BASELINE SURVEY ON BIOMASS DISTRIBUTION IN THE LONG ISLAND SOLAR FARM

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Abstract

As electricity and natural gas consumption continues to increase on Long Island, renewable energy sources will play an important role in Long Island's energy future. To make an efficient and substantial impact on Long Island's energy crisis, a large scale of commercial solar photovoltaic arrays of 32 MW will be constructed on approximately 200 acres at Brookhaven National Laboratory (BNL). Because no other Utility Grade solar installation has been monitored on environmental impact and specifically on vegetation biomass, this research has established baseline scientific data for future studies of assessment on the impacts associated with construction and operation of the Long Island Solar Farm (LISF). Plant biomass, plant diversity, chlorophyll concentrations, and other measures were compared after careful quantitative examination within seven major vegetation types. The seven study sites were selected to represent the variation of plants in the 200 acre proposed solar farm area. Twenty-five meter line-transects and $1m^2$ quadrats were used to measure the estimated plant population and percent ground cover. Ground vegetation samples were clipped and brought to the lab for biomass weighing and chlorophyll analysis. Among all sites, S19 has maximum % dry weight (85.5%; 42.75%C). Bracken fern showed highest values of chlorophyll and Black cherry has larger stomata compared to other species. The under story vegetation biomass throughout the LISF area is dominated by *Gaylussaicia baccata, Vaccinium pallidum, V. corymbosum, and V. angustifolium.*

Introduction

The state of New York has proposed a solar energy project that will provide a sufficient amount of energy to Long Island. Large scale commercial solar photovoltaic (PV) arrays of 32 MW will be constructed on approximately 200 acres at Brookhaven National Laboratory (BNL).

Currently, biomass energy provides 14 percent of the world's main energy consumption. It accounts for 38 percent of the primary energy used in developing countries, as compared to 4 percent for the United States. Research and development efforts are working towards finding more efficient biomass conversion technologies in an effort to take advantage of this natural energy resource. With ample land and agricultural resources, the United States can see biomass energy consumption rise as high as 20 percent within the next 20 years. Some concerns have come to light regarding the current energy crop programs taking place in developing countries as to whether food supplies will suffer as a result of biomass energy needs. Overall, the outlook for biomass energy is promising. Our present-day crisis concerning fuel and energy costs sees biomass energy production as a definite direction for the future [1].

Organic fuels such as gasoline and coal leave behind residue produce harmful gasses during the process needed to convert them to a source of energy. Fossil fuels contain carbon that was removed from the atmosphere, under different environmental conditions, millions of years ago. When burned, this carbon is released back into the atmosphere. Since the carbon being released is from ancient deposits, and new fossil fuels take millions of years to form, burning fossil fuels add more carbon the atmosphere than is being removed. Biomass absorbs atmospheric carbon while it grows and returns it into the atmosphere when it is consumed, all in a relatively short amount of time. Biomass is any organic matter that is renewable over time. Woody biomass can be used for heat, power, and electricity generation; biofuels production; and biochemical’s production (e.g., adhesives, solvents, plastics, inks, and lubricants) [2].

Plants manufacture biomass through the photosynthesis process wherein the chlorophyll in plants absorbs the sun's energy by converting carbon dioxide (CO_2) into carbohydrates. Plants draw CO_2 from the air and water stored in the ground in the making of carbohydrates. When the carbohydrates are burned, they convert back into CO_2 and water. Types of biomass are plants, wood, grass, animal waste, landfill waste, and even sewer waste. The most typical method of accessing the biomass in these materials is through burning; however, most of the energy is lost when biomass is burned, and there are environmental problems to deal with as well. Alternative methods for accessing biomass energy are:

- **Co-firing**-used by power plants in which biomass materials are mixed with coal during the burning process. This cuts down on the pollution factor.
- **Chemical Processing**-where plant oils are chemically converted into liquid for use as fuel
- **Biochemical Processing**-used in sewage treatment plants and waste management facilities; carbohydrates are processed through the fermentation of bacteria, yeasts and enzymes found in waste and sewage.
- **Thermo-chemical**-where plant materials are liquefied instead of burned, providing gases, liquids and solids for use as energy to power electricity and water treatment plants [1].

