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Comparison of Yield in Korean Small Seed Soybean Cultivars with Main Stem and Branch Production

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This study was carried out to investigate the agronomic characteristics of late–planted small seed soybean cultivars and to investigate the effect of number of pods and seeds on main stem and branch against seed yield in Korea. Seed were sown at 17 June 2003 and 16 June 2004 with on a 60 cm row width and 10 cm plant space. The flowering dates in small seed soybean cultivars were on July 26 to August 7 and the maturing dates were on September 23 to October 9. The days of from planting to flowering date and to maturing date were ranged as 39 ~52 and 98~114, respectively. There was a highly significant difference ($r=0.686$, $p<0.01$) between total dry matter (TDM) and LAI at R5 stage. The number of pods on 2nd branch showed the highest value by 7.6, and followed by that of 3rd, 1st and over 4th branch in this order. The seed yield varied from 168 to 289 g m^{-2} and the average of all soybean cultivars was 225 g m^{-2}. The relation between the seed yield and the days of flowering to maturing date was high significant difference ($r=0.575$, $p<0.01$) and there was a high significance difference ($r=0.781$, $p<0.01$) between the seed yield and the days of planting to flowering date. The level of significant difference was higher in the period of vegetative stage than in the period of reproductive stage in small seed soybeans. There was high significance difference ($r=0.556$, $p<0.01$) between the seed yield and LAI in soybean cultivars. A range of LAI for optimal seed yield may be shown about 3.5~4.5 at R5 stage. Also, there was a relationship between the seed yield and the number of pods on 4th and above branch but was no significant relationship between the seed yield and number of pods on 1st branch. The correlation between the seed yield and the pods numbers showed the most value by 0.640 ($p<0.01$) on 3rd branch, and followed 2nd branch, and 4th and above branch in this order. There was a high significant relationship ($r=0.648$, $p<0.01$) between the seed yield and the number of pods on total branch among 22 small seed soybean cultivars. However, the relation between the seed yield and the number of pods on main stem showed no significant relationship ($r=0.089$, ns). These results indicated that in order to optimal seed yield of late planted (mid–June) small seed soybean, soybean cultivars forming more pods on the 2nd and 3rd branch should be bred.

INTRODUCTION

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

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increases every year in worldwide. The yield potential of soybean varies from 3,500 to 6,000 kg per ha. In Japan and USA the yield potential is up to 7,000 kg per ha (Paroda, 1999). But, in Korea, because of low gain yield per unit area and insufficient propagation of mechanization technology, cultivation area of soybean decreased rapidly by 297,000 ha in 1970 to 87,350 ha in 2000 (Cho *et al.*, 2004; Park *et al.* 2001). In Korea, total 103 cultivars including 22 small seed cultivars for vegetative sprout were released since 1906 (Lee and Park, 2001).

Soybean has been cultured as late planting (after mid–June), which is a common limiting factor for soybean production in the southern Korea due to maintain a double cropping after a winter crops. This delay reduced seed yield and affected negatively most agronomic characteristics compared with full season soybean (Quattara & Weaver, 1994). Also, delayed planting reduced the days to maturity and flowering date, and decreased the length of vegetative and reproductive periods of development (Board *et al.*, 1996; Parker *et al.*, 1981). Yield reduction in late–planted determinate soybean has been attributed to reduced vegetative growth caused by insufficient premature before flowering as a result of a shorter photoperiod at later planting dates (Weaver, *et al.* 1991). Pfeiffer & Pilcher (1987) stated that if early flowering would allow a longer period of seed filling, and thus potentially higher yields, the delay of flowering date may shorten the length of the reproductive period below the level needed to sustain high yield. On the other hand, yield responses of determinate soybean to narrow row culture in the southwest Korea have been inconsistent to that at optimal planting dates and some studies have shown a positive yield response to narrow rows when soybean cultivars were sown to narrow row spaces after mid–June (Board *et al.* 1996; Quattara & Weaver, 1994). Therefore, this study was carried out to investigate the agronomic characteristics of late–planted small seed soybean cultivars and to investigate the effect of number of pods and seeds on main stem and branch of Korean small seed soybean cultivars.

