# Genetic Gain × Management Interactions in Soybean: I. Planting Date

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#### ABSTRACT

Planting date is a commonly manipulated management practice in soybean [Glycine max (L.) Merr.] production; however, the impacts of past and ongoing agronomic improvements, such as earlier planting, on genetic yield improvement and associated changes in seed protein and oil have not been evaluated. The objectives of this study were to determine if a 30-d difference in planting date affected measured rates of genetic improvement in (i) yield, (ii) seed mass, and (iii) seed protein and oil in the midwestern United States. Research was conducted at Arlington, WI, Urbana, IL, and Lafayette, IN, during 2010 and 2011, using 59 Maturity Group (MG) II cultivars (released 1928-2008) at Wisconsin, and 57 MG III cultivars (released 1923-2007) at Illinois and Indiana, with targeted planting dates of 1 May and 1 June. Earlier planting provided higher yields (+3.1 kg ha-1 yr-1) than late planting in MG III soybean. Seed protein concentration decreased linearly over cultivar year of release at a rate of 0.191 ( $\pm$  0.069) g kg<sup>-1</sup> yr<sup>-1</sup> for MG II, and 0.242 (± 0.063) g kg<sup>-1</sup> yr<sup>-1</sup> for MG III. Seed oil concentration increased over year of release at a rate of 0.142 (± 0.037) g kg<sup>-1</sup> yr<sup>-1</sup> for MG II, and 0.127 (± 0.039) g kg<sup>-1</sup> yr<sup>-1</sup> for MG III. The interaction between planting date and cultivar year of release for MG III yield suggested that the trend toward earlier planting is one agronomic improvement that, when coupled with genetic improvement, has provided a synergistic increase in on-farm soybean yields in the midwestern United States.

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Abbreviations: MG, Maturity Group.

**C** OYBEAN [*Glycine max* (L.) Merr.] yields in the United States have improved at a rate of 23.4 kg  $ha^{-1}$  yr<sup>-1</sup> since national yield data were first reported in 1924 (USDA-NASS, 2011). The persistence of this annual on-farm yield gain has been attributed to continued cultivar improvement via plant breeding and the periodic adoption of improved agronomic practices by U.S. producers (Specht and Williams, 1984). The contribution of genetic yield gain toward overall yield improvement in soybean has been well documented. However, the relative contribution of individual agronomic advancements remains unclear. Specht et al. (1999) summarized a number of previous genetic gain studies, and based on these studies, reported that the average annual increase in soybean yield due to genetic improvements ranged from 10 to 30 kg ha<sup>-1</sup> yr<sup>-1</sup> (Boerma, 1979; Luedders, 1977; Specht and Williams, 1984; Voldeng et al., 1997; Wilcox et al., 1979). Even with such a wide range, the relative contribution of genetic improvement in the United States (Maturity Group [MG] IV or earlier) was estimated by Specht and Williams (1984) to be 12.5 kg  $ha^{-1}$  yr<sup>-1</sup>, among hybridized cultivars released post-1940 in their research.

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About half of yield gain in soybean can be attributed to genetic improvement. The remaining half is hypothesized to be the result of improved agronomic practices and the potentially synergistic interaction of advances in both agronomics and genetics. Researchers have speculated that a number of changes in agronomic practices have contributed to soybean yield improvement. These include: (i) earlier planting dates (Heatherly and Elmore, 2004; Johnson, 1987; Specht et al., 1999), (ii) narrower row spacing (Heatherly and Elmore, 2004; Specht et al., 1999; Voldeng et al., 1997), (iii) higher seeding rates (Voldeng et al., 1997), (iv) improved weed control and herbicide use (Luedders, 1977; Specht et al., 1999; Voldeng et al., 1997), and (v) reduced harvest losses (Specht et al., 1999). Arguably, the most important and cost-free cultural management decision that a grower can make to maximize grain yield is to sow soybean at a calendar date appropriate for the latitude of production (Cartter and Hartwig, 1963; Robinson et al., 2009). Optimum planting date in the northern United States ranges from early to mid-May (Heatherly and Elmore, 2004). Recent literature suggests that planting in late April can help maximize yields in the Midwest, although seeding soybean before then is not recommended because of increased risk of seedling exposure to frost and no documented yield advantage when compared to late-April and early-May plantings (De Bruin and Pedersen, 2008a; Robinson et al., 2009). Planting dates in the midwestern United States have consistently trended toward earlier calendar dates (USDA-NASS, 2011). However, further research is needed to determine the potential contribution of planting date to soybean yield enhancement, given that yields are also rising due to genetic improvement.

