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Growth Parameters and Seed Yield Compenets by Seeding Time and Seed Density of Non-/Few Branching Soybean Cultivars in Drained Paddy Field

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Abstract: In order to find out beneficial plant density and seeding date of non-/few branching soybean experiment was done with three seed densities 3 and 6 levels in 2006 and 2007, respectively. The results were classified into 3 categories. Firstly, increased seed density in May seeding increased culm length 7, 6 and 8 cm in Taekwangkong, Shinpaldalkong and Jilim21, respectively. In addition, high seeding density in May seeding decreased number of branches by 1.5, 1.2 and 1.2 in Taekwangkong, Shinpaldalkong and Jilim21, respectively, however, number of pods on main branch greatly decreased by 25, 24 and 16 in 1st year experiment. Secondly, seed yield 77 (g m^{-2}) in Shinpaldalkong increased in 1st year experiment with increase plant density by increased pod numbers and 100-seed weight. Seed yield was highest (419 g m^{-2}) in Sinpaldalkong 2 under 30×15 cm seeding distance sown at the middle of June. However, seed yield mostly increased with increasing seeding density in delayed seeding time in non-/few branching soy cultivars. In conclusion, increased plant density by 60×7.5 (cm) in mean of both year experiments increased culm length(cm) by 14, 12 and 10 cm Taekwangkong, Shinpaldalkong and Jilim21, respectively. However, seed yield 419 and 400 (g m^{-2}) was highest in 30×15 and 30×10 cm, respectively in Shinpaldalkong in June seeding treatment but there was no yield increasing in other cultivars and seeding density, therefore double cropping system with non-/few branching soybean cultivar might be possible under effective seed density in the southern part of Suwon in South Korea.

Key words: Soybean (*Glycine max* L.), non-branching type, few-branching type, high seeding density, seed yield

INTRODUCTION

Soybean (*Glycine max* L.) cultivation area was 297,000 ha in 1970, however it was greatly decreased to 75,242 ha in 2008 (http://www.mifaff.go.kr; Cho *et al*., 2003). The main reason of acreage decreasing was excess water damage cultivated in drained paddy field, birds' attack during seed germination and seedling establishment and drought damage during ripening which are main reasons of low soybean productivity (Cho *et al*., 2006). Additionally, most farmers just cultivate soybean single cropping, which also reduced farmer's profit. Even in single soybean cropping system soybean productivity (1.5 t ha^{-1}) was very low compared to USA and other major soybean export countries, it might be originated from many rainy days because the weather condition in S. Korea, getting high rainfall during summer season (June-August), so rice cultivation is very useful than upland crops (Cho *et al*., 2001). Additionally, double cropping system could reduce the soybean yield because of the reduced basic vegetative growth duration (Board and Harville, 1996), however, it could be overcome with high seeding density by improved cultivation method, seeding density and fertilization techniques (Ikeda, 1992, 2000; Ikeda and Sato, 1990; Lueschen and Hicks, 1977). If we improve or maintain of the soybean yield in double cropping system than the single cropping, the farmer's profit would be greatly enhanced. For high seeding density, soybean of non-branching cultivar (Jilim21) and few-branching cultivar Sinpaldalkong are known and several researches were done with high seeding density (Carpenter and Board, 1997; Weber *et al*., 1966). Additionally, high seeding density will be improve seed yield of soybean (Palmer, 1999), however, there is no research done with cropping system and requirement for plant growth characteristics. High branching soybean cultivar should be maintain high row distance for high seed yield (Norsworthy and Emerson, 2005), however, it could be decrease branching number and podding position will be upper part and they will be hamper for safe productivity. Another purpose for increasing seed density could increase leaf area because it positively

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correlated with seed yield and improvement pod numbers per plant also contributed to increasing the seed yield (Malik *et al*., 2006). In previous research with fertilization level on seeding date, increased fertilization level reduced the protein content of late plantings, but it was increased in early plantings and additionally seed yield was also higher in early seeding (Achakzai and Kayani, 2002). Pod numbers per plant will be affected by seeding date and early seeding is better than late seeding (Chu *et al*., 1996) and those results are originated from many branching type, so non- or few-branching type will be showing different pattern. Seed yield in main stem is stable, however that is unstable produced in branched pods (Fredrick *et al*., 2001), so non- or few-branching soybean will be helpful for maintain soybean yield. These experiments were done for evaluation of productivity and productivity related characteristics of three soybean cultivars in high seeding density. So, the aim of this study is to find out valuable seeding date (May or June) and seeding density (row-/hill distance) of non-, few- and branching type of soybean under drained paddy field for double cropping systems between soybean and other winter crop.

