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Growing Three Wild Herbaceous Plants, *Allium victorialis* var. *platyphyllum*, *Ligularia stenocephala*, and *Panax ginseng* in the Understory of *Larix kaempferi* Plantation

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Abstract: Two edible plants, *Allium victorialis* var. *platyphyllum* and *Ligularia stenocephala*, and one medicinal plant, *Panax ginseng*, were cultivated in the understory of an artificial *Larix kaempferi* plantation for ten years. Growth characteristics (number of leaves and flower stalks per plant, and leaf length and width), survival rate, and yield (fresh weight of plants) per unit area (1 m^2) were investigated one year after planting, and six and ten years following cultivation. *P. ginseng* and *L. stenocephala* survived at a high percentage for two years after planting. Results showed that *P. ginseng* had longer and thicker roots when aged; however, a large number of plants died and the yield was low. In contrast, almost half of *A. victorialis* var. *platyphyllum* died within two years of planting. The surviving plants grew well for ten years and the yield was increased. The leaf length and width of *L. stenocephala* increased; however, the survival rate and the number of leaves per plant decreased as the period of cultivation was extended. In contrast, *A. victorialis* var. *platyphyllum* survived at a lower rate (50%) than the two other crops (98% for *L. stenocephala* and 83% for P. ginseng) during the early cultivation period, with little change in the survival rate over an extended time; however, the yields increased. This species showed an increase in the number of flower stalks and leaves, and as a result, the larger leaves increased the yield. We evaluated the understory cultivation of three crops in a *L. kaempferi* plantation under natural conditions, with no irrigation or fertilization, and *Allium victorialis* var. *platyphyllum* showed the greatest growth potential among the three tested crops.

Key words: *agroforestry,* Larix kaempferi plantation, Allium victorialis *var.* platyphyllum, Ligularia stenocephala, Panax ginseng

INTRODUCTION

Leafy green vegetables are important for a healthy diet because they contain a lot of vitamins, minerals and fiber, despite having low calories. Besides of typical green vegetables, forest grown leafy greens are popular and some were cultivated in large scale in agricultural land and greenhouse (Boothroyd et al., 2013). Greenhouse cultivation system provides well controlled environment and have an advantage of higher yield. In contrast it requires expensive facilities to begin and maintenance than the open-field grown ones. Agroforestry is an efficient land use to increase profits by simultaneously producing long-term (timber) and short-term (non-timber) crops to increase farmer income. It is ecologically beneficial to prevent soil erosion and conserve biodiversity. In addition, it requires less expense of facility although it takes long reap products and irregular harvest due to the variable climate. However, forest crops contain more minerals and vitamins, and various flavors than agricultural crops and according to the survey by Hwang et al. (2014) people are willing to purchase forest crops.

Among the valuable non-timber crops for agroforestry, *P. ginseng* is well known and one of old traditional

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medicinal plant and have been cultivated long time in Asia. Many researches proved the effects of the components of Korean ginseng (Patel and Rauf, 2017). Compare to the ginseng grown in agricultural land, forest grown ones are highly prized (Hankins, 2009; Hwang et al., 2014; Jacobson and Burkhart, 2019). The main problem of growing ginseng in agricultural land is disease control which is a big concern to consumers. Because there is no competition with other vegetation in agricultural land, root of ginseng grows much greater than in wild. However, the pesticide residues on or within roots became a severe drawback. Due to these reasons, growing ginseng in forest land such as wild-simulated or wood-cultivate methods are preferred by farmers (Hankins, 2009).

Besides of medicinal crops, wild leafy vegetables are gaining popularity because of their good quality of dietary and medicinal component (Kim et al., 2010). Two species, *A. victorialis* var. *platyphyllum* and *L. stenocephala*, are perennials naturally growing in forest floor in Korea and farmers try to cultivate them in forest. *L. stenocephala* distributes in broadleaved forest floor in Korea. *A. victorialis* var. *platyphyllum* can be found in cool (8-20 °C) and humid (71-74%) places of higher altitude mountain areas in Korea (Park et al., 2009).