In most circumstances, soybean yield declines steadily when planting is delayed after mid-May. In Iowa, yield loss resulting from delayed planting averaged 130 kg ha<sup>-1</sup> wk<sup>-1</sup> (18.6 kg ha<sup>-1</sup> d<sup>-1</sup>) between early and late May and then 404 kg ha<sup>-1</sup> wk<sup>-1</sup> (57.7 kg ha<sup>-1</sup> d<sup>-1</sup>) between late May and early June (De Bruin and Pedersen, 2008a). Soybean yields in Nebraska declined at a linear rate of 119 kg ha<sup>-1</sup>  $wk^{-1}$  (17 kg ha<sup>-1</sup> d<sup>-1</sup>) in 2003 and 301 kg ha<sup>-1</sup> wk<sup>-1</sup> (43 kg ha<sup>-1</sup> d<sup>-1</sup>) in 2004 as planting date was delayed from early May to mid-June (Bastidas et al., 2008). Delayed planting results in decreased plant height (Bastidas et al., 2008; Wilcox and Frankenberger, 1987), decreased pods plant<sup>-1</sup> (Anderson and Vasilas, 1985; Elmore, 1990), decreased pods m<sup>-2</sup> (Pedersen and Lauer, 2004; Robinson et al., 2009), and decreased seeds per unit area (Pedersen and Lauer, 2004), all leading to lower yields. Delayed planting also influences seed protein and oil, frequently resulting in increased seed protein concentration and decreased seed oil concentration (Kane et al., 1997; Pendleton and Hartwig, 1973; Robinson et al., 2009). Lower protein and higher oil concentrations were also associated with more recently released soybean cultivars when compared to older cultivars (Wilcox et al., 1979), although this preliminary observation has yet to be documented with a comprehensive group of cultivars representing a wide range of release years. Seed mass has been shown to decrease (Anderson and Vasilas, 1985; Elmore, 1990), increase (Bastidas et al., 2008), or not change (Pedersen and Lauer, 2004; Wilcox and Frankenberger, 1987) over a range of planting dates. Further research efforts with a greater number of cultivars might help resolve the impact of planting date on seed mass.

Clearly, genetic gain has played an important role in soybean yield improvement over time, but the genetic improvement made by breeders does not account for all of the on-farm improvement in yield to date. Understanding the role of agronomic advancements in past soybean yield gain is key to determining past sources of yield gain, and will ensure that yield improvements will continue to occur in the future. Furthermore, synergistic interactions between agronomic improvements and genetic gain are also assumed to have played a role in past soybean yield gain, and the contribution of these interactions must be discerned and verified. The shift toward earlier planting is just one of many agronomic practices that has changed over time and may be a contributing factor to the yield improvement realized by U.S. soybean growers. The comprehensive study described in this paper, utilizing over 115 public and proprietary cultivars in two maturity groups, was aimed at examining the interaction between planting date and the measured rate of genetic improvement over time. This rich set of soybean cultivars, released over eight decades, provided a unique opportunity to study the impact of early and late planting on the derived estimates of genetic yield improvement. We hypothesized that earlier soybean planting provided a production system environment more favorable for the expression of genetic yield potential in newer cultivars. If so, then the estimated rate of genetic yield gain would be expected to be greater with earlier planting than with later planting (i.e., a synergistic interaction). It is expected that seed mass and seed protein and oil have also been influenced by earlier planting dates and have changed over time as a result of both breeding efforts and earlier planting. To understand the effects of earlier planting on soybean yield gain, seed mass, and seed protein and oil over time in MG II and MG III cultivars in the north-central United States, the objectives of our study were twofold: (i) to compare overall yield, yield response to, and measured rates of yield gain over time among previously released soybean cultivars between two planting dates, 1 May and 1 June; and (ii) to compare changes in soybean mass and seed protein and oil among previously released soybean cultivars at two planting dates, 1 May and 1 June.

