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Effects of fertilizer
on the amphicarpic traits of
Persicaria thunbergii

시비가 고마리 이종과 형성 특성에 미치는 영향

2015년 8월

서울대학교 대학원

과학교육과 생물전공

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Abstract

Effects of fertilizer on the amphicarpic traits of *Persicaria thunbergii*

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This study was performed to investigate the effects of fertilizer on the amphicarpic traits of *Persicaria thunbergii* in a mesocosm experiment. Three fertilizer levels were applied for different lengths of time: no fertilization, fertilization at eight-week intervals, and at four-week intervals. I compared the RGR and biomass allocation of seedlings from aerial seeds (SA) and subterranean seeds (SS) then investigated the flowering time and the seed production traits of *P. thunbergii* according to fertilizer levels. The results showed that RGR, biomass allocation and total biomass were not different between SS and SA at all levels. For the results of

flowering time, aerial flowering started earlier than subterranean flowering unlike with other amphicarpic plants. This indicates that the productive strategy of *P. thunbergii* differs from other amphicarpic plants. Subterranean seed allocation and the number of subterranean seeds were stable regardless of fertilizer levels whereas aerial seed allocation decreased with the increase of fertilizer level and the number of aerial seeds per biomass with low fertilizer was significantly higher than at other levels. *P. thunbergii* showed a different trait of seed production: subterranean seeds appeared to play a role in retaining the mother–site while aerial seeds escaped the site conditions of low fertilizer. In conclusion, SA and SS showed similar life–history strategies according to fertilizer levels. The different traits of the two types of seed production would be increased survivability. Finally, the difference in the productive strategy of *P. thunbergii* would enable it to adapt to wetland habitats unlike other amphicarpic plants that inhabit arid areas.

Keywords: allocation, amphicarphy, fertilizer, life–history strategies

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Contents

Abstract	i
Contents	iii
1. Introduction	1
2. Methods	4
2.1 Fertilizer conditions	4
2.2 Measurement	4
2.3 Analysis of soil nutrient	5
2.4 Statistical analysis	6
3. Results	7
3.1 Growth responses to fertilizer	7
3.2 Effect of fertilizer level on flowering time and seed production of <i>P. thunbergii</i>	15
4. Discussion	19
5. Conclusion	23
References	24
국문 초록	28

Contents of tables

- Table 1** The results of Standardized major axis (SMA) regression for RLB, RSB and RBR with seedling types and fertilizer level in first collected data. T is seedling type. L is fertilizer level. C slope is common slope. *Ci* is 95% confidence interval ----- 13
- Table 2** The number and weight of seeds in a pot with fertilizer level (Average \pm SE, Tukey or permutational pair-wise test $p < 0.05$). ----- 17

Contents of figures

- Fig. 1.** The change in soil nutrient contents. There was significant difference in $\text{NO}_3\text{-N}$ and $\text{NH}_4\text{-N}$ in June. ---- 8
- Fig. 2.** RGR of stem length from May to June. (a) Data from 15 May to 30 May. (b) Data from 30 May to 30 June. ----- 9
- Fig. 3.** The total biomass of *P. thunbergii* at first harvest on 25 July. ----- 10
- Fig. 4.** The SMA regression relationships between Total

biomass and RLB. RBR and RSB of *P. thunbergii*. (a)
Low–Middle and High showed significant different. (b)
Common slop = 1.830 (c) common slop = 3.624. ----- 14

Fig. 5. The flowering time of *P. thunbergii* with fertilizer levels.

The date was recorded when flowering was observed in
the pot. ----- 16

Fig. 6. The characteristics of aerial and subterranean seed

productivity at three fertilization levels. (a) the number
of aerial seeds per biomass (number/g), (b) the number
of subterranean seeds per biomass (number/g), (c) aerial
seed allocation, (d) subterranean seed allocation. ----- 18

1. Introduction

Amphicarpy is a dimorphism trait found in a few plants and enables the propagule of the plant to form above-ground and below-ground seeds (Kaul et al., 2000). Many studies have proposed the ecological and evolutionary significance of amphicarpy (Koller and Roth, 1964; Cheplick, 1983; Schnee and Waller, 1986; Masuda and Yahara, 1994; Sadeh et al., 2009). These studies showed that amphicarpic plants can survive under variable environmental conditions using the two seed types with their different methods of development, function and strategy. (1) Aerial flowers are chasmogamous and are usually cross-pollinated, resulting in seeds that are smaller and lighter than subterranean seeds. Therefore, aerial seeds appear suitable for genetic exchange and dispersal. (2) Subterranean flowers are cleistogamous and only self-pollinated, and also have fewer, larger, and heavier seeds than aerial flowers (Cheplick, 1987; Barker, 2005; Choo et al., 2015). Subterranean seed production evolves independently in phylogenetically diverse taxa, and the relevant selective pressure can be different among species (Cheplick, 1987). The specific responses of amphicarpic plants to disturbances depend on the species and environmental variables. Thus, to fully understand the amphicarpic trait as an adaptive strategy, more information about specific amphicarpic responses of diverse plants under various environments situations is needed.

Persicaria thunbergii (Siebold & Zucc.) H. Gross is Polygonaceae and an annual amphicarpic plant. The shoot tips develop into aerial flowers, and these flowers are usually

chasmogamous and self-pollinated or sometimes cross-pollinated. The aerial flowers produce more and smaller seeds than the subterranean flowers (Suzuki et al., 2007). Subterranean flowers develop from the tips of the creeping stem toward the ground. The flowers are cleistogamous, only self-pollinate and produce a few larger seeds (Kawano et al., 1990). *P. thunbergii* communities are frequently found in wetlands such as riparian zones and lakesides in eastern Asia including in Korea, China, Taiwan, Eastern Russia and Japan (Kawano, 2008; Kim et al., 2012).

