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Maturity Grouping of Korean Soybean Cultivars and Character Relationships According to the Planting Date

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ABSTRACT This study was carried out to classify Korean soybean varieties base on maturity group (MG) and to find character relationships according to planting date for high quality soybean seed production adapted to early season cultivation environment of Miryang. Results of maturity grouping of Korean soybean varieties showed that Keunol (3 cultivars), belonged to Group 0; Seonnok and Danmi in Group II, Shinrok in Group III, Seonyu (17 cultivars), in Group IV, Taekwang (44 cultivars) in Group V, Daewon (25 cultivars) in Group VI, and Kwangdu and Keumdu in Group VII. Agronomic characteristics of 100 soybean varieties were compared based on MG, cultivation year and seeding date. Soybean varieties belonging to the MG VI~VII showed longer days to flowering and growth period, high lodging density and higher yield. Seed quality analysis revealed that as maturity was delayed, seed weight becomes heavier while seed cracks become abundant. In addition, occurrence of purple seed and phomopsis were higher in MG 0~III. Protein content was higher in MG 0~III, and isoflavone content was higher as maturity was delayed. On the other hand, lipid content was generally similar across MGs. Correlation analysis of major agronomic characters showed positive relationships between days to flowering and growth days, seed weight and lodging in MG IV~V, seed crack and growth days in MG 0~III, seed crack and days to flowering in MG IV~V and MG VI~VII, seed crack and lodging in MG IV~V and MG VI~VII, seed crack and seed weight in MG IV~V and MG VI~VII, purple seed and growth days in MG IV~V, purple seed and seed weight in MG VI~VII, phomopsis and growth days in MG IV~V and MG VI~VII, and phomopsis and purple seed in MG IV~V and MG VI~VII . In contrast, a negative relationship was observed between seed weight and lodging in MG 0~III. Correlating yield and major characters revealed negative relationships between days to flowering and growth days in MG 0~III and MG IV~V, whereas positive relationships were obtained on MG VI~VII seeded on April 30. Lodging, seed weight and seed crack were all negatively correlated with yield in the MG IV~V and MG VI~VII. Soybean cultivars identified as adaptable to early season planting for production of high quality soy curd and fermented soybean paste were Seonyu, Kwangdu, and Soho while those suited for the manufacture of soybean sprouts were Sobaeknanul, Kwangan, Sowon, and Bosuk. Geomjeong 2 chosen as best for mixing with rice.

Keywords : soybean, maturity group, seed quality, seed component, planting date

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Soybean that ecotypes are well differentiated and developed is a broadly adapted crop, and is cultivated in the north latitude (52°) of China and (46°) Canada to the south latitude (36°) of Latin America. Climatic ecotypes of soybean are classified into three types: firstly, summer type that have long on critical daylength adaption and high thermo-sensitivity; secondly, fall type that have short on critical daylength adaption and low thermo-sensitivity; and lastly, medium type. But soybean varieties was ecologically ell differentiated resulting to several ecotypes classification by various researchers. Soybean varieties are classified into three groups that include the summer type, medium type and fall type on collected varieties from Japan, Korea, Manchuria and USA (Matsumoto,1942). Varieties from Japan (Kobayasi, 1946) classified by ecological characters are grouped according to moving seeding date. Ariga (1948), on the other hand, made 8 soybean ecotype classifications which are based on ecological characteristics according to moving seeding date and daylength treatment. In USA, 13 soybean maturity groups were classified and being utilized. The 000 group being extremely early type to VIII group being extremely late type (U.S.D.A, 1949). In Korea, Chang (1963) identified 9 maturity groups of soybean while Kweon *et al*. (1974a, b) made 7 maturity group classifications.

During the early times, soybean was classified as a short-day plant (Garner & Allard, 1920), and due to its photoperiodic response, flowering and maturity period in most varieties are said to be delayed as latitude turns higher (Cartter and Hartwig, 1963). But results of several researches had shown that each soybean variety represents a different photoperiodic response (Johnson *et al*., 1960; Byth, 1968). Many researchers took notice of the influence of daylength on post flowering development, such as on flowering duration, rate of flower production and duration of reproductive stages (Boote, 1977; Criswell & Hume, 1972; Fisher, 1963; Fukei and Yarimizu, 1951; Johnson *et al*., 1960; Nagata, 1960; Patterson *et al*., 1977; Thomas & Raper, 1976; Van Schaik and Probst, 1958).

Yield decreases as seeding date is delayed. This is induced by decreased number of branches brought about by the limited development of branch rather than the shortening of days to flowering (Board, 1985; Board and Hall, 1984). Patterson *et al*. (1977) reported that yield increases at longer growth period induced by longer daylength and as a result of an increase number of branch nodes. Furthermore, daylength nearly didn't effect pod number per node, seed number per pod and seed weight. On the contrary, Van Schaik & Probs (1958) reported that pod number per node increases as daylength becomes longer in determinate soybean variety.

Photoperiodic treatment by artificial and natural light showed significant shortening of growth period. Soybean grown under short daylength took fewer days of emergence to maturity, emergence to flowering, flowering to pod setting and flowering to maturity. However, only artificial light showed decrease number of the days from pod setting to maturity.

Consequently, effect of photoperiod treatment was only evident mainly on the number of days of emergence to flowering (Johnson *et al*., 1960). Fukui and Yarimizu (1951) reported that short-day condition induced leaf discolorisation and defoliation, and shortened maturity days which lead to shortened period of flowering to maturity. This phenomenon was clear on soybean varieties having long maturity. In the field, long-day condition prolonged the period of flowering to pod setting (Johnson *et al*., 1960) and flowering to flowering termination (Lawn and Byth, 1973). These results agreed with Nagata's report (1958) that photoperiodic response of soybean presented differentiation at growth stages.

