Asian Journal of Plant Sciences

ISSN 1682-3974

Asian Journal of Plant Sciences 5 (2): 266-270, 2006
ISSN 1682-3974

Characteristics of Photosynthetic Behaviors and Chlorophyll Fluorescence in Different Vegetable Species

[1]Sharmin Khan, [2]Yuichi Yoshida and [1]Shahidul Islam
[1]Deaprtment of Agriculture, University of Arkansas, 1200 North University Drive, Mail Slot 4913, Pine Bluff, AR 71601, USA
[2]Faculty of Agriculture, Okayama University, Okayama, 700-8530, Japan

Abstract: This study investigated the variability in the various physiological characteristics of seven popular commercial vegetable seedlings such as cabbage, spinach, Chinese cabbage, eggplant cucumber, tomato and Chinese radish. The photosynthetic rate (Pn) was higher in cabbage seedlings followed by eggplant seedlings. Chinese cabbage and cabbage seedlings showed higher stomatal conductance (CS) than other vegetables studied. Cucumber seedlings had higher respiration rate followed by tomato, egg plant and Chinese radish. In the case of internal CO_2 concentration, all the species studied differ significantly. Chinese cabbage seedlings exhibited the highest transpiration rate (Tr) and Chinese radish had the lowest. There was little decrease in photochemical efficiency of PS II i.e., *F*v/*F*m value of chlorophyll fluorescence in all species, however cabbage and spinach seedling had the highest *F*v/*F*m value followed by cucumber, tomato and eggplant seedlings. Among all the physiological parameters, Pn was highly correlated with *F*v/*F*m value. The results may be useful in formulating efficient selection and breeding programs in improving desired quality characteristics of plant species.

Key words: Photosynthesis, chlorophyll fluorescence, vegetables, physiological functions

INTRODUCTION

Physiological characters such as photosynthesis (Pn), transpiration (Tr) and stomatol conductance (CS) affect growth and yield in crop plants. Photosynthesis ultimately controls crop productivity. Many factors interact to get quality seedlings of vegetables and one of the most important is Pn. It is now well established that, the photosynthetic characteristics varies many fold among species in normal sunlight. Photosynthesis at 1.0 cal cm^{-2} min^{-1} and 300 ppm CO_2 was shown to vary from 7 to 49 μg CO_2 dm^{-2} h^{-1}. Theoretical causes were analyzed by Rabinowitch (1951) his equation predict that the maximum Pn may be determined by chlorophyll content or the proportionality between absorbed quanta and Pn. Until now several authors supported the theory. Regarding this aspect (i) it is now well known that fluorescence emission provides a non-destructive probe to examine the photochemical events of Pn and (ii) chlorophyll fluorescence has the potential of providing valuable information on Pn.

Chlorophyll fluorescence analysis is a relatively new technology that in recent years has become one of the most powerful and widely used techniques available to plant physiologists and ecophysiologists. It is often used as a very sensitive and intrinsic probe of photosynthetic reactions (Papageorgiou, 1975) and it is increasingly applied in various fields of plant physiology (Smilie and Nott, 1979; Artus *et al*., 1996; Yamada *et al*., 1996; Meyer and Gently, 1998; Griffiths and Maxwell, 1999; Maxwell and Johnson, 2000). Recently, *F*v/*F*m (ratio of variable to maximum fluorescence-the quantum efficiency of open photosystem II centers) value of chlorophyll fluorescence has been using widely for the measurement of the stress conditions of crop plants (Genty *et al*., 1989; Somersalo and Krause, 1989, Sasaki and Oda, 1994). Maxwell and Johnson (2000) reported that the *F*v/*F*m value correlated linearly with the quantum of photosynthesis. The prime objectives of this study are (I) to evaluate the variation of different physiological process especially Pn, Tr, CS and chlorophyll fluorescence of different vegetable species and (ii) selection of physiologically active vegetable species for further studies on details of physiological mechanisms.

MATERIALS AND METHODS

Plant materials and cultural condition: Seedlings of seven vegetables were chosen to compare the characteristics of Pn and chlorophyll fluorescence.