MATERIALS AND METHODS

The research was carried out during 2003 and 2004 at farm affiliated to Honam Agricultural Research Institute in Iksan area, southwest part of Korea. This soil was characterized by a commercial silty clay loam texture. Twenty–two small seed soybean cultivars were used in this experiment. Seeds were sown on 17 June 2003 and 16 June 2004 at 60 cm of row width and 10 cm of plant space. The cultivated area of experimental plots was about 9.6 m^2 per cultivar. This study was conducted randomized block design with three replications. The amount of applied fertilizer was N; 3 g, P_2O_5; 3 g, and K_2O; 3.4 g per m^2 with all basal fertilizations both for two years.

Three weeks after planting (about V3 stage), seedlings were thinned to two plants stand. Weeds were controlled by the incorporation of trifluralin (trifluoro–2, 6–dinitro–*N*, *N*–dipropyl–*p*–toluidine) before sowing and weeded by hand if necessary. Defoliating insects were controlled with insecticides as needed, and overhead sprinklers irrigated plots when needed. Duration of vegetative growth (days up to flowering stage) and reproductive growth (R1∼R8) was recorded by the method described by Fehr *et al.* (1971).

Ten plants per plot of each cultivar were randomly sampled at the pod formation stage (R4) made for the dry matter and LAI. Plant sampled was separated into leaves, main stem and branches. Leaf area was determined by placing the leaf blades through a leaf area meter (LI–COR Li–3100, USA). Thereafter, dry matter was determined by dried in a forced–air dryer at 80 °C for 72 hr. Ten plants per plot were randomly sampled from two interior rows of each plot at maturity and investigated for pod number, seed number, seed weight and sample seed yield.

RESULTS AND DISCUSSION

Flowering and Maturing Dates

The flowering dates in small seed soybean cultivars were on July 26 to August 7 and the maturing dates were on September 23 to October 9 (Table 1). K wangankong showed the latest flowering date on Aug 8 and Hannamkong showed the earliest flowering date on July 26. Hannamkong showed the fastest maturing date on September 23 and Insannamulkong showed the latest maturing date on October 9. The days of from planting to flowering or to maturing were ranged as 39～52 or 98～114, respectively. Thus the difference of the flowering date between the earliest and latest cultivars was about 13 days and that of maturing date was about 16 days.

Table 1. Date of flowering (R1) and maturing (R8) stage, and the days from planting to R1 and R8 stage in late planted 22 small soybean cultivars.

Cultivars	R1 stage (Mon. Day)	R8 stage (Mon. Day)	Days from planting date to	
			R1 stage	R8 stage
Hannamkong	7.26	9.23	39	98
Tawonkong	7.29	9.24	42	99
Sunamkong	7.29	9.25	42	100
Dachaekong	8.03	9.25	47	100
Namhaekong	8.03	9.28	47	103
Sobaegnamulkong	8.02	9.29	46	104
Sohokong	8.02	10.03	46	108
Paldokong	8.01	10.03	45	108
Saebyolkong	8.02	10.01	46	106
Dagikong	8.05	10.01	49	106
Anpyeongkong	8.01	10.02	45	107
Myeongjunamulkong	8.02	10.02	46	107
Eunhakong	8.01	10.01	45	106
Doremikong	8.04	10.03	48	108
Pungsannamulkong	8.06	10.05	50	110
Purwunkong	8.01	10.07	45	112
Kwangankong	8.08	10.07	52	112
Bukwangkong	8.05	10.07	49	112
Sorogkong	8.07	10.07	51	112
Somyeongkong	8.06	10.08	50	113
Sowonkong	8.05	10.08	49	113
Iksannamulkong	8.07	10.09	51	114
Mean	–	–	46.8	106.9

Growth Traits

Stem length at the pod formation (R4) stage ranged from 31 to 57 cm and the averages of stem length showed 43 cm in 22 small seed soybean cultivars. (Table 2).

