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ORIGINAL ARTICLE

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An Investigation into Photosynthesis Related Parameters of Chili Varieties for Agronomic Traits

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A critical investigation into the performance of all known chili varieties in the same agro-climatic conditions in imminent to identify the elite varieties for beneficial agronomic traits. In this perspective, 20 varieties of chilies were collected and planted in A.N.U botanical garden to know about photosynthetic performance measured in terms of photosynthetic rate, chlorophyll and carotenoid content and chlorophyll stability index in a comparative study. The highest stomatal conductance in LCA-305 (0.166 mmol cm^{-2}) and high transpiration rate in LCA-235 (4.46 mol $m^{-2}s^{-1}$) and G-3 (4.43 mol $m^{-2}s^{-1}$) was observed. Whereas the cultivars, LCA-305 (31.2 μmol CO_2 $cm^{-2}s^{-1}$) and Rabbi (31.20 μmol CO_2 $cm^{-2}s^{-1}$) displayed high photosynthetic rates. The genotypes like G-4 (32°C), G-3 (31.3°C) and G-5 (31.2°C) have recorded high canopy temperature. The highest water use efficiency was noted in Aparna (59.93), LCA-334 (16.68), and G-3 (6.40). The highest chlorophyll a content was noticed in LCA-305 (6.68 mg g^{-1}) followed by G-4 (6.12mg g^{-1}), chlorophyll b content in LCA-424 (7.94 mg g^{-1}), total chlorophyll content in LCA-305 (10.58 mg g^{-1}) and carotenoid in LCA-353 (4.40 mg g^{-1}) and G-5 (3.82 mg g^{-1}) was observed. The highest chlorophyll stability index was observed in LCA-305 (0.85 mg g^{-1}) followed by LCA-334 (0.77 mg g^{-1}). Basing on the above data, it can be concluded that in terms of stomatal conductance, photosynthetic rate, CSI value, chlorophyll A and total chlorophyll contents, LCA-305 displayed superior performance indicating that LCA-305 can be projected as superior variety.

Key words: photosynthesis related parameters, chili varieties, Agronomic traits

Chili or Hot Pepper (*Capsicum annuum L.*) is emerging as one of the most important economical and popular vegetable crops grown for its green fruits as vegetable and red form as spice. Besides, it is used in many processing industries for various products such as pepper sauce, pickled pepper, ground pepper and dried pepper. It belongs to family *Solanaceae* and originated in Latin American regions of New Mexico, Guatemala and Bulgaria. India is the largest producer, consumer and exporter of chili in the world with an annual production of 1.30 million tonnes from 0.79 million ha with production share of 22.72%.

The quest for improved varieties in agriculture is a good old practice. Screening for the new and improved varieties of chili has resulted in the development of many varieties with different phenotypes. Many varieties have been developed by selection of natural genetic variation, cross and heterosis breeding, and mutagenesis (Vivian *et al.,* 2019). Recently genetic engineering technology also applied to developed new and improved varieties with tolerance to disease, drought etc., (Prasad *et al.,* 2016). But the journey into the finding of new variety is a continuous process as some varieties may lose phenotypes with age.

Screening of physiological performance by destructive and non-destructive means of agriculture plants is a common practice to assess the field level performance of plants under stressful or non stressful conditions (Fahad *et al.,* 2017).In addition to this, many studies have correlated the high photosynthetic rate of crops to higher yields (Usman *et al.,* 2014). With this background, though many chili varieties are use, no study has been carried out by growing all known varieties in the same agro-climatic conditions (with or without imposition of stress) to pick the best performing variety in terms of photosynthesis and yield related parameters.

Hence in the present study, twenty chili varieties (Table 1) present in the Horticultural Research Station (HRS), Lam Farm were collected and planted in A.N.U Botanical garden for comparative morphological-physiological studies to find out the best performing variety. Indeed, we pick-up some high performing variety in terms of photosynthesis related parameters.

MATERIALS AND METHODS

The experiment was conducted at Acharya Nagarjuna University campus, Guntur. The site of the experiment is situated on 16°2'North latitude and 80°3' East longitude at an altitude of 31.5 m above the mean sea level.

Experimental material

The experimental material consisted of 20 accessions genotypes obtained from germplasm collection of Horticultural Research Station (HRS), Lam-farm, and local market of Guntur, Andhra Pradesh, India. Twenty dissimilar genotypes of chili (*Capsicum annuum* L.) have been used as plant materials for experimentation. The seedlings for the study were raised by sowing the seeds in nursery beds of4m x 1m size prepared after bringing the soil to a fine tilth. Each bed was mixed with 2 kg of Farm Yard Manure (FYM). The beds were levelled and seeds of 20 varieties were sown in lines at 5cm spacing. The soils of the farm are deep, black clay loams with a depth of 6-7 feet, pH of 8.3, EC of 0.16 m. m hos/cm and have good moisture retentive capacity. The suggested dose of fertilizers @ 200:60:80 kg N P K / ha in the form of urea, single super phosphate and muriate of potash respectively were applied. Plants were watered regularly and by monthly with 30 grams per plant of commercial fertilizers. Twelve plants of each genotype were transplanted in each replication in one row. Plot size: One row of 4 m length, Spacing: 75 cm x 30cm, during the experiment, day temperature ranged from 30 to 37°C and night temperatures from 20-25°C. Measurement of plant height from 0.55 m above the soil surface to shoot apices, of leaf (2nd and 3rd developing leaves from shoot apices)

Physiological parameters

The parameters like photosynthetic rate (Pr), stomatal conductance (Gs) and transpiration rate (T) were measured by using Licor–Li 6400 XT portable photosynthetic system. The above were expressed in units viz., µmol of CO_2 fixed per$m^{-2}s^{-1}$, mol of gas evolved per $m^{-2}s^{-1}$ and mmol of water released per $m^{-2}s^{-1}$.

Canopy temperature (°C)

Crop canopy temperature was determined weekly with an infrared thermometer (Raytek Raynger ST80, Burlington). Measurements were made and considered to be maximal (13:00–15:00 h) and expressed in °C.

Water use efficiency (WUE)

Water use efficiency is the ratio between two bio-physical parameters and it is determined by the formula given by Blum (2005) and was expressed in m mol H_2O/μmol CO_2.

$$\text{Water use efficiency (WUE)} = \frac{\text{Rate of transpiration (T)}}{\text{Photosynthetic rate (Pr)}}$$

Leaf chlorophyll (mg g^{-1})

Total leaf chlorophyll of each variety was calculated by using DMSO method (Hiscox and Israelstam, 1979). According to this method, 30 mg of fresh and dark green leaf material was taken into a test tube. To this test tube, 10 ml of dimethyl sulfoxide (DMSO) was added and the entire set up was kept in hot water bath at 60°C for about 30 minutes until the chlorophyll pigment was extracted into DMSO. The optical density was recorded at 645 and 663 nm by using UV–VIS spectrophotometer (Elico SL 159). The amount of Total chlorophyll, chlorophyll a, and bpigments content and carotenoids content present in the sample was calculated by using the following formulae and was expressed as milligrams of chlorophyll per gram fresh weight (mg g^{-1}fr.wt).

$$Ch\text{-}a=12.47A_{665.1} - 3.62A_{649.1}$$

$$Ch\text{-}b=25.06A_{649.1} - 6.5A_{665.1}$$

A = Absorbance, Ch-a = Chlorophyll a, Ch-b = Chlorophyll b

$$\text{Total chlorophyll}= (20.2\times \text{O.D at 645nm}+8.02\times \text{O.D at 663nm}) \times {}^{3}/_{4}\times {}^{V}/_{W}$$

$$\text{Carotenoids} = 7.0\ (\text{O.D at 480 nm})-1.47\ (\text{O.D at 510 nm}) \times \frac{V}{10} \times W$$

Chlorophyll stability index(CSI)

Chlorophyll stability index was determined by the method of Sairam (1994).