The environment affects the nutrient allocation pattern (Bloom et al., 1985; Brouwer, 1962). The most important concept in the life-history theory is resource allocation (Gadgil and Bossert, 1970; Iwasa and Roughgarden, 1984; Gedroc et al., 1996). The capability of plants to obtain nutrients is determined by allocation patterns (Poorter et al., 1990), competition with other species (Tilman, 1988; Grime, 2006), and seed production (Abrahamson and Gadgil, 1973; Schmid and Weiner, 1993).

Earlier studies on the *P. thunbergii* dealt with various environments which are known to impact the population such as light and soil nitrogen levels that affect allocation patterns and seed outputs (Kawano et al., 1990) as well as flooding that impacts plant height and biomass (Kim et al., 2013). The mesocosm experiment on flooding and physical damage determined that *P. thunbergii* changes the allocation to aerial seeds and subterranean seeds (Choo et al., 2014). Especially, Choo et al. (2015) reported that seedlings from subterranean seeds (SS) in the early life history would have greater ability to escape water-logged and shaded conditions and the advantage to retake the mother-site because of higher and faster germination rates than seedlings from aerial seeds

(SA). Thus, they suggested that different seedling types would have different allocation patterns in unfavorable conditions. In addition, Choo et al. (2014) suggested that *P. thunbergii* would have a distinct reproductive strategy from other amphicarpic plants. Accordingly, *P. thunbergii* would not fully satisfy the pessimistic strategy observed in other amphicarpic plants, in which the productivity of subterranean seeds decreases when flooding occurs.

In this study, I tried to understand the amphicarpic traits of *P. thunbergii* under different soil nutrient conditions. The hypotheses are that 1) the biomass allocation of two types of seedlings would be different with different fertilizer levels, 2) flowering time and resource allocation would be different with varying fertilizer levels as a reproductive response.

2. Methods

2.1 Fertilizer conditions

The experiment was conducted at Seoul National University, Korea from May to November 2014. The average temperature was 19.8° C during the experiment period. Thirty oval rubber containers (70 cm W × 100 cm L × 35 cm H) were filled 5 cm deep with coarse sand. The NH₄-N, NO₃-N, and PO₄-P contents of soil in the mesocosms were 2.9±0.7, 1.7±0.5, 24.5±1.7 mg/kg, respectively. Fertilization was performed using 5 g of an 18:2:10 (N:P:K) solid fertilizer (Dongbu-Hannong, Korea). Microelement fertilizer (Plant Nutrition Res. Inst., Daeyu, Korea) containing Boron (2%), Zinc (0.6%), Manganese (0.4%), Copper (0.05%), Iron (0.1%) and Molybdenum (0.0005%) was sprayed in September. There were three fertilizer conditions: no fertilization (Low level), 8-week cycle fertilization (Middle level), and 4-week cycle fertilization (High level).

Ninety subterranean seedlings and ninety aerial seedlings of similar stem length (SA: 5.0±1.1 cm, SS: 5.0±0.6 cm) ($p = 0.831$) were selected and 3 subterranean seedlings and 3 aerial seedlings were planted in each pot on 15 May. I supplied distilled water and the water level was maintained at a depth of no more than 3 cm.

2.2 Measurement

The stem length was measured biweekly until 30 June. I inspected the blooming time for each condition every day.

Subterranean flowering was observed as the tip of the creeping stem began growing up to 10 ~ 15cm on the soil. Harvest was performed two times: the first on 25 July with 15 pots (5 pots for each fertilizer level) and the second on 3 November when the plant foliage withered. The harvested plants were separated into 4 organ parts (leaf, root, stem and seed) and dried in an oven over 48 h at 80°C. I used those measurements to calculate the following:

$$\text{Relative growth rate (RGR) (cm/day)} = (x_2 - x_1) / (t_2 - t_1)$$

(x_1 : the stem length on t_1 time, x_2 : the stem length on t_2 time)

Biomass allocation:

$$\text{Relative stem biomass (RSB)} = \text{stem biomass (g)} / \text{total biomass (g)}$$

$$\text{Relative leaf biomass (RLB)} = \text{leaf biomass (g)} / \text{total biomass (g)}$$

$$\text{Relative root biomass (RBR)} = \text{root biomass (g)} / \text{total biomass (g)}$$

Reproductive allocation pattern:

$$\text{Aerial seed allocation} = \text{aerial seed mass (g)} / \text{total biomass (g)}$$

$$\text{Subterranean seed allocation} = \text{subterranean seed mass (g)} / \text{total biomass (g)}$$

2.3 Analysis of soil nutrient

The soil was sampled a week after each fertilization and sieved using a 2 mm mesh sieve. $\text{NO}_3\text{-N}$ and $\text{NH}_4\text{-N}$ in the soil were extracted with a 2 M KCl solution (Kim et al., 2004) and $\text{PO}_4\text{-P}$ was extracted with Bray No. 1 solution (Bray and Kurtz, 1945). $\text{NO}_3\text{-N}$, $\text{NH}_4\text{-N}$, and $\text{PO}_4\text{-P}$ in water and in the extracted soil solution were analyzed with the hydrazine method (Kamphake et al., 1967), indo-phenol method (Murphy and Riley, 1962), and ascorbic acid reduction method (Solorzano, 1969), respectively.

2.4 Statistical analysis

Data were statistically analyzed using the statistical software environment R (R Development Core Team 2014) for two-way ANOVA with post-hoc test Tukey HSD (honestly significant difference) and PERMANOVA with 999 permutations. In addition, I used the pair-wise permutational t test after PERMANOVA. Standardized major axis (SMA) regression was used to describe the relationship between each combination of traits in seedlings from aerial and subterranean seeds. The SMA method is appropriate when the purpose of the study is to describe how variables are related (Warton et al. 2006).

3. Results

3.1 Growth responses to fertilizer

The RGR of stem length was not different between seedling types but was impacted by fertilizer levels (Fig. 1 and 2). RGR in May were significantly different between high–middle fertilizer levels and low level (two–way ANOVA, $F = 53.04$, $p < 0.001$), but not between seedling types (two–way ANOVA, $F = 0.21$, $p = 0.648$) and there was no interaction between fertilizer levels and seedling types (two–way ANOVA, $F = 1.22$, $p = 0.297$). RGR in June was significantly different across fertilizer levels (PERMANOVA, $F = 359.054$, $p < 0.001$), but there was no significant difference between seedling types (PERMANOVA, $F = 0.7214$, $p = 0.396$) and no significant interaction between fertilizer levels and seedling types (PERMANOVA, $F = 0.9649$, $p < 0.341$).

