Korean J Crop Sci 49(4) 279~283(2004)

Comparison of Two Soybean Cultivars in Dry Matter Production and Ecophysiological Characteristics

Jin-Woong Cho*†, Jung-Joon Lee*, and Choong-Soo Kim**

**Honam Agricultural Research Institute, National Institute of Crop Science, RDA, 570-080, Korea*
***Collage of Agriculture & Life Science, Chungnam National University, Daejon 305-764, Korea*

ABSTRACT: This experiment was carried out at paddy field (commercial silty loam soil) in the southwestern Korea. Pungsannamulkong, a determinate growth habit, was a relatively high yielding and late maturing cultivar, and Hannamkong, a semi determinate growth habit, was a relatively low yielding and early maturing cultivar. Seeds were sowed at two plants and with a planting density of 70 × 10 cm on May 26, 2003. Fertilizer was applied prior to planting at a rate of 3.0 - 3.0 - 3.4 g (N - P_2O_5 - K_2O) per m^2 by all basal fertilizations. Experimental design was a randomized complete block with three replications. Seed yield was higher in Pungsannamulkong by 362 g per m^2 than in Hannamkong of 260 g per m^2. Also, the number of pod, number of seed, and number of seed per pod were greater in Pungsannamulkong than in Hannamkong. The number of leaves per m^2 showed similar with two soybean cultivars up to August 24 but thereafter it decreased in Hannamkong. The leaf area up to August 4 increased in Hannamkong higher than in Pungsannamulkong, but after that time, Pungsannamulkong had greater leaf area than Hannamkong. The shoot and leaf dry matter of two soybean cultivars from June 23 to August 4 were similar but thereafter, Pungsannamulkong had a significantly greater than Hannamkong. Crop growth rate (CGR), relative growth rate (RGR) and net assimilate rate (NAR) for Punsannamulkong were relatively higher than Hannamkong but leaf area ratio (LAR) and specific leaf weight (SLW) showed higher in Hannamkong. Most of leaves distributed in the ranges of 80 ~ 90 cm and 60 ~ 70 cm from the soil surface in Punsannamulkong and Hannamkong, respectively. Pods of Punsannamulkong ranged 10 ~ 80 cm from the soil surface and most of pods were distributed at 40 ~ 50 cm. Photosynthetic rate at the flowering stage showed a significant difference between cultivars in the upper most leaf position. There was no significant difference of the photosynthetic rate at 7th leaf at the flowering stage, and the uppermost and 7th leaf position at the seed development stage between two soybean cultivars.

Keywords: soybean, yield, dry matter, RGR, NAR, LAR, CGR, photosynthetic rate

†Corresponding author (Phone) +82-63-840-2147 (E-mail) c5689@hanmail net <Received March 12, 2004>

Researches on photosynthesis and material production of soybeans had been carried out based on the population structure, the light interception characteristics, the photosynthesis of population, and the photosynthesis ability of leaf (Asanome & Ikeda, 1998; Kokubun *et al*, 1988; Sagawa, 1998; Ookawa *et al.*, 1999) Through out these researches, various factors affecting the photosynthesis of leaf were proved theoretically including the plant type that have light interception characteristics to get high population photosynthesis (Dornhoff & Shibles, 1970) Also, net production of soybean population was highly interrelated among plant density, planting type and canopy structure, leaflet orientation, and photosynthetic rate (Ikeda, 2000; Wofford & Allen, 1982).

On the other hand, the relative growth rate (RGR) takes genotypes and species treated with different environmental factors accounted by dividing the absolute growth rate by initial weight of the plant. RGR is a function of the net assimilation rate (NAR) which is an index of the photosynthetic assimilatory capacity of the plant per unit leaf area and the leaf area ratio (LAR) is an index of the leafiness of the plant. The crop growth rate (CGR) which is one of various plant growth analysis methods is used to an index of the dry matter production with NAR and leaf area index (LAI) of the plant (Hunt, 1982, Ookawa *et al.*, 1999)

Therefore, this research was carried out to compare the difference of yield production ability according to leaf area, dry matter, photosynthetic rate, canopy structure, and various growth analysis methods in soybean canopy between Pungsannamulkong (determinate and late maturing growth habit) and Hannamkong (semi determinate and early maturing growth habit).

MATERIALS AND METHODS

This experiment was carried out at a paddy field (commercial silty loam soil) affiliated to the Honam Agricultural Research Institute in the southwestern Korea.