Statistical analysis

Data were subjected to two-way factorial analysis of variance (ANOVA) followed by the Fisher least significant difference (LSD) test for mean separation. Statistical analyses were performed with Statistica^{TM} Software v.7.00 (Stat Soft Inc. 2004).

RESULTS AND DISCUSSION

Changes in biophysical parameters like photosynthetic rate, stomatal conductance, transpiration rate, water use efficiency (WUE) and canopy temperature (°C); the amount of chlorophyll *a,* chlorophyll *b*, total chlorophyll content, carotenoid and chlorophyll stability index (CSI) of *Capsicum annuum.* L cultivars as per calculations are presented in the following Tables No.1, 2 and shown in the figures 1-11.

The photosynthetic rate was significantly different between different cultivars with rise in soil moisture stress (Table 1). The highest photosynthetic rates were observed in LCA 305 (32.25 μmol CO_2 m^{-2}s^{-1}) followed by G5 (32.12 μmol CO_2 m^{-2}s^{-1}). The lowest photosynthetic rates were seen in Vajra (24.51 μmol CO_2 m^{-2}s^{-1}) followed by LCA-436 (26.38 μmol CO_2 m^{-2}s^{-1}). The photosynthetic data indicate that LCA 305 displayed high photosynthesis performance when compared to other genotypes.

Stomatal conductance (mmol cm^{-2})

The stomatal response in different chili cultivars was measured and expressed in terms of mol m^{-2}s^{-1} and listed in Table 1.The highest stomatal conductance was observed in LCA-305 and LCA-235 (0.16 mol mm^{-2}s^{-1}) followed by LCA-206 (0.12 mol m^{-2}s^{-1}) and 999 (0.10 mol m^{-2}s^{-1}). The lowest stomatal conductance was noticed in Aparna (0.1 mol m^{-2}s^{-1}).

Transpiration rate (mol mm^{-2}s^{-1})

The transpiration rate ranged from 0.04 mol mm^{-2}s^{-1} (Aparna) to 4.39 mol mm^{-2}s^{-1} (LCA-305) (Table 1). The other varieties that has shown high transpiration rate are LCA-235 (4.46 mol mm^{-2}s^{-1}) and LCA-206 (4.26 mol mm^{-2}s^{-1}).

Canopy Temperature(°C)

Among the genotypes of twenty cultivars, the leaf canopy temperature (Table1) ranged from 28.23°C (LCA-235) to 32.15°C (LCA-625) with a mean value of 57.33°C for all the cultivars shown in the Table 1. The genotypes such as LCA-234 (32.21°C), G-3 (31.31°C), G-5 (31.25°C), showed high canopy temperature; but Rabbi (28.36°C) and Suryateja (29.0°C) showed low canopy temperatures.

Water use efficiency(WUE)

Water usage efficiency was ranged from 6.4-59.9 (µml/m mol) in 20 cultivars of studied and are presented in Table1.The WUE was highest 59.9 (m mol H_2O/µ mol CO_2) in varieties of Aparna followed by 16.68, 15.64, 13.55, 13.33, 12.33, 11.68, 10.78, 10.71 and 10.52 (m mol H_2O/µ mol CO_2) LCA-334, LCA-424, G-5, 999, LCA-960, Rabbi, Mycoteja, Suryateja and G- 4 cultivars respectively.

Chlorophyll a (mg g^{-1})

Mean chlorophyll a values among different chili genotypes were ranged from 0.57mg $g^{-1}$to 6.68 mg g^{-1} with a mean value of 1.67 mg g^{-1}presented in Table 2 and Figure 2. Among the various genotypes, highest chlorophyll a content was noticed in LCA-305 (6.68 mg g^{-1}), G-4 (6.12 mg g^{-1}) followed by LCA -206 (2.29 mg g^{-1}) and LCA-353 (1.47 mg g^{-1}), whereas lowest values were observed in Super-10 (0.57 mg g^{-1}), Aparna (0.730 mg g^{-1}), LCA-620 (0.82 mg g^{-1}), Vajra (0.84 mg g^{-1}), LCA-625 (0.87 mg g^{-1}), and LCA-436 (0.97 mg g^{-1}). Cultivars such as LCA-305 (6.68 mg g^{-1}) and G-4 (6.12 mg g^{-1}) have recorded high total chlorophyll a values.

Chlorophyll b(mg g^{-1})

The chlorophyll b content among the cultivars is presented in Table 2 and Figure 3.Among the various genotypes, highest chlorophyll b content was noticed in LCA-353 (8.51 mg g^{-1}) followed by LCA 424 (7.94 mg g^{-1}) and G-5 (7.53 mg g^{-1}); whereas lowest values were observed in G-4 (0.78 mg g^{-1}), super10 (1.88 mg g^{-1}), Suryateja (3.56 mg g^{-1}), LCA-625 (4.29 mg g^{-1}), LCA-206 (4.35 mg g^{-1}), Super10 (6.55 mg g^{-1}), LCA-305 (3.85 mg g^{-1}) and Aparna (3.95 mg g^{-1}). Mean of total chlorophyll value for all the genotypes were 5.32 mg g^{-1}.

Total chlorophyll (mg g^{-1})

The total chlorophyll of different chili cultivars are presented in Table 2 and Figure 4 between the different cultivars, highest chlorophyll content was noticed in LCA-305 (10.58 mg g^{-1}) followed by LCA-424 (9.49 mg g^{-1}) and LCA-436 (6.48 mg g^{-1}); whereas lowest values were observed in Rabbi (8.21 mg g^{-1}), LCA-620 (5.43 mg g^{-1}), Vajra (5.43 mg g^{-1}) and 999 (5.26 mg g^{-1}). Varieties such as LCA-305 (10.58 mg g^{-1}) and LCA-353 (9.72 mg g^{-1}) have recorded high total chlorophyll values and these selections also reported less percent decrease in chlorophyll during vegetative growth such as fruit and flowering stages. The cultivars LCA-625 (5.56 mg g^{-1}), and 999 (5.26 mg g^{-1}) recorded less chlorophyll values under vegetative growth. Mean of the cultivars for total chlorophyll was 6.993 mg g^{-1}.

Chlorophyll Stability Index (CSI)

Chlorophyll stability index varied significantly among all the varieties of chili genotypes are presented in Table 2. It was ranged from 0.49 to 0.77 with a mean value of 0.63. In the varieties like LCA-305 (0.85), LCA-334 (0.77) and Rabbi (0.65), high chlorophyll stability index was observed which proved their recital of stress tolerance activity. Whereas decreased CSI was observed in LCA-206 (0.65) followed by LCA-625 (0.50), LCA-235 (0.53) and G-4 (0.56), Suryateja (0.58) and Mycoteja (0.58). The cultivar LCA305 (0.85) has recorded highest CSI value. The other varieties also reported less percent decrease in chlorophyll stability index i.e. LCA334 (0.77), LCA-620 (0.72) and G-5 (0.65) respectively.

