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Factors Affecting Production of Corn Forage[1]

JAIRO SILVA AND ARNEL R. HALLAUER[2]

Effects of plant densities, hybrid maturities, and harvesting dates were studied for production of forage corn (*Zea mays* L.) in northeastern Iowa. Biomass and grain weights increased with later harvest dates, but stover weight decreased with later harvest dates. Maximum dry weight of biomass was obtained by harvesting late-maturity hybrids at 60 days after flowering (physiological maturity) at the highest plant density (72.4 M plants/ha). Harvest indices decreased with higher plant densities, increased with later harvest dates, and decreased for later-maturity hybrids. The three variables studied (plant densities, hybrid maturities, and harvest dates) affected the amount of forage corn produced, but further study is needed to relate quantity of forage produced and silage quality.

INDEX DESCRIPTORS: Maize, *Zea mays* L., silage, harvest date, hybrid maturity, plant density, harvest index.

Corn (*Zea mays* L.) is an important forage species in the United States and other parts of the world. Forage corn occupied 10.5% of the 1979 corn acreage in the United States and the importance of forage corn is increasing in Europe (Schukking, 1979). Corn silage in Iowa has averaged 5.9% of the total corn acreage (Iowa State Dep. Agric., 1979). Quantity and quality of forage corn are considered important for efficient use of land, and the ability of corn to produce high dry-matter yield of good-quality forage is contributing to its greater use, particularly in northern temperate areas. The primary objectives for the production of forage corn include high dry-matter yield per unit of land, high-quality forage for ruminants, and high dry-matter content to ensure proper ensiling with minimum losses. Breeders have developed cultivars having improved grain yield, cold tolerance, and lodging and pest resistance to permit growing corn in areas previously considered unsuitable, particularly for areas having shorter seasons to produce high-quality forage.

Most corn breeding efforts in North America and Europe have concentrated on developing lines and hybrids for grain production. Two main reasons for this approach are: 1) a general acceptance that the objectives of selection for good forage corn were realized by selection for good grain performance and 2) the relative ease of selection for grain yield only. Gunn (1975), however, questioned whether the selection of hybrids on the basis of grain performance was the most suitable method for selection of hybrids for improved forage production. He compared grain and forage corn for dry-matter yield, ear and dry-matter content, and resistance to lodging; his only conclusion was that ear dry matter was more digestible than stover dry matter. Because Roth et al. (1970) reported evidence of genetic variation for forage traits, Gunn (1975) suggested that corn-forage breeding programs should be established to include higher dry-matter yield, lower moisture content, improved feeding quality, and resistance to lodging.

Trials have been conducted that compared hybrids of different maturities under different management systems (Bryant and Blaser, 1968; Secor, 1969; Genter and Camper, 1973; Bonciarelli and Monotti, 1975). Conclusions from these studies were that: later-maturity hybrids had greater dry matter and in vitro digestible dry matter than earlier-maturity hybrids, earlier-maturity hybrids had a greater harvest index than later-maturity hybrids, and later-maturity hybrids took advantage of their longer functioning leaf area to produce more dry matter. Bryant and Blaser (1968) and Bonciarelli and Monotti (1975) reported that earlier hybrids had relatively greater proportions of grain yield but that the later hybrids had greater production of vegetative parts.

The objectives of our study were to determine 1) the effect of harvest stage on dry-matter yield, 2) the effects of plant densities and hybrid maturity on dry-matter yield, and 3) the effects of plant density and stage of harvest on harvest index of different-maturity hybrids for northeastern Iowa.

MATERIALS AND METHODS

Our study was conducted at the Northeast Iowa Research Center, Nashua, Iowa, in 1978, 1979, and 1980. Field design was a split-split-plot that included four replications each year. Three plant densities were established as the whole plots, and five different-maturity hybrids were the split plots within whole plots. Each split plot included four rows, spaced 76.2 cm, and 5.5 m long. Two rows of each split plot were used to determine mature-plant grain yield, and the plants in the other two rows were used to determine fresh and dry-matter forage yields for three sampling dates. Sampling dates were the split-split-plot treatments.

