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Topping Effect on Growth and Yield of Soybean Growth in Paddy Field

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ABSTRACT : This study was conducted to determine the effects of two plant populations (28 and 14 plants per m^2) and two toppings in conventional plant population (28 plants per m^2) on soybean (*Glycine max* L. cv. Pungsanna-mulkong) cultivated in the paddy field. The two topping time were taken at 6th to 7th and 8th to 9th trifoliolate leaf stages in the conventional plant population. Experimental design for growth data was a randomized complete block with three replications, and samples were taken at R1 (July 31), R3 (August 19), R5 (September 2) and R7 (September 23) growth stages. The branch number of soybean was relatively higher in the low plant population (14 plants per m^2) and with the topping at the 6th to 7th leaf stage, in the conventional plant population (28 plants per m^2), and with topping at the 8th to 9th trifoliolate leaf stage in descending order. The highest average branch length of soybean was observed in the low population and the longest branch length was observed from the soybean with topping at the 6th to 7th leaf stage. The leaf number per plant was decreased in order of in the low population, with the topping at 6th to 7th trifoliolate leaf stage, with the topping at 8th to 9th trifoliolate leaf stage, and in the conventional population. The leaf area was high in the low population and with topping at 6th to 7th trifoliolate leaf stage and was relatively low in the conventional population and with the topping at 8th to 9th trifoliolate leaf stage in soybean. The dry weight of leaves and branches was high in the low population and with the topping at 6th to 7th trifoliolate leaf stage and was relatively low in the conventional population and with topping at 8th to 9th trifoliolate leaf stage. The leaf number per plant was high in the low population and with topping at 6th to 7th trifoliolate leaf stage and was relatively low in the conventional population and with topping at 8th to 9th trifoliolate leaf stage. The grain yield per 10a was high with the topping at 6th to 7th trifoliolate leaf stage.

Keywords : *soybean, plant population, topping, grain yield*

Soybean, which is high content of protein and fat, is used in various sources such as food, industrial material, and forage, and the production and consumption of soybean increases every year in worldwide. But, in Korea, because of low gain yield per unit area and insufficient commitment of mechanization technology, cultivation area of soybean decreased rapidly by 297,000 ha in 1970 to 87,350 ha in 2000. Also the production of soybean was very low and the self-supply of soybean was not more than 26.8 % in 2000. Therefore, in order to elevate the self-supply of soybean in Korea, it is essential to increase the yield per unit area and it is very important to extend the cultivation area, develop the cultivation techniques, and good cultivars (Park *et al.*, 2001; Oh, 2002).

Plant morphology modification to increase quantity of crop production has been recognized as an important agronomic factor for securing high crop yields. The crop yields increase considered as an important agronomic question whether it depend on change of the growth morphology or growth pattern of crop. Bauer *et al.*, (1976) stated that the topping would be a possible way to increase the growth and yield of soybean.

Topping is a cultural practice which is contrary of the apical dominance phenomenon which inhibit growth of main stem but promote the growth of branch stem of soybean therefore increase yield. The effects of topping on soybean had used by purpose of prevention of over growth and lodging, and by the higher yields.

In Japan, exceptionally high yield (6,730 kg ha^{-1}) of soybean had been reported with terminal bud removal (Uryu, 1955), but Greer and Anderson (1965) reported topping at full bloom stage did not alter plant morphologically but did cause a small increase in yields. Also, Nagata (1951) reported that the topping of soybean causing decrease of the growth of top and root and decrease of the yields in summer types. But Shimojima (1953) stated that there was an increase in the yield if topping was carried out to the late maturing soybean cultivars.

Hong *et al.*, (1988) stated that there was no effect 100 grain weight and yield with topping in different soybean cultivars. As discussed above, the effect of topping in soybean was different according to soybean cultivars, cropping pattern, and soil condition and had low effect in dense planting.

