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Effects of Source-Sink Alteration on Dry Matter Accumulation and Protein Content in Soybean

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콩에서 Source-Sink變更이 乾物蓄積과 蛋白質含量에 미치는 影響

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ABSTRACT : Effects of leaf and pod removal on changes in dry weight and protein content of soybean [*Glycine max* (L.) Merr.] cultivar "Hwangkeumkong" were measured at the research farm of Korea University in 1992. The upper 40% and lower 60% of leaves and pods were subjected to treatments at the growth stage of beginning pod(R3). Leaf dry weight of lower part was increased by upper leaf-lower pod removal, but seed dry weight of upper part was decreased. The upper leaf-lower pod removal also increased stem dry weight and decreased upper pod dry weight. Protein content was higher in lower leaves than upper leaves. Seed protein contents were decreased both upper leaf-lower pod removal and lower leaf-upper pod removal treatments. The upper leaf-lower pod removal showed the highest leaf and the lowest seed protein quantities among the five treatments. These results indicated that protein sources were moved from lower to upper parts but weak in remobilization from leaves for the long distance translocation during the reproductive growth period of soybean plants.

Key words : Soybean(*Glycine max* L.), Leaf removal, Pod removal, Dry weight, Protein content, Seed yield.

Seed yield of soybeans [*Glycine max* (L.) Merrill] is dependent upon photosynthesis by the leaves and translocation of assimilates to the seeds[5]. During vegetative growth of soybean plants, most of the photosynthate is not translocated more than one or two nodes[19]. However, during the reproductive growth, long distance translocation from one branch to the other is necessary to support the growth of the filling seeds[8], since the efficiency of assimilate production and translocation by the source leaves increased in response to increased assimilate demand[18].

McAlister and Krober[14] reported that defoliation of soybean plants caused reduction in all measures of yield. Removal of two-thirds of the leaf area reduced the weight per seed near the end of the filling period[4]. Ciha and Brun[1] found that rates of dry matter accumulation were greater in control plants

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than in depodded plants, but total dry matter accumulation at the time of pod maturity was similar in control and depodded plants[11]. Hicks and Pendleton[10] concluded that the yield per plant was reduced with all floral bud removals from either the upper or lower two-thirds of the plant. The determinate cultivars had significantly greater yield reduction from 100% defoliation than did the indeterminate cultivars[7], and the yield loss was primarily attributed to a reduction in number of pods per plant[9]. Sixty-six percent defoliation reduced and 80% depodding increased cotyledon cell number of soybean seeds[6].

Protein is the major component in soybean seeds[3]. Protein contents of the seeds were increased by 66 and 80% depoddings[14,16]. However, partial depodding did not affect on protein contents of the seeds[10,13,17]. Depodding treatments increased leaf protein contents[2,12,15]. Eighty percent defoliation decreased protein content in seeds[14]. This study was conducted to examine the effects of leaf and pod removal to upper and lower parts on the changes in dry matter accumulation and on the contents of protein in leaves and seeds of soybean plants.

Materials and Methods

Seeds of determinate soybean cultivar (Hwangkeumkong) were planted at the Research Farm of Korea University near Seoul on May 22, 1992. The soil type was Baegsan silty loam. The experimental design was a randomized complete block with three replications. Planting density was 70×20 cm with two seeds. Plot size was 4m length with 8 rows. The cultivar was thinned to one plant at growth stage V2. Each plant of upper 40% and lower 60% based on pod numbers was tagged with plastic string at the growth stage of R3. Five treatments were 1. Control, 2. Upper leaf-pod removal, 3. Lower leaf-pod removal, 4. Upper leaf-lower pod removal, and 5. Lower leaf-upper pod removal (Fig. 1). Newly emerged leaves and pods were removed at weekly intervals.

Five soybean plants were sampled at the growth stage of R5, R6, R7 and R8 in each treatment. During the sampling, fallen leaves and pods, and aborted pods were discarded. Collected samples were divided into leaves (including petioles), stems, pods and seeds in each upper and lower parts. Fresh weights and dry weights after drying 75℃ oven for 48 hours were observed in each treatment combination. The dryed leaves and seeds were analyzed in the laboratory. Protein content was obtained multipling by factor 6.25 following Boric acid modification micro-Kjeldahl method. The collected data were analyzed using SAS package.