Three plant densities (whole plots) planned for each year were 50.4, 64.8, and 79.2 M plants/ha. Because of wet conditions, poor seed germination, and cultivator damage, final plant densities were only 39.8, 49.3, and 58.5 M plants/ha in 1978. Final densities were 48.0, 61.5, and 73.8 M plants/ha in 1979 and 50.6, 64.6, and 78.2 M plants/ha in 1980. Average stands for the three plant densities for the 3 years were 47.7, 61.1, and 72.8 M plants/ha. All plots were machine-planted, and some thinning was done to increase uniformity of stand. Growing conditions were very good each year.

Five open-pedigree hybrids were chosen that represented different maturity hybrids available to farmers in northeastern Iowa. The hybrids, their pedigrees, and their estimated relative maturities were:

Hybrid	Pedigree	Relative maturity	Days to 50% silking
1	A619Ht × A632Ht	Early	75.7
2	(H93 × H84)Va26Ht	Intermediate	79.8
3	A632Ht × H99	Intermediate	77.5
4	Mo17Ht × A632Ht	Late intermediate	78.9
5	B73Ht × Mo17Ht	Late	81.2

Hybrid 2 was a modified single cross, whereas the other four hybrids were single crosses. *Ht* was a single-gene trait incorporated in some of the parental lines that conditions resistance to northern corn leaf blight (*Helminthosporium turcicum* Pass.). All hybrids were selected because of their potential to produce high grain yield. Subsequent results showed that hybrid 2 was misclassified because its relative maturity was more similar to hybrid 5 than to hybrid 1.

Fertilizer was applied on all plots at rates considered necessary for high grain production: 196-134-134 kg/ha of elemental N, P_2O_5, and K_2O were applied for 1978, and 202-134-134 kg/ha of elemental N, P_2O_5, and K_2O were applied for 1979 and 1980. Phosphorous and K_2O

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were applied the preceding fall. Nitrogen was spring-applied preplant as anhydrous ammonia in 1978 and as urea in 1979 and 1980. Soybeans (*Glycine max* Merrill) were grown in each of the fields the previous year. Experiments were planted May 6, 1978, May 16, 1979, and May 7, 1980.

The number of days from planting to 50% silk emergence was recorded for all plots to establish the reference point for the three sampling dates. Sampling dates were 30, 45, and 60 days after 50% of the plants within each plot had visible silks. These dates corresponded to late milk, middough, and physiological maturity (black layer) stages. For each sampling date, five competitive plants were cut off near ground level for each hybrid at each plant density. Ears were immediately separated from culms, leaves, and husks. The stover (culms, leaves, and husks) for each five-plant sample was processed through a mechanical chopper in the field, weighed, and placed in a forced-air dryer for 72 hours at 65 C. Fresh weight of ears also was determined immediately after harvest and dried for 72 hours at 65 C. Dry weights of stover and ears were recorded. After weighing, the dried ears were shelled, and grain weight was recorded. Data, therefore, were recorded for each plant density, hybrid, and sampling date for the following traits: fresh stover, ear, and biomass (stover and ear) weights; dried stover, ear, and biomass weights; and dried grain weight. All data were converted from g/plot to t/ha. A harvest index was calculated based on dried stover and grain weights for each plant density, hybrid, and sampling date as grain weight/(grain weight plus stover weight).

Appropriate two-row plots of each split plot were harvested to determine mature-plant yield and grain moisture at harvest. Plots were hand-harvested in 1978 and machine-harvested in 1979 and 1980. Grain moisture was determined from a combined sample of grain for all replications for each hybrid in 1978. In 1979 and 1980, shelled grain weight and grain moisture were recorded for each plot. Grain yield at harvest maturity was corrected to 15.5% grain moisture and expressed as metric tons per hectare (t/ha).