Corresponding Author: Shahidul Islam, Ph.D., Department of Agriculture, University of Arkansas, 1200 North University Drive, Mail Slot 4913, Pine Bluff, Arkansas 71601, USA Tel: 870-575-7239 Fax: 870-575-4676

Table 1: List of the vegetable species used in this study

Common name	Scientific/Botanical name	Sowing date	Measuring date
Cabbage	*Brassica oleracea* L. Capitata	April 19	May 28
Spinach	*Spinacea oleracea* L.	April 21	May 30
Chinese cabbage	*Brassica rapa* L. Pekinensis	June 16	July 27
Eggplant	*Solanum melongena* L.	August 06	September 30
Cucumber	*Cucumis sativus* L.	August 06	September 22
Tomato	*Lycopersicon esculentum* Mill.	April 01	May 02
Chinese radish	*Raphanus sativus* L. var. *Longipinnatus*	June 16	July 25

Information's of the vegetable species used in the study is shown in Table 1. The experiment was conducted at the Department of Agroindustrial Sciences, Kagawa University, Japan during 1997. The seedlings of all the species were grown from seeds in black plastic tray having 128 cells filled with 3 peat and 1 rockwool media (v/v) in a vinyl house (25±3°C) under natural photoperiod. Cabbage (cv. Okina) and spinach (cv. Banchuh Paruku) seedlings were grown in April-May, Chinese cabbage (cv. Muso) in June-July, eggplants (cv. Senryo twogo), cucumber (cv. Sharp 1) in August-September, tomato (cv. Momotaro) in April-May and Chinese radish in June-July. Three seeds were sown in each cell and thinned to one seedling about 4 days after emergence. When the seedlings were about 15 days old they were transplanted to 12 cm diameter polyethylene pots filled with the same media. A 100 mL of modified Hoagland's nutrient solution (Khan and Yoshida, 1996) was supplied 3 times/week/seedling. When the seedlings developed approximately 7-8 leaves, 10 uniform plants of each species were selected and used for the measurements described later.

Determination of photosynthetic characteristics: Photosynthetic characteristics were measured as per the methods described by Khan and Yoshida (1996) using a LI-6200 portable Photosynthetic System (LI-COR, Inc., Lincoln, NE, USA). The measurements were done at room temperature (20-25°C), with 300-400 ppm CO_2 and under natural photoperiod. These measured values were linearly calibrated to the values at 350 ppm. The fourth leaf of each seedling was used for the measurement of the physiological characteristics.

Determination of chlorophyll fluorescence: The chlorophyll fluorescence measurements were analyzed as described by Genty *et al.* (1989) with slight modification. After finishing the measurement of photosynthetic characteristics those leaves were settled with black cuvettes for dark adaptation for 3-4 h. After the seedlings became adapted to darkness at room temperature, chlorophyll fluorescence was measured from photosystem II using actinic light intensity 300 μmol/m^2/s for 150 sec by a fluorometer (CF-1000, P. K. Morgan instrument, Sandoval, MA, USA). The center of the leaf was used for the measurement except for the midrib. Stress is measured as a ratio of *F*v (variable fluorescence) to *F*m (maximum fluorescence). *F*v was calculated as *F*m-*F*o (minimal fluorescence).

Data analysis: Data for the different parameters were analyzed by analysis of variance (ANOVA) procedure and the level of significance was calculated from the F value of ANOVA using the Excel Statistics 2000 program package for Windows (Social Information Service Co. Ltd, Tokyo, Japan). The means were separated at p = 0.05 by least significant test. The relationships among various physiological parameters were described with linear and quadratic correlation analysis using the above statistical program.

RESULTS AND DISCUSSION

For selection and comparative purposes among the seven vegetable species in relation to photosynthetic characteristics at 350 ppm and chlorophyll fluorescence (CF), the data collected during the experiment are presented in Fig. 1. These include photosynthetic rate (Pn), stomatal conductance (CS), stomatal resistance (RS), transpiration rate (Tr), internal CO_2 concentration and Fv/Fm values of chlorophyll fluorescence. All the parameters showed highly significant differences among the species studied. Among the seven species, the seedlings of cabbage had the maximum rate of Pn followed by eggplant. There were no significant difference among the other five species i.e., Chinese cabbage, cucumber and spinach. Chinese cabbage and cabbage seedlings showed higher CS followed by cucumber, Chinese radish, spinach, tomato and eggplant seedlings. Cucumber had the highest RS followed by eggplant, tomato and Chinese radish. There are conflicting reports as to the importance of RS and CS during leaf development. In sugar beat, no change was found in the number of stomata per unit leaf area over a week period (Brown and Rosenburg, 1970). In contrast several authors (Davis *et al.*, 1977; Davis and McCree, 1978; Maxwell and Johnson, 2000) reported that changes in these parameters due to environmental factors