Results and Discussion

Stem dry weight of five soybean plants was decreased with the upper 40% leaf-pod removal (Treatment 2) and lower 60% leaf-pod removal (Treatment 3) which designed to short distance translocation as shown in Table 1. However, the upper 40% leaf-lower 60% pod removal (Treatment 4) increased in lower part of stem dry weight as compared to lower 60% leaf-upper 40% pod removal (Treatment 5), which indicated long distance translocation. Leaf dry weight of treatment 4 was the highest among the treatments and that of treatment 5 was

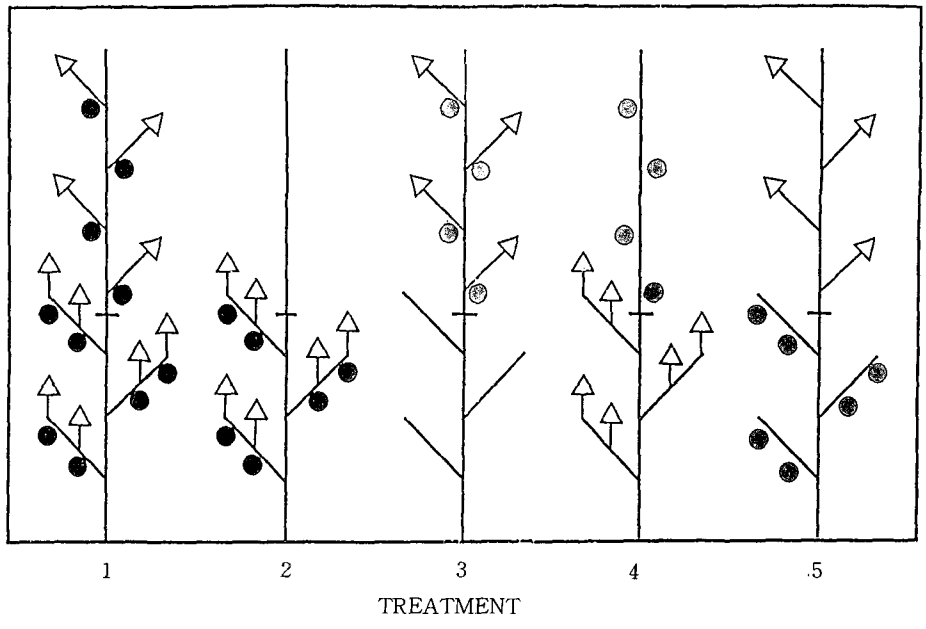

Fig. 1. Leaf and pod removal methods of five treatments.

Table 1. Stem dry weight of reproductive growth stage in five treatments of soybean plants

Treatment	Position	Growth stage					Proportion	
		R5	R6	R7	R8	Mean	Upper	Lower
		·····g/5plants·····					···%···	
1. Control	Upper	28.9	34.6	37.5	26.1	31.8	100	–
	Lower	72.1	82.6	82.0	60.1	74.2	–	100
2. Upper leaf -	Upper	19.9	18.4	20.6	18.8	19.4	61	–
pod removal	Lower	65.9	76.3	70.8	63.7	69.2	–	93
3. Lower leaf -	Upper	31.4	29.8	27.5	18.2	26.7	84	–
pod removal	Lower	65.3	66.7	58.4	48.7	59.8	–	81
4. Upper leaf -	Upper	29.2	27.5	21.9	18.6	24.3	76	–
lower pod removal	Lower	89.9	93.9	83.2	67.4	83.6	–	113
5. Lower leaf -	Upper	28.7	40.6	31.9	24.7	31.5	99	–
upper pod removal	Lower	73.2	82.4	61.0	61.9	69.6	–	94
Mean	Upper	27.6	30.2	27.9	21.3	26.7		
	Lower	73.3	80.4	71.1	60.4	71.3		

$LSD_{0.05}$ A : 8.8(between growth stage) E : 4.1(between growth stage*position)
B : 6.5(between treatment) F : 4.1(between treatment*position)
C : 2.1(between position)
D : 13.1(between growth stage*treatment)

higher compared to the control(Table 2). The lowest pod and seed dry weights were found in treatment 4 among the treatments (Table 3 and 4). McAlister and Krober[14] observed that 80% depodding reduced seed yield but increased stem weight. Schonbeck

Table 2. Leaf dry weight of reproductive growth stage in five treatments of soybean plants

Treatment	Position	Growth stage				Proportion	
		R5	R6	R7	Mean	Upper	Lower
		·····g /5plants·····				·····%·····	
1. Control	Upper	60.9	70.0	43.4	58.1	100	–
	Lower	72.8	81.5	50.8	68.4	–	100
2. Upper leaf - pod removal	Lower	78.1	91.8	38.9	69.6	–	102
3. Lower leaf - pod removal	Upper	68.4	73.3	32.5	58.1	100	–
4. Upper leaf - lower pod removal	Lower	111.6	117.9	73.1	100.9	–	148
5. Lower leaf - upper pod removal	Upper	67.7	92.4	38.8	66.3	114	–
Mean		76.6	87.8	46.3			

$LSD_{0.05}$ A : 21.7(between growth stage)
B : 14.7(between treatment)
C : 25.5(between growth stage*treatment)

