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Yield and Quality of Soybean Forage as Affected by Cultivar and Management Practices

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ABSTRACT

Soybean [*Glycine max* (L.) Merr.] has potential for use as an alternative forage crop, however, little is known about the effects of cultural practices on forage yield and quality. A study was conducted to evaluate the effects of cultivar, row spacing, plant density, and harvest maturity on the yield and quality of soybean forage. The study was conducted at the Univ. of Wisconsin Arlington Agricultural Research Station, Arlington, WI on a Plano silt-loam soil (fine-silty, mixed, mesic, Typic Argiudoll) in 1987 and 1989. The cultivars Corsoy 79, Pella, and Williams 82 were grown at 20- and 76-cm row spacings at planting rates of 280 000 and 890 000 seeds ha^{-1} and were harvested at the R1, R3, R5, and R7 stages of development. Harvest maturity had the greatest effect on soybean forage yield and quality of the management practices evaluated. The yield of soybean forage increased from 2.4 Mg ha^{-1} when harvested at R1 to 7.4 Mg ha^{-1} when harvested at R7, but quality declined between stages R1 and R5 then increased from R5 to R7 as pods developed and seeds filled. Late maturing cultivars (Maturity Group III vs. Maturity Group II) produced greater forage yields but lower quality forage when harvested at the same stage of development. The 20-cm row spacing produced 1.2 Mg ha^{-1} more forage than the 76-cm row spacing, but crude protein concentration was 8 g kg^{-1} less. The results of this experiment indicate that soybean can produce forage similar in quality to alfalfa and that management practices typically used for grain production are suitable for forage production.

Although presently grown almost entirely as an oil-seed crop, soybean was previously a popular summer annual forage legume (USDA, 1940). Perennial species have now largely replaced soybean for forage production; however, soybean is still considered a viable alternative forage during periods of decreased productivity of perennial forage species. Because forage production currently represents less than 3% of the total soybean acreage (USDA, 1989), only a limited amount of research has been conducted to determine the effects of management practices on the yield and quality of soybean forage.

Plant density and harvest maturity effects were evaluated during a single year by Munoz et al. (1983) who reported increased dry matter yields and reduced digestibility as plant density increased and harvest was delayed to late reproductive growth. Willard (1925) also evaluated the effect of harvest maturity on soybean forage yield and concluded that dry matter yields were greatest during late reproductive development when "one-fourth the leaves appear yellow." Ocumpaugh et al. (1981) inter-seeded soybean cultivars from several relative maturity groups into a grass pasture and reported a significant advantage in dry matter yield and crude protein concentration for late-maturing cultivars.

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The effect of row spacing on yield and quality of soybean forage has not been reported, nor have any interactions among cultivar, harvest maturity, row spacing, and plant density. To fully capitalize on the forage potential of soybean it is important to understand the effects management factors can have on the yield and quality of soybean forage. This study was designed to evaluate the effects and interactions of cultivar selection, row spacing, plant density, and harvest maturity on the yield and quality of soybean forage.

MATERIALS AND METHODS

The research was conducted at the University of Wisconsin Arlington Experimental Farm, Arlington, WI on a Plano silt-loam soil during 1987 and 1989. Fertility and climatological data for these two environments are presented in Table 1. The soybean cultivars Corsoy 79, Pella, and Williams 82 were selected for use in this study. Corsoy 79 (Group II) represents a cultivar of adapted maturity for grain production in southern Wisconsin, whereas Pella (Group III) and Williams 82 (Group III) are late and very-late maturing cultivars, respectively. Alachlor (2-chloro-2′, 6′-diethyl-*N*- [methoxymethyl] acetanilide) at the rate of 1.6 kg a.i. ha^{-1} and chloramben (3-amino-2,5-dichlorobenzoic acid) at the rate of 1.6 kg a.i. ha^{-1} were applied pre-emergence for weed control.

Plots 5.3 m in length were established at a 20-cm row spacing with eight rows per plot and a 76-cm row spacing with four rows per plot using a specially designed small-plot planter (Oplinger et al., 1983). Within each row spacing, plots were planted at 280 000 and 890 000 seeds ha^{-1} and produced stands of approximately 247 000 and 740 000 plants ha^{-1} at harvest. Plots were hand harvested at R1, R3, R5 and R7 stages of maturity (Fehr and Caviness, 1977) by removing at ground level a 3.1-m section of the

Table 1. Fertility and climatological data for field plots at Arlington, WI 1987 and 1989.