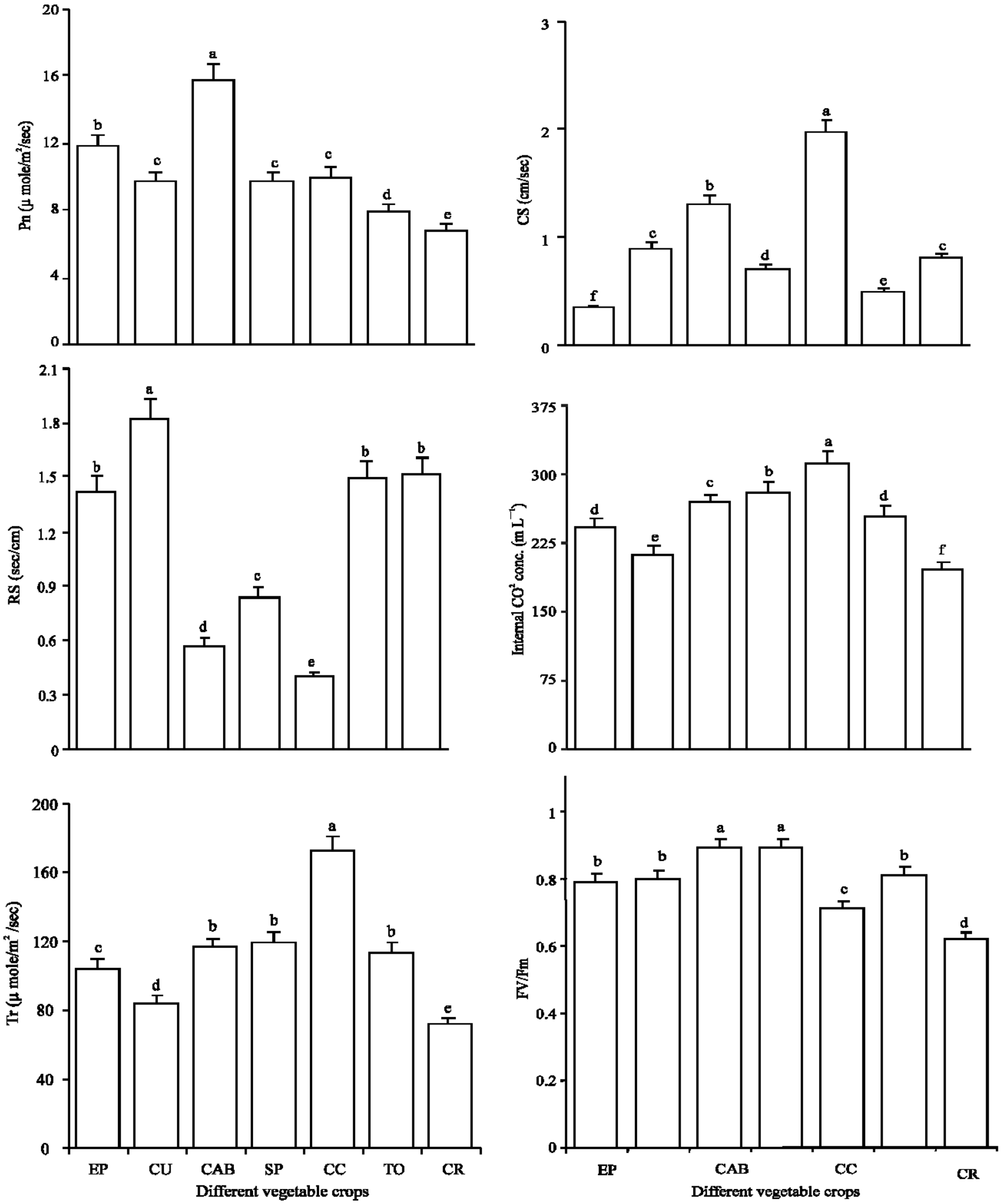

Fig. 1: Comparison in photosynthetic rate (Pn), stomatal conductance (CS), stomatal resistance (RS), internal CO_2 concentration, in transpiration rate (Tr) and *F*v/*F*m value of chlorophyll fluorescence in eggplant (EP), cucumber (CU), cabbage (CAB), spinach , (SP), Chinese cabbage (CC), Tomato (TO) and Chinese radish (CR) seedlings. Bars represent the standard error which, when absent, is concealed by the symbol