Table 1. Experimental	details with respect to	test sites, soils, and dat	es of planting and harvest
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	Arlington, WI		Urba	na, IL	Lafayette, IN		
	Arlington Agricultural Research Station		Crop Sciences Research and Education Center		Throckmorton Purdue Agricultural Center		
Location of research site	43°18′ N,	89°20′ W	40°3′ N,	40°3′ N. 88°14′ W		40°17′ N, 86°54′ W	
Soil series	Plano silt loam		Flanagan silt loam and Drummer silty clay loam		Throckmorton silt loam		
Soil family	Fine-silty, mixe Argii	ed, mesic Typic udoll	Fine-silty, mixe Endoaquoll and mesic Aqu	ed, mesic Typic I fine, smectitic, ic Argiudoll	Fine-silty, mixe Oxyaquic	d, mesic mollic Hapludalf	
Soil fertility				-			
Phosphorus (mg kg <sup>-1</sup> )	44–56		23–34		39–66		
Potassium (mg kg <sup>-1</sup> )	166–173		122		138-	-146	
рН	6.9	-7.1	5.8-	5.8-6.1		-6.1	
Organic matter (g kg <sup>-1</sup> )	3	.2	3.6-	-4.1	2.9–3.0		
Field operations	2010	2011	2010	2011	2010	2011	
Planting date (May PD treatment)	4 May	5 May	15 May	12 May	10 May	17 May	
Planting date (June PD treatment)	1 June	6 June	14 June	8 June	4 June	12 June	
Harvest date (May PD treatment)	8 Oct.	17 Oct.	7 Oct.	11 Oct.	24 Sept.	11 Oct.	
Harvest date (June PD treatment)	13 Oct.	17 Oct.	7 Oct.	11 Oct.	4 Oct.	11 Oct.	
Planting date difference (d)	28	32	30	27	25	26	

## **MATERIALS AND METHODS**

Research was conducted in 2010 and 2011 at Arlington, WI, Urbana, IL, and Lafayette, IN. Location-specific information and soil characteristics for the three sites can be found in Table 1. In both years, soybean followed corn [Zea mays (L.)] harvested for grain at the Illinois and Indiana locations, whereas soybean followed corn harvested for silage at the Wisconsin location. All locations were fall-chiseled, and prepared in the spring with field cultivation (Wisconsin, Indiana) or mulch tillage (Illinois). Fertility and pest management at each location was performed according to local university management recommendations. At each location, cultivars were seeded at two planting dates, with 1 May and 1 June as the desired target dates. The 1 May planting date (early) was selected to represent planting dates growers currently use, whereas the 1 June (late) planting was selected to represent planting dates more commonly used in the past (USDA-NASS, 2011). In both years, weather and soil moisture conditions resulted in planting occurring later than the target dates, though a 25- to 32-d differential in planting date was still achieved (Table 1).

