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1) Soybean plant design for closed ecological life support system.*

Prior to the establishment of the space habitats of the future, the life science program office of the National Aeronautics and Space Administration (NASA) is interested in the development of a ground-based manned demonstration of the closed ecological life support system (CELSS). Since CELSS concept centers around complete recycling of all available resources, a genetic plant design to render the total plant more useful is very important. Previous studies (Phillips, 1977; Phillips et al., 1978) conducted for NASA clearly indicate the usefulness of soybean plants in such a system. It has been suggested that 43% of the cropped area in the manufacturing facility in space be planted under soybeans for feed and food in the space habitat (Phillips, 1977). Research on screening and selection of early maturing and high yielding soybean cultivars has also been recommended (Phillips et al., 1978). We feel that besides being early maturing and high yielding, soybean plant should have high seed yield efficiency (SYE). SYE can be defined as the ratio of seed to non-seed dry matter weight. Highly efficient plants, out of the total energy required, will utilize relatively more energy for the production of seed and less for non-seed plant parts. It is possible to select soybean cultivars

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with high seed yield efficiency along with early maturity and high yielding ability (Joshi and Smith, 1976).

The objective of this study is to identify early maturing genotypes with high seed yield efficiency.

Materials and methods: Thirty-one soybean cultivars were planted in the field on June 27, 1978. Fifteen seeds of each cultivar were planted in rows, distance between rows being 91 cm and seed to seed distance being 3 cm, in three replications. At maturity when almost all the leaves had fallen and 95% of pods had turned brown, 5 plants of each cultivar from each replication were harvested. Plants were harvested by hand at ground level and each plant was stored in a cloth bag for further analysis. Above ground biomass at maturity (leaves and roots excluded) was partioned into three components, i.e., stem and branches, pods, and seeds. These components were dried in an air convection oven at 80°C for 24 hr. After 24 hr drying, the samples were transferred into the dessicator before the actual weighing. The dry matter weight of each component was recorded and the seed yield efficiency of each plant was calculated (SYE = seed dry matter wt./non-seed dry matter wt.). Data were analyzed employing ANOVA; Duncan's Multiple Range Test was used to test significant differences between the means.

Experimental results: Five cultivars, PI 196,530, PI 194,640, PI 194,641, PI 189,868 and PI 205,090, matured in the shortest time period and took only 71 days from seeding to maturity. Another three cultivars, 'Maple Presto', 'Sioux' and FC 30,687, took 2 more days to mature (73 days) (Table 1). Among the 31 cultivars tested, 8 took the longest time to mature, i.e., 93 days. Early maturing soybean cultivars are considered a good candidate for the CELSS program. Eight early maturing cultivars which matured in 71-73 days should be examined critically under controlled environments where these should be grown hydroponically.

Among the early maturing cultivars (71-73 days maturity), the highest SYE was obtained from Maple Presto (0.939), followed closely by PI 196,530 (0.934) and Sioux (0.927) respectively (Table 1). However, the variation in SYE among these three cultivars was not significantly different from each other. Other five early maturing cultivars (PI 194,640, PI 194,641, FC 30,687, PI 189,868 and PI 265,090) had significantly lower SYE as compared to Maple Presto and PI 196,530. Though cultivar Sioux gave quite high SYE (0.927), the SYE was not significantly different as compared to PI 194,640 with an SYE of 0.853. The lowest SYE was obtained from PI 205,090 (0.658).

Further studies of Maple Presto, PI 196,530 and Sioux, to determine the total biomass under controlled environment conditions and their compatibility with other food plants, are in progress.

