GENOTYPIC COMPARISON OF DETERMINATE AND INDTERMINATE SOYBEAN LINES FOR YIELD AND YIELD COMPONENTS

AMMAR KHAN[1]*, FARHATULLAH[1], IQBAL MUNIR[2], SANIA BEGUM[3] AND NEELAM ARA[4]

[1]Department of Plant Breeding Genetics, The University of Agriculture Peshawar, Pakistan
[2]Institute of Biotechnology and Genetic Engineering, The University of Agriculture Peshawar
[3]National Institute for Genomics and Advanced Biotechnology NARC Islamabad Pakistan
[4]Department of Horticulture, The University of Agriculture Peshawar, Pakistan
*Corresponding author's email: ammak403@gmail.com

Abstract

This research was conducted to study the effect of growth habit on yield and yield components of indigenous soybean lines collected from Kurram Agency of Pakistan. Fifteen determinate lines and 15 indeterminate lines were selected and sown in Randomized Complete Block design with three replications for two years (2015-16). Data were recorded on various yield components. Analysis of variance showed highly significant differences among lines, determinate lines, indeterminate lines and determinate vs. indeterminate interactions for all the traits except seeds pod^{-1}. The overall effect of years was non-significant. Lines × year interactions were highly significant. Only indeterminate soybean had significant interactions with years for plant height, yield plant^{-1}, leaf area seed size and 100-seed weight. However, the average performance of indeterminate lines was better than determinate ones for pods plant^{-1}, yield plant^{-1}, plant height, yield plant^{-1} and seeds plant^{-1}. Determinate lines had significant correlations of plant height with yield plant^{-1} (0.25), seeds plant^{-1} with seeds pod^{-1} (0.55) and 100-seed weight (0.46), pods plant^{-1} with seeds plant^{-1} (0.75) and 100-seed weight (0.46). Similarly significant correlations were observed for seeds plant^{-1} with seeds pod^{-1} (0.71) and pods plant^{-1} (0.70). Significant but negative correlations of pod length (-0.21), pods plant^{-1} (-0.22), days to maturity (-0.21) were observed with yield plant^{-1} and positive significant correlation with hundred seed weight (0.27) of indeterminate soybean lines. Similarly significant correlations were observed between days to maturity with seeds plant^{-1} (0.20), pods plant^{-1} (0.38), seed size (0.28) and had significant but negative correlations with yield plant^{-1} (-0.21). These results suggested that indeterminate lines had better performance for plant height, pods plant^{-1}, seeds plant^{-1} and yield plant^{-1} as compared to determinate lines and can be used in breeding high yielding soybean varieties.

Key words: Growth habit, Yield components, Indigenous soybean lines.

Introduction

Soybean (*Glycine max* (L.) Merr.) is an important leguminous and oil seed crop around the world. Soybean belongs to family *Fabaceae* and sub-family *Faboide* (Ali *et al*., 2015). As reported by Akram *et al*. (2011) soybean seed contains 40-42% proteins and 18-22% oil. Oil has 85% of 2 essential fatty acids (lenoleic and linolenic acid). These are not effectively synthesized by the human body (Antalina, 2000; Balasubramaniyan & Palaniappan, 2003). Soy-protein is considered as a good source for the synthesis of hydrolysates (Young, 1991). In Pakistan, in the year 2014 soybean was cultivated on an area of 135 ha having average yield 888.9 kg ha^{-1}. In 2010-11, total cultivated area for soybean was 129 hectares having average yield 573 kgha^{-1} while in 2006 this yield was 1250 kg ha^{-1} (Ali *et al*., 2015).

Stem growth habit is an important key character affecting yield in soybean. Soybeans can be classified into indeterminate, semi-determinate growth and determinate plants on the basis of growth habit that have been controlled by Dt1 and Dt2 loci (Bernard, 1972). Stem growth habit has effect on yield in soybean. In some reports indeterminate genotypes have shown higher yield (Bernard, 1972; Cooper & Waranyuwat, (1985), Shannon *et al*. (1971) and some other scientists have reported a higher yield of determinate type soybean lines (Weaver *et al*., 1991). It has been reported that yield of determinate and indeterminate type depends on location and genetic background (Boerma & Ashley, 1982) as well as interaction between growth habit and location and between growth habit and genetic background (Cober & Tanner, 1995; Ouattara & Weaver, 1995; Wilcox & Frankenberger, 1987). Kato *et al*. (2015) reported that influence of growth habit on seed weight per plant varies with maturity and indeterminate lines have high yield with early maturity. Previous study indicated that grain yield is controlled by various growth and yield components of plant (Mehmet *et al*., 2009).

