# CORN MANAGEMENT

## Corn Hybrid Response to Planting Date in the Northern Corn Belt

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### ABSTRACT

**Growers frequently are concerned about the response of corn (*Zea mays* L.) to planting date. Early planting of corn is recommended because full-season hybrids utilize the entire growing season, achieve physiological maturity before a killing frost, and start to dry, thereby increasing profit through reduced drying costs. The objective was to evaluate the influence of planting date and hybrid maturity on corn grain yield and harvest moisture in Wisconsin. Two or three corn hybrids ranging in relative maturity from 80 to 115 d were planted between 19 April and 22 June at six locations in Wisconsin from 1991 to 1994. In southern Wisconsin locations, the optimum planting date for grain yield of full- and shorter-season hybrids ranged between 1 and 7 May, and was still at 95% of optimum between 9 and 18 May. In northern Wisconsin, the optimum planting date for grain yield of hybrids ranged between 8 and 14 May, and was still at 95% of optimum between 15 and 23 May. Grain yield did not change much when corn was planted between 24 April and 8 May. Grain yield of corn planted after 8 May in southern Wisconsin declined at the rate of 0.5 to 1.1% $d^{-1}$ over the next 2 wk, accelerating to 1.3 to 1.9% $d^{-1}$ and 2.0 to 2.8% $d^{-1}$ over the next two 2-wk periods. Grain yield of corn planted after 8 May in northern Wisconsin declined at the rate of 0.2 to 1.7% $d^{-1}$ over the next 2 wk, accelerating to 1.7 to 2.2% $d^{-1}$ and 3.2 to 3.8% $d^{-1}$ over the next two 2-wk periods. The decision to begin planting corn early should be based on soil temperature and field conditions. After 20 April, planting of full-season hybrids should proceed as rapidly as field conditions allow. The date to switch from full-season to shorter-season hybrids depends on numerous factors, including corn price and drying costs, but generally occurs by mid-May in southern and by late May in northern Wisconsin.**

Producers who plant corn early are concerned about frost, poor emergence, and early plant growth. Producers who plant late wonder what relative maturity hybrids to plant, and how late planting affects final grain yield and moisture. Planting full-season hybrids early is highly recommended because the entire growing season can be used. Physiological maturity can be reached before growth stops because of frost, and some field-drying of corn can occur allowing greater profit margin (Gupta, 1985). These considerations are important for all corn producers, but are even more important for producers on the northern fringes of the Corn Belt, where the growing season often can limit growth and yield.

Current planting date recommendations are summarized in numerous publications (Carter, 1984, 1986, 1992; Benson, 1990; Olson and Sander, 1988; Zuber, 1968). The optimum planting date in the Corn Belt typically occurs between 20 April and 10 May (Benson, 1990). While some studies show an advantage for planting before 20 April, other areas in the northern Corn Belt may yield well when planted around 20 May (Carter, 1984).

Several researchers have described planting date effects on corn (Alessi and Power, 1975; Benson, 1990; Johnson and Mulvaney, 1980; Imholte and Carter, 1987; Nafziger, 1994; Swanson and Wilhelm, 1996). Our objective was to evaluate the influence of planting date and hybrid maturity on corn grain yield and harvest moisture in Wisconsin. This study evaluated the hybrid maturity × planting date interaction on corn grain yield and harvest moisture and identified when hybrids should be switched from full-season to shorter-season maturity for regions where full-season corn ranges between 85 and 110 d relative maturity. Producers can use these results to determine the economic implications of replanting or late planting decisions on corn yields and when to make a hybrid maturity switch.

### MATERIALS AND METHODS

Studies were conducted between 1991 and 1994 at the University of Wisconsin Agricultural Research Stations at Arlington, Hancock, and Lancaster (southern sites) and at Ashland, Marshfield, and Spooner (northern sites). The experimental design at all locations was a randomized complete block in a split-plot arrangement with three replications. Main plots were five to eight planting dates spaced at 10- to 14-d intervals from 19 April to 22 June. Split-plots were two or three corn hybrids differing in maturity (Table 1). Corn hybrids ranged from full- to shorter-season maturity for the location and included the following hybrids (with their Minnesota relative maturity rating, MN RM): Pioneer 3417 (115 d MN RM), Pioneer 3578 (110 d MN RM), Pioneer 3751 (100 d MN RM), DeKalb DK397 (90 d MN RM), Kaltenberg 3800 (85 d MN RM), Pioneer 3921 (85 d MN RM), Northrup King PX9060 (80 d MN RM), Pioneer 3963 (80 d MN RM), Pioneer 3947 (80 d MN RM), and King 127 (80 d MN RM).