At the Wisconsin location, 59 MG II soybean cultivars released over eight decades, from 1928 to 2008 were planted, whereas at the Illinois and Indiana locations, 57 MG III soybean cultivars released from 1923 to 2007 were planted. The cultivars used in the experiment, along with plant introduction number and pedigree information, are provided in Table 2. Each cultivar used in the experiment was unique, novel, or widely grown during the time period of introduction. Cultivars included plant introductions grown about 80 yr ago, along with public and proprietary cultivars derived from further cycles of selection and breeding since then. Seed used for the experiment came from public and private seed sources, with seed increases of all cultivars occurring during the 2009 and 2010 growing seasons. Seed of the MG II cultivars was increased at the University of Nebraska–Lincoln (Lincoln, NE); whereas seed of the MG III cultivars was increased at the University of Illinois at Urbana–Champaign (Urbana, IL). To provide an estimate of experimental error, 13 MG II cultivars and 15 MG III cultivars were replicated twice within each planting date, for a total of 72 plots per planting date treatment in each maturity group. A limited number of cultivars were chosen for replication due to limited seed supply and field space constraints. Replicated cultivars within each maturity group were evenly distributed across years of release. The experiment was replicated by environment, defined as location within year, for each maturity group.

Plots were mechanically seeded in four rows, spaced 76 cm apart, at a rate of 370,650 untreated seeds ha<sup>-1</sup>. Planted plot dimensions at all locations were 3.1 m wide by 4.6 m long. Plant populations were recorded for all plots at the V1 (first trifoliolate) and R8 (95% pod maturity) stages, as defined by Fehr and Caviness (1977). The center two rows of each plot were mechanically harvested a few days after R8. Grain weight and moisture data were collected simultaneously at harvest so that seed yield could be expressed on a 130 g kg<sup>-1</sup> seed moisture content basis. Grain subsamples (approximately 500 g) were collected from each plot for seed protein and oil concentration analysis. Seed protein and oil contents were determined using a Perten DA 7200 Feed Analyzer (Perten Instruments, Stockholm, Sweden). Seed mass (100-seed weight) was estimated by weighing a grain sample collected from each harvested plot.

Yield, seed mass, and seed protein and oil data were subjected to a mixed-effect regression analysis using the PROC MIXED procedure in SAS Version 9.2 (SAS Institute Inc., Cary, NC). Models were constructed for maturity groups separately. The main effects of planting date, cultivar year of release, and the planting date × year of release interaction were treated as fixed effects. Environment and cultivar, along with the planting date × environment, planting date × cultivar, and planting date × environment × cultivar interactions were considered to be random effects. Cultivar was assigned as a random