Pungsannamulkong, a determinate growth habit, was relatively high yielding and late maturing cultivars (Suh *et al.*, 1997) and Hannamkong, a semi determinate growth habit, was relatively low yielding and early maturing cultivars (Shin *et al.,* 1995)

Seeds were sowed at two plants and with the planting density of 70 × 10 cm at May 26, 2003. Based on soil test recommendations, fertilizer was applied prior to planting at a rate of 3.0 - 3.0 - 3.4 g (N - P_2O_5 - K_2O) per m^2 by all basal fertilizations. Weeds, diseases and insects were controlled by recommended pesticides.

Experimental design was a randomized complete block with three replications. The main stem length, leaf number per plant, and dry matter of plant samples were obtained on June 23, July 3, July 14, July 24, August 4, August 14, August 24, and September 4. The number of leaves was counted and leaf area was determined by placing the leaf blades through a leaf area meter (LI - COR Li - 3100, USA).

The photosynthesis was measured the uppermost, fully expanded, terminal leaf and the 7th leaves from base in main stem was measured using portable photosynthesis measuring device (LCA - 4, UK) at flowering (R1 by Fehr *et al.,* 1971) and seed development stage (R5) Measurements were taken from 9 : 30 in the morning to 2 : 30 in the afternoon with six replications of measurements per each cultivar. The light intensity used to measure the photosynthesis was in the range of 1700 ~ 2000 μmol m^{-2} s^{-1} photosynthetically active radiation (PAR). The CO_2 concentration was 330 ~ 370 ppm and the flow rate of the air was 400 ml min^{-1}

RGR, NAR, LAR, CGR, and SLW were derived from following equations (Hunt, 1982) Where W, T, and LA represent weight (g), time (day), and leaf area (m^2), respectively.

$$\mathrm{RGR}\ (\mathrm{mg\ g^{-1}\ d^{-1}}) = 1/W \times \partial W/T,$$
$$\mathrm{NAR}\ (\mathrm{g\ cm^{-2}\ d^{-1}}) = 1/LA \times \partial W/T,$$
$$\mathrm{LAR}\ (\mathrm{cm^{-2}\ g^{-1}}) = LA / W,$$
$$\mathrm{CGR}\ (\mathrm{g\ m^{-2}\ d^{-1}}) = \partial W/\partial T,$$
$$\mathrm{SLW}\ (\mathrm{g\ cm^{2}}) = 1/2\ (LA_2 / W_2 + LA_1 / W_1)$$

RESULTS

Yield and yield components

Yield and yield components of two soybean cultivars were shown in Table 1. The seed yield was greater in Pungsannamulkong by 362 g per m^2 than in Hannamkong. Also, the number of pods per plant, number of seeds, and number of seeds per pod were higher in Pungsannamulkong than in Hannamkong. The seed weight, however, was higher in Hannamkong than in Pungsannumkong.

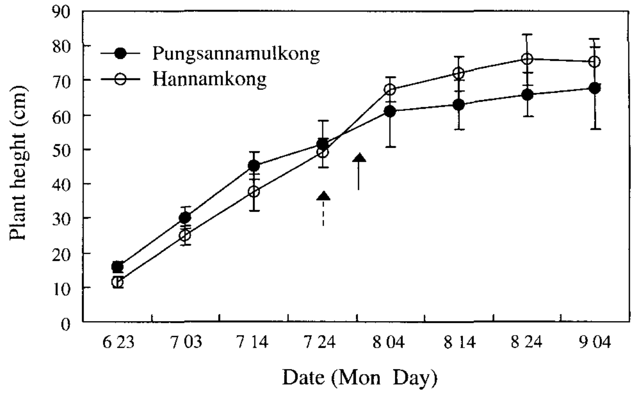

Fig. 1. Change of plant height of two soybean cultivars after emergence Dot and line arrow mark indicate the flowering date in Hannamkong and Pungsannamulkong, respectively. Values are the mean ± SE (n = 10)

Growth traits

Fig. 1 showed the main stem length of two soybean cultivars after emergence. Main stem length was longer in Pungsannamulkong than in Hannamkong up to the flowering stage but thereafter it reversed

The number of leave per square meter was similar in two soybean cultivars up to August 24 but thereafter it decreased more in Hannamkong (Fig. 2). The leaf area of Hannamkong was larger than of Pungsannamulkong up to August 4 but after that time, Pungsannamulkong showed larger leaf area than Hannamkong. The largest leaf area in Pungsannamulkong was 4.2 per m^2 at August 24 and in Hanamkong was 3.7 per m^2 at the same time. Also, leaf area of Hannamkong tended to decrease sharply more than Pungsannamulkong after August 24.