For the interaction effects of temperature and daylength, Board & Hall (1984) reported that reduction of required days to first flowering was longer at high temperature (27℃) than low (21℃). Maximum effect of temperature was greater on short-day length than long-day length, and effect of temperature was more predominant in MG VI and MG VII than MG V. Night temperature could influence photoperiodic response which control soybean flowering (Parker & Borthwick, 1943; van Schaik and Probst, 1958). Low temperature delayed the maturity of all treated varieties across all day-length treatments and critical day length primarily because flowering was changed due to fluctuation in temperature (Steinberg and Garner, 1936). Temperature and day length affecting flowering on field was influenced by low temperature in early growth stage and day length in the latter stage. Short day condition was more effective in shortening days to maturity than low temperature occurrence during fall. There was a close relationship between vegetative growth period and mean temperature. Temperature condition minimizing vegetative growth period corresponded to mean temperature on midsummer which pass the highest temperature and extension of flowering period related to low temperature on late spring or early fall (Garner & Allard, 1930). Although, growth before pod setting was closely related to degree day, the days to maturity from pod setting to maturity is more important than degree day (Howell, 1960).

Early maturing types of soybean are less sensitive to day length than late maturing types (Criswell & Hume, 1972). But, Polson (1972) took notice a delay on maturity of early maturing type of soybean that was known to be insensitive to day length when grown under long day condition. Yoshida (1952) and Pohjakallio & Antila (1957) reported that early maturing types of soybean were insensitive to day length. The clearest difference among soybean varieties differing on days to maturity was observed on the flowering sensitivity as affected by day length, and late maturing varieties are more sensitive than early maturing varieties (Major *et al*., 1975b). Vegetative growth period, reproductive growth period and growing season are affected by seeding date and variety, and in the case of delayed seeding date, yield was evidently affected by the shortened reproductive growth duration, but not clearly affected by the duration of vegetative growth (Boquet *et al*., 1983).

Apparent seed quality are affected by disease, insects and weathering after maturity (Abel, 1961). Early seeded soybeans have poorer seed quality than late seeded soybeans suggesting that damage duration is prolonged by the extension of seed development. Feaster (1949) and Green *et al*. (1965) also reported that seed quality is affected by seeding date.

Several researchers (Fukui & Yarimizu, 1952; Johnson *et al*., 1960; Nagata, 1958) reported that shorter daylength after flowering resulted to shortened duration of seed setting to maturity in both indeterminate and determinate soybean varieties. More so, reproductive growth is affected by temperature whereas sink strength during seed filling is primarily influenced by successive short days but its effect slightly reduced on cooler temperatures (Fukei, 1952; Major *et al*., 1975a, 1975b).

It is well known that environmental conditions during reproductive growth influence on soybean seed quality (Wilson, 2004). Protein and oil content of soybean seed were proven to be greatly influenced by temperature during the reproductive growth period (Wolf *et al*., 1982). An inverse relationship between protein and oil contents was reported by Piper & Boote (1999). Moreover, Beatty *et al*. (1982) reported that protein content of soybean seed was affected by year, seeding date×year and seeding date×variety while oil content was affected by year, seeding date and seeding date×year. Total isoflavone of soybean seed showed a negative relationship on growth temperature (Tzukamoto *et al*., 1995). Furthermore, isoflavones and its glucoside content showed significant difference among varieties and cultivation region. Eldridge and Kwolek, (1983) suggested that annual climate and environmental factors affected isoflavones and its glucoside content. A pigment on the seed coat of black soybean is accumulated by anthocyanin in palisade layer on the epidermis (Todd and Vodkin, 1993).

This study was carried to classify Korean soybean cultivars based on their maturity groups and obtain general agronomic characteristics and identify its relationship with seeding date for high quality soybean seed production adapted to early season cultivation environment.

MATERIALS AND METHODS

The experiment was carried out at the upland field of Department of Functional Crop, NICE situated at Miryang from 2005 to 2006. One hundred (100) domestic soybean varieties (56 for fermentation, 26 for sprouting, 17 for mixed with rice) were used and seeding dates were scheduled at April 30 and May 30. Seeding distance was 70×20 cm with two plants per hill. Fertilization was set at 30-30-34 (N-P_2O_5-K_2O) per ha using urea, magnesium phosphate and potassium chloride.

Maturity Group (MG) was classified by days to maturity: 0 group corresponded to extremely early type, 108~115 in days to maturity; I group 116~123; II group 124~131; III group 132~139; IV group 140~147; V group 148~155; VI group 156~163; and VII group above 164.

Investigated growth characters were flowering date, maturity date, days to flowering, growth days and lodging percent. Seed quality parameters include 100-seed weight, seed crack, purple seed, phomopsis and insect damage. Protein, lipid, isoflavone and anthocyanin contents were likewise investigated for seed components.

The seeds of soybean varieties were finely ground using a coffee grinder (HEICO, LT1-100, Japan). The protein content was determined according to the data from the near-infrared reflectance spectroscopy (NIRS). The NIRS data were collected in the range of 400 to 2500 nm at 2-nm intervals using a Foss NIRSystems spectrophotometer (model 6500, NIRSystem Inc., Silver Spring, MD) and stored as the reciprocal logarithm (log 1/R) of the reflected energy. All statistics, regressions, and predictions were performed using the WINISI software (version 1.05) from Foss NIR System. Coefficient of determination (r^2) and standard errors of calibration (SEC) were used to evaluate how well the calibration of the sample or multiple linear regressions fits the data.

The oil content was measured by Soxhlet method using the Buchi B-811 extracted system (Soxhlet System: BUCHI Labotechnik, B-811, AG., Switzerland). Two grams of the pulverized seed was added to 200 mL of n-hexane in an extraction thimble and boiled for 3 h at 100℃. After cooling to room temperature in a desiccator, the extracted oil was weighed. Total oil contents were determined on a dry matter basis of the seeds.

