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Photosynthetic Response of Korean Ginseng under Saline Condition

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ABSTRACT: This study was conducted to investigate the effect of the salinity on growth, inorganic ion content, and photosynthetic rate (P_N) in Korean ginseng (*Panax ginseng* C. A. Meyer) with complex fertilizer (CF) and NaCl concentrations. The salinity was applied to plant using NaCl and CF, and controlled an EC as 0.0, 1.0, 2.0 and 3.0 dS m^{-1}. The salinity treated three times at 35, 42 and 49 d after transplanting. The leaf area in different electrical conductivity (EC) decreased only the higher NaCl 1.0 dS m^{-1}. The root growth increased with CF and especially, it was two times higher at 3.0 dS m^{-1} than that of control. But the root growth sharply decreased with NaCl compared to CF. The light saturation point of Korean ginseng was around 100 μmol m^{-2}s^{-1} photosynthetically active radiation (PAR), and P_N increased as CF increased but decreased with NaCl, especially at the late growth stage. The Na^+ content in Korean ginseng increased sharply with NaCl.

***Keywords*:** korean ginseng, NaCl, complex fertilizer, photosynthetic rate, Na^+

The salt damages on Korean ginseng were reduction of shoot emergence and growth, etiolating and early defoliation of leaves, reduction of root growth, and etc. The emergency ratio decreases as the salt concentration increases, and decomposition of rhizome increases remarkably by salt. The emergence ratio of two to three years old Korean ginseng has negative correlation with the soil EC, nitrate and ammonium concentration (Kim *et al.*, 1985; Mok *et al.*, 1998). The growth of Korean ginseng was possible at 3~30% of natural sun light and the most suitable light intensity was 2000~4000 lux (Kuribayashi *et al.*, 1971). The maximum photosynthesis occurred at the 1000 lux and the light interception efficiency was around 10~15% (Jo *et al.*, 1986).

Also, the light absorption rate of the Korean ginseng was the most effective at the range of 400~700 nm (Kazutoshi, 1973), and the most suitable temperature was about 20 (Nam, 1992). Seemann (1985) reported about the reduction of the photosynthesis due to the salt stress with the stomatal response and CO_2 fixing ability. With the stomatal response, Seemann & Sharkey (1985) stated that stomatal closing, increasing ABA content in cell, and declining turgor pressure were occurred, and in the CO_2 fixing ability, causing the growth reduction due to high concentration of RuBP carboxylase, decline of RuBP regeneration ability due to high CO_2 concentration, high ion content of chloroplast and cellular, and reduction of enzyme activity. Also, Brugneli & Lauteri (1991) compared the photosynthesis of cotton (salt tolerant crop) and kidney bean (salt sensitive crop) and stated that the cause of photosynthesis reduction under the salt stress primarily appeared by the stomatal closing, and decreased the stomatal conductivity and carbon distribution in cell. Also Brugneli & Lauteri (1991) stated that the dry weight and carbon distribution had a strong relationship with the Pi/Pa rate (Ratio of intercellular and atmospheric CO_2 partial pressure).

Robinson *et al.* (1983) reported the result of the photosynthesis of spinach, which was salt tolerant, treated with the 200 mM NaCl, the chlorophyll a showed little effect but the stomatal conductivity decreased about 70% compared to the control. Rowson *et al.* (1988) also stated that K^+ concentration decreased, but Na^+ and Cl concentration increased, and the photosynthesis decreased by decreased stomatal conductivity and leaf area, and effective distribution of ions in cell reduced accumulation of Na^+ and Cl in chloroplast.

Therefore, this research carried out to investigate responses on the photosynthesis of Korean ginseng in different soil EC by CF and NaCl.

MATERIALS AND METHODS

Plant and growth condition

The experiment was carried out in fields with semi shade ground condition shaded with blue white polyethylene. The samples were two year old Korean ginseng roots (Korean ginseng seedling, 0.8~0.9 g) sterilized by Diethofencarb 500 times solution. The transplant of the Korean ginseng seedling was conducted with the planting density of 8 cm × 8 cm on April 3, 2000.