Total Content of Carotenoids mg g^{-1}.

The content of carotenoids in chili genotypes are presented in Table 2 and Figure 5. The values ranged from 2.50 to 3.82 mg g^{-1} with a mean value of 3.14 mg g^{-1}. Among the various genotypes, highest carotenoids content was noticed in LCA-353 (4.40 mg g^{-1}) followed by G-5 (3.82 mg g^{-1}) and G-4 (3.82 mg g^{-1}); whereas lowest values were observed in Suryateja (2.50 mg g^{-1}), LCA-305 (2.52 mg g^{-1}), Aparna (2.55 mg g^{-1}), LCA-620 (2.55 mg g^{-1}) and Vajra (2.60 mg g^{-1}).The carotenoid contents augmented from the fresh to the mature state, as projected accordingly to the natural biosynthesis of pigments as the seasons. In accordance with the statistical analysis, of chili peppers in the fresh stage, there were significant differences between cultivars, while analysis, showed differences between the all cultivars (Table 2).

Association analysis

The relations between cultivars under vegetative growth and Ripening stages were analysed are shown in Figures 1-11. Vegetative growth and fruit yield was found to have significant positive association with total chlorophyll, *a*, *b* and CSI (Fig 2-4), chlorophyll pigments and water use efficiency (Fig.7). Among the traits tested; chlorophyll stability index was found to have positive correlation with total chlorophyll (Fig.4). Significant positive relationships between photosynthetic rate and chlorophyll (Fig.6), photosynthetic rate and stomatal conductance (Fig.10) were observed. A significant positive relationship was observed among stomatal conductance and transpiration (Fig. 8), whereas a significant converse correlation was noticed between transpiration and water use efficiency (Fig. 9) and stomata conductance and water use efficiency (Fig. 11).

A series of physiological activities that begins with CO_2 diffusion in to the space of leaf by stomata leading to CO_2 assimilation. This in turn affects the accumulation of biomass and its distribution to various organs of the plant, which depends on their automatic growth and development. Photosynthesis rate is the rate at which the plant can make their own food materials. It measures how efficient the plant is in carbon fixation. A mean value of 55.73 µmol CO_2 $m^{-2}s^{-1}$was recorded for all the cultivars.

LCA-305 (31.25 µmol CO_2 cm^{-2} s^{-1}) and Rabbi (31.20 µmol CO_2 $cm^{-2}s^{-1}$) were recorded with high photosynthetic efficiency whereas Vajra cultivar recorded the lowest photosynthetic rate of 24.51 µ mole CO_2 m^{-2} sec^{-1}. Similar results were reported by Magaji *et al.* (2014) from 36 chili cultivars, the photosynthesis rate ranged from 6.02 CO_2 $cm^{-2}s^{-1}$ to 17.62 CO_2 $cm^{-2}s^{-1}$. Ligia (2010) evaluated varieties of tomato, egg plant and sweet pepper, and reported the highest photosynthesis rate for the eggplant. The cumulative net assimilation rates are due to increased intercellular CO_2 concentrations, internal concentration of CO_2 increased in the cultivars which develop more photosynthetic rate and wherever assimilate transport increased. The differences observed in the present study from between the 20 cultivars could useful for selection of elite varieties by correlating with yield related parameters.

Kinoshita *et al.* (2003) studied the blue light effects on the photosynthetic activity for being liable for the maintenance of the electric potential in the membranes of guard cells and for the stomata opening, resulting in the upsurge in the concentration of CO_2 inside the mesophyll (Farquhar and Wand, 1984). Moreover, the equilibrium between the wavelength in the red and blue spectrum might stimulate the increase in the net photosynthesis (Kong *et al.,* 2012). The synthesis and degradation of the photosynthetic pigments are related with the floras adaptability to dissimilar environments.

A lowest stomatal conductance of 0.04 mol CO_2 cm^{-2} s^{-1} was observed in Aparna and a maximum of 0.166 mol CO_2 $cm^{-2}s^{-1}$ were observed in LCA-305 with a mean value of 0.185 mol CO_2 $cm^{-2}s^{-1}$ for all cultivars. Similar results were observed by Jorge *et al.* (2016), by evaluating physiological traits of fourteen species grown under stress conditions. The photosynthesis rate values ranged from 0.8 to 30.6 mol CO_2 $cm^{-2}s^{-1}$ and the stomatal conductance from 0.01 to 0.62 mol CO_2 $cm^{-2}s^{-1}$. Closing of stomata could take place the condition of increased humidity, CO_2, high light intensity and dependent on diversity of cultivars. The stomatal aperture is the first diffusional barrier for entry of CO_2 into photosynthetic assimilation in plants. The expanse of the stomatal pore can directly affect photosynthetic rate by substrate (CO_2) for fixation (Medeiros *et al.,* 2015). However, the decrement of the internal CO_2 concentration (Ci) by photosynthesis, accumulation of photosynthesis-derived metabolites and the transport in the adjacent guard cells to control stomatal movements (Lawson and Blatt. 2014). As a result, photosynthesis is not the only process that influences the stomatal movements (Medeiros *et al.,* 2015).

A maximum transpiration rate of 4.46 mmol $m^{-2}s^{-1}$ was observed in LCA-235 and a minimum of 0.46 m mol m^{-2} s^{-1} for Aparna with a mean value of 5.67 mmol m^{-2} s^{-1} for all cultivars. The lower levels of transpiration among the cultivars owing to closure stomata and increasing of the concentration of the CO_2 closure of stomata may be due to unfavorable environmental conditions and these results are in agreement with those reported by Ligia 2010 in tomato and egg plant the transpiration rate in egg plant was ranged between1.93-3.01 mmol $m^{-2}s^{-1}$ from base to top of the plant. Rita *et al.* (2013) studied relationship among photosynthesis and respiration on 24 accessions of 17 species and eight genomes of rice (*Oryza sativa* and *O.glaberrima*), and a significant positive association between thick leaf and leaf transpiration efficiency reported. Leaf hydraulic architecture might contribute to association between leaf structure and transpiration. Bundle sheath may facilitate leaf water conductivity through the mesophyll to the stomata (Guyot *et al.,* 2012). Tarawalie *et al.* (2012) evaluated photosynthesis rate, stomatal conductance, transpiration rate and yield of hot pepper in a comparative study on 4 plants growth periods up to fruiting. The mean moisture content of all treatments was 25.20%.The high photosynthesis rate was with irrigation at vegetative growth, whereas high stomatal conductance and transpiration rates were recorded in the 4 stages of growth (Tarawalie *et al.,* 2012).

The cultivars G-4 (32°C), G-3 (31.31°C), G-5 (31.25°C) have recorded high leaf canopy temperature. While less leaf canopy temperature during water availability was observed in Rabbi (28.36°C) and Vajra (28.45°C). These results were agreement with published reports. The leaf canopy temperature might have increased due to stress imposed by reduction in soil moisture content. The values of leaf canopy temperatures were higher before irrigation and the lower after irrigation. Gardner *et al.* (1981) observed that canopy temperature of watered Sorghum was little bit higher (0.5°C) than air temperature and after wards temperature difference was 1-2ºC. Thus, they determined that crop canopy temperature factor may be a sensitive indicator of water stress and can be used to measure the efficiency of various irrigation scheduling practices. Variations in canopy temperature during day time could be due to increased CO_2 from free-air CO_2 enrichment experiments at concentrations 550 µmol mol^{-1}. Triggs *et al.* (2004) studied on Sorghum and Magliulo *et al.* (2003) in Potatoes. Increasing temperature and carbon-dioxide are due to change in climate (Jagadish *et al.,* 2016). The decrease in leaf transpiration reduces evaporative cooling with an increase in canopy temperatures. Increased temperatures may depend on species and environmental conditions. The canopy temperature variations are probable reasons for shifts in the optimum geographic weather areas for growth of crops and other plant species (Jagadish *et al.,* 2016).