Table 2. Growth characteristics of 22 small seed soybean cultivars at the pod formation stage (R4).

Cultivars	Stem length (cm)	Number of node (no. plant^{-1})	Number of branch (no. plant^{-1})	LAI	TDM. (g plant^{-1})
Hannamkong	41 ±3.0	15.0 ±1.8	2.7 ±1.3	3.8 ±0.3	29 ±6.3
Tawonkong	33 ±2.8	11.1 ±0.7	2.8 ±1.2	2.6 ±0.2	27 ±6.9
Sunamkong	43 ±3.5	12.6 ±0.9	3.0 ±0.8	3.3 ±0.6	31 ±5.9
Dachaekong	32 ±3.7	11.8 ±0.7	3.0 ±1.1	2.7 ±0.4	28 ±5.1
Namhaekong	47 ±4.3	11.9 ±0.8	3.6 ±1.3	3.0 ±0.2	37 ±5.5
Sobaegnamulkong	31 ±3.1	10.8 ±1.1	3.0 ±0.9	5.3 ±0.6	40 ±4.6
Sohokong	43 ±4.1	12.5 ±1.1	3.9 ±1.5	2.5 ±0.3	33 ±5.1
Paldokong	49 ±3.2	9.9 ±0.4	3.0 ±1.0	4.4 ±0.4	46 ±7.1
Saebyolkong	49 ±2.8	13.1 ±1.2	3.4 ±0.5	5.7 ±0.5	42 ±6.9
Dagikong	38 ±1.9	11.8 ±1.1	3.5 ±1.1	2.8 ±0.3	32 ±6.9
Anpyeongkong	41 ±2.1	11.5 ±0.3	3.9 ±1.3	2.5 ±0.3	29 ±4.1
Myeongjunamulkong	33 ±1.5	13.2 ±0.7	3.8 ±0.8	3.6 ±0.6	47 ±5.0
Eunhakong	44 ±3.5	11.9 ±1.1	4.5 ±1.0	6.1 ±0.4	46 ±7.2
Doremikong	46 ±3.9	12.6 ±0.8	4.0 ±1.7	3.2 ±0.2	48 ±8.2
Pungsannamulkong	35 ±3.6	12.2 ±1.1	4.3 ±1.3	3.6 ±0.4	49 ±7.3
Purwunkong	57 ±2.8	14.4 ±1.1	3.0 ±0.6	4.8 ±0.4	41 ±5.0
Kwangankong	48 ±3.3	12.7 ±0.9	4.2 ±1.2	4.2 ±0.3	53 ±7.7
Bukwangkong	50 ±2.2	13.2 ±1.0	3.9 ±0.8	3.7 ±0.5	51 ±6.3
Sorogkong	52 ±3.8	13.7 ±0.8	4.0 ±1.1	4.7 ±0.4	54 ±6.1
Somyeongkong	37 ±2.0	13.3 ±1.2	3.8 ±1.4	3.9 ±0.3	41 ±6.1
Sowonkong	41 ±2.7	13.4 ±1.2	4.1 ±1.0	3.4 ±0.2	52 ±5.9
Iksannamulkong	49 ±2.8	12.9 ±1.1	3.8 ±1.5	3.9 ±0.4	52 ±9.5
Mean	43 ±7.0	12.5 ±1.2	3.6 ±0.6	3.8 ±1.1	41 ±9.0

LAI: leaf area index, TDM: total dry matter.

Sobaegnamulkong showed the smallest stem length of 31 cm and Pureunkong showed the longest stem length of 57 cm. Among small seed soybean cultivars, the number of node and branch was ranged from 9.9 to 15.0 and from 2.7 to 4.5 and the averages of the number of node and branch were 12.5 and 3.6, respectively. In the case of leaf area index (LAI) at R4 stage, the average was 3.8, and Eunhakong, Sabyolkong and Sobaegnamulkong showed comparatively high LAI by 6.1, 5.7, and 5.3, respectively. Tawonkong, Dachaekong, Sohokong, Dagikong and Anpyeongkong were relatively low by 2.6, 2.7, 2.5, 2.8, and 2.5 of LAI, respectively. The total dry matter (TDM) ranged from 27 to 54 g per plant, and Sorokong was the greatest value by 54 g at R4 stage and Tawonkong was the lowest by 27 g. The average of TDM in 22 small seed soybean cultivars was 41 g per plant (Table 2). There was a highly significant difference ($r=0.686$) at $P<0.01$ levels between TDM and LAI at R5 stage in 22 small soybean cultivars (Fig. 1).