The total biomass of SA and SS in late July (Fig. 3) respectively averaged 1.11 ± 0.77 g and 1.03 ± 0.80 g under low fertilizer conditions, 12.49 ± 5.81 g and 11.35 ± 5.96 g under middle fertilizer conditions, and 22.66 ± 7.02 g and 27 ± 8.03 g under high fertilizer conditions. There was no significant difference between seedling types (PERMANOVA, $F = 0.77$, $p = 0.391$) and no significant interaction between fertilizer levels and type (PERMANOVA, $F = 2.13$, $p = 0.127$), but there was significant difference across fertilizer levels (PERMANOVA, $F = 205.49$, $p < 0.001$).

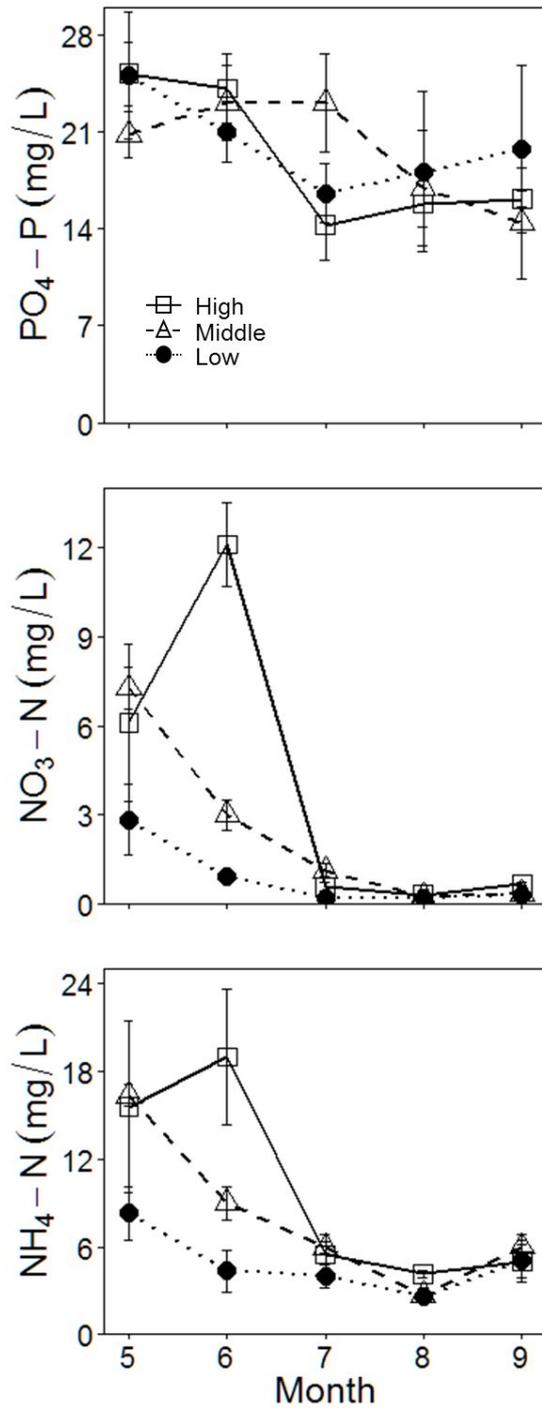


Fig. 1. The change in soil nutrient contents. There was significant difference in NO_3-N and NH_4-N in June.