	Year 1987	Year 1989
Fertility		
pH	6.8	6.8
P (kg ha^{-1})	60	70
K (kg ha^{-1})	220	300
Organic matter (g kg^{-1})	34.0	35.3
Average daily mean temperature (°C)		
May	15.9	17.8
June	21.5	19.0
July	23.6	22.7
August	20.3	21.0
September	16.4	16.0
Total precipitation (mm)		
May	119.4	33.8
June	15.5	51.1
July	102.1	96.0
August	124.5	110.2
September	124.7	97.3

Abbreviations: CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; ADL, acid detergent lignin; and EE, ether extract.

center four rows of 20-cm row spacing plots and the center two rows of 76-cm row spacing plots. Specific harvest dates and days from planting are presented in Table 2.

The experiment was conducted as a split-plot arrangement of a randomized complete-block design with four replications. Row-spacings were the whole plots and a factorial combination of cultivars, plant densities, and harvest maturities were the sub-plots.

At harvest a sub-sample was removed from each plot and dried for 48 h at 60 °C to determine dry matter concentration and was ground to pass a 1-mm screen in a Thomas-Wiley mill for use in chemical analysis. For plots harvested at R5 and R7 an additional sample was harvested and divided into vegetative and pod components and dried at 60 °C for 48 h to determine the relative contribution of pods to the total plant weight.

Analysis for neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) was by the amylase modification of the sequential analysis procedure of Robertson and Van Soest (1981). Kjeldahl N content of samples was determined using the micro-Kjeldahl procedure of Bremner and Breitenbeck (1983). Crude protein (CP) concentration was calculated by multiplying the Kjeldahl N value by 6.25. Ether extract (EE) concentrations of the whole plant forage was calculated by multiplying the ether extract concentration of separated pod samples harvested during stage R5 and R7 by the proportion of pods in the total plant dry matter. Ether extract concentration of pods was determined by loss of weight upon refluxing in boiling ether for 96 h.

Table 2. Planting and harvesting dates for soybean grown as forage in 1987 and 1989 and Arlington, WI.

		Year 1987	1989
Planting dates		5 June	16 May
Harvest dates			
R1	Corsoy 79	20 July (45)†	14 July (59)
	Pella	23 July (48)	14 July (59)
	Williams 82	29 July (54)	24 July (69)
R3	Corsoy 79	29 July (54)	28 July (73)
	Pella	3 Aug. (59)	31 July (76)
	Williams 82	7 Aug. (63)	9 Aug. (85)
R5	Corsoy 79	13 Aug. (69)	9 Aug. (85)
	Pella	18 Aug. (74)	16 Aug. (92)
	Williams 82	27 Aug. (83)	23 Aug. (99)
R7	Corsoy 79	15 Sep. (102)	20 Sept. (127)
	Pella	29 Sep. (116)	25 Sept. (132)
	Williams 82	3 Oct. (120)	25 Sept. (132)

† Numbers in parenthesis are days after planting.

RESULTS AND DISCUSSION

Combined across years, statistically significant differences ($P < 0.05$) were present for the main effects of cultivars, harvest maturities, and planting rate on dry matter yield, CP, NDF, ADF, and ADL concentrations (Table 3). Row spacing affected only dry matter yield. The only interactions ($P < 0.05$) detected among main effects were the planting rate-by-harvest maturity interaction for dry matter yield and the cultivar-by-harvest maturity interaction for EE concentration. The interaction of planting rate and harvest maturity is a result of the higher planting rate giving greater dry matter yields when harvested during early reproductive growth, but lower yields when harvested at more mature growth stages (data not shown). The cultivar-by-harvest maturity interaction for EE concentration results from the low EE concentration of Williams 82 at the R7 harvest compared to the other two cultivars (Table 4).

The narrow row spacing produced greater forage yields than the wide row spacing, but forage composition was not affected. Combined over other main effects, the 20-cm row spacing produced 0.9 Mg ha^{-1} more forage than the 76-cm spacing (Table 3).

Although statistically significant, the effects of planting rate on the yield and quality of soybean forage were of small magnitude. Averaged over all other main effects, the higher planting rate produced 0.1 Mg ha^{-1} more forage, but the forage was slightly lower in CP and higher in NDF, ADF, and ADL concentrations than that produced under the lower planting rate.