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Table 1. Chemical properties of soil used for paddy field experiment.

pH (1:5)	O.M. ($g\ kg^{-1}$)	T-N (%)	P_2O_5 ($mg\ kg^{-1}$)	Ex. Cat.($cmol^+\ kg^{-1}$)			EC ($dS\ m^{-1}$)	CEC ($cmol^+\ kg^{-1}$)
				K	Ca	Mg		
5.8	26.2	0.24	111	0.44	1.70	0.20	0.24	3.8

This research carried out to investigate effects of topping on the growth and yield of soybean and to provide the data for the cultivation techniques in double cropping system with winter crops at paddy field in Korea.

MATERIALS AND METHODS

A field study was conducted in 2002 at the Honam Agricultural Experiment Station, Rural Development Agriculture, Jeonbuk Province on a silty loam soil using determinate type cultivar (cv. Pungsannamulkong), and chemical characteristics of experimented soils were shown in Table 1. Fertilizer (N-P-K) was applied before planting with the ratio of 3.0-3.0-3.4 kg/10a according to soil test recommendation. Seed were machine planted at May 27, 2002 with the plant population of 28 plants/m^2 (conventional population: 70 cm row width by 10cm intercrop spacing) and with the plant population of 14 plants/ m^2 (low population: 70 cm row width by 20 cm intercrop spacing). Experimental plots were 4 continuous rows with a 20 m row length. Prior to V3, plots were thinned to two plant populations with two plants per hill: low (14 plant per m^2) and conventional (28 plants per m^2) plant populations. The topping was treated to soybean plant of the conventional population at the 6^{th} to 7^{th} and 8^{th} to 9^{th} trifoliolate leaf leaf stages, respectively. Experimental design for growth data was a randomized complete block with three replications. The data were taken at R1 (July 31), R3 (August 19), R5 (September 2) and R7 (September 23) stage, respectively. Branch number, branch length, main stem and branch leaf number, dry weight of main and branch parts (leaf and stem), pod number, yields, and 100 grain weight were taken.

RESULTS AND DISCUSSION

Branch number and length

Fig. 1 shows the branch number at different soybean growth stages of the low and conventional plant populations (low: 14 plants/m^2 and conventional: 28 plant/m^2) and two toppings at 6^{th} to 7^{th} and 8^{th} to 9^{th} trifoliolate leaf stages. The number of soybean branches at the R1 stage was almost the same for all four treatments. In low population, however, the number of branches increased rapidly after R1 and showed

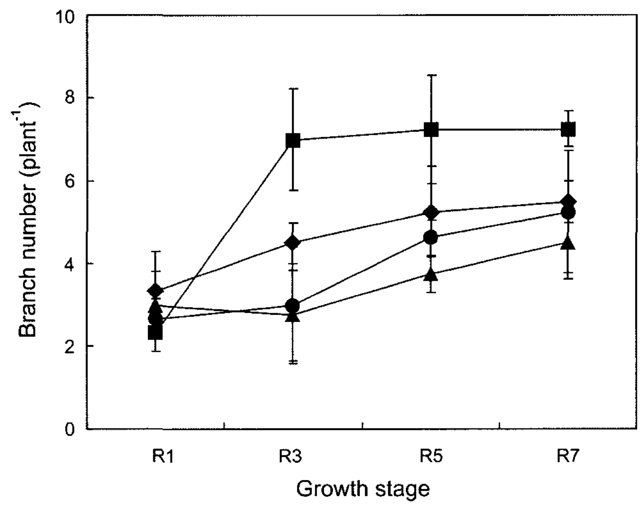

Fig. 1. Changes in number of branches per plant at various growth stage of soybean affected by toppings and planting populations. ●-● ; conventional population (28 plants per m^2), ■-■ ; low population (14 plants per m^2), ◆-◆ ; topping at 6^{th} to 7^{th} trifoliolate leaf stage in the conventional population and ▲-▲ ; topping at 8^{th} to 9^{th} trifoliolate leaf stage in the conventional population of soybean.

maximum number of branches of 7 at R3 stage then there was no change of the branch number after that. But the branch number increased slightly until at R5 stage in the conventional population. The branch number of soybean with topping at the 6^{th} to 7^{th} trifoliolate leaf stage showed continuous increasing trend up to R7 stage. Also, the branch number with topping at the 8^{th} to 9^{th} trifoliolate leaf stage showed increasing trend after the R3 stage but showed the lowest number of branches among 4 treatments.