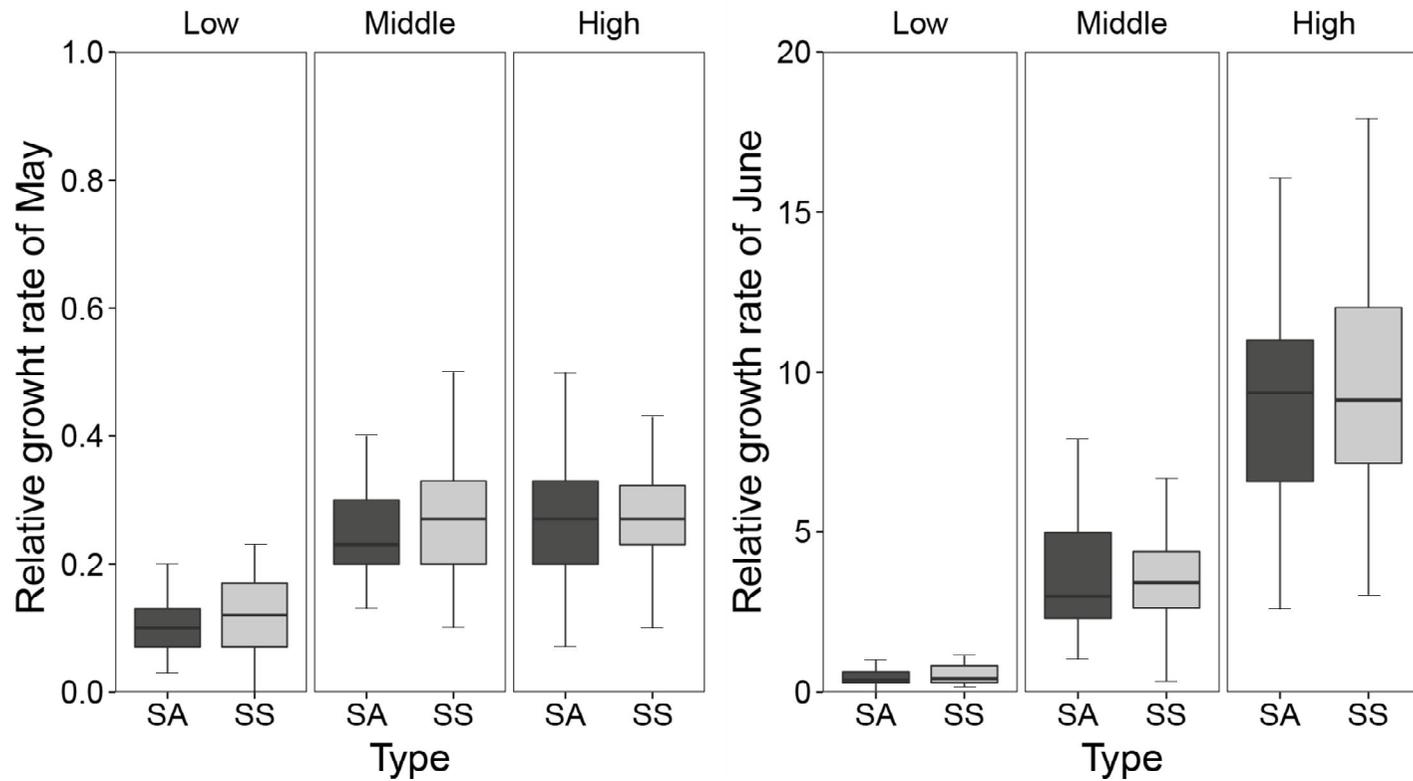


Fig. 2. RGR of stem length from May to June. (a) Data from 15 May to 30 May. (b) Data from 30 May to 30 June.

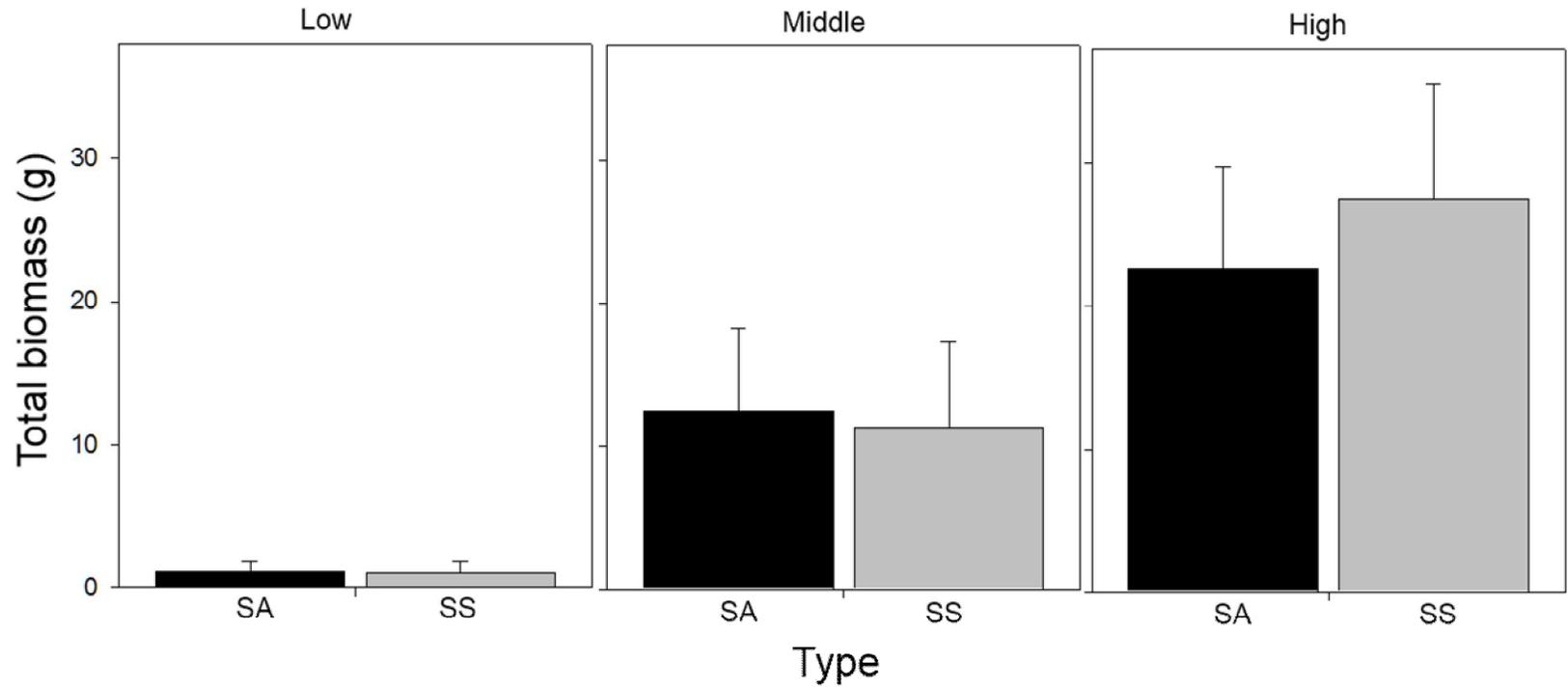


Fig. 3. The total biomass of *P. thunbergii* at first harvest on 25 July.

In the relative leaves biomass (RLB) of high fertilizer level, the individual slopes of SA and SS were homogeneous ($p = 0.30$) and negatively correlated with total biomass (common slope = -1.48) (Table 1). SA and SS individual slopes of RLB at the middle level were homogenous ($p = 0.94$) and negatively correlated with total biomass (common slope = -2.74). The individual slopes of SA and SS of RLB at low level were also non-heterogeneous ($p = 0.60$) and negatively correlated with total biomass (common slope = -2.75). RLB was not significantly different between fertilizer levels (two-way ANOVA, $F = 0.375$, $p = 0.542$) or seedling types (two-way ANOVA, $F = 0.022$, $p = 0.884$) and there was no interaction between fertilizer levels and seedling types (two-way ANOVA, $F = 0.088$, $p = 0.767$).

