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Dry Matter Distribution during Seedling Development in Soybean

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콩의 幼苗期間 中 乾物重의 分配

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ABSTRACT : To obtain the basic information about the translocation of seed reserves of soybean[*Glycine max*(L.) Merrill] cultivars, 'Hill', 'Paldalkong' and 'Jangyeobkong', the dry matter changes of emerging organs during the germination and seedling development were observed at the research farm of College of Natural Resources, Korea University, on May 26, June 5 and June 14. Mean fresh weight, dry weight and moisture content of three soybean cultivars were increased until the V2 stage in all seedling parts except cotyledons. Cotyledon dry weight was continuously decreased and the decreased amount at the V2 stage was about 80% of the cotyledon dry weight at the germination stage. Structural component of cotyledons was 22.2% of the cotyledon dry weight at the germination stage. Metabolic components of cotyledons were markedly decreased until V2 stage, and about 91% of cotyledon metabolic components at germination stage was utilized. However, those of whole seedling were increased after the V1 stage. Therefore, it appeared that role of cotyledons as nutrient supplier for germination and seedling growth was important until the V1 stage especially.

Key words : Soybean[*Glycine max*(L.) Merrill], Seedling development, Dry weight, Moisture content, Structural component, and Metabolic component.

Seed germination and seedling growth of crop plant in the field is one of the important factors for crop canopy establishment. Its improvement can be achieved by the sufficient digestion of seed reserves and the translocation of digested material to emerging organs and continous seedling growth.

Whalley et al.[16] divided the growth of a grass seedling into heterotrophic stage, transition stage, and autotrophic stage, and Loomis[8] postulated the theory about transport mechanism of corn seed reserves and assimilates. During the early stage of seedling growth, dry weight of seedling was slightly decreased at the early time but increased after this time. In the seedling parts, dry weight of cotyledons was decreased but those of roots, stem, and leaves were increased[2,9,10]. It was reported that significant physiological changes during seed

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germination and seedling development were the loss of dry matter by metabolic respiration, the digestion and mobilization of seed reserves to axis growth, and the dry matter increase by photosynthesis at the emerging leaves[3,6,11,12,14,15,18]. The soybean fresh cotyledons have a function as storage reserves, protein, oil, soluble sugar, and starch. The mobilization patterns of these reserves have been characterized[4,5]. However little attention has been paid to how specific storage reserves related to the dry matter increase in the seedling.

Data referenced about these concerns were partially reported from foreign cultivars, but it thought that basic research to improved soybean cultivars in Korea should be preceded for the exact study on the cultivars[7,13], although the result might be similar to those from foreign. To obtain the basic information about the translocation of seed reserves of soybean, it is important to visualize energy balance of emerging organs by measuring quantitative changes of seed reserves in each seedling part during the germination and seedling growth. The objective of this study was to examine the dry matter distributions of emerging organs during seedling development in soybeans cultivated in Korea.

MATERIALS AND METHODS

Seedling developments of three soybean [*Glycine max*(L.) Merrill] cultivars(Table 1), 'Hill', 'Paldalkong' and 'Jangyeobkong', were observed at the research farm of College of Natural Resources, Korea University, on May 26, June 5 and June 14. One to four hundred seeds were planted in washed sand soil using plastic box(55×35×15cm) with holes. Completely randomized design was used with three replications per planting. Each seed bed was watered fully without stress. Temperatures during experiment from May 26 to July 6 were ranged minimum of 11.8℃ to maximum of 33.0℃. Samples were taken to each developing stage(Table 2) and seperated to roots, cotyledons, stems, unifoliolate and trifoliolate leaves. Fresh weight of each seedling part was determined. Each sample was dried at 70℃ oven for 48 hours and grinded with Udy cyclon miller(0.5mm screen). Nitrogen content was measured by boric acid modification Micro-Kjeldahl me-

Table 1. The seed morphological characteristics and chemical compositions of three soybean cultivars

Cultivars	Seed coat colour	Hilum colour	Cotyledon colour	Seed shape	One hundred seed weight (g)	Protein content (%)	Oil content (%)	Sugar content (%)	Starch content (%)
Hill	Yellow	Brown	Yellow	Spherical	11.6	35.5	21.3	11.1	3.1
Paldalkong	Yellow	Black	Yellow	Long spherical	13.4	40.8	19.2	9.1	3.2
Jangyeob-kong	Yellow	Yellow	Yellow	Spherical	23.2	38.8	21.4	10.3	3.5

Table 2. Number of days required from one stage to the next of the vegetative stages in three soybean cultivars

Stage	Average number of days	Range in number of days	Number of seeds or plants	Description
Seed	0	0	100	Seed.
Germination	1	1	100	1 day after imbibition
VE (Emergence)	6	5~6	300	Cotyledons above the soil surface
VC (Cotyledon)	3	2~5	400	Unifoliolate leaves unrolled sufficiently so the leaf edges are not touching
V1 (First node)	7	6~8	400	Fully developed leaves at unifoliolate nodes
V2 (Second node)	6	5~9	400	Fully developed trifoliolate leaf at node above the unifoliolate nodes

thod[1], and multiplied factor 6.25 to obtain protein content. Oil content was determined by Soxhlet method. Sugar and starch contents were determined using Anthrone method[17]. The collected data were analyzed using SAS package.