The shoot and leaf dry matter of two soybean cultivars on August 4 was similar but thereafter Pungsannamulkong exhibited a significantly greater the shoot and leaf dry matter than Hannamkong (Fig. 4). Both cultivars showed the largest leaf dry matter at August 24.

Table 1. Yield and yield components of two soybean cultivars

Cultivars	No. of pod (no plant^{-1})	No of seed (no plant^{-1})	Seed per pod (no.)	Seed weight (g 100 seed^{-1})	Yield (g m^{-2})
Pungsannamulkong	60.0 ± 5 8	119 7 ± 11 3	2 00 ± 0 5	10.9 ± 0.4	362 ± 45.0
Hannamkong	40 0 ± 5.4	71 5 ± 8 7	1.80 ± 0 4	12.3 ± 0 3	260 ± 30 3
LSD (5%)	11 9	34.1	ns	0 9	87.0

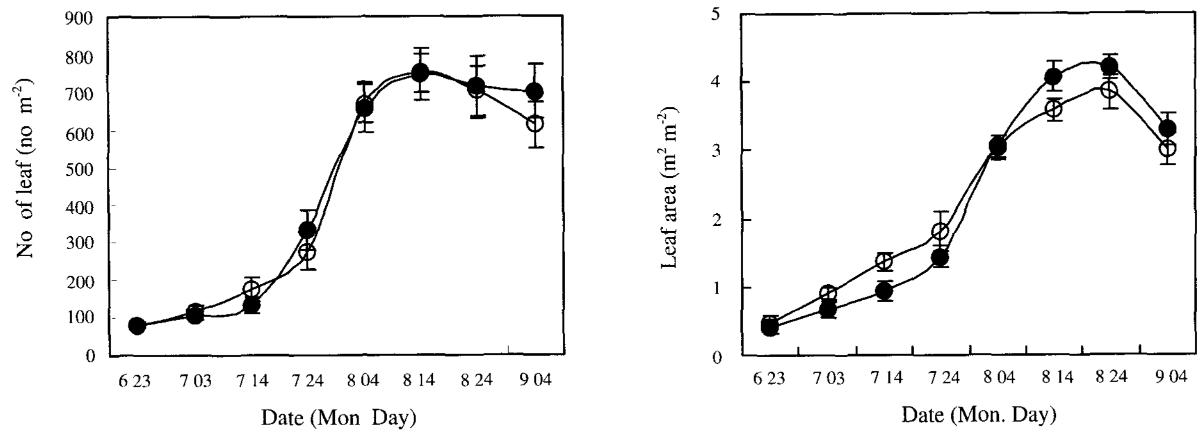

Fig. 2. Change of number of leaves and leaf area during growth period in two soybean cultivars. Dark circle indicates Punsannamulkong and white circle indicates Hannamkong Values are the mean ±SE (n = 10).

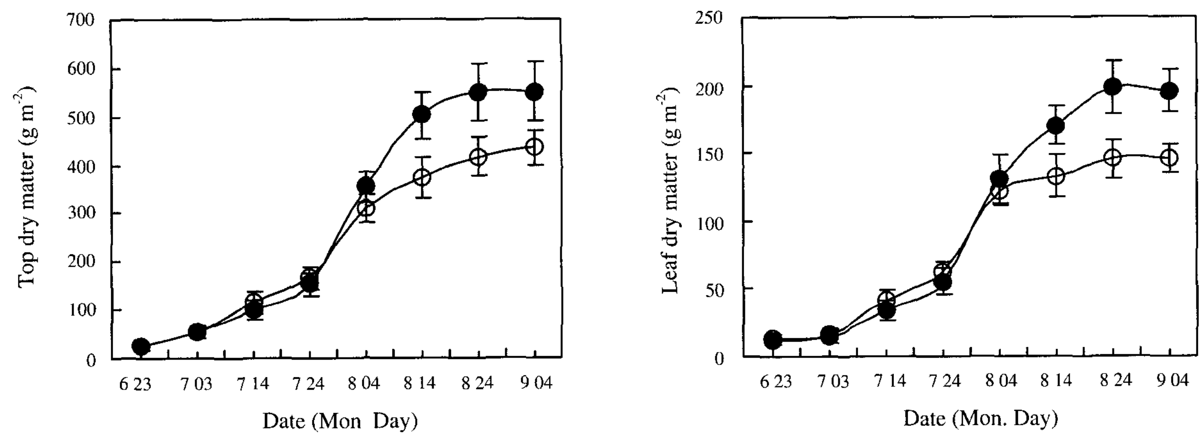

Fig. 3. Changes of shoot and leaf dry matter during growth period in two soybean cultivars. Dark circle indicates Punsannamulkong and white circle indicates Hannamkong Values are the mean ±SE (n = 10)