Water use efficiency (WUE) parameter provides the information about the assimilation of dry mass produced per unit of lost water by transpiration. This factor is important for giving the information about the water management to agricultural productivity. WUE increased from the root to top of plant and becomes superior in ripening stage once the foliar apparatus is fully developed. Water usage efficiency ranged from 6.4-59.9 (µml/m mol) in 20 cultivars of studied. The Wue was higher 59.9 (mmol H_2O/µ mol CO_2) in varieties of Aparna. The current results are in agreement with Tarawalie *et al.* (2012) with respect to water use efficiency and yield of hot pepper. Kara and Yıldırım (2015) evaluated the effect of different irrigation systems on pepper plant (*Capsicum annuum* L. cv. Carliston) vegetative growth, water use efficiency, radiation use efficiency for yield and total dry matter. chili plants produced the highest yields when the 518 mm and 646 mm amount of water applied respectively. Several aspects that influence stomata and their response to the environs is often observed (Ball *et al.,* 1987). Therefore irrigation provided chili cultivars gave high yield. Consequently, that water is a significant resource for development and yield of agricultural crops, therefore scarcity water supply will affect viz., growth and yield, thus water use efficiency reflecting.

Perceptibly, the total chlorophyll or its fractions (Chl. *a* or chl. *b*) of each species were differed among different genotypes investigated. It appears that, the highest chlorophyll content *a* & *b* equivalent to the lowest chlorophyll a/b ratio and vice versa. This may be due to chlorophyll balanced in all genotypes types as adaptive topographies in plants responded to high light intensities predominant in the current investigation. Chlorophyll and green colour maintenance in plants produced from freshly harvested leaves were dependent on chili genotypes. Higher concentrations of chlorophyll in various types of genotypes can lead to darker or more intense green colour of produced homogenate, and help maintain visual green colour of leaf samples but does not necessarily affect stability. LCA-305 had the highest total chlorophyll content as well as LCA-353 genotypes had the second highest chlorophyll content. Our results also suggest that higher chlorophyll content plants will give more yields along with the flowers of raw material production. Li *et al.* (2010) revealed, the red and blue monochromatic light delivered superior control of the stomata opening resulting in improved photosynthetic efficiency and therefore greater dry matter production in *Gossypium hirsutum* L. by in vitro method. Pacheco *et al.* (2013) studied an upsurge in stomata conductance and in the internal concentration of CO_2 in *Piper aduncum* cultivated in environment augmented by red light.

Chlorophyll contents like 890 mg kg $^{-1}$ and 288 mg kg^{-1} for chlorophyll *a* and chlorophyll *b* respectively in Parsley (Belitz *et al.,* 2009); 946 mg kg^{-1} of chlorophyll *a* and 202 mg kg^{-1} of chlorophyll *b* for Spinach (Belitz *et al.,* 2009); 4.6 to 33.5 µg mg^{-1} chlorophyll *a* and 3.2 to 25.1 µg mg^{-1}of chlorophyll *b* in Lettuce (Cadwell and Britz 2006) reported. The measured concentrations chlorophyll *a* and *b* of different genotypes in this study are lower than those stated for different types of vegetables like lettuce.

The chlorophylls are typically synthesized and photo-oxidized in the presence of sunlight. However, high light can degrade the levels of total chlorophylls (Gonçalves and Santos 2005). However under low light conditions, the plants set a series of mechanisms into motion a like a substantial increase in photosynthetic pigments, whence carotenoids can play a major role in light absorption and its relocation to chlorophyll cells (Xiao, 2016). The higher chlorophyll stability index (CSI) was observed in LCA-305 (0.85) and lower in LCA-206 (0.49). Other varieties displayed less percent in chlorophyll stability index; which proved the recital of stress tolerance activity. Similar results were reported by Ramesh and Devasenapathy 2006 in Cowpea and Sabale and Kale 2007 in Coriander. Krishna *et al.* (2018) studied CSI of hot pepper cultivars treated with *Arbuscular mycorrhiza* fungi displayed CSI values for the pepper cultivars viz., US-341 (64.05%),VNR-314 (63.12%), VNR-145 (65.17%) and Indam-05 (51.15%). With increase in the intensity of stress, stability index reduced in all plants (Farghali *et al.,* 2014).

The carotenoid pigment content increased from the immature to mature state according to the natural biosynthesis of pigments. In accordance with the statistical analysis of chili in the fresh stage, there were significant differences between chili varieties with highest value in LCA-353 (4.404 mg g^{-1}) followed by Suryateja (2.505 mg g^{-1}) (Table 3).This is due to the ability of leafs and fruits to produce carotenoids during the growth and ripening process irrespective of the genotypes. Therefore, no connotation was found between the concentration of carotenoids and the topographical origin. In environments with great solar radiation, the up surge of photo-oxidation of chlorophylls depends up on the concentration of carotenoids, which can prevent chlorophylls photo-oxidation (Gonçalves *et al.,* 2005). The results presented overhead could be affected also by the ecological conditions like, temperature, pH and humidity, as well as the kind of soil, which of course are related to the proximity of the different genotypes. The amount of carotenoids in leaf tissue depends on factors such as cultivar, maturity stage and mounting conditions.

The physiological factors are responsible for growth and yield of the plants. The fruit yield and number of fruits per plant of chili cultivars diverse significantly among the varieties. The increase in yield could be ascribed to several growth, biophysical, physiological and biochemical characteristics studied. The fruit yield which could be due to their effect of photosynthetic rate, stomatal conductance, transpiration rate, canopy temperature (°C) chlorophyll content and chlorophyll stability index. Similar results were observed in several cases (Kalpana, 2003). Highly significant positive correlation was observed between the chlorophyll a, b, total chlorophyll, carotenoids and chlorophyll stability index (CSI). Chlorophyll *a*, *b*, total chlorophyll and carotenoids positively correlated with chlorophyll stability index (CSI), Again photosynthetic rate exhibited highly significant positive correlation with transpiration rate. Yield per plant showed highly significant positive correlation with photosynthetic rate (Pr), stomatal conductance (Gs), transpiration rate and canopy temperature, Chlorophyll *a*, *b*, total chlorophyll and carotenoids with chlorophyll stability index.

Table 1. Assesment of photosynthetic performance of different *Capsicum annuum* L cultivars.

