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Soybean Field Losses as Influenced by Harvest Delays

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ABSTRACT

Conflicts for time and machinery can postpone harvests beyond the initial time when optimum conditions exist. This study was conduced to determine the effects of delaying soybean [*Glycine max* (L.) Merr.] harvests on grain losses in the field. Field studies were conducted each year from 1983 to 1986 at Arlington, WI. Two cultivars from each of maturity groups (MG) 0, I, and II, one more susceptible to lodging than the other, were used. Initial harvest for each maturity group began 3 to 7 d beyond stage, R8. Three additional harvests were made for each maturity group at 14, 28 and 42 d beyond their initial harvest. Average soybean field losses were 10% of the potential yield, but ranged from 5.5% in 1983 to 12.7% in 1984. Loss of potential yield increased linearly at a rate of 0.2% d^{-1} from an average of 6.1% at the initial harvest to 13.9% 42 d later. In 1984 and 1986 net yields were reduced 14 and 18 kg ha^{-1} d^{-1} respectively. Harvest delays of 42 d resulted in plant deterioration and, in turn, lodging increased 20%, and preharvest, shatter, and stem losses increased 62, 95, and 70 kg ha^{-1}, respectively. Shatter losses were influenced by moisture conditions at harvest, but plant deterioration also increased shattering beyond that accounted for by moisture. On the average the MG I cultivars Hardin and Northrup King S1346 lost only 7.3 and 8.3% of their potential yield versus 10.4 and 11.4% for the MG O cultivars Ozzie and Evans, and 10.8 and 9.2% for MG II cultivars Wells II and Corsoy 79. Both of the MG I cultivars exhibited slower rates of harvest loss increases. The proportion of potential yield lost was inversely related to potential yield, indicating that harvest efficiency was improved with higher yields. Harvest delays can ultimately result in plant deterioration, increased grain losses, increased harvesting difficulties, and reductions in net yield of 11 kg $ha^{-1}d^{-1}$.

HARVEST delays for a portion of the soybean crop are inevitable each year. Unsuitable weather can postpone soybean harvest when the grower is otherwise prepared to harvest. Availability of labor and equipment can delay harvesting of soybean for several weeks after their harvest maturity.

Nave et al. (1973) reported little progress in Illinois since the mid-1920s in reducing harvesting losses in soybean, from an average total loss of 11.7% of the potential yield in 1927 to 9.2% in 1968. Schnug and Beuerlein (1987) report that average soybean harvest losses remain greater than 10% of the harvestable seeds remaining on the plants at harvest, but with proper machine operation and adjustment, losses can be reduced to 1 to 3%. Burnside et al. (1969) attributed high harvest losses from the combine gathering unit to harvest delays while waiting for weeds to desiccate.

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In an Ohio study soybean yield losses due to pre-harvest shattering were negligible prior to the crop reaching 100 g kg^{-1} grain moisture, but increased up to 1% d^{-1} when the crop remained in the field with grain moisture below 100 g kg^{-1} (Lamp et al. 1962). Shatter losses during harvesting of soybeans also increased as grain and pod moistures decreased. The gathering unit is the source of greatest loss during soybean harvest, and grain shattering makes up the largest proportion (80%) of the total gathering unit losses (Schnug and Beuerlein, 1987).

Lodging in two separate studies was responsible for 1.1 and 1.3% out of 9.7 and 8.0% total field losses, respectively (Park and Webb, 1959; Weber and Fehr, 1966). Other factors reported to affect harvest losses include plant population, time of day, row width, crop condition, weed infestations, and weather patterns (Nave and Cooper, 1974; Nave et al., 1973; Nave and Wax, 1971; Burnside et al., 1969; Weber and Fehr, 1966; Lamp et al., 1962). Schnug and Beuerlein (1987) recommended that soybean harvest begin when the crop reaches 170 to 190 g kg^{-1} grain moisture, with most efficient harvest occurring between 130 to 160 g kg^{-1} grain moisture.

Only brief attention has been given to the specific effects of harvest delays on harvest losses. Lamp et al. (1962) devoted 2 yr of a 5-yr study to the examination of harvest date effects on soybean with average potential yields of only 1685 kg ha^{-1}. Our study was initiated to examine the effects of delaying soybean harvest on field and harvest losses, and associated yield reductions. Our objective was to compare the influence of harvest delays on field and harvest losses among cultivars of differing lodging susceptibilities and maturities.

MATERIALS AND METHODS

Field studies were conducted each year from 1983 to 1986 at Arlington, WI (43°20’N, 89°25’W) on a Plano silt loam (fine-silty, mixed, mesic Typic Argiudolls) soil with a pH of 6.5, 3.4% organic matter, and an average of 464 kg of K and 122 kg of P ha^{-1}. In all years maize (*Zea Mays* L.) was the preceding crop. Plots, 7.6 m long, were planted using a specially designed plot planter (Oplinger et al., 1983) and consisted of 11 rows spaced 0.18 m. Planting was on 26 May 1983, 31 May 1984, 7 May 1985, and 6 May 1986 at 12 seeds m^{-1}. Plots were end trimmed to 6.4 m between the V1 and V3 growth stages, and the center seven rows were harvested with an ALMACO (Allen Machine Co., Nevada, IA 50201) SPC Model 20 plot combine.

