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Phosphate Fertilizer Influences Growth and Photosynthesis of Pepper Seedlings

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인산시비가 고추 플러그묘의 생장과 광합성에 미치는 영향

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Abstract. Seedlings of 'Nokgwang' and 'Kwari' green pepper were cultured in 32-cell plug trays in TK_2 medium to find out optimal concentrations of phosphate. Seedling growth of both 'Nokgwang' and 'Kwari' cultivars was affected by phosphate strength. Applying P fertilizer to the plug system caused a marked increase in plant height and leaf area at 1.0 phosphate strength. On the other hand, total dry weight increased with increasing phosphate strength. Higher chlorophyll content was observed in 'Nokgwang' than 'Kwari' in all treatments. Phosphate strength greater than 0.5 gave similar chlorophyll content. Photosynthetic rate was higher for plants fertilized with 1.0 strength for 'Nokgwang' and 0.5 strength for 'Kwari' than the other treatments. Higher concentrations of phosphate reduced photosynthesis in both cultivars. With 'Nokgwang' increasing concentration of phosphate up to 1.0 strength resulted in increase in stomatal conductance and transpiration rate.

Key words : phosphorus, photosynthesis, chlorophyll, stomatal conductance

Introduction

Plant growth is related to internal nutrient concentrations. The identification of critical nutrient concentrations, that is the minimum concentration required for near-maximum growth or yield, has been the subject of much study by plant nutritionists. Many nutrients are multifunctional in plants, yet the determination of critical concentrations remains largely empirical with little attempt to relate critical concentrations to specific functions. Only a few studies have focused on the relationship between photosynthetic rate and plant productivity or growth (Zelitch, 1982). Measurement of gas exchange for whole plants have also been compared to measurements of plant height and the number of lateral shoots using clones of *Ficus benjamina* (Ottosen et al., 1989). Therefore, the objective of this study was to examine the relationship between phosphate fertilizer and photosynthetic rate and growth rate of green pepper seedlings.

Materials and Methods

Field experiments were conducted at the Miryang National University Horticulture Research field in Miryang. In all experiments, seeds of 'Nokgwang' and 'Kwari' green peppers were sown in 32-cell plug trays containing a peat-based TK_2 medium on 4 April, 1997. Plants were grown in a glasshouse under natural conditions. Phosphate was applied at 0, 0.5, 1.0, 1.5, and 2.0 strength of Yamajaki's solution for peppers. The experimental design in the field trial was 2×4 factorial in a randomized complete block with three replications. The factors included cultivars and phosphate concentrations.

For growth analysis, plants were excavated at 15 days intervals during seedling growth after bedding. Fresh tissue was rinsed in tap water and dried at 70°C in a forced-air oven for 2 days. Individual plant shoot, leaf, and root dry weight were measured.

The Minolta SPAD 502 meters was used to obtain chlorophyll content on the third leaf from the top of plant. Net photosynthesis, stomatal conductance, and transpiration rate were obtained using the portable photosynthesis system (Model 6400, LI-COR, Lincoln, Nebraska, USA). Mean relative humidity, temperature, and CO_2 concentration in leaf chamber during measurements were 65±7%, 28±2°C, and 360±28 mg·L^{-1}, respectively. Three plants per treatment were randomly selected on 60 days after bedding. Data analysis for mean comparisons was made using Duncan's multiple range test at p=0.05 and 0.01.

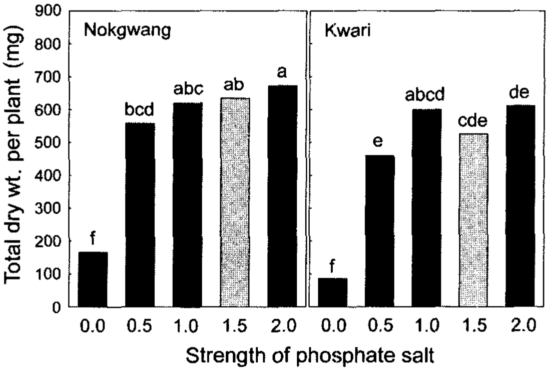

Fig. 3. Effect of phosphate strength in the nutrient solution on plant dry weight of green pepper (cv. 'Nokgwang' and 'Kwari') in plug system. Mean separation within treatments by DMRT at 5% level.

