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Yield and Quality of Forage Soybean

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ABSTRACT

Tall forage soybean [*Glycine max* (L.) Merr.] cultivars in maturity groups V, VI, and VII have been developed to supply forage. Our objective was to determine the effect of harvest date and row spacing on the forage yield and quality of these new soybean cultivars. We grew forage and standard grain soybean in Minnesota with harvests in early and late September. Average maturity of tall forage soybean was R3 (early harvest) to R4 or R5 (late harvest) and average maturity of grain soybean was R6 (early harvest) to R7 (late harvest). Herbage of forage soybean was mostly leaves and stems at both harvests, whereas herbage of grain soybean contained an average of 400 and 595 g kg^{-1} pods at the early and late harvests, respectively. There was no harvest date $\times$ soybean entry interaction for forage yield or forage quality. Forage and grain soybean had similar forage yields (~8.8 Mg ha^{-1}). Because adapted grain soybean was more mature and had a greater pod proportion than forage soybean, grain soybean had greater crude protein (CP) and lower fiber concentration than forage soybean. Average forage CP for forage and grain types was 146 and 218 g kg^{-1}, respectively, while neutral-detergent fiber (NDF) concentration was 523 and 400 g kg^{-1}, respectively. Decreasing row width from 76 to 25 cm increased forage yield 0.8 Mg ha^{-1} but had no effect on total herbage quality.

Soybean was introduced to the USA in the mid 1800s and was initially promoted as a forage crop (Williams, 1897; Arny, 1926). Hackleman (1924) concluded that "...soybeans are the best annual nitrogenous seed and hay-producing plant." By the late 1940s, the focus had shifted almost entirely from forage to soybean grain production. Soybean use for forage in the northern Midwest has been limited to situations where there is a shortage of forage from other sources or when frost damage limits grain harvest. There is now an opportunity for increased use of soybean as a forage in Midwest crop rotations because of the increased use of corn (*Zea mays* L.) silage and the decreased reliance on alfalfa (*Medicago sativa* L.) by livestock producers.

Limited research on use of soybean for forage shows the potential benefits of soybean as a forage crop. Hintz et al. (1992) reported forage yields from grain-type soybean in Wisconsin ranging from 2.4 to 7.4 Mg ha^{-1}, depending on the stage of maturity at harvest. They concluded that grain soybean cultivars harvested at the R7 stage (one seed pod at mature color; 50% of leaves yellow) produced forage that was similar in quality to alfalfa harvested at early bloom. When soybean was grown as an intercrop with corn, the forage CP concentration was increased by 30 to 43% compared with corn alone (Herbert et al., 1984). Forage yields of the soybean and corn intercrop were comparable with those of the corn monoculture. Sod-seeding soybean into tall fescue (*Festuca arundinacea* Schreb) increased forage yield by 300% compared with tall fescue alone and increased the CP concentration of the forage by 10% (Ocumpaugh et al., 1981).

As soybean matures from stage R1 (beginning bloom) to R7, the leaf proportion declines (Fehr et al., 1971). Changes in the stem proportion with soybean maturation are less consistent. Hintz and Albrecht (1994) reported that the leaf concentration of grain soybean decreased from 708 g kg^{-1} at R1 to 168 g kg^{-1} at R7. Meanwhile, the stem fraction increased from 292 g kg^{-1} at R1 to 383 g kg^{-1} at R5 (beginning seed development) and then declined to 283 g kg^{-1} at R7 as the pod and seed components increased.

The harvest of soybean for forage at R6 (full seed) to R7 maximizes both the dry matter yield and forage quality (Hintz et al., 1992; Munoz et al., 1983). However, while the dry matter yield of soybean forage typically increases with advancing maturity, changes in the forage quality are less consistent. This is due to changes in the proportions of the leaf, stem, and pod fractions as well as the translocation of nutrients to the grain and increases in the lipid concentration of the seed (Hanway and Weber, 1971). Hintz et al. (1992) reported that CP concentrations declined from R1 to R3, remained constant between R3 and R5, and increased from R5 to R7. Whole-plant fiber concentrations increased from R1 to R5 and decreased from R5 to R7.

Reducing row spacing from a traditional width of 76 cm to 25 cm or less is recommended to enhance soybean grain yields (Naeve, 1999). In southern Minnesota, grain yields are typically increased by about 5%. Likewise, Hintz et al. (1992) reported that for grain soybean, a 20-cm row spacing produced more forage than a 76-cm row spacing. They also observed that decreasing row spacing increased the stem diameter but that row spacing had no effect on the total forage quality.

Tall forage soybean cultivars in maturity groups V,

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Published in Agron. J. 93:99–106 (2001).

Abbreviations: ADF, acid-detergent fiber; ANOVA, analysis of variance; CP, crude protein; NDF, neutral-detergent fiber; NIRS, near-infrared reflectance spectroscopy; WISC.BK, Wisconsin Black soybean.

VI, and VII that reach a height of 1.5 to 2 m and have high yield potential have recently been released (Devine and Hatley, 1998; Devine et al., 1998a, 1998b). The forage soybean cultivars 'Derry', 'Donegal', and 'Tyrone' had average forage yields of 9.3 Mg ha^{-1} compared with 7.6 Mg ha^{-1} for grain soybean cultivars in Iowa, New York, and Virginia. These new forage soybean cultivars have different relative maturity and stem traits than grain cultivars and may respond differently to changes in row spacing and harvest date. Our objective was to determine the effect of the harvest date and row spacing on the forage yield and quality of forage soybean in the upper Midwest.

