韓草誌(J. Korean Grassl. Sci.) 15(1) : 19 ~ 23, 1995

Cotyledon and Leaf Development Associated with Seedling Vigor of Six Forage Legumes

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여섯가지 荳科牧草의 幼植物 活力과 關聯된 子葉과 葉의 發達

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摘　　要

여섯가지의 主要 荳科牧草의 子葉과 葉의 發達이 幼植物 生長에 얼마나 貢獻하는 가에 대한 硏究를 위하여 草種間 比較 檢討를 하였다.

두과 목초의 子葉은 출현 후 1주일 동안은 크기가 급격하게 증가하다가 그 이후는 最大 面積에 이를 때까지 서서히 확장되었다. 큰 종자일수록 子葉 面積이 컸으며, 子葉 伸張速度는 유식물 생장과 高度의 相關關係가 있었다. 잎이 일찍 발생되고 빨리 展開되는 것이 초기 유식물 생장에 결정적인 要因으로 작용하였다. 종자가 비교적 큰 alfalfa와 red clover는 광합성을 할 수 있는 기관의 면적이 크기 때문에 유식물 활력도 좋았다. Alsike clover와 white clover는 종자는 적으나 유식물 활력은 좋은 편이었는데 이들 荳科는 초기에 빨리 잎을 전개하였으며 비교적 광합성율도 높았다. 반면 lespedeza는 종자는 무겁지만 유식물 활력은 매우 불량하였는데, 이것은 낮은 광합성 면적의 증가와 낮은 광합성율에 기인되었다.

I. INTRODUCTION

Many investigators have shown that larger seeds produce vigorous seedlings associated with greater reserve carbohydrate storage in the large seeds (Beveridge and Wilsie, 1959; Black, 1956). Black(1956), however, indicated that the quantity of reserve carbohydrate available upon emergence might have little or no influence on subsequent plant growth and that the significance of seed size lay in the fact that larger seeds produced seedlings with larger cotyledon and leaf areas.

Photosynthesis by forage legume cotyledons is critically important for normal seedling development. Williams et al. (1968) and Machado et al. (1974) reported that cotyledons of subclover (*Trifolium subterraneum* L.) were decisively important as photosynthetic organs. Lovell and Moore (1970) also stressed the importance of cotyledons of red clover (*Trifolium pratense* L.). Cooper and Fransen (1974) reported that first leaf formation and expansion of sainfoin (*Onobrychis viciifolia* Scop.) seedling depended on cotyledonary photosynthesis. Shibles and MacDonald (1962) presented the importance of photosynthetic area of birdsfoot trefoil cotyledons for early seedling growth, and that photosynthetic rate of cotyledons was equal to that of leaves. In this study, sequential cotyledon size attached to the plant, initial leaf development, and photosynthetic ability of some important forage legumes were compared to know the seedling characteristics of them.

Contributions from the Korea Science and Engineering Foundation, Daejeon, Korea, and the Missouri Agricultural Experiment Station, University of Missouri, Columbia, MO 65211 U.S.A. are acknowledged.
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Ⅱ. MATERIALS AND METHODS

Seeds of alfalfa(*Medicago sativa* L.), alsike clover (*Trifolium hybridum* L.), red clover (*Trifolium partense* L.), white clover(*Trifolium repens* L.), birdsfoot trefoil (*Lotus corniculatus* L.), and lespedeza(*Lespedeza striata*) with 100-seed weight of 227, 80, 182, 71, 90, and 131 mg were used.

Seedlings germinated at 20℃ were planted to plastic pots, 10 cm wide by 15 cm deep, filled with a soil mixture of Mexico silt loam, peat, and sand in a 2:1:1 ratio. Two seedlings were planted per pot, and pots were placed at random distribution in a growth chamber with a 14 hour photoperiod at 20℃. Relative humidity was maintained around 70% with light intensity of 500 $\mu E \cdot m^{-2} \cdot s^{-1}$ by cool-white flurorescent and incandescent bulbs. Most seedlings were emerged in two days except those of lespedeza which were emerged in three days. Seedlings were watered during experiment period with 50 ml of Hoagland's complete nutrient solution weekly and distilled water when needed.