The salinity was applied to sample using NaCl and CF (13 g N, 18 g P_2O_5, 0.1 g MnO and 0.15 g CuO) and controlled an

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EC as 0.0, 1.0, 2.0 and 3.0 dS m^{-1}. The salinity treated three times at 35, 42 and 49 d after transplanting, and the amount of irrigated solutions was flushed by overhead flooding method to secure leaching in the root system.

Photosynthetic rate

Photosynthetic rate (P_N) and stomatal conductivity (g_s) were measured with the largest leaf using a portable photosynthesis system (Li 6400, LI COR, USA) on June 1, July 1, July 29 and August 13. Five replications of measurement per each plant were conducted. The light radiation was arranged in the range of 0 to 500 μmol m^{-2} s^{-1} PAR (photosynthetically activity radiation) and response time was set about 160 seconds. The CO_2 concentration was 330~370 ppm and the flow rate of the air was 500 *l* min^{-1}.

Na^+ concentration

Inorganic concentration of Korean ginseng harvested at June 5 and August 7 was measured from leaves, stems and roots. Samples, dried at 80°C for 7 days, were weighted then grounded into a fine powder. The samples then were measured with 1 g correctly and extracted for a day in 1 N HCl. Na^+ was measured at 589.6 nm using an atomic absorption spectrophotometer (Shimazu AA 6800, Japan).

RESULTS AND DISCUSSION

Fig. 1 showed the leaf area and root dry matter of Korean ginseng harvested at June 5 and August 7. The leaf area at June 5 with CF showed no change among different concentrations, but which of Korean ginseng at August 7 increased with CF compared to that of non treatment and showed the largest leaf area at the EC 1.0 dS m^{-1}. The leaf area of NaCl stressed plant, however, showed reducing tendency with increasing EC level. Reduction of the leaf area against NaCl at August 7 was much higher than that of at June 5. These results were opposite result reported that if EC of soils was high, the stem length and the stem diameter decreased greatly from leaf's base parts due to low leaf expansion (Nam 1992). However, the stem length and the leaf area of Korean ginseng sharply reduced with increased NaCl concentration. This showed similar results reported by Mok *et al.* (1998) who stated that the salt damage of Korean ginseng varied with different kinds of salts and different concentration of salt, and especially the Na^+ or Cl caused the growth reduction. And, this research considered that the reason of the growth reduction of Korean ginseng by salt stress appeared at the late growth stage was caused to the salt which continuously affected soil and incomplete exclusion of salt from soil, and thus, the salt must be excluded as early as possible in Korean ginseng fields.