Apart from the planting date treatments, all plots were managed using practices similar to those used by producers in the surrounding area of the location (Table 1). Plots were established by seeding at a constant rate on every planting date. At all locations except Ashland, grain yield was determined by machine-harvesting the center two rows of each plot. At Ashland and for the last planting date at Arlington, Marshfield, and Spooner during 1992, the center two rows of

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**Abbreviations:** MN RM, Minnesota relative maturity [rating].

**Table 1. General plot management characteristics and descriptors of six Wisconsin locations used in the study of corn hybrid response to planting date.**

| Descriptor | Lancaster | Arlington | Hancock | Marshfield | Spooner | Ashland |
|---|---|---|---|---|---|---|
| Latitude | 42°50′ N | 43°18′ N | 44°7′ N | 44°39′ N | 45°49′ N | 46°34′ N |
| Soil series | Rozetta silt loam–Fayette silt loam | Plano silt loam | Plainfield sand | Withee silt loam | Haugen silt loam– Antigo silt loam | Superior sandy loam |
| Soil family | fine-silty, mixed, superactive, mesic | fine-silty, mixed, superactive, mesic | mixed, mesic | fine-loamy, mixed | coarse-loamy–coarse-loamy over sandy or sandy skeletal, mixed, superactive, frigid | coarse-loamy over clayey, mixed, frigid |
| Soil subgroup | Typic Hapludalfs | Typic Argiudolls | Typic Udipsamments | Aquic Glossoboralfs | Oxyaquic Glossudalfs–Haplic Glossudalfs | Alfic Haplorthods |
| Tillage, primary | No-till | Chisel plow | Moldboard plow | Moldboard plow | Moldboard plow | Moldboard plow |
| Tillage, secondary | — | Field cultivate | Drag | Spring disk and field cultivate | Disk and drag | Disk and field cultivate |
| Previous crop† | | | | | | |
| 1991 | corn | soybean | soybean | alfalfa | soybean | corn |
| 1992 | corn | wheat | corn | alfalfa | corn | corn |
| 1993 | alfalfa | soybean | soybean | not planted | corn | corn |
| 1994 | alfalfa | soybean | sudangrass | soybean | alfalfa | alfalfa |
| Soil fertility | | | | | | |
| pH | 6.6–7.2 | 6.1–6.9 | 6.4–6.7 | 6.8–7.4 | 5.8–6.5 | 6.5–7.1 |
| P, $\mu g\ g^{-1}$ | 33–55 | 30–79 | 90–125 | 59–70 | 17–100 | 60–192 |
| K, $\mu g\ g^{-1}$ | 220–245 | 185–220 | 68–150 | 160–300 | 98–240 | 150–300 |
| OM, $g\ kg^{-1}$ | 28–33 | 27–34 | 7–8 | 29–30 | 23–24 | 28–32 |
| Plant density, no. $ha^{-1}$ | 70 000 | 73 300 | 69 300 | 64 200 | 50 200 | 73 800 |
| Hybrid‡ | | | | | | |
| Full-season | P3417 | P3417 and P3578 | P3578 | P3751 | P3921 or DK397 | P3921 |
| Shorter-season | P3751 | P3751 | P3751 | P3921 and P3963 | P3963 or NK PX9060 or King 127 | K3800, P3963 or NK PX9060 |
| Ultra-short-season | P3963 and P3921 | P3963, P3921, and NK PX9060 | CX75, P3963, and NK PX9060 | K3800 and P3947 | — | — |
| Fall frost date§ | | | | | | |
| 1991 | 20 Sept. | 20 Sept. | 20 Sept. | 19 Sept. | 20 Sept. | 27 Sept. |
| 1992 | 16 Oct. | 29 Sept. | 29 Sept. | 29 Sept. | 11 Sept. | 23 Sept. |
| 1993 | 9 Oct. | 29 Sept. | 29 Sept. | not planted | 11 Sept. | 19 Sept. |
| 1994 | 27 Oct. | 10 Oct. | 9 Oct. | 10 Oct. | 9 Oct. | 2 Oct. |
| Harvest date | | | | | | |
| 1991 | 3 Oct. | 24 Sept.; 12 Oct. | 10 Oct. | 5 Nov. | 2 Oct. | 7 Oct. |
| 1992 | 29 Oct. | 28 Oct.; 16 Nov. | 13 Nov. | 11 Nov. | 30 Oct. | 5 Oct. |
| 1993 | 22 Oct. | 23 Oct.; 11 Nov. | 27 Oct. | not planted | 27 Oct. | 4 Oct. |
| 1994 | 28 Oct. | 3 Nov. | 27 Oct. | 27 Oct. | 26 Oct. | 4 Oct. |