S.No	Cultivars	Photosynthe tic Rate(Pr) (μmol CO_2 $m^{-2}s^{-1}$)	Stomatal conducta nce (Gs) (mol $m^{-2}s^{-1}$)	Transpirati on Rate(T) (mmol $m^{-2}s^{-1}$)	Canopy temperature (°C)	WUE-water use efficiency (mmol H_2O/ μmol CO_2)
1	G-3	28.38	0.14	4.43	31.31	**6.40**
2	G-4	31.35	0.08	2.98	32.00	10.52
3	G-5	**32.12**	0.06	2.37	31.25	13.55
4	L.C.A-206	29.28	0.12	4.26	29.12	6.87
5	L.C.A-235	30.25	**0.16**	**4. 46**	28.23	6.89
6	L.C.A-305	**31.25**	**0.16**	4. 39	31.15	7.00
7	L.C.A-334	28.36	**0.04**	1.7	**32.21**	16.68
8	L.C.A-353	27.25	0.09	3.44	30.16	7.92
9	L.C.A-424	31.28	0.05	2.0	29.24	15.64
10	L.C.A-436	26.38	0.12	3.63	30.00	7.26
11	L.C.A-620	31.14	0.10	3.38	31.17	9.50
12	L.C.A-625	31.00	0.11	3.59	32.15	8.63
13	L.C.A-960	26.14	0.06	2.12	28.26	12.33
14	Aparna	28.05	0.1	**0.46**	29.35	**59.93**
15	Vajra	**24.51**	0.07	2.83	28.45	8.66
16	Super 10	26.32	0.08	3.04	30.26	8.65
17	Rabbi	31.00	0.07	2.67	28.36	11.68
18	999	31.14	0.10	2.41	29.33	13.33
19	Suryateja	29.32	0.10	2.73	**29.00**	10.71
20	Mycoteja	28.47	0.10	2.64	31.18	10.78
	Average	**55.73**	**0.18**	**5.67**	**57.33**	**12.65**
	SEM	**0.75**	**0.03**	**0.10**	**0.50**	**0.59**
	SED	**1.06**	**0.04**	**0.14**	**0.71**	**0.83**
	CD	**2.08**	**NON SIG**	**0.28**	**1.39**	**1.64**
	CV (%)	**4.4**	**48.6**	**5.8**	**2.9**	**8.4**

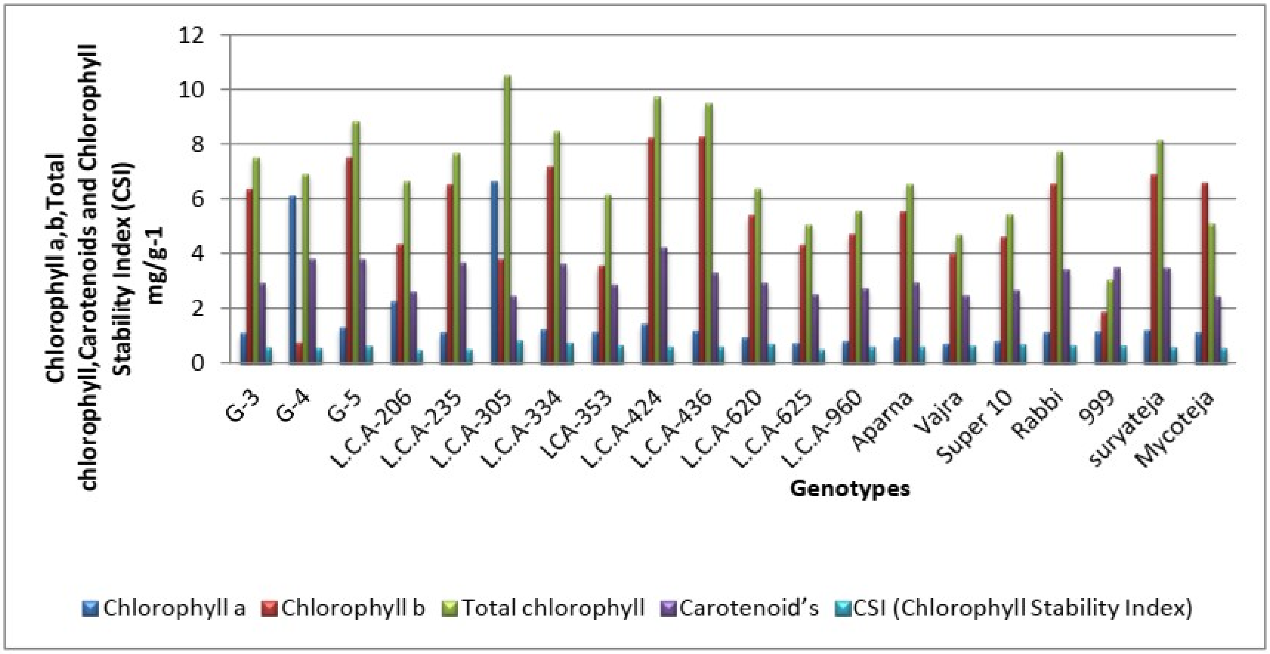

Figure 1: Associations between different physiological parameters under growth conditions

Table 2. Estimation of chlorophyll a, b, total chlorophyll and carotenoids contents o f *Capsicum annuum* L cultivars.

S.No	Cultivars	Chlorophy ll a (mg g-1)	Chlorophy ll b (mg g-1)	Total chlorophyll (mg g-1)	Carotenoids (mg g-1)	CSI
1	G-3	1.13	6.29	7.53	2.90	0.60
2	G-4	6.12	**0.78**	6.89	3.82	0.56
3	G-5	1.35	7.53	8.62	3.82	0.65
4	L.C.A-206	2.29	4.36	6.59	2.63	**0.49**
5	L.C.A-235	1.34	6.53	7.73	3.55	0.53
6	L.C.A-305	**6.68**	3.85	**10.58**	2.52	0.85
7	L.C.A-334	1.28	7.28	8.42	3.69	**0.77**
8	L.C.A-353	1.47	**8.51**	9.72	**4.40**	0.66
9	L.C.A-424	1.24	7.94	9.49	3.57	0.63
10	L.C.A-436	0.97	5.38	6.48	2.65	0.61
11	L.C.A-620	0.82	4.40	5.43	2.55	0.72
12	L.C.A-625	0.87	4.62	5.56	2.70	0.50
13	L.C.A-960	0.96	5.52	6.58	2.95	0.60
14	Aparna	0.73	3.95	5.43	2.55	0.63
15	Vajra	0.84	4.62	5.43	2.60	0.63
16	Super 10	**0.57**	6.55	**3.28**	3.47	0.69
17	Rabbi	1.17	1.88	8.21	3.53	0.65
18	999	1.23	6.60	5.26	3.57	0.64
19	Suryateja	1.17	3.56	6.23	**2.50**	0.58
20	Mycoteja	1.19	6.24	6.31	2.86	0.58
Average		**1.67**	**5.32**	**6.99**	**3.14**	**0.63**
SEM		**0.06**	**0.06**	**0.06**	**0.06**	**0.01**
SED		**0.08**	**0.08**	**0.09**	**0.08**	**0.00**
CD		**0.17**	**0.17**	**0.18**	**0.17**	**0.02**
CV (%)		**8.4**	**2.6**	**2.1**	**4.4**	**3.4**