In the relative roots biomass (RBR) at the high level, the individual slopes of SA and SS were homogeneous ($p = 0.98$) and positively correlated with total biomass (common slope = 1.83). SA and SS individual slopes of RBR at the middle level were homogenous ($p = 0.98$) and positively correlated with total biomass (common slope = 2.27). The individual slopes of the SA and SS of RBR at the low level were also non-heterogeneous ($p = 0.32$) and positively correlated with total biomass (common slope = 1.56). RBR was not significantly different between seedling types (PERMANOVA, $F = 1.632$, $p = 0.200$) or fertilizer levels (PERMANOVA, $F = 3.238$, $p = 0.061$) and there was no interaction between seedling types and fertilizer levels (PERMANOVA, $F = 1.697$, $p = 0.193$).

In the relative stems biomass (RSB) at the high level, the individual slopes of SA and SS were homogeneous ($p = 0.51$) and positively correlated with total biomass (common slope = 2.60). SA

and SS individual slopes of RSB at the middle level were homogenous ($p = 0.29$) and positively correlated with total biomass (common slope = 4.83). The individual slopes of SA and SS of RSB at low level were also non-heterogeneous ($p = 0.41$) and negatively correlated with total biomass (common slope = -3.69). RSB was not significantly different between seedling types (two-way ANOVA, $F = 1.117$, $p = 0.294$), and there was no interaction between fertilizer levels and seedling types (two-way ANOVA, $F = 0.868$, $p = 0.354$), but RSB at the high level was significantly higher than at the middle level (two-way ANOVA, $F = 5.304$, $p = 0.024$).

Lastly, in RLB of *P. thunbergii*, the slope of each fertilizer level were heterogeneous between low-middle and high ($p < 0.01$). However, every fertilizer level slopes was homogeneous in RBR and RSB (Fig. 4).

Table 1 The results of Standardized major axis (SMA) regression for RLB, RSB and RBR with seedling types and fertilizer level in first collected data. T is seedling type. L is fertilizer level. C slope is common slope. Ci is 95% confidence interval

Trait Y(X)	T	L	Slope	r ²	SMA Pval	Ci	C slope	
RLB (total biomass)	SA	High	-0.083	0.023	0.30	-2.14	-1.03	-1.48
	SS		-0.458	0.338				
	SA	Middle	-0.256	0.483	0.94	-3.55	-2.12	-2.74
	SS		-0.294	0.659				
	SA	Low	-0.208	0.275	0.60	-3.91	-1.93	-2.75
	SS		0.142	0.185				
RBR (total biomass)	SA	High	-0.096	0.047	0.12	1.24	2.66	1.83
	SS		0.217	0.383				
	SA	Middle	0.173	0.797	0.98	1.53	3.38	2.27
	SS		0.16	0.397				
	SA	Low	-0.149	0.229	0.32	1.09	2.24	1.56
	SS		-0.055	0.058				
RSB (total biomass)	SA	High	-0.066	0.008	0.51	1.82	3.68	2.60
	SS		0.234	0.296				
	SA	Middle	<0.005	<0.005	0.29	3.80	6.05	4.83
	SS		0.031	0.234				
	SA	Low	0.451	0.372	0.41	-5.37	-2.54	-3.69
	SS		-0.039	0.006				

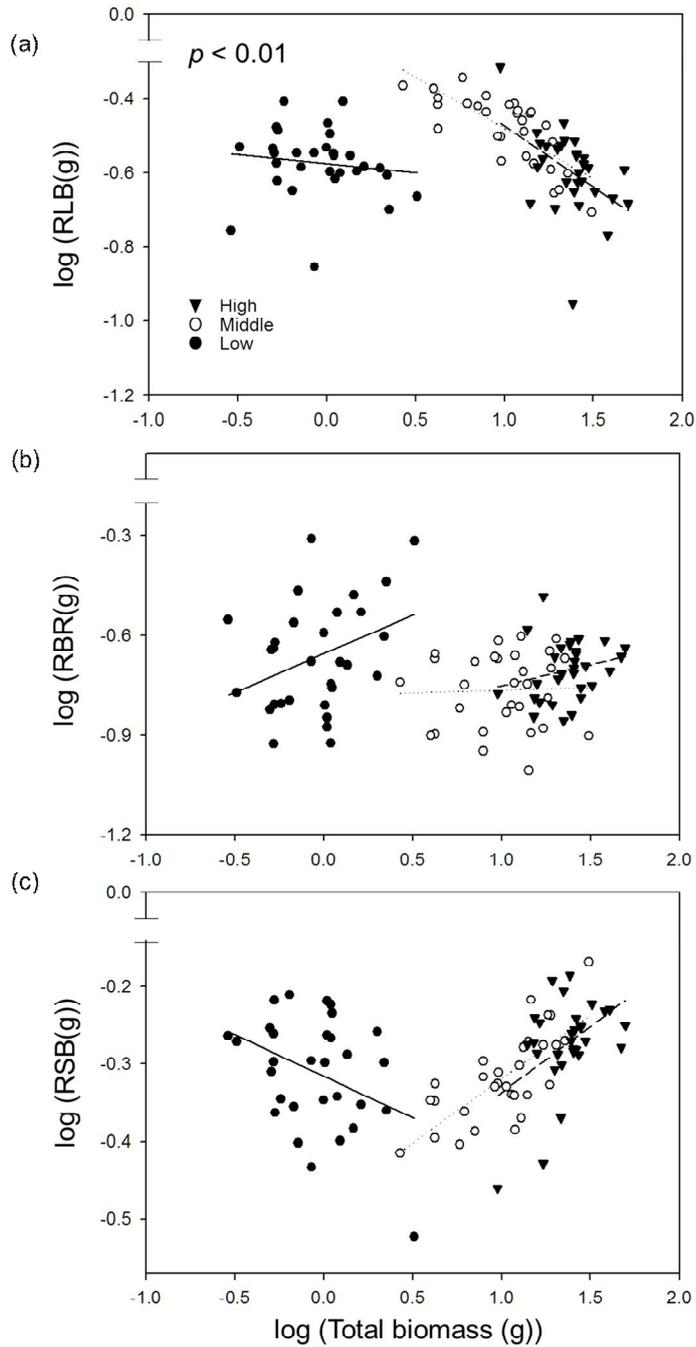


Fig. 4. The SMA regression relationships between Total biomass and RLB, RBR and RSB of *P. thunbergii*. (a) Low–Middle and High showed significant different. (b) Common slop = 1.830 (c) common slop = 3.624.

