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Variation of Leaflet Traits and Their Association with Agronomic Traits of Soybean Germplasm

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콩 遺傳資源의 小葉形質 變異와 農業形質과의 關係

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ABSTRACT : To determine variations in leaflet length (LL), leaflet width (LW), leaflet size (LS), and leaflet shape index (LSI), and their association with eight agronomic traits, characterization data of 884 soybean accessions which were grown in the autumn of 1992 in Taiwan were analyzed. LL ranged from 4.3 to 14.7 cm, and LW ranged from 2.8 to 9.7 cm. Also, LS (LL × LW) ranged from 12.1 to 124.6 cm^2. The absolute variation of LL, LW, and LS was not large because of limitation in vegetative growth by short day length. None was classified as a large leaflet based on the International Board for Plant Genetic Resources (IBPGR) descriptors. LSI (LL/LW) ranged from 1.21 to 3.06, and three accessions were classified as narrow leaflet. There were differences in ranges and means of LL, LW, LS, and LSI between and within temperate and tropical accessions. LL, LW, LS, and LSI had highly significant positive correlations with seven agronomic traits and highly significant negative correlation with 100-seed weight except LW for all accessions. There was variation in the closeness of association among leaflet traits, and between and within temperate and tropical accessions. Generally, LL, LW, and LS were more closely associated with days to flowering, plant height at R_1 and R_8, number of pods per plant; LSI was more closely associated with 100-seed weight than other traits.

Key words : Leaflet length, Leaflet width, Leaflet size, Leaflet shape, Soybean, Germplasm, Agronomic traits, Correlation.

IBPGR[2] prescribed definitions for characterizing LS and leaflet shape (LSH) for soybean. LS is recorded as LL × LW, and LSH is judged from the ratio of LL/LW. Many scientists reported the broad type completely dominant to the narrow type(Domingo[1], Takahashi[5], Woodworth[6]). Since then, Sawada[3] reported that the intermediate type as well as the broad type were genetically dominant to the narrow type and proposed a LSI value of 2.6 as a criterion for the classification between broad and narrow types.

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Sawada[4] also reported that LSH is determined at an early stage of growth, and left and right leaflets of each leaf on the main stem had almost the same shape, but their LSI values were smaller than that of central leaflets in all three shapes. Domingo[1] reported that LSH and the number of seeds per pod were linked.

The objectives of this study were to determine variations in LL, LW, LS, and LSI over a large number of accessions and the association between leaflet traits and eight agronomic traits in the autumn of Taiwan.

MATERIALS AND METHODS

In 1992, 1000 accessions from the Asian Vegetable Research and Development Center(AVRDC) soybean germplasm collection were planted in nonreplicated two-row plots, 4 m long with 0.5 m between rows. These accessions originated from 29 countries, mainly from Brazil, China, Indonesia, Japan, Korea, and USA. The experiment was planted on 22 September on the AVRDC farm, Shanhua, Tainan, Taiwan (120°17'E, 23°7'N). Ten days after germination, the plants were thinned to 10 cm apart. For characterization, 26 different traits were observed using the IBPGR[2] and AVRDC descriptors. Among 26 traits, the following 12 traits were used for this study: LL and LW were measured from the fully developed terminal leaflet on the fourth node from the terminal of the main stems from 10 randomly selected plants. LS was recorded as LL×LW, and LSI was calculated with LL/LW from the means of 10 leaflets. Plant height, number of primary branches per plant at maturity, number of pods per plant, and number of seeds per pod were measured by the AVRDC descriptors. Days to flowering, lodging score, and 100-seed weight were measured by the IBPGR method[2]. Since 116 accessions did not germinate or segregate for qualitative traits, the data from only 884 accessions were analyzed.

RESULTS AND DISCUSSION

The range of LL for 884 accessions was 4.3 to 14.7 cm, and the mean was 8.55 cm (Table 1). The range of LL for the tropical accessions was distributed towards the longer classes than that for the temperate accessions. The mean of LL for the tropical accessions was 41% longer than that of the temperate accessions. The mean of the Brazilian accessions was longer than that of the Indonesian accessions, and the mean of the Chinese accessions was larger than that of the Japanese, Korean, and USA accessions (Tables 1 and 2). It seems that the large difference in means of LL between temperate and tropical accessions was caused by the difference in days to flowering between temperate and tropical accessions(Table 1). The longest accession in this study was not as long as the longest one of three varieties reported by Sawada[4]. It is supposed that the difference between the two results was caused by the difference in day length.