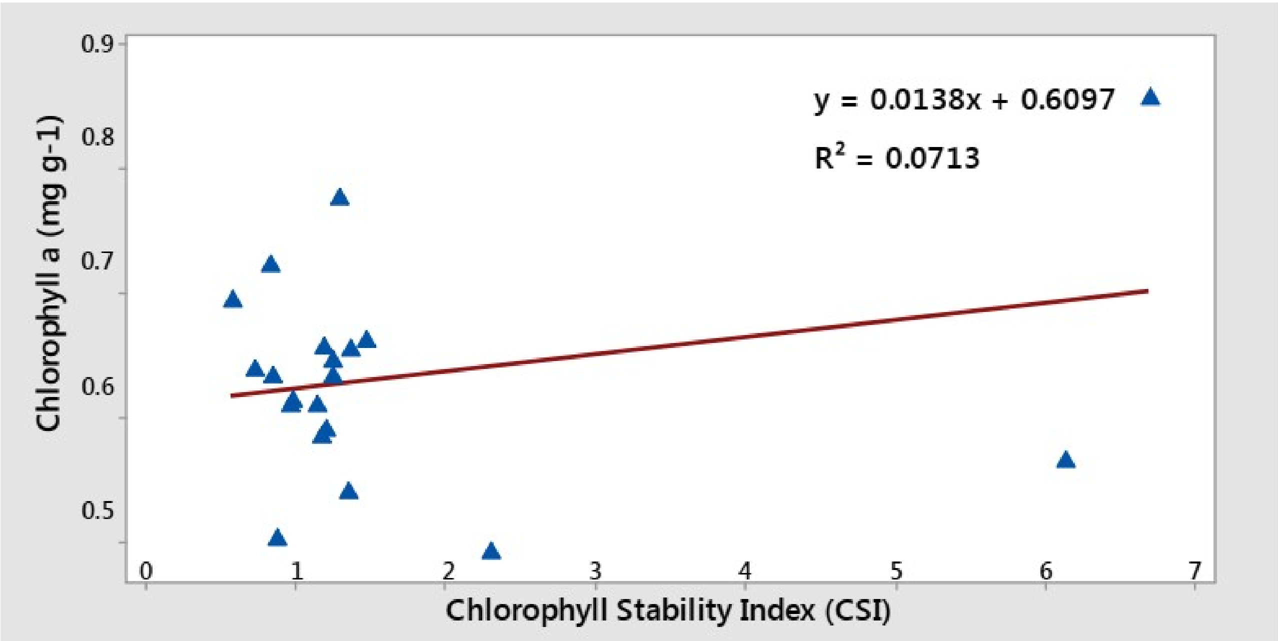

Figure 2: Relationships between chlorophyll a and C.S.I reading

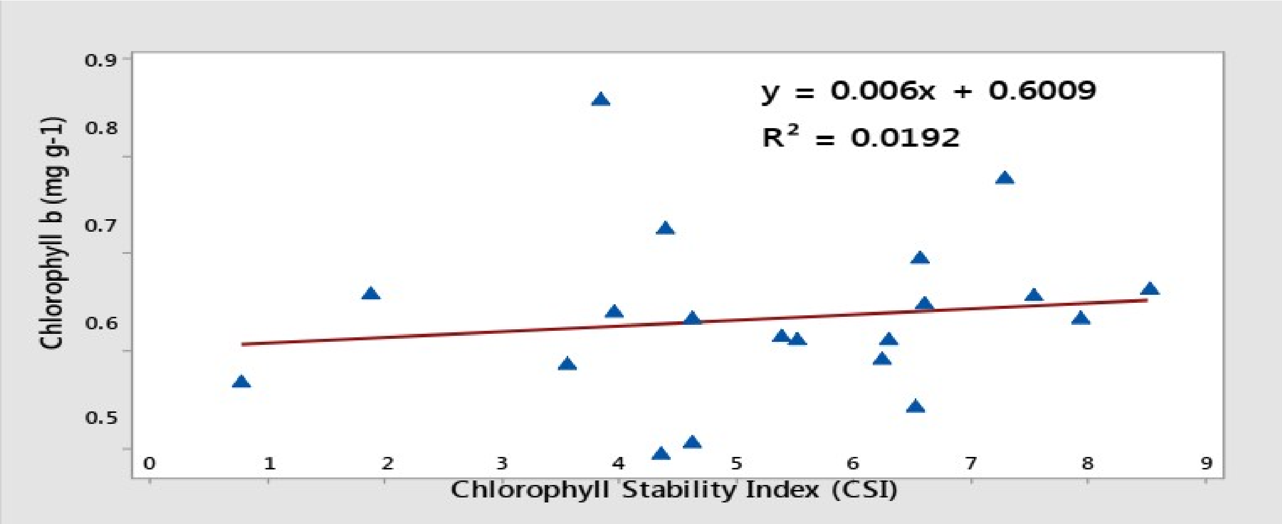

Figure 3: Relationships between chlorophyll b and C.S.I reading

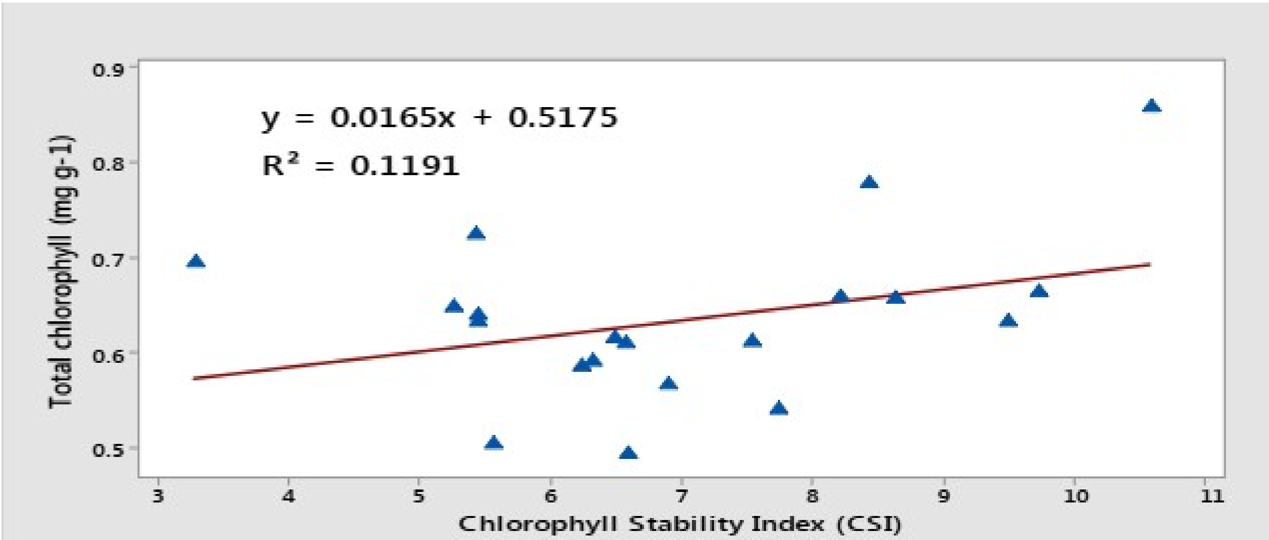

Figure 4**:** Relationships between Total chlorophyll and C.S.I reading