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Table 1

Seed yield efficiency of certain soybean cultivars

Cultivar	SYE	Seeding to maturity (days)	Cultivar	SYE	Seeding to maturity (days)
PI 196,491	1.223a	93	PI 257,429	0.803e-i	77
PI 194,639	1.158a	93	PI 189,963	0.789f-j	86
PI 196,485	1.001b	93	Ottawa	0.788f-j	77
PI 196,501	0.971bc	86	PI 153,293	0.784g-j	85
Maple Presto	0.939bc	73	PI 194,656	0.783g-j	93
PI 196,530	0.934bc	71	PI 194,641	0.782g-j	71
Sioux	0.927b-d	73	PI 153,296	0.778g-j	85
PI 052,903	0.891c-e	77	PI 159,764	0.773g-j	86
PI 189,867	0.891c-e	86	FC 30,687	0.729h-k	73
PI 196,529	0.858d-f	93	PI 189,868	0.722h-k	71
PI 194,640	0.853d-g	71	PI 196,526	0.715i-k	86
Agate	0.847e-g	77	PI 194,632	0.714i-k	93
PI 154,198	0.836e-g	85	PI 189,869	0.703k	93
Pando	0.831e-g	77	PI 194,633	0.702k	86
PI 196,528	0.823e-g	93	PI 205,090	0.658k	71
PI 196,502	0.814e-h	86			

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2) Effect of row spacing and seed rate on soybean pod damage by Heliothis zea-Boddie under normal and late planting.*

Corn earworm (Heliothis zea-Boddie) is one of the most destructive pests of soybeans (Glycine max [L.] Merrill). Cultural practices, since early days, have been known to play an important role in controlling insect pests in various crops. Some researchers have observed that soybeans with closed canopy escape corn earworm damage (Dietz et al., 1976) but recent reports from extension entomologists in Maryland are contrary to this effect. Since open or close canopy is a function of seed rate and row spacing, the present investigation was undertaken to determine the effect of row spacing and seed rate on soybean pod damage by corn earworm under normal and late planting.

Materials and methods: Soybean cultivar 'Delmar' was planted at normal (May 13) and late (June 24 and July 8) planting times during 1977. Four row spacings, i.e., 11, 23, 46 and 91 cm apart rows, and 3 different seed rates, i.e., 4, 8 and 12 seeds/0.3 m were evaluated. The experiment was laid out in a split plot design with 4 replications. Each plot consisted of 4 rows, each being 6 m long. Net experimental row was 4.9 m long. At maturity, damaged pods were counted on each plant in one of the center rows in each treatment. The results were analyzed statistically using ANOVA and Duncan's Multiple Range Test. Means not followed by the same letter in all tables given in text were statistically different at the 0.05 probability level according to Duncan's Multiple Range Test.

Experimental results: Variations in canopy development were achieved by using different seed rates and row spacings. The number of plants at maturity were not the same as the number of seeds planted/0.3 m for 8 and 12 seeds treatments. The final stand for 8 and 12 seeds was 7 and 9 plants/0.3 m respectively. There was a considerable loss of plants in 12 seeds/0.3 m treatment and this may be attributed to higher competition.

The number of damaged pods for each planting date has been given in Table 1. Though minimum pod damage was observed in June 24 planting, it was not significantly different from May 13 planting. Maximum pod damage was observed in July 8 planting but was not significantly different from May 13 planting. July 8 planting becomes relatively more susceptible to this pest as is indicated by the highest number of damaged pods (Table 1).

Row spacing in soybeans also seems to exert considerable influence on the pod damage (Table 2). Minimum pod damage was observed in rows 11 cm apart. However, this pod damage was not significantly different from that of 46 cm apart rows. Twenty-three and 91 cm row spacing produced the same number of damaged pods and there was no significant difference between these two row spacings and 46 cm apart rows. These data indicate that soybeans planted in 11 cm apart rows, which is virtually a solid stand situation, are not preferred by corn earworm. However, it may be noted that pod damage calculations based on per unit area will yield quite different results. For example, in an area of 4.5 m^2, 8 rows 11 cm apart, 4 rows 23 cm apart, 2 rows 46 cm apart and only 1 row 91 cm can be accommodated. Pod damage/4.5 m^2 area for various row spacings is given in Table 2. Pod damage/unit area increased significantly as the distance between rows is reduced. This may be due to the fact that more

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Table 1

Effect of planting dates on pod damage

Planting date	Damaged pods/ 4.9 m row (#)
May 13	25.4ab
June 24	23.0b
July 8	27.8a

Table 2

Effect of row spacing on pod damage

Row spacing (cm)	Damaged pods/ 4.9 m row (#)	Damaged pods/ 4.5 m^2
11	22.1b	176.7a
23	27.1a	108.4b
46	25.1ab	50.2c
91	27.2a	27.2d

plants are available for oviposition in narrow row spacings than in wider row spacings.

