Korean J. Ecol., 21(4):329~335, 1998

Effects of Light and Nitrogen on the Growth of Pokeberry

Park, Bum-Jin Kee-Ryong Choi* and Yong-Mok Park

Department of Biology, Chongju University, Chongju, 360-764, Korea

*Department of Biological Science, University of Ulsan**

미국자리공의 생장에 미치는 광과 질소의 영향

박범진 · 최기룡* · 박용목

청주대학 이공대학 생물학과, 울산대학교 자연대 생물학과*

ABSTRACT

The growth of *Phytolacca americana* L. grown under three light regimes at three nutrient concentrations was analyzed. The effect of shading treatment on plant growth was greater than that of nutrient treatment. Plant dry mass increased more than 5-fold during 21 days under 33 % and 100 % irradiances, whereas that was strongly reduced under 8 % irradiance. Net assimilation rate decreased with plant growth irrespective of light and nutrient treatments, though the highest net assimilation rate was shown under 100 % irradiance. Under 33 % irradiance leaf area in plants supplied with nutrient solution increased to such extent as to compensate reduction in net assimilation rate, which maintains almost identical growth rate with that under 100 % irradiance. The relationship between total plant nitrogen and leaf nitrogen content was dependent on the growth irradiance. Moreover, leaf nitrogen and specific leaf weight were also changed depending on the light regimes. The synchronical change on leaf nitrogen content and specific leaf weight is highly adaptable characteristics to light and nutrient conditions.

Based on these findings, it is suggested that the adaptive characteristics of Pokeberry plant to light and nutrient conditions may contribute to rapid extension of Pokeberry habitat in Korea recently.

Key words: Habitat extension, Leaf nitrogen content, Plant nitrogen, Pokeberry, Specific leaf weight.

INTRODUCTION

Pokeberry (*Phytolacca americana* L.) commonly grows on roadsides, and farm lands (Bailey 1935, Vose 1957) and its fruit is an important food source for song birds in the United States (Martin *et al.* 1951). In Korea, roots of Pokeberry have been used as a folk medicine in the treatment of edema and rheumatism (Heo 1613, Yu *et al.* 1433) and Pokeberry plant has been cultivated even in agricultural field. In addition, the components of Pokeberry plant have been isolated and tested for pharmacological use (Lee *et al.* 1982, Woo and Kang 1974, Woo and Kang 1975).

In contrast with pharmacological usefulness, in Korea, Pokeberry plant has been treated as a plant destroying ecosystem, even indicator of environmental pollution, because the habitat of Pokeberry plant was rapidly extended with increase of environmental pollution into industrial area, in which local vegetation has been destroyed by environmental pollution (DongA-Ilbo 1993). Thus, the habitat extension phenomenon of Pokeberry plants gave Korean a great deal of anxiety several years ago. However, this phenomenon has not been scientifically explained as yet. Consequently, it is strongly required to carry out scientific study on the ecological characteristics of Pokeberry plants.

The objectives of this study are to investigate ecological characteristics of Pokeberry plant under the light and nutrient regimes, and to give basic data on ecology of Pokeberry plant as a necessary first step to solve the problem of vegetation destruction by Pokeberry in Korea.