MATERIALS AND METHODS

This both year (2006 and 2007) experiment were designed as randomized block design with three replications. In 1st year experiment, rice (*Oryza sativa* L.) was cultivated before the experiment for more than 20 years and this soybean (*Glycine max* L.) experiments were done between 2005 and 2006 after making open ditch for escaping wet damage. Before the experiment, soil chemical characteristics were pH, 5.67; N, 0.13(%); O.M, 1.71(%); CEC, 8.31(me/100 g); P_2O_5, 108 (ppm); SiO_2, 58.4 (ppm). The soil physical characteristics of soil texture was loam soil (sand, silt and clay contents were 53, 21 and 25%, respectively) and bulk density(g/cc) was 1.2 and 1.4 of 0-15 and 15-30 cm soil depth. The fertilization amounts of RDA standard (3-3-4.5 g m^{-3}, N-P-K) for soybean were spread on soil surface then rotary cultivated for mixing well for 15cm soil depth and soybean seeding. Three soybean cultivars Jilin21 for non-branching type, Sinpaldalkong 2 for few-branching type and Taekwangkong for conventional cultivar branching type were used. Seeding date was May late and density were 22,000 (60×15 cm) 33,000 (60×10 cm) and 44,000 (60×7.5 cm) with 3 seeds per hill and maintained two plants after seedling establishment. In 2nd year experiment, field condition was maintained of 1st year and other experimental methods were same, however, seeding date was added on June mid and seeding density of 44,000 (30×15 cm), 66,000 (30×10 cm), 88,000 (30×7.5 cm) were added. Soybean plant sampling was done for measuring stem length with 10 hills in 3 sub-plots. Seed yield was measured 4 rows x 2 m (hill distance). After harvesting seed weight (g/100-seed) was measured and yield related characteristics were also measured with 5 other plants and measuring methods followed by the Research manual Standard (Anonymous, 2003). All obtained data was subjected to statistical Analysis of Variance (ANOVA) by using SAS statistical software. And it was used F test to find out mean grouping for the mean values.

RESULTS AND DISCUSSION

Growth characteristics of soybean: In 1st year experiment, stem length was longest in Taekwangkong (TK: 106-120 cm) was followed by Shinpaldalkong2 (SP2: 73-90 cm) and Gilim21 (63-75 cm) was shortest (Table 1). Stem length increased with increasing seeding density and variation by seeding was highest in SP2.

The node numbers in main stem was similar pattern by stem length, however, it was not significant statistically. Branch number was the highest in TK (3-4) and followed by SP2 (1-3) and lowest in Ginlin21 (0-1). That results same pattern as known by the breeders and cultivator even different seeding density and cultivation area (Board and Harville, 1996).

The node of 1st branch position was highest in TK (4-8) then followed by SP2 (3-4) and lowest in Gilin21 (0-2). The numbers of pod was highest in SP2 (25-35) and followed by Gilin21 (19-30) and lowest in TK (5-24). Pod numbers in main stem was decreased with increasing seeding density which is reasonable because high plant density resulted in competition neighbor plants, so just increasing plant height which also bring about weakness in insect-pest attack, however seeding density should be increased in no- or few branching type of soybean for high seed yield (Carpenter and Board, 1997; Weber *et al*., 1966). Pod numbers in branch was highest in TK and followed by SP2 and lowest in Gilin21, however it was highest (18, 15 in 1st and 2nd year) distance (60×15 cm) (Table 1). That reason might be originated from the open canopy structure. So, light penetration increased and no competition with other weeds and neighbor soybean plants. In 2nd year experiment, July mid. Seeding time and seeding row distance 30 cm were added in 1st year experiment.