Grain yield and grain moisture at harvest maturity, plant density, and days from planting to 50% visible silk were analyzed as a split-plot design. Split-plot data were used for these analyses. A split-split-plot analysis was used for the traits (fresh and dry stover weights, fresh and dry ear weights, dried grain weight, fresh and dry biomass weights, and harvest index) measured for the three sampling dates (30, 45, and 60 days after 50% silk). Analyses of variance were calculated for each trait for each year and combined for the 2 and 3 years. Results, however, will be given for only the combined analyses.

In 1978, only one forage harvesting date was sampled; Hoeffliger (1980), however, sampled the three dates and reported the laboratory analyses. Dried ear and grain weights were not recorded in 1978. Because grain moisture at harvest was determined from a bulk sample of kernels from ears from all replications in 1978, mean grain moisture was recorded for each entry, but an analysis of variance to determine an estimate of experimental error was not possible. Appropriate adjustments for degrees of freedom for the sources of variation were made in the analyses of variance. Complete data sets including the 30-, 45-, and 60-day sampling dates after 50% silk emergence were available for 1979 and 1980.

Product-moment correlation coefficients were calculated to determine the level of relationship between pairs of traits. The correlations were determined for the five hybrids, three plant densities, and three sampling dates. The linear and quadratic regression effects were determined for the plant densities and sampling dates on the different forage and grain traits. All effects except years were considered fixed in the analyses.

RESULTS

Combined analyses of variance for 1978-79 and 1978-80 data are summarized in Table 1. Main effects (plant densities, hybrids, and sampling dates) were significant ($P \leq 0.05$ or 0.01) in all instances except for harvest index for plant densities and hybrids and grain moisture at harvest maturity for plant densities. The plant density by year and hybrid by year interactions were significant for harvest index, and the tests of main effects of harvest index were not significant because of the large interaction effects and low power (df) of the F-tests. Linear response of harvest index for plant density approached significance at $P \leq 0.05$ level. Interactions of plant densities and years were significant only for the four interrelated traits of dry ear weight, dry biomass weight, dry grain weight, and harvest index. Interactions of hybrids by years, however, were significant for all traits except dry stover weight, fresh ear weight, dry biomass weight, and grain yield. There was a significant interaction of the effects of sampling dates and years for all instances. Except for the interactions of hybrids and sampling dates with years, most of the interaction effects were not significant (Table 1). Interactions of traits with years primarily were due to magnitudinal changes. The rankings among hybrids for grain moisture at harvest maturity, for example, were similar among the 3 years, but the 1979 grain-moisture readings were 7.6 and 6.2% greater than for 1978 and 1980, respectively. Interactions of hybrids with years for fresh stover weight, fresh biomass weight, and harvest index also were due to magnitudinal changes among years, which were influenced by the plant densities available each year.

Although the differences among sampling dates were signifiant in all instances, there also were significant interactions of sampling dates with years for all traits. Unlike the main effects of sampling dates and their interactions with years, very few of the interactions of sampling dates with plant densities and hybrids were significant. Stover and biomass fresh weights and harvest index were the only traits that had significant interactions with years and plant densities.

Means for plant densities, hybrids, and sampling dates for 12 traits are listed in Table 2. Amounts of forage and grain increased with greater plant densities, but the differences for ear and grain weights, however, were not significant when stands were greater than 61.1 M plants/ha. Later-maturity hybrids (based on days to 50% silk and grain moisture at harvest, Table 2) had greater fresh and dry weights and yields than did the earlier-maturity hybrids. Harvested grain yield significantly increased when plant density increased from 47.7 to 61.1 M plants/ha, but no further increase occurred from 61.1 to 72.8 M plants/ha; yield at 72.8 M plants/ha, however, was not significantly lower than at 61.1 M plants/ha. A619 × A632*Ht* has been a widely grown hybrid in northeastern Iowa. A619 × A632*Ht*, A632*Ht* × H99, and Mo17*Ht* × A634*Ht* had similar grain moisture at harvest maturity, but Mo17*Ht* × A634*Ht* had significantly greater stover, ear, and biomass weights than did the other two hybrids. B73*Ht* × Mo17*Ht* and (H93 × H84)Va26*Ht* were significantly later flowering and had significantly greater grain moisture at harvest than did A619 × A632*Ht*. Both hybrids were too late for commercial grain production in northeastern Iowa. But both B73*Ht* × Mo17*Ht* and (H93 × H84)Va26*Ht* had significantly greater fresh and dry weights of stover, ears, and biomass than did A619 × A632*Ht*. Though (H93 × H84)Va26*Ht* had greater tonnages than A619 × A632*Ht*, the hybrid had less ear weight than Mo17*Ht* × A634*Ht*, and A632*Ht* × H99; Mo17*Ht* × A634*Ht* had biomass weight similar to that of (H93 × H84)Va26*Ht*. (H93 × H84)Va26*Ht* produced a greater quantity of stover/ha, but it had a lower harvest index than did A632*Ht* × H99 and Mo17*Ht* × A634*Ht* (Table 2).