To extract isoflavone, 1.0 g of soybean sample was mixed with 20 mL of 50% aqueous methanol in a 50 mL centrifuge bottle (Nalge Company, Rochester, NY, USA). The sample bottles were vortexed for 1 min and then placed in a shaker (Eyela, Japan) for 12 h at room temperature. The extracts were then centrifuged for 10 min at 3000 rpm using a VS-6000 centrifuge (Vision, Korea). The supernatant was filtered with a 0.45 μm membrane filter prior to HPLC. HPLC analyses were conducted on an Agilent 1100 series HPLC with diode array detection (DAD). A sample (20 μl) of the 50% methanolic extract was injected onto an analytical reverse phase C-18 column (125 mm × 4 mm, LichroCART, 5 μm, Merck KGaA). The mobile phase was composed of 0.1% acetic acid (TFA) in water (A) and 0.1% acetic acid in acetonitrile (B). The gradient conditions were as follows: 0 min, 10% B; 20 min, 20% B; 30 min, 25% B; 40 min, 35% B; 50 min, 40% B and then the column was equilibrated 10 min at 10% B between runs. Other HPLC conditions were as follow: a flow rate of 1.0 mL min^{-1}; column temperature, 30℃; detection, 260 nm; and sample size, 20 μl. Isoflavone standards calibrations were performed using an Agilent 1100 series HPLC as essentially the same procedures above mentions. The twelve isoflavone standards stock solutions were prepared by dissolving in 50% methanol to give 1.0 mg mL-1 concentration. Calibration curves were made for each standard with ten different concentrations (0.625, 1.25, 2.5, 5, 10, 20, 40, 60, 80, 100 μg mL). A high linearity (r^2 > 0.998) was obtained for each standards curves (Table 1).

Table 1. Calibration curves of the 12 individual isoflavone standards

Standards	Equation	
Daidzein	$y = 122.2x + 18.39$	$r^2 = 0.999$***
Genistein	$y = 183.72x + 10.55$	$r^2 = 0.999$***
Glycitein	$y = 94.45x - 5.51$	$r^2 = 0.999$***
Daidzin	$y = 83.21x - 134.32$	$r^2 = 0.998$***
Genistin	$y = 96.78x + 54.32$	$r^2 = 0.999$***
Glycitin	$y = 32.1x - 8.69$	$r^2 = 0.997$***
Malonyl-Daidzin	$y = 69.33x + 25.58$	$r^2 = 0.999$***
Malonyl-Genistin	$y = 81.06x - 56.3$	$r^2 = 0.999$***
Malonyl-Glycitin	$y = 74.15x - 35.9$	$r^2 = 0.999$***
Acetyl-Daidzin	$y = 50.22x + 72.28$	$r^2 = 0.998$***
Acetyl-Genistin	$y = 83.51x + 10.05$	$r^2 = 0.999$***
Acetyl-Glycitin	$y = 59.16x + 53.39$	$r^2 = 0.999$***

The anthocyanin content was measured by HPLC analysis. Hand-peeled seed coats (0.2 g) of black soybean cultivars, were extracted with 20 mL of 40% methanol (1% HCl) for 2 days at 4 ℃, in darkness. The anthocyanin extracts were filtered through a 0.45 μm filter unit prior to HPLC analysis. HPLC analyses were conducted on an Agilent 1100 series HPLC with diode array detection (DAD). A sample (20 μl) of the crude acidic methanolic extract was injected onto an analytical reverse phase C-18 column (125 mm × 4 mm, LichroCART, 5 μm, Merck KGaA). The mobile phase was composed of 0.1% TFA in water (A) and 0.1% TFA in methanol (B). The gradient conditions were as follows: 0 min, 15% B; 2 min, 20% B; 30 min, 35% B and then the column was equilibrated 10 min at 15% B between runs. Other HPLC conditions were as follow: a flow rate of 0.8 mL min^{-1}; column temperature, 30 ℃; detection, 530 nm; and sample size, 20 μl.

RESULTS AND DISCUSSION

Table 2 showed the climatic conditions during the soybean growth at Miryang in 2005~2006. Rainfall from May to July, which coincided with the vegetative growth period, was higher in 2006 than 2005. In 2006, daily range of rainfall was wider on May to June while it was narrower in 2005, it was widest on the July month. During the reproductive growth period (August to October), solar radiation was stronger in 2006 and temperature on August and October was higher in 2006 than 2005. However, September mean temperature was higher in 2005 while daily range temperature was wider in 2006.

Table 2. Climatic conditions during soybean growth at Miryang

Month	Year	Rainfall (mm)	Solar radiation ($MW/m^2/d$)	Temperature (℃)			
				Mean	Max.	Min.	Dairy range
5	2005	64	699	18.6	26.8	14.8	12.0
	2006	192	531	18.4	25.2	12.5	12.7
6	2005	141	573	23.8	30.5	18.4	12.0
	2006	164	550	22.7	29.6	17.2	12.3
7	2005	207	480	25.6	31.5	21.3	10.1
	2006	573	337	24.4	29.2	21.3	8.0
8	2005	244	465	25.6	31.6	21.4	10.3
	2006	118	559	27.7	34.9	22.8	12.1
9	2005	72	364	22.5	28.0	18.2	9.8
	2006	80	414	19.9	26.6	14.6	12.1
10	2005	8	241	16.0	24.3	9.3	15.0
	2006	0	281	18.3	27.5	11.5	16.0

※ Data of Oct.: Oct. 1~Oct. 20

Classification of maturity group and days to maturity

Results of maturity grouping for 100 domestic soybean varieties by means of Kweon *et al.*'s method (1974b) that utilizes time of maturity to settle optimum cultivation region for yield enlargement and high quality soybean production are presented in Table 3. Maturity grouping of Korean soybean varieties showed that Keunol, which was represented by 3 varieties, belonged to Group 0, Seonnok and Danmi in Group II, Shinrok in Group III, Seonyu represented by 17 varieties in Group IV, Taekwang represented