Stem length was shortened with 30-50 cm compared to 1st year experiment even same seeding time treatment. Additionally, it was ranged between 77 and 83 cm in TK which was shorter than 1st year experiment which ranged longer than 100 cm. The main reason of high stem length

Table 1: Mean values for the soybean growth and podding as affected by seeding time, soybean cultivar and seeding density in 2006 and 2007

Seeding date	Cultivar	Seeding	Culm length (cm)		Nod No. in main stem (No.)		Branch No. (No./pl)		Nod of 1st branch		Pod No. (No./pl)	
(Mon./Date)	Soybean cultivar	distance (cm)	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
5/31	TK	60×15	106	66	18	15	4.2	6.2	4.3	4.3	54	32
	Taekwang-kong	60×10	104	77	17	14	3.1	4.3	8.2	4.2	41	29
	Taekwang-kong	60×7.5	120	73	16	14	2.7	5.1	6.1	4.0	29	34
	SP2	60×15	73	60	17	14	3.3	2.4	3.4	3.4	58	37
	Shinpaldal-kong 2	60×10	85	59	17	14	1.4	3.2	4.3	4.3	37	39
	Shinpaldal-kong 2	60×7.5	90	66	17	13	2.1	2.1	4.2	3.0	34	30
	JL21	60×15	63	58	15	14	1.3	3.7	2.3	4.3	35	45
	Jilim 21	60×10	66	67	15	13	0.3	2.8	0.3	4.1	22	31
	Jilim 21	60×7.5	75	66	14	14	0.1	2.5	0.3	4.2	19	31
6/13	TK	30×15	-	77	-	14	-	4.4	-	4.2	-	28
	Taekwang-kong	30×10	-	82	-	15	-	4.2	-	4.8	-	29
	Taekwang-kong	30×7.5	-	83	-	13	-	3.6	-	4.1	-	27
	Taekwang-kong	60×15	-	69	-	14	-	4.8	-	4.0	-	38
	Taekwang-kong	60×10	-	58	-	13	-	3.3	-	3.9	-	25
	Taekwang-kong	60×7.5	-	66	-	13	-	4.1	-	4.7	-	25
	SP2	30×15	-	57	-	13	-	2.4	-	3.3	-	28
	Shinpaldal-kong 2	30×10	-	65	-	13	-	2.1	-	4.2	-	29
	Shinpaldal-kong 2	30×7.5	-	64	-	13	-	1.8	-	3.1	-	26
	Shinpaldal-kong 2	60×15	-	50	-	13	-	3.3	-	2.8	-	45
	Shinpaldal-kong 2	60×10	-	53	-	13	-	2.4	-	3.8	-	33
	Shinpaldal-kong 2	60×7.5	-	59	-	13	-	2.6	-	3.7	-	30
	JL21	30×15	-	60	-	13	-	3.3	-	3.2	-	37
	Jilim 21	30×10	-	58	-	13	-	2.4	-	4.2	-	32
	Jilim 21	30×7.5	-	61	-	13	-	1.9	-	4.1	-	30
	Jilim 21	60×15	-	51	-	13	-	3.4	-	3.3	-	58
	Jilim 21	60×10	-	51	-	13	-	3.2	-	3.1	-	38
	Jilim 21	60×7.5	-	58	-	14	-	2.5	-	3.9	-	39

was might be originated from many rainy days because the weather condition in S. Korea, getting high rainfall during summer season (June-August), so rice cultivation is very useful than upland crops (data not shown) during early growing stage of soybean in 1st year and soil fertility might be also contributed because before the experiment start, the field was maintained with paddy field which release more ammonium ion content than drained condition. One more reason was a little drought damage effect of the soybean in 2nd year. Special characteristic was found in 2nd year experiment which was branch numbers increased contrary to decreased plant height.