MATERIALS AND METHODS

Separate studies were conducted in 1995 and 1996 at the Rosemount Experiment Station, Rosemount (44°43′ N, 93°06′ W), MN and at the Southern Experiment Station, Waseca (44°04′ N, 93°31′ W), MN. The soil at Rosemount was a Waukegan silt loam (fine-silty over sandy-skeletal, mixed mesic Typic Hapludoll), and at Waseca, it was a Webster clay loam (fine-loamy, mixed mesic Typic Haplaquoll). The Soil pH, extractable P, and exchangeable K were maintained at 6.5, 70 kg ha^{-1}, and 300 kg ha^{-1}, respectively, at Rosemount. At Waseca, the soil pH, extractable P, and exchangeable K were 6.5, 50 kg ha^{-1}, and 300 kg ha^{-1}, respectively. Weed control at both locations was achieved by a preemergence application of trifluralin [2,6-dinitro-*N*, *N*-dipropyl-4-(trifluoromethyl) benzenamine] at 1 kg a.i. ha^{-1}. The previous crop at both locations was corn.

The 1995 experiment was planted on 5 May at Rosemount and 2 May at Waseca. The experimental design was a split-plot with three replicates. Whole plots were two harvest dates and subplots were 10 soybean entries. All of the plots were 3 m wide by 6 m long, with soybean planted at 90 kg ha^{-1} (475 000 seeds ha^{-1}). The plots contained 4 rows spaced 76 cm apart. The soybean entries planted in 1995 included seven forage types: The varieties Tyrone, Derry, and Donegal (Devine and Hatley, 1998; Devine et al., 1998a, 1998b) and the experimental lines OR 13-12-3, OR 14-11-2, OR 19-12-2, and PA 5-2-1 that were developed at Beltsville, MD. Two types of standard grain soybean was included: 'Sturdy', developed at the University of Minnesota as a high-yielding grain soybean (Orf et al., 1991); and 'IA 2008 BC', developed at Iowa State University. Wisconsin Black (WISC.BK; PI 153271), an older forage-type soybean of Belgian origin, was also included (USDA-ARS, 1999). The maturity groups for soybean entries are shown in Table 1.

Table 1. Maturity of soybean entries at early and late harvests in 1995 and 1996. Maturity was defined using R-stage criteria (Fehr et al., 1971).

Soybean entry	Maturity group	1995 Early	1995 Late	1996 Early	1996 Late
		R stage†			
Forage type					
OR 5-12-1T	**V**	**4**	**5**	**3**	**4**
OR 13-12-3	**VI**	**3**	**5**	**na‡**	**na**
OR 14-11-2	**VI**	**3**	**5**	**na**	**na**
Derry	**VI**	**3**	**5**	**2**	**4**
OR 19-12-2	**V**	**4**	**5**	**na**	**na**
PA 5-2-1	**IV**	**5**	**6**	**4**	**6**
Donegal	**V**	**4**	**6**	**5**	**5**
Tyrone	**VII**	**na**	**na**	**2**	**2**
Average		**3**	**5**	**3**	**4**
Sturdy	**II**	**6**	**8**	**6**	**8**
IA 2008 BC	**II**	**6**	**7**	**na**	**na**
IA 2007 R	**II**	**na**	**na**	**6**	**7**
Average		**6**	**7**	**6**	**7**
WISC.BK	**I**	**7**	**7**	**na**	**na**
Average all types		**4**	**6**	**4**	**6**

† R3, beginning pod; R4, full pod; R5, beginning seed; R6, full seed (greed seed); R7, beginning maturity.
‡ Data not available.

The 1996 experiment was planted on 28 May at Rosemount and 30 May at Waseca. The experimental design was a split-split plot with three replicates. Whole-plot treatments were two harvest dates, subplot treatments were two row widths (25 and 75 cm), and sub-subplot treatments were seven soybean entries. The plot size and seeding rate were similar to those used in 1995, except that the plots contained either four rows spaced 75 cm apart or eight rows spaced 25 cm apart. The soybean entries included five forage types (Tyrone, Derry, PA 5-2-1, Donegal, OR 5-12-16) and two standard grain types (Sturdy and IA 2007 R).

Each year, the soybean forage yield was measured by harvesting a 2- by 5- m area from the middle of each plot. A randomly collected 10-plant subsample of soybean forage was manually cut to a 2-cm height and was chopped for analysis of the whole-plant moisture and forage quality. The whole-plant moisture content was determined by drying a 500-g sample at 60°C for 48 h. An additional 10-plant subsample was staged for maturity (Fehr et al., 1971) and separated into leaf, stem, and pod fractions before drying. The leaf fraction included leaves and petioles, the stem fraction included stems, and the pod fraction included pods and seeds.

Soybean forage was harvested on 31 Aug. and 19 Sept. 1995 at Rosemount and on 8 and 22 Sept. 1995 at Waseca. All of the entries were harvested at the early harvest date at both locations. Only the seven forage types were harvested at the late harvest date in 1995 because the early maturing grain types and WISC.BK had significant leaf loss. In 1996, the seven soybean entries were harvested on 3 and 19 September at Rosemount and on 10 September and 1 October at Waseca. The early and late harvest dates were selected based on an average target maturity stages of R6 and R7 for the grain soybean, respectively. Because of the diversity of maturity among the entries, it was not possible to harvest all of the entries at a similar maturity.

