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Soybean Harvest Index in Hill-Plots[1]

R. I. Buzzell and B. R. Buttery[2]

ABSTRACT

Seed and plant weight of mature soybeans (*Glycine max* (L.) Merr.) were measured in hill-plots to determine if the evaluation of harvest index (seed yield/mature plant dry weight) by a micro-plot technique would be useful as a selection criterion. Harvest index did not change in response to increasing plant population within hills. Thus, screening can not be carried out in this manner to obtain cultivars which would maintain a high harvest index under high plant density in row culture. Furthermore, harvest index was negatively associated with yield and maturity, and appears to be of little value as an indicator of yielding ability.

***Additional index words:* *Glycine max*, Breeding, Selection, Plant population.**

SHIBLES and Weber (1966) suggested that one possible approach to maximize soybean (*Glycine max* (L.) Merr.) yields would be to select for a greater diversion of photosynthate to seed production, i.e. for a higher harvest index as defined by Donald (1962). They found that high population or close plant spacing in any one direction tended to result in a lower harvest index for the 'Hawkeye' cultivar. Buttery (1969) also observed a decrease in harvest index with increasing population using 'Harosoy 63' at 4, 8, 16, and 32 plants m^{-2}. Wilcox (1974) observed a general decrease in harvest index with soybean cultivars under equidistant spacings as population increased from 2.5 to 58.2 plants m^{-2}. Selection of genotypes that would maintain a high harvest index under high populations should help to maximize yields.

Since plant breeding requires the yield testing of many lines, selection for harvest index, or 'migration coefficient' as suggested by Beaven (1920), should be worthwhile if it is associated with yield and is more easily and accurately measurable. Singh and Stoskopf (1971) reported that harvest index was positively correlated with grain yield in cereals and Fischer and Kertesz (1976) found that harvest index was an indicator of yielding ability in spring wheat (*Triticum aestivum* L.).

Hill-plots, which have been used in soybeans by Green et al. (1974), Shannon et al. (1971), and others, allow economical use of manpower and land and offer one possibility for determining harvest index as well as seed yield. We tested cultivars, selections and plant populations in hills to determine if hill-plots could be used in screening breeding material for harvest index responses. In addition we evaluated the use of harvest index as a predictor of yielding ability.

MATERIALS AND METHODS

Plants were grown compactly arranged within each hill-plot, i.e. the basal stems were within a 5-cm-diameter circle. Hill-plots were grown each year on a sandy soil (Hapludalf) at Harrow, Ontario. Fertilizer at 500 kg/ha of 5-10-15, and chloramben at 2.5 kg/ha for weed control, were applied each year. Hill spacing within and between rows was 0.30 × 0.91 m in 1964 to 1966. Spacing in 1968 to 1974 was changed to 1.02 × 0.61 m. Beginning in 1968, rainfall was supplemented with water from overhead sprinkler irrigation each year to supply ample moisture for growth and pod filling. Mature plants were cut at the soil level, dried if necessary, and stored. Plant numbers and weight were recorded prior to threshing and obtaining seed weight. Harvest index was computed as seed weight divided by unthreshed plant weight times 100 following Wilcox (1974) and as such differs from harvest index in cereals because of the leaf and petiole drop in soybeans.

Population Effects. 'Amsoy', 'Chippewa 64,' 'Hark,' and 'Harman' were each grown in a 10-replicate test in 1968 and 1969, Each plot was over-seeded and thinned to one, three, five, or seven plants per hill. Each cultivar was also grown in a four-replicate test in 1970 and 1971. Plots were planted at 4, 6, 8, or 10 seeds per hill and were not thinned.

Indirect Selection Potential. Forty-one cultivars covering Maturity Groups OO to IV were grown with three plants per hill in a two-replicate hill-plot test in 1965 and 1966. Using the results from the 2 years, correlations were run between variables and heritability estimates were obtained from variance components. In addition, the coefficient of variability for seed yield and harvest index in 18 four-replicate breeding tests with the number of entries ranging from 20 to 120 were examined during 1968 to 1974.

F_4 progenies (derived from 150 random F_3 plants) of 0-4323 × 'Lindarin' were grown in a two-replicate hill-plot test in 1964 with three plants per hill. Fifteen lines were selected for yield and 15 lines were selected for harvest index. These selections were tested in two-replicate tests at Harrow and Woodslee, Ontario in 1965 and 1966 using single-row plots 4.9 m long and 0.91 m between rows. In addition, progeny from the cross 'Corsoy' × Chippewa 64 were tested in a four-replicate hill-plot test in 1974 using F_8 lines that had been derived by single seed descent from random F_2 plants.

RESULTS AND DISCUSSION

Population Effects. The harvest index of cultivars responded differently to increasing population from one to seven plants per hill, but there were no significant differences in harvest index within the range of 5 or 6 to 8 or 10 plants per hill for each of the cultivars (Table 1). This lack of effect at the higher population is in contrast to a marked decrease in harvest index for cultivars grown at high populations under row culture. For example, the harvest index for a density trial conducted in 1970 with Chippewa 64, Harosoy 63, Amsoy, and Harman averaged 57.0% at 1.2 plants m^{-2} compared to 48.4% at 43.1 plants m^{-2} (B. R. Buttery, unpublished results). Although plants may be at a high density within compact hills, on a plot-area basis the populations ranged from 1.6 to 15.4 plants m^{-2} and the open space around each hill must influence plant growth and pod-filling, thereby maintaining harvest index. Increasing the seeding rate of cultivars (results not presented) up to 20 seeds/hill did not greatly increase plant population because of self-thinning. Thus, hill-plot populations grown under our conditions with the plants compactly arranged in the hills can not be used to screen for genotypes that would maintain a high harvest index under high plant density in row culture.