† Alfalfa: *Medicago sativa* L.; soybean: *Glycine max* (L.) Merr.; sudangrass: *Sorghum bicolor* (L.) Moench; wheat: *Triticum aestivum* L.; corn: *Zea mays* L.
‡ C, Carhart's; DK, DeKalb; K, Kaltenberg; NK, Northrup King; P, Pioneer.
§ Frost date: <0°C.

each plot were hand-harvested and moisture was determined on representative ears. Grain yields were adjusted to 155 g $kg^{-1}$ moisture. The experiment was not planted in Marshfield in 1993, due to cool, wet weather during May and June.

Five response models (linear, quadratic, plateau-plus-linear, plateau-plus-quadratic, and square root) were fit to replicate mean data for each hybrid–location–year combination by using the NLIN (Ihnen and Goodnight, 1985) or GLM (Spector et al., 1985) procedure. Planting date was expressed as day of year (1 May = 121). Similar to Johnson and Mulvaney (1980), Nafziger (1994), and Swanson and Wilhelm (1996), the quadratic model usually had the highest $R^2$ value and was selected for data analysis in this study. The quadratic model is defined as

$$Y = b_0 + b_1 x + b_2 x^2 \quad [1]$$

where $Y$ is the yield of grain (Mg $ha^{-1}$) and $x$ is the planting day of year; $b_0$ (intercept), $b_1$ (linear coefficient), and $b_2$ (quadratic coefficients) are constants obtained by fitting the model to the data.

Models were developed using replicate data for environments with five or more planting dates. For each replicate, the optimum yield, optimum planting date, date when 95% of maximum yield occurred, and daily yield changes were calculated. Predicted optimum yields were obtained by equating the first derivatives of the response equation to zero, solving for $x$ (optimum planting date), substituting $x$ into the response equation, and solving for $Y$. If the calculated optimum date was outside of the planting date range for each hybrid–location–year combination, then the optimum date was the same as the date of actual maximum yield. The date at which yields were 95% of optimum $Y$ was calculated by substituting 95% of optimum yield into the model and solving for $x$, with the latter of the two values obtained being the latest planting date. Yield changes were calculated beginning on 24 April by substituting $x$ into the model and measuring the average rate of change over 2-wk periods. PROC GLM (Spector et al., 1985) was used to analyze optimum yield, optimum planting date, date when 95% of maximum yield occurred, and daily yield changes.

The planting date for switching from full- to shorter-season hybrids was calculated for various corn production systems. Grower return is defined as

$$GR = (Y \times P) - C \quad [2]$$

where GR is grower return (\$ $ha^{-1}$), $Y$ is the yield of grain (Mg $ha^{-1}$), $P$ is corn price (\$ $Mg^{-1}$), and $C$ is costs (\$ $ha^{-1}$). Corn prices used were \$79, \$108, and \$138 $Mg^{-1}$ (\$2.00, \$2.75, and \$3.50 $bushel^{-1}$). Costs were calculated at the following rates: handling, \$0.67 $Mg^{-1}$ (\$0.017 $bushel^{-1}$); hauling, \$1.58 $Mg^{-1}$ (\$0.04 $bushel^{-1}$); and drying, \$0 \$0.059, and \$0.118 g $kg^{-1}$ moisture $Mg^{-1}$ (\$0, \$0.015, and \$0.03 moisture $point^{-1}$ $bushel^{-1}$) (Duffy and Judd, 1992).