In 1995, forage quality analysis was conducted on OR 13-12-3, OR 14-11-2, PA 5-2-1, Sturdy, and WISC.BK at the early harvest and on OR 13-12-3, OR 14-11-2, and PA 5-2-1 at the late harvest. In 1996, forage quality analysis was done on Derry, PA 5-2-1, Tyrone, and Sturdy at both harvests. Whole-plant and plant fraction samples were ground to pass a 1-mm screen. Forage dry matter subsamples of whole-plant samples and plant components of selected entries were analyzed for CP, acid-detergent fiber (ADF), and NDF via near-infrared reflectance spectroscopy (NIRS). Spectra for NIRS analysis were collected with a NIRSystems[1] (Silver Springs, MD) Model 6500 scanning monochrometer with a range of 400 to 2500 nm. A calibration set of samples was selected. Samples in the calibration set were analyzed for NDF and ADF according to the procedures of Goering and Van Soest (1970) and for Kjeldahl CP (Kjeldahl N × 6.25). Results from analysis of the calibration set were used to develop prediction equations using the Infrasoft International (ISI, Port Matilda, PA) NIRS 3 v. 4.0 software program Calibrate, with the modified

[1] Mention of a proprietary product does not constitute a recommendation or warranty of the product by the University of Minnesota and does not imply approval to the exclusion of other suitable products.

partial least squares regression option (Shenk and Westerhaus, 1991). The standard errors of calibration for CP, ADF, and NDF were 8.0, 9.4, and 8.3 g kg^{-1}, respectively, and the R^2 values for all variables were >0.99.

Statistical Analysis

Data on the yield; proportion of leaf, stem, and pod components; and forage quality of the leaf, stem, pod, and total herbage were subjected to analyses of variance via the general linear models (GLM) procedure of SAS (SAS Inst., 1996). Years were analyzed separately because different soybean entries and different experimental designs were used in 1995 and 1996. In 1995, data on the forage yield and the leaf, stem, and pod proportion for the seven forage soybean were analyzed as a split-plot design, with the harvest dates as whole plots and the entries as subplots. The homogeneity of error variances was tested on the within-location analyses using Bartlett's test (Steel and Torrie, 1980). The combined analysis across two locations was done following the procedures of Gomez and Gomez (1984). Data on the forage yield and the leaf, stem, and pod proportion for 10 soybean entries in the early harvest were analyzed in a split-plot design, with the entries as treatments and combined across two locations. Forage quality data for five soybean entries at early harvest were analyzed in a split-plot design, with the entries as treatments and combined across two locations. The randomized complete block analysis showed significant location × entry interactions for forage quality, so three contrasts of entries were tested within the locations: grain type vs. forage type, grain type vs. WISC.BK, and forage type vs. WISC.BK.

In 1996, data on the forage yield and the leaf, stem, and pod proportion from seven entries, including five tall forage types and two grain types, were analyzed as a split split-plot design, with the harvest dates as whole plots, the row widths as subplots, and the soybean entries as sub-subplots combined across two locations. A similar split split-plot design combined across locations was used to analyze the forage quality data from Derry, PA 5-2-1, Tyrone, and Sturdy. There were significant location × harvest date × entry interactions for the total herbage CP, ADF, and NDF; however, the entry rankings remained the same in all four location × harvest date combinations, and there were only magnitude differences between the harvests. Therefore, a grain type vs. forage type contrast was tested within locations following the split split-plot analyses.

Table 3. Forage yields of soybean entries at Rosemount and Waseca, MN in 1995 and 1996.

Soybean entry	1995† Rosemount	1995† Waseca	1996 Rosemount	1996 Waseca
	Mg ha^{-1}			
Forage type				
OR 5-12-1T	7.1	9.1	10.7	10.6
OR 13-12-3	6.7	9.6	na‡	na
OR 14-11-2	7.7	9.0	na	na
Derry	6.8	9.6	10.0	9.8
OR 19-12-2	6.7	8.0	na	na
PA 5-2-1	6.5	8.4	10.3	9.1
Donegal	6.4	9.2	10.0	8.8
Tyrone	na	na	10.7	9.6
Average	6.8	9.0	10.3	9.6
Grain type				
Sturdy	7.4	7.2	10.4	8.5
IA 2008 BC	6.7	9.0	na	na
IA 2007 R	na	na	10.7	9.5
Average	7.1	8.1	10.6	9.0
WISC.BK	5.5	5.9	na	na
Entries $LSD_{0.05}$§	1.4	1.3	0.6	0.8
Types $LSD_{0.05}$¶	0.4	0.8	0.6	0.5

† Data from early harvest only in 1995 due to lack of late harvest data for grain soybean and Wisconsin Black (WISC.BK). In 1996, data are averaged for early and late harvests.
‡ Data not available; entry not evaluated.
§ Least significant difference (α = 0.05) for comparing soybean entries within location-years.
¶ Least significant difference (α = 0.05) for comparing averages of soybean types within location-years.

RESULTS AND DISCUSSION

Harvest Date and Soybean Entry Effects

The dry matter yield of soybean forage increased from the early to late harvest date at both locations and for all soybean entries in 1995 and 1996. There were no location × harvest date or harvest date × entry interac-

Table 2. Analysis of variance for total herbage yield and proportions of leaf, stem, and pod material in grain, forage, and Wisconsin Black (WISC.BK) soybean in 1995 and 1996†.