Differences among cultivars for yield and forage quality appear to be related to the maturity group of the cultivars. When harvested at R7 the earliest maturing cultivar, Corsoy 79, produced 1.2 Mg ha^{-1} less forage than Williams 82, the latest maturing cultivar, but produced forage with higher CP and lower NDF, ADF, and ADL concentrations.

Maturity stage at time of harvest had a greater effect on the yield and quality of forage produced than any of the other factors evaluated (Table 3). Dry matter yields increased with each advance in maturity stage at harvest, but quality parameters followed a different pattern. Crude protein concentrations declined from R1 to R3, remained constant between R3 and R5 but then increased from R5 to R7. Neutral detergent fiber, ADF and ADL concentrations increased from R1 to R5 and then decreased from R5 to R7. A change in soybean forage quality with advancing maturity has been described previously (Ocumpaugh et al., 1981; Hanway and Weber, 1971a) and is attributed to improvements in forage quality due to increased seed mass off-setting the decline in forage quality of vegetative structures.

It has been recommended that soybean forage be harvested between stages R6 and R7 (Willard, 1925; Munoz et al., 1983) and this recommendation is supported by our observations. Although the R7 harvest provided the greatest dry matter yields of the four harvest stages evaluated, some leaf senescence had occurred, therefore, yields were probably lower than if the plants had been harvested slightly earlier. After R7, leaves senescence rapidly and dry matter yields would decrease quickly (Ritchie et al., 1982; Hanway and Weber, 1971b). For this reason the harvest of soybean as a forage should be completed no later than the R7 stage of maturity. Harvesting soybean forage during early reproductive development (R1-R5) results in significantly lower dry matter yields than harvesting at a later stage, and is not recommended.

Because there is an obvious advantage to harvesting soybean forage at or near stage R7, the effects of the various management factors at that stage warrant further discussion. Averaged over all other main effects, the 20-cm row spacing produced 1.2 Mg ha^{-1} more forage than the 76-cm row spacing harvested at R7 (Table 4). The CP concentration of forage grown at the wider row spacing was significantly greater than that of forage grown at the narrow row spacing, but

Table 3. Effect of management factors on the yield and quality of soybean forage harvested at Arlington, WI in 1987 and 1989.

Main effect	Level	Yield	CP	NDF	ADF	ADL	EE[†]
		Mg/Ha			g/kg		
Row Spacing							
	20 cm	5.3	187	421	308	64	55
	76 cm	4.4	191	420	307	65	57
	LSD (0.05)	0.2	N.S.	N.S.	N.S.	N.S.	N.S.
Planting rate (Seeds / Ha)							
	280 000	4.8	193	416	303	63	57
	890 000	4.9	185	424	312	65	55
	LSD (0.05)	0.1	3	4	4	1	N.S.
Cultivar							
	Corsoy 79	4.4	196	407	297	62	67
	Pella	4.7	190	426	311	66	66
	Williams 82	5.4	182	428	315	65	36
	LSD (0.05)	0.2	4	5	5	1	8
Harvest stage							
	R1	2.4	201	386	282	59	–
	R3	3.9	181	431	319	66	–
	R5	5.7	182	457	337	71	9
	R7	7.4	192	407	293	62	105
	LSD (0.05)	0.2	5	6	5	2	6

[†] EE data collected only at stages R5 and R7.

the magnitude of the difference is small and probably of little practical importance.

Although the composition of the forage produced at the two row spacings was similar, it was observed that plants grown at the 76-cm row spacing produced finer stems than plants grown at the 20-cm spacing. The smaller stem diameter of plants grown in wider row spacings should provide faster drying at harvest and may reduce the sorting of coarse stem sections by animals at feeding. Both of these topics have been identified as major problems in the production and utilization of soybean forage (Gupta et al., 1973; and Willard, 1925). Producers will need to consider the yield benefits of narrow row spacings and the potential benefits of faster field drying and reduced sorting of coarse stems that may be associated with wide row spacings in selecting a row width.

produced stems with smaller diameter than plants grown under the low density, which may reduce sorting and hasten field drying.