Chlorophyll concentrations were used to calculate the biomass in the most dominant species within the LISF. Chlorophyll is the green molecule in plant cells that carries out the bulk of energy fixation in the process of photosynthesis during light. Chlorophyll makes it possible for plants to convert CO_2 and water, in the presence of sunlight, into oxygen and glucose. Besides its importance in photosynthesis, chlorophyll is probably the most-often used estimator of a biomass. During this process of photosynthesis, chlorophyll produces energy, in the form of carbohydrates, which will power all of the plant's essential growth and development. Chlorophyll itself is actually not a single molecule but a family of

related molecules, designated chlorophyll *a, b, c,* and *d*. Chlorophyll *a* is the molecule found in all plant cells and therefore its concentration is what is reported during chlorophyll analysis [3].

The underlying objective is to have reliable estimates of living biomass and chlorophyll concentrations of the species groups expressed per known ground surface area. Although understory vegetation usually represents a relatively minor component of the whole biomass of high forests, it can play an important role in the annual biomass production and hence also in the nutrient cycling of forest ecosystem. It covers and protects the soil from erosion and alters its moisture contents and temperature. Knowing the biomass of different components of standing ground vegetation is essential to be able to quantify nutrient budgets in different forest vegetation [4].

The goal of this research was to establish a baseline data of understory vegetation biomass for the Long Island Solar Farm (LISF). Specific objectives of this study were to: (a) determine the dry weight biomass and (b) determine chlorophyll concentrations and stomatal distribution in dominant species of LISF. In addition, we are documenting the density and size of stomata of selective and dominant species to explore the relationship between stomatal distribution and chlorophyll concentrations to photosynthetic rates of vegetation of LISF. For future research, this analysis will help provide the information needed to study the rates at which plants are grown. Inferences will then be made on which plants can be produced in abundance for biomass and could be used to generate alternate source of energy.

Materials and Methods

A total of seven study sites and three controls were selected to represent the variation of plants in the 200 acre proposed solar farm area on BNL campus (figure 1). The line-transects method was used to estimate the plant population and percentage ground cover. Twenty-five meter line-transects and 6 $1m^2$ quadrats were used to estimate plant population within the different study sites. Vegetation

was quantified within each plot of each quadrat and recorded as a tally. On each quadrat, height, percent cover, and biomass were measured for each quadrat. In addition, we have collected the under story vegetation samples randomly from two LISF sites (S13 and S17) to determine the biomass, chlorophyll concentrations, and stomatal distribution. Cover was estimated as a vertical projection of ground surface covered by the plant in percent classes. Height of all plants was measured from the forest floor to estimated average height. “Average height” of single-stem species was determined by taking an average of all plants of a species on the quadrat. The heights of each species were measured using a Lufkin meter stick. Estimated percent ground cover and over story composition was also recorded. The pH levels were measured using an electrode pH instrument. Plot 1 of quadrats one and four were clipped for biomass. A larger area (more sampling units or larger frames) needs to be collected in case the vegetation is very heterogeneous (a large number of different species) or the biomass of the collected samples is small (e.g. the coverage is scarce and dominated by small lichens or bryophytes). The aim of sampling is to have a representative sample of the ground vegetation in each quadrat and transect. The samples of each quadrat are stored separately in plastic bags or durable paper bags to be transported to a laboratory for further analysis. Fresh weights were taken for all clippings using the Scout Pro 200g weighing scale. All biomass samples were oven dried in Fisher Scientific Isotemp oven. Each sample was dried for 36-48 hours or until the sample weight stabilized and then weighed to the nearest 0.02 g at 70°C. The presence of woody material may requires a longer drying period. Once dried, samples were weighed for dry biomass weight. Using the same methods control transects were laid outside of the 200 acre proposed LISF area. The individual quadrat biomass values were then averaged for each plot to generate an overall biomass value. The baseline biomass data on LISF sites and control areas were documented for comparison with biomass of post installation of solar farm.