Table 3. Classification of maturity group of soybean varieties

Maturity group	Varieties			No. of variety
	For fermentation	For sprouting	For mixed with rice	
0	Keunol, Hwaseong, Daol			3
I	Seokryang, Saeol, Dajin, Hwaeom,		Geomjeongol Geomjeongsaeol	6
II	Seonnok, Danmi,			2
III	Sinrok,			1
IV	Malli, Muhan, Dankyung, Danwon, Jinmi, Seonyou, Dongbuktae	Namhae, Eunha, Hannam, Dagi, Seonam, Dachae, Aga	Ilpumgeomjeong Geomjeong1, Cheongja,	17
V	Taekwang, Samnam, Shinpaldal2, Bokwang, Jangsu, Baekun, Saeal, Hwangkeum, Jangyeob, Jangmi, Dajang, Jinpum2, Kumgang, Duyou, Soyang, Hojang, Soho, Jangwon, Ilmi,Shingi, Jangbaek, Miryang119, Bongeui, Miltae, Jangdanbaekmok, Jangkyung, Buseok	Myeongju, Rogchae, Pureun, Bukwang Anpyeong, Saebyeol, Doremi, Sogang, Paldo, Boseok	Dawon, Geomjeong2, Geomjeong3, Geomjeong4, Jinyul, Seonheuk Cheongja2	44
VI	Daewon, Alchan, Jinpum, Danbaek, Daehwang, Daemang, Daepung, Suwon224, Sodam, Songhak, Baekcheon,	Orialtae, Somyeong, Sojin, Sorok, Pungsan Sowon, Iksan, Sobaek,Kwangan	Heukcheong, Galmi, Cheongdu1, Cheongja3, Ajukari	25
VII	Kwangdu, Keumdu,			2
Total	57 varieties	26 varieties	17 varieties	100

by 44 varieties in Group V, Daewon with 25 varieties in Group VI, and Kwangdu and Keumdu in Group VII, and most of varieties belonged to maturity group IV, V, and VI. This result is similar to Kweon *et al.*'s result (1974b) that most of native varieties of soybean in Korean belong to maturity groups IV and V, and some extend distribution to maturity group VI because of the increase population of late maturing type cultivation giving the first consideration to single cropping. The main difference between this experiment and that of Kweon *et al.* (1974b) were the planting region and planting date. This experiment was conducted on April 30 at Miryang while Kweon *et al.* was conducted on May 23 in Seoul.

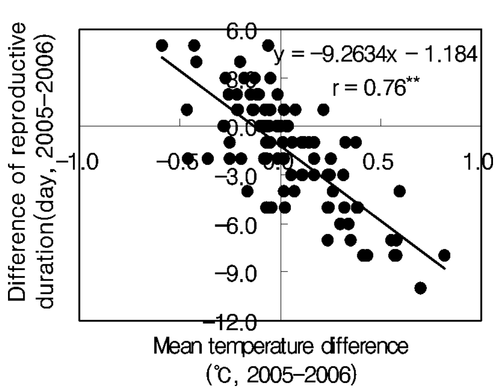
Flowering date, days to flowering, maturity date and days to maturity of 100 soybean varieties are presented in Table 4. Flowering date on April 30 seeding was observed from June 18 to July 27 while on May 30 seeding, it was July 5~August 7. It took an average of 71 days for the April 30 seeded soybeans to flower which was 20 days longer than May 30. Maturity time for the April 30 seeded soybeans were observed from August 19~October 21 while for May 30 it was from August 25~October 24. Mean days to maturity was 149 on April 30 seeding, which was 28 days longer than May 30. These observations may be due to the elongation of flowering duration caused by low temperature and long daylength as seeding date was advanced. In addition, elongation of maturity by low temperature from flowering to maturity on late maturity varieties was found to be photosensitive and thermo-sensitive.

The maturity days were delayed by 9.3 days for those seeded on April 30, and 8.3 days for those seeded on May 30. Within this period, mean temperature from flowering to maturity decreased by 1℃. In general, velocity of substance moving to seed is faster by means of increased activity of enzymes related to substance moving and synthesis of reserve substance on high temperature during maturity. Yield is decreased by means of shortening the "keeping" activity of enzymes (reference). Accordingly, it is beneficial to prolong maturity duration while keeping optimum temperature for grain filling. However, further research are needed to support this claim..

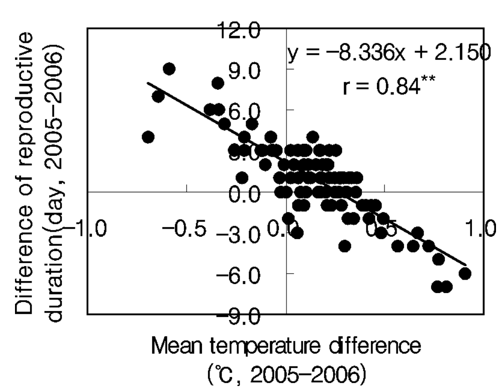
Data for occurrence of black root rot and insect damage are shown in Table 5. Occurrence of black root rot was more prevalent in 2005 than in 2006, which was possibly due to the heavier rainfall from R2 to R4 stage of soybean. High temperature from R2 to R4 stage of soybean in 2006

Table 4. Flowering and maturity dates of 100 soybean varieties according to seeding dates

Planting date	Flowering date		Days to flowering		Maturity date		Days to maturity	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Apr.30(A)	7.11	6.18~7.27	71	51~89	9.24	8.19~10.21	149	113~176
May30(B)	7.21	7. 5~8. 7	51	36~66	9.30	8.25~10.24	121	86~145
A-B	-10	-	20	-	-6	-	28	-



< Seeding date: April 30 >



< Seeding date: May 30 >

Fig. 1. Relationship between annual mean temperature and reproductive duration of 100 soybean varieties ('05-'06).