MATERIAL AND METHODS

In October 1995, seeds of Pokeberry collected from the communities of *Phytolacca americana* at Yochondong in the center of chemical industry complex of Ulsan City, one of the representative industrial areas in Korea. After stratification, seeds were germinated in Petri dishes in a green house. On July 14, 1996, at the 3～4 leaf stage, one seedling was transplanted into each plastic pot (9-cm diameter, 22 cm high) filled with sand originated from the Miho stream neighboring on Chongju City located approximately 100 km south of Seoul. The total nitrogen content in soil was 3.97 mg nitrogen per g dried-sand. A week after transplantation, pots were arranged with sufficient space to avoid mutual shading in a green house and were watered daily to the drip point throughout the experiment. Each pot was given 60 ml of nutrient solution every 3 days until the start of treatment. The composition of nutrient solution was prepared as described by Park (Park 1992). Two hundred and sixteen pots used in the experiment were divided into nine groups according to the combination of nutrient (no treatment, given a standard solution and given two-fold strength solution of standard) and irradiance levels (8 %, 33 % and 100 % natural daylight). The nylon net was used for reduction of light intensity. Pots treated with nutrient solution were additionally given 60 ml of nutrient solution every 4 days throughout the experiment. During the experiment maximum and minimum temperatures changed from 25℃ to 45℃ and 19℃ to 25℃, respectively. Sampling was conducted at 7-day intervals. The dry weights of leaves, stems and roots were determined after oven-drying at 80℃ for 48 h. Leaf area was measured with a leaf area meter (AAM-8, Hayashi Denkou, Japan). Nitrogen content was determined by nitrogen analyzer (VS-KT-P, Mitamura Riken Kogyo, Japan).

RESULTS AND DISCUSSION

Fig. 1 shows the changes of dry mass according to light and nutrient levels. The effect of shading treatment on plant growth was greater than that of nutrient treatment. This suggests that light conditions may be the main factor limiting the growth of Pokeberry plants. Under 100 % and 33 % irradiances plant dry mass increased more than 5-fold during 21 days and between the two light regimes there was only little difference in plant growth (Fig. 1). On the other hand, plant dry mass under 8 % irradiance was strongly reduced irrespective of nutrient treatments (Fig. 1). Growth analysis was conducted with the changes of plant dry weight (Fig. 2). Growth rate (GR) was analyzed into product of net assimilation rate (NAR) and leaf area (LA).

$$\frac{dM}{dt} = \frac{1}{L} \cdot \frac{dM}{dt} \times L$$

where M stands for plant dry weight, L for leaf area, and t for time.

From the changes of plant dry weight GR was computed and NAR was calculated from GR and LA. LA was taken as average from the data of leaf area between the two sampling dates on the assumption that leaf area grows exponentially. Under 100 %

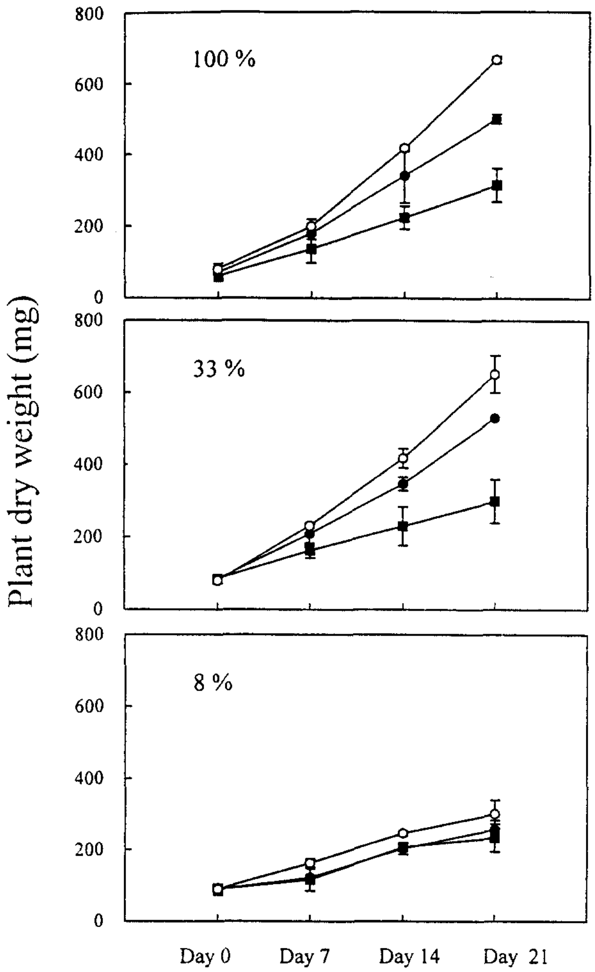

Fig. 1. Changes of plant dry weight of *Phytolacca americana* grown under three growth irradiances at three nutrient conditions. Symbols refer to control plant(■), plants given standard nutrient solution(●) and two-fold strength nutrient solution(○). Vertical bars indicate standard errors(n=6).