Leaf samples of dominant and selective species found within the LISF were also collected for stomata and chlorophyll analysis. Fresh leaf weights were measured using the Scout Pro 200g weighing scale of 0.02g accuracy. Leaf samples were measured at approximately 0.02 g and were immersed in 10 mL of 95% C_2H_5OH (ethanol). Samples were stored in a cool, dark place for 24 hours. Chlorophyll extracted into ethanol was decanted and absorbance was measured using Spectrophotometer at 665 nm and 649 nm wavelengths to determine the levels of chlorophyll a and b. Chlorophyll concentrations were measured using the following formulae [6]:

Chlorophyll a µg /mL = (13.70) * (A 649 nm) – (5.76) * (A649 nm)

Chlorophyll b µg /mL = (25.80) * (A 649 nm) – (7.60) * (A665 nm)

Leaves from a number of plant species were collected from the LISF area. Leaves of Black Cherry (*Prunus serotina),* Late Low-bush Blueberry (*Vaccinium angustifolium*), and Huckleberry (*Gaylussacia baccata*) were brought to the lab for stomatal analysis and observations. Leaves were cut into approximately 2cm squares and put into distilled water. Because the trichome layer completely covers the ventral surface of the leaves of huckleberry and prevents visualization of stomata the epi-dermal surface and the trichome layer was peeled from each leaf. Observations were made using an Olympus BX 41 Spectra microscope. The leaf surface was observed directly under the microscope us-ing leaves washed with distilled water. Images of ventral surface of the three species were captured at 40X using a Power Shot SD790 IS Digital Elph camera. Stomata were counted manually on the screen and lengths and widths of ten stomata of each leaf sample were recorded to assess the accuracy and re-producibility of the method.

Results

Among all sites, S19 has maximum % dry weight (85.5%; 42.75%C). Bracken fern showed highest values of chlorophyll and Black cherry has larger stomata compared to other species. Throughout the LISF area understory vegetation biomass is dominated by *Gaylussaicia baccata, Vaccinium pallidum, V. corymbosum, and V. angustifolium.*

Biomass: As shown in figure 2, S19 has the maximum dry weight percent biomass compared to the percentages of the rest of the sites. The biodversity of this site or the species ability to sequester CO_2 was approximately 42% based on earlier reports on biomass to C conversions [7]. The percent dry weight in S26 is significantly lower in relation to other study sites. The high percentage dry weights of Seedbox (*Ludwigia altemifolia*) and Pitch Pine Seedlings (*Uvularia puberula*) reflecting the density of the population of these species in S13 and S14 randomly selected to study individual % dry weight biomass (Figure 3).

Stomatal size: The large stoma size in Blackcherry (*Prunus serotina*) implies that the transporation of water and gases could be geater compared to Lowbush Blueberry (*Vaccinium angustifolium*) and Highbush blueberry(*Vaccinium corymbosum*) as shown in figure 4. Further investigations are needed to test this hypothesis.

Stomatal Density: As shown in figure 5, Lowbush Blueberry has a greater stomatal density than Highbush Blueberry and Black cherry leaves.

Chlorophyll: Among various species investigated for chlorophyll concentrations, order of highest to lowest showed the following order: HBB>HB>LB as shown in figure 6.

Discussion and Conclusion

Understory vegetation represents a relative component of the whole biomass of high forests. Plants manufacture biomass through the photosynthesis process wherein the chlorophyll in plants absorbs the sun's energy and convert carbon dioxide into carbohydrates (chemical energy).

Since chlorophyll content is often closely related to plant production, any reduction in leaf chlorophyll would limit net photosynthesis and thus diminish total plant growth. Stomata regulate the exchange of water vapor and CO_2 between the plant and the atmosphere, mainly through changes in the stomatal pore. Therefore, stomata play a pivotal role in controlling the balance between water loss and carbon gain. Moreover, the direct correlations between estimating biomass, chlorophyll concentration, and measuring the number and of stomata have played an important role in many studies of anatomical, physiological, ecological agricultural interests [8].