The greatest stover, ear, and biomass weights and grain yield at harvest were produced by B73*Ht* × Mo17*Ht*. B73*Ht* × Mo17*Ht*, however, is a long-season hybrid that generally is too late to be considered for grain production in northeastern Iowa. If the decision was made to produce only forage corn, then B73*Ht* × Mo17*Ht* could be used to produce maximum tonnage of stover and biomass. Mo17*Ht* × A634*Ht* seems an excellent compromise for producing

Table 1. Combined analysis of variance of 12 traits measured in experiments conducted at Nashua, Iowa, in 1978, 1979, and 1980.

Source	Degrees of freedom	Stover weight		Ear weight		Biomass weight	
		Fresh	Dry	Fresh	Dry	Fresh	Dry
Years (Y)	2 (1)[a]	**[b]	**	ns	ns	**	ns
Replications/Y	7 (6)	*	ns	ns	*	*	*
Plant densities (D)	2	**	**	**	**	**	**
Linear	1	**	**	**	*	**	**
Quadratic	1	*	ns	ns	ns	ns	ns
DY	4 (2)	ns	ns	ns	**	ns	*
Error a	18 (12)	2.65	0.13	0.38	0.11	3.82	0.45
Hybrids (H)	4	**	**	**	*	**	**
HY	8 (4)	**	ns	ns	*	**	ns
HD	8	*	*	ns	ns	*	ns
HDY	16 (8)	ns	ns	ns	ns	ns	ns
Error b	84 (72)	2.05	0.09	0.58	0.20	3.59	0.42
Sampling dates (S)	2	**	**	**	**	**	**
Linear	1	*	ns	ns	*	ns	ns
Quadratic	1	ns	ns	ns	ns	ns	ns
SY	2	**	**	**	**	**	**
SD	4	*	ns	ns	ns	*	ns
SH	8	ns	ns	ns	ns	ns	ns
SDY	4	ns	ns	ns	ns	ns	ns
SHY	8	**	**	ns	ns	**	ns
SHD	16	ns	ns	ns	ns	ns	ns
SHDY	16	ns	ns	ns	ns	ns	ns
Error c	180	1.54	0.08	0.54	0.18	3.25	0.37

Source	Degrees of freedom	Dried grain	Harvest index	Grain yield	Grain moisture	Days to 50% silk	Stand
Years (Y)	2 (1)	ns	ns	**	**	**	**
Replications/Y	7 (6)	*	**	ns	**	**	ns
Plant densities (D)	2	*	ns	**	ns	**	*
Linear	1	**	ns	ns	ns	**	*
Quadratic	1	ns	ns	**	ns	ns	ns
DY	4 (2)	**	*	ns	ns	ns	ns
Error a	18	0.12	2.4	2.4	3.6	8.6	53.7
Hybrids (H)	4	*	ns	**	**	*	ns
HY	8 (4)	*	**	ns	**	*	**
HD	8	ns	ns	ns	ns	ns	ns
HDY	16 (8)	ns	ns	ns	ns	ns	ns
Error b	84 (72)	0.16	2.7	1.9	3.4	2.7	28.1
Sampling dates (S)	2	**	*				
Linear	1	*	*				
Quadratic	1	ns	ns				
SY	2	**	**				
SD	4	*	ns				
SH	8	ns	ns				
SDY	4	ns	ns				
SHY	8	ns	ns				
SHD	16	ns	ns				
SHDY	16	ns	ns				
Error c	180	0.13	2.1				

[a] Degrees of freedom in parentheses for traits for which data were collected for only 2 years.