Results and Discussion

Pepper seedling growth were affected by phosphate strength in both 'Nokgwang' and 'Kwari' cultivars (Figs. 1, 2, 3). Applying P fertilizer to the plug system caused a marked increase in plant height and leaf area of plants at control (1.0 phosphate strength), but lower or higher concentrations decreased plant height and leaf area. On the other hand, total dry weight increased with increasing phosphate strength.

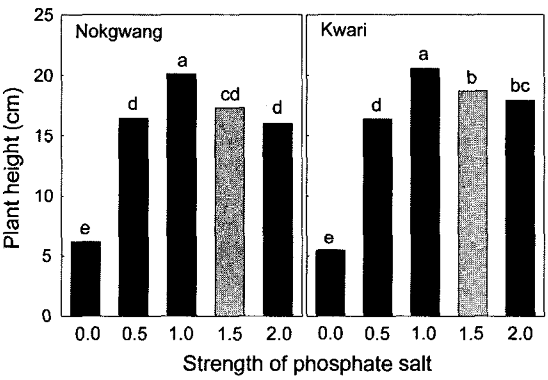

Fig. 1. Effect of phosphate strength in the nutrient solution on plant height of green pepper (cv. 'Nokgwang' and 'Kwari') in plug system. Mean separation within treatments by DMRT at 5% level.

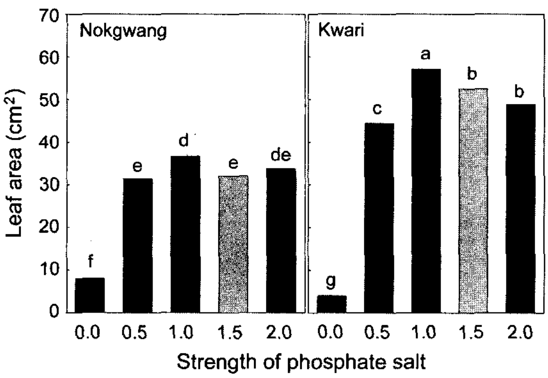

Fig 2. Effect of phosphate strength in the nutrient solution on leaf area of green pepper (cv. 'Nokgwang' and 'Kwari') in plug system. Mean separation within treatments by DMRT at 5% level.

Because P efficiency ratio is equivalent to the reciprocal of P concentrations in plants, differences in P efficiency ratio between germplasm corresponded to differences in plants. Phosphate efficiency ratio declined with increasing P concentration, which indicates decline in the internal utilization of P to produce dry mass. The term 'nutrient efficiency' has been used widely as a measure of the capacity of a plant to require and utilize nutrients for production of crops. Identification of germplasm or species with differing nutrient efficiencies generally includes investigation of potential morphological, physiological, and biological mechanisms involved. The mechanisms have been well reviewed (Caradus, 1990). However, it is often difficult to separate cause from effect when evaluating potential mechanisms of efficient nutrient uptake and utilization. Considering these factors, it is suggested that the close relationship between root and shoot activities may mean that differences in yield or nutrient accumulation by plants, resulting from differences in metabolic activity.

Fig. 4 showed the effect of different phosphate strength on chlorophyll content. Higher chlorophyll contents were

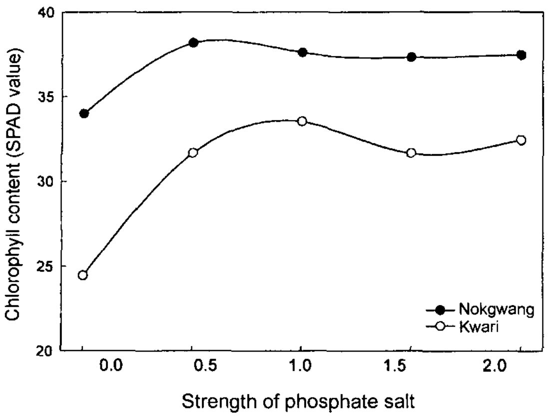

Fig. 4. Effect of phosphate strength in the nutrient solution on chlorophyll content (SPAD value) of green pepper (cv. 'Nokgwang' and 'Kwari') in plug system.

observed with 'Nokgwang' than 'Kwari' in all treatments. Chlorophyll contents in P strength greater than 0.5 were similar, while chlorophyll content in 0 strength decreased significanly.