Table 2. CGR, RGR, NAR, LAR and SLW in two soybean cultivars

Growth stage	Cultivars	CGR (g day^{-1})	RGR (mg m^{-2} day^{-1})	NAR (g m^{-2} day^{-1})	LAR (cm^2 g^{-1})	SLW (g cm^{-2})
R1 ~ R3[J]	Pungsannamulkong	20.2	84 0	9 4	89 5	111 2
	Hannamkong	14 8	63 3	6.0	105.5	94 5
R3 ~ R5	Pungsannamulkong	14.7	34.7	4 2	83 5	119 7
	Hannamkong	6 9	19 7	2.0	97.3	102 8
R5 ~ R6	Pungsannamulkong	4 7	8 9	1 1	78 7	127 1
	Hannamkong	3.4	8.6	0 9	92 8	107.8

[J] According to Fehr *et al.* (1971).

Growth analysis and canopy architecture

CGR, RGR, and NAR of Punsannamulkong were relatively higher than Hannamkong, but LAR and SLW were higher in Hannamkong. The greatest value of CGR, RGR, NAR, LAR, and SLW for two cultivars was recorded during R1 ~ R3 stage (Table 2).

Canopy architecture of two soybean cultivars at R5 growth stage was shown in Fig. 4. Leaf position by the plant height was in the range of 20 ~ 100 cm from the soil surface in two cultivars. Most of leaves in Punsannamulkong and Hannamkong was located at in the range of 80 ~ 90 cm and

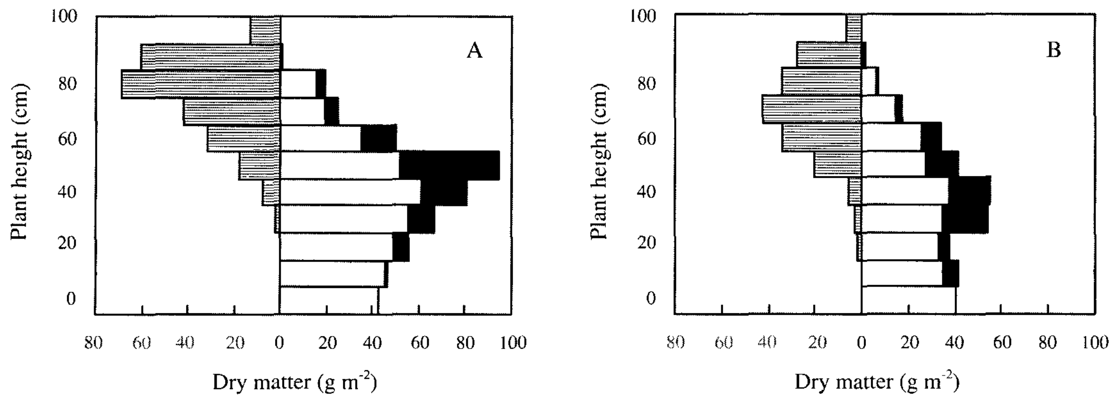

Fig. 4. Canopy architecture of two soybean cultivars at the seed development stage. A: Pungsannamulkong, B: Hannamkong, ▤: leaf dry matter, □: non assimilatory organ dry matter, ■: pod dry matter

Table 3. Photosynthetic rate (CO_2 mol m^{-2} s^{-1}) at the uppermost and 7th leaf position from base in two soybean cultivars at flowering and seed development stages.

Cultivars	Flowering stage†		Seed development stage	
	Uppermost leaf	7th leaf	Uppermost leaf	7th leaf
Pungsannamulkong	34.9 ± 4.8	22.8 ± 5.9	32.5 ± 5.0	14.0 ± 6.4
Hannamkong	25.9 ± 4.9	22.5 ± 4.5	30.4 ± 6.9	17.6 ± 5.8

† The times of flowering and seed development stages in Pungsannamulkong and Hannamkong were August 3 and July 24, and August 24 and August 14, respectively. Values are the mean ± SE (n = 6).

60 ~ 70 cm from the soil surface, respectively.

Pods in Punsannamulkong were distributed in the range of 10 ~ 80 cm from soil surface and most of pods were distributed at 40 ~ 50 cm. Also, pods of Hannamkong were distributed extensively in the range of to 10 ~ 90 cm and most of pods were distributed at 30 ~ 40 cm.