Sequential development of cotyledon size attached to the plant was measured with compass and read with ocular magnifier to nearest 0.1 mm from emergence to senescence at 2 days interval with 10 replications of each species. The ratio of cotyledon length to width was almost constant within species and time. Cotyledon width could be measured with relative accuracy and calculated with the formula by Hur et al. (1995). Speed of cotyledon expansion was measured by the area increase per unit of area per unit of time (cm^2/cm^2/day) and leaf development was measured by the method of Carlson (1966). Every week seedlings were harvested to measure net photosynthetic rate, cotyledon area, leaf area, and seedling dry weight.

Ⅲ. RESULTS AND DISCUSSION

As shown in Fig. 1, most cotyledons expanded rapidly during first one week, then expanded slightly until maximum size were reached at near 3 weeks after emergence. After 3 weeks their cotyledons entered senescence and began to fall. Seedlings from large seeds produced a greater cotyledons except lespedeza. And there were divergences in speed of cotyledon expansion which were independent of initial cotyledon area. Maximum cotyledon area of red clover, alfalfa, alsike clover, white clover, and birdsfoot trefoil were 9.5, 6.5, 6.4 6.3, and 4.5 times larger compared to the area at emergence, while cotyledon area of lespedeza expanded only 2.9 times more than the area at emergence. One mg of lespedeza seed produced cotyledon area of 0.15 cm^2, but other species produced two or three times more cotyledon area than lespedeza. Amounts of epigeous cotyledon expansion varies among species (Marshall and Kozlowski, 1977; Lovell and Moore, 1970), up to fifty-fold in cucumber (Lovell and Moore, 1970). Hur et al. (1995) also indicated that cotyledons of trefoil species expanded rapidly during first one week, then the rate of expansion declined and entered senescence 3 weeks after emergence.

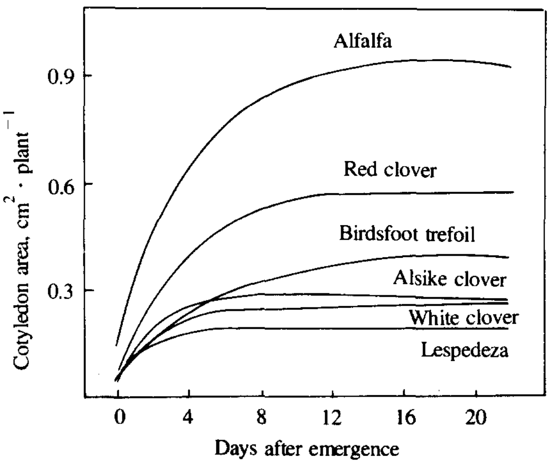

Fig. 1. Cotyledon area expansion of six forage legumes.

Table 1 shows that larger seeds produced greater cotyledon area and speed of cotyledon expansion was closely related with seedling growth. Photosynthetic rate of seedlings was also correlated with seedling vigor and species with large leaf area were vigorous during seedling stage. Alfalfa seedlings produced first leaf earlier and more leaves rapidly than the other species (Table 2). Birdsfoot trefoil and lespedeza produced their first leaf slowly. Although red clover produced fewer leaves than birdsfoot trefoil, its leaf area per plant was more than 3 times wider than birdsfoot trefoil (Fig. 2).

The development of photosynthetic area followed a similar relationship as that of seedling growth (Fig. 2, and 3). Seed weight of lespedeza was much heavier than alsike clover or white clover, however, its cotyledon and leaf area development were very poor with less seedling vigor. Birdsfoot trefoil expanded cotyledon area more than alsike clover or white clover, but it produced first leaf slowly and less leaf area showing poor seedling vigor. Alfalfa and red clover produced photosynthetic area earlier and more leaves with heavier seed weights than the other species. Alsike and white clover had small cotyledons but they showed good seedling vigor with early leaf development and good photosynthetic ability.

Consequently, the cotyledons with a high expansion factor had high photosynthetic ability, whereas cotyledons with low cotyledon expansion rate were less well adapted for photosynthesis as indicated by Lovell and Moore (1970). Earlier onset of leaf production and earlier leaf development contributed to the vigorous seedling growth, and photosynthetic area which was not attributed to seed size was important factor for initial seedling growth.