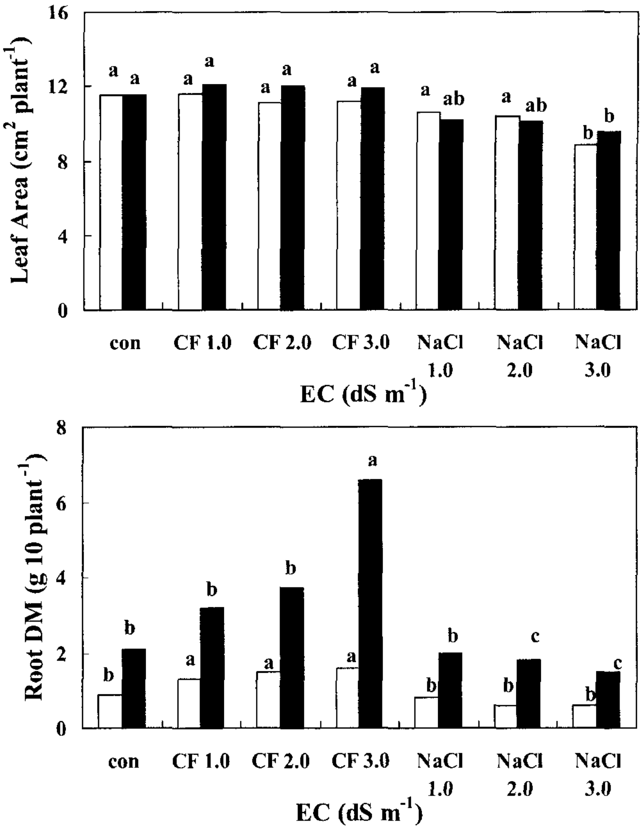

Fig. 1. Leaf area and root dry matter of 2 years old ginseng as affected by controlled salinity with CF and NaCl treatments at June 5(□) and August 7(■). Means followed by same letters are significantly ($p<0.05$) different according to DMRT. CF; complete fertilizer.

On the other hand, the root dry matter increased at higher CF concentration but decreased at higher EC by NaCl. Also, the reduction of growth at late growth stage (August 7) was greater than that of early growth stage (June 5). This result considered to be that NaCl permeated continuously from the surface layer to the rooting zone of Korean ginseng field such that the NaCl stress was higher at the late growth stage.

Also, the NaCl concentration that influenced the roots growth was more than 1.0 dS m^{-1}. Munns & Termeat (1986) and Shalhevet *et al.* (1995) reported that the leaf growth was more sensitive to salinity than root growth and the salinity generally reduced shoot growth more than root growth. However, this was opposite result that salt stress more affected the growth reduction of root than that of shoot (Kim *et al.*, 1985).

P_N of the Korean ginseng with CF and NaCl in different light intensities was shown in Fig. 2. P_N was measured on June 1, July 1, July 29, and August 13, respectively. In P_N in

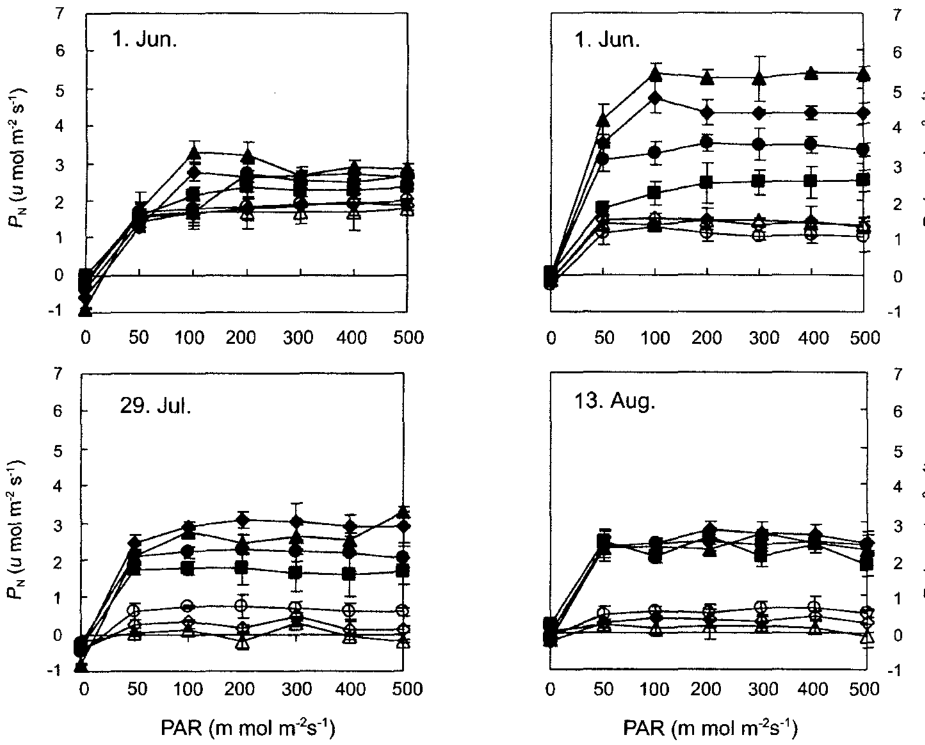

Fig. 2. Photosynthetic rate (P_N) to PAR of 2 years old Korean ginseng as affected by controlled salinity with CF and NaCl treatments. ■control ● EC 1.0 (CF) ◆ EC 2.0 (CF) ▲ EC 3.0 (CF) ○ EC 1.0 (NaCl) ◇ EC 2.0 (NaCl) △ EC 3.0 (NaCl). Means are shown±SE (n=5).