Correlation coefficients is very effective in determining the size and relationship of various yield related traits. Ali *et al*. (2015); Chandrawat *et al*. (2015); Mahbub *et al*. (2015); Ali *et al*. (2013); Bekele & Alemahu (2011); Iqbal *et al*. (2010) and Malik *et al*. (2006) also used analysis of variance and correlation coefficients technique for the estimation of genetic variability and association among various yield related traits in selected varieties of soybean.

The present research was conducted to study the effect of growth habit on yield and yield components and to study association and relationship among various traits of local germplasm of soybean. The specific objectives of this experiment were also have to determine the effect of growth habit on seed yield and to study the relationship between yield contributing traits and the stem growth habit (determinate vs. indeterminate).

Materials and Methods

Fifteen determinate and 15 indeterminate soybean accessions were collected from Kurram Agency of Pakistan during the year 2014 and were then sown in a Randomized Complete Block (RCB) manner for two consecutive years i.e. 2015 and 2016 at The University of Agriculture, Peshawar. Row length and row to row distance was kept 3 m and 0.75 m respectively. Plant to plant distance was 0.32 m. All recommended culture practices were applied during the experiment (Kato *et al.*, 2015). Data were recorded on 5 randomly selected plants and were averaged. Averaged data were then used in the analysis without transformation. Traits studied were leaf area, plant height, days to maturity, pods plant^{-1}, pod length, seeds pod^{-1}, seeds plant^{-1}, seed size, 100-seed weight and yield plant^{-1}.

Data were analyzed to study variation among the lines using analysis of variance technique proposed by Steel & Torrie, 1980. Correlation was calculated to find out association between traits using the 'Pearson Product-moment correlation analysis'. A p-value of <0.05 was considered to be statistically significant according to Kato *et al.* (2015).

Results and Discussion

Analysis of variance revealed that the overall effect of years was non-significant. Lines revealed significant differences for all the studied traits except seeds pod^{-1}. Determinate lines had significant differences for all the traits except seeds pod^{-1}. Similarly indeterminate lines also had significant variation for all the studied traits except seeds pod and 100-seed weight. Lines ×years interactions were highly significant for all the traits. Determinate ×years interactions were not significant for all the traits while indeterminate × years interactions were significant for leaf area, plant height, seed size 100-seed weight and yield plant^{-1}. Determinate vs. indeterminate contrast was significant for all traits except seeds pod^{-1} and 100-seed weight (Tables 1 and 2). In determinate lines, maximum leaf area ranged from 7.17 to 22.04 cm^2 with average mean of 12.48 cm^2 while in indeterminate lines, leaf area ranged from 7.55 to 13.55 cm^2 and average was 10.38 cm^2 (Table

3). In indeterminate lines, plant height ranged from 73.33 to 117.58 cm having an average mean of 87.64 cm while plant height of determinate lines was in the range of 63.67-98.17 cm and average plant height was 81.19 cm (Table 3). In determinate lines, days to maturity were in the range of 106.21-130.88 days with a mean of 120.30 while in indeterminate lines this range was 93.76-131.19 days with an average of 113.51 (Table 3). Pods plant^{-1} were in the range of 41.17-85.25 with average of 59.54 for determinate lines and 52.83-81.67 with average of 65.80 for indeterminate lines (Table 3). Pod length of determinate lines ranged from 3.03 to 3.78 with an average of 3.30 while in determinate this range was 3.20-3.69 and mean was 3.42 (Table 3). Number of seeds pod^{-1} were in the range of 2.33-275 with an average of 2.46 in determinate lines while in indeterminate lines this range was 2.33-2.75 and mean was 2.53 (Table 3). In determinate lines, number of seeds plant^{-1} ranged from 89.29 to 219.42 with average mean of 136.8 while in indeterminate lines this range was 13.25-196.53 with a mean of 165.49 (Table 3). Seed size of determinate lines was in the range of 21.00-35.95 mm^2 with average of 26.20 mm^2. Similarly, in indeterminate lines seed size ranged from 18.60 to 33.07 mm^2 with average of 23.85 mm^2 (Table 3). Hundred-seed weight was in the range of 6.17-9.52 g with an average of 7.35 g while in indeterminate lines this range was 6.01-9.01 g with average of 7.36 g (Table 3). Yield plant^{-1} of determinate lines was in range of 6.17–10.34 g with a mean of 7.48 g. Similarly, in indeterminate lines yield plant^{-1} ranged from 6.14 to 15.35 g with an average of 8.62 g. These results revealed that growth habit influenced some of these traits significantly. There are significant variations in lines of both types of growth habits. Similar results for the presence of variations in various yield related traits were also reported by Mehbub *et al.* (2015); Ali *et al.* (2015); Bekele & Alemahu (2011); Aditya *et al.* (2011); Iqbal *et al.* (2010); Malik *et al.* (2007) and (2006); Arshad *et al.* (2006); Rajesh *et al.* (2004) and Gawande *et al.* (2002). However, the performance of indeterminate lines were better than determinate lines for plant height, pods plant^{-1}, seeds pod^{-1}, seeds plant^{-1}, yield plant^{-1} under the environmental condition at The University of Agriculture Peshawar and were also earliest in maturity than determinate lines (Table 3).