Switch date is defined as the date when the shorter-season hybrids equal full-season hybrids for grower return under various corn prices and drying cost scenarios. To accomplish this, grower returns for each production system were calculated for each plot. The relationship between grower return and planting date was determined for full- and shorter-season hybrids for each corn production system using replicate means for each location-year. These models were defined as

$$GR_{full} = b_{0,full} + b_{1,full}\,x + b_{2,full}\,x^2 \quad [3a]$$

$$GR_{shorter} = b_{0,shorter} + b_{1,shorter}\,x + b_{2,shorter}\,x^2 \quad [3b]$$

where $x$ is the planting day of year and $b_0$ (intercept), $b_1$ (linear coefficient), and $b_2$ (quadratic coefficient) are constants obtained by fitting the model to replicate mean data of full- and shorter-season hybrids. The switch date is when grower return from the shorter-season hybrids equals that from full-season hybrids:

$$GR_{full} = GR_{shorter} \quad [4]$$

By substitution,

$$b_{0,full} + b_{1,full}\,x + b_{2,full}\,x^2 = b_{0,shorter} + b_{1,shorter}\,x + b_{2,shorter}\,x^2 \quad [5]$$

and the equation can be solved for $x$, the date when grower return from shorter-season hybrids equals that from full-season hybrids. PROC REG (SAS Inst., 1985) was used to calcu-