Table 5. Black root rot and insect damage during experiment

Black root rot (%, 2005)			Insect damage (%,2006)		
Degree	April	May	Degree	April	May
1 (-1%)	0	9	1 (0-0.9%)	26	36
3 (2-10%)	35	64	3 (1-5.9%)	49	55
5 (11-20%)	35	25	5 (6-10.9%)	13	5
7 (21-40%)	29	2	7 (11-30.9%)	11	4
9 (41-%)	1	0	9 (31-%)	1	0

resulted to severe insect damage caused by stink bugs. Also, occurrence of black root rot and insect damage was more predominant on April 30 seeding than on May 30 seeding, which was an outcome of the relatively long growth period of the April 30 seeding.

Table 6 showed the mean and range of major characters of 100 soybean varieties as affected by seeding date and cultivation year within each maturity group. Days to flowering and growth period were longer as maturity group approached VI~VII and shorter as seeding date was delayed, which are good reflection of maturity group characteristics. Lodging density was lower in MG0~III than MGIV~V and MGVI~VII which is attributed to short stem length and short growth period in the field. In terms of apparent seed quality, which is generally accounted to varietal differences, lighter seed weight was observed as MG becomes higher and became heavier on April 30 seeding. Seed crack was high as MG becomes higher and notably higher on April 30 seeding. These observation is possibly due to exposure to various environmental changes, reciprocal condition of humidity and dry etc, as growth period was prolonged.

Table 6. Growth duration, apparent seed quality and major constituents of 100 soybean varieties as affected by seeding date

Item	Year	Seeding date (m.dd)	Maturing group < Mean (Range) >		
			0~III	IV~V	VI~VII
Days to flowering	2005	4.30	56(51~61)	68(58~79)	73(61~88)
		5.30	39(36~43)	48(39~54)	50(39~63)
	2006	4.30	61(55~66)	74(59~84)	78(65~89)
		5.30	45(38~52)	54(50~60)	57(52~66)
Days to maturity	2005	4.30	120(113~131)	148(135~157)	161(153~176)
		5.30	97(86~105)	121(105~134)	132(124~145)
	2006	4.30	121(114~137)	151(141~158)	161(156~171)
		5.30	96(88~105)	121(104~132)	129(123~139)
Lodging (0-9)	2005	4.30	3(1~5)	7(3~9)	7(3~9)
		5.30	3(1~9)	6(1~9)	6(3~9)
	2006	4.30	4(3~5)	7(3~9)	6(3~9)
		5.30	4(1~7)	5(1~9)	4(1~7)
100-seed weight (g)	2005	4.30	30.9(25.3~34.7)	20.2(5.5~33.6)	19.7(9.8~34.2)
		5.30	30.3(24.5~37.0)	18.7(5.7~31.2)	18.4(9.3~32.4)
	2006	4.30	28.5(22.6~32.5)	20.6(4.4~37.2)	20.1(10.8~35.6)
		5.30	28.3(24.8~34.0)	20.8(4.7~33.7)	19.8(9.5~35.5)
Crack seed (%)	2005	4.30	6.3(0.0~17.1)	13.3(0.0~85.3)	17.2(0.0~99.4)
		5.30	5.3(0.0~27.7)	7.7(0.0~60.1)	7.9(0.0~98.9)
	2006	4.30	8.5(0.0~23.0)	17.6(0.0~62.0)	21.0(0.0~74.3)
		5.30	5.3(0.0~27.7)	7.7(0.0~60.1)	7.9(0.0~98.9)

Table 6. Continued.

Purple seed (%)	2005	4.30	5.5(0.0~20.6)	6.2(0.0~32.2)	4.3(0.0~31.2)
		5.30	14.3(0.0~60.7)	3.4(0.0~26.1)	2.5(0.0~25.2)
	2006	4.30	1.4(0.0~4.9)	2.1(0.0~9.7)	0.5(0.0~5.6)
		5.30	2.8(0.0~7.0)	1.0(0.0~4.9)	0.2(0.0~1.6)
Phomopsis (%)	2005	4.30	19.3(2.4~56.1)	4.8(0.0~21.6)	1.5(0.0~9.9)
		5.30	3.1(0.0~11.3)	1.4(0.0~10.2)	0.3(0.0~1.7)
	2006	4.30	9.5(1.6~48.0)	2.0(0.0~14.6)	0.5(0.0~2.9)
		5.30	3.6(0.0~8.2)	0.4(0.0~5.1)	0.2(0.0~2.0)
Yield (kg/10a)	2005	4.30	212(145~308)	265(26~451)	283(40~494)
		5.30	228(165~298)	280(19~443)	294(160~406)
	2006	4.30	74(8~147)	202(49~395)	264(39~502)
		5.30	167(64~270)	277(67~399)	341(121~524)
Protein (%)	2005	4.30	43.9(42.1~45.7)	42.6(37.2~47.0)	42.0(36.0~50.5)
		5.30	43.7(40.2~46.4)	41.9(37.4~46.4)	41.7(37.4~50.2)
	2006	4.30	45.0(42.1~48.3)	42.1(38.5~44.9)	41.8(35.8~51.0)
		5.30	42.5(38.6~45.4)	41.8(37.7~44.6)	41.8(36.7~51.0)
Crude oil (%)	2005	4.30	16.7(15.1~18.8)	17.3(12.9~20.6)	16.7(12.8~20.3)
		5.30	16.1(14.1~19.9)	16.8(11.8~19.9)	16.7(13.0~19.1)
	2006	4.30	18.2(12.7~20.6)	18.4(15.4~22.0)	18.3(13.7~22.1)
		5.30	18.2(11.8~21.5)	18.0(14.9~22.2)	18.4(13.1~22.5)
Isoflavone (mg/g)	2005	4.30	0.7(0.5~1.2)	1.5(0.3~3.1)	1.8(0.4~3.3)
		5.30	1.0(0.6~1.8)	2.1(0.1~3.8)	2.5(0.9~4.3)
	2006	4.30	0.5(0.3~0.9)	1.8(0.4~4.6)	2.3(0.8~4.0)
		5.30	0.7(0.4~1.1)	2.4(1.0~5.1)	2.7(1.2~4.2)

Major agronomic characters in maturity groups

Purple seed and phomopsis were high in MG 0~III. Yield was higher as MG approached VI~VII, which was generally accounted to varietal differences. Generally, long growth duration of soybean induces more pod number and higher yield via prolonged accumulation of photosynthates. In this experiment, May 30 seeding produced higher yield than April 30 seeding, which means that April 30 seeding generally have lower temperature condition resulting to longer growth period. In terms of major seed constituent, protein content was higher as MG nears 0~III. Lipid content showed no difference as seeding date was advanced, and isoflavone content was higher as MG and seeding date were delayed.