The range of LW for 884 accessions was 2.8 to 9.7 cm, and the mean of LW was 5.27 cm (Table 1). The range of LW for the tropical accessions was distributed over wider classes than that for the temperate accessions. The mean of LW for the tropical accessions was 34% wider than that for the temperate accessions. There was no differ-

Table 1. Range and mean of leaflet length, leaflet width, leaflet size, leaflet shape index, and days to flowering by origin

Origin	No. of accs.	Item	Leaflet length(cm)	Leaflet width(cm)	Leaflet size(cm^2)	Leaflet shape index	Days to flowering
World	884	Range	4.3~14.7	2.8~9.7	12.1~124.6	1.21~3.06	25~65
		Mean	8.55	5.27	46.4	1.63	33.0
Temperate	606	Range	4.3~11.8	2.8~7.4	12.1~84.2	1.21~2.30	25~46
countries		Mean	8.01	5.04	41.2	1.60	31.1
China	109	Range	5.0~11.4	3.1~7.4	16.4~84.2	1.26~2.30	25~41
		Mean	8.44	5.08	43.6	1.67	31.4
Japan	189	Range	4.3~11.6	2.8~7.0	12.1~80.7	1.25~2.05	26~40
		Mean	8.02	5.09	41.6	1.58	30.9
Korea	240	Range	4.9~11.8	3.4~7.3	17.2~82.6	1.21~2.17	25~42
		Mean	7.80	5.04	40.0	1.55	30.0
USA	68	Range	5.6~10.6	3.1~7.0	18.0~72.8	1.38~2.19	26~46
		Mean	8.05	4.86	40.1	1.67	34.7
Tropical	102	Range	8.3~14.7	4.1~8.7	33.8~115.6	1.25~2.04	31~65
countries		Mean	11.26	6.67	75.8	1.69	45.0
Brazil	35	Range	8.3~14.7	4.1~8.5	33.8~115.6	1.47~2.04	31~65
		Mean	11.67	6.65	78.8	1.76	45.7
Indonesia	67	Range	8.8~13.0	5.1~8.7	45.7~108.2	1.25~1.95	33~55
		Mean	11.04	6.69	74.2	1.66	44.6
Others	176	Range	6.1~13.3	3.1~9.7	21.6~124.6	1.32~3.06	25~56
(23 countries)		Mean	8.85	5.22	47.4	1.71	32.8

Table 2. T-values for comparison between mean of country group, and zonal group for leaflet length, leaflet width, leaflet size, and leaflet shape index

Comparison	Leaflet length	Leaflet width	Leaflet size	Leaflet shape index
Temperate vs. tropical	23.835 **	19.866 **	25.751 **	5.421 **
Within temperate				
China vs. Japan	2.793 **	0.158 ns	1.384 ns	4.510 **
China vs. Korea	4.444 **	0.454 ns	2.619 **	6.776 **
China vs. USA	2.017 *	1.739 ns	1.869 ns	0.361 ns
Japan vs. Korea	1.815 ns	0.745 ns	1.389 ns	2.162 *
Japan vs. USA	0.170 ns	2.085 *	0.909 ns	3.565 **
Korea vs. USA	1.462 ns	1.732 ns	0.031 ns	5.481 **
Within tropical				
Brazil vs. Indonesia	2.353 *	0.214 ns	1.406 ns	3.322 **

*, ** = Significant at the 5% and 1% levels, respectively. ns = Non-significant

ence in the mean of LW within zonal groups, except between Japanese and USA accessions (Table 2).