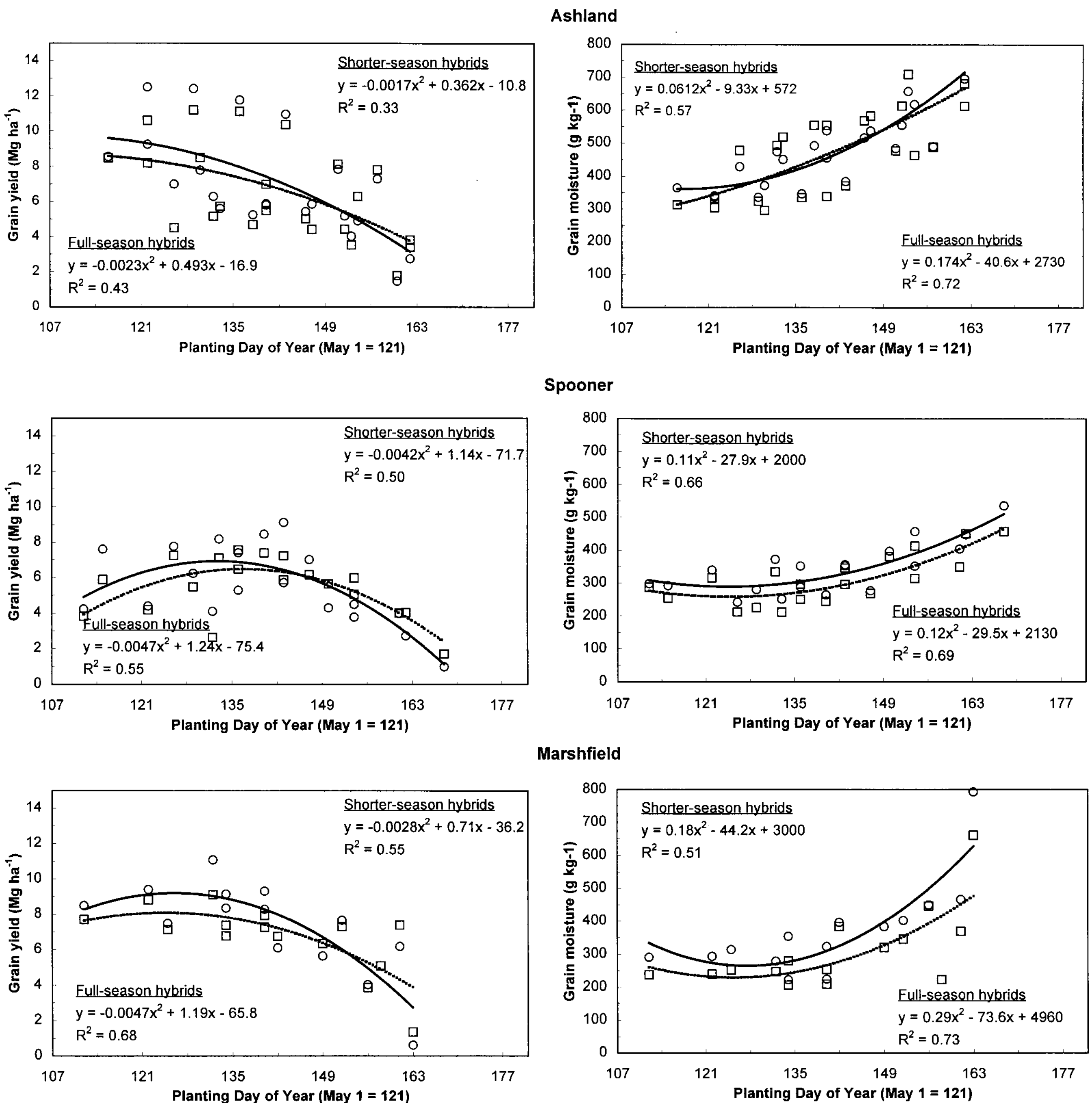


**Fig. 1. Relationship between grain yield and planting day of year of full-season (circles; solid lines) and shorter-season (squares; broken lines) corn hybrids in northern Wisconsin.**

late regression coefficients and the coefficient of determination ($R^2$) for yield and grower return models of full- and shorter-season hybrids in each corn production system.

## RESULTS AND DISCUSSION

Record state yields were observed in 1991 and 1994, while 1992 and 1993 were cool with relatively low yields statewide. Growing degree unit accumulations during the 1992 and 1993 cropping seasons were 85 and 94% of the 30-yr average. Optimum planting dates did not change between years. In all years, corn planted in late May yielded at least 30% less than corn planted in early May (Fig. 1 and 2). During the high-production years 1991 and 1994, a clear yield advantage of 15% with early planting existed for full-season hybrids, with no strong yield drop until after 15 May (year data not shown). During 1992 and 1993, years with a cool growing season, grain yields declined immediately, with no advantage between full- and shorter-season hybrids, not even with early planting in April. Yields were still within 95% of the yield on the optimum planting date, even though early-planted corn had some early frost damage in 1992.