[b] * and ** indicate differences were significant at the 0.05 and 0.01 probability levels. ns indicates not significantly different.

large tonnages of stover, ears, and biomass, and the hybrid would have acceptable maturity if a portion of the area planted to the hybrid was to be harvested for grain. A619 × A632*Ht* and A632*Ht* × H99 have acceptable maturities for grain production, but both hybrids produced significantly less stover and biomass.

Sampling date data show the expected results for the three dates of harvest from 50% silk emergence. Fresh stover and biomass weights significantly decreased with later harvesting dates because of plant senescence (Table 2). Dried stover weight also decreased with later harvest dates because of less plant material available, but dried biomass weights increased because of greater ear weights. Fresh and dried ear, dried grain, and dried biomass weights increased with the later harvest dates. All these increases occurred because of increased grain filling with later harvesting. Ear moisture decreased about 10% for each of the two later harvest dates.

Trends for the harvest index were evident for plant densities and sampling dates; harvest index significantly decreased for greater plant densities and significantly increased with later sampling dates. These trends seem reasonable because ear size would be affected (reduced) by increased plant densities, and harvest index would be expected to increase with later sampling dates. Because of excellent growth conditions, plant development was good for all plant densities, but competitive effects for ear development would occur at higher plant densities. A greater harvest index for later sampling dates would be expected to occur because of 1) loss of plant material with senescence, 2) rapid grain fill until physiological maturity (approximately 60 days after flowering), and 3) translocation of sugars from culm to ears. Harvest index values ranged from 33.2% for (H93 × H84)Va26*Ht* to 41.1% for A632*Ht* × H99. The ratio of grain to biomass was poorest for (H93 × H84)Va26*Ht*, which produced 18.0 t/ha of dried biomass but only 6.2 t/ha dried grain. Mo17*Ht* × A634*Ht* had the second highest harvest index (38.9%) and seems to represent a good compromise between the earlier- and later-maturity hybrids for producing large tonnages of forage.

Table 2. Means of 12 traits for three plant densities, five hybrids, and three sampling dates measured in experiments conducted in 1978, 1979, and 1980 near Nashua, Iowa.

Main effects	Stover weight		Ear weight		Biomass weight		Dried grain
	Fresh	Dried	Fresh	Dried	Fresh	Dried	
	t/ha						
Densities, M/ha							
47.7	36.4	8.2	14.8	7.6	51.1	15.8	6.3
61.1	40.0	9.1	15.4	7.8	55.4	16.9	6.4
72.8	42.6	9.9	15.4	7.6	57.9	17.5	6.2
LSD (.05)	1.4	0.3	0.5	0.4	1.7	0.6	0.4
Hybrids							
A619 × A632*Ht*	35.3	8.3	14.3	7.3	49.6	15.5	6.0
(H93 × H84)Va26*Ht*	43.0	10.4	15.1	7.6	58.1	18.0	6.2
A632*Ht* × H99	35.9	8.1	15.4	8.2	51.3	16.3	6.8
Mo17*Ht* × A634*Ht*	41.6	9.1	16.6	8.4	58.2	17.5	6.9
B73*Ht* × Mo17*Ht*	46.7	10.4	16.6	8.3	63.3	18.6	6.9
LSD (.05)	0.7	0.1	0.4	0.3	0.9	0.3	0.2
Sampling dates[d]							
30	47.1	10.0	14.9	6.1	62.0	16.1	4.6
45	40.0	9.1	15.1	7.5	55.0	16.6	6.2
60	34.5	8.7	16.8	10.1	51.2	18.8	8.8
LSD (.05)	0.4	0.1	0.2	0.1	0.4	0.1	0.1
Average	40.5	9.3	15.6	7.9	56.1	17.2	6.6
C.V. (%)	12.1	12.6	18.5	21.3	13.0	13.6	21.7