irradiance GR showed a rapid increase for 14 days, followed by a slight increase (Fig. 2). GR under 33 % irradiance was similar to that under 100 % irradiance, though a slightly lower value in plants supplied with standard nutrient solution was shown at the early stage of experiment (Fig. 2). Under 8 % irradiance GR showed more or less constant value (about 11.0 mg day^{-1}), which was lower than those under 100 % and 33 % irradiances. NAR was reduced with plant growth irrespective of light and nutrient treatments, though the highest NAR was shown under 100 % irradiance (Fig. 2). In contrast with NAR there was a significant difference in leaf area growth among treatments. LAs in plants supplied with nutrient solution under 33 % irradiance and in plant given two-fold strength nutrient solution under 8 % increased markedly in comparison with plants shown a slight increase in LA under 100 % irradiance (Fig. 2). The increase growth of LA in plants given nutrient solution under 33 % irradiance compensated reduction in NAR and in turn maintained GR highly (Fig. 2). Under 8 % irradiance, however, GR was not compensated by increase of LA due to a marked reduction in NARs compared with those under other light regimes. In contrast with plant dry weight, the difference in plant nitrogen content among light regimes was small (Fig. 3). The matter productivity of a unit amount of nitrogen taken up affects plant growth and even local plant distribution (Hirose 1975, Park 1992). Really, more than 50 % of leaf nitrogen content (LNC) is derived from RuBPcarboxylase (RuBPCase) which is the first carboxylating enzyme in the process of photosynthesis (Medina 1971). Thus, there is a linear relationship between photosynthetic capacity of leaves and leaf nitrogen content (Sage and Pearcy 1987). Leaf nitrogen content as a function of total plant nitrogen was changed with light regimes, which indicates a different allocation of nitrogen to leaves depending on light conditions (Fig. 4). This result is supported by the hypothesis that leaf nitrogen depending on light conditions is distributed to maximize carbon gain for a whole canopy (Field 1983). Really, the distribution of leaf nitrogen content was highly correlated with relative photon flux density in the canopy (Hirose 1986, Terashima and Evans 1988). There was a negative correlation between leaf nitrogen content and specific leaf weight, and the relationship between them was changed with light regimes (Fig. 5). The results from Figs. 4 and 5 indicated that leaf nitrogen content and specific leaf weight of Pokeberry plants can be synchronically changed with light conditions, which is highly adaptable characteristics to