Climatic conditions during reproductive growth period and quality of soybean seeds according to maturity groups from 2005 to 2006 are shown in Table 7. Climatic conditions during reproductive growth period revealed that MG becomes longer as mean temperature and mean rainfall decreases.

In terms of seed constituents, protein content decreased while isoflavone and lipid content was increased as MG becomes higher. Considering the variation on seed constituent as affected by climatic condition, rainfall seemed to cause great variation on maturity period. As heavy rain greatly effected mean rainfall, it can therefore be concluded that rainfall would be related to temperature.

On the other hand, purple seed and phomopsis damage was high as MG becomes lower. These diseases were induced by mold which were due to high temperature and rainfall. More researches have to be conducted to verify this claim.

Variation of major agronomic characters according to seeding date within maturity group is shown in Table 8. Days to flowering between April 30 and May 30 seeding showed 16.2~21.3 days difference while mean days from flowering to maturity had 7.9~9.4 days difference as MG

Table 7. Climatic conditions and quality of soybean seeds according to maturity groups

Item	Year	Maturity group							
		0	I	II	III	IV	V	VI	VII
Mean temp. during maturity (℃)	2005	26.2	26.0	25.8	25.7	25.3	24.9	24.2	23.1
	2006	26.6	26.2	26.2	25.9	25.2	24.7	24.2	23.2
Mean precipitation during maturity (mm)	2005	8.0	7.6	7.4	6.9	5.6	5.1	4.4	3.7
	2006	11.8	11.1	10.8	9.6	5.6	5.2	4.1	2.4
Cracked seed (%)	2005	9.3	2.8	9.1	12.6	7.7	15.5	18.0	8.2
	2006	6.3	8.2	12.5	8.8	15.7	18.4	21.8	10.8
Purple seed (%)	2005	7.1	5.4	4.4	3.5	3.3	7.3	4.6	0.5
	2006	0.8	1.7	0.8	2.8	2.2	2.0	0.5	0.2
Phomopsis (%)	2005	29.5	22.0	3.8	4.2	5.3	4.6	1.6	0.0
	2006	20.8	7.6	2.0	1.9	2.9	1.7	0.6	0.0
Protein content (%)	2005	44.5	43.5	44.3	43.9	42.6	42.6	42.4	37.3
	2006	47.3	44.8	43.5	42.1	42.1	42.1	42.2	37.1
Oil content (%)	2005	16.5	16.8	16.7	16.4	17.1	17.4	16.6	18.6
	2006	16.5	18.3	20.2	18.7	18.4	18.4	18.1	21.0
Isoflavone (mg/g)	2005	0.72	0.85	0.59	0.71	1.44	1.57	1.81	2.26
	2006	0.46	0.55	0.53	0.71	1.80	1.92	2.40	2.30

Table 8. Variation of major characters according to seeding date (2005~2006)

Maturity group	Seeding date	DF (days)	GD (days)	Lodging (0-9)	SW (g)	SC (%)
0~III	Apr. 30	58.3	120.6	3.4	29.7	7.4
	May 30	42.1	96.5	3.7	29.3	5.3
	LSD (5%)	0.9**	1.1**	0.7	1.3	1.9
IV~V	Apr. 30	71.2	149.4	6.8	20.4	15.5
	May 30	51.1	120.8	5.3	19.8	7.7
	LSD (5%)	0.5**	0.6**	0.4**	0.5**	2.0
VI~VII	Apr. 30	75.2	161.2	6.4	19.9	19.1
	May 30	53.9	130.5	5.4	19.1	7.9
	LSD (5%)	0.8**	0.9**	0.5**	0.5*	4.7**

Maturity type	Seeding date	PS (%)	PM (%)	Yield (kg/10a)	PT (%)	CO (%)	ISF (mg/g)
0~III	Apr. 30	3.5	14.4	143.0	44.4	17.4	0.65
	May 30	8.6	3.3	197.5	43.1	17.1	0.89
	LSD (5%)	5.1	4.6**	27.5**	1.2	1.2	0.11*
IV~V	Apr. 30	4.1	3.4	233.6	42.3	17.8	1.71
	May 30	2.2	0.8	278.4	41.8	17.4	2.30
	LSD (5%)	1.1*	0.5**	19.2**	0.3*	0.4	0.10**
VI~VII	Apr. 30	2.4	1.0	273.5	41.9	17.5	2.12
	May 30	1.4	0.3	317.6	41.8	17.5	2.65
	LSD (5%)	1.7	0.4*	31.0*	0.6	0.6	0.15**

DF: Days to flowering, GD: Growth duration, SW: 100-seed weight, SC: Seed crack, PS: Purple seed, PM: Phomopsis, PT: Protein, CO: Crude oil ISF : Isoflavone.

becomes higher. Regardless of maturity group, lodging density, seed crack, purple seed and phomopsis on April 30 seeding were higher than May 30 seeding. Also, 100 seed weight and protein content comparatively higher on April 30 seeding than May 30 seeding while the opposite was observed on isoflavone content. Yield of May 30 seeded soybeans was significantly higher than April 30 seeded.

Variation on major ingredients of soybean seeds according to cultivation year and seeding date is shown in Table 9. Protein content appears to be similar between the two years and the two seeding dates, suggesting that environmental effect is not significant. On the contrary, lipid and isoflavone content showed significant difference between the two years and seeding dates presented high environmental effect, especially on isoflavone content. These results are similar to Beatty *et al.*'s (1982) where they reported that lipid content was influenced by seeding date, year and seeding date×year.