Pod damage is also influenced significantly by seed rate (Table 3). Maximum pod damage was observed when 8 seeds/0.3 m were planted and the damage was significantly higher than 4 seeds/0.3 m. Though pod damage was higher for 8 seeds/0.3 m than 12 seeds/0.3 m, it was not statistically different from each other. It appears that 4 seeds/0.3 m (4 plants at maturity) and 12 seeds/ 0.3 m (9 plants at maturity) are not conducive to corn earworm egg laying. This implies that very low and high plant populations are not preferred by corn earworm.

Table 3

Effect of seed rate on pod damage

Seed rate/0.3 m	Damaged pods/4.9 m row (#)
4	23.7b
8	27.3a
12	25.2ab

When soybeans were planted on May 13, minimum pod damage was observed in 91 cm row spacing with 12 seeds/0.3 m and the damage was significantly low as compared with 46 cm row spacing with the seeding rate of 8 seeds/0.3 m and 23 cm row spacing with 4 seeds/0.3 m (Table 4). In the June 24 planting, best results were obtained in 46 cm apart rows with 4 and 8 seeds/0.3 m but the pod damage was not significantly different from the other treatments except when soybeans were planted at the seeding rate of 8 seeds/0.3 m in 11 cm rows in which case the pod damage was maximum. Minimum pod damage was observed in July 8 planting in 11 cm apart rows with 4 seeds/0.3 m. This damage was significantly low as compared with 8 seeds/0.3 m in 23, 46 and 91 cm apart rows, and 12 seeds/0.3 m in 23, 46 and 91 cm apart rows. Maximum pod damage was

Table 4

Pod damage as affected by planting dates x seed rates x row spacing

Planting dates								
May 13			June 24			July 8		
Seed rate/ 0.3 m	Row spacing (cm)	Pod damage/ 4.9 m row	Seed rate/ 0.3 m	Row spacing (cm)	Pod damage/ 4.9 m row	Seed rate/ 0.3 m	Row spacing (cm)	Pod damage/ 4.9 m row
4	11	22.5c-f	4	11	20.8c-f	4	11	13.3ef
4	23	31.3a-e	4	23	27.5a-f	4	23	24.0b-f
4	46	27.0b-f	4	46	18.3d-f	4	46	24.8b-f
4	91	20.8c-f	4	91	26.8b-f	4	91	27.3a-f
8	11	28.3a-e	8	11	31.5a-e	8	11	20.0d-f
8	23	24.3b-f	8	23	25.0b-f	8	23	34.8a-c
8	46	26.3b-f	8	46	18.0ef	8	46	28.0a-e
8	91	28.8a-e	8	91	25.8b-f	8	91	37.0ab
12	11	21.5c-f	12	11	21.8c-f	12	11	19.3d-f
12	23	24.3b-f	12	23	20.5c-f	12	23	32.5a-d
12	46	31.8a-e	12	46	20.5c-f	12	46	31.5a-e
12	91	18.3d-f	12	91	19.5d-f	12	91	41.0a

observed on soybeans planted at the rate of 12 seeds/0.3 m in 91 cm apart rows. These data indicate that pod damage by corn earworm can be reduced by choosing proper seed rate and row spacing for different planting times.