The experiment was designed as a randomized complete block with a split plot arrangement of treatments and four replicates. Main plots consisted of six cultivars, two similarly maturing cultivars from each of the three maturity groups 0 (Ozzie and Evans), I (Northrup King S 1346 [NK1346] and Hardin), and II (Wells II and Corsoy 79). Cultivars were selected to have low (Ozzie, NK1346, and Wells II) versus high (Evans, Hardin, and Corsoy 79) lodging. Determination of these characteristics were based on multiple-year cultivar evaluation results in southern Wisconsin (Oplinger et al., 1982). Subplots were four scheduled harvest dates at 0, 14, 28 and 42 d after harvest maturity. Harvest maturity occurred 3 to 7 d after growth stage R8 when grain moisture first neared 160 g kg^{-1}. Harvests were made as scheduled or at the first opportunity after the scheduled harvest that weather permitted. The combine was adjusted and operated consistently, utilizing a cutting height of 0.076 m at each harvest date in order to minimize variation due to harvest mechanics.

Plant population and plant height were determined in each plot just prior to harvest. Lodging was evaluated just prior to harvest using a rating from 1, all plants erect, to 5, all plants prostrate. Grain moisture and seed weight were determined using harvested grain samples.

Soybean losses were determined using modifications of the methods most recently described by Schnug and Beuerlein (1987). Losses were determined inside of a 0.93 m^2 rectangular frame, which extended across all harvested rows (1.24 m) and a 0.75 m length of row. One end of the frame was removable so the frame could be slid into the plot from the side, thus facilitating measurement of preharvest losses without damaging the standing plants. Each soybean seed on the ground was counted whether it was free from the pod, in a detached pod, or in a pod that was attached to a detached portion of stem. In 1983 as seeds comprising preharvest and harvest losses were counted they were removed from the measurement area. The same specific portion of the plot was used for determining all other loss categories. A portion of the plot was harvested and the combine was backed up in order to determine seeds lost due to the action of the gathering unit prior to the trash being dropped in that area. The combine then completed the plot, and soybean seeds which came out of the back of the combine were counted. In 1984 to 1986 soybean from the sampled area was not removed after counting. Instead when the front of the combine had progressed through the plot, the machine was stopped, the sieves were swept clean, and then the combine continued through the plot. Seeds lost from the action of the gathering unit could then be determined from the portion of the plot last harvested and those seeds forced out of the back of the combine were counted from the portion first harvested. This procedure was more efficient in that harvest loss data could be collected later without occupying the combine or operator's time. Harvest loss categories were then determined by subtraction of overlapping categories (seed number from the first harvested plot portion – seed number from the last harvested plot portion) – seed number prior to harvest = seeds lost during threshing). The following preharvest and harvest loss categories were measured:

1) Preharvest losses: All seeds detached from standing soybean plants prior to harvest.
2) Gathering Unit losses: All seeds lost due to the action of the combine header during harvest.
    a) Shatter losses: All seeds free from pods or in detached pods.
    b) Stem losses: All seeds attached to stems that were broken or cut free from the harvested plants.
    c) Stubble losses: All seeds on the remaining stem portion below the point were the plants were cut off during harvesting or remaining on uncut lodged plants.
3) Threshing: All seeds which came out of the back of the combine by contact with the cylinder or sieves, with the trash, or during winnowing.
4) Combine losses: All the soybean seeds lost that were attributed to the harvest machinery which was the total of the gathering unit and threshing losses.
5) Total losses: All soybean seeds lost in all categories (preharvest and combine).

Losses on an area basis were calculated using counted seed numbers and seed weight measurements. Two types of grain yield were determined and were defined as:

1) Net yield: Determined from the total weight of soybean actually harvested by the combine and adjusted to 130 g kg^{-1} moisture.
2) Potential yield: Yield that would have been obtained from a plot if it had been harvested at the initial opportunity with a machine that had no losses (net yield + [total losses – initial harvest preharvest losses]).

All data were subjected to analysis of variance. Some comparisons between treatment means were made using Fischer's protected LSD test. Sums of squares for single degree of freedom comparisons between treatment means were made using Fisher's protected LSD test. Sums of squares for single degree of freedom comparisons and orthogonal polynomials were partitioned using treatment totals.

RESULTS AND DISCUSSION

Weather

Seasonal precipitation and temperatures were near to or greater than the 20-yr means in each year of the study. In September, October, and November 1985, when all harvesting was done, precipitation was 70, 16, and 152% above normal, respectively (data not shown). In 1985 the last plots of groups I and II cultivars were scheduled to be harvested on 9 and 14 November, respectively, but 305 mm of snow on 9 November precluded harvesting of those plots. This was followed by near record snowfall throughout. The bean crop was not harvested until the spring of 1986 (Wisconsin Agricultural Statistics, 1986). Field losses for the remaining plots in 1985 were considered to be 100%. Weather conditions throughout the harvest season in 1985 prevented obtaining a complete set of harvest loss data beyond the second harvest. Therefore, discussion of the 1985 data will be omitted from the results.

Table 1. Harvest maturity date, accumulated heating degree units (HDU), and actual harvest delays for 1983 to 1986.