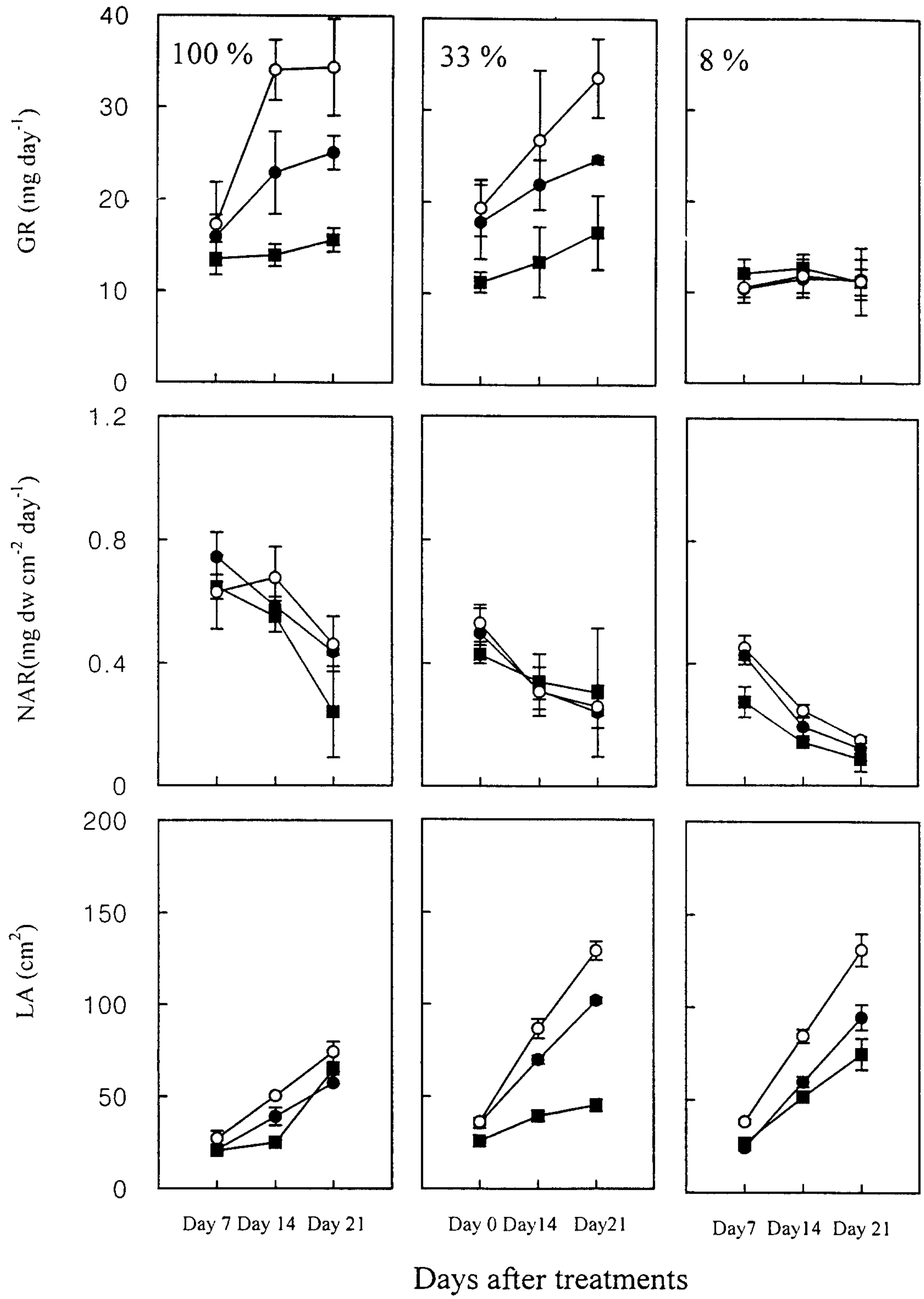

Fig. 2. Growth analysis of *Phytolacca americana* grown under three growth irradiances at three nutrient conditions. Symbols refer to control plant(■), plants given standard nutrient solution(●) and two-fold strength nutrient solution(○). Vertical bars indicate standard errors (n=6).