Table 1. Mean squares for various traits of determinate and indeterminate lines.

Source of variation	Df	Leaf area	Plant height	Days to maturity	Pods plant^{-1}	Pod length
Years	1	5.84	26.65	27.81	11.91	0.002
Reps	4	3.63	49.49	46.37	33.47	0.02
Lines	29	65.96**	922.27**	725.95**	797.62**	0.23**
Determinate (Det)	14	101.15**	750.77**	304.69**	1116.84**	0.32**
Indeterminate (Ind)	14	16.62**	1026.03**	1050.80**	409.27**	0.12**
Det× Y	14	3.69	40.93	0.95	70.96	0.01
Ind x Y	14	16.78**	397.80**	6.63	46.15	0.03
Lines x Y	29	900.03**	45149.63**	85548.04**	25173.67**	70.44**
Ind vs. Det	1	264.14**	1870.56**	2075.70**	1765.32**	0.68**
Error	116	5.83	42.51	10.07	59.94	0.02
Total	179					
CV (%)		**20.81**	**7.72**	**2.09**	**12.35**	**4.18**

*, ** = Significant and highly significant at 5% and 1% probability level respectively

Table 2. Mean squares for various traits of determinate and indeterminate lines.

Source of variation	df	Seeds pod^{-1}	Seeds plant^{-1}	Seed size	100 seed weight	Yield plant^{-1}
Years	1	1.03	295.74	7.97	7.52*	0.014
Reps	4	0.82	3838.46	8.21	0.97	1.12
Lines	29	0.17	6912.58**	79.31**	5.36**	19.33**
Determinate (Det)	14	0.21	8785.08**	83.59**	6.37**	7.77**
Indeterminate (Ind)	14	0.12	2899.21**	63.06**	4.73	28.05**
Det x Y	14	0.10	1522.77	12.73	0.4	0.11
Ind x Y	14	0.05	333.66	26.97**	2.70*	3.79**
Lines x Y	29	38.82**	148756.4**	3966.26**	340.87**	421.48**
Ind vs. Det	1	0.24	36884.74**	246.97**	0.0005	58.98**
Error	116	0.37	1263.37	10.84	1.54	0.683
Total	179					
CV (%)		24.44	13.06	13.15	16.87	10.27

*, ** = Significant and highly significant at 5% and 1% probability level respectively

Table 3. Means of various traits of determinate and indeterminate soybean lines evaluated at AUP during 2015-16.