Further studies on interrelationships between stomatal density and distribution and chlorophyll concentrations on overall rate of photosynthesis and biomass production in LISF sites are warranted.

Acknowledgements

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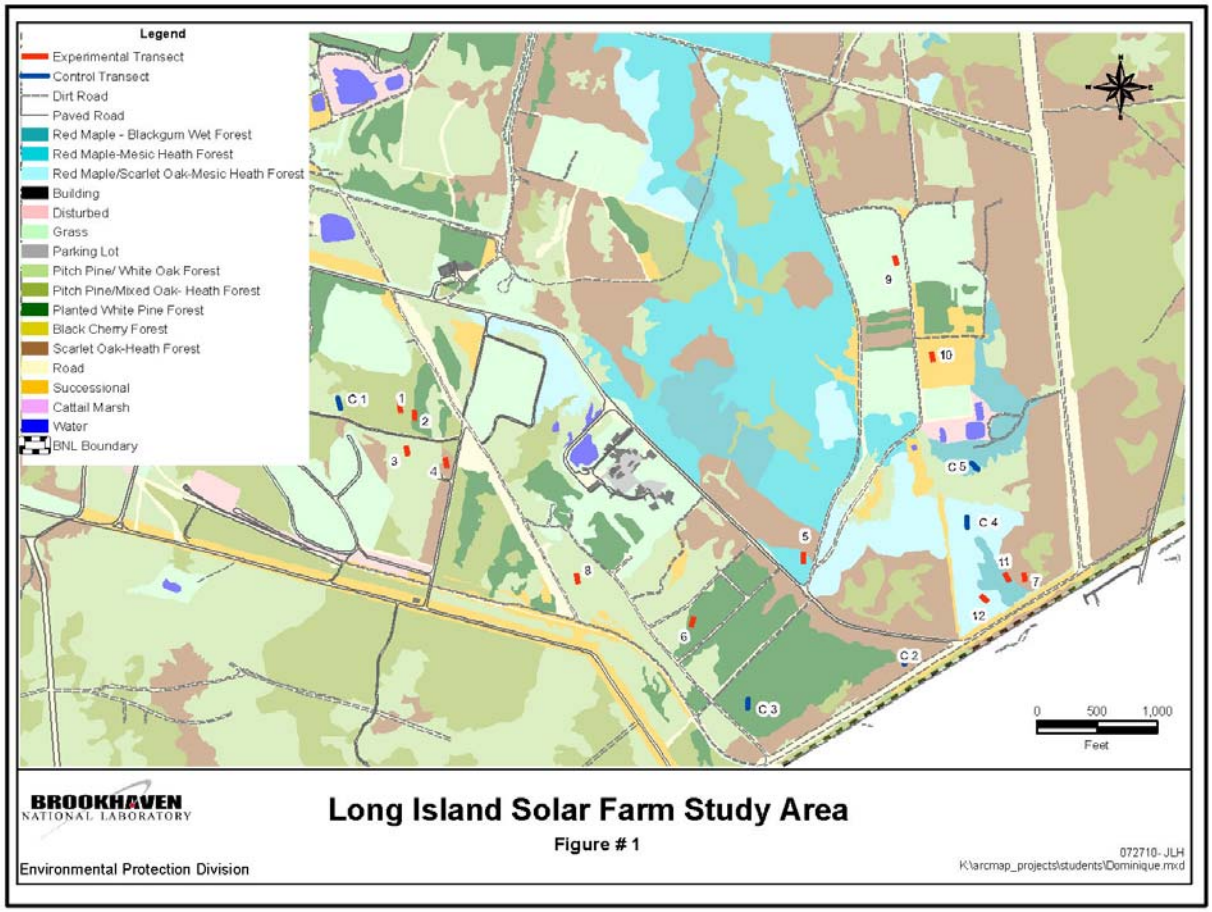
Tables and Figures