RESULTS AND DISCUSSION

The observations of fresh weight, dry weight and moisture content were highly significant among soybean cultivars, developing stages and organic parts, and showed the same trends to the increments or decrements in each independent variable(Appendix 1).

The mean fresh weight of each component part during seedling growth stages of three soybean cultivars is shown in Fig. 1 and Table 3. Total fresh weight of whole seedling was linearly increased until the V2 stage. However, cotyledon fresh weight was showed nearly constant for this period.

Mean dry weight of three soybean cultivars was shown at Fig. 2 and Table 4. Total dry weight of whole seedling was slightly

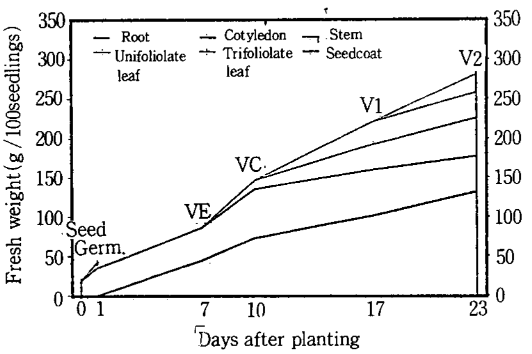

Fig. 1. Mean fresh weight of each component part during the seedling growth stages of three soybean cultivars.

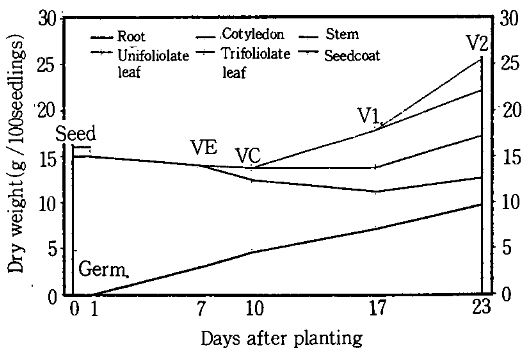

Fig. 2. Mean dry weight of each component part during the seedling growth stages of three soybean cultivars.

Table 3. Fresh weight of each component part during developing vegetative stages of three soybean cultivars

Vegetative stage	Variety	Fresh weight (g / 100 seedlings)						
		Seed	Seedcoat	Root + hypocotyl	Cotyledon	Stem + epicotyl	Unifoliolate leaf	Trifoliolate leaf
Seed	Hill	12.90						
	Paldalkong	14.87						
	Jangyeobkong	25.94						
Germ	Hill	26.99	3.57					
	Paldalkong	31.50	4.92					
	Jangyeobkong	52.11	5.60					
VE	Hill			37.39	29.84			
	Paldalkong			40.21	34.14			
	Jangyeobkong			54.09	62.84			
VC	Hill			58.42	42.42	10.08		
	Paldalkong			64.92	50.92	9.65		
	Jangyeobkong			95.69	93.85	11.88		
V1	Hill			80.66	33.47	28.87	24.27	
	Paldalkong			93.46	49.82	23.81	23.88	
	Jangyeobkong			132.79	89.59	45.00	39.39	
V2	Hill			108.83	18.88	42.47	26.55	21.93
	Paldalkong			122.11	42.39	35.01	26.93	22.17
	Jangyeobkong			165.41	73.22	67.83	45.34	24.46

Table 4. Dry weight of each component part during developing vegetative stages of three soybean cultivars

