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Harvest Index of Soybeans as Affected by Planting Date and Maturity Rating[1]

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ABSTRACT

Selection for high harvest index has been used by plant breeders to improve the seed yield of several crop plants, but in soybean [*Glycine max* (L.) Merrill] errors in the estimate of harvest index may occur because of interactions with maturity or seeding date and because harvest index measured at maturity does not include leaf and petiole dry weights. The objective of this study was to examine harvest indices of 10 soybean genotypes representing a wide range of maturity and seeded on several dates and to compare estimates of harvest index calculated from biological yield measurements with and without leaf and petiole dry weights.

Vegetative yield at the time of leaf senescence and seed yield at maturity were measured in 10 cultivars of soybean (two from each of maturity groups I-V) planted in a silt loam soil (fine, montmorillonitic, mesic Udollic Ochraqualfs) at five dates from late April through early July. Biological yield was defined as total above ground plant yield and harvest index was calculated as the ratio of seed yield to biological yield. A positive relationship was detected between biological and seed yield, presumably because of a strong photoperiod response. As biological yield increased, seed yield increased proportionally and harvest index stayed the same. Premature killing by frost decreased the harvest index. Variability for harvest index among cultivars within the same maturity group was indicated, but this was influenced by planting date and maturity group. It was concluded that selection for increased harvest index in soybean would have to be done within cultivars representing a narrow range of maturity and planted at the same time.

Additional index words: *Glycine max* (L.) Merrill, Seed yield, Biological yield, Migration coefficient.

HARVEST index (Donald, 1962) is the ratio of seed yield to total plant biological yield, and is recognized by many plant breeders as an important criterion in the search for higher yielding genotypes. Chandler (1969) reported that new high yielding rice (*Oryza sativa* L.) cultivars have a harvest index of 0.47 to 0.57 while the traditional rice plant has a harvest index of 0.23 to 0.37. The breeding of higher yielding wheat (*Triticum aestivum* L.) cultivars has resulted in an increase in the harvest index from 0.34 to 0.40 (Van Dobben, 1962). Singh and Stoskopf (1971) and Nass (1973) found that harvest index was positively correlated with seed yield of wheat.

There are indications that soybean [*Glycine max* (L.) Merrill] produces excessive vegetative growth. Weber (1955) found that yield was not reduced even with up to 50% defoliation before bloom. Sakamoto and Shaw (1967) calculated that, when the open space between rows was small, only 41 to 67% of the leaf area index (LAI) was "effective" (defined as the percent of the LAI that intercepted 90% of the sunlight). Beuerlein et al. (1971) reduced LAI by 50% by debranching soybeans, but did not change the seed yield. Bauer et al. (1976) found that vegetative dry weight decreased when the terminal bud was removed after flowering, but the seed yield was not changed.

The overproduction of vegetative dry matter did not always reduce seed yields, but better partitioning of dry weight could result in higher seed yields (Shibles and Weber, 1966; Beuerlein et al., 1971). Williams and Park (1917) studied 16 soybean cultivars and found that the cultivars with the highest seed yields also had the lowest straw yields. For convenience, harvest index is commonly calculated as the final seed weight divided by the final seed plus stem weight at harvest. This is not a true harvest index because it does not include the leaf and petiole weights. Buzzell and Buttery (1977) found that soybean harvest index measured after leaf drop was not influenced by plant population density (number of plants per hill) but they found that seed yield was negatively correlated with harvest index. Through selection, harvest index was increased 9.4% but yield decreased 17.8% and maturity was hastened by 14 days.

Selection of soybean genotypes based on harvest index may result in errors because of interactions with

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maturity or seeding date, and because many harvest index estimates do not include leaf and petiole dry weights in the biological yield estimate. Our objective was to examine harvest index of soybeans representing a wide range of maturity and seeded on several dates and to compare estimates of harvest index calculated from above ground biological yield estimates with and without leaf and petiole dry weights.