Common Name	**Abv.**	**Genus**	**Species**
Bracken Fern	**BF**	*Pteridium*	*aquilinum*
Black cherry	**BC**	*Berberis*	*Thunbergii*
Early Lowbush Blueberry	**EB**	*Vaccinium*	*pallidum*
Greenbrier	**GB**	*Smilax*	*rotundifolia*
Highbush Blueberry	**HBB**	*Vaccinium*	*corymbosum*
Huckleberry	**HB**	*Gaylussacia*	*bacatta*
Late Lowbush Blueberry	**LB**	*Vaccinium*	*angustifolium*
Maple Seedling	**MS**	*Acer*	*rubrum*
Pine Barren Bellwort	**PBB**	*Uvularia*	*puberula*
Seedbox	**SB**	*Ludwiga*	*alemifolia*
Virginia Creeper	**VC**	*Parthenocissus*	*quinquefolla*

Table 1: Vegetation in LISF Experimental sites

% Carbon Concentration of Dry Weight Biomass		
Sites	**% dwt/m^2**	**% Carbon**
Controls	68.89	34.44
S26	49.90	24.95
S19	85.50	42.75
S17	79.46	39.73
S13	79.26	39.63
S18	59.79	29.89
S14	63.09	31.54
S4	59.41	29.70

Table 2: Conversion of dry weight biomass to Carbon sequestration [7]


Legend
Experimental Transect
Control Transect
Dirt Road
Paved Road
Red Maple - Blackgum Wet Forest
Red Maple-Mesic Heath Forest
Red Maple/Scarlet Oak-Mesic Heath Forest
Building
Disturbed
Grass
Parking Lot
Pitch Pine/ White Oak Forest
Pitch Pine/Mixed Oak- Heath Forest
Planted White Pine Forest
Black Cherry Forest
Scarlet Oak-Heath Forest
Road
Successional
Cattail Marsh
Water
BNL Boundary
C 1
C 2
C 3
C 4
C 5
0 500 1,000
Feet
BROOKHAVEN NATIONAL LABORATORY
Long Island Solar Farm Study Area
Figure # 1
Environmental Protection Division
072710- JLH
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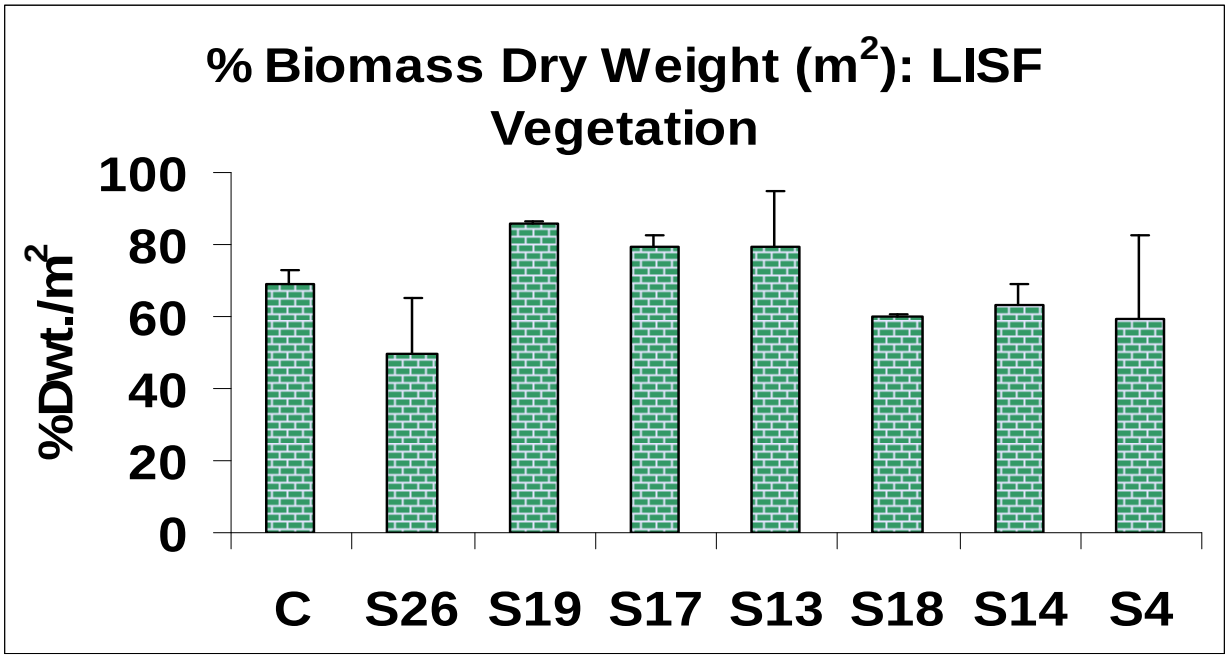
% Biomass Dry Weight (m2): LISF Vegetation
%Dwt./m2
100
80
60
40
20
0
C
S26
S19
S17
S13
S18
S14
S4

