regulates sex expression rather than their absolute quantities.

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Response of soybeans to varying planting patterns[1]

Resumen. Se investigó la respuesta de la soya sembrada bajo un sistema lineal, rectangular y triangular. El rendimiento de semilla (kg/ha) fue de 1839, 1959 y 1762 para los patrones lineal, rectangular y triangular, respectivamente.

Las relaciones entre el rendimiento de semilla en el tallo y en las ramas fueron 1.04, 1.13 y 1.17 para los tres patrones de siembra, indicando que los tallos fueron más importantes en la determinación del rendimiento para las ramas. Sin embargo, la relación número de vainas/m² en los tallos y en las ramas fue inferior a la unidad y osciló entre 0.97 y 0.98. El tamaño de las semillas para la relación tallo/rama varió entre 1.0 y 1.1, indicando que las semillas provenientes del tallo eran mayores que las producidas en las ramas. La relación entre el índice de área foliar (LAI) y el peso específico de la hoja (SLW) en el tallo/rama fue mayor que la unidad, ocurriendo el inverso para la relación área foliar (LAR) y el área específica de la hoja (SLA).

1 Contribution from Crop Production Department, Bunda College of Agriculture

Numerous studies have been made on the effects of planting patterns on yield of several crops. Generally narrow rows, square and narrow rectangular planting patterns have resulted in increased seed yields due to more efficient light utilization (6, 8, 9, 12, 14), less erosion and higher water infiltration rate (4) and weed supression (5, 11).

Recently, the concept of plant types (ideotypes) as a means of increasing grain legume yields have begun to receive some attention. The construction of the ideotypes has been based on mostly morphological characteristics such as the number of branches/plant, stem diameter, number and size of leaves, inflorescence/plant, pods/plant, growth habit and seed size (1, 7). One of the morphological characteristics that could conceivably influence seed yield is the number of branches/plant. Apart from the results of Lehman and Lambert (3), very little information is available on the relative importance of branches in yield determination, especially at varying planting patterns.

The experiment reported here was to evaluate the relative importance of branches in yield determination and also to determine whether planting pattern has any effect on the role of branches in seed yields.

Materials and methods

The experiment was conducted at Bunda College of Agriculture Farm (33°4' S and 14°11' E, altitude 1 118 m). Soybean seeds (*Glycine max* L. (Merill)), cultivar Geduld, inoculated with *Rhizobium japanicum* strain 63, were planted on 17th December, 1975. Each treatment which was replicated three times consisted of three gross ridges each 14 m long and 91 cm apart. All plots received 16.5 kg/ha of P and 7.5 kg/ha of K before planting and the fertilizer was banded. The sources of P and K were single superphosphate and muriate of potash, respectively. Three planting patterns were used. These were (i) single row per ridge at 5 cm between plants (linear); (ii) two rows per ridge with 10 cm between plants with seeds sown in opposite planting holes (rectangular) and (iii) two rows per ridge with 10 cm between plants and seeds sown in alternate planting holes (triangular). Dry matter distribution and accumulation were determined at three stages of growth and development from 0.91 m^2 (1 m from the middle ridge). Leaf area index (LAI) was determined using leaf area and leaf-weight relationship from discs obtained with a cork borer (10). Specific leaf weight (SLA) was leaf area (dm^2)/leaf tissue (g); leaf area ratio (LAR) was leaf area (dm^2/total plant DM above ground and specific leaf weight (SLW) was DM leaf tissue (mg)/leaf area (cm^2). Dry matter distribution, LAI, SLA, LAR and SLW were determined for branches and stems separately. Canopy height was the average "height" (including foliage tips) of the plants on 14 m ridge, while the canopy width was a measure of the spread of the plants from the center of the ridge to one edge of the ridge, an index of the rate at which plants close up the inter-row spacing. Pod clearance was the height of the plant from the transition zone to the tip of the first pod, while plant height which was determined at harvest maturity was the distance from the transition zone to the tip of the growing point. The transition zone was the constricted part of the stem-root section.

Yield and yield components were determined at harvest maturity from 4 m of the middle ridge. Seed size (g/100 seeds) was the weight of 10 whole clean seeds multiplied by 10. This was done because some of the treatments, when separated into pod frequency, had fewer than 100 seeds each. Lodging score was determined at harvest maturity on a one to five scale: 1 = upright; 5 = prostrate (12).