different growth stage with various light intensities, Korean ginseng with CF showed higher P_N than that of the control at June 1, but NaCl showed lower P_N compared to the control. Also, the P_N increased at higher light intensity, and the light saturation point was shown at 100 μmol m^{-2} s^{-1} PAR. The P_N measured at July 1 and July 29 showed similar with that of the P_N at June 1. At this growth stage (July 1 and July 29), however, the P_N against NaCl was even less than that of CF or control, and showed no P_N at August 13. Meanwhile, the light saturation point of non stressed Korean ginseng was shown around at 100 μmol m^{-2} s^{-1} PAR regardless the growth stages, and the highest P_N was at July 1, and then it was gradually decreased and reached to the lowest at August 13.

Grushitskii & Novichova (1975) reported that the light saturation point of ginseng such as Korean and Manchuria ginseng was obtained at 0.8% of CO_2 and 22 klux, and Jo & Won (1984) also reported that the light saturation point of Korean ginseng was obtained at 10 klux with the Korean ginseng leaves under the sunshine and at 4 klux with the Korean ginseng leaves under the shade. Also, Lee (1997) reported that the light saturation point was found at 18.4% of nature light in their light intercepting effects experiment of Korean ginseng. Also, Hyun & Yoo (1996) stated that ginseng leaves adapted to 100 μmol m^{-2}s^{-1} PAR had a peak response similar to that of 200 μmol m^{-2} s^{-1} PAR at 18°C, but in above PAR, it was not increase.

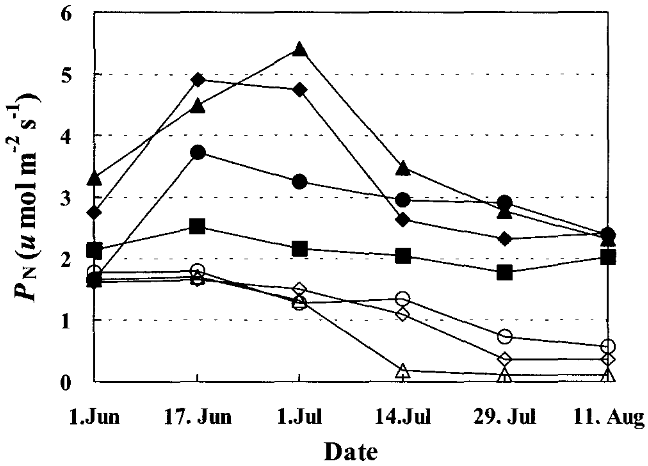

Fig. 3. P_N of 2 years old Korean ginseng as affected by controlled salinity with CF and NaCl treatments at 100 μmol m^{-2}s^{-1} PAR. ■ control ● EC 1.0 (CF) ◆ EC 2.0 (CF) ▲ EC 3.0 (CF) ○EC 1.0 (NaCl) ◇EC 2.0 (NaCl) △EC 3.0 (NaCl).

The P_N of Korean ginseng with CF and NaCl showed clear effect at vigorous leaf development stage, and showed small effect at late growth stage. Therefore, this research considered that the effect of salinity on the photosynthesis of the Korean ginseng could be known clearly at vigorous growth stage. Also, the light saturation point of 2 years old Korean ginseng was thought to be at the light intensity in the