Isoflavone and anthocyanin content variation according to seeding date, variety and cultivation year are shown Tables 10 and 11. Isoflavone content showed significant difference in terms of seeding date, variety and cultivation year. Anthocyanin content, on the other hand showed significant difference in seeding date and variety, but not in cultivation year. As earlier mentioned, isoflavone content on May 30 seeding was vastly higher than April 30 seeding. Similar observations were then noted in each kind glucosides of isoflavone and anthocyanin. Eldridge & Kwolek (1983) suggested that annual variation of isoflavone and its glucosides are correlated to changes on climatic or environmental factors. In detail, anthocyanin content on May 30 seeding was higher than on April 30 seeding, this result agreed with the findings of Ubi *et al*. (2006), that anthocyanin synthesis were higher on low temperatures than

Table 9. Variation of major ingredients of soybean seeds according to cultivation year and seeding date (mean of 100 varieties)

Year	Seeding date	Protein (%)	Crude oil (%)	Isoflavone content (mg/g)
2005	April 30	42.6	17.1	1.53
	May 30	42.4	18.3	1.86
	Mean	42.5	17.7*	1.70*
2006	April 30	42.0	16.7	2.12
	May 30	41.9	18.1*	2.34
	Mean	42.0	17.4	2.23*
Total mean		42.2	17.6*	1.96*

Table 10. Significance analysis of isoflavones contents according to cultivated year and seeding date

Source	SUM	F-value				
		Daidzin	Glycitin	Genistin	Mal-daidzin	Mal-glicitin
Seeding date (S)	201.44**	59.53**	34.47**	57.88**	328.13**	3.82
Variety	17.84**	5.61**	9.08**	5.19**	14.38**	15.67*
Year (Y)	54.22**	218.93**	51.79**	84.01**	19.62**	16.22*
S×Y	2.37	12.74**	10.35**	21.99**	116.37**	0.04

Source	F-value				
	Mal-genistin	Acet-daidzin	Acet-genistin	Daizein	Genistein
Seeding date (S)	76.84**	2.65	0.01	4.02*	14.83**
Variety	15.99**	1.00	8.72**	6.65**	3.51**
Year (Y)	14.11	2.65	0.87	50.7**	21.87**
S×Y	0.01	2.61	2.28	76.12**	86.15**

Table 11. Significance analysis of anthocyanin contents according to cultivated years and seeding dates

Source	F-value						
	SUM	Dp3glc	Cy3gal	Cy3glc	Pt3glc	Pg3glc	Pn3glc
Seeding date	14.13**	0.82	15.65**	12.7**	5.81*	5.61*	1.99
Variety	14.59**	25.49**	11.73**	10.02**	21.13**	8.98**	5.18**
Year	4.52	15.84**	16.18	10.48**	9.15**	5.37*	0.78

Dp3glc: Delphinidin-3-glucoside, Pt3glc: Petunidin-3-glucoside, Cy3glc: Cyanidin-3-glucose, Pn3glc: Peonidin-3-glucoside, Pg3glc: Pelargonidin-3-glucoside, Cy3gal: Cyanidin-3-galactose

high temperatures. Varieties which contained high isoflavone content were Hojang, Geomjeong3, Saebyeol, Paldo, Saeol, Rogchae, Cheongdu1, Boseok and Suwon224 whereas, varieties which contained high anthocyanin content were Cheongja3, Cheongja2, Geomjeong2 and Geomjeong3.

Correlation among major agronomic characters

Table 12 shows the correlation of major agronomic characters as observed with each MG. Positive correlation was obtained between days to flowering and lodging density, and between growth day and lodging density in MG IV~V and MGVI~VII. These results indicate that lodging occurred easily on varieties with long vegetative growth period and long growth period in the field. Negative correlation was observed between seed weight and lodging density in MG 0~III, which could be due to poor assimilation of photosynthates as a consequence of lodging. The relationship was positive between seed weight and days to flowering in MG IV~V, which was due to heavier seed weight on April 30 as a result of longer days to flowering. In a similar manner, positive correlation was observed between seed weight and lodging in MG IV~V, which could be due to nutrient con-

Table 12. Correlation coefficients among major characters of 100 soybean varieties

Characters	Maturity group	DF	GD	Lodging	SW	SC	PS
GD (days)	0~III	0.82**					
	IV~V	0.87**					
	VI~VII	0.89**					
Lodging (0-9)	0~III	0.02	-0.14				
	IV~V	0.38**	0.37**				
	VI~VII	0.23*	0.29**				
SW (g)	0~III	-0.02	-0.01	-0.50**			
	IV~V	0.05*	0.10	0.17**			
	VI~VII	-0.08	0.06	0.01			
SC (%)	0~III	0.20	0.30*	-0.06	-0.03		
	IV~V	0.21**	0.26**	0.26**	0.35**		
	VI~VII	0.21*	0.24*	0.22*	0.42**		
PS (%)	0~III	-0.39**	-0.14	-0.22	0.36	-0.12	
	IV~V	-0.01	0.19**	0.04	0.07	0.12	
	VI~VII	-0.17	0.08	-0.09	0.25**	-0.12	
PM (%)	0~III	0.22	0.27	-0.11**	0.34	-0.09	0.09
	IV~V	0.20**	0.33**	0.14*	0.06	0.07	0.48**
	VI~VII	0.08	0.24*	0.03	0.20	-0.10	0.53**

DF: Days to flowering, GD: Growth duration, SW: 100-seed weight, SC: Seed crack, PS: Purple seed, PM: Phomopsis centrating on the top plant during seed filling stage rather than minimization of pod number by lodging in R2 stage.