The range of LS for 884 accessions was 12.1 to 124.6 cm^2, and the mean of LS was 46.4 cm^2 (Table 1). The range of LS for the tropical accessions was distributed over larger classes than that for the temperate accessions. The LS of the largest accession was 10.3 times larger than that of the smallest one. The mean of LS for the tropical accessions was 84% larger than that for the

Table 3. Correlation between leaflet length and agronomic traits by origin

Origin	No. of accs.	Days to flowering	Plant ht. at R_1	Plant ht. at R_8	Branch no. per plant	Pod no. per plant	Seed no. per pod	100-seed weight	Lodging score
World	884	0.606**	0.713**	0.739**	0.118**	0.657**	0.466**	−0.254**	0.646**
Temp. countries	606	0.106**	0.549**	0.552**	−0.035ns	0.464**	0.263**	0.108**	0.178**
China	109	0.146ns	0.530**	0.522**	−0.095ns	0.322**	0.092ns	0.406**	0.114ns
Japan	189	0.004ns	0.471**	0.479**	−0.128ns	0.361**	0.214**	0.031ns	0.196**
Korea	240	0.105ns	0.582**	0.528**	0.049ns	0.604**	0.327**	0.181**	0.237**
USA	68	0.103ns	0.607**	0.693**	−0.034ns	0.521**	0.222ns	0.093ns	0.086ns
Trop. countries	102	0.709**	0.481**	0.299**	0.058ns	0.270**	0.335**	−0.008ns	0.188ns
Brazil	35	0.816**	0.825**	0.510**	−0.211ns	0.447**	0.494**	−0.283ns	0.475**
Indonesia	67	0.587**	0.472**	0.533**	0.130ns	0.338**	0.103ns	0.197ns	0.237ns

*,** = Significant at 5% and 1% levels, respectively.
ns = Non-significant.

temperate accessions. There was no difference in means of LS within zonal groups except between Chinese and Korean accessions (Tables 1 and 2). Among 884 accessions, 802 were classified as small sized ($LS \leq 70$ cm^2) and as to medium sized (70 cm^2 $< LS <$ 150 cm^2) by the IBPGR classification[2]. None of the accessions was classified as large sized ($LS \geq 150$ cm^2). It seems that the result was caused by determination of the growth period for the temperate accessions under the short day length in the autumn of Taiwan.

The range of LSI for 884 accessions was 1.21 to 3.06, and the mean of LSI was 1.63 (Table 1). The range of LSI for the tropical accessions was narrower than that for the temperate accessions. The mean of LSI for the tropical accessions was higher than that for the temperate accessions. There was a significant difference in the mean of LSI within zonal groups, except between Chinese and USA accessions (Tables 1 and 2). Among 884 accessions, 814 were classified as broad leaflet ($LSI < 1.9$), 67 as intermediate in LSH ($1.9 \leq LSI < 2.2$), and 3 as narrow ($LSI \geq 2.2$), based on the IBPGR classification[2]. All accessions except one were classified as broad LSH ($LSI < 2.6$) using Sawada's classification[3].

LL had highly significant positive correlations with days to flowering, plant height at R_1 and R_8, number of primary branches per plant, number of pods per plant, number of seeds per pod, and lodging score, and highly significant negative correlation with 100-seed weight for all accessions (Table 3).

However, LL was not associated with days to flowering, number of primary branches per plant, number of seeds per pod, 100-seed weight, and lodging score in some cases within zonal groups and within country groups. Generally, LL was more closely associated with days to flowering, plant height, and number of pods per plant than with other agronomic traits.

LW had highly significant positive correlations with days to flowering, plant height at R_1 and R_8, number of pods per plant, number of seeds per pod and lodging score for all accessions (Table 4). However, LW was not associated with days to flowering, number of pods per plant, number of seeds