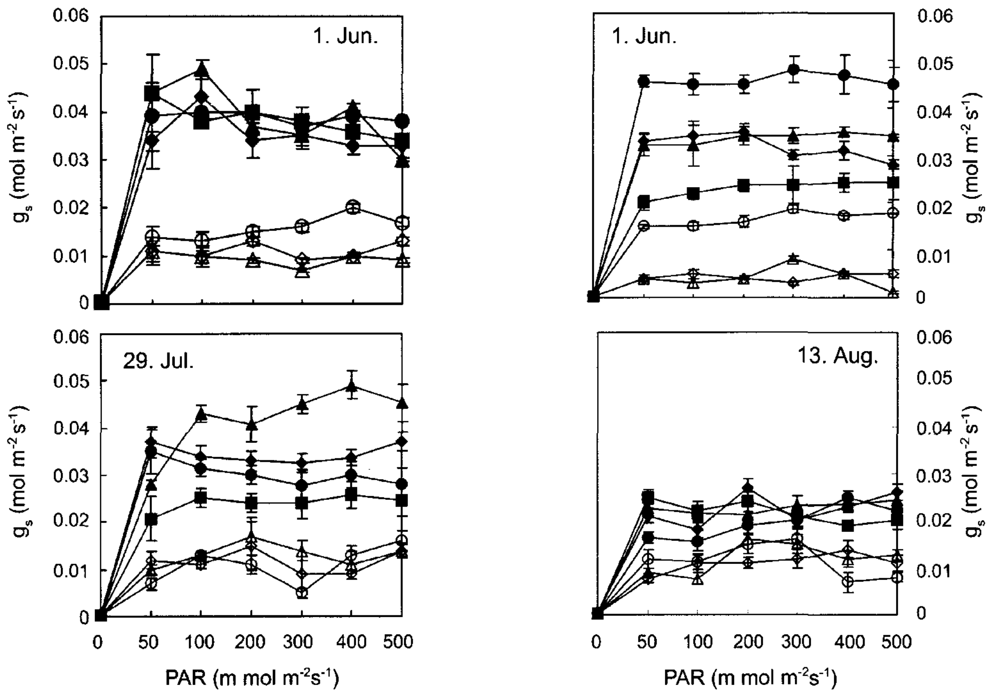

Fig. 4. Stomatal conductivity (g_s) to PAR of 2 years old Korean ginseng as affected by controlled salinity with CF and NaCl treatments. ■control ● EC 1.0 (CF) ◆ EC 2.0 (CF) ▲ EC 3.0 (CF) ○ EC 1.0 (NaCl) ◇ EC 2.0 (NaCl) △ EC 3.0 (NaCl). Means are shown±SE (n=5).