Oh (2002) and Johnson and Harris (1967) reported that the branch number decreased as the plant population increased and it's decrease level was higher in cultivars that had high branch number than cultivars that had low branch number. Although there was no significant difference of the branch number between the soybean with the topping at 8^{th} to 9^{th} trifoliolate leaf stage and non - topping in the conventional population, but there was significant difference of the branch number with the topping at the 6^{th} to 7^{th} trifoliolate leaf stage compared with non-topping (conventional population) at the R3 growth stage. Results from this research showed similar results from Bauer et al. (1976) carried out the topping at 6, 8, and 10 leaf stage and stated that the branch number increased with the topping at 6 leaf stage, meanwhile, the branch number with the topping at 8 and 10 leaf stage showed no significant difference compared to that of non-topping.

The longest branch length per plant averaged 23 cm at the R7 stage with the topping at 6^{th} to 7^{th} stage and the next longest one was plants with the topping at 8^{th} to 9^{th} stage, in the low population, and in the conventional population in descending order.

Also, the longest total length of branches per individual plant was 168.4 cm in the low population and the next longest one was plants with the topping at 6^{th} to 7^{th} trifoliolate leaf stage, plants with the topping at 8^{th} to 9^{th} trifoliolate leaf stage, and the conventional population in descending order (Fig. 2).

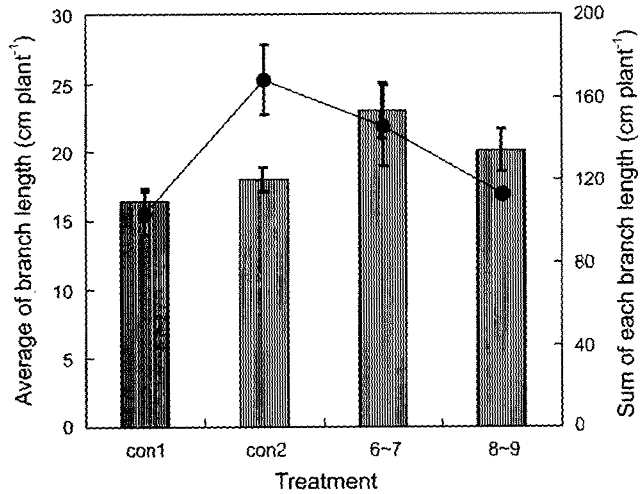

Fig. 2. Average of branch length and sum of each branch length per plant at R7 growth stage of soybean with two toppings and plant populations. Solid and curved line showed the average of branch length and lines showed the total branch length. Con1 and con2 are conventional (28 plants per m^2) and low (14 plants per m^2) populations, and 6~7 and 8~9 means the topping at the 6^{th} to 7^{th} and 8^{th} to 9^{th} trifoliolate leaf stage in conventional population, respectively.

From this experiment, the topping resulted to decrease the branch length which was opposite to the result reported by Hong *et al.*, (1987). Hong et al. (1987) stated that the topping increased the total length of branch in different soybean cultivars.

As long as the topping time was extended, the length of branches decreased. The length of branches, however, with the topping at the 6^{th} to 7^{th} stage was longer than the length of branches in the low population.

Leaf number and leaf area

The leaf number per plant and the leaf number ratio on the branch and the main stem per plant were shown in Fig. 3A. The leaf number at the conventional population was about 42 at the R1 stage and increased sharply up to the number of 103 at the R3 stage, and then it remained almost the same after R3 stage.

In the low population, the leaf number was about 49 at the R1 stage, and then it increased slightly to 67.3 at the R7 stage. Also, the leaf number with the topping at the R1 stage was less than that of the low population and the leaf number at 6^{th} to 7^{th} and 8^{th} to 9^{th} trifoliolate leaf stage was 26.7 and 24.4, respectively. Even though the leaf number with the topping at 6^{th} to 7^{th} trifoliolate leaf stage increased sharply up to at R5 stage, the leaf number with the topping at 8^{th} to 9^{th} trifoliolate leaf stage showed the almost the same as the conventional population.