Results and discussion

Yield

Planting pattern had no significant effect on seed yield (Table 1). However, rectangular planting pattern yielded 6.1 and 10.1 percent higher than linear and triangular planting patterns, respectively. From the practical point of view, the yield increase of rectangular over linear and triangular planting patterns is important since it is easier to make planting holes by hand at the former than the two latter planting patterns. Data for yield and yield components for stems and branches were determined separately to evaluate their relative importance in yield contribution as suggested by Lehman and Lambert (3). Yield differences between stems and branches were significant and yields for stem/branch ratios were 1.04, 1.13 and 1.17 for linear, rectangular and triangular planting patterns, respectively, indicating that stems were more important in yield determination than branches at all planting patterns. Lehman and Lambert (3) reported that the importance of branch in yield determination varied with spacing, cultivar and location, but had no effect on the overall seed yield. The results of the present study would suggest that planting pattern should be considered when choosing an ideotype since spatial arrangement would influence the relative importance of branches, one of the important agronomic characteristics of an ideotype, since a large number of fruiting branches can increase potential sink sites and hence yield.

After harvest, pods from stems and branches were separated into empty-, one-, two-, three- and four-

Table 1. Yield (kg/ha) of one-, two-, and three-seeded pods from stems and branches of soybeans at three planting patterns.

Planting pattern	One-seeded			Two-seeded			Three-seeded			Grand total			Yield stem/branch ratio
	Stem	Branches	Total	Stem	Branches	Total	Stem	Branches	Total	Stem	Branches	Total	
Linear	117	78	195	342	419	761	477	406	883	936	903	1 839	1.04
Rectangular	95	91	186	450	439	889	493	391	884	1 038	921	1 959	1.13
Triangular	106	75	181	364	395	759	479	343	822	949	813	1 762	1.17
Mean	106	81	187	385	417	803	483	380	863	973	879	1 853	–
S.E.±	–	4.2	–	–	21.8	–	–	22.2	–	–	–	–	–

seed frequencies; but the three- and the four-seeded pods were pooled and classified as three-seeded because the four-seeded pods did not occur in all replicates and treatments. Yields from one-, two- and three-seeded pods were 187, 803 and 863 kg/ha, respectively. Stems produced significantly higher yields of one- and three- seeded pods than branches. The yield differences between stems and branches for two-seeded pods were significant in favour of the latter.

Yield components

Data for yield components are presented in Table 2. The number of seeded pods/m^2 from linear, rectangular and triangular planting patterns were 449.3, 451.6 and 428.7, respectively; and two-seeded pods occurred more frequently than any other. There were no significant differences between stems and branches in the number of empty- and three-seeded pods; while stems produced significantly higher one-seeded pods than branches. The reverse was true for two-seeded pods. Planting pattern had no significant effect on pod length. Branches produced 9.8 percent significantly more two-seeded pods than stems. Seed sizes (g/100 seeds) were 19.6, 18.2 and 18.1 for the linear, rectangular and triangular planting patterns, respectively. Seed sizes for stem/branch ratios were comparable for all planting patterns and ranged from 1.0 to 1.1, indicating that seed sizes of stems were generally larger than those of branches.

Growth analysis

The results of LAI, LAR, SLW and SLA determined at three stages of growth and development are presented in Table 3. Planting pattern had no significant effect on LAI; however, LAI differences between stems and branches were significant at the first and third sampling dates. The correlation between LAI and yield from stems were 0.23, -0.48 and 0.50 at the first, second and third sampling dates compared to the correlation between LAI and yield of branches of 0.44, -0.66 and -0.49 for the respective sampling periods. Planting pattern had no significant effect on LAR; but were consistently higher in branches than in stems although the differences were not significant. The higher LAR for branches was attributed to higher DM in stems than a higher leaf area in branches. For instance, leaf area and total DM of stems and leaves on stems were 7 780.8 cm^2 and 39.2 g, respectively, compared to 1 331.2 cm^2 and 3.7 g for leaf area DM of branches and leaves on branches at the first sampling date; indicating that stems had 5.8 times greater leaf area and 10.6 times higher DM than branches. Branches had significantly higher SLA at the second and at the third sampling periods and not at the first; indicanting that leaves from branches had thinner cross-sections and probably higher midribs and veins.

Planting pattern had significant effect on petiols and leaflet weight only at the second sampling date (Table 4). However, the stem DM of petioles and leaflets were significantly higher than those of branches. Stems produced significantly higher DM than petioles (Table 5)

Other agronomic characteristics

Data for other agronomic characteristics are presented in Tables 6 and 7. Plant height, canopy height and canopy width were relatively unaffected by planting pattern; and at full flowering the distance between ridges had been covered by foliage with the rectangular and triangular planting patterns covering the inter-ridge spacing (furrow) four to five days earlier than the linear planting pattern (Table 6). While erosion and weeds were not problems at the experimental site, rapid ground cover could be an advantage in soil and water conservation (4) and in weed control (2).