*3.2 Effect of fertilizer level on flowering time and seed production of *P. thunbergii**

Flowering time was affected by fertility level and differed between aerial and subterranean flowers (Fig. 5). The initial flowering time at the high level was faster than at other levels. The aerial flower was faster than the subterranean flower with its initial timing (Fig. 5).

The number of aerial and subterranean seeds were significantly different (two-way ANOVA, $F = 6.413$, $p < 0.01$), and the number of seeds significantly increased with fertilizer levels (two-way ANOVA, $F = 223.844$, $p < 0.001$) (Table 2). The weight of aerial and subterranean seeds were significantly different (PERMANOVA, $F = 5.370$, $p < 0.05$), and the weight of seeds significantly increased with fertilizer levels (PERMANOVA, $F = 161.602$, $p < 0.001$) (Table 2).

The number of seeds per biomass was significantly different across fertilizer levels for aerial seeds but not for subterranean seeds (two-way ANOVA, $F = 12.576$, $p < 0.001$) (Fig. 6a and 6b). At low levels, the number of aerial seeds per biomass was higher than for the other conditions ($p < 0.05$, Tukey HSD). Aerial seed allocation was significantly increased with the increase of fertilizer level but not subterranean seed allocation (two-way ANOVA, $F = 14.134$, $p < 0.001$). This was due to the dissimilar low (1.2 %) and high (0.8 %) fertilizer levels ($p < 0.05$, Tukey HSD) (Fig. 6c and 6d).

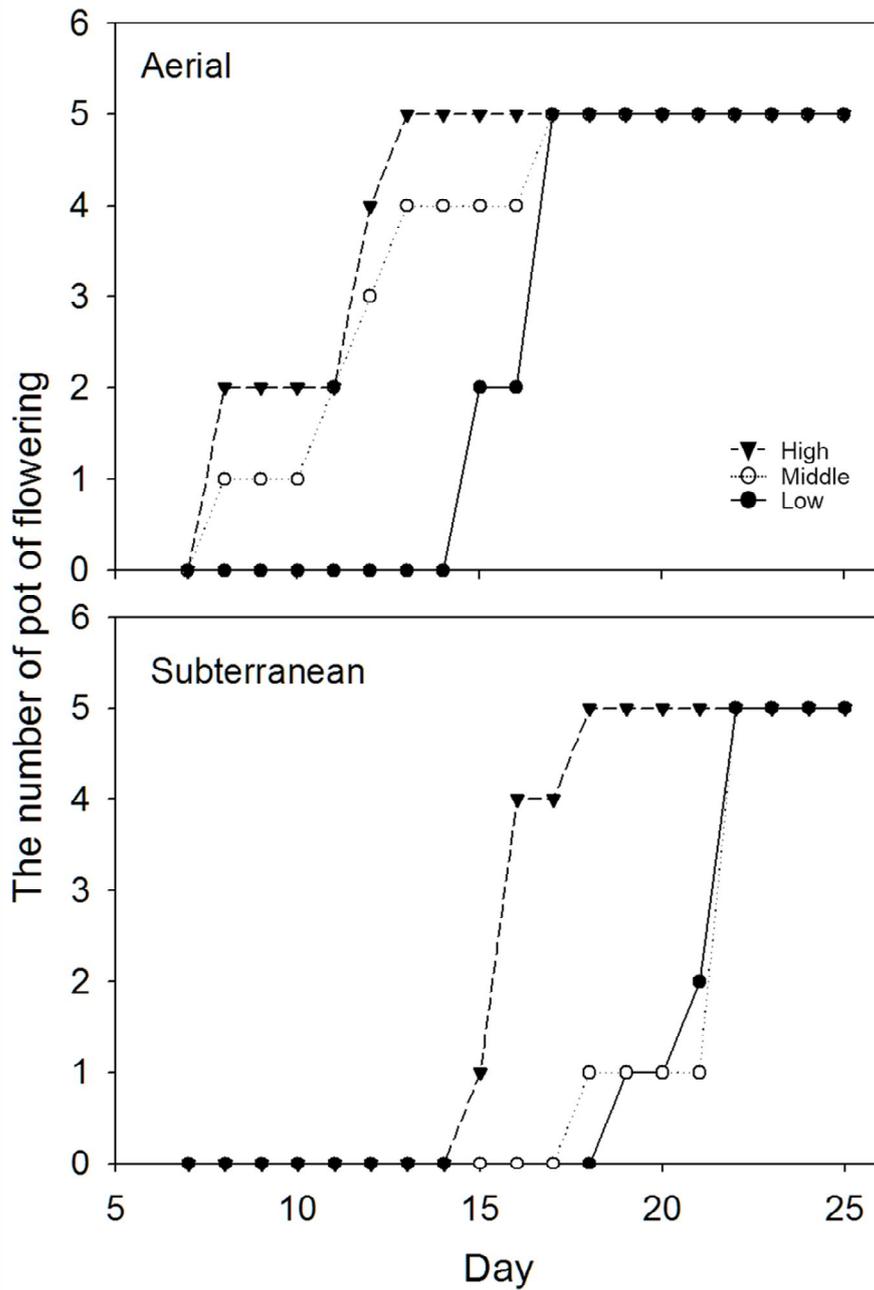


Fig. 5. The flowering time of *P. thunbergii* with fertilizer levels. The date was recorded when flowering was observed in the pot.

Table 2 The number and weight of seeds in a pot with fertilizer level (Average \pm SE, Tukey or permutational pair-wise test $p < 0.05$).