Meanwhile, the branch/total leaf number ratio at R1 stage

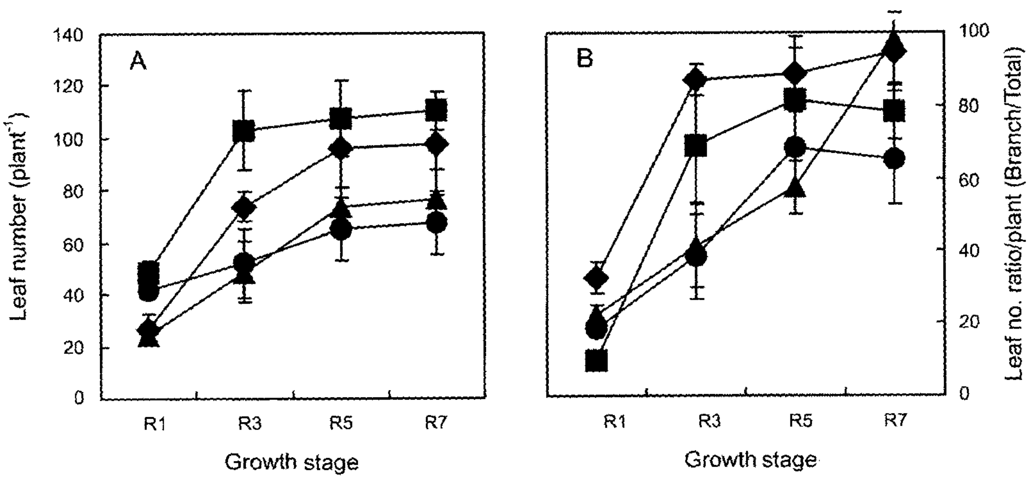

Fig. 3. The progressive change of leaf number (A) and branch/total leaf number ratio (B) of various growth stages of soybean with two plant populations and two toppings. ● - ● ; the conventional population (28 plants per m^2), ■-■; the low population (14 plants per m^2), ◆-◆ ; topping at the 6^{th} to 7^{th} trifoliolate leaf stage and ▲ - ▲ ; topping at the 8^{th} to 9^{th} trifoliolate leaf stage in conventional population.

in the low population showed the lowest ratio of 9.7 %, and then the ratio increased to 69% at the R3 stage due to increase of the branch leaves. The branch/total leaf number ratio in the conventional population was 18.6 % at the R1 stage, and then the ratio increased gradually up to 68.8 % at the R5 stage. The branch/total leaf number ratio, however, with the topping at the 6th to 7th trifoliolate leaf stage at the R1 stage was the highest of 32.5% among four treatments, and then the ratio increased rapidly up to 86.8 % at the R3 stage and it showed no difference after that. The branch/total leaf number ratio with the topping at the 8th to 9th trifoliolate leaf stage at the R1 stage was 22.1%, and then the ratio increased rapidly up to 97.7% at the R7 stage (Fig. 3B).

The leaf area per plant of the two plant populations and two toppings of four treatments was shown in Fig. 4A. The leaf area in the conventional population at the R1 stage was the largest of 2116 cm^2, 3061 cm^2 at the R5 stage, and 2108 cm^2 at the R7 stage. The leaf area in the low population at the R1 stage was 1908 cm^2, and it increased rapidly up to the R5 stage then decreased slightly at the R7 stage.

Even though the leaf area with the topping at the R1 stage was a little less than the control (i.e., non-topping in the conventional population), the leaf area at the 6th to 7th trifoliolate leaf stage with the topping increased rapidly such that the leaf area at the R5 stage showed the largest of 5737 cm^2. The leaf area with the topping at the 8th to 9th trifoliolate leaf stage showed the smallest area during the R5 through R7 stage but the leaf area at the R7 stage was 2887 cm^2 which was a little larger than the conventional population.

The branch/total leaf area ratio at the R1 stage showed the highest of 61.7% with the topping at the 6th to 7th trifoliolate leaf stage, and at the R7 stage showed the highest of 97.0% with the topping at 8th to 9th trifoliolate leaf stage (Fig. 4B).