Table 3. Pod dry weight of reproductive growth stage in five treatments of soybean plants

Treatment	Position	Growth stage					Proportion	
		R5	R6	R7	R8	Mean	Upper	Lower
		·····g /5plants·····					·····%·····	
1. Control	Upper	22.2	34.0	35.4	31.0	30.7	100	–
	Lower	35.1	41.2	48.3	42.9	41.9	–	100
2. Upper leaf - pod removal	Lower	32.5	52.9	56.3	49.1	47.7	–	114
3. Lower leaf - pod removal	Upper	25.5	39.6	43.2	38.8	36.8	120	–
4. Upper leaf - lower pod removal	Upper	17.8	22.0	21.3	19.5	20.1	66	–
5. Lower leaf - upper pod removal	Lower	29.3	37.4	37.2	41.1	36.3	–	87
Mean		27.1	37.8	40.3	37.1			

$LSD_{0.05}$ A : 5.6(between growth stage)
B : 4.8(between treatment)
C : 9.6(between growth stage*treatment)

et al.[17] reported that removal of about 40% of the pods significantly shifted dry matter partitioning in favor of vegetative tissues. When all floral buds were removed from either the upper or lower two-thirds of the plant, the seed yield per plant was reduced[10]. Gent[8] indicated that long distance translocation and partitioning of carbon and nitrogen might limit seed yields of soybeans.

Protein contents of leaf and seed on upper and lower parts of soybean plants in five treatments are shown in Table 5 and 6. Leaf

Table 4. Seed dry weight of reproductive growth stage in five treatments of soybean plants

Treatment	Position	Growth stage				Proportion	
		R5	R6	R7	Mean	Upper	Lower
		·····g/5plants·····				·····%·····	
1. Control	Upper	9.3	40.5	73.3	41.1	100	–
	Lower	20.2	64.9	109.0	64.7	–	100
2. Upper leaf - pod removal	Lower	14.5	65.9	127.0	69.1	–	107
3. Lower leaf - pod removal	Upper	8.4	42.7	88.1	46.4	113	–
4. Upper leaf - lower pod removal	Upper	5.8	27.7	41.6	25.0	61	–
5. Lower leaf - upper pod removal	Lower	13.2	49.6	82.2	48.4	–	75
Mean		11.9	48.6	86.9			

$LSD_{0.05}$ A : 7.4(between growth stage)
B : 9.9(between treatment)
C : 19.7(between growth stage*treatment)

Table 5. Leaf protein content of reproductive growth stage in five treatments of soybean plants

Treatment	Position	Growth stage				Proportion	
		R5	R6	R7	Mean	Upper	Lower
		·····g/5plants·····				·····%·····	
1. Control	Upper	20.6	19.7	12.0	17.4	100	–
	Lower	20.4	20.6	15.6	18.9	–	100
2. Upper leaf - pod removal	Lower	21.5	21.4	15.3	19.4	–	103
3. Lower leaf - pod removal	Upper	20.9	19.5	16.3	18.9	109	–
4. Upper leaf - lower pod removal	Lower	20.2	20.6	17.6	19.4	–	103
5. Lower leaf - upper pod removal	Upper	20.8	20.2	15.2	18.7	107	–
Mean		20.7	20.3	15.4			

$LSD_{0.05}$ A : 0.9(between growth stage)
B : 0.5(between treatment)
C : 0.9(between growth stage*treatment)

protein contents were higher in lower part than that of upper part(Table 5), but treatment 3 and 5 showed higher leaf protein content in upper parts compared to control. Lauer and Shibles[12] found that leaf protein content was increased in the later period of growth by pod removal. Seed protein contents were increased from growth stage R5 to R8(Table 6). Seed protein contents of upper part in treatment 4 and lower part in treatment 5 were decreased as compared to the other treatments. Openshaw et al.[16]

Table 6. Seed protein content of reproductive growth stage in five treatments of soybean plants

Treatment	Position	Growth stage				Proportion	
		R5	R6	R7	Mean	Upper	Lower
		·····g/5plants·····				·····%·····	
1. Control	Upper	37.8	40.1	41.1	39.7	100	–
	Lower	37.3	37.9	40.4	38.5	–	100
2. Upper leaf - pod removal	Lower	37.6	39.4	39.1	38.7	–	101
3. Lower leaf - pod removal	Upper	38.6	37.8	40.9	39.1	98	–
4. Upper leaf - lower pod removal	Upper	35.8	36.4	36.9	36.4	92	–
5. Lower leaf - upper pod removal	Lower	35.5	35.2	36.6	35.8	–	93
Mean		37.1	37.8	39.2			

$LSD_{0.05}$ A : 0.6(between growth stage)
B : 0.9(between treatment)
C : 1.8(between growth stage*treatment)

reported that seed protein content was increased by depodding[14,17]. Crafts-Brandner and Egli[2] indicated that deflowering led to decreased leaf protein remobilization. Leaf senescence at the growth stage of R7 was accelerated in treatment 3 and delayed in treatment 5 for a few days, and was prolonged over one week in treatment 4 compared to the control (Data not shown). These results were primarily attributed to carbon and nitrogen compound accumulationsin lower leaves of treatment 4 as reported[2,10,15].