Photosynthesis

The photosynthetic rates at the uppermost and the 7th leaf position from base at the flowering and seed development stages in two soybean cultivars were shown in Table 3. At the flowering stage, photosynthetic rate was significantly different between cultivars at the upper most leaf position. The photosynthetic rate of Pungsanamulkong was higher in 34.9 CO_2 μmol m^{-2} s^{-1} than that of Hannamkong in 25.9 CO_2 μmol m^{-2} s^{-1}. There was no significant difference in photosynthetic rate at 7th leaf at flowering stage and also at the uppermost leaf and the 7th leaf position from base at seed development stage between two soybean cultivars.

DISCUSSION

This study was conducted to compare the yield potential of two soybean cultivars, Pungsannamulkong that determinate growth habit was a late maturing soybean cultivar (Suh *et al.*, 1997) and Hannamkong that semi determinate growth habit was a little early maturing soybean cultivar (Shin *et al.*, 1995), by analyzing the growth characteristics, the growth analysis, and the photosynthesis. Pungsannamulkong had greater more yield per square meter compared with Hannamkong due to higher number of pods, number of seeds, and seeds per pod except for seed weight. Yield difference between soybean cultivars has been reported by many researchers, and it has been known that the yield changed with the plant density, planting time, maturing habit, and plant type (Ford *et al.*, 1983; Ikeda, 2000; Kokubun *et al.*, 1988; Kokubun & Watanabe, 1982; Ookawa *et al.*, 1999).

The number of leaves from June 23 to August 24 of two cultivars was similar to each other. Leaf area from the emergence to the flowering stage was higher in Hannamkong than in Pungsannamulkong, but thereafter, the leaf area was higher in Punsannamulkong compared with Hannamkong. Shoot and leaf dry matter also tended to increase more in Pungsannamulkong than in Hannamkong. The main factor of much more seed yield in Pungsannamulkong compared with in Hannamkong was due to a high dry matter production. The CGR in reproductive stages (R1 ~ R6) of Pungsannamulkong was higher than in Hannamkong The CGR of Punsannamulkong increased about 5.4 g per day compared with Hannamkong during R1 R3 stage and during R3 ~ R5 stage and the CGR was almost twice in Punsannamulkong compared with the Hannamkong. Thus, the relatively high CGR in Pungsannamulkong may be resulted due to greater leaf area and leaf dry matter during R1 to R5 growth stages. Leaf area and leaf dry matter after August 4 was significantly higher in Punsannamulkong. Greater leaf area and dry matter in soybean can be observed better by comparing RGR during reproductive growth stages.

The RGR that depended on the NAR and the LAR explained accumulation of dry matter during the growth times. The RGR was higher in Punsannamukong than in Hannamkong at the same periods. The NAR also was higher in Punsannamulkong. On the other hand, there were many reports stated that the photosynthesis had positive correlation with SLW (Buttery & Buzzell, 1977; Cho *et al.*, 2003; Sagawa, 1998). In this experiment, the photosynthetic rate during reproductive stages in Hannamkong was less than in Punsannamulkong, and there was a high relationship between the seed yield and the relatively low SLW, and the high leaf dry matter production.

The photosynthetic rate at the uppermost leaf position between two cultivars at the flowering stage, Punsannamulkong showed higher by 34.9 CO_2 μmol m^{-2} s^{-1} than Hannamkong by 25.9 CO_2 μmol m^{-2} s^{-1}. Also, there was more photosynthetic rate in Punsannamulkong than that of Hannamkong at the 7^{th} leaf position at the seed development stage. Cho *et al.* (2003) reported that photosynthesis at seed development stages among soybean cultivars showed positive correlation with seed yield in middle and lower leaf position And Sagawa (1997) also showed the positive correlation with yields at seed development stage. From this experiment, higher yield of Punsannamulkong compared with that of Hannamkong may cause to increasing photosynthetic rate at middle and lower leaf as well as 7^{th} leaf position at the seed development stage. Some reporters stated that there was no correlation between the photosynthesis and yield because photosynthesis was measured with flourished leaves (Ford *et al.*, 1983, Kokubun *et al.*, 1988).

On the other hand, most of leaf in the canopy architecture of two soybean cultivars was distributed at further level from the soil surface in Punsannamulkong compared with in Hannamkong Generally, the leaf distribution of upper layer in canopy could influence greatly photosynthesis in soybean because of the interruption of transmission of the light irradiation into middle position (Kokubun & Watanabe, 1982; Ikeda, 2000; Ookawa *et al.*, 1999). Nevertheless, the high photosynthetic rate at the 7^{th} leaf position in Pungsannumkong may be resulted due to longer duration of leaf life of Pungsannumkong than that of Hannamkong. Sagawa (1997) stated that soybean cultivars that had a longer duration of leaf life and less defoliation might get relatively more grain yield.

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