Maturity group	Year	Harvest maturity date†	HDU from planting to maturity‡	Scheduled harvest delays (d)			
				0	14	28	42
				Actual harvest delays (d)			
0	1983	6 Sept.	1078	8	18	30	47
	1984	15 Sept.	1141	0	14	37	45
	1985	9 Sept.	1321	0	19	28	42
	1986	8 Sept.	1321	0	19	30	40
	$\bar{X}$	10 Sept.	1215	2	18	31	44
I	1983	1 Oct.	1342	0	14	29	42
	1984	20 Sept.	1194	0	14	32	43
	1985	28 Sept.	1521	0	16	29	§
	1986	29 Sept.	1542	9	19	31	42
	$\bar{X}$	27 Sept.	1400	2	16	30	42
II	1983	8 Oct.	1416	0	17	28	41
	1984	29 Sept.	1289	0	23	31	43
	1985	3 Oct.	1574	0	14	36	§
	1986	5 Oct.	1606	3	13	29	42
	$\bar{X}$	4 Oct.	1471	1	17	31	42

† Date cultivars could first be mechanically harvested if weather conditions permitted.
‡ 10°C base.
§ 305 mm of snow on 9 Nov. 1985 precluded harvesting of the remaining plots.

Weather conditions in 1986 also made the harvest season unusually difficult in much of the Midwest. September rainfall was 268% of the previous 20-yr average, and was distributed over 3 d more than in the previous 3 yr of the study (data not shown). A period of good weather at the beginning of September 1986 permitted the initial harvest of the early maturing cultivars (Table 1). The mid- and late-maturing cultivars would have reached harvest maturity, but persistent wet weather conditions postponed the initial harvest dates by an estimated 9 and 3 d, respectively (Table 1).

Sources of Field Losses

Lodging and preharvest loss increased with harvest delays. These increases indicate that plant deterioration became greater with harvest delays beyond harvest maturity. When averaged over all years lodging increased quadratically with time (Table 2).

Table 2. Highest order orthogonal polynomials for significant ($P < 0.05$) mean harvest date responses of selected variables, and by year when an interaction occurred, 1983, 1984, and 1986.

Year	Lodging†	Grain moisture	Net yield	Sources of field losses: Pre-harvest	Shatter	Stem†	Threshing	Total	% Loss of potential yield
1983		C**	NS	Q**	C**		NS	L**	L**
1984		C**	L**	Q**	C**		Q**	C**	L**
1986		C**	L**	Q**	Q*		NS	L**	Q*
Mean	Q**‡	Q*	L**	Q**	C**	L**	Q**	L**	L**
Error b Mean Square (df = 162)	0.2	0.9	115 087	851	3 917	3 178	10 760	13 500	8.8

*,** significant at the 0.05 and 0.01 levels of probability, respectively. NS = not significant.
† A year × harvest interaction was not apparent for these variables, therefore only the reponse of the main effects are presented.
‡ L, Q, and C indicate linear, quadratic and cubic responses, respectively.

Table 3. Net yield, grain moisture, and lodging among six cultivars and four harvest delays in 1983, 1984, 1986, and the means across years.

Cultivar	Harvest delay	Net yield 1983	Net yield 1984	Net yield 1986	Net yield Mean	Grain moisture 1983	Grain moisture 1984	Grain moisture 1986	Grain moisture Mean	Lodging† 1983	Lodging† 1984	Lodging† 1986	Lodging† Mean
	d	Kg ha⁻¹				g Kg⁻¹							
Ozzie	0	3660	3608	4058	3775	134	154	131	140	1.8	1.0	1.8	1.5
	14	3161	3441	3988	3530	156	166	188	170	1.3	1.0	1.5	1.3
	28	3404	3298	3747	3483	180	225	190	198	1.8	1.0	2.0	1.6
	42	3540	2652	3399	3197	184	200	165	183	1.8	1.0	2.0	1.6
Evans	0	3532	3341	3414	3429	133	153	132	139	3.3	1.0	2.3	2.2
	14	3506	3245	3876	3542	153	162	181	165	2.8	1.0	2.8	2.2
	28	3641	2787	3271	3233	176	214	184	191	3.8	1.0	3.0	2.6
	42	3717	2489	3266	3157	193	192	164	183	3.3	1.5	3.3	2.7
NK1346	0	4472	3542	4480	4165	144	148	199	164	2.3	1.0	3.3	2.2
	14	4632	3399	3897	3976	164	114	171	150	2.5	1.0	3.3	2.3
	28	4489	3063	4089	3881	137	225	196	186	2.0	1.0	3.5	2.2
	42	4467	3266	3763	3832	206	227	164	199	3.0	2.0	3.3	2.8
Hardin	0	3938	3682	3845	3822	167	180	210	186	3.3	2.3	4.5	3.3
	14	4573	3454	3879	3969	166	120	176	154	3.8	2.0	4.8	3.5
	28	4135	3244	3646	3675	143	227	181	184	3.5	2.0	4.8	3.4
	42	4175	3153	3542	3623	212	240	167	206	4.8	2.5	5.0	4.1
Wells II	0	3879	2971	3057	3302	177	169	189	178	2.5	1.0	2.8	2.1
	14	4223	2784	2806	3271	189	211	166	189	3.3	1.0	2.8	2.3
	28	3619	2556	2298	2825	156	189	172	172	3.3	1.5	2.0	2.3
	42	3940	2332	1880	2717	228	224	144	199	3.3	2.0	3.0	2.8
Corsoy 79	0	4078	3340	4243	3887	174	181	225	193	3.5	2.8	4.3	3.5
	14	4239	2929	3719	3629	197	229	183	203	4.0	2.5	4.0	3.5
	28	4100	3011	3370	3494	162	200	178	180	4.3	2.8	4.5	3.8
	42	3960	3053	2893	3302	233	261	150	215	4.5	3.5	4.8	4.3
Mean		3962	3110	3518	3530	173	192	175	180	3.0	1.6	3.3	2.7
LSD (0.05)													
Harvests within cultivars			475‡		274§		13‡		8§		0.6‡		NS
Cultivars within or across harvests			511		295		15		9		0.9		NS