Main effects	Harvest index	Yield[a]	Grain moisture[b]	Days to 50% silk[c]	Stand
	%	t/ha	%	no.	M/ha
Densities, M/ha					
47.7	39.6	10.0	22.9	77.1	47.7
61.1	37.0	11.6	23.3	78.2	61.1
72.8	34.5	10.8	23.4	79.2	72.8
LSD (.05)	1.3	1.3	1.6	2.5	6.3
Hybrids					
A619 × A632*Ht*	36.8	10.2	22.0	75.4	61.7
(H93 × H84)Va26*Ht*	33.2	11.3	25.2	79.6	60.1
A632*Ht* × H99	41.1	11.3	21.2	76.9	61.3
Mo17*Ht* × A634*Ht*	38.9	10.7	22.0	78.4	60.0
B73*Ht* × Mo17*Ht*	35.5	12.2	25.4	80.4	60.2
LSD (.05)	0.8	0.6	0.7	1.6	2.1
Sampling dates[d]					
30	28.0	—	59.1[e]	—	—
45	36.8	—	50.3[e]	—	—
60	46.5	—	39.9[e]	—	—
Average	37.1	11.2	23.2	78.2	60.7
C.V. (%)	12.3	12.5	7.9	2.1	8.7

[a] Yield of shelled grain at harvest maturity adjusted to 15.5% grain moisture.

[b] Moisture of shelled grain recorded at harvest maturity.

[c] Number of days from planting to 50% visible silks.

[d] Sampling dates were 30, 45, and 60 days after 50% visible silks were present.

[e] Moisture of ears calculated from the fresh and dry ear weight measurements.

Table 3. Ratios of dry weight and fresh weight for plant, ear, and biomass traits, harvest index, and growth rate index for three plant densities, five hybrids, and three sampling dates measured in experiments conducted in 1978, 1979, and 1980 at Nashua, Iowa.

	Dry weight/fresh weight			Fresh stover wt/ fresh biomass wt	Dried stover wt/ dried biomass wt	Harvest index[a]	Growth rate index[b]
	Stover	Ear	Biomass				
				%			
Stands, M/ha							
47.7	22.5	51.4	31.0	71.2	51.9	0.40	0.13
61.1	22.8	50.6	30.5	72.2	54.0	0.37	0.14
72.8	23.2	49.4	30.2	73.5	56.7	0.34	0.14
Hybrids							
A619 × A632*Ht*	23.4	50.6	31.2	71.1	53.4	0.37	0.13
(H93 × H84)Va26*Ht*	24.3	50.4	31.0	74.0	58.0	0.33	0.14
A632*Ht* × H99	22.6	53.3	31.7	69.9	49.9	0.41	0.13
Mo17*Ht* × A634*Ht*	22.0	51.0	30.1	71.5	52.2	0.39	0.14
B73*Ht* × Mo17*Ht*	22.2	50.2	29.4	73.8	55.6	0.36	0.15
	Dry weight/fresh weight			Fresh stover wt/ fresh biomass wt	Dried stover wt/ dried biomass wt	Harvest index[a]	Growth rate index[b]
	Stover	Ear	Biomass				
				%			
Sampling dates[c]							
30	21.2	40.8	26.0	75.9	62.1	0.28	0.15
45	22.8	49.6	30.2	72.6	54.9	0.37	0.13
60	25.2	60.4	36.7	67.2	46.1	0.46	0.14
Average	22.9	50.6	30.6	72.2	54.0	0.37	0.14

[a] Ratio of dried grain weight to dried biomass (plant and grain).