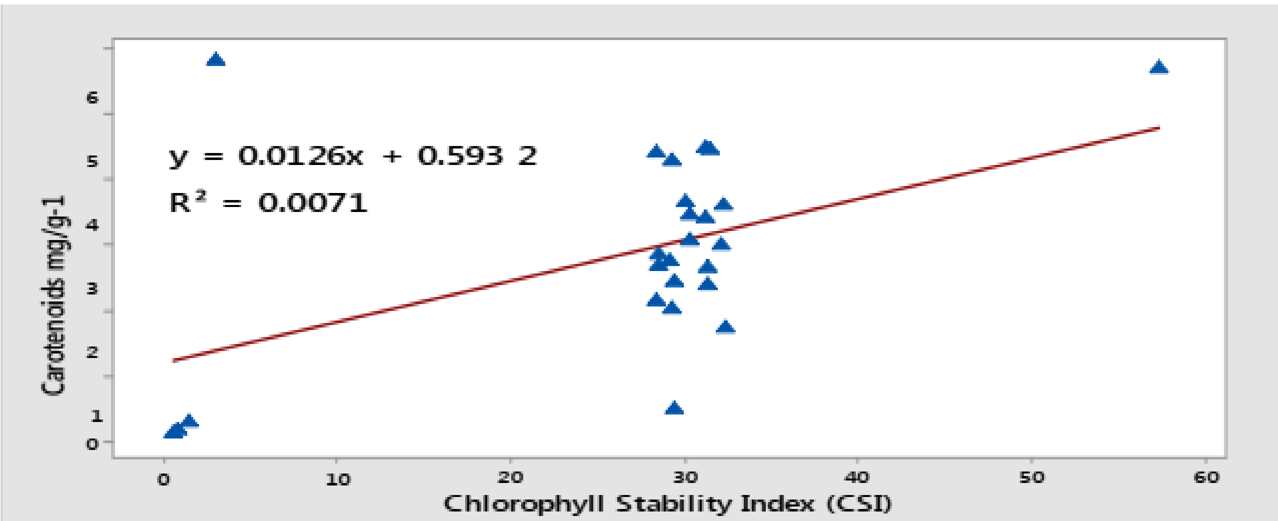

Figure 5: Relationships between Carotenoid's and C.S.I reading

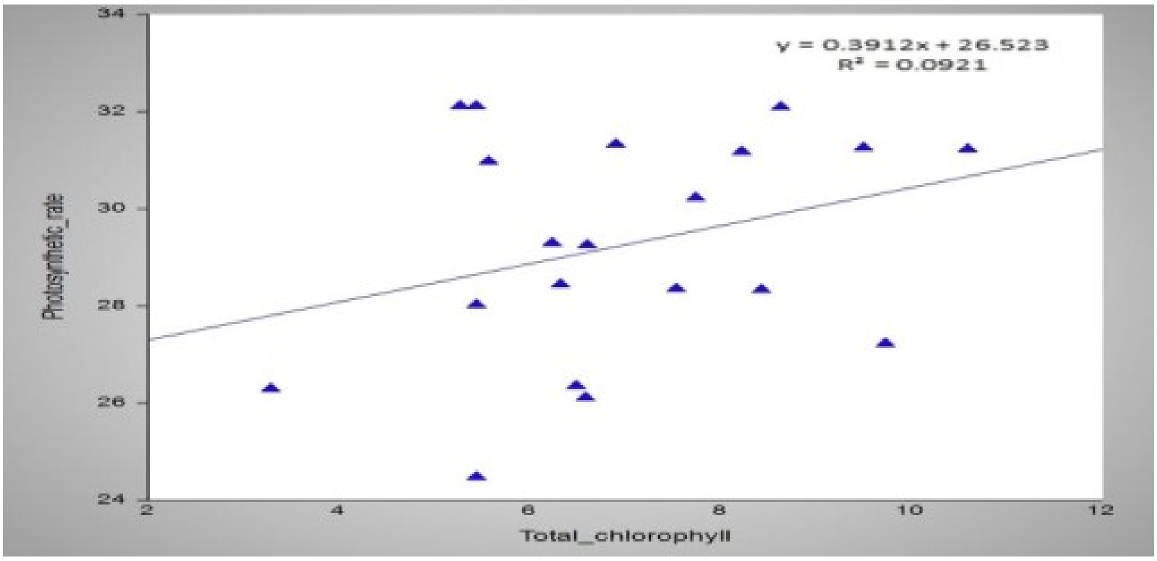

Figure 6: Relationships between Photosynthetic rate and Total chlorophyll

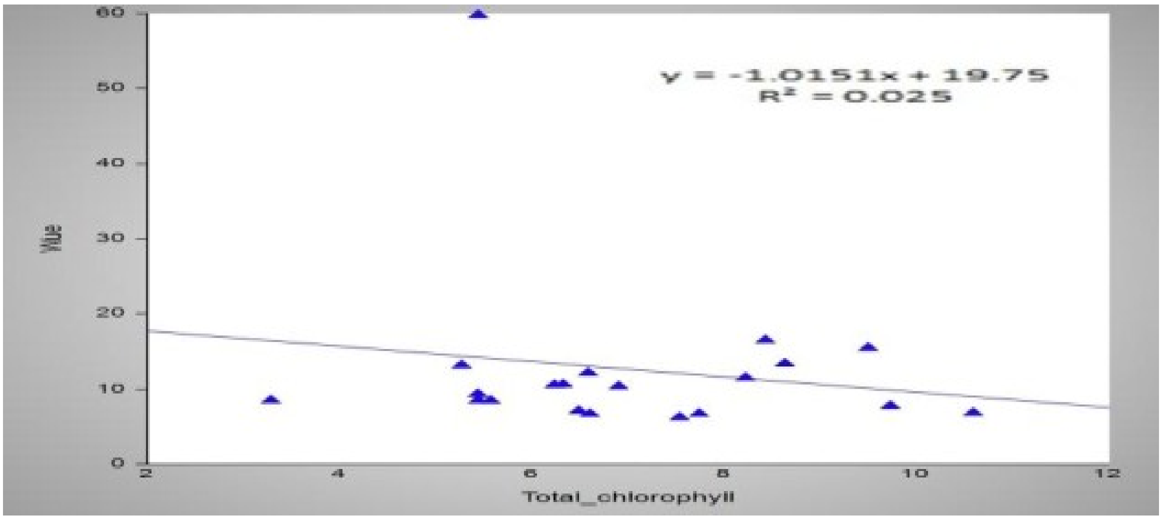

Figure 7**:** Relationships between Total chlorophyll vs water use efficiency (Wue)