† Lodging scale 1 = all plants erect to 5 = all plants prostrate.
‡ Year × cultivar × harvest delay interactions were significant ($P < 0.05$).
§ Cultivar × harvest delay interactions were significant ($P < 0.05$).
NS = Not significant.

Lodging did not differ among the first three harvests with average scores of 2.5, 2.5, and 2.6, respectively, but significantly increased to a score of 3.0 with 42-d delays. In 1984, lodging was less for all cultivars than in 1983 or 1986 (Table 3). Lodging did not increase due to harvest delays for Ozzie in any year, for Evans and Hardin in 1984, or for NK1346 or Hardin in 1986. However, Hardin was severely lodged from the first harvest in 1986. Plant deterioration of this type has been indicated to contribute to harvest losses (Weber and Fehr 1966, Nave and Cooper 1974).

Preharvest. Some preharvest loss is common and, in this study, it averaged only 8.6% of the total soybean loss, and less than 1% of the potential yield. However, preharvest loss increased with harvest delays in each year (Table 2). Preharvest losses showed a gradual increase with harvest delays up to 28 d, then increased at a more rapid rate at the 42-d delay (Fig. 1). In 1983 all of the increase in preharvest losses was between the first and second harvest, while in 1984 and 1986 the increased losses occurred at each successive harvest after the second harvest (Table 4). Wells II had large increases in preharvest losses by the third harvest in 1984, and again a large increase by the fourth harvest in 1984 and 1986 (Table 5). The average rate of preharvest loss increased after the third harvest (Fig. 1), however, MG 0 cultivars had significant increases in the preharvest losses by the third harvest in 1986, and MG II cultivars in 1984. (Table 5).

Gathering Unit. Gathering unit losses were near 60% of the total losses (data not shown), which is less than those described by some authors (Park and Webb, 1959; Lamp et. al., 1962). However, a range existed from 55% in the wet year of 1986 to a high near 77% in 1983 when percent loss of potential yield was considerably lower (Fig. 2). Early cultivars had lower grain moistures at harvest than the other cultivars (Table 3) which likely contributed to their greater shatter losses.

Shatter. Shatter losses contributed 37% to the total losses, which was more than any other source (Fig. 1). A significant cubic response to harvest delays occurred over all years with nearly all of the shatter loss increases between the 14-d and the 28-d harvest delays (Tables 2 and 4, Fig. 1). In 1986 shatter losses increased with each harvest after the second and the overall response was quadratic (Tables 2 and 4). Shatter losses did not differ between the first two dates in any year (Table 4).