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3) Evaluation of soybean germplasm for resistance to corn earworm—III.*

During previous years (1974-75), soybean cultivars belonging to Maturity Groups 00 to IV were tested in the screenhouse for corn earworm (*Heliothis zea*-Boddie) resistance and the results were reported in the 1978 issue of Soybean Genetics Newsletter (Joshi, 1978a, 1978b). A new batch of soybean cultivars, 30 belonging to Maturity Group IV and 39 to Maturity Group V, were tested in the screenhouse (54' x 72' x 15') during 1976. Ten seeds of each cultivar were planted on June 16, 1976 in 4 replications, the seeds being 2" apart within the row and rows being 36" apart. Screenhouse was infested by releasing 528 corn earworm moths. The moth releases were started on August 16 and continued until August 23. Plants were harvested at maturity and the number of undamaged and damaged pods was recorded for each cultivar. Data were analyzed employing ANOVA; Duncan's Multiple Range Test was used to test significant difference between the means.

The mean numbers of undamaged and damaged pods per plant for each cultivar are reported below. The means not followed by the same letter are significantly different at the 0.05 probability level according to Duncan's Multiple Range Test. Among the 30 cultivars tested in Maturity Group IV, PI 253,652 produced the highest number of undamaged pods/plant (Table 1), followed by cultivar 'Scott' which produced 81.1 undamaged pods/plant. The number of damaged pods/plant for PI 253,652 and Scott were 3.6 and 2.9 respectively. The correlation coefficient between undamaged pods/plant and seed yield was quite high ($r = 0.802$). Seed yield/plant was 26.08g and 16.28g for PI 253,652 and Scott respectively. Cultivar 'Scioto' was observed to have the highest number of damaged pods/plant (18.4 pods). Though Scioto showed a high degree of preference for pod damage by corn earworm, its yield (22.45g) was not significantly different from PI 253,652, indicating a high degree of tolerance to this pest.

Among the tested cultivars in Maturity Group V, the highest number of undamaged pods/plant was produced by PI 60,273 (93.4 pods), followed by cultivar 'Peking' (77.5), PI 381,671 (71.3), 'Hill' (68.5), FC 31,721 (65.3),

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Table 1

Mean undamaged and damaged pods for certain soybean cultivars

	Undamaged pods/plant	Damaged pods/plant	Cultivar	Undamaged pods/plant	Damaged pods/plant
			Maturity Group IV		
PI 60,970	22.0f	1.43d-f	Mokapu Summer	45.0c-f	5.4b-f
PI 72,227	24.2f	0.68ef	PI 340,010	48.3c-f	2.8b-f
PI 229,319	29.8ef	2.4b-f	PI 226,591	48.6c-f	1.6d-f
PI 61,944	34.8d-f	0.4f	Roe	48.9c-f	8.4b
Bonus	36.2d-f	2.0b-f	PI 253,651[B]	50.8c-f	2.9b-f
PI 54,617	37.2d-f	5.2b-f	Clark 63	51.1c-f	6.9b-f
PI 246,367	38.3c-f	2.6b-f	Kaikoo	52.7c-f	8.2bc
SRF 450	39.9c-f	3.7b-f	PI 181,550	58.5c-f	2.2b-f
PI 87,623	40.1c-f	1.1d-f	Delmar	60.6c-f	7.3b-d
PI 88,302	41.6c-f	3.8b-f	PI 157,419	63.7b-f	1.4d-f
PI 157,437	42.9c-f	2.1b-f	PI 157,452	68.2b-e	1.6d-f
Cutler 71	43.6c-f	7.1b-e	Bethel	70.4b-e	5.6b-f
PI 340,012	44.1c-f	1.1d-f	Scioto	77.4b-d	18.4a
PI 88,814	44.4c-f	1.8c-f	Scott	81.1bc	2.9b-f
SRF 425	44.9c-f	2.1b-f	PI 253,652	102.7a	3.6b-f
			Maturity Group V		
PI 157,470	21.6i	0.4e	FC 31,683	52.0b-i	3.6a-e
PI 157,394	24.0hi	1.7de	PI 71,465	52.1b-i	3.5a-e
PI 83,942	28.5g-i	0.1e	PI 200,450	52.7b-i	2.3c-e
PI 340,051	30.3f-i	1.3de	PI 79,932	53.5b-i	2.2de
PI 81,780S	30.9f-i	2.9b-e	Arlington	54.2b-h	3.1a-e
S-100	33.65e-i	3.7a-e	PI 96,789	54.3b-h	7.2ab
PI 181,546	34.6e-i	2.5c-e	D67,3297	57.9b-g	2.2de
PI 82,589	36.0d-i	2.9b-e	PI 196,177	58.7b-g	1.8de
PI 95,959	36.1d-i	0.7de	Essex	59.2b-g	4.7a-e
PI 340,019	36.4d-i	4.9a-e	Dorman	59.7b-g	5.0a-e
PI 157,451	38.2d-i	4.0a-e	Shore	60.9b-g	2.0de
PI 170,893	39.9c-i	7.8a	PI 342,003	62.4b-f	2.1de
PI 371,611	40.9c-i	4.6a-e	FC 30,265	64.0a-e	5.6a-d
PI 181,544	42.8c-i	3.1a-e	PI 381,675	64.2a-e	3.6a-e
PI 87,542	43.7c-i	1.1de	FC 31,721	65.3a-e	7.1a-c
PI 62,203	45.0c-i	7.3a	Hill	68.5a-d	3.8a-e
PI 65,342	45.7b-i	1.8de	PI 381,671	71.3a-c	4.0a-e
Dortchsoy	49.5b-i	2.1de	Peking	77.5ab	1.4de
York	50.0b-i	3.6a-e	PI 60,273	93.4a	3.4a-e
PI 371,610	51.8b-i	4.4a-e			