Traits	Years	Determinate				Indeterminate		
		2015	2016	2015-2016		2015	2016	2015- 2016
Leaf area (cm^2)	Ranges	7.85-22.35	6.43-21.72	7.17-22.04		13.57-7.35	7.72-17.86	7.55-13.55
	Mean	13.13	12.48	12.80		10.42	10.34	10.38
	LSD (0.05)	3.76	4.10	2.76		3.76	4.10	2.76
Plant height (cm)	Ranges	63.67-98.17	60.83-100	62.6-98.66		69.19-114.78	71.5-141.83	69-117.58
	Mean	81.85	80.52	81.19		87.74	87.53	87.64
	LSD (0.05)	9.05	12.03	7.46		9.05	12.03	7.46
Days to maturity (no.)	Ranges	106.50-132.00	105.92-129.75	106.21-130.88		94.33-131.50	92.97-130.89	93.76-131.19
	Means	120.53	120.06	120.30		114.06	112.96	113.51
	LSD (0.05)	5.12	5.15	3.63		5.12	5.15	3.63
Pods plant^{-1} (no.)	Ranges	40.33-80.47	40.17-92.67	41.17-85.25		49.50-82.67	55.17-80.67	52.83-81.67
	Mean	59.40	59.68	59.54		66.46	65.14	65.80
	LSD (0.05)	9.88	14.94	8.85		9.88	14.94	8.85
Pod length (cm)	Ranges	3.08-3.77	3.03-3.78	3.06-3.78		3.17-3.67	3.12-3.70	3.20-3.69
	Mean	3.30	3.30	3.30		3.43	3.42	3.42
	LSD (0.05)	0.24	0.22	0.16		0.24	0.22	0.16
Seeds pod^{-1} (no.)	Ranges	2.17-2.67	2.17-3.00	2.33-2.75		2.33-2.67	2.33-2.83	2.33-2.75
	Mean	2.36	2.56	2.46		2.47	2.58	2.53
	LSD (0.05)	0.93	1.04	0.70		0.93	1.04	0.70
Seeds plant^{-1} (no.)	Ranges	94.45-181.71	73.17-261.50	89.29-219.42		134.50-197.50	129.67-210.17	132.25-196.53
	Mean	139.79	133.92	136.8		165.12	165.86	165.49
	LSD (0.05)	65.87	49.20	40.65		65.87	49.20	40.65
Seed size (mm^2)	Ranges	21.53-36.42	18.98-35.48	21.00-35.95		19.83-32.98	16.94-33.15	18.60-33.07
	Mean	26.45	25.95	26.20		24.02	23.68	23.85
	LSD (0.05)	5.35	5.37	3.76		5.35	5.37	3.76
100-seed weight (g)	Ranges	6.18-9.43	6.16-9.60	6.17-9.52		5.97- 9.16	5.04-9.23	6.01-9.01
	Mean	7.35	7.35	7.35		7.76	6.94	7.36
	LSD (0.05)	1.06	2.67	1.42		1.06	2.67	1.42
Yield plant^{-1} (g)	Ranges	6.30-10.70	6.22-9.99	6.17-10.34		6.57-13.56	5.71-17.14	6.14-15.35
	Mean	7.49	7.45	7.48		8.58	8.65	8.62
	LSD (0.05)	1.17	1.51	0.95		1.17	1.51	0.95

Correlation coefficients: Leaf area of determinate lines had significant positive correlations with pod length (0.20), plant height (0.32) and negative significant correlation with hundred seed weight (-0.41). Leaf area of indeterminate lines showed negative significant correlation with seed size (-0.26) and days to maturity (-0.24). In determinate lines, plant height had significant correlations with pod length (0.43), seed yield plant^{-1} (0.25) and pods plant^{-1} (0.20). In indeterminate lines, plant height showed significant correlation with days to maturity (0.21). In determinate lines significant correlations were recorded among days to maturity with pods plant^{-1} (0.26) and seeds plant^{-1} (0.23). In indeterminate lines days to maturity had significant correlations with seed size (0.28), seeds plant^{-1} (0.20)

and yield plant (-0.21). Number of pods plant^{-1} of determinate lines exhibited significant correlations with seeds plant^{-1} (0.75) and hundred seed weight (0.46). Number of pods plant^{-1} of indeterminate lines was positively significantly correlated with seeds plant^{-1} (0.70) and was negatively significantly correlated with yield plant^{-1} (-0.22). Pod length of indeterminate lines had negative significant correlation with yield plant^{-1} (-0.21). Number of seeds pod^{-1} of determinate lines showed significant correlation with seeds plant^{-1} (0.55). Number of seeds pod^{-1} of indeterminate lines showed significant correlation with seeds plant^{-1} (0.71) and 100 seed weight (0.41). Hundred seed weight (Table 4) of indeterminate lines was significantly correlated with yield plant^{-1} (27).

Table 4. Correlation co efficient among different traits of determinate (below diagonal) and indeterminate (above diagonal) soybean lines.