Figure 2

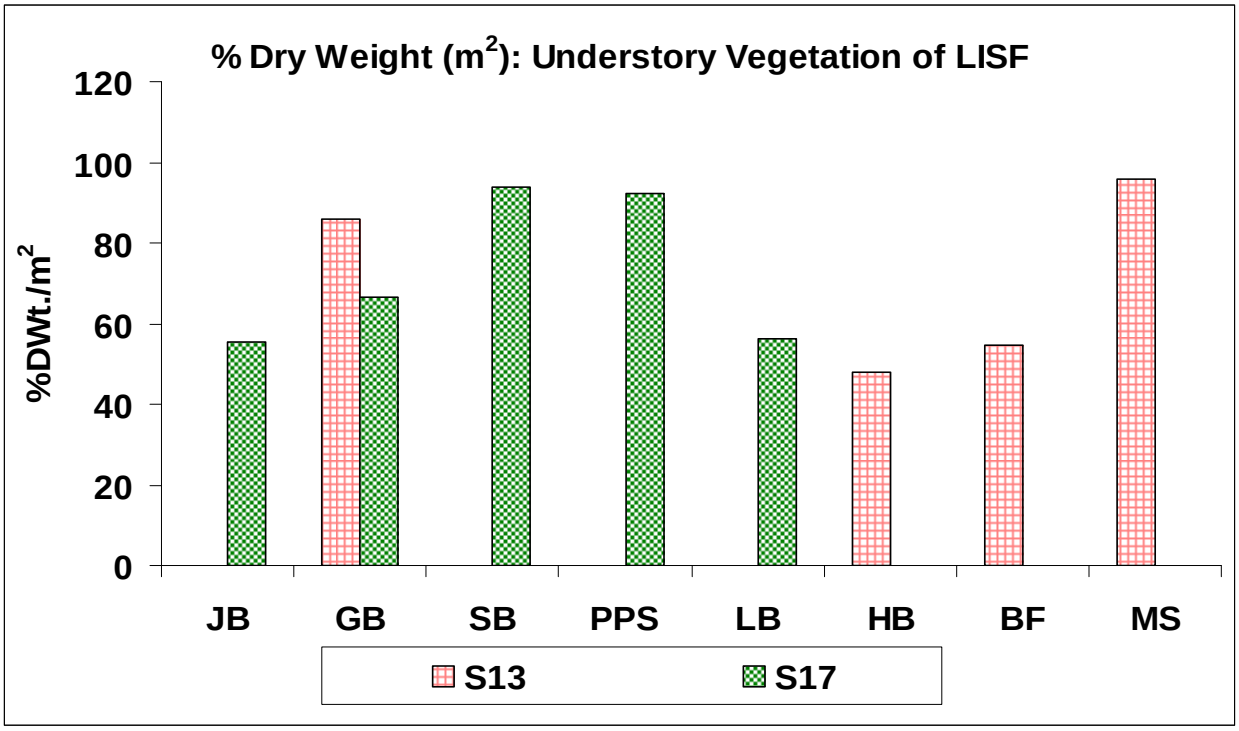

Figure 3