Dry weight

The dry weight per soybean plant of two plant populations and two toppings at 6th to 7th and 8th to 9th trifoliolate leaf stage was showed in Fig. 5. Leaf dry weight in conventional population showed almost the same level from R1 to R7 (Fig. 5A). The leaf dry weight of soybean in the low population at the R1 stage was 6.6 g and it was similar to the soybean in the conventional population, and then the leaf dry weight gradually increased to 14.3 g at the R7 stage.

The leaf dry weight of soybean with the topping at the 6th to 7th trifoliolate leaf stage was 6.53 g at the R1 stage, and then it was increased rapidly after the R3 stage and it reached to 13.7 g at the R7 stage. The topping at the 8th to 9th trifoliolate leaf stage showed the lightest leaf dry weight of 3.6 g at the R1 growth stage and of 6.97 g at the R7 growth stage. Also, it was smallest increase of the leaf dry weight among four treatments.

The highest branch/total leaf dry weight ratio was observed with topping at the 6th to 7th trifoliolate leaf stage, and then in the low population, with the topping at the 8th to 9th trifoliolate leaf stage, and in the conventional population in descending order. Meanwhile, the leaf dry weight of soybean with the topping at the 8th to 9th trifoliolate leaf stage increased rapidly after the R5 growth stage, then the leaf dry weight at the R7 growth stage was similar to that of soybean with topping at the 6th to 7th trifoliolate leaf stage (Fig. 5A-1). Hong *et al.,* (1987) reported that significant difference between the branch leaf dry weight and the total leaf dry weight occurred at 58 days after planting, and then it was highly significant as the growth stage proceeded. The result from this research, the difference of the branch/total leaf dry weight ratio of soybean with the topping at 6th to 7th trifoli-

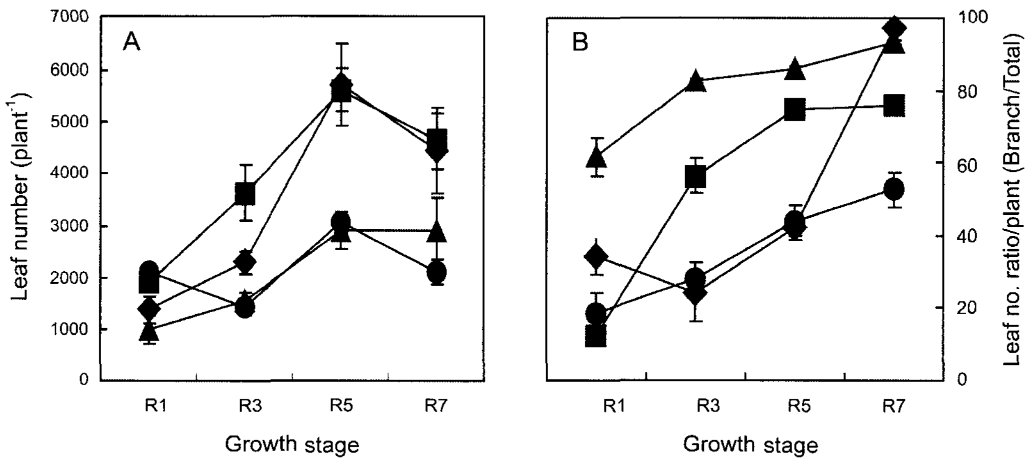

Fig. 4. The progressive change of the leaf area (A) and the branch/total leaf area ratio (B) of the soybean with two plant populations and two toppings. ● - ● ; the conventional population (28 plants per m^2), ■ - ■ ; the low population (14 plants per m^2), ◆-◆ ; topping at the 6th to 7th trifoliolate leaf stage and ▲ - ▲ ; topping at the 8th to 9th trifoliolate leaf stage in conventional population.