MATERIALS AND METHODS

Two soybean cultivars from each of five maturity groups (MG) were planted at five dates, each 2 or 3 weeks apart, at the Agronomy Research Center near Columbia, Missouri (38°57′ N Lat.) in 1971 and 1973. The cultivars were 'Chippewa 64' and 'Hark' (MG I), 'Amsoy 71' and 'Beeson' (MG II), 'Calland' and 'Williams' (MG III), 'Clark 63' and 'Cutler 71' (MG IV), and 'Hill' and 'Dare' (MG V). The Group I cultivars are too early and the Group V cultivars are too late for good seed production in central Missouri. The dates of seeding were 22 April, 17 May, 1 June, 21 June, and 22 July in 1971 and 29 April, 15 May, 31 May, 21 June, and 11 July in 1973. The soil was a Mexico silt loam soil classified as a fine, montmorillonitic, mesic Udollic Ochraqualfs. This soil type has a dark gray, silt loam surface and clay-pan subsoil.

Plots consisted of eight rows, 28 cm apart and 5.5 m long, with three replications in a split-split plot design. Planting dates, maturity groups, and cultivars within maturity groups were the main plots, subplots, and sub-subplots, respectively. Soybean leaves senesce and fall before maximum seed yield, so half of each plot (two bordered rows × 4.6 m) was harvested after vegetative growth had ceased (when 90% of the plants had ceased flowering) and before the leaves fell from the plants. This occurred at about stage R-6 as outlined by Fehr et al. (1971). No attempt was made to salvage the small number of leaves that had fallen during the season.

The other half of each plot (two bordered rows × 4.6 m) was harvested when 95% of the pods were brown (stage R-9). The whole plants (stems, pods, and seeds) were harvested and weighed. Harvested material was threshed and seed weight was recorded.

Biological yield was calculated as the vegetative component for the first harvest plus the seed yield from the second harvest. Harvest index was calculated as the ratio of mature seed yield to biological yield. Analyses of variance were performed on the seed yields, biological yields, and harvest indices, and correlation coefficients between these variables were determined. Harvest index was also calculated from seed and biological yields from the second harvest and the correlation coefficient between the two estimates of harvest index was determined.

RESULTS AND DISCUSSION

Significant effects due to planting dates and maturity groups were detected for seed yield, biological yield, and harvest index (Table 1). The two cultivars within each maturity group were arranged for analysis according to maturity. The interactions of cultivars within maturity groups (C/MG) with seeding dates (D) for harvest index occurred because, in 1971, the average harvest index for seeding date 5 of the early cultivar was lower (0.28) than the average of the late cultivars (0.32) whereas the harvest index was similar between the two groups at the other seeding dates. The interaction of maturity groups (MG) with cultivars within maturity groups (C/MG) for 1971 and 1973 meant that earliness within maturity groups did not influence harvest index. This suggested that, within a narrow range of maturity, significant differences exist for harvest index. With only two cultivars within each maturity group, however, it was not possible to determine the amount of variability that might be expected in a population of soybeans of similar maturity.

The early cultivars flowered too early in the season to make best use of the growing season. This was demonstrated in a previous study on these same cultivars (Major et al., 1975a) where more growing degree days were required from planting to flowering for the third than the first or fifth planting dates. As a result, the planting date that gave the highest yield was not the same for all maturity groups (Table 2). Planting dates from late April through early June all gave about the same yields within the "non-adapted" MG I and MG V cultivars. The mid-May planting date was best for the MG II cultivars while the "best-adapted" MG III and IV cultivars had highest yields in late April to mid-May plantings. Yield of MG V cultivars was lower in 1971 than in 1973 because of early frost in 1971. The biological yield of MG V cultivars, however, was often the highest in the experiment.

The soybean cultivars used in this study were found to have a strong response to photoperiod, and this influenced both the time from emergence to flowering and the time from flowering to maturity (Major et al., 1975b). These two stages of development, the vegetative and ripening phases, respectively, were always changed proportionally by planting date. A late planting date resulted in short vegetative and ripening phases. Probably because of this close relationship between the timing of these phases, there was a good relationship between seed yield and biological yield ($r = 0.89$, significant at the 5% level), and therefore,

Table 1. F values from the analyses of variance of seed yield, biological yield, and harvest index of 10 soybean cultivars planted at five dates in 1971 and 1973.