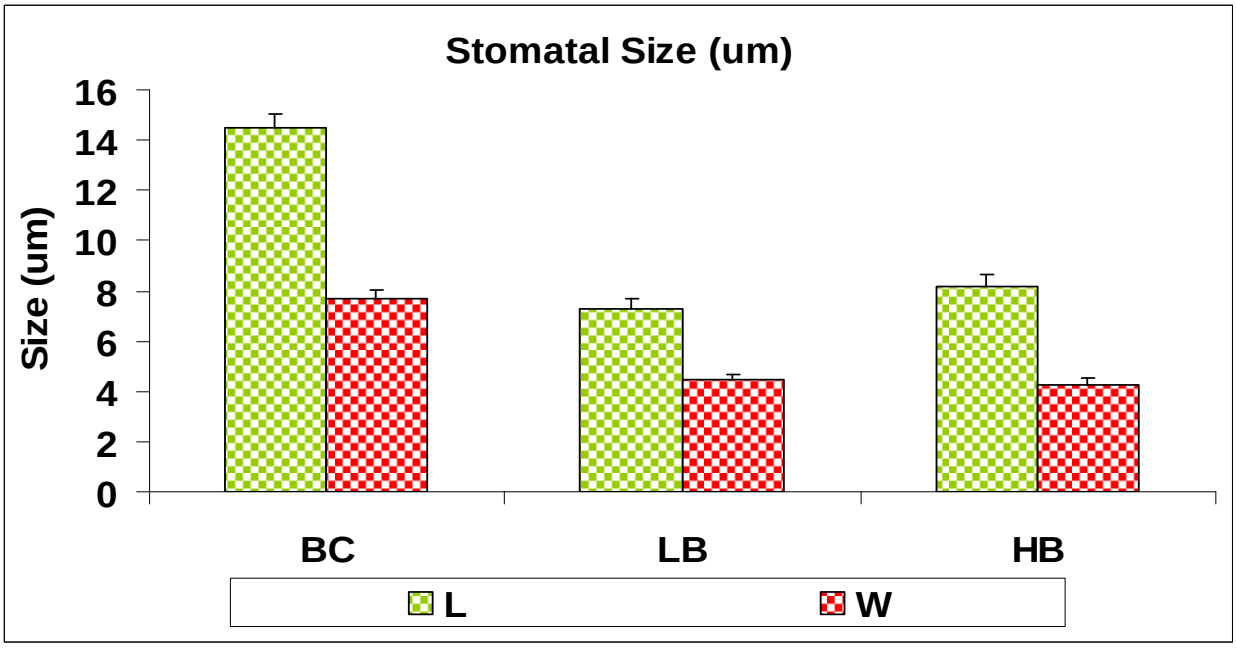

Figure 4

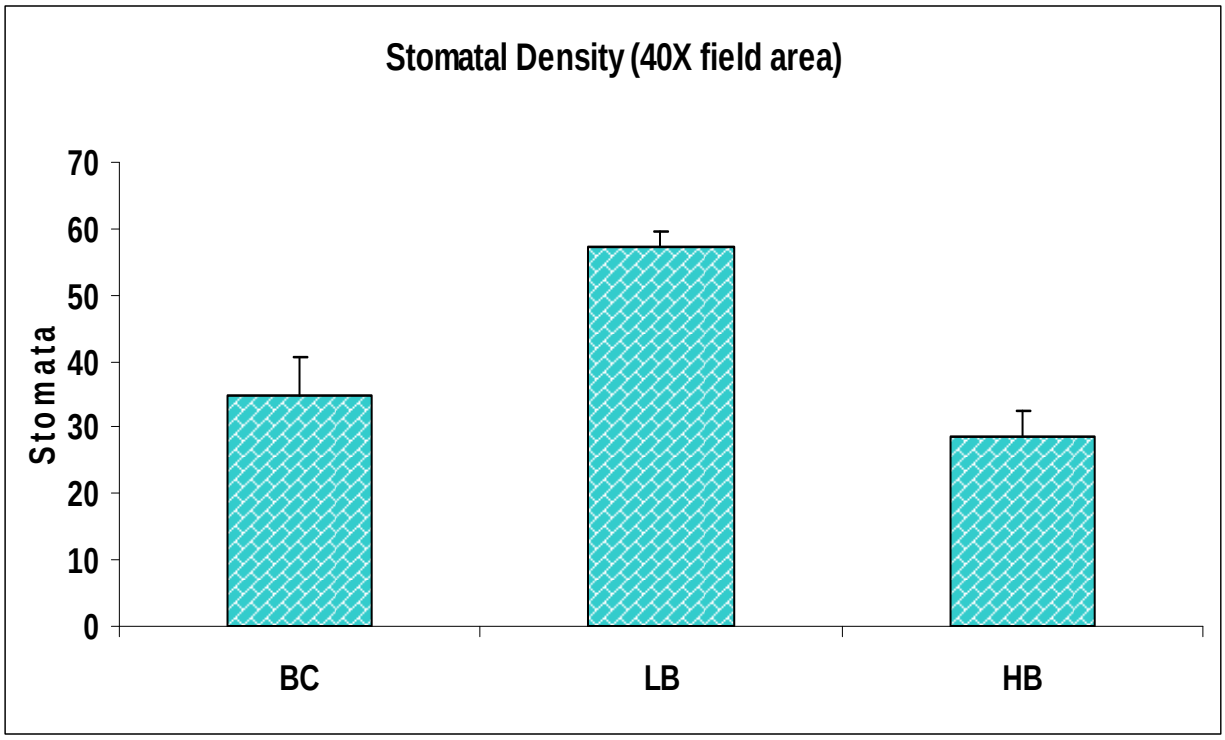