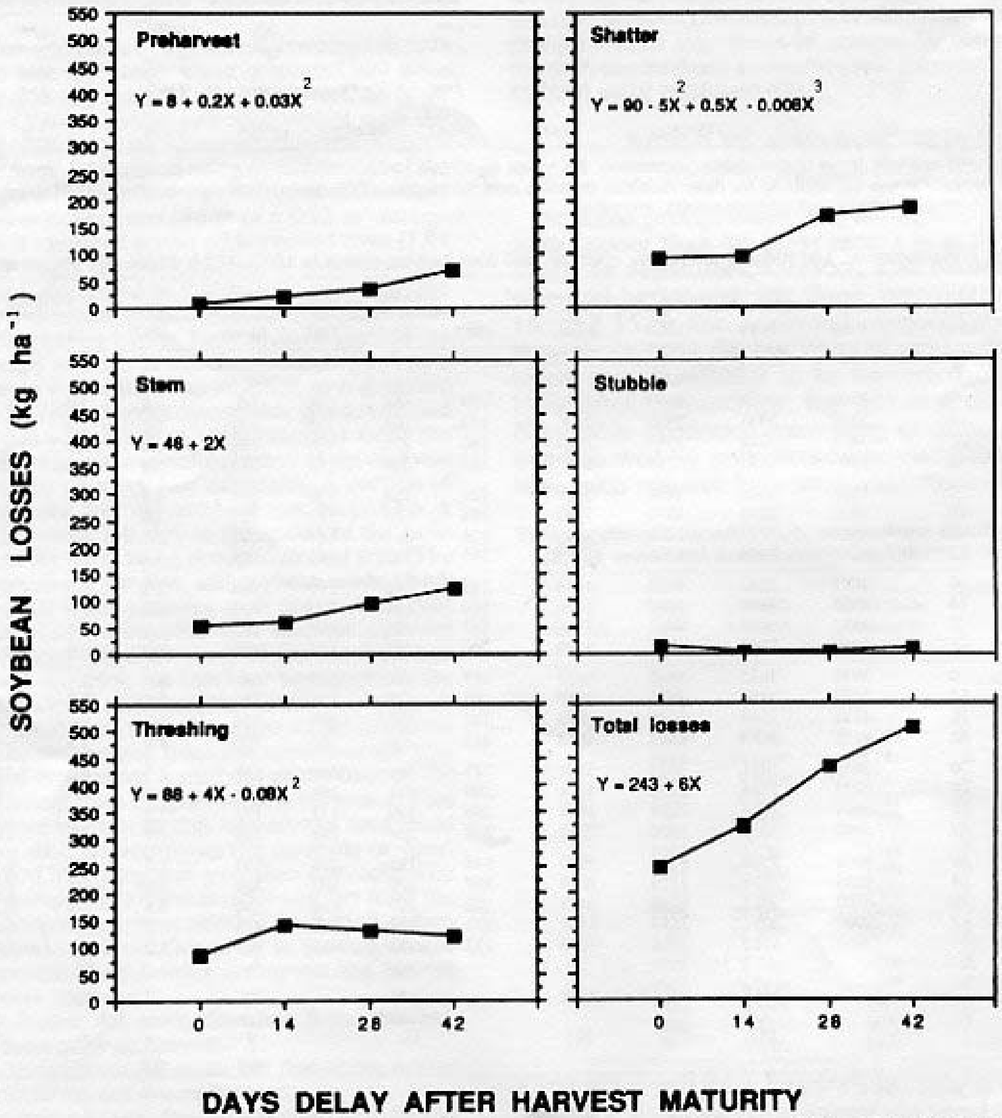

Fig. 1. Average preharvest, shatter, stem, stubble, threshing, and total soybean losses over four harvest delays across years, 1983, 1984, and 1986.

Table 4. Single degree of freedom comparisons among harvest delays for significant nonlinear responses in 1983, 1984, 1986, and across years.

Harvest delay comparison	Lodging†	Grain moisture				Sources of field losses: Preharvest				Shatter				Threshing		Total	Loss of potential yield
	Mean	1983	1984	1986	Mean	1983	1984	1986	Mean	1983	1984	1986	Mean	1984	Mean	1984	1986
(d)		(g kg⁻¹)				(kg ha⁻¹)											(%)
0 vs.	2.5	155	164	181	167	4	2	14	7	85	83	102	90	93	84	246	7.5
14	2.5	171	167	177	172	35**	5	20	20**	84	110	94	96	180**	140**	347**	9.2**
14 vs.	2.5	171	167	177	172	35	5	20	20	84	110	94	96	180	140	347	9.2
28	2.6	159	213**	184**	185**	31	33**	38**	34**	123**	240**	146*	170**	201	128	567**	12.1**
28 vs.	2.6	159	213	184**	185	31	33	38	34	123	240	146	170	201	128	567	12.1
42	3.0**	209**	224**	159	197**	17	109**	81**	69**	110	245	201**	185	153	120	612	16.9**
0 & 14 vs.	2.5	163	166	179**	170	20	4	17	14	85	97	98	93	137	112	297	8.4
28 & 42	2.8**	184	219**	172	191**	24	71**	60**	52**	117**	243**	174**	178**	177*	124	590**	14.5**
Error b Mean Square (df = 162)	0.2		0.9					851				3 917			10 760	13 500	8.8

*,** Indicate significantly greater values within a comparison at the 0.05 and 0.01 levels of probability, respectively.
† Lodging scale 1 = all plants erect to 5 = all plants prostrate.

Table 5. Preharvest, shatter, threshing, combine, and potential yield losses among six cultivars and four harvest delays in 1983, 1984, 1986, and across years.