The difference between planting patterns for minimum number of pods/node, plant height and the distance between the transition zone and the first branch were significant (Table 7) but the other parameters were not. The correlation between the number of nodes and yield was negative (r = 0.40) while that between branches and yield was only 0.30. Weber, Shibles and Byth (12) reported that branching in soybean was not a critical factor in maximum seed production since treatments with the lowest branching frequency had the highest yield. However, increase in branch frequency could be an advantage provided majority of the branches bear pods and the stem is sturdy enough to bear the load of extra pods.

Summary

The response of soybeans to varying planting patterns, linear, rectangular and triangular, was investigated. Seed yields (kg/ha) were 1839, 1959 and 1762 for linear, rectangular and triangular planting patterns, respectively

Seed yields for stem/branch ratios were 1.04, 1.13 and 1.17 for the three respective planting patterns, indicating that stems were more important in yield determination than branches. However, the ratio of number of pods/m^2 for stem/branch were generally less than one and ranged from 0.97 to 0.98. But seed sizes for stem/branch ratios ranged from 1.0 to 1.1, indicating that stem produced larger seeds than

Table 2. Pods/m², pod length and seed size of empty, one-, two-, and three-seeded pods from stems and branches at three planting patterns at harvest maturity.

Planting patterns	Pod description											
	Empty			One-seeded			Two-seeded			Three-seeded		
	Stem	Branches	Total/Mean	Stem	Branches	Total/Mean	Stem	Branches	Total/Mean	Stem	Branches	Total/Mean
	Pod/m²											
Linear	7.3	5.8	13.1	58.2	38.2	96.8	85.6	111.4	197.0	78.3	77.2	155.5
Rectangular	3.6	7.1	10.7	47.5	50.0	97.5	91.1	115.5	206.6	83.5	64.0	147.5
Triangular	8.9	7.5	16.4	52.7	38.1	90.8	80.4	107.1	187.5	80.2	70.2	150.4
Mean	6.6	6.8	13.4	52.8	42.2	95.0	85.7	111.3	197.0	80.6	70.4	151.1
S.E.±	–	0.8	–	–	1.4	–	–	4.4	–	–	7.1	–
	Pod length, cm											
Linear	3.9	3.6	3.8	3.6	4.0	3.8	4.1	4.5	4.3	4.8	4.7	4.8
Rectangular	3.7	3.6	3.7	3.8	4.1	4.0	4.1	4.6	4.4	4.7	4.7	4.7
Triangular	4.0	3.4	3.7	3.8	4.1	4.0	4.1	4.5	4.3	4.7	4.6	4.7
Mean	3.8	3.5	3.7	3.7	4.0	3.9	4.1	4.5	4.3	4.7	4.6	4.7
S.E.±	–	0.11	–	–	0.10	–	–	0.10	–	–	0.05	–
	Seed size, g/100 seeds											
Linear	–	–	–	21.7	19.3	20.5	19.9	20.3	20.1	19.1	17.5	18.3
Rectangular	–	–	–	18.8	15.9	17.4	19.4	18.6	19.0	18.3	18.1	18.2
Triangular	–	–	–	19.1	17.5	18.3	18.0	17.7	17.9	17.8	18.2	18.0
Mean	–	–	–	19.8	17.5	–	19.1	18.8	–	18.4	17.9	–
S.E.±	–	0.76	–	–	0.76	–	–	0.75	–	–	0.42	–

Table 3. LAI, LAR, SLW and SLA of stems and branches at three planting patterns at three stages of growth and development.

Planting patterns	Days from planting								
	45			59			73		
	Stem	Branches	Total	Stem	Branches	Total	Stem	Branches	Total
					LAI				
Linear	0.85	0.41	1 26	1 37	0 89	2 26	1 83	0 92	2 75
Rectangular	0 99	0 23	1.22	1 47	0 94	2 41	2 50	1 64	4 14
Triangular	0 89	0 15	1 04	1 54	1 45	2 99	2 13	1 45	3 58
Mean	0 91	0.26	1 17	1.46	1 09	2.55	2 15	1 34	3 49
S E ±	–	0 10	–	–	0 15	–	–	0.25	–
					LAR				
Linear	1.99	3 64	6.12	1 73	3 86	5.59	1.44	1 60	3.04
Rectangular	2 06	3 87	5 93	1 39	2 86	4 25	1 22	1 88	3 10
Triangular	1.93	6 22	8.15	1.28	3 51	4 79	1 14	1 89	3 10
Mean	1.99	4 58	–	1 46	3 41	–	1 26	1 79	–
S E ±	–	0 96	–	–	0 24	–	–	0 10	–
					SLW				
Linear	2.74	1 82	4.56	3 05	3 45	6 50	3 23	2.27	5 80
Rectangular	2 83	2 27	5 10	1 41	1 81	3.22	3 11	2 27	5 38
Triangular	2 86	1 93	4 79	1 10	1 58	1 68	3 35	2.09	5 44
Mean	2 81	2 00	–	1 85	2 28	–	2 23	2 31	–
S.E ±	–	0 28	–	–	0 20	–	–	0.13	–
					SLA				
Linear	3 67	4 50	8 17	3 26	6 80	10 06	2 97	4 00	6 97
Rectangular	3 57	3 35	6 92	2 87	5 20	8.07	3 17	4.40	7.57
Triangular	3 53	4 05	7 58	2 43	6 03	8.96	3 03	4 70	7 73
Mean	3 59	3 96	7 59	3 02	6 01	9 03	3 05	4 36	–
S.E ±	–	1 40	–	–	0.44	–	–	0 16	–