For these crops, there is an additional advantage of cultivating in forest. These species grow shade areas, covered 70~75% shade which is not needed to construct the facility like agricultural land (Hyeon et al., 2009). In general, broad leaved forest are favored for agroforestry to provide enough shade and less allelopathic effect that may inhibit the growth of agroforestry crops. However, the use of synthetic pesticides can reduce because allelochemicals from the forest trees have a positive effect of preventing the spread of pathogens (Garima and Devi, 2017).

L. kaempferi is a major tree species for timber production and the areas of plantation have been increasing last decades. As the purposes of agroforestry, valuable herbaceous crops were cultivated in the space after a thinning practice of the *L. kaempferi* plantation. In this study, we investigated the growth habit of three herbaceous crops for long period of cultivation without any treatments, fertilization or pesticide spray.

MATERIALS AND METHODS

1. Planting sites

L. kaempferi plantation is located in research forest of Kangwon National University, Chuncheon, Gangwon do, Korea. Plantation was created in 1970~1980, thinning practice was performed at 20~25% level in 2000~2001. Vegetation of the planting sites were surveyed in May through June 2002.

Soil samples were collected from the cultivation sites and chemical properties were examined. Collected soils were mixed with water in 1:1 (soil: water) and stirred for 12 hours on magnetic stirrer. Soil pH and EC was analyzed by HM-30G (TOA) and Orion-1230 respectively. Total nitrogen was analyzed by Kjeltec 2200 (Foss Co.) using Kjeldahl method. Available phosphorus was determined using sodium bicarbonate method. Other macronutrients (K, Mg, and Ca) were extracted with 0.05N NH4OAc buffered at pH 7.0 then determined atomic absorption spectrometer. Air temperature was measured by automatic meteorological equipment and data was downloaded to computer.

2. Plant materials

The seedlings of *A. victorialis* var. *platyphyllum* were originated from Ulnung Island that are grown in greenhouse in Kangwon National University for one year before planting in the forest floor. Seeds of *P. ginseng* were obtained from the farmers in Inje, Gangwon do and also grown in greenhouse for one year before planting. For herbaceous plant experiment, two quadrats (10m x 10m) were prepared understory of the plantation. Each crop was randomly planted in 1m x 1m sub-quadrat. Nine of *P. ginseng* was planted in each sub quadrat and 25 plantlets of *L. stenocephala* and *A. victorialis* var. *platyphyllum* were planted in sub-quadrat. Total of 3 sub-quadrats of the species in each quadrat were planted. During the cultivation, there was no treatment at all such as fertilization or pesticide spray.

3. Plant growth habit

Plantlets were planted in spring (April) of 2002. Survivals of plants were surveyed three times, a year (2003), 6

(2009) and 10 (2012) years after planting. Growth parameters were number of leaves in a stalk, length and width of leaves. Fresh weight of above ground for two wild greens and root for P. ginseng. Root length and diameter of *P. ginseng* was measured each time with ruler. Data was collected from the plantation 3 times after the planting as described above.

4. Statistical analysis

All collected data were statistically analyzed using SPSS Statistics 24 (IBM). One way analysis of variance (ANOVA) was performed at $p<0.05$ and post-hoc test by Turkey's.

RESULTS

1. Environmental conditions of plantation

The plantation faces to south west and slope is 20~30° which is relatively steep area. The crown layer is dominated by *L. kaempferi* which were 25~41 years old, 17~25 m tall and 16~30 cm of DBH. There were shrub species appeared in the area such as *Weigela subsessilis, Styrax obassia, Acer pictum* subsp. *mono, Sambucus nigra, Morus bombycis, Rhus javanica , Actinidia arguta, Vitis coignetiae, Quercus variabilis, Lindera obtusiloba, Acer pseudosiebolianum, Corylus heterophylla, Hovenia dulcis, Cornus controversa, Lonicera maackii, Aralia elata, Rubus crafaegifolius, Symplocos chinensis, Rhododendron mucronulatum* and etc. The light intensity on forest floor was around 20~25% of the full sunlight. The average temperature in the forest on April through September was 10~21 °C and outside of the forest was 20~25 °C. It is mostly resulted from the light intensity to the forest floor. The highest and lowest temperature (more than 10 °C of difference) of the day varied outside of forest than in forest and especially the fluctuation was greater in early spring (April through May).