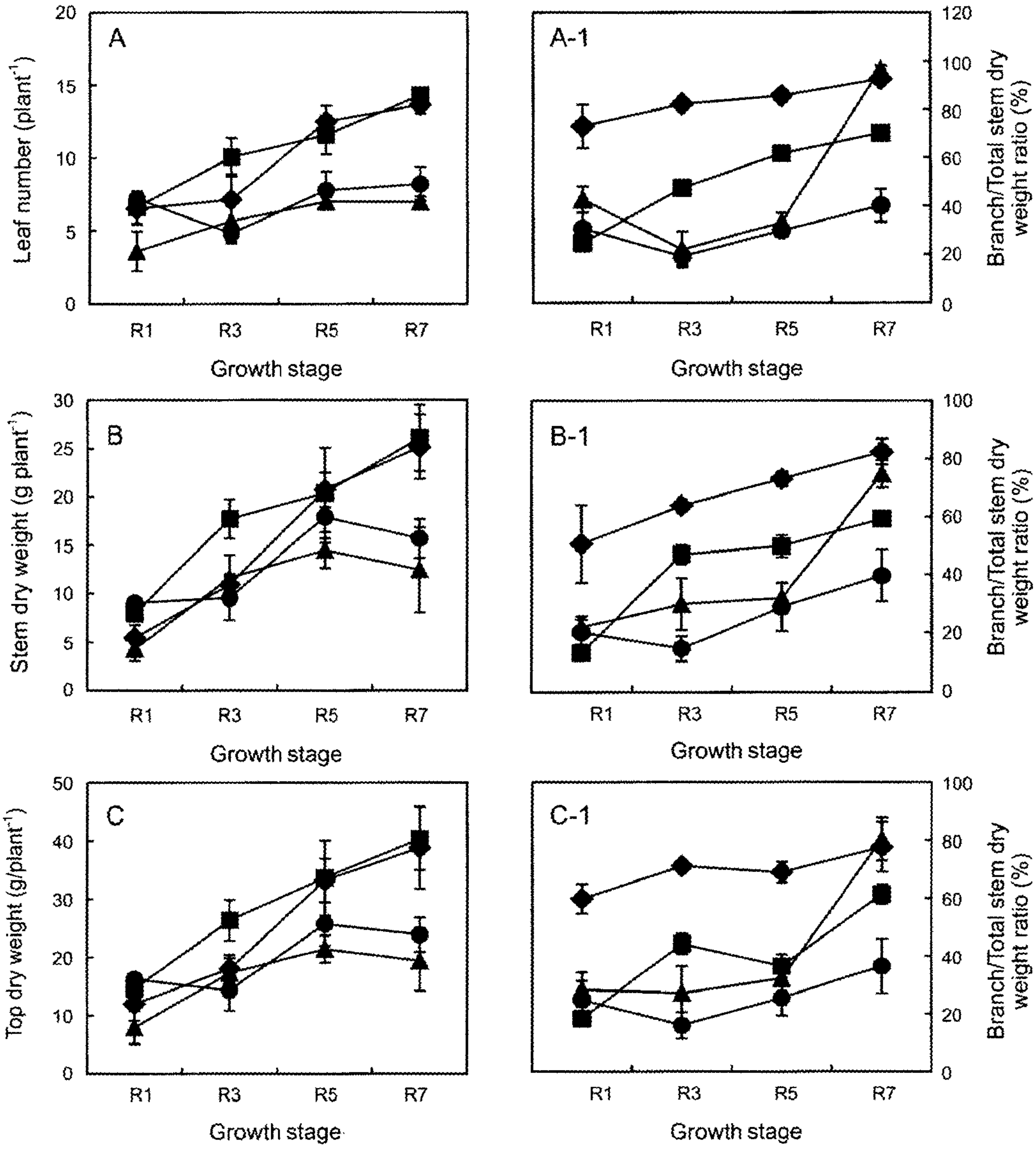

Fig. 5. The progressive changes of the dry weight of soybean parts and the branch and total dry weight ratio with two populations and two toppings. ● - ● ; the conventional population (28 plants per m^2), ■-■ ; the low population (14 plants per m^2), ◆-◆ ; topping at the 6th to 7th trifoliolate leaf stage and ▲ - ▲ ; topping at the 8th to 9th trifoliolate leaf stage in conventional population.

olate leaf stage was the same result.