Table 4. Correlation between leaflet width and agronomic traits by origin

Origin	No. of accs.	Days to flowering	Plant ht. at R_1	Plant ht. at R_8	Branch no. per plant	Pod no. per plant	Seed no. per pod	100-seed weight	Lodging score
World	884	0.498**	0.677**	0.644**	0.027^{ns}	0.542**	0.354**	−0.055^{ns}	0.565**
Temp.									
countries	606	−0.050^{ns}	0.523**	0.373**	−0.089*	0.268**	0.141**	0.381**	0.041^{ns}
China	109	0.025^{ns}	0.471**	0.371**	−0.229*	0.254**	0.022^{ns}	0.565**	−0.088^{ns}
Japan	189	−0.148*	0.554**	0.386**	−0.125^{ns}	0.169*	0.149*	0.320**	0.090^{ns}
Korea	240	0.064^{ns}	0.535**	0.373**	−0.045^{ns}	0.426**	0.183**	0.408**	0.159*
USA	68	−0.051^{ns}	0.543**	0.562**	−0.012^{ns}	0.450**	0.363**	0.310*	−0.049^{ns}
Trop									
countries	102	0.517**	0.506**	0.335**	−0.140^{ns}	0.278**	0.275**	−0.116^{ns}	0.275**
Brazil	35	0.653**	0.717**	0.394*	−0.070^{ns}	0.454**	0.429*	−0.231^{ns}	0.382*
Indonesia	67	0.386**	0.409**	0.380**	−0.183^{ns}	0.218^{ns}	0.159^{ns}	−0.081^{ns}	0.255*

*,** = Significant at 5% and 1% levels, respectively.
ns = Non-significant.

Table 5. Correlation between leaflet size and agronomic traits by origin

Origin	No.of accs.	Days to flowering	Plant ht. at R_1	Plant ht. at R_8	Branch no. per plant	Pod no. per plant	Seed no. per pod	100-seed weight	Lodging score
World	884	0.625**	0.750**	0.743**	0.087^{ns}	0.641**	0.431**	−0.191**	0.662**
Temp.									
countries	606	0.048^{ns}	0.561**	0.485**	−0.057^{ns}	0.383**	0.207**	0.264**	0.116**
China	109	0.105^{ns}	0.518**	0.454**	−0.159^{ns}	0.292**	0.030^{ns}	0.535**	−0.055^{ns}
Japan	189	−0.068^{ns}	0.533**	0.450**	−0.129^{ns}	0.264**	0.188**	0.187*	0.159*
Korea	240	0.111^{ns}	0.586**	0.472**	0.054^{ns}	0.541**	0.273**	0.319**	0.212**
USA	68	0.046^{ns}	0.598**	0.660**	−0.021^{ns}	0.514**	0.296*	0.215^{ns}	0.007^{ns}
Trop									
countries	102	0.665**	0.524**	0.329**	−0.042^{ns}	0.292**	0.329**	−0.047^{ns}	0.230*
Brazil	35	0.778**	0.823**	0.464**	−0.170^{ns}	0.477**	0.473**	−0.258^{ns}	0.453**
Indonesia	67	0.527**	0.477**	0.503**	−0.044^{ns}	0.303*	0.149^{ns}	−0.152^{ns}	0.254*

*,** = Significant at 5% and 1% levels, respectively.
ns = Non-significant.

per pod, and lodging score in some cases within zonal groups and within country groups. LW was not associtated with the number of primary branches except within Chinese accessions and 100-seed weight for all accessions of tropical zone. Generally, LW was more closely associated with days to flowering, plant height, and number of pods per plant than with other agronomic traits.

LS had highly significant positive correlations with days to flowering, plant height at R_1 and R_8, number of primary branches per plant, number of pods per plant, number of seeds per pod, and lodging score, and highly significant negative correlation with 100-seed weight for all accessions (Table 5).

However, LS was not associated with days to flowering, number of primary branches per plant, number of seeds per pod, 100-seed weight, and lodging score in some cases within zonal groups and within country

Table 6. Correlation between leaflet shape index and agronomic traits by origin

Origin	No. of accs.	Days to flowering	Plant ht. at R_1	Plant ht. at R_8	Branch no. per plant	Pod no. per plant	Seed no. per pod	100-seed weight	Lodging score
World	884	0.235**	0.144**	0.240**	0.145**	0.259**	0.246**	−0.366**	0.202**
Temp. countries	606	0.237**	0.066ns	0.294**	0.074ns	0.308**	0.199**	−0.408**	0.226**
China	109	0.168ns	0.026ns	0.180ns	0.193*	0.068ns	0.076ns	−0.251**	0.148ns
Japan	189	0.252**	−0.120ns	0.166*	−0.030ns	0.306**	0.122ns	−0.475**	0.177*
Korea	240	0.050ns	0.184**	0.328**	0.006ns	0.358**	0.263**	−0.325**	0.178**
USA	68	0.260*	−0.007ns	0.111ns	−0.011ns	0.028ns	−0.255*	−0.388**	0.220ns
Trop. countries	102	0.256**	−0.021ns	−0.034ns	0.259**	−0.008ns	0.086ns	0.127ns	−0.116ns
Brazil	35	0.341*	0.270ns	0.226ns	−0.235ns	0.040ns	0.124ns	−0.168ns	0.191ns
Indonesia	67	−0.160ns	−0.004ns	0.102ns	0.395**	0.093ns	−0.043ns	−0.094ns	−0.081ns