Both late planting date and low plant density can

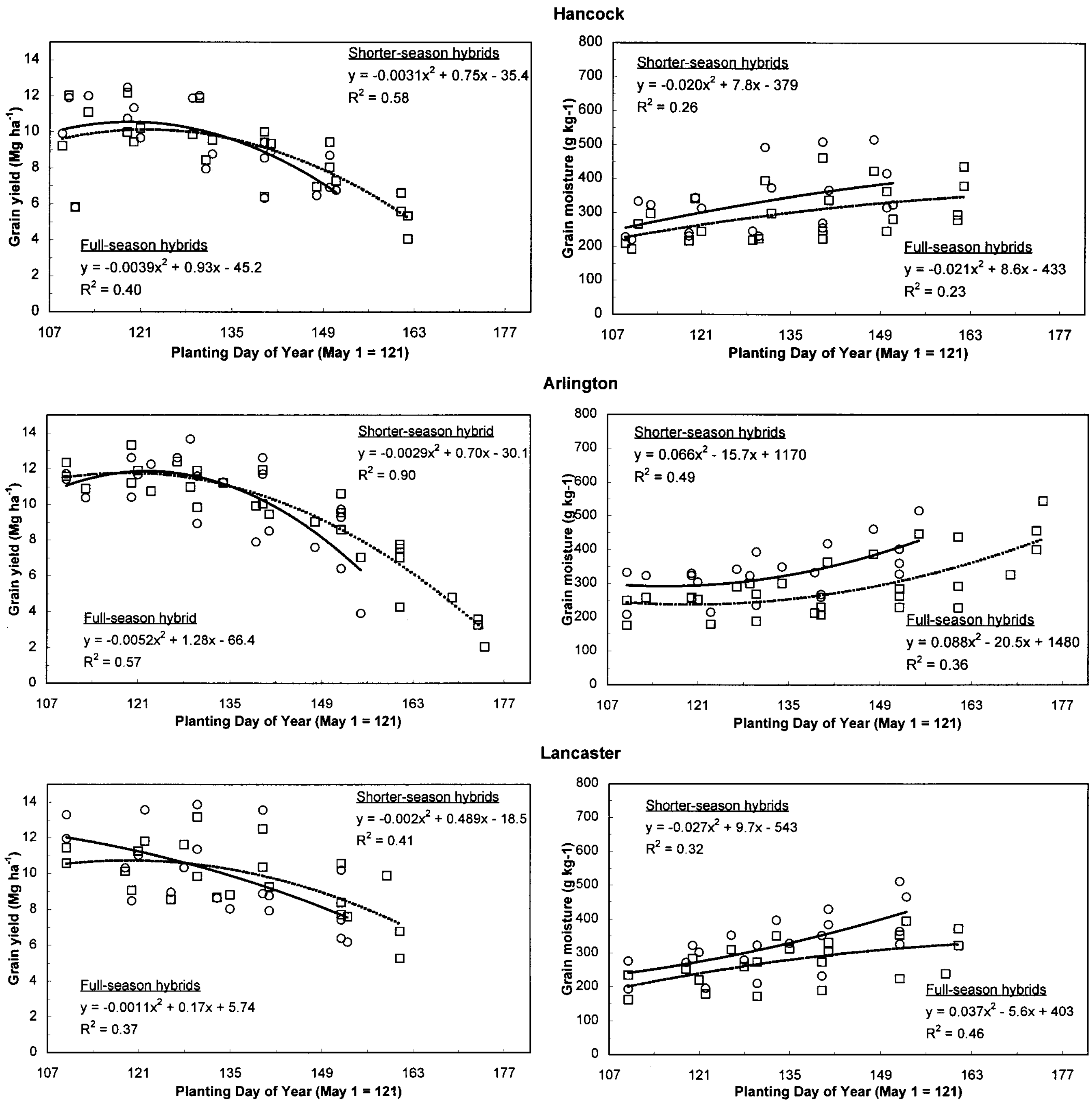


**Fig. 2. Relationship between grain yield and planting day of year of full-season (circles; solid lines) and shorter-season (squares; broken lines) corn hybrids in southern Wisconsin.**

**Table 2. Grain yield optimum planting dates and daily rates of change for corn grown at six locations in Wisconsin between 1991 and 1994.**

| Location and hybrid maturity | Optimum date | Predicted grain yield on optimum date | Latest date at 95% of optimum grain yield | Predicted daily average yield change between dates: 24 Apr. to 8 May | 8 May to 22 May | 22 May to 5 June | 5 June to 19 June |
|---|---|---|---|---|---|---|---|
| | | Mg ha$^{-1}$ | | % d$^{-1}$ | | | |
| | | | Northern Wisconsin | | | | |
| Ashland, full-season | 11 May | 8.21 | 17 May | 0.1 | −0.5 | −2.1 | −3.7 |
| Ashland, shorter-season | 12 May | 7.57 | 20 May | 1.6 | −0.4 | −1.9 | −3.5 |
| LSD (0.05) | NS | 0.60 | 3 d | 1.0 | NS | NS | NS |
| Spooner, full-season | 8 May | 6.87 | 15 May | 0.8 | −0.8 | −2.2 | −3.8 |
| Spooner, shorter-season | 11 May | 6.43 | 18 May | 0.6 | −1.7 | −1.7 | −3.5 |
| LSD (0.05) | NS | NS | NS | NS | 0.6 | 0.4 | NS |
| Marshfield, full-season | 12 May | 9.23 | 19 May | 1.3 | −0.9 | −2.2 | −3.4 |
| Marshfield, shorter-season | 14 May | 7.84 | 23 May | 1.3 | −0.2 | −1.7 | −3.2 |
| LSD (0.05) | NS | 1.28 | 4 d | NS | NS | NS | NS |
| | | | Southern Wisconsin | | | | |
| Hancock, full-season | 5 May | 10.99 | 9 May | −0.3 | −1.0 | −1.8 | −2.6 |
| Hancock, shorter-season | 4 May | 10.70 | 12 May | 0.1 | −0.7 | −1.6 | −2.4 |
| LSD (0.05) | NS | NS | 2 d | NS | 0.2 | NS | NS |
| Arlington, full-season | 7 May | 11.63 | 14 May | −0.2 | −1.1 | −1.9 | −2.8 |
| Arlington, shorter-season | 1 May | 12.12 | 12 May | −0.2 | −0.8 | −1.4 | −2.0 |
| LSD (0.05) | NS | NS | NS | NS | 0.2 | 0.4 | NS |
| Lancaster, full-season | 3 May | 11.27 | 12 May | −0.1 | −0.9 | −1.7 | −2.7 |
| Lancaster, shorter-season | 5 May | 10.95 | 18 May | 0.2 | −0.5 | −1.3 | −2.0 |
| LSD (0.05) | NS | NS | NS | NS | 0.1 | NS | NS |