Table 1. Correlation coefficients among seed weight, cotyledon area, leaf area, speed of cotyledon expansion, photosynthetic rate, and seedling dry weight

	Cotyledon area	Leaf area	Speed of cotyledon expansion	Photosynthetic rate	Seedling dry weight
Seed weight	0.883**	0.465	0.825*	0.465	0.651
Cotyledon area		0.696	0.856*	0.733	0.859*
Leaf area			0.727	0.607	0.935**
Speed of cotyledon expansion				0.864*	0.919**
Photosynthetic rate					0.814*

*, ** Statistically significant at 0.05 and 0.01 probability level, respectively.

Table 2. Initial leaf production of six forage legumes(number of leaves).

Species	Days after emergence								
	4	6	8	10	12	14	16	18	20
Alfalfa	0.5	1.0	1.2	1.7	2.3	3.3	3.8	4.4	5.2
Alsike clover	0.4	1.0	1.2	1.7	2.1	2.8	3.3	3.7	4.9
White clover	0.3	0.7	0.9	1.5	1.9	2.4	3.1	3.6	4.7
Red clover	0.0	0.6	1.0	1.2	1.5	1.9	2.2	2.5	3.0
Birdsfoot trefoil	0.0	0.2	0.8	1.2	1.9	2.3	3.3	3.7	4.4
Lespedeza	0.0	0.3	0.5	0.9	1.1	1.2	1.4	1.6	2.1

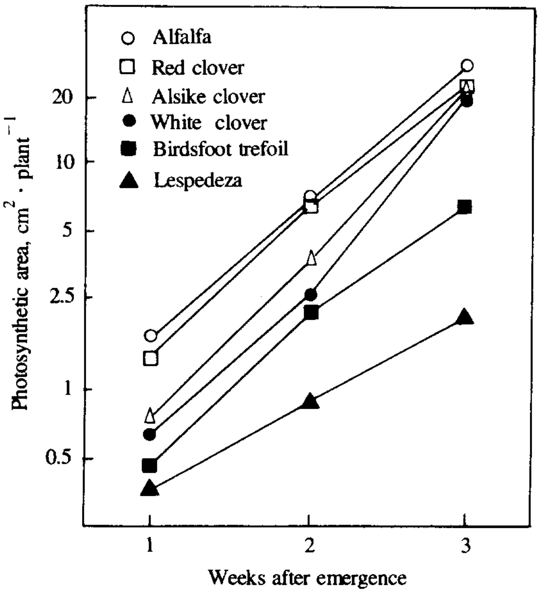

Fig. 2. Logarithmic plot of photosynthetic area development in six forage legumes.

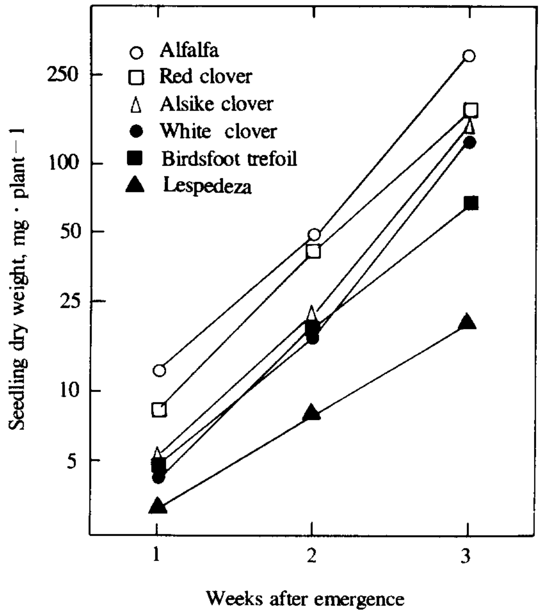

Fig. 3. Logarithmic plot of seedling dry weight accumulation in six forage legumes.

Ⅳ. SUMMARY

Cotyledon and leaf development of six important forage legumes were compared to study their contribution to the seedling growth, Cotyledons of forage legumes expanded their size rapidly during one week after emergence, then slightly expanded until maximum size was reached and entered senescence. Larger seeds produced greater cotyledon area, and speed of cotyledon expansion was closely associated with seedling growth. Earlier onset of leaf production and earlier leaf development were major determinant factor for initial seedling growth. Alfalfa and red clover which have larger seeds were good in seedling vigor with larger photosynthetic area. Alsike clover and white clover with small seeds showed also good seedling vigor, as they developed leaves early with relatively high photosynthetic rate. On the other hand, though lespedeza has heavy seeds, its seedling vigor was very poor with slow photosynthetic area development and low photosynthetic rate.

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