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Genotypic Variation in Flowering and Maturing Periods and Their Relations with Plant Yield and Yield Components in Soybean

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ABSTRACT : Improvement of crop yield can be achieved through understanding genetic variation in reproductive characters and its impact on yield components. The present study was performed to evaluate genetic diversity for reproductive growth characters in exotic germplasm resources and to determine the relationships between developmental and growth periods with yield and yield components in soybean cultivar groups. For phenotypic evaluation such as reproductive and agronomic traits, a total of 80 indigenous and exotic soybean cultivars collected from four different geographical regions (China, Japan, Korea, and Vietnam) were grown from May to November of 2003 at the Seoul National University Farm, Suwon, Korea (127°02'E longitude, 37°26'N latitude). Most of all the characters exhibited wide range of phenotypic variation, of which pod number, seed number, and plant yield showed greater range as compared to other characters. Korean cultivar groups showed greater diversity than the other cultivar groups in seven characters. Correlation analysis showed that days to flowering (DTF) and days to maturity (DTM) had close association with agronomic traits as well as yield and yield components. Both DTF and DTM had positive correlation with the other characters except one hundred seed weight. Stepwise multiple linear regression revealed that seed and pod number were identified as being significant for plant yield. The results in this study indicated wide variation in agronomic traits including DTF and DTM, suggesting the valuable genetic resources in a soybean breeding program.

Keywords: soybean, genetic diversity, days to flowering, days to maturity, yield components

Soybean, *Glycine max* (L.) Merrill, legume native from East Asia, is currently one of the most important crops worldwide due to its broad utility as well as extraordinary qualities. Identification and utilization of diverse germplasm are the central issue in plant breeding. With knowledge of genetic diversity of soybean crop, parental selection is more feasible because genetic improvement could be maximized.

Germplasm provides new sources of genetic variation for future gain. Genetic diversity and agronomic value are considered as selection criteria for parental stock (Brown-Guedira *et al.*, 2000). Facilitating introgression of diverse germplasm into the current commercial soybean genetic base could help future breeding strategies (Baranek *et al.*, 2002). In soybean and many other crops, selection for major agronomic traits has been one of major breeding targets for development of new cultivar with superior performance and adaptation (Kim & Cho, 2005; Lee *et al.*, 1996; Truong *et al.*, 2005). Yield and yield components analyses are simple and straightforward because they can provide strategies for selection of a trait of higher yield (Johnson *et al.*, 1955a).

The reproductive success of plant cultivars is often dependent on their flowering time being adapted to the environment where they grow (Pineiro & Coupland, 1998). An understanding of how cultural and environmental factors influence yield can have practical implications for solving agronomic problems (Cho *et al.*, 2004). Maximizing soybean yield depends on creating an optimum amount of dry matter at some critical stage associated with optimum production of critical yield components. Identification of this yield formation process would aid in advising growers how to improve their yield.

The interest of researchers on improved and more productive soybean cultivars have helped to increase soybean production (Smith & Huyser, 1987). Planting time and cultivar maturity in addition to row spacing and plant population altered crop growth rate (CGR) and light interception (LI) during the reproductive period. Seed number, pod number, pods per reproductive node, reproductive node number, and node number were identified as being important to yield formation (Board *et al.*, 1990; 1992; Board & Harville, 1993; Board & Tan, 1995).

Agronomic performance of exotic germplasm in a target environment may be taken into account in parental selection. Geographic origin and plant morphology data are available for most of the introduction germplasm collections and frequently serve as criteria for selection of genetically diverse parents. Geographic origin also may not be an adequate indicator of genetic diversity (Brown-Guedira *et al.*, 2000). Generations of new and improved cultivars can be enhanced by new sources of genetic variation. Therefore,

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criteria for parental stock selection need to be considered not only by agronomic value, but also from the point of view of their genetic dissimilarity (Hudcovicova & Kraic, 2003).

The objectives of this study were to determine genetic variation of soybean cultivar groups collected from different Asian countries on the basis of agronomic characters and analyze the relationships of vegetative and reproduction growth periods that influenced on final yield and yield components.

MATERIALS AND METHODS

Plant materials and evaluation of agronomic traits

A total of eighty soybean cultivars were collected from four different geographical regions such as Chinese, Japan, Korea, and Vietnam (Table 1). A total of 20 Vietnamese cultivars belong to low-latitude group, while the other 60 cultivars, including Chinese, Japanese, and Korean cultivars, are originated from high-latitude one. For phenotypic evaluation, soybean plants were grown from May to November 2003, at the Experimental Farm, Seoul National University, Suwon, Korea (127°02'E longitude and 37°26'N latitude).