The 1st branch of SP2 was positioned on the 4th node which was same as 1st year experiment, however, Gilin21 was a little highly positioned and same as SP2 which main reasons might be originated from un-normal growth by wet damage and Ginlin21 was basically cultivated in north-east part of China, so it especially weak in wet damage (no previous report).

Pod numbers was higher in 2nd year experiment than 1st year except conventional seeding density (60×15 cm) of TK and SP2 (Table 2). The pod number among seeding date, June mid was higher than May late which result was different to previous reports (Chu *et al*., 1996; Malik *et al*., 2006; Park *et al*., 1987) and that reason was heavy seeding density with drought damage might be hampered seedling establishment and plant growth even longer vegetative growth stage than delayed seeding treatment. In TK, pod number was higher in high density than low density which was different to previous report (Board and Harville, 1996) and general pattern, however, it estimated by the sun light and vegetative growth duration were enough for receiving them even high seeding density (Ogbuchi and Brandle, 1981).

Pod numbers of plant in TK were higher (10-20) in 1st year experiment than 2nd year except 60×7.5 cm treatment. And SP2 was same as Taekwangkong without and different pattern by seeding density. However it was higher in Gilin21 in 2nd year experiment and generally it was higher in low density condition than high density except hill distance 10 and 7.5 cm with 30 cm row distance of TK sown mid of June in 2nd year experiment. However it was higher in dense seeding condition than high density in area based total pod number.

Stem characteristics and seed yield of soybean: The 1st year experiment, Ginlin21 was the height seed yield (419 and 400 g m^{-2}) then followed by TK and SP2 among the soybean cultivars sown in May seeding treatment (Table 2). However, seed yield in 1st year (372 g m^{-2} in SP2 in 1st year) was highest in 60×7.5 cm seeding distance and 100-seed weight (29 g) in TK in 1st year May seeding was also higher in high seeding density treatment. Generally high seeding density enhanced vegetative

Table 2: Mean values for the seed yield and yield components of soybean as affected by seeding time, soybean cultivar and seeding density in 2006 and 2007

Seeding date (Mon./Date)	Cultivar Soybean cultivar	Seeding distance (cm)	Seed yield (g m^{-3}) '06	Seed yield (g m^{-3}) '07	Ripening (%) '06 Total	Ripening (%) '07 Main stem	Ripening (%) '07 Branch	Pod number (m^{-3}) '06 Total	Pod number (m^{-3}) '07 Pod of main stem (%)		100 seed weight (g) '06	100 seed weight (g) '07
5/31	TK	60×15	374ab*	330	93	89	87	1,206	1,421	22	27	27
	Taekwang-kong	60×10	396a	314	94	86	85	1,381	966	31	29	26
	Taekwang-kong	60×7.5	374ab	324	89	89	84	1,151	755	27	29	27
	SP2	60×15	295b	319a	89	87	85	1,116	1,643	73	21	23
	Shinpaldal-kong 2	60×10	309b	294b	88	80	85	1,246	1,332	65	22	24
	Shinpaldal-kong 2	60×7.5	372a	301ab	88	87	80	1,427	666	67	24	24
	JL21	60×15	82ab	372a	44	86	80	674	1,998	60	26	21
	Jilim 21	60×10	88a	371a	57	76	71	853	1,032	68	24	21
	Jilim 21	60×7.5	75b	371a	44	77	82	849	688	71	23	21
6/13	TK SP2	30×15	-	386a	-	83	76	-	1,244	43	-	25.5
	Taekwang-kong	30×10	-	358b	-	80	84	-	1,933	48	-	26.6
	Taekwang-kong	30×7.5	-	371ab	-	81	77	-	2,400	26	-	24.7
	Taekwang-kong	60×15	-	337c	-	88	81	-	1,689	34	-	25.5
	Taekwang-kong	60×10	-	320d	-	76	75	-	1,666	44	-	25.2
	Taekwang-kong	60×7.5	-	282e	-	78	75	-	2,222	36	-	25.3
	JL21	30×15	-	419a	-	80	60	-	1,244	82	-	20.8
	Shinpaldal-kong 2	30×10	-	400ab	-	86	60	-	1,934	76	-	22.2
	Shinpaldal-kong 2	30×7.5	-	383b	-	88	72	-	2,311	77	-	21.1
	Shinpaldal-kong 2	60×15	-	356c	-	83	61	-	1,822	61	-	25.8
	Shinpaldal-kong 2	60×10	-	357c	-	82	69	-	2,200	73	-	20.9
	Shinpaldal-kong 2	60×7.5	-	317d	-	83	66	-	2,667	73	-	20.6
	Jilim 21	30×15	-	393a	-	88	76	-	1,644	68	-	24.1
	Jilim 21	30×10	-	379ab	-	90	76	-	2,200	70	-	23.8
	Jilim 21	30×7.5	-	355b	-	86	75	-	2,755	81	-	22.8
	Jilim 21	60×15	-	259d	-	92	93	-	2,578	50	-	20.7
	Jilim 21	60×10	-	304c	-	89	83	-	2,534	58	-	23.9
	Jilim 21	60×7.5	-	288cd	-	90	79	-	3,466	62	-	22.1