Traits	Leaf Area	Pod length	Pods plant[-1]	Plant height	Seeds plant[-1]	Seeds pod[-1]	Yield plant[-1]	Seed size	Hundred seed weight	Days to maturity
Leaf area		0.16	0.06	0.04	0.10	0.10	-0.14	-0.26**	-0.11	-0.24**
Pod length	0.20*		0.08	0.08	-0.02	-0.05	-0.21*	0.07	-0.12	0.18
Pods plant[-1]	-0.15	0.29**		0.13	0.70**	0.06	-0.22*	0.09	0.16	0.38**
Plant height	0.32**	0.43**	0.20*		0.10	-0.006	0.02	0.11	0.17	0.21*
Seeds plant[-1]	-0.14	0.16	0.75**	0.19		0.71**	-0.16	0.07	0.10	0.20*
Seeds pod[-1]	0.05	-0.03	0.11	0.11	0.55**		-0.02	0.05	-0.01	-0.04
Yield plant[-1]	0.15	0.18	0.08	0.25**	0.12	0.06		0.05	0.27**	-0.21*
Seed size	0.15	0.11	0.11	-0.01	0.02	-0.08	0.09		0.07	0.28**
100 seed weight	-0.41*	0.008	0.46**	-0.03	0.41**	0.009	0.02	0.18		-0.01
Days to maturity	0.09	0.16	0.26**	0.09	0.23*	0.005	-0.07	-0.01	0.14	

*, ** Significant and highly significant at 5% and 1% respectively

Yield plant[-1] of determinate lines was significantly correlated with plant height (0.25). Similarly, yield plant[-1] of indeterminate lines (Table 4) also showed negative significant correlations pod length (-0.21), pods plant[-1] (-0.22), days to maturity (-0.21) and positive significant correlation with hundred seed weight (0.27). Similar results were also reported by Sousa *et al.* (2015) and Ramteke *et al.* (2010) using different set of genotypes. Aditya *et al.* (2011) reported non-significant correlations of yield plant[-1] with pods plant[-1], hundred seed weight and plant height while the results of Ali *et al.* (2015); Malik *et al.* (2007) and Arshad *et al.* (2006) showed significant correlations of yield plant[-1] with plant height, pods plant[-1] and hundred seed weight.

References

Aditya, J.P., P. Bhartiya and A. Bhartiya. 2011. Genetic variability, heritability and character association for yield and component characters in soybean (*G. max* (L.) Merrill). *J. Cent. Europ. Agri.*, 12(1): 27-34.

Akram, R.M., W.M. Fares, H.S.A. Fateh and A.M.A. Rizk. 2011. Genetic variability, correlation and path analysis in soybean. *Egypt. J. Plant Breed.*, 15(1): 89-102.

Ali, A., S.A. Khan, E. Khan, N. Ali, I. Hussain and F. Ahmad. 2015. Genetic studies among diverse soybean (*Glycine max* (L.) Merrill) genotypes for variability and correlation at Swat. *Int. J. Bio. Sci.*, 6(4): 165-169.

Ali, A., Z. Iqbal, M.E. Safdar, M. Ashraf, M. Aziz, M. Asif, M. Mubeen, I.R. Noorka and A. Rehman. 2013. Comparison of yield performance of soybean varieties under semi-arid conditions. *J. Anim. Pl. Sci.*, 23(3): 828-832.

Antalina, S. 2000. Modern processing and utilization of legumes. Recent Research and Industrial achievement for soybean food in Japan. Proceeding of RILET-JIRCAS. Workshop on Soybean Research September 28, Malang-Indonesia.

Arshad, M., N. Ali and A. Ghafoor. 2006. Character correlation and path coefficient in Soybean (*Glycine max* (L.) Merr.). *Pak. J. Bot.*, 38(1):121-130.

Balasubramaniyan, P. and S.P. Palaniappan. 2003. Principles and practices of agronomy. Field crops. 45-46. Publishers Agr. Bios. India.

Bekele, A. and G. Alemahu. 2011. Desirable Traits Influencing Grain Yield in Soybean. *Innov. Sys. Design Engg.*, 2222-2871.

Bernard, R.L. 1972. Two genes affecting stem termination in Soybeans. *Crop Sci.*, 12:235-239.

Boerma, H.R. and D.A. Ashley. 1982. Irrigation, row spacing and genotype effects on late and ultra-late- planted soybeans. *Agron. J.*, 74: 495-499.