[b] Ratio of dried biomass (plant and grain) to days from planting to 45 days after 50% midsilk for all but the three sampling dates where days from planting to 30, 45, and 60 days after 50% midsilk.

[c] Three sampling dates were 30, 45, and 60 days after 50% midsilk.

Dry-weight to fresh-weight ratios, harvest indices, and growth-rate indices for plant densities, hybrids, and sampling dates are listed in Table 3. Averaged over plant densities, hybrids, and sampling dates, dry weights of stover, ears, and biomass to the respective fresh weights were 22.9, 50.6, and 30.6%. As expected, the ratios of dry weights to fresh weights increased with the later sampling dates. Ear dry weight increased about 10% with each sampling date. Fresh and dry stover relative to fresh and dry biomass had small increases with greater plant densities, but they decreased with later sampling dates. Relative to biomass, the later hybrids had the largest ratios. A growth rate index was calculated, but the differences among plant densities, hybrids, and sampling dates ranged from only 0.13 to 0.15. (H93 × H84)Va26*Ht* tended to have the largest ratios for the different traits, but it also had the smallest harvest index (Table 3).

Correlations for pairs of traits were relatively large and significant in most instances (Table 4). Fresh stover weight and days from planting to 50% silk emergence, for example, were significantly correlated with all traits. Later flowering was positively related with stover, ear, and biomass weights and with grain yield, and grain moisture at harvest. The only negative correlation of days from planting to 50% visible silks with the other traits was for harvest index; earlier-maturity hybrids had a greater harvest index than later-maturity hybrids. Harvest index, as expected, was negatively correlated with fresh and dry stover and biomass weights. Grain yield at harvest maturity was positively correlated with all traits except harvest index. Later-maturity hybrids produced greater quantities of stover, grain, and biomass, but they also had lower harvest indexes.

Table 4. Correlations between traits combined over hybrids and plant densities for experiments conducted in 1979 and 1980 at Nashua, Iowa.

Traits	Dried stover	Ear		Biomass		Dried grain	Harvest index	Grain yield	Grain moisture	Days to 50% silk
		Fresh	Dry	Fresh	Dry					
Fresh stover	0.93	0.71	0.44	0.99	0.98	0.36	−0.58	0.70	0.82	0.96
Dried stover		0.43	0.14[a]	0.88	0.92	0.05[a]	−0.80	0.60	0.95	0.95
Fresh ear			0.92	0.79	0.74	0.89	0.15[a]	0.63	0.19[a]	0.66
Dried ear				0.54	0.52	0.99	0.47	0.61	−0.10[a]	0.44
Fresh biomass					0.80	0.47	−0.48	0.72	0.74	0.95
Dried biomass						0.50	−0.51	0.76	0.78	0.99
Dried grain							0.55	0.59	−0.18[a]	0.36
Harvest index								0.14[a]	−0.90	−0.57
Grain yield									0.56	0.76
Grain moisture										0.83

[a] Correlations are not significantly different from zero; all others were significant for $P \leq 0.05$.

DISCUSSION

Three factors have been considered important in choosing corn hybrids for forage production: grain dry matter, dry-matter content of whole plants (biomass), and feeding value. Yield of grain and biomass and the ratio of these two components (harvest index) were considered in our study for five different maturity hybrids grown at three plant densities and sampled 30, 45, and 60 days after 50% midsilk. Dried biomass increased 10.8% from 47.7 to 72.8 M plants/ha and 16.8% from 30 to 60 days after 50% midsilk. Grain yield decreased 1.6% from 47.7 to 72.8 M plants/ha, but increased 34.8% from 30 to 45 days after midsilk or 91.3% from 30 to 60 days after midsilk. Differences in dried grain yield and biomass among hybrids were related to relative maturity. B73*Ht* × Mo17*Ht*, the latest hybrid, had 20% greater biomass when averaged over plant densities and sampling dates than did A619 × A632*Ht*, the earliest hybrid.