PI 381,675 (64.2) and FC 30,265 (64.0). These seven cultivars produced significantly higher number of undamaged pods/plant as compared to the other 32 cultivars tested. Though the highest seed yield/plant (19.2g) was obtained from PI 342,003, this PI produced significantly fewer undamaged pods/plant (62.4). It appears that PI 342,003 might have an excellent ability for compensation. The second high yielding cultivar was PI 60,273 (18.2g) which also happened to be the cultivar with the highest number of undamaged pods/plant.

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4) Soybean germplasm resistant to *Heliothis zea*-Boddie.*

Corn earworm (*Heliothis zea*-Boddie) is a very destructive pest of soybeans (*Glycine max* [L.] Merrill). It feeds both on foliage as well as developing pods. Each larva is capable of damaging 6 to 8.2 pods or 7.1 seeds between 4th and 6th (both inclusive) instars (Boldt *et al.*, 1975; Smith and Bass, 1972). On the Eastern Shore of Maryland, after about the middle of August, when the corn silks have withered and turned brown, corn earworm adults prefer to lay eggs on soybean plants. Other researchers have also found that soybeans become primary host as corn and cotton become more mature (Freeman *et al.*, 1967). Though leaf feeding resistance to corn earworm has been discovered in some soybean cultivars (Hatchett *et al.*, 1976; Joshi and Wutoh, 1972), very little research work has been done to identify soybean germplasm which is capable of resisting pod damage from this pest. The present investigation was undertaken to identify soybean germplasm resistant to pod damage by corn earworm.

Materials and methods: Soybean germplasm (3,045 cultivars) belonging to Maturity Groups 00 to V was evaluated in the field for pod damage by corn earworm from 1974 to 1978. Every year cultivars with pod damage were eliminated from further testing. During 1974, 25 seeds of each cultivar were planted in the field from May 15 to May 28, in rows 91 cm long and 91 cm apart. In 1975, 798 cultivars were evaluated; 550 cultivars from Maturity Groups 00 to IV were planted on May 28 and another batch of 248 cultivars from Maturity Group V was planted on June 5. During 1976, 10 seeds

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of each of 32 cultivars of Maturity Group V and 26 of Maturity Group IV were planted in the field on June 26 in 4 replications. Again in 1977, 478 cultivars were evaluated under late planting conditions and the plantings were made on July 5, 6 and 7 in three replications. Any cultivar with pod damage in any replication was eliminated from further testing. Fourteen seeds of each of the 27 cultivars were planted again on July 1, 1978 in 4 replications. Corn earworm population in the environments for the months of August and September was measured by using blacklight trap.