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[2] Breeder and physiologist, respectively.

Table 1. Average plant population and harvest index for soybean cultivars grown in hill-plots during 1968 and 1969 and during 1970 and 1971.

Chippewa 64		Hark		Amsoy		Harman	
Plants/hill	Harvest index	Plants/hill	Harvest index	Plants/hill	Harvest index	Plants/hill	Harvest index
No.	%	No.	%	No.	%	No.	%
			1968 and 1969 Experiment†				
1.0	56.6 a*	1.0	54.5 a	1.0	55.4 a	1.0	58.3 b
3.0	58.7 b	3.0	55.7 ab	3.0	55.9 ab	3.0	58.2 b
5.0	58.5 b	5.0	55.4 b	5.0	56.7 b	5.0	57.9 b
7.0	58.2 b	7.0	56.9 c	7.0	57.0 b	7.0	57.0 a
C.V. %	3.5		1.8		3.0		2.0
			1970 and 1971 Experiment				
3.2	56.2 a	3.6	56.6 a	3.9	58.2 a	3.6	57.3 a
5.2	57.1 ab	5.8	57.3 a	5.2	58.9 a	5.9	57.1 a
6.5	57.2 b	7.5	58.0 a	7.6	58.3 a	7.4	57.0 a
8.1	57.9 b	9.1	57.8 a	9.6	59.0 a	9.0	56.4 a
C.V. %	1.5		2.0		2.0		2.1

* Means followed by same letter in columns for experiments do not differ at the 5% level according to Duncan's multiple range test.
†Over-seeded with each treatment thinned to a uniform number of plants per hill.

Table 2. Range and average performance of soybean lines selected for high harvest index and for high seed yield and tested at Harrow and Woodslee, 1965 to 1966.

	Harvest index	Seed yield	Straw weight	Plant height	Date mature
	%	kg/ha	kg/ha	cm	
		Selection for high harvest index†			
Range	45.7-51.9	1540-3380	1670-3420	71-105	6 Sept.-25 Sept.
X	48.9	2640	2740	91	16 Sept.
		Selection for high seed yield†			
Range	41.8-46.9	2830-3690	3470-4550	104-127	21 Sept.-5 Oct.
X	44.7	3210	4010	112	30 Sept.

† Fifteen selections of each from 150 F_4 lines of 0-4323 × Lindarin grown in hill plots, 1964.

Indirect Selection Potential. In the hillplot test of cultivars grown at one location in 2 years, harvest index ranged from 42% for 'Chief' to 60% for 'Mandarin'-(Ottawa) thereby indicating that varietal variability existed for this character. If harvest index was less variable than yield and was positively associated with yield, its measurement should be of value in preliminary culling in breeding work.

In the hillplot test of cultivars, the broad-sense heritability estimate of 82% obtained for harvest index was higher than that for yield at 68% but similar to that for plant height at 80%. The hill-plot test variability for yield and harvest index was measured by the coefficient of variability (C.V.). The C.V.'s for seed yield ranged from 13 to 20% with an average of 15% which is slightly higher than that obtained by Torrie (1962) for four-replicate 15-plant hill tests. The C.V.'s for harvest index were much lower than for seed yield ranging from 2 to 6% and averaging 3%. Although harvest index requires the measurement of yield, the lower C.V.'s indicate that it is less variable than seed yield.

In the cultivar hill-plot test, harvest index was negatively correlated ($P<0.01$) with bean yield ($r=-0.40$), with straw weight ($r=-0.77$), and with plant height ($r=-0.62$). Bean yield was positively correlated ($P<0.01$) with straw weight ($r=0.89$) and plant height ($r=0.71$).

A negative correlation ($P<0.01$) of -0.41 between harvest index and yield was also found in the F_4 progeny hill-plot test of 0-4323 × Lindarin. Selection for high harvest index and for high bean yield using these data resulted in different lines being selected by each method. When tested in rows at two locations in 2 years, the group selected for harvest index averaged 9.4% higher in harvest index, 17.8% lower in yield, 21 cm shorter, and 14 days earlier maturing than the group selected for yield (Table 2). These row-test results confirm the negative correlation observed between harvest index and yield in the hill-plots. Similarly, with F_8 lines of Corsoy × Chippewa 64 there was a negative correlation ($P<0.05$) of -0.19 between harvest index and yield. In this cross, harvest index was negatively correlated ($P<0.01$) with maturity ($r=-0.60$), whereas bean yield was positively correlated ($P<0.01$) with maturity (0.61). Our results agree with those in the literature (Brim, 1973; Johnson and Bernard, 1963) in that higher yield tends to be correlated with later maturity in soybeans. Thus, in general harvest index does not show potential as an indicator of yielding ability in soybeans because of negative relationships with maturity and yield. Nevertheless, evaluation of maturity and yield in conjunction with harvest index would allow breeders to select for an improved harvest index which should aid in maximizing yield as suggested by Shibles and Weber (1966).

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