Table 4. DM (g/m^2) of plant parts from stems and branches of soybeans at three planting patterns at three stages of growth and development.

Planting patterns	Days from planting								
	45			59			73		
	Stem	Branch	Total	Stem	Branch	Total	Stem	Branch	Total
					Petioles				
Linear	4.8	0.4	5.2	12.2	3.1	15.3	20.6	8.0	28.6
Rectangular	5.8	0.7	6.5	15.1	4.8	19.9	30.4	13.9	44.3
Triangular	5.3	0.5	5.8	18.1	6.4	24.5	26.4	10.7	37.1
Mean	5.3	0.5	–	15.1	4.7	–	25.8	10.8	–
S.E.±	–	0.58	–	–	0.85	–	–	2.70	–
					Leaflets				
Linear	23.4	2.6	26.0	41.8	12.5	54.3	58.3	23.7	82.4
Rectangular	29.8	3.5	33.3	50.8	17.0	67.8	77.8	37.3	115.1
Triangular	24.3	2.7	27.0	53.1	22.9	76.0	71.2	30.3	101.5
Mean	25.8	2.9	–	48.5	17.4	–	69.2	30.4	–
S.E.±	–	1.95	–	–	2.18	–	–	6.48	–

Table 5. Dry matter (DM) (g/m^2) of stems and branches at three planting patterns and three stages of growth and development.

Planting patterns	Days from planting								
	45			59			73		
	Stem	Branch	Total	Stem	Branch	Total	Stem	Branch	Total
Linear	14.9	1.0	15.9	26.6	6.4	33.0	38.6	13.9	52.5
Rectangular	16.4	1.6	18.0	39.2	8.5	17.7	78.5	19.1	97.6
Triangular	15.8	1.0	16.8	50.1	10.9	61.0	72.2	16.4	88.6
Mean	15.7	1.2	–	38.6	8.6	–	63.1	16.4	–
S.E.±	1.50	–	–	–	2.22	–	–	6.40	–

Table 6. Plant height (cm), canopy height (cm) and canopy width (cm) of soybean at three planting patterns at three stages of growth and development.

Planting patterns	Days from planting								
	45			59			73		
	Plant height	Canopy height	Canopy width	Plant height	Canopy height	Canopy width	Plant height	Canopy height	Canopy width
Linear	20 8	26 0	15 0	38.2	47 7	29 7	52.9	57 6	over 45 cm
Rectangular	22 4	23.0	22 3	38.9	39 3	32.7	48 8	60 0	over 45 cm
Triangular	20 7	22 4	14 7	40 7	41 0	30 0	51 7	54.4	over 45 cm
Mean	21.8	23.2	17 3	–	–	30.8	–	–	–
S									
S.E ±	1 5	3 5	1.9	3.0	2 6	2.6	3 8	1 6	–

Table 7. No of pods/node, nodes/plant, branches/plant, lodging and other agronomic characteristics of soybean at three planting patterns.

Planting patterns	No. pods/node		No. nodes/ plant	No. branches/ plant	Lodging score	Plant height (cm)	Distance from transition zone to first branch (cm)	Pod clearance (distance (cm) from transition zone to first pod)
	Min.	Max						
Linear	1 1	2.9	14 6	4.1	1.2	62 5	14 1	15 2
Rectangular	1 2	3 0	14 4	4 2	1.5	52.7	12 1	12.9
Triangular	1 3	2 7	15 4	3 7	1.4	57 8	13 5	14 6
Mean	1 2	2 8	14.8	4 0	1 3	57 6	13 2	14 2
S E ±	0.03	0 26	0 35	0.22	0 07	1.39	0.30	0.59

branches. LAI and SLW for stem/branch ratios were generally higher than unity while the reverse was true for LAR and SLA.

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