reduce yield (Nafziger, 1994; Benson, 1990). In this study, all plots were seeded at the same density within a location-year, and usually plant density was affected by one or more planting dates. In this study, no obvious planting date pattern consistently affected harvest plant density. Low plant densities occurred among early, mid, and late planting dates with equal frequency.

Results of this study indicate that for each location an optimum planting date for grain yield exists and that planting before or after that optimum date results in a yield reduction (Fig. 1 and 2). At every location, grain yields decreased with later planting date. Among all hybrids, the optimum planting date for grain yield ranged between 1 and 7 May in southern Wisconsin and between 8 and 14 May in northern Wisconsin (Table 2). No differences were detected between full- and shorter-season hybrids for optimum planting dates. For full-season hybrids, grain yields were still at 95% of optimum as late as 14 May in southern and 19 May in northern Wisconsin, but grain moisture in all cases was increasing (Fig. 1 and 2).

Full-season hybrids usually yielded more than shorter-season hybrids planted during late April and early May (Fig. 1 and 2). In southern Wisconsin, small yield changes were observed for corn planted between 24 April and 8 May, but for the next three 2-wk periods, yield decreased at the rate of 0.5 to 1.1, 1.3 to 1.9, and 2.0 to 2.8% d$^{-1}$ (Table 2). In northern Wisconsin, grain yield increased 0.1 to 1.6% d$^{-1}$ for corn planted between 24 April and 8 May, but for the next three 2-wk periods, yield decreased at the rate of 0.2 to 1.7% d$^{-1}$, 1.7 to 2.2% d$^{-1}$, and 3.2 to 3.8% d$^{-1}$. Yield of full-season hybrids usually declined at a greater rate than shorter-season hybrids.

A progression of optimum planting dates was observed across different latitudes in Wisconsin (Table 2). Depending on location, the optimum planting date was between early May for southern and mid-May for north-