Photosynthesis per unit leaf area increased to a maximum during leaf ontogeny, and thereafter it declined, while photosynthesis expressed per chlorophyll content was constant or declined over this period of time (Austin et al., 1982; Treharne et al., 1968). In cocoa leaves the same pattern of development of both photosynthesis per leaf area and per chlorophyll content was reported (Barker and Hardwick, 1973). Similar results were obtained for photosynthesis during leaf development on both dry matter and chlorophyll basis (Valanne et al., 1981). From these results, we suggest that it is very important to find out optimal conditions for large chlorophyll number and size.

Net photosynthesis was higher for plants fertilized with 1.0 strength P for 'Nokgwang' and between 0.5 and 1.5 strength P for 'Kwari'. However, higher concentrations reduced photosynthesis in all cultivars. Pepper seedlings of 'Kwari' obtained with 1.0 strength P showed lower stomatal conductance and transpiration rate. With 'Nokgwang' increasing concentration of phosphate up to 1.0 strength resulted in increase in stomatal conductance and transpiration rate.

Mineral nutrition affects the formation of the photosynthesis apparatus, determines the development of leaf area and structure and the chemical composition of

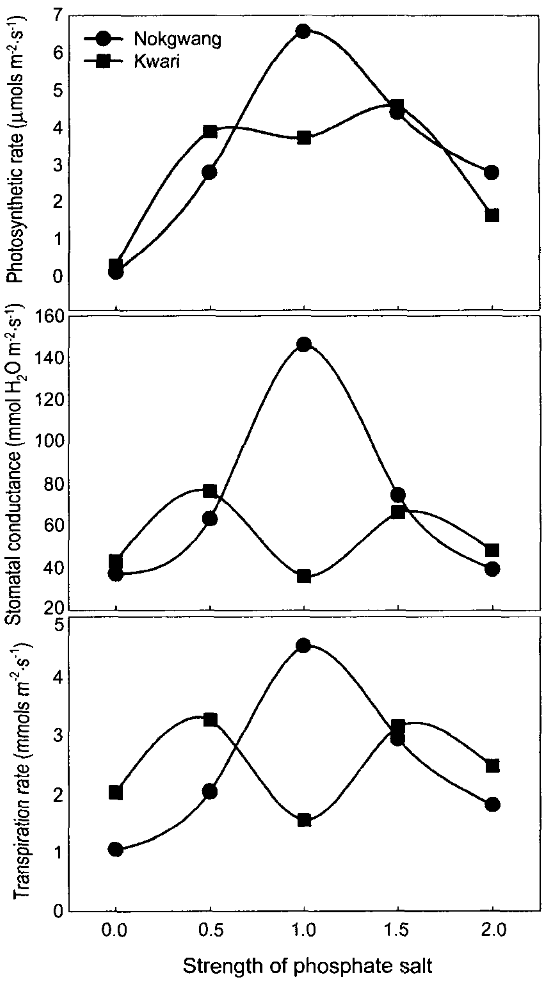

Fig. 5. Effect of phosphate strength in the nutrient solution on photosynthetic rate, stomatal conductance, and transpiration rate of green pepper (cv. 'Nokgwang' and 'Kwari') in plug system.

leaves, especially that of the thylakoid membrane. It affects conductances for CO_2 transfer and membrane permeability. Mineral elements are not only necessary components for the synthesis of structural compounds of the cells, but they also directly participate in individual photosynthesis reactions. The general ontogenetic pattern of photosynthesis was found in different plant types (Hopkinson, 1964). The rate of CO_2 uptake is decreased by phosphorus or other mineral deficiency (Dale, 1972). The supply of inorganic phosphorus plays a key role in the Calvin cycle and in the transport of metabolites and assimilates. Phosphate deficiency results in accumulation of assimilates (sucrose and starch) in the chloroplasts and depresses photosynthesis even under otherwise favourable conditions. Considering all factors in photosynthesis, biochemical effects on photosynthesis and respiration result from the fact that the minerals either are incorporated in enzymes and pigments, or participate directly as activators in the process of photosynthesis. Therefore, it is very important to find optimal concentrations of phosphate.

