plastic mulch although lettuce grown with yellow plastic mulch had higher concentration of chlorophyll b but it did not differ significantly with those grown with the red plastic mulch.

Table4. *Chlorophyll b concentration(µg/mL) of leaf lettuce grown with different colored plastic mulch*

MULCH COLOR	VARIETY		MEAN
	Looseleaf lettuce	Romaine lettuce	
Silver	4.33^{ab}	6.73^{b}	5.53^{d}
Red	6.62^{ab}	12.59^{a}	9.60^{ab}
Orange	7.64^{ab}	7.04^{b}	7.34^{cd}
Yellow	9.33^{a}	13.73^{a}	11.53^{a}
Green	4.30^{b}	13.63^{a}	8.96^{bc}
Mean	6.44^{b}	10.74^{a}	

Means in the same column or row followed by a common letter(s) are not significantly different at 5% level by LSD

CONCLUSION

The color of the plastic mulch has a significant effect on the total soluble solids, total sugars and chlorophyll content of lettuce which could be due to the different patterns of light which was reflected from the mulch color.

ACKNOWLEDGEMENT

The author is very grateful to the Department of Science and Technology Science Education Institute for the funding of this research. Likewise, acknowledgement ia also extended to the following persons; Dr. Renato C. Mabesa, Dr. Rene Rafael C. Espino, Dr. Edralina P. Serrano and Dr. Eduardo P. Paningbatan for the support. The author also extends his gratitude to the University of the Philippines Los Bańos.

REFERENCES

[1] Abou El-Yazied, A. and M.A. Mady. Effect of naphthalene acetic acid and yeast extract application on growth and productivity of tomato (Lycopersicon esculentum Mill.) plants. Res. J. Agric. J. Agric. and Biol. Sci., 7(2): 271-281, 2011.

[2] Antonious J. F., M. J. Kasperbauer, M. E. Bryers. Light reflected from colored mulches to growing turnip leaves affects glucosinate and sugar contents of edible roots. Photochem. Photobiol. 64: 605-610, 1996.

[3] Antonious, G. F. and M. J. Kasperbauer. Color of light reflected to leaves modifies nutrient content of carrot roots. Crop Sci 42. 1211-1216, 2002.

[4] Arnon D.I., Copper enzymes in isolated chloroplasts, polyphenoxidase in beta vulgaris. Plant physiology 24: 1-15, 1949.

[5] Bradburne, J. A., M. J. Kasperbauer, J. N. Mathis. Reflected far red light effects on chlorophyll and light harvesting chlorophyll protein (LHC II) contents under field conditions. Plant Physiol. 91: 800-803, 1989.

[6] Buysse, J., and R. Merckx. An improved colorimetric method to quantify sugar content of plant tissue. J. Experimental Botany 44:1627.–1629, 1993.

[7] Coventry, J.M., K.H. Fisher, J.N. Strommer, and A.G. Reynolds. 2003. Reflective mulch to Enhance Berry Quality in Ontario Wine Grapes. ISHS Acta Horticulturae 689: VII

[8] Crop Service International; Soil Testing, Consulting, agricultural Products. Nutrient Density, The goal of Nontoxic, Sustainable, Biological farming is to grow high Brix, high nutrient, 2014.

[9] Decoteau, D. R. Leaf area distribution of tomato plants as influenced by polyethylene mulch surface color. HortTechnology. 17 (3). 341-345, 2007.

[10] George, G., R. Reed, B. Tansel and Gary Gordon. Growth profile of chamaedorea (cascade palm) seedlings with different colored plastic mulch. J. of Agricultural Sci. 3. No. 3, 2011.

[11] Hamide Fatemi, Hossein Aroiueer, Majid, Azizi, Hossein Nematizizi. Influenced of Quality of Light Reflevted of Colored Mulch on *Cucurbita pepo* var. Rada under Field Condition, International Journal of Agriculture: Research and Review. Vol., 3 (2), 374-380, 2013.