	Types	High level (n=5)	Middle level (n=5)	Low level (n=5)
Number	aerial seeds	1330.8(\pm 135.55)a	648.4(\pm 34.79)b	48.2(\pm 12.76)c
	subterranean seeds	1543.4(\pm 166.48)a	959.0(\pm 54.68)b	91.8(\pm 14.50)c
Weight	total aerial seeds	16.379(\pm 1.513)a	7.169(\pm 0.647)b	0.418(\pm 0.134)c
	total subterranean seeds	19.197(\pm 2.665)a	11.319(\pm 1.157)b	1.062(\pm 0.189)c

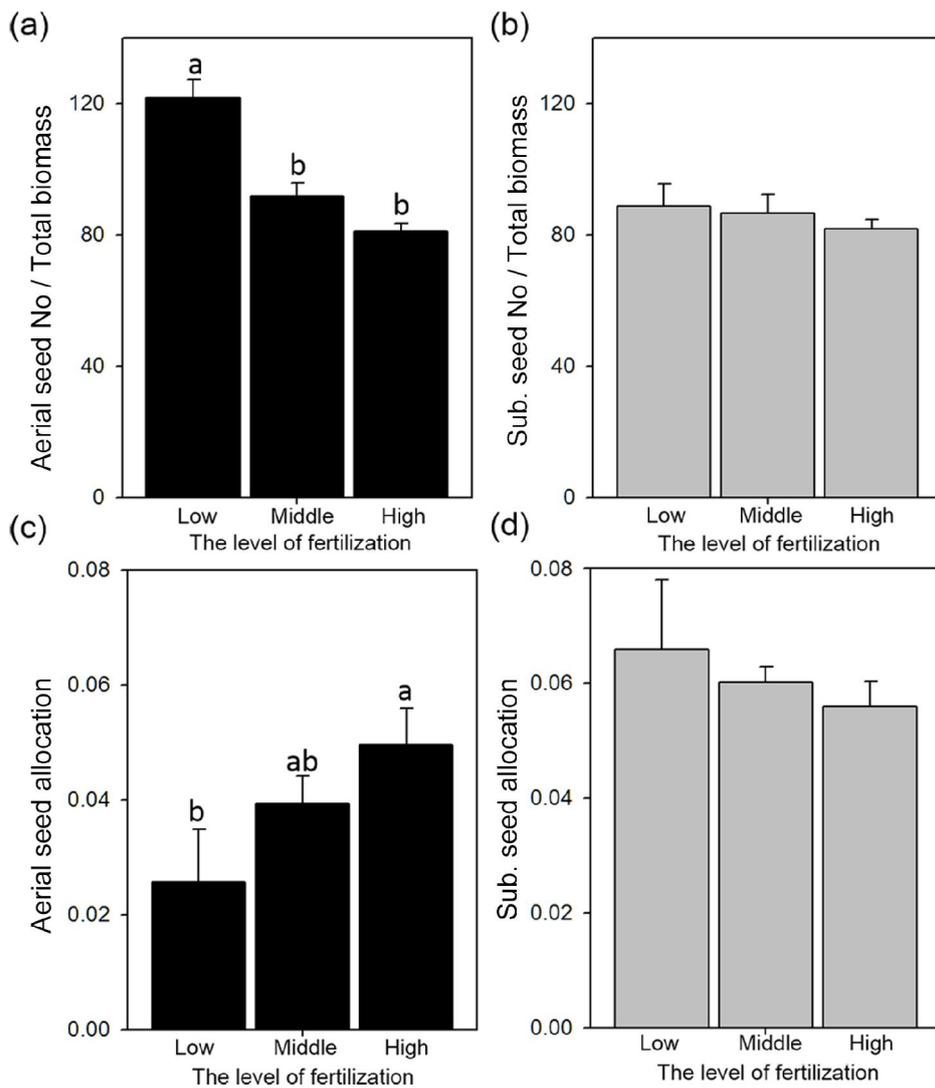


Fig. 6. The characteristics of aerial and subterranean seed productivity at three fertilization levels. (a) the number of aerial seeds per biomass (number/g), (b) the number of subterranean seeds per biomass (number/g), (c) aerial seed allocation, (d) subterranean seed allocation.

4. Discussion

In general, plant species are incapable of high RGR at habitats with low fertilizer levels (Chapin 1980). This study supported the observation (Fig. 1 and 2). The RGR of *P. thunbergii* increased less at low fertilizer levels in May and June, and there was similarity between SS and SA. In addition, the RGR of *P. thunbergii* increased when the fertilizer levels increased and was similar between SS and SA at each fertilizer level. Also, the total biomass was similar between the two seedling types (Fig. 2 and 3). Moreover, the biomass allocations showed analogous patterns in SA and SS (Table 1). A contradictory result was reported by Choo et al., (2015) who found that the biomass allocation was different under flooding and shading conditions

The ability of plants to capture resources was highly reflected by nutrient allocation patterns (Poorter et al., 1990). In nutrient limited environments, plants tend to allocate proportionally more resources to roots in order to increase (Linkohr et al., 2002). In *P. thunbergii*, RBR which first collected data increased with the total biomass, at all nutrient levels (Fig. 4). In first harvest in this study, RLB showed different pattern among nutrient levels in SMA result. RLB at high level decreased less with total biomass than RLB at low–middle level (Fig. 4). Finally, RSB increased with total biomass regardless of nutrient levels. To sum up, *P. thunbergii* more invested to root and stem when total biomass increased. Especially, the leaf of *P. thunbergii* was different investment that was depended on fertilizer level. *P. thunbergii* more invested resource when nutrient is sufficient. Kawano et al. (1990)

suggested that the allocation pattern in *P. thunbergii* was affected by nutrient but only root allocation impacted on field experiment. However, this study results suggest that *P. thunbergii* responded to fertilizer only leaves, but root and stem increased with total biomass such as in *Poa pratensis* (Müller et al., 2000).