Table 2: Correlation coefficient (R^2) between physiological characteristics of the seven vegetable seedlings studied (n = 80)

Physiological Characters	Correlation Type	Internal CO_2	Stomatal Conductance	Transpiration rate	*Fv/Fm* value
Photosynthatic rate	Linear	0.010ns	0.005ns	0.005ns	0.232***
	Quadratic	0.010ns	0.018ns	0.021ns	0.232***
Internal CO_2	Linear		0.408***	0.492***	0.021ns
	Quadratic		0.497***	0.570***	0.021ns
Stomatal conductance	Linear			0.762***	0.192***
	Quadratic			0.809***	0.327***
Transpiration rate	Linear				0.081*
	Quadratic				0.142***

ns, *, **, ***: non significant, significant at 0.05, 0.01 and 0.001 level, respectively

are common in different other crop species. In case of the internal CO_2 concentration, Chinese cabbage showed highest rate followed by spinach. Chinese radish exhibited the lowest internal CO_2 concentration followed by cucumber. The transpiration rate (Tr) among the species also differed widely and Chinese cabbage seedlings had highest Tr rate followed by spinach, cabbage and tomato. The Chinese radish seedlings showed lowest rate of Tr followed by cucumber and eggplant. In general, where water availability limits crop growth, maximum productivity can be expected from species which use water in the most efficient manner. Efficiency depends on the relationship between Pn and Tr and increases with an increase in Pn/Tr (Downese, 1969; Khan and Yoshida, 1996).

Figure 1 also shows the relation of variable to maximum fluorescence (*F*v/*F*m) emitted from photosystem II (PS II). It may serve as a quantitative indicator of the efficiency of the photochemistry of PS II. Among the seven species, the seedlings of cabbage and spinach had the highest *F*v/*F*m value followed by cucumber, tomato and eggplant. The Chinese radish and Chinese cabbage seedlings showed lowest values. There was relatively little difference in the photochemical efficiency of PS II i.e., *F*v/*F*m value in all the species compared to other parameters studied. Table 2 shows the relationship among the physiological characters studied. Photosynthetic rate of the species had a highly significant positive relationship with only the *F*v/*F*m value of chlorophyll fluorescence. These data indicated that efficiency of photosynthetic activities was associated with *F*v/*F*m value and vise versa. Tr, CS and internal CO_2 were highly significantly correlated with each other. Stomatal conductance also showed significant association with Tr and internal CO_2 concentration. The findings of the results suggests that Tr depends on the opening and closing of the stomata. The differences in Pn have been associated with a number of different factors in different species, including stomatal and mesophyll resistance, RuDP carboxylase activityand mesophyll cell size (Evan, 1973; Schreiber *et al*., 1995), as well as chlorophyll content and chloroplast numbers (Ojima, 1974 Buttery and Buzzell, 1977; Schreiber *et al*., 1995). Using seven different vegetable species grown in the glasshouses and with Pn rate measured at room temperature, we have demonstrate a close association between Pn and *F*v/*F*m value of chlorophyll fluorescence. The cabbage seedlings had highest Pn rate which was associated with highest *F*v/*F*m value. Therefore the relation *F*v/*F*m can be used as characteristic of photosynthetical activity of phytoplankton. Since the measurements are non-intrusive, fast and reliable, these make chlorophyll fluorescence an attractive tool for physiological research and for breeding purposes.

Based on the results of the physiological characteristics namely performance of the photosynthetic rate and chlorophyll fluorescence of the vegetables species, cabbage, spinach and eggplant seedlings were chosen for further physiological and biochemical studies under different stress conditions. Furthermore, the results of the studies provide information on the seedling quality evaluation of vegetable species that may be helpful to plant breeder and plant physiologist.