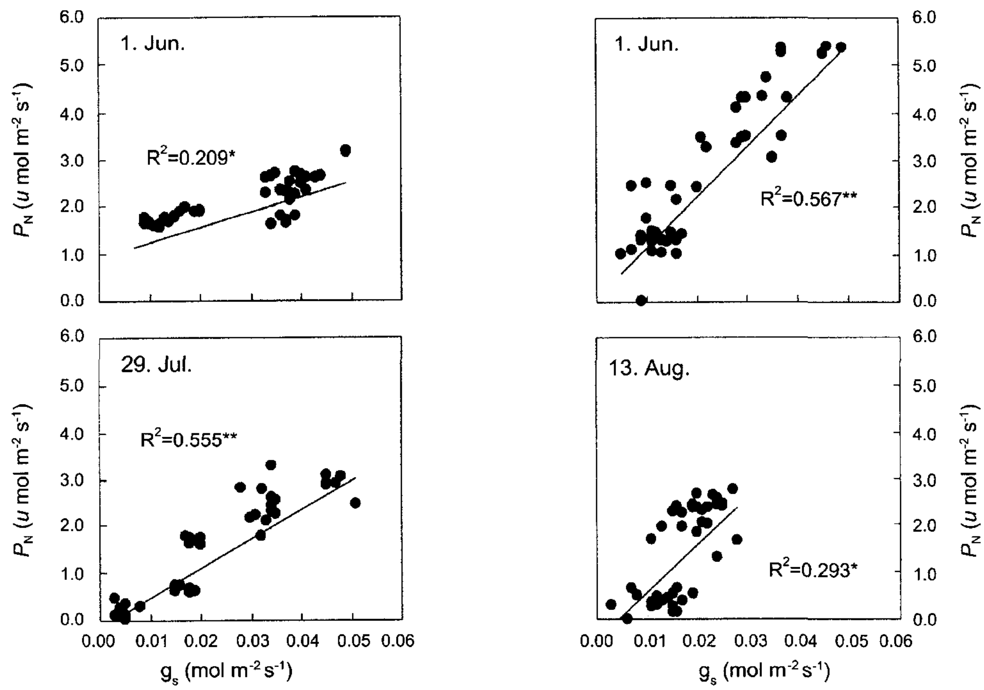

Fig. 5. Relationship between P_N and g_s in 2 years old Korean ginseng leaves as affected by controlled salinity with CF and NaCl treatments. *, ** Denotes significant at the 0.05 and 0.01 levels of probability, respectively.

range of 50~100 μmol $m^{-2} s^{-1}$ PAR.

At the 100 μmol $m^{-2}s^{-1}$ PAR, the P_N, although the control did not show a great difference at different growth stage, treated with CF increased greatly compared to control, especially, it was significantly increased at June 17 and July 14. But, the P_N with NaCl decreased greatly compared to control, and it begun to decrease remarkably compared to control from June 17, especially, and then showed no P_N from

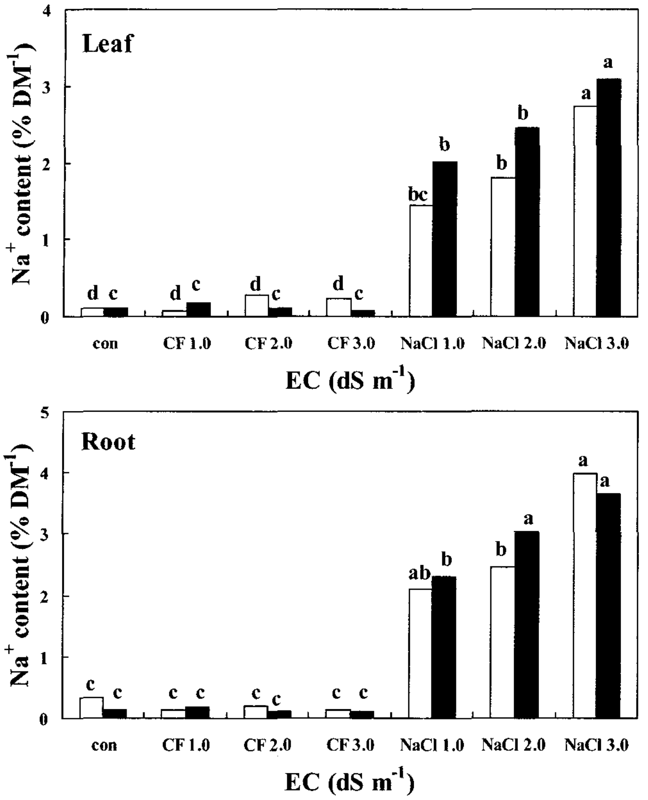

Fig. 6. Stomatal conductivity (g_s) to PAR of 2 years old Korean ginseng at June 5 (□) and August 7 (■) as affected by controlled salinity with CF and NaCl treatments. Means followed by the same letters are not significantly different according to DMRT (P<0.05).

July 29. These results indicated the CF increased the P_N of Korean ginseng, and kept high photosynthesis until the late growth stages (Fig. 3).

The g_s of the Korean ginseng by CF and NaCl was shown in Fig. 4. g_s was also measured at June 1, July 1, July 29 and August 13, respectively. g_s by CF were higher than control at July 1 and 29, but at August 13 was no fixed tendency. At June 1, g_s was not significant with CF compared to that of control but g_s with CF showed higher than that of control at July 1 and July 29. 1.0 EC dS m^{-1} of CF was the highest g_s at July 1. g_s by CF was the highest at 1.0 EC dS m^{-1}. But g_s reduced with NaCl concentration at all stages except for August 13. There was a significant correlation between P_N and g_s at all Korean ginseng growth stages (Fig. 5).