Vegetative stage	Variety	Dry weight (g / 100 seedlings)						
		Seed	Seedcoat	Root + hypocotyl	Cotyledon	Stem + epicotyl	Unifoliolate leaf	Trifoliolate leaf
Seed	Hill	11.57						
	Paldalkong	13.41						
	Jangyeobkong	23.19						
Germ	Hill	10.75	0.88					
	Paldalkong	13.02	1.11					
	Jangyeobkong	21.15	1.33					
VE	Hill			2.28	7.54			
	Paldalkong			2.42	8.49			
	Jangyeobkong			3.68	17.62			
VC	Hill			3.57	5.17	1.23		
	Paldalkong			3.84	6.00	1.14		
	Jangyeobkong			6.31	12.54	1.57		
V1	Hill			5.81	2.38	2.42	3.30	
	Paldalkong			6.46	3.48	2.18	3.45	
	Jangyeobkong			8.90	6.27	3.45	5.51	
V2	Hill			8.50	1.76	4.57	4.06	3.22
	Paldalkong			9.16	2.64	3.42	4.07	3.25
	Jangyeobkong			11.51	4.40	5.91	6.25	3.75

decreased until the VC stage but increased after this stage. Cotyledon dry weight decreased continuously until the V2 stage and the decreased amount was about 80% of the cotyledon dry weight at the germination stage. This result was consistent with the previous studies[2,4,9,10]. Brown & Huber[4,5] reported that the dry weight loss of early seedling was due to metabolic respiration and the dry weight increase after this time was due to stored reserve mobilization and carbon supplied via cotyledonary photosynthesis. Also, they suggested that cotyledonary photosynthesis might be of greater significance than previouslv indicated.

Moisture content changes were similar to those of fresh weight and also increased until the V2 stage in all parts except the cotyledons(Fig. 3 and Table 5).

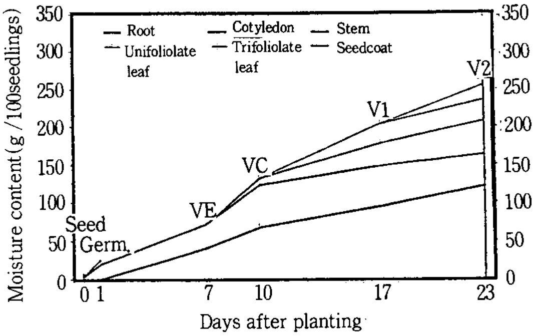

Fig. 3. Mean moisture content of each component part during the seedling growth stages of three soybean cultivars.

Quantitative changes of structural and metabolic components of whole seedling showed on Fig. 4 and 5. Structural components were calculated by substracting metabolic components from total dry weight,

Table 5. Moisture content of each component part during developing vegetative stages of three soybean cultivars

Vegetative stage	Variety	Moisture content(g /100 seedlings) Seed	Seedcoat	Root + hypocotyl	Cotyledon	Stem + epicotyl	Unifoliolate leaf	Trifoliolate leaf
Seed	Hill	1.32						
	Paldalkong	1.46						
	Jangyeobkong	2.75						
Germ	Hill	16.24	2.68					
	Paldalkong	18.48	3.81					
	Jangyeobkong	30.95	4.27					
VE	Hill			22.26	35.11			
	Paldalkong			25.65	37.79			
	Jangyeobkong			45.22	50.41			
VC	Hill			37.24	54.84	8.85		
	Paldalkong			44.92	61.07	8.50		
	Jangyeobkong			81.31	89.37	10.31		
V1	Hill			31.09	74.85	26.44	20.97	
	Paldalkong			46.34	87.00	21.63	20.43	
	Jangyeobkong			83.31	123.89	41.55	33.88	
V2	Hill			17.12	100.33	37.89	22.49	18.71
	Paldalkong			39.75	112.94	31.58	22.86	18.92
	Jangyeobkong			68.82	153.89	61.91	39.09	20.71

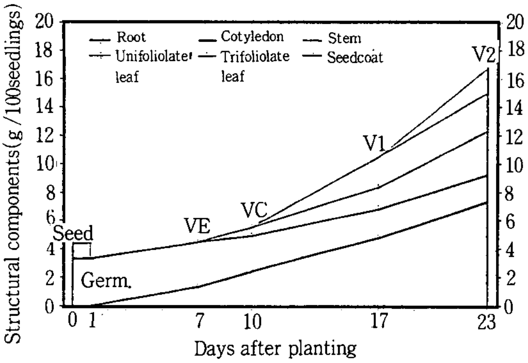

Fig. 4. Mean structural component of each part during the seedling growth stages of three soybean cultivars.