Chandrawat, K.S., K.S. Baig, D.H. Sarang, P.H. KiihneDumai, P.U. Dhone and A. Kumar. 2015. Association analysis for yield contributing and quality parameters in soybean. *Int. J. Envion. Sci.*, 7: 113-118.

Cober, E.R. and J.W. Tanner. 1995. Performance of related indeterminate and tall determinate soybean lines in short-season areas. *Crop Sci.*, 35: 361-364.

Cooper, R.L. and A. Waranyuwat. 1985. Effect of three genes (Pd, Rps and In) on plant height, lodging and seed yield in indeterminate and determinate near-isogenic lines of Soybeans. *Crop Sci.*, 25: 90-92.

Gawande, P., S. Patil, M. Kumari and V.J. Bailkwad. 2002. Selection of superior germplasm lines of soybean (*Gycine max* (L.) Merr) for breeding. *J. Soils Crops*, 12(2): 236-240.

Iqbal. Z., M. Arshad, M. Ashraf, R. Naeem, M.F. Malik and A. Waheed. 2010. Genetic divergence and correlation studies of soybean (*Glycine max* (L.) Merr.) genotypes. *Pak. J. Bot.*, 42(2): 971-976.

Kato, S., K. Fujii, S. Yumoto, M. Ishimoto, T.Shiraiwa, T. Sayama, A. Kikuchi and T. Nishio. 2015. Seed yield and its components of indeterminate and determinate lines in recombinant inbred lines of soybean. *Breed. Sci.*, 65: 154-160.

Mahbub, M.M., M.M. Rahman, M.S. Hossain, F. Mahmud and M.M. Kabir. 2015. Genetic variability, correlation and path analysis for yield and yield components in soybean. *American-Eurasian J. Agri. Environ. Sci.*, 15(2): 231-236.

Malik, M.F., M. Ashraf, A.S. Qureshi and A. Ghafoor. 2006. Genetic variability of the main yield related characters in Soybean. *Int. J. Agri. Biol.*, 8(6): 815-819.

Malik, M.F., M. Ashraf, A.S. Qureshi and A. Ghafoor. 2007. Assessment of genetic variability, correlation and path analysis for yield and its components in soybean. *Pak. J. Bot.*, 39(2): 405-413.

Mehmet, O.Z., A. Karasu, A.T. Goksoy and Z.M. Turan. 2009. Interrelationships of agronomical characteristics in soybean (*Glycine max*) grown in different environments. *Int. J. Agri. Biol.*, 11(1): 85-88.

Ouattara, S. and D.B. Weaver. 1995. Effect of growth habit on yield components of late-planted soybean. *Crop Sci.*, 35: 411-415.

Rajesh, S., J.S. Hooda, R.D. Vashishtha and B.P.S. Malik. 2004. Genetic divergence in soybean (*Glycine max* (L.) Merrill). *Ann. Biol.*, 20(1): 17-21.

Ramteke, R., V. Kumar, P. Murlidharan and D.K. Agarwal. 2010. Study on genetic variability and traits interrelationship among released soybean varieties of India (*Glycine max* (L.) Merrill). *Elec. J. Pl. Breed.*, 1(6): 1483-1487.

Shannon, J.G., J.R. Wilcox and A.H. Probst. 1971. Response of Soybean genotypes to spacing in hill plots. *Crop Sci.*, 11: 38-40.

Sousa, L.B., O.T. Hamawaki, C.D. Santos, V.M. Oliveira, A.P.O. Nogueira, F.M. Mundim, R.L. Hamawaki and C.D.L. Hamawaki. 2015. Correlation between yield components in F6 soybean progenies derived from seven biparental crosses. *Biosci. J. Uberlandia.*, 31(6): 1692-1699.

Steel, R.G.D. and J.H. Torrie. 1980. Principals and procedure of statistics. 2nd. McGraw Hill Book, Co., Inc. London, pp: 560.

Weaver, D.D., R.L. Akridge and C.A. Thomas. 1991. Growth habit, planting date and row-spacing effects on late planted soybean. *Crop Sci.*, 31: 805-810.

Wilcox, J.R. and E.M. Frankenberger. 1987. Indeterminate and determinate soybean responses to planting date. *Agron. J.*, 79: 1074-1078.

Young, V.R. 1991. Soy-protein in relation to human amino acid nutrition. *J. Am. Assoc.*, 7: 828-835.