적 요

풋고추 플러그 육묘시에 인산의 최적 시비농도를 구명하기 위하여 32구 플러그 트레이에 TK2를 채워서 종자를 파종한 다음 인산을 농도별로 처리하여 식물체의 생육과 광합성에 미치는 효과를 조사하였다. '녹광'과 '꽈리' 두 품종의 생장은 표준 농도인 1.0배로 처리하였을 때에 엽면적과 초장의 생장이 가장 촉진되었으며, 1.5배 이상의 농도에서는 농도가 높을수록 생육이 억제되었다. 반면 식물체의 총 건물중은 인산의 농도가 증가할수록 무거웠다. 엽록소의 함량은 '꽈리' 보다 '녹광'이 더 높았는데, 0.5배 이상의 농도에서는 농도간의 차이가 없었다. 광합성율은 '녹광'의 경우에는 1.0배, '꽈리'의 경우에는 0.5배의 농도로 시비하였을 때에 가장 높았으며, 식물체의 생장과 마찬가지로 고 농도의 인산시비는 두 품종 모두 광합성을 억제시켰다. 기공전도도와 수분증발율은 '녹광'의 경우에는 1.0배까지 인산의 농도를 높일수록 증가하였으나, 1.5배 이상의 고농도에서는 감소하였다.

주제어 : 인산, 광합성, 엽록소, 기공전도도

Literature cited

1. Austin, R.B., C.L. Morgan, M.A. Ford, and S.G. Bhagwat. 1982. Flag leaf photosynthesis of *Triticum aestivum* and related diploid and tetraploid species. Ann. Bot. 49:177-189.
2. Barker, N.R. and K. Hardwick. 1973. Biochemical and physiological aspects of photosynthetic units in cocoa (*Theobroma cacoa*). III. Development of chlorophyll and photosynthetic acitivty. New Phytol. 72:1315-1324.
3. Caradus, J.R. 1990. Mechanisms improving nutrient use by crop and herbage legumes. In: Crops as enhancers of nutrient use. V.C. Baligar and R.R. Duncan. (eds.) pp. 253-209. Academic Press, Inc., San Diego, CA.
4. Dale, J.E. 1972. Growth and photosynthesis in the first leaf of barley. The effect of time application of nitrogen. Ann. Bot. 36:967-979.
5. Hopkinson, J.M. 1964. Studies on the expansion of the leaf surface. IV. The carbon and phosphorus economy of a leaf. J. Exp. Bot. 15:125-137.
6. Ottosen, C.O., A. Anderson, and O.V. Christensen. 1989. Clonal variation of net photosynthetic rate of *Ficus benzamina* L. in relation to height growth. Gartenbauwissenschaft 54:208-211.
7. Treharne, K.J., J.P. Cooper, and T.H. Taylor. 1968. Growth response of orchard-grass (*Dactylis glomerata* L.) to different light and temperature environments. II. Leaf age and photosynthetic activity. Crop Sci. 8:441-445.
8. Valanne, N., T. Valanne, H. Niemi, and E.M. Aro. 1981. The development of the photosynthetic apparatus during leaf opening in silver birth (*Betula pendula Roth.*). In: Photosynthesis. Vol. V. The development of the photosynthetic apparatus during leaf opening in silver birch (*Betula pendula* Roth.). G. Akoyunoglou. (ed.) pp. 397-406. Balaban Int. Sci. Serv., Philadelphia.
9. Zelitch, I. 1982. The close relationship between net photosynthesis and crop yield. BioScience 32:796-802.