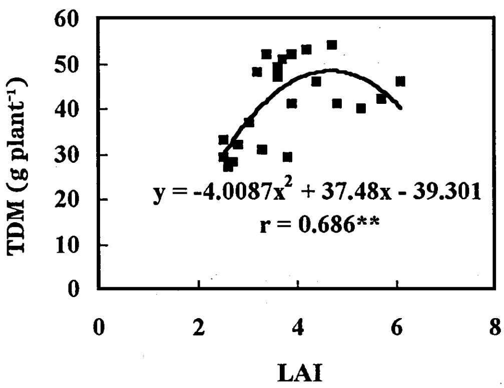

Fig. 1. Relationship between LAI and total dry matter (TDM) in 22 small seed soybean cultivars at seed development (R5) stage. **: significance at $p < 0.01$.

Seed yield and Yield components

The number of pods on total branch ranged from 15.6 to 46.6 per plant and the average number of pods was 27.0 (Table 3). The number of pods was collected each branch, 1st, 2nd, 3rd, and 4th and above branch and counted. The number of pods on 2nd branch showed the highest value by 7.6, and followed by that of 3rd, 1st and over 4th branch in this order. The number of pods on main stem ranged from 17.1 to 30.9 and the average number of pods on main stem in 22 soybean cultivars was 21.2. Therefore, the number of pods was more in branch than in main stem. However, Hannamkong, Tawonkong, Sobaegnamulkong and Paldokong showed lower pods in branch than in main stem. Also, the number of seeds in soybean cultivars was similar tendency as the number of pods (Table 3). The seed yield varied from 168 to 289 g m^{-2} and the average of 22 small seed soybean cultivars was 225 g m^{-2}. The seed yield showed the greatest value in Sorokong of 289 g m^{-2} and the lowest value in Hannamkong of 168 g m^{-2}.

Relationship between seed yield and growth traits

The relationship between the seed yield and the days from flowering to maturing date was high significant difference ($r=0.575$, $p<0.01$) in 22 small seed soybean cultivars and there was a high significance difference ($r=0.781$, $p<0.01$) between the seed yield and the days of planting to flowering date (Fig. 2). Previous studies conducted at optimal planting dates (mid–May) concluded that yield was more affected by altered source strength during the reproductive periods (R1–R7, stages according to Fehr *et al.*, 1971) rather than by the vegetative period (emergence to R1) (Christy and Porter, 1982; Jiang and Egli, 1993). Also, Saitoh *et al.* (2003) reported that the seed yield was higher in the late maturing cultivars than in the early maturing cultivars at mid–June planting date. Parker *et al.* (1981) reported that the yield of early maturing soybean cultivars decreased more than that of the late maturing soybean cultivars planted after mid–June and the

Table 3. Seed yield and yield components of branch and main stem in 22 small seed soybean cultivars.