	F-values from analysis of variance							
	1995				1996			
Source of variation	Yield	Leaf	Stem	Pod	Yield	Leaf	Stem	Pod
Location	32.8**	50.8**	17.7**	271.7**	40.4**	206.1**	1.6	66.6**
Rep(Location)								
Entry	8.1**	55.4**	70.7**	392.8**	5.8**	270.8**	151.9**	914.0**
Location × Entry	2.7*	4.6**	2.5*	15.4**	3.2**	7.8**	<1	11.0**
Rosemount								
Grain vs. Forage‡	0.3	74.9**	193.3**	1191.7**	1.4	624.5**	481.1**	2019.2**
Grain vs. WISC.BK	26.2**	11.0**	<1	27.6**				
Forage vs. WISC.BK	37.5**	208.5**	255.2**	2214.5**				
Residual	1.8	<1	2.6	7.7*	2.1	15.3**	43.1**	107.7**
Waseca								
Grain vs. Forage	6.6*	298.5**	312.7**	1327.4**	6.3*	737.4**	363.4**	2922.3**
Grain vs. WISC.BK	15.4**	1.7	3.8	11.9**				
Forage vs. WISC.BK	41.2**	131.0**	121.4**	546.5**				
Residual	<1	9.3**	13.7**	49.7**	16.1**	48.3**	17.4**	166.5**

* Significant at the 0.05 level.
** Significant at the 0.01 level.
† 1995 analysis includes early harvest data only. In 1996, the analysis is for an average of early and late harvests.
‡ Grain soybean entries were Sturdy and IA 2008 BC in 1995 and Sturdy and IA 2007 R in 1996. Forage soybean entries in 1995 were Derry, Donegal, OR 5-12-1T, OR 13-12-3, OR 14-11-2, OR 19-12-2, and PA 5-2-1. In 1996, forage entries were Tyrone, Derry, Donegal, PA 5-2-1, and OR 5-12-1T. WISC.BK was only planted in 1995, not in 1996.