Protein quantities of leaf and seed were calculated from Table 2 and 5, and Table 4 and 6, respectively(Fig. 2). Leaf protein was increased 52% in lower part of treatment 4 and 23% in upper part of treatment 5 compared to the control. However, seed pro-

Table 7. Seed yield, protein content and quantity in five treatments of soybean plants

Treatment	Position	Seed yield	Proportion		Protein content	Protein quantity	Proportion	
		···g/5plants···	·····%·····		···%···	···g/5plants···	·····%·····	
1. Control	Upper	69.0	100	–	42.2	29.1	100	–
	Lower	110.0	–	100	41.6	45.8	–	100
2. Upper leaf - pod removal	Lower	112.0	–	102	40.4	45.2	–	99
3. Lower leaf - pod removal	Upper	83.5	121	–	41.7	34.8	120	–
4. Upper leaf - lower pod removal	Upper	38.9	56	–	39.1	15.2	52	–
5. Lower leaf - upper pod removal	Lower	88.9	–	81	39.0	34.7	–	76

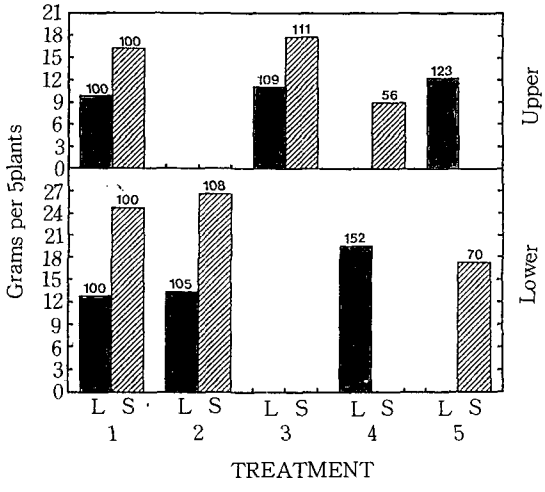

Fig. 2. Mean leaf(L) and seed(S) protein quantities of reproductive growth stage in five treatments of soybean plants.

tein was decreased 44% in upper part of treatment 4 and 30% in lower part of treatment 5. Final seed yield was decreased 44% in upper part of treatment 4 and 19% in lower part of treatment 5 compared to the control(Table 7). Seed protein was also decreased 48% in upper part of treatment 4 and 24% in lower part of treatment 5, which showing the similar trends with Fig. 2.

Long distance translocation of assimilates in soybean plants was different between lower leaves to upper seeds and upper leaves to lower seeds. Downward translocation of assimilates was stronger than upward translocation during the reproductive growth stages. Soybean plants of upper leaf-lower pod removal showed higher stem and leaf and lower pod and seed dry weights than the plants of lower leaf-upper pod removal treatment. Protein which came from roots would be translocated from lower leaves to upper seeds, however it was weak in remobilization from leaves for the long distance translocation. Both upper leaf-lower pod removal and lower leaf-upper pod removal treatments showed higher stem dry weights than the treatments for short distance translocation.

摘 要

콩의 乾物蓄積과 蛋白質轉流에 대한 Source-Sink變更의 效果를 究明하기 위하여 1992年에 高麗大學校 自然資源大學 實驗農場에서 황금콩을 供試品種으로 着莢時期(R3)에 上位 40%, 下位 60%의 葉과 莢을 除去하여 乾物重 및 蛋白質含量의 變化를 調査한 結果는 다음과 같다.

1. 上葉-下莢除去處理에서 下位 葉과 莖 乾物重이 增加하였고, 上位 種實과 莢 乾物重은 減少하였다.
2. 葉의 蛋白質含量은 上位 葉보다 下位 葉에서 높았다.
3. 種實의 蛋白質含量은 上葉-下莢除去와 下葉-上莢除去處理에서 낮았다.
4. 上葉-下莢除去處理에서 葉의 蛋白質含量은 가장 높았고 種實 蛋白質含量은 가장 낮았다.
5. 본 실험의 結果에서 콩의 蛋白質源은 下部에서 上部로 移動하나 生殖生長期間中의 長距離 轉流를 위한 葉 蛋白質의 再移動은 弱한 것으로 나타났다.

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