Cultivar	Harvest delays	Preharvest				Shatter				Threshing				Combine				Loss of potential yield†			
		1983	1984	1986	Mean	1983	1984	1986	Mean	1983	1984	1986	Mean	1983	1984	1986	Mean	1983	1984	1986	Mean
	(d)	(Kg ha⁻¹)																(%)			
Ozzie	0	0	0	2	1	123	101	146	123	42	37	23	34	206	239	275	240	5.4	6.3	6.4	6.0
	14	0	8	15	8	57	75	125	86	14	132	191	112	116	269	435	274	3.6	7.5	10.0	7.0
	28	37	4	55	32	113	329	202	215	31	142	168	114	171	545	584	433	5.7	14.3	14.5	11.5
	42	6	54	46	35	184	434	310	310	64	91	238	131	396	642	787	608	10.3	20.8	19.6	16.9
Evans	0	2	0	2	1	156	111	178	148	65	30	61	52	268	192	379	280	7.1	5.5	10.6	7.7
	14	1	5	26	11	79	108	115	101	25	152	144	107	142	329	330	267	3.8	9.4	8.3	7.2
	28	4	5	58	22	133	267	142	181	39	279	219	179	286	609	495	463	7.4	18.0	15.1	13.5
	42	8	38	41	29	126	314	234	225	34	334	154	174	363	742	561	555	9.0	23.8	15.4	16.0
NK1346	0	1	2	24	9	67	103	103	91	24	137	232	131	134	269	466	290	2.9	7.1	9.4	6.5
	14	117	2	30	50	128	113	76	106	40	82	266	129	257	227	400	294	7.3	6.3	9.6	7.7
	28	38	38	42	39	165	75	135	125	22	392	116	177	313	513	313	380	7.4	15.3	7.7	10.1
	42	23	75	151	83	77	198	193	156	19	86	64	56	157	347	363	289	3.8	11.4	11.5	8.9
Hardin	0	2	6	12	7	41	56	62	53	25	142	259	142	101	228	349	226	2.5	5.9	8.2	5.5
	14	44	11	10	22	69	84	86	80	14	192	213	140	136	285	367	262	3.7	7.7	8.5	6.7
	28	9	25	14	16	108	139	114	120	32	251	40	108	226	465	215	302	5.7	13.1	5.7	8.1
	42	21	124	47	64	63	157	97	106	16	119	97	77	157	355	323	278	4.0	13.2	9.2	8.8
Wells II	0	17	4	25	16	67	81	59	69	26	77	81	61	167	239	204	203	4.0	7.4	6.3	5.9
	14	22	2	25	16	96	184	88	123	54	253	245	184	298	492	379	390	6.5	15.2	11.7	11.1
	28	69	100	31	67	116	391	209	239	30	62	184	92	223	579	518	440	7.0	21.0	18.4	15.5
	42	27	290	158	159	113	138	157	136	16	214	287	172	244	507	598	449	6.0	25.3	27.6	19.7
Corsoy 79	0	5	1	17	8	53	44	62	53	34	133	86	84	110	299	177	195	2.7	8.2	4.1	5.0
	14	24	3	12	13	73	98	75	82	72	268	169	170	222	447	304	324	5.4	13.3	7.4	8.7
	28	29	27	25	27	103	239	73	138	17	81	203	100	178	495	401	358	4.6	14.7	11.1	10.1
	42	19	75	43	46	97	228	216	180	23	73	227	108	301	421	604	442	7.5	14.0	18.0	13.2
Mean		22	37	38	32	100	170	136	135	32	157	165	118	216	406	409	343	5.5	12.7	11.4	9.9
LSD (0.05) Harvests within cultivars			20‡		12§		44‡		25§		73‡		NS		82‡		47§		2.1‡		1.2§
Cultivars within or across harvests			40		23		86		49		147		NS		159		92		4.2		2.4

† Potential yield = Net yield + total losses − preharvest losses at the initial harvest.
‡ Year × cultivar × harvest date interactions were significant ($P < 0.05$).
§ Cultivar × harvest date interactions were significant ($P < 0.05$).
NS = Not significant.

Greater shatter losses have previously been reported to be closely linked with low grain moistures at harvest (Lamp et al., 1962; Schnug and Beuerlein, 1987). Grain moisture increased after 14 d of harvest delay and the last two harvest dates averaged greater shatter losses than the first two (Table 4). However, average grain moistures in 1984 where greater at each successive harvest after the second, but shatter losses increased between the second and third harvests. Grain moisture decreased and shatter losses increased between the third and fourth harvests, in 1986, but shatter losses were higher at the third harvest than the second when grain moisture increased. Shatter losses for the early cultivars declined between the first two harvests (Table 5) while grain moisture increased (Table 3). Shattering also increased over the final two harvests even though grain moistures were also greater. This suggests that early shatter losses are a function of grain and plant moisture, but plant weathering and deterioration begin to make greater contributions to shatter losses when harvesting is delayed longer than 14 d.

Stem. Stem losses increased linearly with harvest delays (Table 2, Fig. 1). This source of loss was responsible for 22% of the total field losses at the initial harvest and 27% at the final harvest (Fig. 1). As lodging increased there was an increase in upper portions of stems cut or broken off.

Stubble and Threshing. A consistently low cutter bar height was maintained, therefore, stubble losses were negligible and did not differ among harvest delays (Fig. 1). Average threshing losses increased between the first and second harvests, but remained consistent among the final three harvests (Tables 2 and 4, Fig. 1). Higher grain and plant moistures at the final three harvests in 1984 may have contributed to poorer separation of grain and trash on the sieves.

Cultivars

Group I cultivars had greater net yields than the other cultivar maturity groups (Table 6). Group II cultivars did not differ from group 0 cultivars.

Cultivars exhibited the predicted lodging differences (Table 6) except that Evans did not differ from Ozzie in 1984 (Table 3). Single degree of freedom comparisons indicated that cultivars with low lodging susceptibility had greater susceptibility to preharvest, shatter, and potential yield losses (Table 6).

Harvest difficulties normally associated with lodged soybean that could contribute to total loss, especially to stem, stubble, and threshing losses, were not found. However, in high lodging cultivars, preharvest, shatter, and total losses were less than for low lodging cultivars, which corresponded to less fluctuation in grain moisture of the lodged plants. Grain moistures were significantly correlated to lodging with r values of 0.40, 0.41, and 0.25 in 1983, 1984, and 1986, respectively. Better air movement through the erect plants hastens drying, and would likely increase the magnitude and frequency of wetting and drying cycles. We observed that, upon rewetting, previously dry soybean seeds could imbibe enough water to swell and split pods. Most seeds remained in the pod upon redrying, but many shattered onto the ground with contact by the combine header.