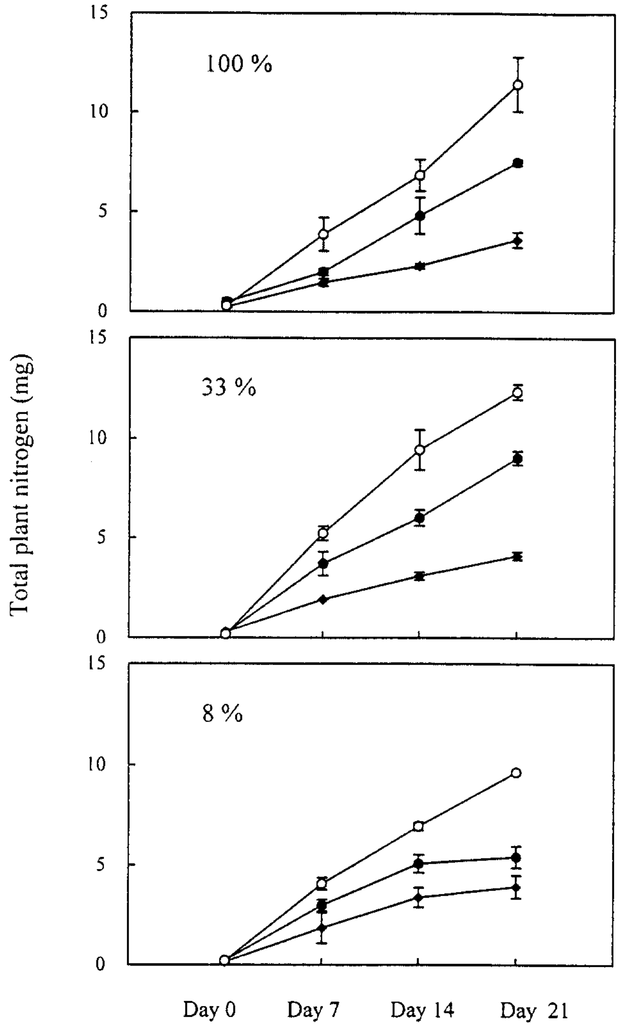

Fig. 3. Changes of total plant nitrogen of *Phytolacca americana* grown under three growth irradiances at three nutrient conditions. Symbols refer to control plant(■), plants given standard nutrient solution(●) and two-fold strength nutrient solution(○). Vertical bars indicate standard errors(n=6).

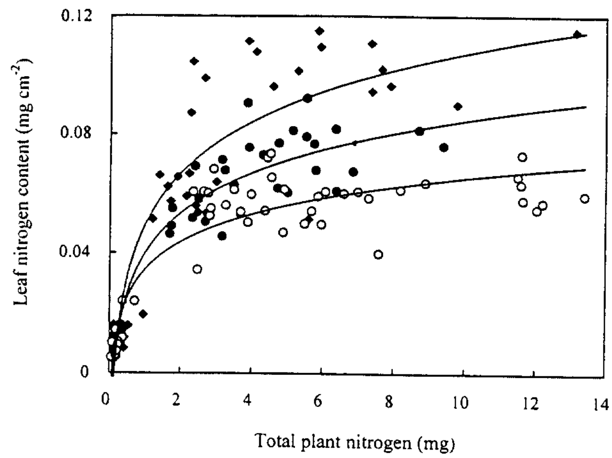

Fig. 4. Relationship between leaf nitrogen content per leaf area and total plant nitrogen. Symbols refer to 100%(◆), 33%(●) and 8%(○) irradiances.

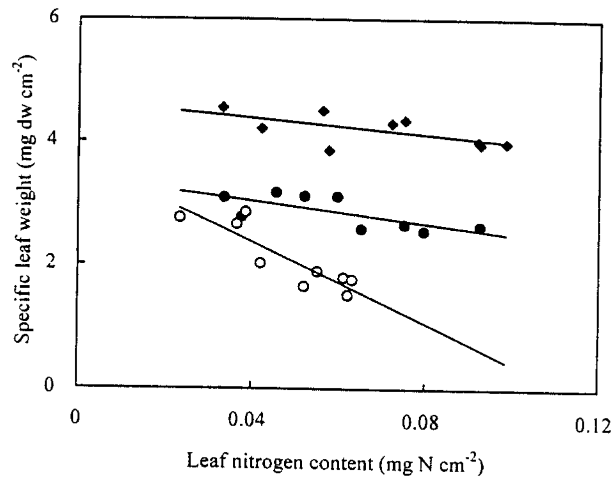

Fig. 5. Relationship between specific leaf weight and leaf nitrogen content per leaf area. Symbols refer to 100%(◆), 33%(●) and 8%(○) irradiances. Each point of symbols was plotted with the mean of six replicates.