Cultivars	Branch										Main stem		100 seed w.t. (g)	Seed yield (g m^{-2})
	1st		2nd		3rd		Over 4th		Total					
	Pod No.	Seed No.	Pod No.	Seed No.	Pod No.	Seed No.	Pod No.	Seed No.	Pod No.	Seed No.	Pod No.	Seed No.		
Hannamkong	5.2	10.7	4.8	8.8	3.5	5.6	2.1	4.1	15.6	29.2	23.8	51.1	8.9	168
Tawonkong	6.3	12.1	8.4	16.3	6.3	13.8	2.0	4.4	23.0	46.6	28.4	53.4	7.7	189
Sunamkong	5.8	12.4	8.1	17.3	6.9	13.0	4.0	7.3	24.8	50.0	24.3	48.1	9.6	190
Dachaekong	5.6	12.5	7.2	16.3	6.0	13.7	3.4	7.9	22.2	50.4	19.0	42.9	7.2	169
Namhaekong	5.0	9.2	7.4	14.6	6.9	13.9	5.0	9.9	24.2	47.7	23.5	37.2	14.4	269
Sobaegnamulkong	5.5	10.5	6.5	13.7	4.0	7.7	2.8	5.9	18.7	37.7	22.0	42.1	9.2	222
Sohokong	3.9	7.7	6.7	14.6	7.8	14.9	9.3	18.1	27.7	55.6	19.7	38.2	11.5	217
Paldokong	6.7	13.3	7.5	15.6	5.1	10.8	1.4	2.9	20.6	42.6	26.2	50.8	12.8	242
Saebyolkong	7.2	15.0	8.3	17.7	6.5	14.9	3.3	7.3	25.4	55.0	22.5	48.2	12.6	219
Dagikong	5.2	11.7	4.7	12.2	4.7	10.4	5.2	14.6	19.8	48.9	19.3	45.6	12.0	226
Anpyeongkong	3.6	7.3	4.9	11.4	5.7	13.5	4.2	10.4	18.4	42.6	17.1	40.5	10.7	204
Myeongjunamulkong	7.9	12.6	7.8	13.0	9.5	15.2	11.5	21.8	36.7	62.7	21.5	49.6	11.3	219
Eunhakong	7.6	15.7	7.2	18.9	8.4	20.5	6.2	14.0	29.4	69.1	18.2	42.9	10.4	215
Doremikong	4.7	9.8	7.4	17.6	6.8	16.4	8.9	22.3	27.7	66.1	22.1	45.7	10.0	260
Pungsannamulkong	7.8	16.4	10.2	22.1	8.2	16.9	11.2	23.9	37.3	79.2	28.7	66.5	9.1	241
Purwunkong	5.4	12.9	8.1	18.6	10.0	12.4	2.9	6.3	26.4	50.1	15.3	27.7	14.0	263
Kwangankong	6.4	13.0	7.1	16.3	7.0	12.9	8.5	15.0	29.0	57.3	17.5	37.5	12.2	275
Bukwangkong	6.4	11.9	9.2	18.1	8.9	17.5	8.2	17.4	32.6	64.9	20.2	38.8	14.0	258
Sorogkong	9.0	17.1	12.7	23.5	13.3	24.0	11.6	20.5	46.6	85.2	30.9	61.0	10.4	289
Somyeongkong	9.9	22.7	12.5	28.3	11.4	22.2	6.2	14.1	40.0	87.3	29.5	67.8	7.4	278
Sowonkong	8.5	19.2	12.9	30.7	9.5	22.4	10.0	37.4	41.0	109.8	18.3	43.2	9.6	267
Iksannamulkong	6.3	12.4	9.2	19.1	9.2	18.1	8.8	18.3	33.6	68.0	20.6	41.4	11.5	282
Mean	5.9	12.4	7.6	16.7	7.0	14.4	5.8	13.2	27.0	56.8	21.2	44.4	10.8	225
LSD (5 %)	–	–	–	–	–	–	–	–	5.9	11.3	8.1	14.5	1.0	24.5