Source of variation	Degrees of freedom	Seed yield		Biological yield		Harvest index	
		1971	1973	1971	1973	1971	1973
		F values					
Replications (R)	2	3.42	2.37	6.82*	2.80	7.08*	0.82
Planting dates (D)	4	55.66**	5.27	75.43**	14.43**	5.84*	11.02**
Error a	8						
Maturity groups (MG)	4	21.79**	37.00**	37.63**	51.89**	35.42**	22.84**
D × MG	16	4.97**	8.01**	6.25**	3.48**	1.15	2.63**
Error b	40						
Cultivars within MG (C/MG)	1	13.87**	11.23**	16.20**	21.92**	3.74	0.27
D × C/MG	4	1.22	1.49	3.25*	1.72	5.96**	1.35
MG × C/MG	4	4.94**	3.37*	2.82*	3.89**	2.97*	3.26*
D × MG × C/MG	16	2.14*	1.90	2.09	2.68**	2.76**	1.84
Error c	50						

*,** Denote significance at the 0.05 and 0.01 probability levels, respectively.

Table 2. Average seed yield of two soybean cultivars from each of five maturity groups planted at five dates in 1971 and 1973.

Maturity group	1971 planting dates					
	22 April	17 May	1 June	21 June	22 July	Mean
	kg/ha					
I	2,404	2,309	2,430	2,099	888	1,992
II	2,801	3,281	2,763	2,511	1,101	2,491
III	3,422	2,830	2,826	2,267	928	2,455
IV	3,257	2,998	2,685	1,995	777	2,343
V	2,234	2,036	2,142	1,999	1,158	1,914
Mean	2,824	2,691	2,569	2,174	930	2,238
L.S.D. 0.05 = 369						
	1973 planting dates					
	29 April	15 May	31 May	21 June	11 July	Mean
	kg/ha					
I	2,034	2,242	2,476	1,530	1,696	1,996
II	2,345	2,964	2,773	2,065	1,893	2,408
III	2,260	2,753	2,294	2,479	2,136	2,384
IV	2,623	2,032	1,671	2,345	1,656	2,065
V	2,780	2,751	2,878	2,806	2,372	2,717
Mean	2,409	2,548	2,419	2,245	1,951	2,315
L.S.D. 0.05 = 0.04						

Table 3. Average harvest index of two soybean cultivars from each of five maturity groups planted at five dates in 1971 and 1973.

Maturity group	1971 planting dates					
	22 April	17 May	1 June	21 June	22 July	Mean
I	0.37	0.34	0.37	0.37	0.31	0.35
II	0.39	0.38	0.37	0.41	0.35	0.38
III	0.34	0.33	0.34	0.35	0.27†	0.33
IV	0.35	0.33	0.33	0.34	0.29†	0.33
V	0.25†	0.26†	0.26†	0.24†	0.27†	0.26
Mean	0.34	0.33	0.33	0.34	0.30	0.33
L.S.D. 0.05 = 0.14						
	1973 planting dates					
	29 April	15 May	31 May	21 June	11 July	Mean
I	0.39	0.36	0.37	0.29	0.38	0.36
II	0.41	0.40	0.36	0.35	0.40	0.38
III	0.34	0.33	0.27	0.35	0.35	0.33
IV	0.33	0.25	0.25	0.34	0.30	0.29
V	0.35	0.31	0.33	0.36	0.36	0.34
Mean	0.36	0.33	0.32	0.34	0.36	0.34
L.S.D. 0.05 = 0.05						

† Killed by frost.

the correlation coefficient between harvest index and seed yield was not significant ($r = 0.26$).

The effects of planting date and maturity group on biological yield, seed yield, and harvest index were examined by the method described by Donald and Hamblin (1976), which involved ranking the biological yield of wheat. The data from our study resembled Donald and Hamblin's, where, as biological yield increased, seed yield increased proportionally and, consequently, harvest index stayed the same (Table 3). Premature killing of MG V cultivars by frost decreased the harvest index. The MG II cultivars had high harvest index in both years, and this may have been a genotypic difference.

Measurement of biological yield at maturity permitted comparison of harvest indices at maturity with harvest indices calculated using vegetative yields at stage R-6. Harvest indices calculated using final vegetative yields decreased from MG I cultivars to MG V cultivars and increased as planting was delayed. The relationship between the two estimates of harvest index was low ($r = 0.38$, significant at 5% level). The correlation coefficient between seed yield and harvest index at maturity was 0.30 (significant at the 5% level) and harvest index at R-6 was 0.26. Although a significant relationship existed between seed yield and harvest index at maturity, measurement of biological yield of soybeans at maturity does not account for leaf weight, inflates the true value of the harvest index, and can lead to selection of earlier maturity than higher yield (Buzzell and Buttery, 1977).