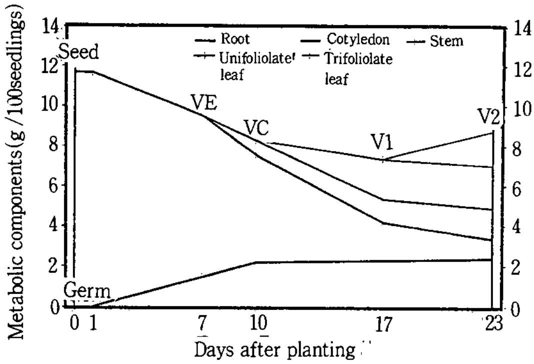

Fig. 5. Mean metabolic components(total of protein, oil, sugar and starch components) of each component part during the seedling growth stages of three soybean cultivars.

and metabolic components were indicated by the summation of protein, oil, sugar, and starch contents as shown in Table 6. Total structural components of whole seedling were increased steeply with seedling growth. But structural components of cotyledons were slightly decreased. Amount of cotyledon structural components was 22.2%

Table 6. Metabolic component(total of protein, oil, sugar, and starch) of each component part during developing vegetative stages of three soybean cultivars

Vegetative stage	Variety	Metabolic component (g /100 seedlings)					
		Seed	Root + hypocotyl	Cotyledon	Stem + epicotyl	Unifoliolate leaf	Trifoliolate leaf
Seed	Hill	8.20					
	Paldalkong	9.68					
	Jangyeobkong	17.13					
Germ	Hill	8.44					
	Paldalkong	10.03					
	Jangyeobkong	16.44					
VE	Hill		1.13	5.24			
	Paldalkong		1.38	6.10			
	Jangyeobkong		1.94	12.77			
VC	Hill		1.55	3.25	0.65		
	Paldalkong		1.91	4.27	0.62		
	Jangyeobkong		2.94	8.60	0.87		
V1	Hill		1.60	0.92	0.90	1.51	
	Paldalkong		2.04	1.79	0.98	1.70	
	Jangyeobkong		3.23	3.06	1.54	2.69	
V2	Hill		1.69	0.43	1.21	1.55	1.49
	Paldalkong		2.19	0.89	1.20	1.75	1.60
	Jangyeobkong		3.29	1.62	2.27	2.93	2.01

of the cotyledon dry weight at the germination stage. Therefore, it appeared that structural components of cotyledons were not nearly utilized as nutrient material for the development of emerging organs.

On the other hand, metabolic components of whole seedling were decreased until V1 stage and increased after the V1 stage. This decrease until V1 stage was due to the decrease of cotyledon metabolic components. Metabolic components of cotyledons were markedly decreased until V2 stage, and about 91% of cotyledon metabolic components at germination stage was utilized(Fig. 5 and Table 6). The increase of whole metabolic components at the V2 stage was thought to be come from the carbon assimilation of unifoliolate leaves emerged at VC stage[4]. Therefore, it appeared that role of cotyledons as nutrient supplier by mobile reserves and carbon assimilation during seedling growth was important until the V1 stage especially.

적 요

콩[*Glycine max* (L.) Merrill] 종자내 저장양분의 전류에 대한 기초자료를 얻기 위하여, 콩 품종 '힐콩', '팔달콩', 및 '장엽콩'의 발아와 초기 유묘발달단계 동안 유묘의 각 기관별 건물중의 변화를 고려대학교 자연자원대학 부속농장에서 5월 26일, 6월 5일, 및 6월 14일에 각각 조사하였다. 콩 세품종의 평균 생체중, 평균 건물중 및 평균 수분함량은 자엽부위를 제외한 유묘의 모든 기관에서 V2단계까지 증가하였다. 자엽의 평균 건물중은 V2단계까지 계속 감소하였으며, 발아단계시 자엽 건물중의 약 80%가 감소되었다. 발아단계에서 자엽의 구조성분은 자엽 건물중의 약 22.2%였다. 자엽의 대사성분은 V2단계까지 급격히 감소하였으며, 발아단계시 자엽 대사성분의 약 91%가 이용되었다. 그러나 전체 유묘의 대사성분은 V1단계 이후에 증가하였음을 보였다. 따라서 종자의 발아와 유묘발달을 위하여 종자내 저장양분의 이동 및 탄소동화작용에 의한 양분 공급자로서 자엽의 역할은 특히, V1단계까지 중요한 것으로 나타났다.

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Appendix 1. Analysis of variance of dependent variables in soybean seedlings by cultivars, stages, and component parts

Dependent variable	Source	DF	Sum of square	Mean square	F value
Fresh weight	Cultivars	2	22965.72	11482.86	10.27**
	Stages	5	26718.69	5343.74	4.79**
	Parts	6	101020.26	16836.71	27.43**
Dry weight	Cultivars	2	430.68	215.34	9.70**
	Stages	5	1176.84	235.37	13.40**
	Parts	6	2221.45	370.24	35.15**
Moisture content	Cultivars	2	17111.98	8555.99	8.00**
	Stages	5	37028.15	7405.63	7.74**
	Parts	6	101134.67	16855.78	32.18**

*, ** : Significant at the 0.05 and 0.01 levels of error probability, respectively.