The stem dry weight of the soybean in the conventional and low plant population was similar at the R1 growth stage, but in the low plant population, the stem dry weight increased rapidly after the R1 stage and it reached the highest of 26.1 g at the R7 stage (Fig. 5B). Meanwhile, the stem dry weight in the conventional population was 17.9 g at the R5 growth stage, and then it decreased at the R7 growth stage.

Even the stem dry weight with the topping in the low and the conventional population decreased until the R1 stage, the stem dry weight of soybean with the topping at the 6th to 7th trifoliolate leaf stage increased after the R1 stage and reached to 25.2 g at the R7 stage, which was similar to the stem dry weight of the soybean in the low population. However, the stem dry weight with the topping at the 8th to 9th trifoliolate leaf stage was the lowest of 4.3 g at the R1 stage and 12.5 g at the R7 stage, which was the lowest increase of the stem dry weight. The highest branch/total stem dry weight ratio resulted in the topping at the 6th to 7th trifoliolate leaf stage, and then, the topping at the 8th to 9th trifoliolate leaf stage, the low plant population, and the conventional plant population in descending order (Fig. 5B-1).

The total dry weight was 16.2 g and 23.9 g at the R1 and the R7 stage, respectively, in the conventional population and was 14.6 g and 40.4 g at the R1 and R7 stage, respectively, in the low population, and it was the highest among the four treatments in soybean. The total dry weight with the topping at 6th to 7th trifoliolate leaf stage was 12.0 g at the R1 stage, and then the dry weight increased rapidly and reached to similar weight in the low population at the R5 stage. The dry weight further increased to 38.8 g at the R7 stage and showed the highest dry weight increase among the four treatments. The dry weight with the topping at 8th to 9th trifoliolate leaf stage, however, was the smallest of 7.9 g at the R1 growth stage, and then the dry weight increase was very small and showed the dry weight of 19.4 g at the R7 growth stage. The highest branch/total dry weight ratio was observed at the topping at 6th to 7th trifoliolate leaf stages and the lowest was observed at the conventional plant population (Fig. 5C-1).

Yield

The pod number of the soybean in the conventional plant population at the R3 stage was lowest of 2.5 and was 10.3 in the low plant population. Thereafter, the pod number increased sharply after the R3 stage and reached to 72.0 and 83.5 at R5 stage in the conventional and the low plant population, respectively.

The pod number of the topping at the 6th to 7th and 8th to 9th stages was 12.3 and 5.8 at R1 stage, respectively. The pod number increased until the R7 stage by the topping, and it was 82.5 and 72.0 with the topping at the 6th to 7th and the 8th to 9th trifoliolate leaf stage, respectively (Fig. 6A).

Also, the highest branch/total pod number ratio resulted in with the topping at the 6th to 7th trifoliolate leaf stage, and the most of pods were found at branch stems. Pods founded at branch stems in the conventional and the low plant population ranged 60-67% and 69-73%, respectively (Fig. 6B).

Board et al. (1996) reported that yield differences with narrow (50 cm) and wide (91 cm) row culture within a late planting were attributed largely to differences in pod number, and that total dry matter at R5 stage was the most highly correlated with yield across different row spacing or within the same row spacing. Also, Board *et al.*, (1996) reported