[12] Kasperbauer, M. J and J.H. Loughrin. Aroma content of fresh basil (Ocimum basilicum L.) leaves is affected by light reflected from colored mulches. J Agric Food Chem. 51(8):2272-6, 2003.

[13] Kasperbauer, M. J., Far red light reflection from green leaves and effects on phytochrome mediated assimilate partioning under field conditions. Plant Physiol. 85: 350-354, 1987.

[14] Kasperbauer, M. J., R. E. Wilkinson. Mulch surface color affects surface accumulation of epicuticular wax on developing leaves. Photochem. Photobiol. 62: 940-944, 1995.

[15] Kasperbauer, M.J. 2000. Strawberry yield over red versus black plastic mulch. Crop Sci. 40: 171-174, 2000.

[16] Kasperbauer, M.J., J.H. Loughrin and S.Y. Wang. Light reflected from red mulch to ripening strawberries affects aroma, sugar and organic acid concentrations. Photochemistry and Photobiology 74:103-107. 2001.

[17] Kleinhenz, M. D. and Natalie R. Bumgarner. Using brix as an indicator of vegetable quality linking measured values to crop management. Fact Sheet Agriculture and Natural Resources. The Ohio State University, 2012.

[18] Lebeda A., E.J. Ryder, R. Grube, I. Dolezalova, E. Kristkova. Lettuce (Asteraceae; Lactuca spp.). In:SINGH R.J. (ed.), Genetic Resources, Chromosome Engineering, and Crop Improvement, Vol. 3, Vegetable Crops. Boca Raton, CRC Press, Tailor and Francis Group: 377–472.Breckling, Ed., The Analysis of Directional Time Series: Applications to Wind Speed and Direction, ser. Lecture Notes in Statistics. Berlin, Germany: Springer, 1989, vol. 61, 2007.

[19] Lee, S. and T. Hahn. Two light-responsive elements of pea chloroplastic fructose-1, 6-bisphosphatase gene involved in the red-light-specific gene expression in transgenic tobaccos. Biochem. Biophys. Acta 1579, 8-17, 2002.

[20] Panchal, S. C., R. Bhatnagar, R.A. Momin and N.P. Chauhan. Influence of cultural practices on quality of green and red chilli (Capsicum annum L.) fruit. Indian J. Agric. Biochem., 14, 21-24, 2001.

[21] Posada F., E. Fonesca, G. Vaughan. Fruit quality in strawberry (Fragaria sp) grown on colored plastic mulch. Agro Colombiana. 29 (3) 407-413, 2011.

[22] Rubatzky, V.E., M. Yamaguchi. World Vegetables.New York, Chapman & Hall. 572 pp., 1997.

[23] Tarara J.M., Microclimate modifications with plastic mulch. Hort. Sci. 35(2):169-180, 2000.

[24] Vassey, T., Phytochrome mediated regulation of sucrose phosphate synthase activity in maize. Plant Physiol. 88, 540-542, 1988.

[25] Wang. S.Y., W. Zhang, G. J, Galleta and M. J. Camp. Mulch type affects fruit quality and composition of two strawberry genotypes. Hort. Sci. 33: 636-640, 1998.

[26] Zhong – Xi Chu, Thong Zhe, Feng Li Jie, Zhang Qun, Wen Xiao Gang and Song Zen Tian. Effect of different light quality on photosynthetic characteristics of cucumber leaves. Acta Botanica, 1999.

AUTHOR'S BIOGRAPHY

Edmar N. Franquera, was born in Philippines 16th May 1980. Started to study elementary and secondary in Tarlac Philippines. In 1999 graduated a certificate in agriculture and in 2002 graduated a Bachelor of Science in Agriculture. In 2007, graduated Master of Science in Agriculture in Tarlac College of Agriculture and continue to study in PhD in Agriculture major in Horticulture and minor in Soil Science at University of the Philippines Los Bańos and graduated in 2014. He is now the Chairman of the Department of Crop Science at the Institute of Agriculture, Tarlac College of Agriculture Philippines. Dr. Edmar N. Franquera is a member of the Philippine Association of Agriculturists (PAA) and Philippine Fruit Association.