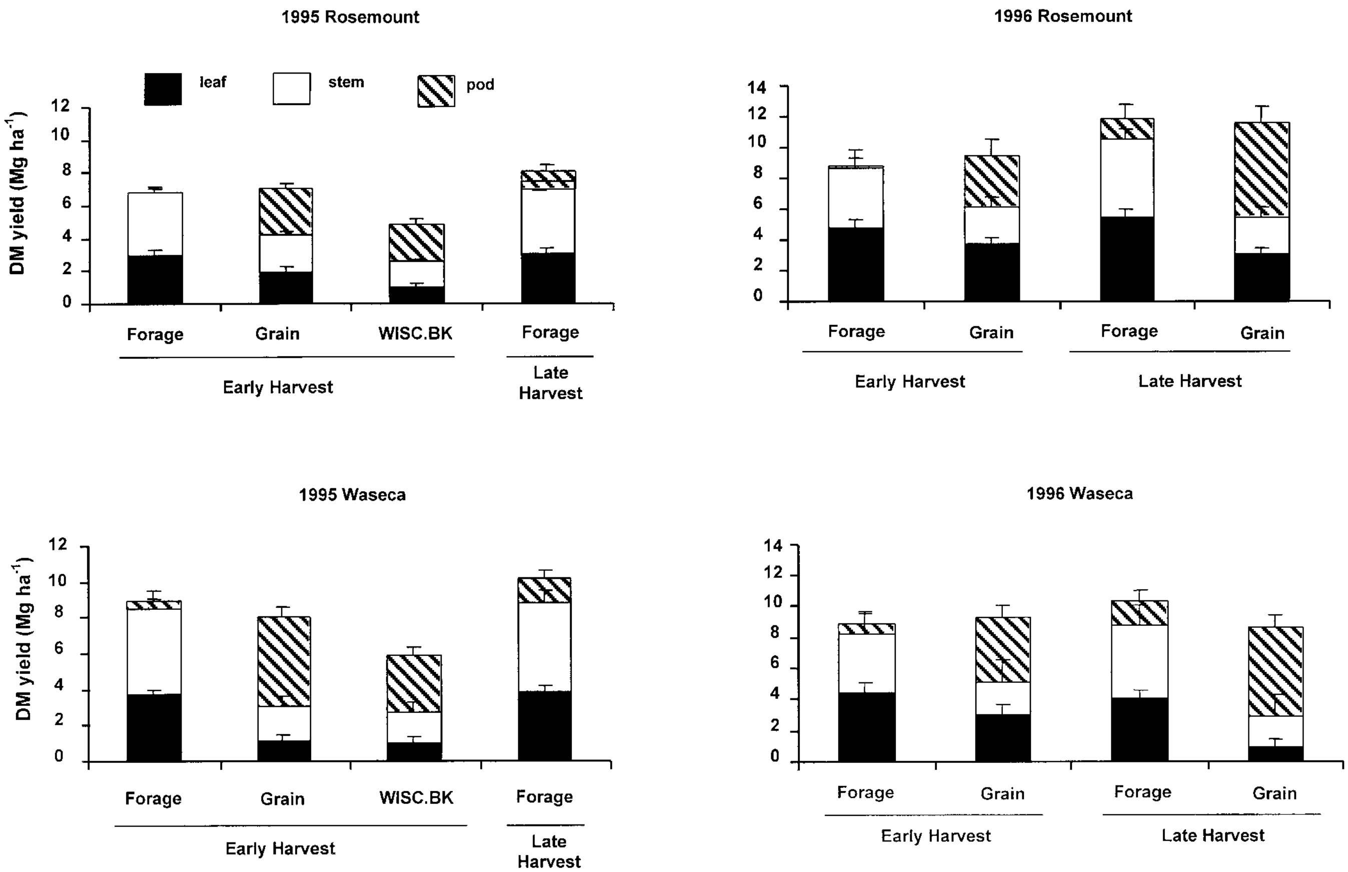

Fig. 1. Average total dry matter (DM) yield and proportion of leaves, stems, and pods of forage, grain, and Wisconsin Black (WISC.BK) soybean at early harvest and forage soybean at late harvest in 1995; and forage and grain soybean at early and late harvest in 1996. In 1995, data are the average for the forage soybean OR 5-12-1T, Derry, Donegal, OR 13-12-3, OR 14-11-2, OR 19-12-2, and PA 5-2-1; and for the grain soybean Sturdy and IA 2008 R. In 1996, the forage soybean were Tyrone, Derry, Donegal, OR 5-12-1T, and PA 5-2-1; and the grain soybean were Sturdy and IA 2007 R.

tions for the yield in 1995. The location × harvest date interaction in 1996 was due to magnitude differences, and the harvest date × entry interaction was due to magnitude differences plus one entry rank change; thus, we will discuss the harvest date means for yield. In 1995, an average maturity increase for all soybean types from R4 at early harvest to R6 at late harvest coincided with a 20% yield increase—from 7.9 to 9.2 Mg ha^{-1}. Likewise, in 1996, the yield increased by 20%—from 9.0 to 10.8 Mg ha^{-1} from early to late harvest. This was accompanied by increases in the average maturity—from R3 to R4 for forage types and from R6 to R7 for grain types. An enhanced forage yield with maturity is consistent with results of Hintz et al. (1992) and Munoz et al. (1983), who reported increases in soybean forage yield up to R7.

The soybean entries differed in yield, but the differences were not consistent over years and locations within forage or grain types. The soybean type and maturity group were confounded in this study because the forage-type soybean entries were in maturity groups V, VI, or VII, but the grain entries and WISC.BK were in maturity groups I or II. Contrast analysis revealed that there were yield differences between the soybean types at Rosemount and Waseca in 1995 and at Waseca in 1996 (Table 2). The forage and grain-type soybean yielded 25 to 50% more than WISC.BK in 1995 (Table 3). Grain and forage types had similar average yields at Rosemount in both years, but the forage types had average yields that were slightly higher at Waseca. These small differences in yield between forage and grain types contrast to the 23% yield advantage reported in Iowa (Devine et al., 1998a) for the forage type, Derry, compared with a standard grain soybean, 'Sherman'. A comparison of the average 1995 grain-type yields from the early harvest with the average forage-type yields from the late harvest showed greater yields from the forage types at both locations (Fig. 1) even though the late-harvested forage types still lagged in maturity compared with the early-harvested grain types. The grain and forage soybean yields were similar at the early and late harvests at both locations in 1996 even though the forage types lagged an average of three R stages behind the grain types at both harvests. These results suggest that forage soybean would have superior dry matter yields to the grain types if harvested at a similar maturity stage. Our maximum forage yields (~9 and 10 Mg ha^{-1} for grain and forage soybean, respectively) exceeded those reported by Hintz et al. (1992) for grain soybean in southern Wisconsin. Our soybean forage yields were often greater than those reported for commonly used single- or multiple-cut alternative forages grown in Minnesota such as sudangrass [*Sorghum* × *drummondii* (Steudel)