Seed crack in MG 0~III was positively correlated with growth duration while seed crack in MG IV~V and MG VI~VII was positively correlated with days to flowering, growth days, lodging density and seed weight. Unfavorable environment during maturity of MG IV~V and MG VI~VII caused by lodging have resulted to longer growth days hence, this observation. Reciprocal condition of humidity and dry (Wolf *et al*., 1981) as well as cool temperature during flowering period were reported to be the cause of seed crack, however, reason of seed crack occurrence is still not clearly elucidated. Futhermore, the degree of seed cracks was found to be higher as seed weight becomes heavier. This is in agreement with the report of Yang *et al*. (2002) that seed crack was correlated with seed weight.

Purple seed in MG IV~V was positively correlated with growth days while purple seed in MG VI~VII was positively correlated with seed weight. These could be because growth days was closely related to easy occurrence of disease and that seed weight is related to increased seed weight instead of reduction of pod number which resulted from lodging, respectively.

Positive correlation was obtained between phomopsis and growth days in MG IV~V and MG VI~VII. This result suggested that longer growing days condition could lead to longer days of disease infestation on seeds. More so, positive correlation was observed between phomopsis and purple seed in MG IV~V and MG VI~VII, which could be due to the high occurrence of mold under the condition of high temperature and humidity which coincided with the reproductive stage of the abovementioned MGs.

Correlation between yield and major characters in two soybean planting dates is shown in Table 13. Yield was negatively correlated with days to flowering and growth days in MG 0~III and MG IV~V. Prolonging growth days proved to be disadvantageous to early maturing groups as yield decreases due to high incidence of disease that infects seeds.

Yield in MG VI~VII was positively correlated with growth days on April 30 seeding and with days to flowering on May 30 seeding. Although these results were contrary to the findings of Boquet *et al*. (1983) that in case of shortened growth period, yield was influenced by reproductive growth period and not by vegetative growth period, this experiment carried under full growth duration might not be enough to have similar conclusions.

Generally, long growth period and adequate soil moisture lead to improved yield by means of sufficient absorption and accumulation of assimilate. Lodging was known to cause yield reduction and in this experiment, was negatively correlated with yield in MG IV~V and MG VI~VII.

Yield was negatively correlated with seed weight in MG IV~V and MG VI~VII, which could have been due to the reduction of pod number as a result of lodging. Yield in both seeding dates and mean value was negatively cor-

Table 13. Correlation between yield and major characters in two soybean planting dates

Maturity group	Seeding date	DA (days)	GD (days)	L (0-9)	SW (g)	SC (%)	PS (%)	PM (%)
0～III	Apr.30	-0.23	0.09	-0.21	0.23	-0.06	0.34	-0.02
	May30	0.01	-0.12	0.11	0.29	0.05	0.20	-0.39
	Mean	-0.37**	-0.32*	0.00	0.21	-0.06	0.27	-0.20
IV～V	Apr.30	-0.15	0.07	-0.28**	-0.12	-0.39**	0.07	0.01
	May30	-0.03	0.05	-0.14	-0.03	-0.29**	0.16	-0.01
	Mean	-0.28**	-0.23**	-0.28**	-0.08	-0.38**	0.05	-0.10
VI～VII	Apr.30	0.16	0.33*	-0.24	-0.39**	-0.51**	0.11	-0.09
	May30	0.33*	-0.07	-0.33*	-0.44**	-0.31*	-0.02	0.02
	Mean	-0.08	-0.16	-0.31**	-0.41**	-0.47**	0.04	-0.13

DA: Days to flowering, GD: Growth duration, L: Lodging, SW: 100-seed weight, SC: Seed crack, PS: Purple seed, PM: Phomopsis

Table 14. Promising soybean varieties adaptable to early season cultivation for good quality seed production

Classification	Variety	Seeding date	Crack (%)	Purple (%)	Phomopsis (%)	Protein (%)	Crude oil (%)	Isoflavone (mg/g)
For fermentation	Seonyou	April	3.6	1.7	0.9	41.4	19.2	1.35
		May	0.6	0.5	0.5	41.6	18.1	2.14
	Soho	April	2.6	0.7	1.6	42.6	16.8	2.94
		May	0.0	0.5	0.5	41.5	17.0	3.59
	Kwangdu	April	4.6	0.5	0.0	35.9	20.5	2.82
		May	1.4	0.7	0.0	39.8	19.3	2.83
For sprouting	Sobaek	April	1.3	1.0	0.7	40.2	16.5	1.96
		May	0.3	0.5	0.3	40.9	18.0	2.29
	Kwangan	April	0.0	0.3	2.1	46.8	13.3	1.09
		May	0.0	0.4	0.2	45.4	13.4	1.42
	Sowon	April	0.6	0.0	0.0	38.1	19.9	2.63
		May	0.0	0.0	0.2	40.1	18.7	4.01
	Boseok	April	1.1	1.5	1.7	41.5	17.9	2.44
		May	0.0	0.4	0.5	42.5	17.4	3.36
For mixed with rice	Geomjeong2,	April	0.8	0.0	1.4	42.2	18.0	2.56
		May	1.2	0.0	0.0	41.9	17.5	2.62

related with seed crack, which could be explained by the same logic that seed weight was negatively correlated with yield. Major varieties affected by the negative relationship between seed crack and yield, as manifested on their low yield and high seed crack incidence, were Saeal, Jinpum2, Jinpum, Hojang, Geomjeong4, Jangwon, Heukcheong, Galmi, Ilmi and Bongeui.

In summary, April 30 seeding as compared with May 30 seeding showed longer growth period, heavier seed weight and poorer apparent seed quality (increased lodging, purple seed and phomopsis). Accordingly, we have selected varieties adaptable to early season cultivation. These are varieties with high yield and have lower seed cracks, purple seed and phomopsis, characters that are essential for high quality seed production (Table 14). Soybean cultivars adaptable to early season planting for production of high quality tofu and fermented soybean paste were Seonyu, Kwangdu, and Soho while those suited for the manufacture of soybean sprouts were Sobaeknanul, Kwangan, Sowon, and Bosuk in sprout soybean. Geomjeong 2 was best variety for mixing with rice.

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