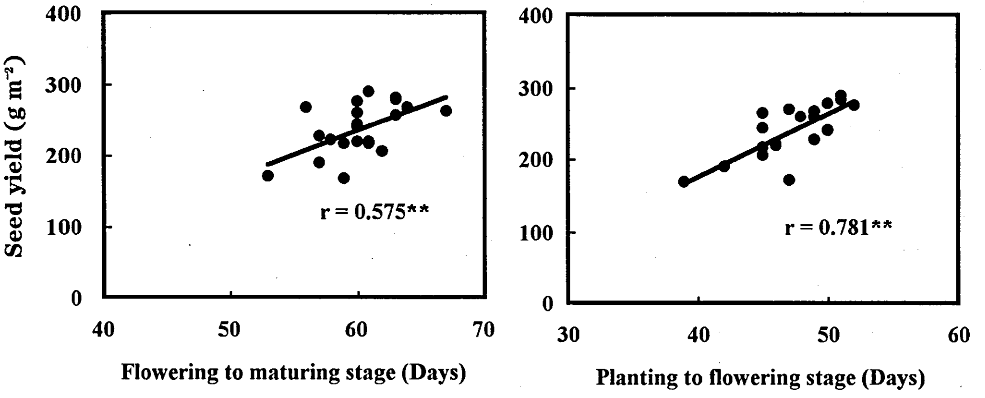

Fig. 2. Relationship between the seed yield and the days of flowering to maturing date or planting to flowering date in 22 small seed soybean cultivars. **: significance at $p<0.01$.

maturity date of the early maturing cultivars was affected more by planting date than that of the late maturing cultivars. In this study, however, the seed yield had a higher correlation with the period of vegetative stage than the period of reproductive stage. Therefore, this result indicated that soybean planted at mid-June need to maintain the days of the vegetative period in order to ensure high productivity in small seed soybean cultivars.

On the other hand, there was a high significance ($r=0.556$, $p<0.01$) between the seed yield and LAI at R5 stage in soybean cultivars (Fig. 3). A range of LAI for the optimal seed yield may be shown about 3.5~4.5 at R5 stage in small seed soybean cultivars. Board *et al.* (1996) reported that differences among cultivars significantly

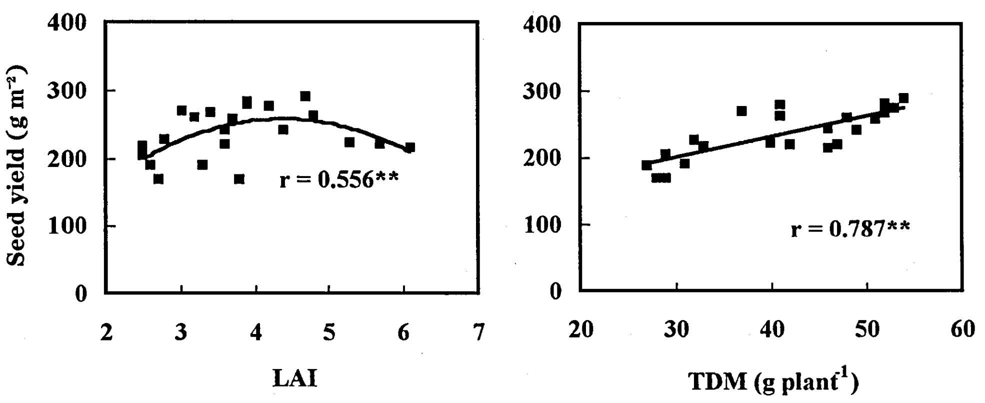

Fig. 3. Relationship the seed yield, and LAI or total dry matter (TDM) of small seed cultivars at R5 stages. **: significance at $p<0.01$.

affected TDM and LAI, and the seed yield was most highly correlated with TDM at R5 stage. The relation between the seed yield and TDM also showed high positive significance ($r=0.787$, $p<0.01$). The statistical significance ($p<0.01$) between the seed yield and the pod number by branch showed the 2nd and 3rd branches in 22 soybean cultivars (Fig. 4). Also, there was a significant relationship between the seed yield and the number of pods on 4th and above branches but was no significant relationship between