light environments. In result, the difference in specific leaf weight (SLW) according to light regimes differently contributed to NAR (Fig. 6), which was responsible for the difference in GR among treatments. This plasticity shown in LNC and SLW may enables Pokeberry to inhabit various environmental conditions. From the data measured at about 100 places in which Pokeberry plant was distributed, Park *et al.* (1997) suggested that Pokeberry plants need more than 10 % natural daylight to inhabit in the field. Generally, Pokeberry plant is well known as species occurring in early stages of succession in America. We confirmed this fact from the results obtained here and newly found another interesting fact that the growth of Pokeberry plant can be retarded in nitrogen-deficient soil, even under 33 % daylight conditions. This result suggests that the

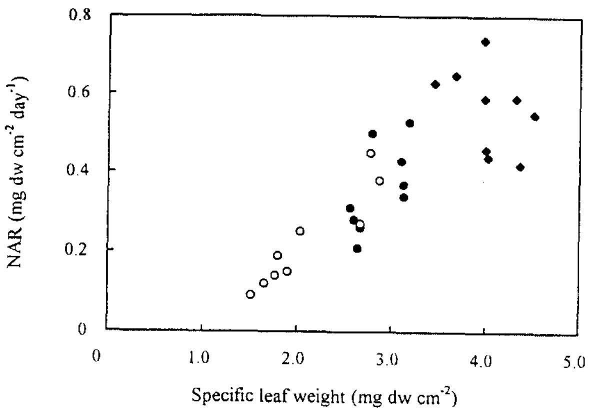

Fig. 6. Relationship between net assimilation rate (NAR) and specific leaf weight. Symbols refer to 100%(◆), 33%(●) and 8%(○) irradiances.

growth of Pokeberry plant may be also affected by nutrient conditions in soil.

Taking these conditions into account, it is evident that Pokeberry plant needs a sunny space and/or fertile soil as habitat. This indicates that Pokeberry plant is able to inhabit everywhere if the light regime is good and nutrient regime is appropriate for leaf growth. Consequently, it is possible for Pokeberry plants to invade everywhere including industrial area and even forest as the structure of closed canopy was destroyed by environmental pollution. It is concluded that the main factor responsible for rapid extension of Pokeberry habitat in Korea may be vegetation destruction by environmental pollution and by development for human beings.

적 요

최근 급격한 분포확대로 논란이 되고 있는 미국자리공의 생태적 특성을 규명하고 분포확대의 기작을 밝히는 기초적 정보를 얻기 위하여 생장에 있어서 광과 질소의 영향을 조사하였다. 광조건과 영양조건을 9가지로 조합하여 생장 시킨 결과, 미국자리공의 생장은 영양조건보다 광조건에 더욱 크게 영향을 받아 상대조도 8%의 조건하에서는 영양조건에 관계없이 현저한 생장 저하를 나타내었다. 그러나 상대조도 33%의 광 조건하에서는 영양처리한 식물체는 대조구와 비슷한 생장을 나타내었다. 이것은 33 % 처리구에서 잎의 면적 생장이 현저하게 증가하여 낮아진 순동화률을 보완하였기 때문으로 밝혀졌다. 또한 미국자리공은 광조건에 따라 식물체 질소량에 대한 잎의 질소농도를 조절하고, 같은 엽면적당 잎의 질소량에서도 광조건에 따라 specific leaf weight를 조절함으로써 폭 넓은 환경에서 생육할 수 있는 가능성을 보였다.

ACKNOWLEDGEMENT

This work was supported by a grant from the Korea Science and Engineering Foundation, No. 951-0505-030-2.

We thank Yong-Sam Park and Myung-Ho Kim for their helpful assistance.

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(Received July 10, 1998)