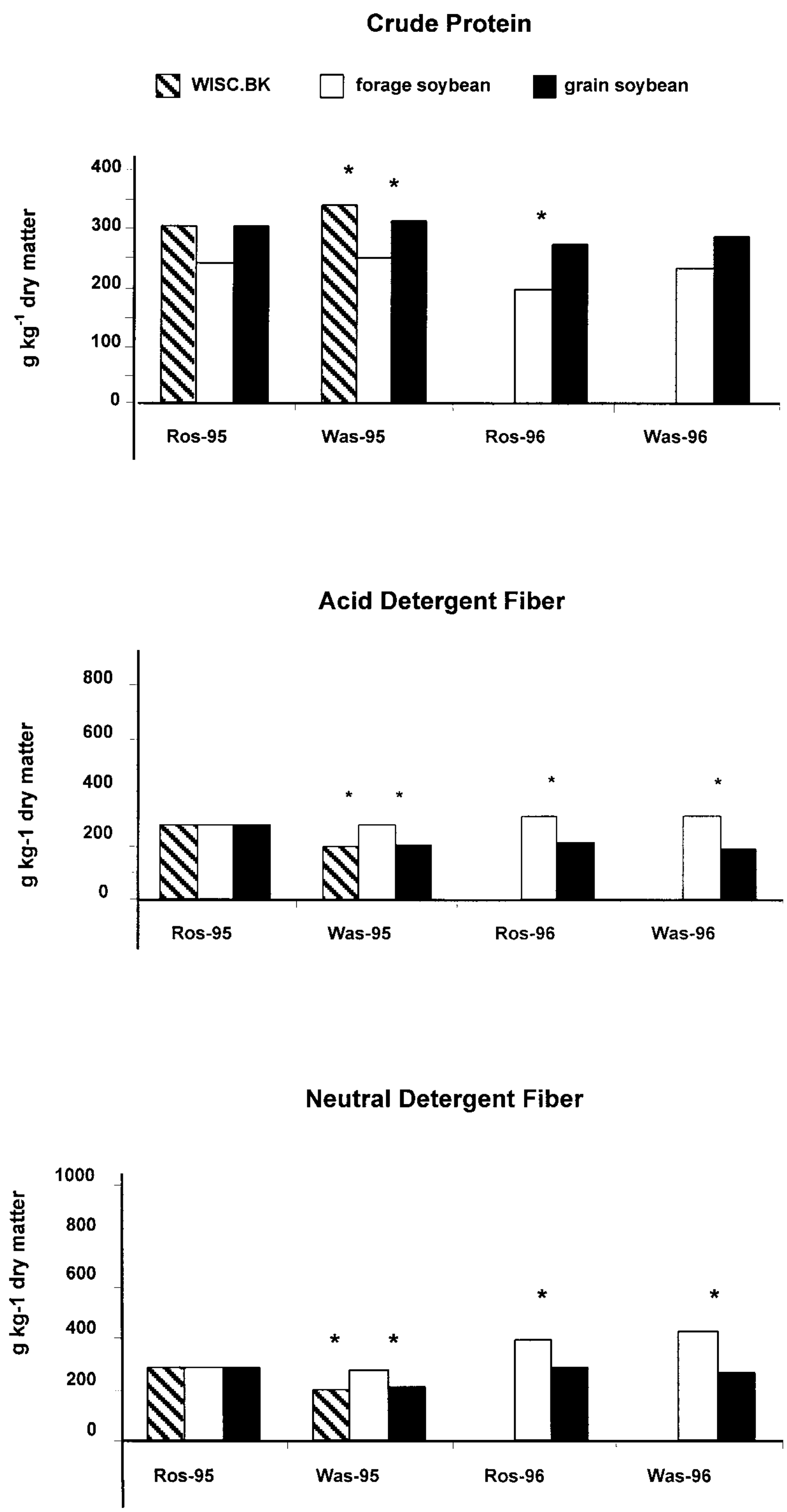

Fig. 2. Average crude protein (CP), acid-detergent fiber (ADF), and neutral-detergent fiber (NDF) concentrations of soybean leaves and stems at early harvest for forage, grain, and Wisconsin Black (WISC.BK) soybean at Rosemount (Ros) and Waseca (Was), MN. In 1995, data are average for the forage soybean OR 13-12-3, OR 14-11-2, and PA 5-2-1; and for the grain soybean Sturdy and Wisconsin Black (WISC.BK). In 1996, the forage soybean were Derry, PA 5-2-1, and Tyrone. The grain soybean was Sturdy.

Millsp. & Chase] and pearl millet [*Pennisteum americanum* (L.) Leeke] (Martin and Linn, 1992).

Maturity differences due to the harvest date and soybean type interacted to affect the proportion of leaves, stems, and pods in soybean forage. For forage soybean in 1995, the leaf proportion declined by about 12%, the stem proportion declined by 6%, and the pod proportion increased nearly 300% between the early and late harvest even though the pod fraction was very small. Late-harvest data were not available for grain and hay