Each cultivar was planted on May 30 at a distance of 60 cm between rows and 15 cm between plants within a row. Seedlings were thinned to two plants per hill ten days after sowing (DAS). Data were collected on days to flowering (DTF), and days to maturity (DTM). Other agronomic characters, plant yield and yield components were also recorded after maturity. The late maturing cultivar mainly from Vietnam was harvested around 20 of November. Mean values and standard error of the agronomic traits and yield and yield components were calculated for the five plants selected at random for each cultivar.

Statistical analysis

Descriptive statistics and simple correlation were mainly used in this study. In addition, to determine the relationship among developing stages with agronomic characters, correlation analysis of DTF and DTM with agronomic traits were made for each group. Stepwise multiple linear regression procedures (SAS Institute, 2000) were used to determine the relative importance of growth stages with agronomic characters and yield components in determining final seed yield. Forward and reverse stepwise models were used for this purpose, and variables were selected for inclusion in the model at $P < 0.05$.

RESULTS AND DISCUSSIONS

Agronomic trait performances

Differences among four cultivar groups were detected in all studied characters (Table 2). There was a fairly large variation in DTF, ranging from forty seven to eighty six days. Chinese cultivar group was flowering early, about forty-seven DAS (Table 2). When compared to Korean and Japanese cultivar groups, Vietnamese cultivar group was flowering very late (eighty six DAS). DTM ranged from four to five months. The early-flowering cultivars normally matured early. Chinese cultivar group had short maturity as compared with other cultivar groups, while Vietnamese cultivar group matured more than five months after sowing. Tropical soybean cultivars grown in temperate latitudes were so sensitive to climate, especially to photoperiod. Shanmugasundaram (1981) concluded the difference of flowering time could be considered as criteria for evaluating photo-sensitive soybean cultivars. This was also confirmed again by the previous studies by Whigham (1983) and Summerfield & Robert (1985).

Plant height at R8 stage ranged from 73 to 172 cm. When compared to the other groups Vietnamese cultivar group was characterized with high plant height. The Vietnamese cultivar group, when grown in Korea, is exposed to longer day length, causing delay in flower bud formation and flowering time. The later flowering time, the taller plant height. Contrary to this, if soybean plants adapted to high latitude was grown in the low latitude, then they were

Table 1. Number and origin of soybean cultivars used in experiment.

Cultivar group	Number	Collection site	Latitude	Longitude
China†	20	Heilongjiang; Jilin; Liaoning	39°-54°00'N	130°00'-138°00'E
Japan†	20	Hokkaido; Honshu; Kyushu	30°-46°00'N	130°00'-144°00'E
Korea†	20	Gyeonggi; Gangwon; Chungcheong; Cheolla	33°-39°00'N	124°11'-131°52'E
Vietnam‡	20	North; Central; South	8°30'-23°25'N	102°10'-109°30'E
Total	80			

†Source: Genebank, RDA, Korea.
‡Source: CanTho University, Vietnam

Table 2. Descriptive statistics for major agronomic traits based on the cultivar groups.

Characters	Cultivar groups	Range	Mean ± S.E.	Phenotypic variance	Coefficient variation (%)
Days to flowering (days)	China	40-54	47 ± 0.94	17.8	8.97
	Japan	42-69	50 ± 1.48	43.8	13.2
	Korea	43-66	52 ± 1.33	35.3	11.4
	Viet Nam	72-104	86 ± 2.60	135.0	13.5
Days to maturity (days)	China	116-132	128 ± 1.46	42.6	5.10
	Japan	118-156	135 ± 1.88	71.0	6.24
	Korea	119-156	133 ± 2.81	157.4	9.43
	Viet Nam	126-171	156 ± 3.23	209.2	9.27
Plant height (cm)	China	75-140	105.6 ± 4.40	386.4	18.6
	Japan	70-145	98.7 ± 3.58	256.8	16.2
	Korea	40-117	72.9 ± 6.23	775.2	38.2
	Viet Nam	124-188	172.4 ± 4.30	366.9	11.1
Internode length (cm)	China	8.3-15.8	11.7± 0.18	4.35	17.9
	Japan	8.9-15.0	10.7± 0.36	2.33	14.3
	Korea	5.4-11.7	8.4± 0.43	3.65	22.8
	Viet Nam	12.5-21.3	17.1 ± 0.54	5.94	14.2
Pod number/plant	China	16-49	33 ± 2.19	95.5	29.8
	Japan	10-52	27 ± 2.39	113.9	40.1
	Korea	15-48	24 ± 2.21	97.9	41.1
	Viet Nam	15-53	38 ± 2.48	123.1	29.5
One hundred seed weight (g)	China	14.9-22.0	17.8 ± 0.45	4.1	11.4
	Japan	15.2-26.1	20.6 ± 0.68	9.4	14.9
	Korea	14.5-34.5	24.8 ± 1.73	60.1	31.3
	Viet Nam	14.4-26.7	18.5 ± 0.67	15.3	21.1
Seed number/plant	China	50-186	116 ± 7.33	1076	28.3
	Japan	31-156	79 ± 6.53	853	37.0
	Korea	30-210	91 ± 11.3	2542	55.6
	Viet Nam	64-167	95 ± 6.44	829	30.2
Plant yield (g)	China	9.3-47.5	30.3 ± 2.70	145	39.8
	Japan	9.4-48.1	20.2 ± 1.73	60	38.3
	Korea	5.9-51.6	24.1 ± 2.97	177	55.2
	VietNam	6.6-44.6	26.9 ± 2.12	90	35.3