Soil was loam and sandy loam and it is well drained. The chemical properties of soil were summarized in Table 1. Each layer had different properties and organic layer composes the greatest nutrients (N, P, Ca, K, and Mg) and EC. Acidity of soil ranged 4.6~5.8 and EC of organic, A and B layers were 203~244, 15~33, and 11~17 μs/cm respectively. The available phosphorous was lowest in B layer (5.2~13.9) and two to three times more in A and organic layers (20.5~34.6 ppm).

The temperatures of the understory (in forest) and field (outside of forest) were different through the growing season and differences of the temperature were large in spring season and it was narrowed at fall (Figure 1).

2. Survival rate of crops

In a relatively short cultivation in forest floor, the survival rate of the crops was significantly different from the species (Figure 2). Almost half of *A. victorialis* var. *platyphyllum* died within two years of cultivation. On the other hand, *L. stenocephala* survived all and more than 80% of *P. ginseng* survived well at early years of cultivation. However, survival rates of these two species dramatically decreased 6 years later of cultivation and similar number of plants remained at 10 years of cultivation. In contrast, there was no big differences in survival rate of *A. victorialis* var. *platyphyllum* for 10 years of cultivation. Finally, survival rates of three species were 42.7 (*A. victorialis* var. *platyphyllum*), 29.6 (P. ginseng) and 26% (*L. stenocephala*), respectively, at 10^{th} year of cultivation. There were no statistical differences between the cultivation sites (sub-quadrat) in all species.

The average numbers of the survived plants of each

Table 1. Chemical properties of soil in *L. kaempferi* plantation.

	pH	EC (μs/cm)	Total nitrogen (%)	P_2O_5 (ppm)	Exchangeable cation (me/100g)		
					Ca^{2+}	Mg^{2+}	K^{+}
Organic layer	4.6-4.9	203-244	1.58-1.82	30.4-34.6	1.21-1.56	0.85-1.25	0.49-0.99
A layer	5.3-5.8	15-33	0.14-0.28	20.5-35.1	0.18-0.80	0.33-0.52	0.05-0.47
B layer	5.3-5.7	11-18	0.06-0.19	5.2-13.9	0.11-0.27	0.10-0.23	0.08-0.21