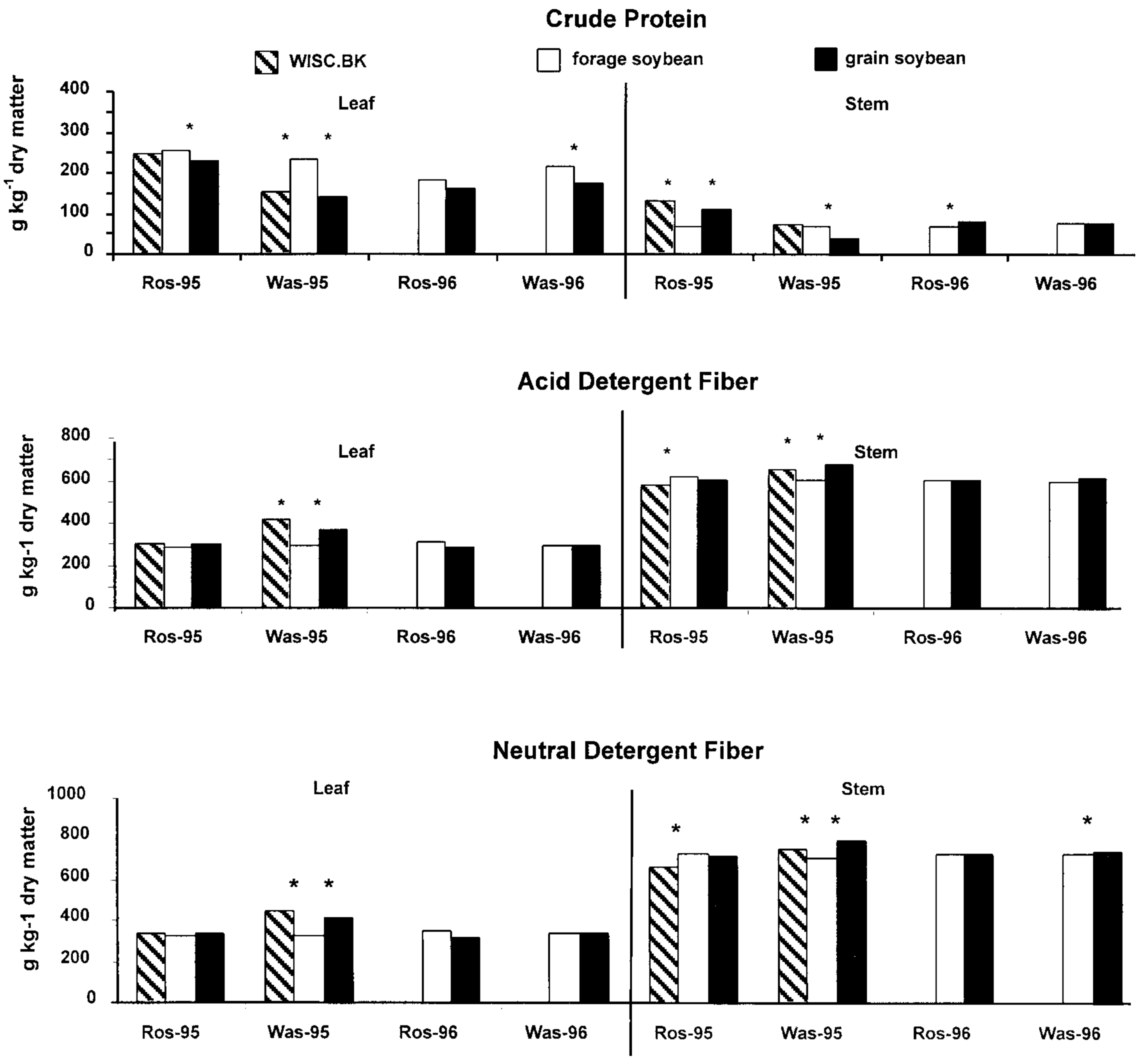

Fig. 3. Average crude protein (CP), acid-detergent fiber (ADF) and neutral-detergent fiber (NDF) concentrations in pods at early harvest for forage, grain, and Wisconsin Black (WISC.BK) soybean at Rosemount (Ros) and Waseca (Was), MN. In 1995, data are the average for the forage soybean OR 13-12-3, OR 14-11-2, and PA 5-2-1; and the grain soybean Sturdy and WISC.BK. In 1996, the forage soybean were Derry, PA 5-2-1, and Tyrone. The grain soybean was Sturdy. By harvest at Rosemount in 1995, and at both locations in 1996, the only forage soybean with pods was PA 5-2-1; thus, the values for the pod quality at these three site-years are the averages for PA 5-2-1.

types in 1995. For grain and forage types in 1996, the leaf proportion declined by about 34%, the stem proportion did not change, and the pod proportion nearly doubled between the early and late harvests. The leaf, stem, and pod proportion of forage soybean differed from grain types and WISC.BK at all locations and for all years.

Within a harvest date, forage soybean had more leaf and stem yield and less pod yield than grain soybean each year at both locations and more leaf and stem yield and less pod yield than WISC.BK at the early harvest in 1995 (Fig. 1). A comparison of soybean types for the leaf, stem, and pod proportion was possible at the early harvest in 1995. The dry matter yield of forage soybean at an average maturity of R3 was composed of approximately equal proportions of leaf and stem material, with very little yield from pods. The more mature (R6 and R7) grain entries and WISC.BK contained 440 and 580 g kg^{-1} pods at Rosemount and Waseca, respectively. A comparison of forage and grain soybean in 1996 showed that the pod contribution to the forage yield of forage soybean was minimal at the early harvest and 10 g kg^{-1} at the late harvest. The leaf contribution was 400 g kg^{-1} for forage types at the late harvest. The pod contribution for the grain soybean increased from 350 g kg^{-1} at the early harvest to 530 g kg^{-1} at the late harvest at Rosemount and from 450 to 660 g kg^{-1} at Waseca. Increases in the grain-type pod proportion were accompanied by decreases in the leaf proportion and an increase in maturity—from R6 to R7. Hintz and Albrecht (1994) reported a leaf, stem, and pod proportion of 168, 282, and 485 g kg^{-1}, respectively, for grain soybean at R7. Thus, the grain soybean and WISC.BK in this study had leaf, stem, and pod proportions that were similar to previous reports; but the less-mature forage soybean entries had less pod and more leaves.

Maturity and possibly other differences between soybean types affected the forage quality of the leaves,

Table 4. Analysis of variance for total herbage crude protein (CP), acid-detergent fiber (ADF), and neutral-detergent fiber (NDF) for soybean in 1995 and 1996.†

	F-values from analysis of variance					
	1995			1996		
Source of variation	CP	ADF	NDF	CP	ADF	NDF
Location	<1	19**	34**	73**	5	<1
Rep(Location)						
Entry	489**	219**	163**	121**	311**	290**
Location × Entry	4*	3*	8**	2	2	3
Rosemount						
Grain vs. Forage‡	536**	546**	414**	87**	515**	489**
Grain vs. WISC.BK	5	14**	2			
Tall vs. WISC.BK	415**	356**	347**			
Residual	27**	35**	38**	6*	10**	2
Waseca						
Grain vs. Forage	767**	283**	237**	322**	399**	369**
Grain vs. WISC.BK	<1	19**	21**			
Tall vs. WISC.BK	719**	132**	97**			
Residual	35**	4	<1	15**	<1	2

* Significant at the 0.05 level.
** Significant at the 0.01 level.
† Early harvest data only in 1995. In 1996, the analysis was for an average of early and late harvests.
‡ Grain soybean entry was Sturdy in 1995 and 1996. Forage soybeans in 1995 were OR 13-12-3, OR 14-11-2, and PA-5-2-1. In 1996, forage entries were Tyrone, Derry, and PA 5-2-1. Wisconsin Black (WISC.BK) was only planted in 1995, not in 1996.