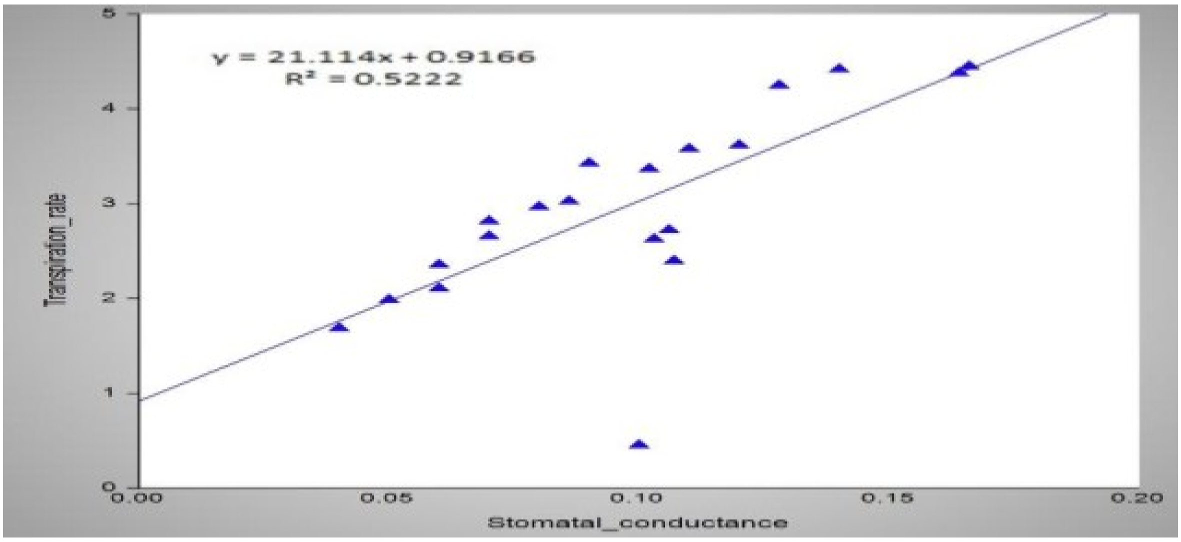

Figure 8**:** Relationships between Transpiration rate vs stomatal conductance

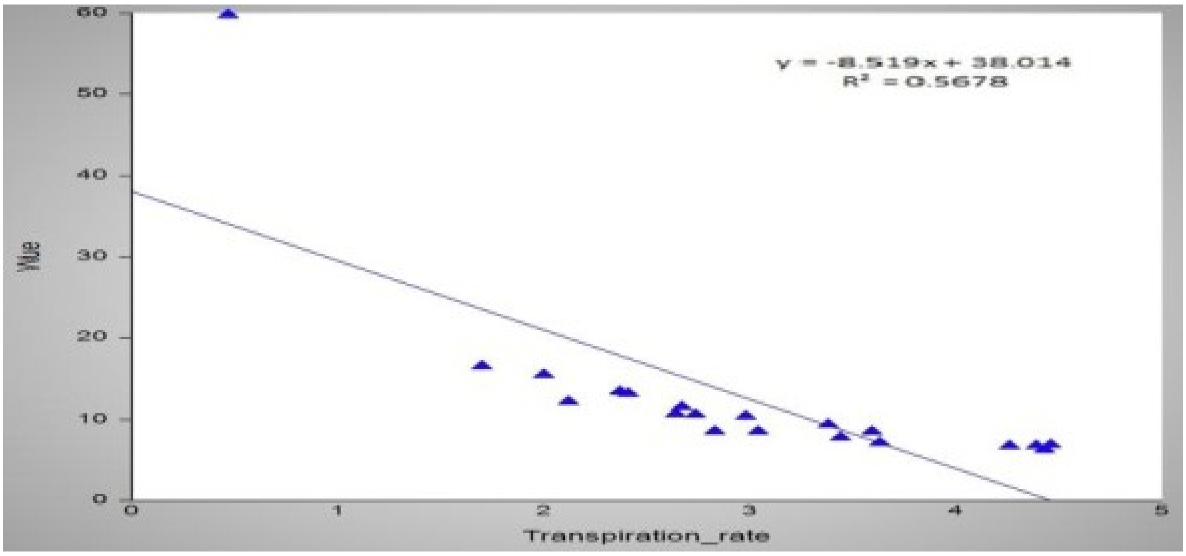

Figure 9: Relationships between Water use efficiency (WUE) vs transpiration rate

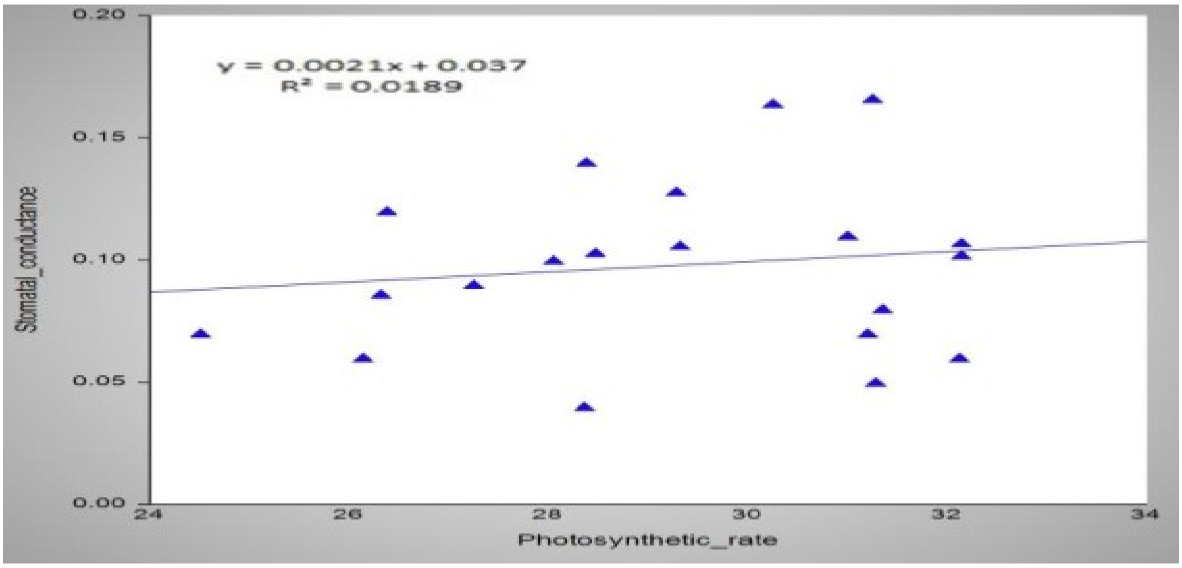

Figure 10**:** Relationships between Stomatal conductance vs photosynthetic rate

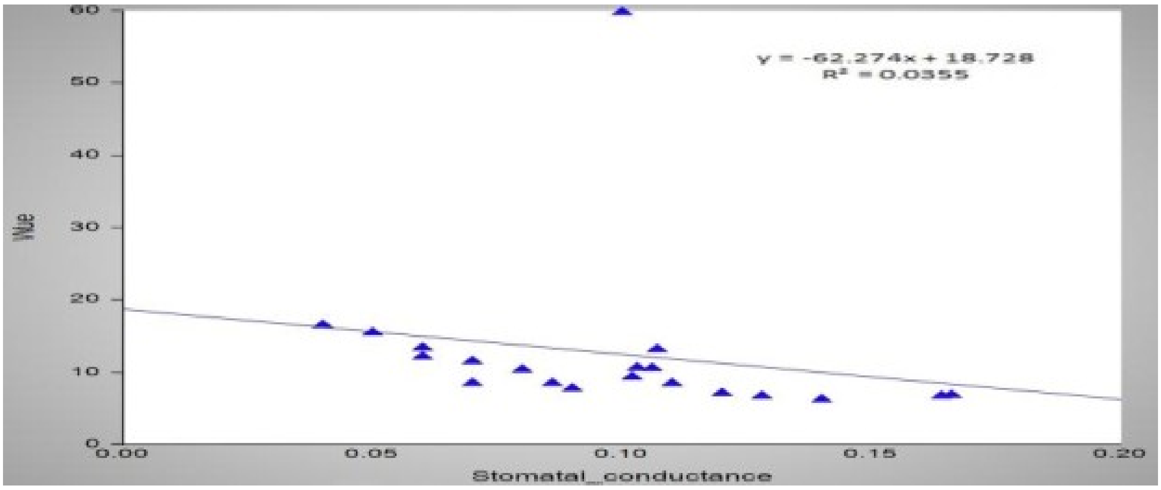

Figure 11: Relationships between Water use efficiency (WUE) vs stomatal conductance

CONCLUSION

The twenty different genotypes cultivated at experimental site showed the greatest growth. The larger production of chlorophyll *a*, *b*, CSI, photosynthetic rate, and carotenoids was observed. From the different chili genotypes, LCA-305 and LCA-424 could be selected as the highest mean yield per plant coupled with quality traits based on current study of bio-physical parameters, chlorophyll content, chlorophyll stability index (CSI) and carotenoids estimations.

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