These results indicated that, because of the strong photoperiod response of soybeans, which controls the lengths of the vegetative and ripening phases, seed yield and biological yield are closely associated so that caution is needed if harvest index is to be used as a selection tool in soybean breeding. These results do not rule out the possibility that differences in harvest indices could be caused by other environmental factors such as moisture availability. Excessive rainfall early in the season often promotes vegetative growth and lodging, resulting in low seed yields, and this would produce a low harvest index.

Our technique of calculating harvest index based on vegetative harvest at the time of maximum plant dry matter may have resulted in an underestimate of the true harvest index since the value for biological yield included the weight of nutrients that might have been translocated into the seed as leaves senesced. This error was probably small compared to the error when calculating harvest index using only stem, pod, and seed weights at final harvest time.

The poor correlation between the two methods of calculating harvest index indicated that the traditional "harvest index", calculated using total plant weight at harvest, is not a good estimate of the true harvest index and is inadequate for screening purposes. Our results and those of Buzzell and Buttery (1977) indicate that when leaf weight is not included, early maturing genotypes have a higher harvest index and selection for high harvest index would result in earlier maturity. Presumably, harvest index estimates that include leaf weights should permit selection for higher yield without altering maturity.

LITERATURE CITED

1. Bauer, M. E., J. W. Pendleton, J. E. Beuerlein, and S. R. Ghorashy. 1976. Influence of terminal bud removal on the growth and seed yield of soybeans. Agron. J. 68:709-711.
2. Beuerlein, J. E., J. W. Pendleton, M. E. Bauer, and S. R. Ghorashy. 1971. Effect of branch removal and plant populations at equidistant spacings on yield and light use efficiency of soybean canopies. Agron. J. 63:317-319.
3. Buzzell, R. I., and B. R. Buttery. 1977. Soybean harvest index in hill plots. Crop Sci. 17:968-970.
4. Chandler, R. F., Jr. 1969. Plant morphology and stand geometry in relation to nitrogen. p. 265-285. *In* J. D. Eastin, F. A. Haskins, C. Y. Sullivan, and C. H. M. Van Bavel (eds.) Physiological aspects of crop yield. Am. Soc. Agron., Madison, WI.
5. Donald, C. M. 1962. In search of yield. J. Aust. Inst. Agric. Sci. 28:171-178.
6. ———, and J. Hamblin. 1976. The biological yield and harvest index of cereals as agronomic and plant breeding criteria. Adv. Agron. 28:361-405.

7. Fehr, W. R., C. E. Caviness, D. T. Burmood, and J. S. Pennington. 1971. Stage of development descriptions for soybeans, *Glycine max* (L.) Merrill. Crop Sci. 11:929-931.
8. Major, D. J., D. R. Johnson, and V. D. Luedders. 1975a. Evaluation of eleven thermal unit methods for predicting soybean development. Crop Sci. 15:172-174.
9. ———, ———, J. W. Tanner, and I. C. Anderson. 1975b. Effects of daylength and temperature on soybean development. Crop Sci. 15:174-179.
10. Nass, H. G. 1973. Determination of characters for yield selection in spring wheat. Can. J. Plant Sci. 53:755-762.
11. Sakamoto, C. M., and R. H. Shaw. 1967. Apparent photosynthesis in field soybean communities. Agron. J. 59:73-75.
12. Shibles, R. M., and C. R. Weber. 1966. Interception of solar radiation and dry matter production by various soybean planting patterns. Crop Sci. 6:55-59.
13. Singh, I. D., and N. C. Stoskopf. 1971. Harvest index in cereals. Agron. J. 63:224-226.
14. Van Dobben, W. H. 1962. Influence of temperature and light conditions on dry matter distribution, development rate, and yield in arable crops. Neth. J. Agric. Sci. 10:377-389.
15. Weber, C. R. 1955. Effect of defoliation and topping simulating hail injury to soybeans. Agron. J. 47:262-266.
16. Williams, C. G., and J. B. Park. 1917. Soybeans: Their culture and uses. Ohio Agric. Exp. Stn. Bull. 312.