stems, and pods. As previously reported by Hintz et al. (1992) for grain soybean, the stems of all of the soybean entries had a lower forage quality; that is, they had lower CP and a higher ADF and NDF than the leaves or pods. In our study, the leaves of forage soybean usually had higher CP than the leaves of grain soybean because forage soybean had no significant seed production (Fig. 2 and 3). During grain formation, N is translocated from the leaves to grain (Hanway and Weber, 1971). Grain and WISC.BK soybean had pods that were higher in quality than leaves, but for forage types with little seed development, the pods often had a forage quality that was similar to leaves. The lower pod CP and higher pod ADF and NDF in forage than in grain soybean was likely due to a greater proportion of high-quality seeds in the more mature grain types. By harvest at Rosemount in 1995, and at both locations in 1996, the only forage soybean with pod development was PA 5-2-1; thus, the values for the pod quality at these sites are averages for this entry.

Contrast analysis showed that forage soybean differed from grain and WISC.BK soybean for the CP, ADF, and NDF of the total herbage at both locations (Table 4). Forage soybean had lower CP and higher ADF and NDF in the total herbage than either grain or WISC.BK at both locations in 1995 (Table 5) and lower CP and higher ADF and NDF in the total herbage than grain soybean at both locations in 1996 (Table 6). This difference in the total herbage forage quality was related to the maturity; therefore, it was related to the leaf, stem, and pod proportion of the forage as well as the seed proportion of the pod fraction. Forage from mature grain and WISC.BK soybean with a large proportion of high-quality pod material had the highest forage quality. Less-mature forage soybean with little pod and seed had the lowest forage quality. The forage soybean PA 5-2-1 had the highest CP and the lowest ADF and NDF of the tall types in 1995, and it had similar quality as Derry in 1996. More research is needed to determine whether a forage soybean at R6 or R7 would have forage quality comparable to that of a grain soybean at R6 or R7.

Row Width Effects

Reducing the row width increased the soybean dry matter yields at both locations. Soybean that was sown in narrow (25 cm) rows produced an average dry matter yield of 10.3 Mg ha^{-1} while soybean sown in wide (76 cm) rows produced an average dry matter yield of 9.5 Mg ha^{-1} (LSD = 0.3 Mg ha^{-1}). There was no row width × entry interaction, which indicated that narrow rows increased yields similarly for both forage and grain soybean. Hintz et al. (1992) had reported a 1.2 Mg ha^{-1} yield increase for grain soybean as the row spacing decreased from 76 to 20 cm.

The forage quality of the total herbage, leaves, and pods was not affected by the row width, but the row width had a small effect on the stem ADF and NDF concentration. The stem ADF concentration was 596 and 603 g kg^{-1}, respectively, for narrow and wide rows (LSD = 7 g kg^{-1}). The stem NDF concentration was 707 and 719 g kg^{-1}, respectively, for narrow and wide

Table 5. Forage quality in total herbage of soybean entries at Rosemount and Waseca, MN at early harvest in 1995.

	Rosemount			Waseca		
Soybean entry	CP†	ADF‡	NDF§	CP	ADF	NDF
	g kg^{-1} dry matter					
OR 13-12-3	143	486	565	132	469	541
OR 14-11-2	137	492	571	145	459	534
PA 5-2-1	160	461	539	158	447	529
Average	147	480	558	145	458	535
Sturdy	230	375	467	233	325	386
WISC.BK	220	395	475	230	367	440
$LSD_{0.05}$¶	10	13	13	9	22	27

† CP, crude protein.
‡ ADF, acid-detergent fiber.
§ NDF, neutral-detergent fiber.
¶ Least significant difference for comparing soybean entries.

Table 6. Forage quality in total herbage of soybean entries at Rosemount and Waseca, MN. Average of early and late harvests in 1996.

	Rosemount			Waseca		
Soybean entry	CP†	ADF‡	NDF§	CP	ADF	NDF
	g kg^{-1} dry matter					
Derry	145	423	492	158	403	475
PA 5-2-1	149	416	496	162	419	507
Tyrone	125	443	516	136	440	517
Average	140	427	501	152	421	500
Sturdy	190	314	378	218	302	368
$LSD_{0.05}$¶	14	13	14	9	15	17

† CP, crude protein.
‡ ADF, acid-detergent fiber.
§ NDF, neutral-detergent fiber.
¶ Least significant difference for comparing soybean entries.

rows (LSD = 9 g kg^{-1}). These forage quality differences are not likely to have practical significance, especially because differences in the total herbage forage quality were apparently determined mostly by the pod fraction. Our results on the impact of row spacing on yield and quality are consistent with those of Hintz et al. (1992), except we saw no effect of the row spacing on the CP concentration, and our forage yield differences were somewhat less.

CONCLUSIONS

Previous research (e.g., Hintz et al., 1992) has shown that the greatest yield and highest quality of soybean forage is reached at R6 to R7 when the pod proportion of the total forage is high. This occurs because the grain component is high in quality, and the plant has not had significant leaf loss. In Minnesota, tall forage soybean in maturity groups V, VI, and VII did not reach these R stages at harvest in late September before a killing frost. Although the forage yield was similar to adapted maturity group II cultivars, the forage quality was less because of a lack of grain production. A tall forage soybean cultivar that is adapted to upper Midwest latitude and climatic conditions and will reach the R6 stage by harvest may have an improved dry matter yield and similar forage quality compared with existing tall forage cultivars. Forage and grain soybean should be grown in 25-cm rows rather than 76-cm rows to increase the dry matter yield.

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