*Mean separation within columns by DMRT at 5% level

growth per area and that will be decreasing hamper reproductive growth, however, contrary to the conventional branching type of soybean, non-branching and few-branching type reduced vegetative growth per plant, so 100-seed weight was increased. Pod weight of TK was mostly depends on branch(145-301 g $plant^{-1}$) than main stem (43-116) (Table 3), however, it was higher in main stem (151-198 and 159-241) than branch in SP2 and Gilin21. Pod numbers per plant also resulted same pattern of pod weight, however, perfect seed percentage was not different among the cultivars. However, stem length increased with increasing seeding density.

Seed yield was the highest (317-419 g m^{-2}) in Shinpaldalkong2 and followed by TK(282-386) and Gilin21(259-393) sown in June (Table 2). Especially, seed yield was highest in 30×15cm in SP2419 (g m^{-2}) of all the treatments and it was more 100 (g m^{-2}) than other treatments.

Seed yield of June seeding soybean was higher in 30 cm (>355 and 383 g m^{-2} : Sp2 and Jilin21) row distance in few-branching soybean and generally branching type of soybean will be low seed yield in short row distance and it depending on main stem seeds, however, it will be branch dependent type in long row distance (Norsworthy and Emerson, 2005). Contrary to conventional branching type, seed yield of SP2 (317-419 g m^{-2}) and Gilin21 (259-393 g m^{-2}) was main stem dependent more than 60% and if we shortening row distance like 20×15 cm could be increase more seed yield. In both year experiment, seed yield of TK (374-396 g m^{-2}) and SP2 (295-372 g m^{-2}) was higher in 1st year than 2nd year sown in May late, however, it in Jilim21 was higher in 2nd year than 1st year which main reason was heavy rain during 1st year experiment and Gilin21 was very sensitive high soil moisture condition than other cultivars. However, seed yield in Gilin21 (75-82 in 1st year and 259-393 g m^{-2} in 2nd year) was almost 4 times enhanced compared to 1st year and it means that Ginlin21 was more susceptible in excess soil moisture condition than drought condition.

Seed yield (358-371, 383-419 and 355-393 g m^{-2} for 30 cm distance; 282-337, 317-357 and 259-304 g m^{-2} for 60 cm distance) between row distances, 30 cm was more than 60 cm in all soybean cultivars and all hill distance. Especially SP2 (419 and 400 g m^{-2}) recorded the highest seed yield in 30 cm raw distance sown June mid among other seeding distance treatment (Palmer, 1999).