Early season cultivars exceeded both mid- and late-season cultivars in shatter loss. However, MG 0 cultivars had less preharvest loss than either of the later groups (Table 6) due to less weathering of mature plants under the more favorable weather conditions of early September.

Average loss of potential yield increased as harvest was delayed for all cultivars, especially group 0 and Wells II (Table 5). The group I cultivars, NK, 1346 and Hardin, were the most resistant to harvest losses at later dates. Potential yield losses for these cultivars did not increase until the third harvest in

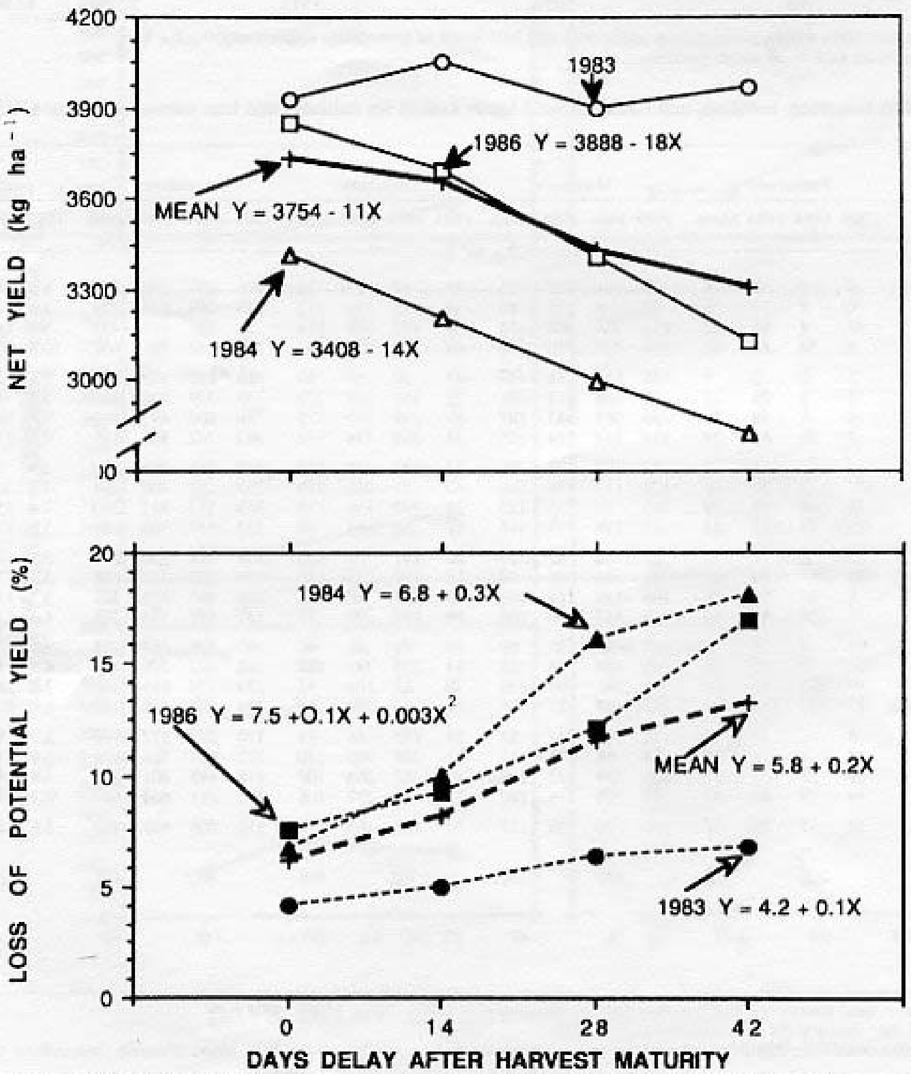

Fig. 2. Net yield and loss of potential yield of soybeans over four harvest delays for 1983, 1984, 1986, and the mean over all years.

1986, and losses only increased after the second harvest in 1984 (Tables 5). The group I cultivars also averaged less total and potential yield losses than the other maturity groups over all years (Table 6).

Evans has relatively low potential yield loss at the second harvest in 1986 (Table 5). This may have been due to a 49 g kg^{-1} grain moisture increase from the first to the second harvest which helped to reduce shatter losses by 35% (Tables 3 and 5). Grain moistures for Evans were also higher at the last two harvests than at the first, but shatter and potential yield losses increased beyond that of the first harvest. This indicates that plant deterioration contributes greatly to shatter losses with harvest delays longer than 14 D.

Loss of potential yield for Wells II was comparable to other cultivars at the initial harvest date, but by the last harvest in 1984 and 1986, it had lost more than 25% of its potential yield (Table 5). This included a fivefold increase in preharvest losses between the third and fourth harvests in 1986 . These large harvest loss increases along with relatively large proportions of preharvest, shatter, and stem losses indicate that the condition of Wells II deteriorated rapidly over time. Corsoy 79, the other late maturing cultivar, differed from Wells II in 1984 with nearly all of its potential yield loss occurring between the first and second harvest dates (Table 5). Corsoy 79 also averaged less preharvest, shatter, total, and potential yield losses, and had greater net yields than Wells II over all years (Table 6).