Munoz et al. (1983) evaluated the production of soybean forage at plant densities ranging from 97 100 to 291 300 plants ha^{-1} but observed an increase in forage yields with increased plant densities. The highest plant density evaluated by Munoz et al. (1983) was approximately equal to the low density of this study, and the discrepancy in yield response to increasing plant density may be due to the plant densities evaluated in each study. Combining the results of the two studies indicates that there may be a plateau plant density for soybean forage production of approximately 250 000 to 300 000 plants ha^{-1}. The data of Munoz et al. suggests that plant densities below 291 300 plants ha^{-1} do not allow for maximum dry matter accumulation, whereas the data presented in this study suggest that dry matter accumulation is not affected by increasing density to approximately 741 300 plants ha^{-1}. These results indicate that plant densities

Table 4. Effect of management factors on the yield and quality of soybean forage harvested at R7 at Arlington, WI in 1987 and 1989.

Main effect	Level	Yield	CP	NDF	ADF	ADL	EE
		- Mg/Ha -			g/kg		
Row spacing							
	20 cm	8.0	188	409	296	62	101
	76 cm	6.8	196	405	290	61	109
	LSD (0.05)	0.6	6	N.S.	N.S.	N.S.	N.S.
Planting rate (Seeds / Ha)							
	280 000	7.5	192	404	289	60	111
	890 000	7.3	192	411	296	63	99
	LSD (0.05)	N.S.	N.S.	N.S.	N.S.	3	6
Cultivar							
	Corsoy 79	6.8	205	405	287	60	118
	Pella	7.5	190	395	285	59	126
	Williams 82	8.0	182	422	306	65	71
	LSD (0.05)	0.6	9	14	12	4	7

Increasing planting rate from 280 000 to 890 000 seeds ha^{-1} did not affect forage yields but did result in slightly higher ADL and lower EE concentrations (Table 4). Plants grown under the high plant density similar to those used in soybean seed production should also be suitable for forage production.

Williams 82, the cultivar with the latest relative maturity, produced 1.2 Mg ha^{-1} more forage at R7 than the earliest maturity cultivar, Corsoy 79. The forage produced by Williams 82 was significantly lower in CP and EE but higher in NDF, ADF, and ADL concentrations than that produced by Corsoy 79. Pella produced forage with dry matter yield and CP concentration intermediate to the other two cultivars. Neutral detergent fiber, ADF, and ADL concentrations of Pella were similar to those of Corsoy 79.

Ocumpaugh et al. (1981) evaluated the yield and forage quality of four soybean cultivars interseeded into a tall fescue sod and also observed that dry matter yields increased for later maturing soybean cultivars. Contrary to the findings of this study, however, Ocumpaugh et al. (1981) reported that CP concentrations increased for later maturing cultivars. The reasons for the discrepancy conerning cultivar effects on CP concentrations between the two studies is unclear but may be related to the fact that the soybean forage produced by Ocumpaugh et al. (1981) was interseeded into an actively growing cool season grass, and the forage produced in this study was grown in a pure stand. The large increase in forage yield and small effect on forage quality associated with growing cultivars of later than normal maturity suggests that cultivars of later maturity than those that are locally adapted for seed production may be the best choice for forage production of soybean.

Soybean forage harvested at R7 is comparable in CP, NDF, ADF, and ADL to alfalfa hay harvested at an early bloom stage of development (NRC, 1989), and has potential as a high-quality alternative forage. Although similar to alfalfa in these quality characteristics, soybean contains a much higher EE concentration. The NRC (1989) reports EE concentrations of alfalfa to be approximately 20 g kg^{-1}, but we observed EE values for whole-plant soybean forage up to 126 g kg^{-1}. The presence of a large EE fraction would be expected in soybean because the seeds have a high oil concentration and comprise a large portion of the total plant dry matter at late reproductive stages of development (Willard, 1925).

The nutritional impact of the large EE component of soybean forage is difficult to interpret. The additional energy contained in the EE fraction at first would appear to be a desirable feature, however, feeding large amounts of vegetable fats to ruminant livestock has not always proven beneficial (Palmquist and Jenkins, 1980). Increasing the EE content of diets fed to lactating dairy cattle can increase milk production but can also decrease intake and reduce fiber digestion if the EE is too high. To avoid negative impacts of feeding high levels of EE, it is recommended that the dietary EE concentration for lactating dairy cattle not exceed 5% of the total ration dry matter (Palmquist and Jenkins, 1980). Given the EE concentrations observed in this study, soybean forage harvested at R7 should be limited to no more than 50% of the total ration dry matter.

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