With the annual amphicarpic plant *Amphicarpum purshii*, Cheplick and Quinn (1982) suggested that the allocation of component plant parts differed between the two types of seedlings with different levels of soil moisture, and that these differences were responsible for seedlings from subterranean seeds having greater survivorship than seedlings from aerial seeds. With *P. thunbergii*, Choo et al. (2015) showed that seedlings from subterranean seeds in early growth stages had more advantages to survive and seemed to have more invested leaves. However, this study showed that different seedling types showed similar RGR and total biomass at first harvest. Thus, the ability to survive or compete under various fertilizer conditions would not be different between SA and SS. Moreover, the productivity would be similar between SA and SS because most plant productivity depend on plant size (Gadgil and Bossert, 1970; Abrahamson and Gadgil, 1973). In addition, amphicarpic plants have a strong relationship between the amphicapy ratio (aerial propagule : subterranean propagule) and the total biomass (Trapp and Hendrix, 1988; Kawano et al., 1990). Most amphicarpic plants demonstrate changeable allocation to aerial production with plant biomass but no allocation to subterranean production (Cheplick., 1994). However, *P. thunbergii* has a different seed allocation pattern corresponding to subterranean flower timing. Choo et al. (2014) reported that the timing of subterranean and aerial flowering was different and this

could impact their populations. The reproduction strategy of *P. thunbergii* appears different from other amphicarpic plants as the subterranean flower did not form earlier than the aerial. This study supported previous results on the timing of aerial and subterranean flowers. As a result, I support Choo et al. (2014) in that the pessimistic strategy might not hold true for *P. thunbergii* with the production of subterranean seeds. *P. thunbergii* does not follow the trend of amphicarpic plants that utilize the pessimistic (or timid) strategy, but adapts to unpredictable environments using a different life history strategy similar to the bold strategy in subterranean flowers (Zeide, 1978; Satake et al., 2001).

The bold strategy is one in which the plant produces seed when it is thoroughly grown. The advantage would be maximum fecundity and as a result, the later production of flower and fruit (Satake et al., 2001; Sadeh et al., 2009). Thus, the late flowering of subterranean over aerial flowers suggests that *P. thunbergii* adopts a bold strategy over a pessimistic (or timid) strategy for subterranean flower production. This difference would be reflected in the habitat; most amphicarpic plants inhabit arid or semi-arid habitats but *P. thunbergii* inhabits wetlands (Cheplick, 1987; Kim et al., 2012).

Habitat conditions like nutrient availability may modulate the amphicarpy trade-off. Aerial seed allocation decreased in insufficient fertilizer conditions (Fig. 5c). Additionally, the number of aerial seeds per biomass in insufficient fertilizer conditions was significantly higher than in sufficient fertilizer conditions (Fig. 5a). This response would increase the probability for escape in a habitat that is unfriendly for maintaining the population (Cheplick, 1987; 1994). The subterranean seed allocation and the number of seeds

per biomass were, however, stable at all three fertilizer levels (Fig. 5c and 5d). Even in unfavorable conditions, source dispersal increases the opportunity to maintain mother-sites (Urbanska, 1997).

5. Conclusion

SA and SS were not significantly different in RGR, total biomass and allocation patterns at different fertilizer levels. This means that SA and SS had similar life–history strategies in various nutrient environments. The traits for the two seed types had different reproductive allocation patterns and seed numbers per biomass. This suggests that *P. thunbergii* can retain its mother–site using stable productive traits with subterranean seeds and also has a high probability to escape an insufficient nutrient habitat by changing the productive traits of aerial seeds. In addition, subterranean flowering occurred later than aerial flowering, demonstrating the reproductive strategy of the wetland–inhabiting *P. thunbergii*, which differs from other amphicarpic plants that inhabit arid or semi–arid habitats.

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국문 초록

양분에 따른 고마리(*Persicaria thunbergii*)의 이종과의 특성을 이해하기 위해 메조코즘 실험을 수행하였다. 총 세가지 양분조건(저양분, 중양분, 고양분)을 준비하였으며, 저양분은 비료 처리를 따로 하지 않았고 중양분과 고양분의 경우 각각 8주와 4주 간격으로 5g씩 시비하였다. 지상부 종자에서 나온 유묘(Seedling form Aerial seed: SA)와 지하부에서 나온 유묘(Seedling form Subterranean seed: SS)가 양분에 다르게 반응하는지 보기 위해 초기의 줄기 성장률과 자원분배를 알아보았으며, 개화시기와 지상부 종자와 지하부 종자의 생산성을 알아보았다. 본 연구의 결과로 SA와 SS간의 초기 생장은 양분에 따라 차이가 보이지 않았고, 양분에 따른 자원분배의 경우도 SA와 SS간의 차이를 보이지 않았다. 또한 중간 수확 시기의 전체생물량도 위와 같은 결과를 보였다. 또한 고마리는 다른 이종과 형성 식물과 다르게 지하부 꽃이 지상부 꽃보다 늦게 개화 하는 것을 확인 할 수 있었다. 이는 고마리의 생산전략이 전형적인 이종과 형성 식물과 다르다는 것을 의미한다. 각 종자별 자원분배와 생물량 당 종자 갯수의 경우 지하부 종자는 양분의 양에 따라 자원분배와 생물량 당 종자 갯수의 차이를 보이지 않았다. 하지만 지상부 종자의 경우 양분이 부족할 때 자원분배가 작아지고, 생물량 당 갯수는 높아진다. 이는 지하부 종자는 안정적으로 생산하여 개체의 mother-site를 유지하고, 양분이 부족한 환경에서의 고마리의 생존전략으로써 지상부 종자의 생산을 높여 양분이 부족한 환경을 벗어날 수 있는 확률을 높이려는 것으로 보인다. 결과적으로, 양분이 다른 환경에서는 고마리의 SA와 SS간의 생활사전략은 비슷한 것으로 보인다. 또한 이종과 간의 생산 특성을 달리하여 생존 확률을 높이는 것으로 보인다. 그리고 생산전략은 다른 이종과 형성 식물과는 다르게 보인다. 이는 습지에서 서식하는 이종과 형성 식물인 고마리는 건조한 지역에 사는 이종과 식물과 다른 적응 방법을 보여준다고 할 수 있을 것이다.

주요어 : 생활사 전략, 양분, 이종과 형성, 자원분배

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