Harvest Delays

Net yields were significantly reduced 11 kg ha^{-1} d^{-1} (Fig. 2) and total losses increased (Table 2) as harvest was delayed. No net yield change occurred in 1983, however total losses increased linearly at 3 kg ha^{-1} d^{-1} and loss of potential yield increased by 0.1% d^{-1}, or 2.6% of the potential yield over a 42-d harvest delay. Harvest losses in 1983 were also less than in other years (Fig. 2) reflecting the good weather conditions during the harvest season of that year. In 1984 and 1986, net yield was reduced linearly at 14 and 18 kg ha^{-1} d^{-1}, respectively, with harvest delays up to 42 d after harvest maturity (Table 2, Fig. 2). Total losses were nearly 10% of potential yield (Table 5), which Schnug and Beuerlein (1987) also reported to be average. Potential yield losses increased linearly 0.2% d^{-1} (Table 2, Fig. 2).

Table 6. Single degree of freedom comparisons for yield and harvest loss components among cultivars based on maturity and lodging classifications.

Comparison					Harvest loss sources							
Maturity group	Lodging tendency	Cultivar	Net yield	Lodging†	Pre-harvest	Shatter	Stem	Stubble	Gathering unit	Combine	Total	Loss of potential yield
			kg ha^{-1}		kg ha^{-1}							%
0	Low	Ozzie vs.	3496	1.5	19	183	100	7	291	389	408	10.4
	High	Evans	3340	2.4**	16	164	88	12	263	391	407	11.1
I	Low	NK1346 vs.	3963*	2.3	45**	119*	58	13*	190*	313*	358*	8.3
	High	Hardin	3772	3.6**	27	90	57	4	150	267	294	7.3
II	Low	Wells II vs.	3029	2.4	64**	142**	99	3	243	371	435**	13.0**
	High	Corsoy 79	3578**	3.8**	23	114	90	11*	214	330	353	9.2
0 vs.			3418	2.0	18	174**	94**	10	277**	390**	408**	10.8**
I			3868**	3.0**	36**	105	58	9	170	290	326	7.8
I vs.			3868**	3.0	36	105	58	9	170	290	326	7.8
II			3304	3.1	44	128**	95**	7	229**	351**	394**	11.1**
0 vs.			3418	2.0	18	174**	94	10	277**	390*	408	10.8
II			3304	3.1**	44**	128	95	7	229	351	394	11.1
	Low vs.		3496	2.1	43**	148**	86	8	241**	358*	400**	10.6**
	High		3563	3.3**	22	123	78	9	209	329	351	9.2
Error a mean squares (df=45)			180 630	0.3	732	3 081	3 301	378	8 884	10 436	11 539	9.2

*,** Indicate significantly different values ($P < 0.05$ and 0.01, respectively) within a comparision.
† Lodging scale 1 = all plants erect to 5 = all plants prostrate.

Losses at the first harvest were below the season average at 5, 7, and 7% of the potential yield in 1983, 1984, and 1986, respectively (Fig. 2). After 28 d, losses of potential yield in 1984 and 1986 exceeded 11% and continued higher with further delays (Table 4, Fig. 2). In 1986, the rate of potential yield loss increased after 14 d of delay (Table 2, Fig. 2) as did total losses in 1984 (Table 4). This supports the suggestion by Lamp et. al (1962) and Schnug and Beuerlein (1987) that, in order to reduce field losses, harvesting should begin at high grain moistures (15-20%) with the goal to complete harvest as soon as possible after initial maturity.

Loss of potential yield had a negative correlation to potential yield in 1984 and 1986 with *r* values of –0.34, and -0.53, respectively. This is an indication that harvest efficiency is improved with high yield situations, which agrees with the previous report of Park and Webb (1959).

CONCLUSIONS

Harvest losses clearly increase with delays in harvesting the crop. More erect plants had greater pre-harvest, shatter, and potential yield losses than lodged plants. As lodging increased over time plant deterioration occurred, which was related to increased field losses. Lodging, preharvest, and shatter losses at the latter harvests, indicate that plant deterioration contributed substantially to total losses later in the season. However, lodging may have also contributed to protecting some cultivars from wide and rapid moisture fluctuations in the early harvest season. Shattering was the largest source of field losses, but this type of loss can be controlled with timely harvest. Loss of potential yield increased with harvest delays, particularly beyond 14 d after harvest maturity. Cultivars were different in their response to harvest delays in that Hardin and NK 1346 cultivars showed resistance to harvest losses, while Wells II was very susceptible. Early cultivars were less exposed than later cultivars to unfavorable weather conditions when harvested at initial maturity, but they were also more susceptible to shatter losses due to dryer conditions in the early harvest season. These results demonstrate the need for soybean growers and researchers to harvest soybean within 14 d of harvest maturity. Further delays only enhance harvest problems and the likelihood of leaving more potential yield in the field. Results of this study can be used to establish early harvest season time frames relative to cultivar maturity and may be helpful to prioritize soybean harvest for specific grower operations.

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