REFERENCES

Artus, N.N., M. Uemura, P.L. Steponkus, S J. Gilmour, C. Lin and M.F. Thomashow, 1996. Constitutive expression of the cold-regulated Arabidopsis thaliana COR15a gene affects both chloroplast and protoplast freezing tolerance. Proc. Natl. Acad. Sci., 93: 13404-13409.

Brown, K.W. and N.J. Rosenburg, 1970. Influence of leaf age illumination and upper and lower surface differenceson stomatal resistance of sugar beet (*Beta vulgaris*) leaves. Agron. J., 62: 20-24.

Buttery, B.R. and R.I. Buzzell, 1977. The relationship between chlorophyll content and rate of photosynthesis in soybeans. Canadian J. Plant Sci., 57: 1-5.

Davis, S.D., C. Van and K.J. McCree, 1977. Effect of leaf aging upon stomatal resistance in bean plants. Crop Sci., 17: 640-645.

Davis, S.D. and K.J. McCree, 1978. Photosynthetic rate and diffusion conductance as a function of age of leaves of bean plant. Crop Sci., 18: 280-282.

Downes, R.W., 1969. Differences in transpiration rates between tropical and temperate grasses under controlled conditions. Plant., 88: 261-273.

Evans, L.T., 1973. The Effect of Light on Plant Growth, Development and Yield. In: Plant Response to Climatic Factors, (Slatyr, R.D. Ed.), UNESCO, Paris, pp: 21-35.

Genty, B., J.M. Briantas and N.R. Baker, 1989. The relationship between the quantum yield of photosynthetic electron transport and quenching of chlorophyll fluorescence. Biochem. Biophys. Acta, 990: 87-92.

Griffiths, H. and K. Maxwell, 1999. In memory of CS Pittendrigh: Photoprotective strategies in epiphytic bromeliads in relation to exposure within the forest canopy. Functional Ecol., 13: 15-23.

Khan, S. and Y. Yoshida, 1996. Photosynthetic behaviors and chlorophyll fluorescence of cabbage seedlings exposed to high temperature. J. Japan Soc. Hortic. Sci., 65: 649-650.

Krause, G.H. and E. Weis, 1991. Chlorophyll fluorescence and photosynthesis: The basics. Ann. Rev. Plant Physiol. Plant Mol. Biol., 42: 313-349.

Maxwell, K. and G.N. Johnson, 2000. Chlorophyll fluorescence-a practical guide. J. Expt. Bol., 51: 659-668.

Meyer, S. and B. Genty, 1998. Mapping intercellular CO_2 mole fraction in *Rosa rubiginosa* leaves fed with abscisic acid by using chlorophyll fluorescence imaging. Plant Physiol., 116: 947-957.

Ojima, M., 1974. Improvement of photosynthetic capacity in soybean variety. Japan Agric. Res. Quart., 8: 6-12.

Papageorgiou, G., 1975. Chlorophyll fluorescence: An intrinsic prob of photosynthesis. In: Bioenergetics of photosynthesis, (Govindjee Ed.), Academic press, New York, 319-337.

Robinowitch, E.I., 1951. Photosynthesis and Related Process. Interscience Pub. Inc., New York, USA.

Sasaki, H.L.K. and M. Oda, 1994. Factors effecting the measurement of chlorophyll a fluorescence in cucumber leaves. Japan Agril. Res. Quart., 28: 242-246.

Schreiber, U., W. Bilger and C. Neubauer, 1995. Chlorophyll Fluorescence as a Nonintrusive Indicator of Rapid Assessment of *in vivo* Photosynthesis. In: Ecophysiology of Photosynthesis, (Schultze E.O. and Caldwell, M.M., Eds), Springer Verlag, New York, pp: 48-70.

Smile, R.M. and R. Nott, 1979. Heat injury in leaves of alpine, temperate and tropical plants. Australian J. Plant Physiol., 6: 135-141.

Somersalo, S. and G.H. Krause, 1989. Photoinhibition at chilling temperature. Plant., 177: 409-416.

Yamada, M., T. Hidaka and H. Fukamachi, 1996. Heat tolerance in leaves of tropical fruit crops as measured by chlorophyll fluorescence. Sci. Hortic., 67: 39-48.