**Table 3. Date for switching hybrids from full- to shorter-season relative maturity in three corn production systems.**

| System | Drying costs | Corn price | Northern Wisconsin: Ashland | Spooner | Marshfield | Southern Wisconsin: Hancock | Arlington | Lancaster |
|---|---|---|---|---|---|---|---|---|
| | \$ g kg$^{-1}$ Mg$^{-1}$ | \$ Mg$^{-1}$ | | | | | | |
| Commercial | 0.118 | 79.00 | 17 May | 13 May | 14 May | † | † | † |
| | | 108.00 | 19 May | 16 May | 23 May | † | † | † |
| | | 138.00 | 19 May | 17 May | 26 May | 2 May | † | 2 May |
| Farm | 0.059 | 79.00 | 19 May | 19 May | 28 May | 6 May | † | 3 May |
| | | 108.00 | 19 May | 20 May | 29 May | 8 May | † | 4 May |
| | | 138.00 | 21 May | 20 May | 30 May | 9 May | † | 5 May |
| Livestock | 0.000 | 79.00 | 21 May | 23 May | 1 June | 15 May | 15 May | 8 May |
| | | 108.00 | 21 May | 23 May | 1 June | 15 May | 15 May | 8 May |
| | | 138.00 | 21 May | 23 May | 1 June | 15 May | 15 May | 8 May |
| $R^2$, average, full-season hybrid | | | 0.46 | 0.75 | 0.70 | 0.38 | 0.55 | 0.38 |
| $R^2$, average, shorter-season hybrid | | | 0.37 | 0.88 | 0.58 | 0.53 | 0.87 | 0.38 |
| $R^2$, range, full-season hybrid | | | 0.43–0.51 | 0.74–0.76 | 0.66–0.75 | 0.34–0.40 | 0.49–0.57 | 0.37–0.39 |
| $R^2$, range, shorter-season hybrid | | | 0.33–0.43 | 0.86–0.90 | 0.52–0.67 | 0.46–0.58 | 0.82–0.90 | 0.35–0.41 |

† The shorter-season hybrid had greater grower return than the full-season hybrid on every planting date.

ern Wisconsin. Optimum planting dates in southern Wisconsin were slightly later than those found in a study by Nafziger (1994), who reported that the optimum planting date for corn in central and northern Illinois was 27 April. In an earlier study for Illinois, Johnson and Mulvaney (1980) reported an optimum planting date of 6 May. More recently, Swanson and Wilhelm (1996) reported an optimum planting date of 10 May in Nebraska.

The relationship between grain moisture and planting date was opposite the relationship between yield and planting date (Fig. 1 and 2). In general, as grain yield decreased with later planting date, grain moisture increased with later planting date. Corn planted on the earliest date yielded less than on subsequent planting dates in 29 of 48 hybrid environments, but often had less grain moisture (individual data not shown). Thus, grower return of these earliest planting dates was equivalent to optimum planting dates. Even though full-season hybrids yielded 10 to 15% more than shorter-season hybrids early in the planting period, this resulted in only a slight increase in grower return, due to the higher drying costs associated with the full-season hybrids. At four of six locations, ultra-short-season hybrids were planted on the latest planting dates instead of full-season hybrids. Ultra-short-season hybrids yielded less than shorter-season hybrids (5.3 vs. 5.8 Mg $ha^{-1}$); however, grain moisture of ultra-short-season hybrids was less than grain moisture of the shorter-season hybrids (338 vs. 385 g $kg^{-1}$).

Switch date inferences are heavily weighted by the hybrids used in this study, as only a limited set of hybrids was used. Switching from full-season to shorter-season hybrids should occur by 15 May in southern Wisconsin and by 1 June in northern Wisconsin (Table 3). In general, maturity switches should occur at progressively later dates as locations change from southern to northern Wisconsin, although numerous factors may affect the switch date, such as drying costs and corn price. Bauer and Carter (1986) reported increased kernel breakage susceptibility at later planting dates and with shorter-season hybrids, with subsequent market quality problems. In a corn production system for livestock where drying costs are not a factor, the most economical switch date is the same as the switch date for producing optimum grain yields, regardless of corn price (Fig. 1 and 2; Table 3). As energy costs increase, either with on-farm drying or commercial elevator drying systems, switch dates occur 4 to 17 d earlier (Table 3). At all southern locations in production systems with higher drying costs and low corn prices, no switch dates were observed, since the shorter-season hybrid had greater grower return on all planting dates. Corn price did not usually affect the switch date as much as drying cost did. At most locations, switch dates were 2 to 4 d earlier with lower corn prices, but adjustments of up to 12 d were observed at Marshfield. These results are similar to the guidelines described by Hicks (1979, 1985) and Gupta (1985).

There is still some risk with early planting dates. If corn is planted prior to 20 and 30 April in southern and northern Wisconsin, respectively, the decision probably should be based on soil temperature and field conditions. After 20 and 30 April, corn planting of full-season hybrids should proceed as rapidly as field conditions allow and should be completed by 14 May for southern Wisconsin and 19 May for northern Wisconsin (Table 2). Otherwise, corn producers will suffer significant yield penalties with further delays in planting.

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