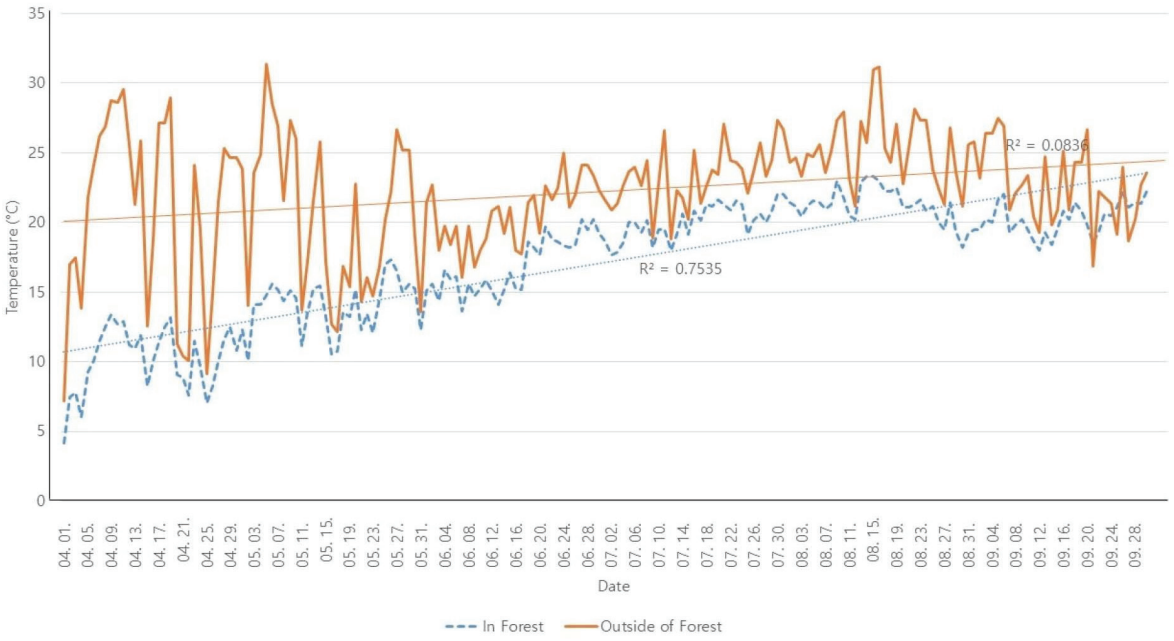

Figure 1. Temperature changes of understory of forest and outside of forest during the cultivation (April through September in 2009).

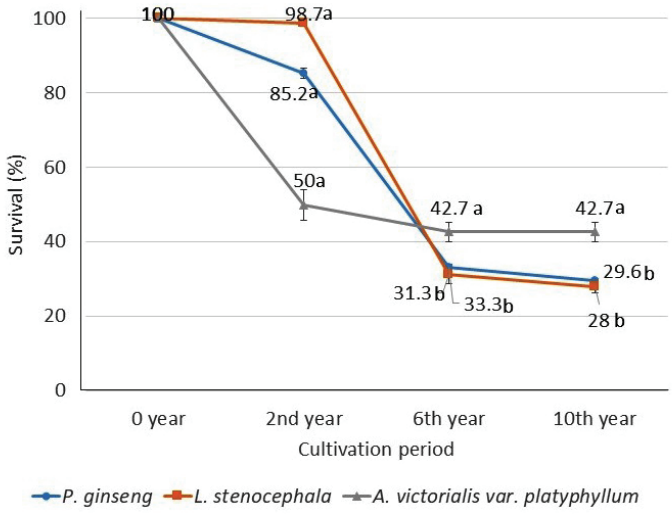

Figure 2. Survival rate of three wild crops under the forest of *L. kaempferi* for ten years cultivation.

* The different letters among the treatments for each year indicate significance at $p < 0.05$. Vertical bars represent standard error

species per one sub-quadrat (1 m x 1 m) at 10th year were 10.8 (*A. victorialis* var. *platyphyllum*), 7.5 (P. ginseng) and 7.0 (*L. stenocephala*), respectively (Table 2). There were no significant differences between the sub-quadrat.

3. Growth of crops

1) *A. victorialis* var. *platyphyllum*

Growth parameters were shown in Figure 3 for this species. At two years of cultivation, they have very small number of leaves (about 1 per plant) and stem per plant and with no flower stalk was observed. As the plant adapted to the environment, number leaves and stem were greatly increased at 6th year of cultivation. Also, flower stalks were observed. Plants had many leaves and multiple stems. At 10th year of cultivation, leaf number and stem number kept increased. Average number of flower stalk

Table 2. Average number of survived plants by cultivation years.

Species	Years of cultivation			
	0 (initial planting)	2 years	6 years	10 years
A. victorialis var. *platyphyllum*	25	12.5±4.1a*	10.7±2.6b	10.7±2.6b
L. stenocephala	25	24.7±0.5a	7.8±2.5b	7.0±1.7b
P. ginseng	25	7.7±1.4a	3.0±0.6b	2.7±0.5b

* The different letter among each species represent a significant difference at $p<0.05$.