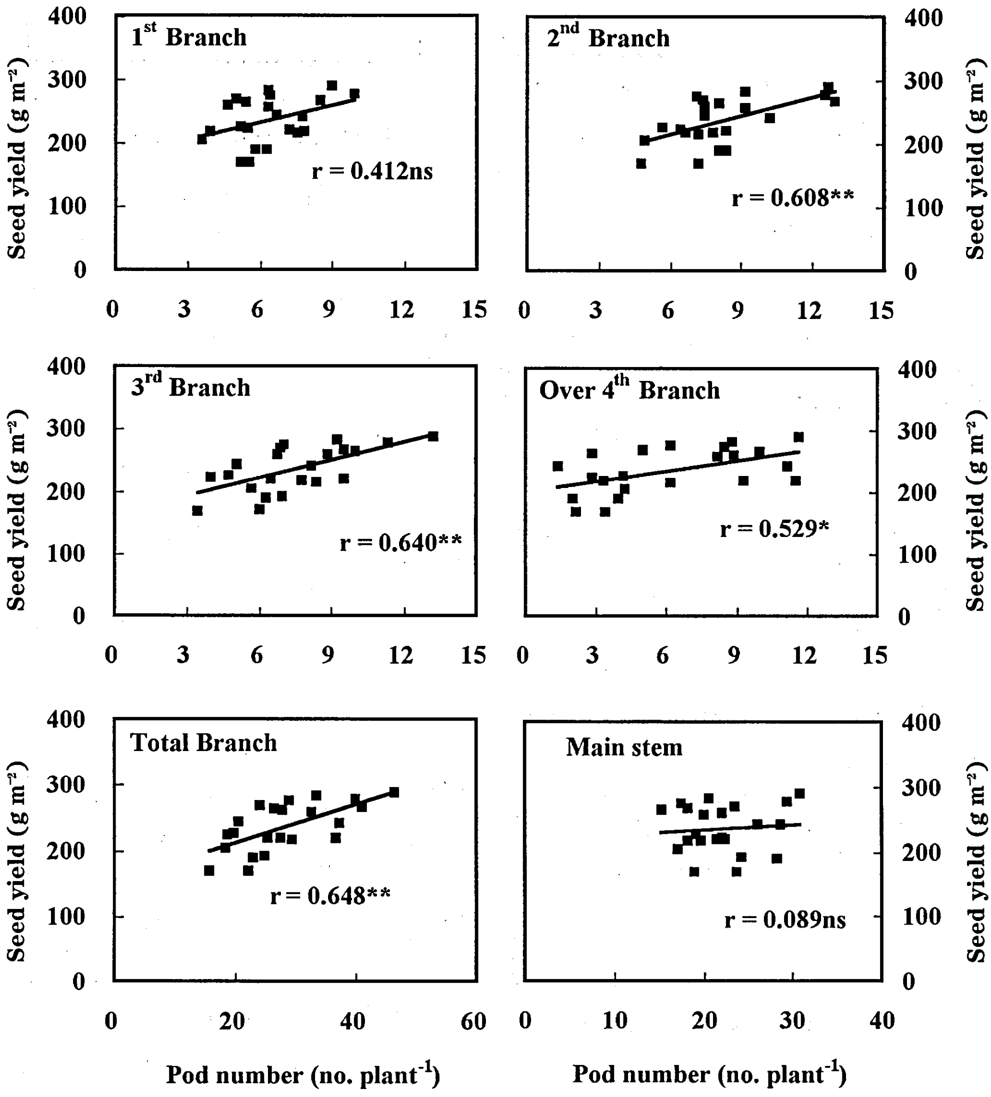

Fig. 4. Relationship between the yield and the pod number on main stem and branch in 22 small seed soybean cultivars. **: significance at $p<0.01$, *: significance at $p<0.05$ and ns: no significance.

the seed yield and the number of pods on 1st branch. The correlation showed the highest significance by 0.640 in relation with 3rd branch, and followed by 2nd, and 4th and above branches in this order. Therefore, there was a high significant relationship ($r=0.648$, $p<0.01$) between the seed yield and the number of pods on total branches among 22 small seed soybean cultivars. Board (1985) reported that seed yield reductions of soybean at mid-June planting dates were more associated with reductions in branch rather than main stem seed yield. However, the relation between the seed yield and the number of pods on main stem showed no significant relationship ($r=0.089$, ns). Results from this study indicated that in order to optimal seed yield of late planted (mid-June) small seed soybean cultivars, some cultivars could be breed which had more pods on the 2nd and 3rd branch.

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