Experimental results: Corn earworm population for the months of August and September during the selection process is given below.

Year	Total moths
1974	679
1975	968
1976	4,778
1977	6,404
1978	2,591

Corn earworm population in the environment increased markedly every year until 1977 and during 1978 population decreased sharply yet it was a considerably higher level than 1974 and 1975. Maximal severity of infestation occurred during 1977.

During the first year 625 cultivars out of 2,797 did not show any pod damage. Maturity Group V germplasm (248 cultivars) was not included in 1974 test. In 1975, 550 out of 625 cultivars with yellow seed coat were selected for further evaluation and 248 additional cultivars of Maturity Group V were also evaluated. Four hundred and sixty-one out of 550 and 65 out of 248 of Maturity Group V were not damaged by corn earworm. During 1976, out of 32 cultivars of Maturity Group V, five cultivars, namely 'Arlington', 'Peking', PI 96,786, PI 340,051 and PI 371,610, did not show any pod damage; and 11 cultivars (SRF 425, 'Bonus', 'Clark 63', 'Cutler 71', PI 61,944, PI 72,227, PI 87,623, PI 88,304, PI 253,651, PI 253,652 and PI 340,012) of Maturity Group IV did not show any pod damage.

Since it has been discovered that late planted soybeans become more susceptible to corn earworm damage (Dietz et al., 1976; Joshi, 1977), during 1977, 478 cultivars belonging to Maturity Groups 00 through V were again evaluated under late planting conditions. The corn earworm population (6,404 moths) was extremely high during this year and only 27 cultivars escaped damage. These 27 cultivars were again evaluated under late sown conditions in the field during 1978 and none of these cultivars showed any pod damage at maturity. It appears that these cultivars have the capability to resist pod damage. The list of 27 resistant cultivars is given below.

Maturity Group 00	Maturity Group I	Maturity Group II	Maturity Group III	Maturity Group IV	Maturity Group V
Ada	PI 68,572	PI 68,694	PI 70,199	PI 72,227	Arlington
Portage	PI 84,964	PI 68,521	PI 70,500	PI 87,623	Peking
PI 361,108	PI 88,443	PI 68,658	PI 88,354	PI 89,010	PI 96,786
		PI 68,670-2	PI 196,156	PI 229,319	PI 340,051
Maturity Group 0		PI 70,077			PI 371,610
PI 370,057A		PI 70,503			
PI 372,424					

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1) Characterization of several abnormal nodulation reactions in soybeans.

Several abnormal nodulation reactions in soybeans are known. These range from a complete lack of nodules, caused by the non-nodulating gene (Williams and Lynch, 1954) to plants with normal-appearing nodules (Vest et al., 1973), but low nitrogen fixation as exemplified by the 'Peking'-strain 123 combination. The purpose of the study reported here was threefold. First, we wished to examine several known abnormal nodulation reactions; second, we wished to make comparisons between abnormal and normal nodulation reactions; and third, we wished to evaluate a recently observed abnormal nodulation reaction between *Rhizobium japonicum* strain 62 and the soybean variety 'Amsoy 71'.

Varieties used in the study were Amsoy 71, 'Anoka', 'Dunfield', 'Hardee' and Peking. Surface-sterilized seed from each variety was inoculated with *R. japonicum* strains 61, 62, 110, 123 and 138. An uninoculated control for each variety was also included. Leonard jar assemblies were used to maintain sterile conditions. Data were taken on plant height, chlorosis, top dry weight, vegetative stage, nodule number and nodule weight. Total nodule activity (TNA) and specific nodule activity (SNA) were calculated on the basis