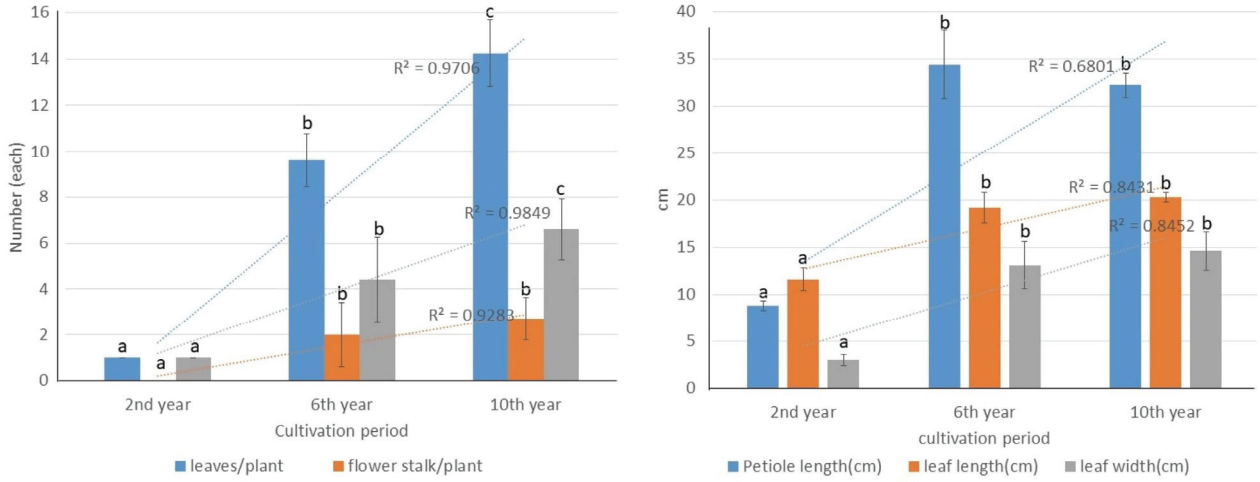

Figure 3. Growth characteristics of *A. victorialis* var. *platyphyllum* under the forest of *L. kaempferi* for ten years cultivation. The different letters among the treatments for each year indicate significance at $p<0.05$. Vertical bars represent standard error.

per plant was 2~3 which is not significantly different as time went on. There was great changes in leaf width during the cultivation. Leaf length from the tip to the base were about 20 cm when the plants are young (3 years old). Leaf width was 3 cm in wide at second year which was a long and narrow pointed shape of leaf. The width increased to 13 cm at 6th year that resulted long and wider shape of leaves. Petiole length ranges 27.8 cm to 28.4 cm, there was very little differences. The species continued to grow well from the young plants. Although the number of leaves were small, size of leaves, leaf length and width, and leaf stem length, were similar all through the cultivation period.

2) *L. stenocephala*

Figure 4 showed the growth of *L. stenocephala*. Unlike the other, it has highest number of leaves (~ 8 per plant) and flower stalk (~ 1 per plant) at second year of the cultivation and the average number was slightly decreased as cultivated was continued to ten years. It started to flower as early as 3 years old but the number of flowers per plant decreased as time went on. The number of flowers was less than one per plant, which means not all plants bloom. The size of leaves was small at second year but the length and the width increased dramatically at 10 years of cultivation but stem length was slightly decreased at 10 years. The ratio of leaf length: leaf width was 1.45.

3) *P. ginseng*

The growth of *P. ginseng* was appeared in Figure 4. The growth pattern was similar to *L. stenocephala*. Not only the length and width of root but also shoot length grow bigger as cultivation continued. While the variation of length of shoot was great, there was very few variations in the length of root at 6th year but the variation became narrow at 10th year of cultivation. Growth trend of