Harvest index decreased with greater plant densities (12.9% from 47.7 to 72.8 M plants/ha) and increased 66% from 30 to 60 days harvest after midsilk. The changes in harvest index among plant densities and sampling dates were related primarily to differences in dried grain for sampling dates and dried biomass for plant densities. The later-maturity hybrids also tended to have lower harvest indices, except (H93 × H84)Va26*Ht*, which had the greatest dried stover weight, but had lower dried grain weight. Dried biomass was greater for the higher plant densities and for the later maturity hybrids, but dried grain did not increase from the intermediate to highest plant density. Dried stover weight, however, increased significantly with greater plant densities. Our results were not consistent in all instances with those reported by Bryant and Blaser (1968), Secor (1969), Genter and Camper (1973), and Bonciarelli and Monotti (1975). Differences in results may be related to plant densities, relative maturity of hybrids, and relative tolerance of hybrids to range of plant densities included. For northeast Iowa, the intermediate plant density of 61.1 M plants/ha was representative of the planting rate for commercial grain production of hybrids having maturity similar to A619 × A632*Ht* and A632*Ht* × H99. Maximum tonnage of biomass was realized at the 72.8 M plants/ha for the latest maturity hybrids. B73*Ht* × Mo17*Ht* and (H93 × H84)Va26*Ht* were the latest maturity hybrids and both had significantly greater biomass than the earlier hybrids over all planting rates. Mo17*Ht* × A634*Ht*, however, would be a good choice; this hybrid was earlier than the two latest hybrids, but it had total biomass nearly as high as the two latest hybrids.

Greatest dried biomass and grain weights were obtained at the last (60 days after 50% mid-silk) harvest date. Fresh and dried stover weights decreased for the later harvest dates due to plant senescence. Increased grain weight from first harvest to approximate physiological maturity (60 days) compensated for the loss of leaf material. Grain moisture at 60 days after 50% mid-silk averaged 39.9%. If the greatest tonnage of forage corn was the primary concern (not considering the factors of forage quality), later maturity hybrids grown at greater than normal planting rates and harvested at approximate physiological maturity would be most appropriate.

Harvest index was suggested as a measure of plant efficiency (Donald, 1962) and as an indication of the partition of photosynthates (DeLoughery and Crookston, 1979). Although harvest index decreased with greater plant densities, the differences were not statistically significant. Contrasts among hybrids suggested that (H93 × H84)Va26*Ht* partitioned less photosynthate to the grain than did the other hybrids. Significant linear effects among harvest dates suggested more photosynthate was partitioned to the grain from the earliest to the latest harvest dates. Increased harvest indices with later harvest dates seem consistent with maturation of grain after flowering. It is during this period of corn development that there is a rapid translocation of photosynthate from the leaves and stalk to the kernels. Our estimates of harvest index were similar to those reported by DeLoughery and Crookston (1979). They also reported that harvest indices seemed more affected by environment than by plant density and hybrid maturity; significant interactions with years also were detected in our study (Table 1). Although the effects of harvest index were not significant in all instances, further studies should provide additional information for optimum plant densities for corn forage production. If certain standards were required for the ratio of grain to biomass for high quality forage, the harvest index would be a useful parameter. Harvest index also would be useful to determine the relative partitioning of photosynthate among hybrids; e.g., (H93 × H84)Va26*Ht*.

Data for quality of forage was not available from our study. Hoeffliger (1980) conducted preliminary analyses for the same experiments conducted in 1978 and 1979. Plant density effects were minimal for percentage of crude protein and in vitro digestible dry matter, and the differences among hybrids for nutritive value were not consistent for the 2 years. Although dry matter yield was greatest for B73*Ht* × Mo17*Ht*, it also was lowest for percentages of whole-plant in vitro digestible dry matter and crude protein. There were no disadvantages, as measured by percentages of in vitro digestible dry matter and crude protein, for harvesting at earlier stages except that an acceptable level of dry matter percentage would be needed to ensure proper fermentation. Hoeffliger (1980) concluded that there were differences among hybrids for yield and nutritive values, but that it may be difficult to select for hybrids that have both high grain yield and high quality silage.

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