flowering early in response to the short-day length. Internode length was less various within groups as well as between groups (Table 2). Tall plant cultivars gave greater internode length than short-plant ones.

Total pod number per plant including one-seeded, two-seeded, and three-seeded pods showed wide range of variation. Chinese and Vietnamese cultivar groups showed the high pod number per plant. Seed number per plant varied among groups and within a group (Table 2). Chinese group had more seed number per plant than the other groups. The plant with greater pod-number had the tendency to have more seed number per plant. However, the increase of pod and seed number could cause the decrease of seed weight due to the incomplete grain filling, which was observed frequently in Vietnamese cultivars. Of 20 soybean genotypes collected from Vietnam, 13 represented more than 160 DTM, indicating that these soybean genotype did not reached maturity before the first frost which resulted in incomplete grain filling.

One hundred seed weight varied from 18 to 25 g (Table 2). Seed size of the Korean cultivar group was larger than that of Chinese and Vietnamese group. The average plant

Table 3. Correlation coefficients of flowering time and maturity with other agronomic traits.

	Groups	Plant height	Internode length	Pod number	100-seed weight	Seed number	Plant yield
Days to flowering	China	0.71**	0.65**	0.39ns	-0.56**	0.31ns	0.37ns
	Japan	0.59**	0.0005 ns	0.59**	-0.38ns	0.51*	0.57**
	Korea	0.67**	0.44**	0.67**	-0.52*	0.34ns	0.53*
	Viet Nam	0.56**	-0.07ns	0.38ns	-0.32ns	0.37ns	0.33ns
	Total	0.83**	0.72**	0.48**	-0.28*	0.10ns	0.21ns
Days to maturity	China	0.56**	0.53*	0.45*	-0.60**	0.77**	0.77**
	Japan	0.72**	0.61**	0.70**	-0.47*	0.55*	0.84**
	Korea	0.94**	0.86**	0.64**	-0.64**	0.46*	0.52*
	Viet Nam	0.88**	0.78**	0.89**	-0.59**	0.66**	0.53*
	Total	0.82**	0.73**	0.65**	-0.42**	0.29**	0.39**

yield ranged from 20 to 30 g. Japanese group showed the lowest yield, while Chinese group produced the highest yield.

Generally, all the characters exhibited wide range of phenotypic variation. Among them, pod number, seed number, and plant yield showed greater range as compared to other characters. Greater diversity was shown in most characters within Korean and Japanese cultivar groups, whereas Chinese group was comparatively less diverse. This may be due to the narrow variation caused by fastened flowering of Chinese group cultivars in Suwon with shorter daylength than Manchuria.

Correlation among characters

Both DTF and DTM were significantly correlated with agronomic traits as well as yield and yield components (Table 3). DTM gave better correlation with plant characters than DTF. Both DTF and DTM had positive correlation with other traits except one hundred seed weight. The negative correlation of DTF and DTM with one hundred seed weight can be explained by the relationship between sink and source. The longer in DTF and DTM, the greater in biomass including higher stem and leave growth as well as the greater seed number. Using a total of 67 genotypes of which 13 genotypes from Vietnam showing incomplete grain filling were discarded, correlation analysis revealed the same relationship remained between DTM with other growth characters (data not shown).

Significant correlations of DTM more than DTF were present with other characters. DTF was positively correlated with plant height and number of pods as well as internode length. This is consistent with the results by Shuping et al. (1994). One hundred seed weight had negative correlation with days to flowering and maturity. Yang & Wang (2000) also reported negative correlation of seed size with DTF and DTM. However, depending on the genotypes used, there may be a possibility to have positive relationship. Phenotypic correlation of DTF with yield and yield components was fairly low. Hence, DTF may not be a good criterion to select soybean cultivar for improving yield. Further studies are needed to clarify the incomplete relationship of DTF with seed number and plant yield.