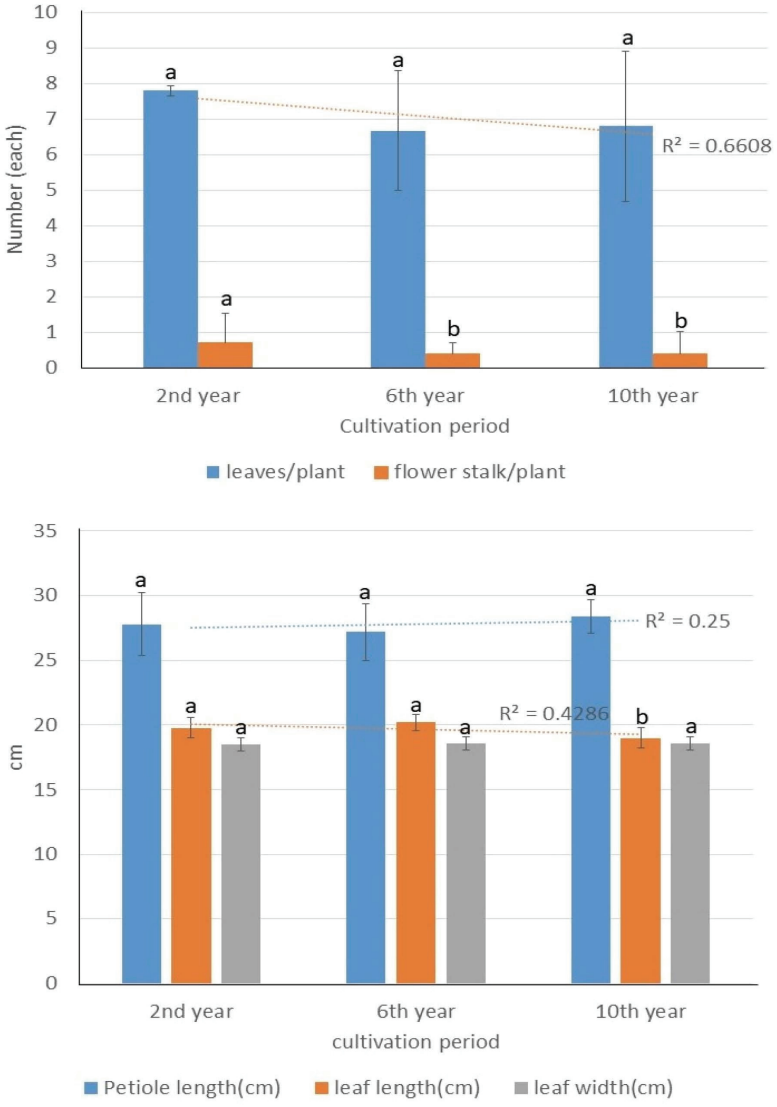

Figure 4. Growth characteristics of *L. stenocephala* under the forest of *L. kaempferi* for ten years cultivation.
The different letters among the treatments for each year indicate significance at $p<0.05$. Vertical bars represent standard error.

shoot (including leaves) and root were positively related and the growth rate of shoot was faster than that of roots (Figure 5).

DISCUSSION

These three plant species were known to grow well under shaded area in forest (Bae and Hong, 1995; Lee, 2010). Although survival rates were decreased and different by the species, the survived plants adapted to the environmental condition of the *L. kaempferi* plantation for a long time of cultivation without any treatments.

Bae and Hong (1995) surveyed the morphological variations of *A. victorialis* var. *platyphyllum* from three different habitats with an average of 10~11 cm in length and a width of 3~6 cm. Leaf size is much smaller than the ones in grown in *L. kaempferi* plantation in this study. The differences were caused by the age of the observation or cultivation site, because generally its size is 20~30 cm in length when they are grown in agricultural land (Park et al., 2014). Plants grown on forest floor in this study had little wider leaves than ones in other reports. It is also known that *A. victorialis* var. *platyphyllum* from Ulnung Island had larger leaves than ones from Odae Mt in

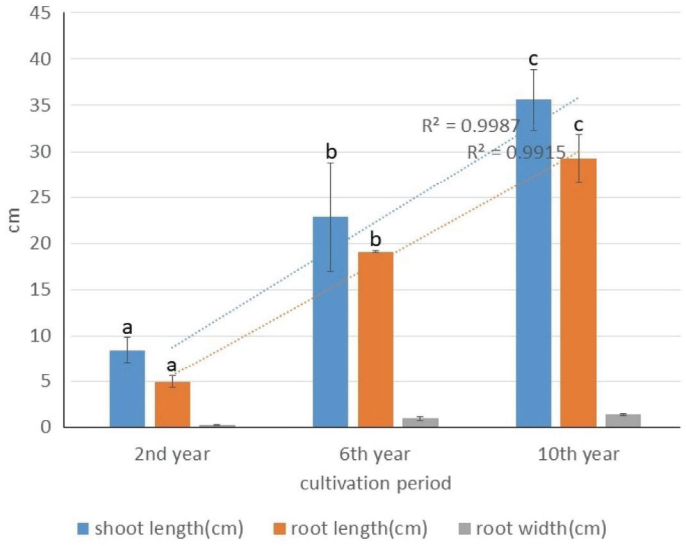

Figure 5. Growth characteristics of *P. ginseng* under the forest of *L. kaempferi* for ten years cultivation.
The different letters among the treatments for each year indicate significance at $p<0.05$. Vertical bars represent standard error.