The ripening percent was higher in TK (89-94%) in 1st year experiment and it recorded 84% in 2nd year, so it was higher (3-5 and 3-5% in TK and SP2, respectively) in 1st year than 2nd year experiment. In 2nd year experiment, ripening percentage was higher(76-88:75-84, 80-88:60:69,

Table 3: Mean values for the soybean growth (leaf area, culm length) and dry weight of stem and pod as affected by seeding time, soybean cultivar and seeding density ('06-'07) in 2006 and 2007

Seeding date (Mon./Date)	Cultivar soybean cultivar	Seeding distance (cm)	Dry stem weight (g m^{-3})	Dry pod weight (g)		Leaf area index	Plant height (cm)
				Main stem	Branch		
5/31	TK	60×15	101	*43c	145b	3.7	66
	Taekwang-kong	60×10	133	80b	162b	4.9	77
	Taekwang-kong	60×7.5	194	116a	301a	5.5	73
	SP22	60×15	79	151ab	52c	3.3	60
	Shinpaldal-kong 2	60×10	142	197a	113a	4.4	59
	Shinpaldal-kong 2	60×7.5	132	198a	95b	6.2	66
	JL21	60×15	83	159b	85a	3.9	58
	Jilim 21	60×10	95	154b	61c	3.7	67
	Jilim 21	60×7.5	116	241a	72b	4.6	66
6/13	TK SP22	30×15	134	154b	167c	3.2	77
	Taekwang-kong	30×10	212	236a	239b	4.0	82
	Taekwang-kong	30×7.5	240	151b	436a	5.9	83
	Taekwang-kong	60×15	82	86c	143cd	2.1	69
	Taekwang-kong	60×10	82	91c	111d	2.7	58
	Taekwang-kong	60×7.5	135	97c	160c	3.1	66
	JL21	30×15	99	236c	41c	2.8	57
	Shinpaldal-kong 2	30×10	148	337b	57ab	3.4	65
	Shinpaldal-kong 2	30×7.5	185	417a	80a	4.7	64
	Shinpaldal-kong 2	60×15	59	148e	59ab	1.4	50
	Shinpaldal-kong 2	60×10	69	184d	49b	2.1	53
	Shinpaldal-kong 2	60×7.5	96	219cd	52b	3.9	59
	Jilim 21	30×15	120	303c	120c	4.1	60
	Jilim 21	30×10	157	405b	144b	3.3	58
	Jilim 21	30×7.5	190	520a	109c	4.4	61
	Jilim 21	60×15	92	186f	168a	1.7	51
	Jilim 21	60×10	85	203e	115c	1.6	48
	Jilim 21	60×7.5	104	253d	151ab	2.7	55

*Mean separation within columns by DMRT at 5% level

83-92:66-93 in 1st and 2nd year in TK, SP2, Jinlin21, respectively) in main stem than branch seeds. It was higher in 1st year than 2nd year experiment (previous data, Table 2) and the pattern was similar between Shinpaldalkong2 and TK. In 2nd year experiment, it was higher in main stem (previous data, Table 2) than branch in two seed density level except 60×10 cm. That in Gilin21 was almost two times higher in 2nd year (76-86%) than 1st year (44-57%) experiment and mostly main stem (83-92:66-93) dependent except 60×7.5 cm distance (77:82). TK sown in mid of June, seed ripening percentage was higher in main stem than branch seeds, however, it was higher in branch than main stem in 30×10 cm plot. That was 2.5% higher in main stem in 30×7.5 cm then 60×7.5 cm in all stem. Seed ripening percentage in main stem was higher in Shinpaldalkong2 and Ginlin21 which reason was originated from the non- or few branching pattern and it was especially higher in 30 cm row distance than 60 cm, however it was reversely higher in 60 cm than 30 cm distance.

CONCLUSION

Soybean cultivar non-branching type Jinlin21 was very weak in excess soil water condition, especially drained paddy field (Cho *et al*., 2004), however it well adapted in drought damage than other few-branching and branching type of soybean. A little delayed seeding of no- and few-branching soybean in mid. of June was produced more seed yield than early seeding in high seeding density treatment. The best row distance for high seed yield was 30 cm in non- or few-branching soybean types. For improving farmer's profit with soybean cultivation, double cropping system of soybean with other winter or spring crops are recommended because in delayed seeding for double cropped soybean will give same or higher profit as soybean single cropping system because of a little improved seed yield and shortened soybean cultivation duration, additionally it give pre-crop's benefit together during winter and spring season.

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