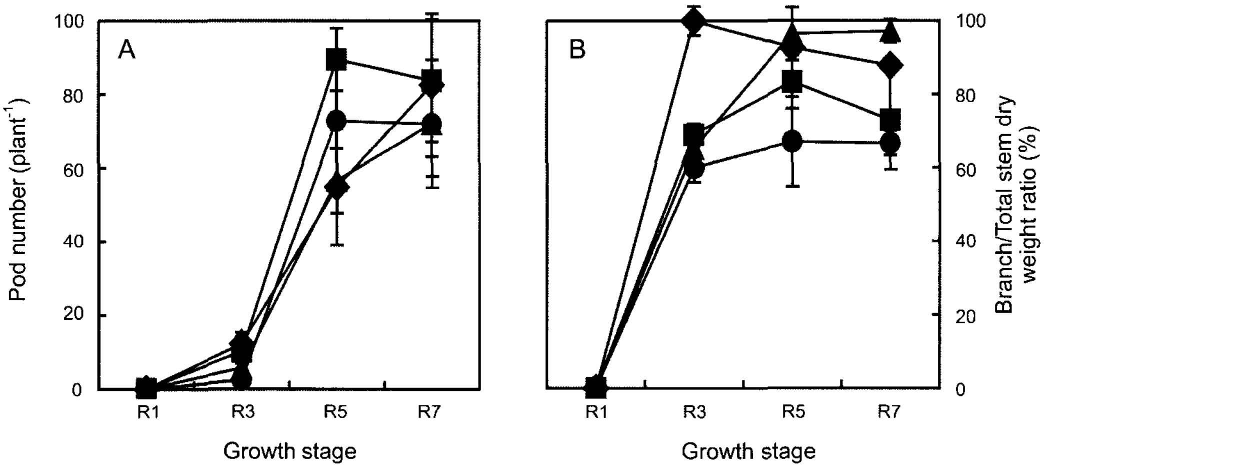

Fig. 6. The progressive changes of the pod number (A) and branch/total pod number ratio (B) with two plant populations and two toppings. ● - ● ; the conventional population (28 plants per m^2), ■ - ■ ; the low population (14 plants per m^2), ◆ - ◆ ; topping at the 6th to 7th trifoliolate leaf stage and ▲ - ▲ ; topping at the 8th to 9th trifoliolate leaf stage in conventional population.

Table 2. The grain yield and yield component with two plant populations (the conventional and the low population is 28 and 14 plants per m^2, respectively) and two toppings (topping was conducted at the 6th to 7th and the 8th to 9th trifoliolate leaf stage in the conventional population)

Treatment	No. of seed (plant^{-1})			Seed no. per pod			100 grain W.t.(g)	Grain yield (g 10a^{-1})
	Main stem	Branch	Total	Main stem	Branch	Total		
Con 1	35.2a	88.8c	124.0c	1.6b	1.5b	1.6b	13.1a	248ab
Con 2	39.4a	157.6a	197.0a	2.3a	2.3a	2.1a	12.9a	250ab
Topping 1	3.4c	142.4a	145.8b	1.8b	2.2a	2.2a	13.9a	281a
Topping 2	16.9b	106.2b	123.1c	1.8b	1.0c	1.0c	12.7a	259ab

[J]means followed by different letters within the same column are significantly ($p<0.05$) different according to DMRT.
Con 1 and con 2 are conventional (28 plants per m^2) and low population (14 plants per m^2), respectively.
Topping 1 and topping 2 are taken at 6th to 7th and 8th to 9th trifoliolate leaf stage, respectively.

that although greater light interception occurred throughout the growing season in narrow compared to wide rows, increased crop growth rate occurred only during vegetative and early reproductive periods and the main factors responsible for increased yield in narrow rows were greater fertile node production and increased pod per fertile node. Therefore, the yield components were primarily determined during the vegetative and early reproductive periods.

The grain yield and yield component of the soybean at the two plant populations and with two toppings shown in Table 2. Seed number per plant was the most at low plant population of 197.0 but the lowest with topping at 6^{th}~7^{th} trifoliate stage.

The grain yield of soybean at the conventional and the low plant population was 248 g and 250 g, respectively. The grain yield of soybean with the topping at 6th to 7th trifoliolate leaf stage was the highest of 280 g and which of the topping at the 8^{th} to 9^{th} trifoliolate leaf stage was 259 g.

Nogota (1953) reported that the growth and yield with the topping at 3-4 leaf stage in different types of soybean decreased in the summer type but increased in the autumn type soybean. And Hisao & Komito (1950) reported that c type of soybean showed increase of the yield by topping but not of c type soybean. As Seo *et al.,* (1997) stated that the maturity time of Pungsannamulkong belong to a middle-late maturities, this research considered that there was effective increasing yield with the topping to soybean cultivars with the longer maturity periods. The 100 grain weight of soybean topped at 6^{th} to 7^{th} trifoliolate leaf stage was 13.9 g, but there was no significant difference among treatments.

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