*, ** = Significant at 5% and 1% levels, respectively.
ns = Non-significant.

groups. Generally, LS was more closely associated with days to flowering, plant height, and number of pods per plant, and lodging score than with other agronomic traits. The associations of LS with agronomic traits were very similar to the results of LL.

LSI had highly significant positive correlations with days to flowering, plant height at R_1 and R_8, number of primary branches per plant, number of pods per plant, number of seeds per pod and lodging score, and highly significant negative correlation with 100-seed weight for all accessions (Table 6). However, LSI was not associated with days to flowering, plant height at R_1 and R_8, number of primary branches per plant, number of pods per plant, number of seeds per pod, 100-seed weight, and lodging score in some cases within zonal groups and within country groups. Generally, LSI was more closely associated with 100-seed weight than with other agronomic traits. The result that the number of seeds per pod was associated with LSI for all accessions agreed with the findings of Domingo[1].

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적 요

엽장, 엽폭, 엽의 크기와 엽형지수 등 소엽(leaflet) 형질의 변이와 8개 농업형질과의 관계를 구명하기 위하여 1992년도 대만에서 가을에 재배된 콩 유전자원 884 품종의 특성조사 자료를 분석하였던 바 주요 결과를 요약하면 다음과 같다.

1. 콩 유전자원들의 소엽 형질들의 변이를 보면 엽장은 4.3~14.7cm, 엽폭은 2.8~9.7cm에 분포하였으며, 엽의 크기(엽장×엽폭)는 12.1~124.6cm^2 였다.
2. 엽장, 엽폭과 엽의 크기의 절대적 변이는 단일에 따른 영양생장량의 제한 때문에 크지 않았

다. 또한 국제식물유전자원위원회(IBPGR)의 기준에 따른 분류시 엽의 크기가 대에 속하는 것은 없었다.

3. 엽형지수는 1.21~3.06의 변이를 보였으며 3품종은 피침형에 속하였고 나머지는 모두 난형 또는 중간형에 속하였다.
4. 엽장, 엽폭, 엽의 크기, 엽형지수의 범위와 평균은 온대품종군과 열대품종군간과 품종군내에서 차이가 있었다.
5. 엽장, 엽폭, 엽의 크기와 엽형지수는 100립중을 제외한 7개 형질과 고도로 유의한 정상관을 보였고 100립중과는 엽장, 엽의 크기 및 엽형지수와 고도로 유의한 부상관을 보였다.
6. 소엽 형질들의 농업형질과의 상관관계를 보면 소엽 형질간에 변이가 컸으며 엽장, 엽폭과 엽의 크기는 개화일수, R_1기 와 R_8기의 경장, 개체당협수와 밀접한 관계가 있었고 엽형지수는 다른 형질보다 100립중과 밀접한 관계가 있었다.

LITERATURE CITED

1. Domingo W.E. 1945. Inheritance of number of seeds per pod and leaflet shape in the soybean. Journal of Agricultural Research 70:251-268.
2. IBPGR. 1984. Descriptors for soybean. IBPGR Secretariat, Rome, Italy. p. 38.
3. Sawada S. 1988. Inheritance of leaflet shape in soybean. Soybean Genetics Newsletter 16:61-65.
4. _____. 1992. Time of determination and variations within and between plants in leaf shape of soybean. Japanese Journal of Crop Science 61(1):96-100.
5. Takahashi N. 1934. Linkage relation between the genes for the forms of leaves and number of seeds per pod of soybeans. Japanese Journal of Genetics 9:208-225.
6. Woodworth C.M. 1932. Genetics and breeding in the improvement of the soybean. Illinois Agricultural Experiment Station Bulletin 384:297-404.