On the other hand, the Na^+ content in leaves and stems at June 5 increased at higher CF concentration, the Na^+ content also increased in roots. The Na^+ content increased rapidly at higher NaCl concentration compared to the control. Specially, in roots, there was the highest increase of Na^+ content among other parts of Korean ginseng. Also, at August 7, the Na^+ content with NaCl increased sharply at higher NaCl concentration (Fig. 6).

REFERENCES

Brugneli, E. and M. Lauteri. 1991. Effects of salinity on stomatal conductance, photosynthetic capacity and carbon isotope discrimination of salt tolerant (*Gossppium hirsutum* L.) and salt sensitive (*Phaselus vulgaris* L.) C_3 non halophytes. Plant Physiol. 95 : 628-635.

Grushitskii, I. V. and L. M. Novichova. 1975. Photosynthesis in ginseng. Bot. 2h. 42 : 751.

Hyun, D. Y. and N. H. Yoo. 1996. Effect of leaf temperature on light response and respiration in *Panax ginseng* C. A. Meyer. Korean J. Crop Sci. 41 : 725-728.

Jo, J. S. and J. Y. Won. 1984. Studies on the photosynthesis of Korean ginseng. I. Sesonal changes in photosynthetic ability young aged Korean ginseng (*Panax ginseng* C.A. Mayer). Korean J. Crop Sci. 29 : 98-101.

Jo, J. S., J. Y. Won, and S. K. Mok. 1986. Studies on the photosynthesis of Korean ginseng. III. Effect of light transparent rate of shading on the photosynthetic ability of Korean ginseng plant (*Panax ginseng* C. A. Mayer). Korean J. Crop Sci. 31 : 408- 415.

Kazutoshi, Y. and K. Bak. 1973. The dependence of photosynthesis in several vegetables on light quality. J. Agri. Meteorol. Japan. 29 : 17-23.

Kim, M. S., S. K. Hong, and T. S. Lee. 1985. The control method for physiological injury in Korean ginseng. Ginseng research Reports. Korea Ginseng and Tobacco Research Institute. 787-857.

Kim, J. M., S. S. Lee, S. R. Cheon, and S. K. Cheon. 1982. Relationship between environmental conditions and the growth of ginseng plant in field. Korean J. Crop Sci. 27 : 94-98.

Kuribayashi, T., Okamura, M., and Ohashi. 1971. Effects of light intensity and soil pH on growth (in Japanse). Syoyakugaku Zasshi. 25 : 110-116.

Lee, S. S. 1997. Growth characteristics by shading rates in *Panax ginseng* C. A. Meyer. Korean J. Crop Sci. 42 : 292-298.

Mok, S. K., Y. S. Ban, T. S. Lee, and S. K. Chun. 1998. Study on the alternated cultivation for quality in Korean ginseng. Ginseng research Reports. Korea Ginseng and Tobacco Research Institute. 17-39.

Munns, R. and A. Termeat. 1986. Whole plant response to salinity. Aust. J. Plant Physiol. 13 : 143-160.

Nam, K. Y. 1992. Effects of soil salt concentration on the growth and yields of Korean ginseng plant (*Panax ginseng* C. A. Mayer). Ph. D Thesis in Chungnam National University Daejeon in Korea.

Rowson, H. M., Richards, R. A., and R. Munns. 1988. An examination of selection criteria for salt tolerance in wheat, barley, and triticale genetypes. Aust. J. Agric. Res. 39 : 759-772.

Robinson, S. P., Downton, W. J., and Millhouse. J. A. 1983. Photosynthesis and ion content of leaves and isolated chloroplast of salt stressed spinach. Plant Physiol. 73 : 238-242.

Seemann, J. R. and T. D. Sharkey. 1986. Salinity and nitrogen on photosynthesis ribulose 1,5 bisphosphate carboxylase and metabolitic pool sizes in *Phaselus vulgaris* L. Plant Physiol. 82 : 555-560.

Shalhevet, J., M. G. Huck, and B. P. Schroeder. 1995. Root and shoot growth responses to salinity in maize and soybean. Agron. J. 87 : 512-516.