Seed number and seed size are two important components influencing plant yield. Egli *et al.* (1978) found that yield was correlated with seed number and not with seed size and also reported that seed size was more likely to fluctuate with changes in environment than seed number per plant. Significant correlation of yield with yield components was also reported in several other studies (Burton, 1987; Johnson *et al.*,1955b).

Stepwise multiple linear regression

Based on the stepwise multiple linear regression analyses of plant yield with all the agronmoic traits using forward and reverse procedures, parameters were estimated (Table 4). DTM was a significant component influencing final yield for Japanese cultivar group. Japanese cultivar group consisted of germplasm collections from a large area covering north to the south of Japan, indicating the large difference in latitude of collection sites. Meanwhile, seed number was identified as being significant for plant yield in Vietnamese cultivar group. One hundred seed weight and seed number per plant were thought to be significant for prediciting plant yield in China cultivar group, whereas one hundred seed weight and pod number were in Korean cultivar group. Using pooled data across four different groups, pod number and seed number were detected as being important variables influencing on final yield. This is similar to previous findings by Malhotra *et al.* (1972) and Sharia (1980). Morrison *et al.* (2000) considered plant breeders in short season can

Table 4. Multiple stepwise regression of plant yield with seven characters such as days to flowering, days to maturity, plant height, internode length, pod number per plant, one hundred seed weight, and seed number per plant.

Groups	Variables	Parameter estimates	Standard error	*F* value	P
Total	Intercept	0.68947	2.3583	0.09	0.7708
	Pod number	0.09536	0.0271	12.40	0.0007
	Seed number	0.00556	0.0008	52.00	< 0.0001
China	Intercept	37.15520	18.6034	3.99	0.0621
	100 seed weight	-1.98210	0.8499	5.44	0.0322
	Seed number	0.00808	0.0018	21.30	0.0002
Japan	Intercept	-83.62660	16.0862	27.00	<0.0001
	Days to maturity	0.76697	0.1186	41.80	<0.0001
Korea	Intercept	44.26040	10.5575	17.60	0.0006
	Pod number	0.12185	0.0675	3.26	0.0889
	100 seed weight	-1.16775	0.2607	20.10	0.0003
Viet Nam	Intercept	1.54682	4.4259	0.12	0.7308
	Seed number	0.00891	0.0015	35.80	<0.0001

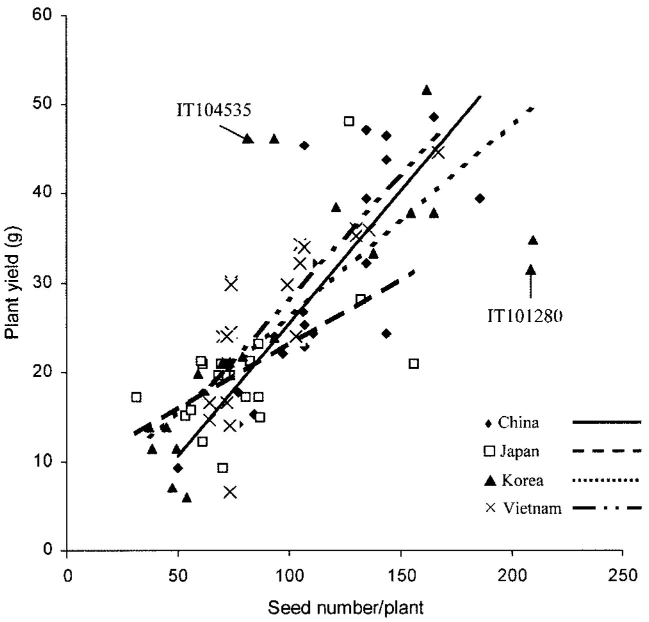

Fig. 1. Relationship of plant yield with seed number per plant in four different soybean cultivar groups.

improve yield by increasing the number of seeds per plant, not by increasing seed size. While considerable variation was observed in seed size among cultivars, seed size was less phenotypically stable than seed number per plant.

Stepwise multiple linear regression analysis revealed the close relationship of plant yield with seed number per plant. As the seed number per plant increased, the plant yield increased, regardless of soybean cultivar groups (Fig. 1). Large number of seeds per plant showed the tendency to achieve high plant yield. Of specific interest were two soybean genotypes, IT101280 and IT104535, derived from Korean cultivar group. IT101280 characterized with great seed number showed comparatively low yield, whereas IT104535 with small seed number did great yield.

In conclusions, soybean cultivars collected from different Asian countries exhibited wide ranges in agronomic characters, yield and yield components. Abundant genetic resources could provide valuable for improving soybean cultivar improvement. DTM had closer relationship with agronomic traits than DTF, suggesting that consideration should be needed when selection was made for soybean cultivar originated from other ecological regions.

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