Gangwon do (National Institute of Forest Science, 2014). Plants in this study supposed to exhibit its genetic characteristics even when they grow in different environmental condition than the natural habitat. According to the cultivation guide published by National Institute of Forest Science (2014), the density of the six-year-old plants in understory of the forest was about 12 per m^2 which is similar number of our study. It also reported the young seedlings of the species are very sensitive to the light intensity and bulbs are not tolerant when they were transplanted. It is supposed that the severe loss of the plants at 2nd year in our study resulted from the transplanting, suppressed by weeds or inappropriate conditions for the young plants. Yet, adapted plants in the study area grew well and it had good number and size of leaves compare to the grown in field with managements such as shade and cold protection. In order to increase the production and reduce the initial investment, it need to plant optimum density of the species and minimum management such as weed control.

In case of *L. stenocephala*, it is recorded that grow in wet, moist and dark places in forest (Kim et al., 2013). The survival rate at 2nd year of cultivation was highest among three crops that was 98% despite it decreased sharply in 6th year. While *A. victorialis* var. *platyphyllum* had a greater number of leaves and larger size of leaves through the long cultivation period, this species had similar number and size of leaves all through the cultivation. Both are known perennial plants growing in low light conditions, the difference of the number and size of leaves, and survival rate was resulted from the nature of their growth form. Generally, *A. victorialis* var. *platyphyllum* stored nutrients in the bulbs and the size of shoots and leaves were dependent on the age of bulb. To grow the maximum size of the plant, it takes at least 3~5 years. In addition, young bulbs are very susceptible to transferring and special care such as shade and watering, is needed when the young bulbs are planted (National Institute of Forest Science, 2014). Low survival rate of *A. victorialis* var. *platyphyllum* at second year was resulted because there was any management taken for young bulbs and planting materials were not enough to tolerate the harsh environment. Meanwhile, *L. stenocephala* grow directly from the root and roots don't thicken as much as *A. victorialis* var. *platyphyllum* does. It has matured form including flowers relatively short cycle and the form of plants are not differ from the age of roots. Kim et al (2010) addressed the species grow in early season (May) than other green leafy plants and growth was declined after the peak. Some researchers investigated that the growth of the *L. stenocephala* under different intensity of light and found it grew best at about 60% of full light

(Kim et al., 2015) and 50% of shad (Park et al., 2011). It is thought that the understory conditions of the *L. kaempferi* plantation would fit to the crop but considerations on choosing planting materials and management is needed to maintain the production.

Forest environment for *P. ginseng* in several regions in Korea was investigated by Lee (2010), vegetation was composed of broad leaved (oak trees) and coniferous mixed forest and faced North, Northeast or Northwest. Forest floor was covered with canopy 70~90% but seedling emergence was greatest when crown density was 90%. Seedling emergence at early stage was influenced by the water retain ability, however it was greatly decreased from the third year after the sowing (Lee, 2010). A year-old seedling of ginseng survived well at first year after transplanting without any management according to our study. Like *A. victorialis* var. *platyphyllum*, this species needed several years to reach the maximum size of the shoot which is continuously increased as time goes on. Growth of ginseng root was greatly influenced by the temperature because of the root respiration (Jeon, 2008). It could grow well because of low temperature of the understory of the forest which was lower than the outside of the forest.

When herbaceous plants (crops) were grown understory of the forest, the interactions between plants, allelopathic compatibility should be a consideration (Singh et al., 2012). There were some negative relations in many aspects such as competition and chemical components between tree species in canopy layer and crops in understory (Garima and Devi, 2017). Mostly growth crops in understory were inhibited by the tree species. Therefore, ginsengs were usually grown broad-leaved deciduous tree species like oak tree than conifers that are known to release inhibitory exudates to the soil. We did not find evidence of the negative effect by the *L. kaempferi* in the study because crops could grow normal size and have life cycle for long time of cultivation. The results of the study showed that the cultivation of three crops under *L. kaempferi* plantation without any anthropogenic maintenance. However, some managing practices such as weed control excluding chemical spray or fertilization may improve total production of the crops.

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