Figure 5

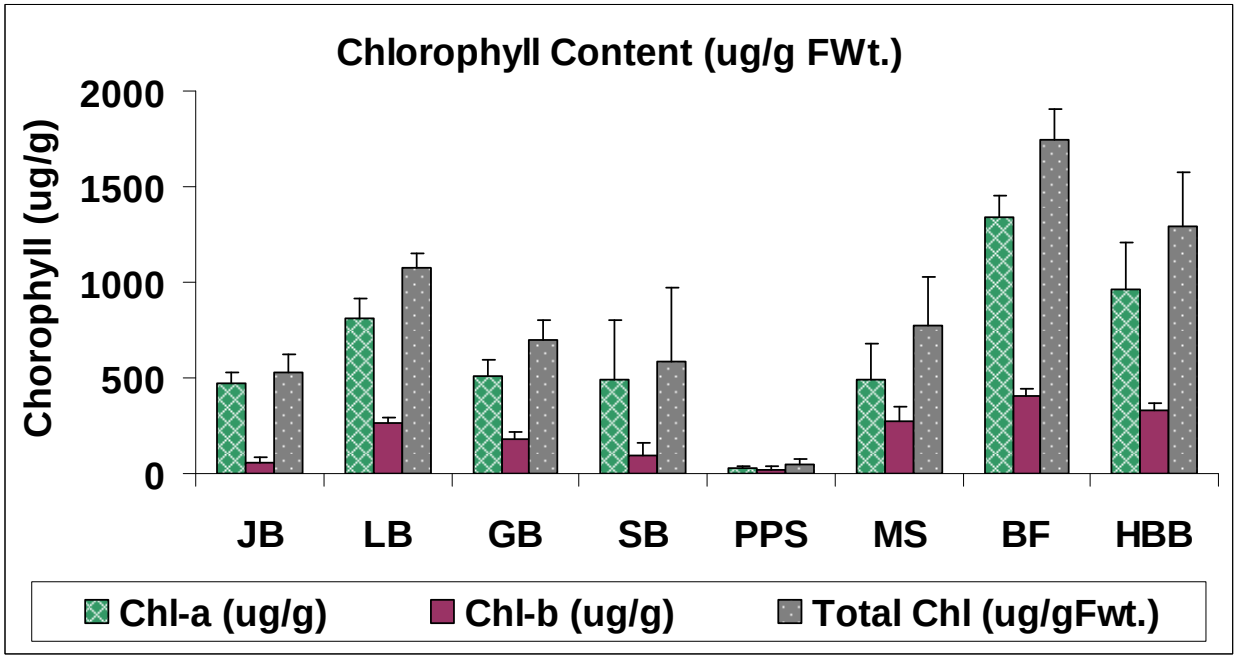

Figure 6