## Table 2. List of soybean cultivars, year of release, maturity group, plant introduction (PI) number, and pedigree.

Cutival     Package     Matching Upp     Privac     Package       Unified     1927     III     Pis648348     Selection from AK. In 1920       Noroan1     1222     III     Pis648348     Selection from AK. In 1920       AK, Harrwyll     1322     III     Pis648348     Selection from AK. In 1920       Mandell     1332     III     Pis648361     Selection from Marchuin 1326       Mandell     1334     III     Pis648361     Selection from Marchuin 1326       Mandon     13440     III     Pis648361     Selection from Marchuin 1326       Lincolnf     13441     III     Pis648272     Muldom x Richland       Harweyel     1347     III     Pis648273     Muldom x Richland       Horosoyo7     1051     III     Pis64873     Lincoln (12) x Kelland       Lindarin     1968     III     Pis64874     Lincoln (2) x Kelland       Horosoy 63     1963     III     Pis64874     Lincoln (2) x Kelland       Horosoy 63     1963     III     Pis64874     Lincoln (2) x Kelland       <	Cultivor	Year of	Moturity group	DLNo	Dedigroo
Durnhold     Field     PI-848318     PI-08484     <	Cultivar	release	Maturity group	PI NO.	Pealgree
Illin'     1927     III     PH548348     Selection from A.K. (n. 1920)       AK (Parowa)     1998     III     PH548980     From China       AK (Parowa)     1998     III     PH548916     PL552031RE China)       Mandell     1993     III     PH548916     PL552031RE China)       Mango     1993     III     PH548918     Selection from Manchu in 1524       Lincoln     1983     III     PH548920     Minishing       Mango     1983     III     PH548920     Minishing       Hawkeya <sup>1</sup> 1997     II     PH548920     Minishing       Hawkeya <sup>1</sup> 1997     II     PH54892     Mandain (Dtawa)2 x AK, (Harow)       Ladorin     1988     III     PH54893     Mandain (Dtawa)2 x AK, (Harow)       Ladorin     1988     III     PH54897     Mandain (Dtawa)2 x AK, (Harow)       Ladorin     1988     III     PH54893     Mandain (Dtawa)2 x AK, (Harow)       Ladorin     1988     III     PH54897     Hawkey (Y, Selochtawk       Harosy 33     1983 <td< td=""><td>Dunfield<sup>1</sup></td><td>1923</td><td>III </td><td>PI548318</td><td>P.I. 36846 (NE China)</td></td<>	Dunfield <sup>1</sup>	1923	III 	PI548318	P.I. 36846 (NE China)
Korean <sup>1</sup> 1928     II     PH84880     From China     K. (by 1926)       Mukden <sup>1</sup> 1992     II     Ph84891     Section from A.K. (by 1926)       Mukden <sup>1</sup> 1992     II     Ph84891     Section from Manchu in 1926       Binhurd     1998     II     Ph84896     Section from Manchu in 1924       Mukden <sup>1</sup> 1993     II     Ph84892     Mundarin (Stawal)       Hawkoy <sup>0</sup> 1947     II     Ph84892     Mundarin (Stawal)       Hawkoy <sup>0</sup> 1947     II     Ph84892     Mundarin (Stawal)     K. (Harrow)       Auima     1948     II     Ph84892     Mundarin (Stawal)     K. (Harrow)       Lindoin     1958     II     Ph84892     Lincoln ()     K. (Harrow)       Rota     1958     II <t< td=""><td>Illini</td><td>1927</td><td>    </td><td>PI548348</td><td>Selection from A.K. in 1920</td></t<>	Illini	1927	 	PI548348	Selection from A.K. in 1920
AK (Harrow)     Fib38     H     PH38294     Selection from AK (by 1828)       Mundel     1934     H     PH546361     Selection from Manchu In 1926       Binchand1     1934     H     PH546381     Selection from Manchu In 1924       Lincoln     1940     H     PH548388     Selection from Manchu In 1924       Lincoln     1943     H     PH548582     Mindarin * Manchu       Hawkeyei     1947     H     PH548573     Mandarin * Manchu       Hawkeyei     1948     H     PH548573     Mandarin * Manchu       Harosoyi     1951     H     PH548572     Lincoln f(2) * Richland       Indianin     1958     H     PH548572     Lincoln f(2) * Richland       Ford     1958     H     PH548572     Manchu * Lincoln       Roso     1963     H     PH548572 <td>Korean</td> <td>1928</td> <td>II </td> <td>PI548360</td> <td>From China</td>	Korean	1928	II 	PI548360	From China
Macken     Hsk2     II     Hb38531     Petabasis	AK (Harrow)	1928	III 	PI548298	Selection from A.K. (by 1928)
Mancall     1944     III     PH34381     Selection from Manchu in 1926       Alingo     1840     III     PH546368     Selection from Manchu in 1924       Lincoln'     1843     III     PH546368     Selection from Manchu in 1924       Hawkaye'     1847     II     PH545377     Mukdan × Richland       Hawkaye'     1947     II     PH545373     Mandam (Dtawn)////////////////////////////////////	Mukden	1932	 	PI548391	P.I. 50523 (NE China)
Hohland"     1938     II     PH54268     F17.05022 (NE China)       Mingo     1940     III     PH54288     Selecton from Monchu in 1924       Lincoln"     1943     III     PH54282     Mandam's Manchu       Hewkayef     1947     II     PH548573     Mandam's Manchu in 1924       Adams     1948     III     PH548582     Mandam (Diswa)(2) × A.K. (Harrow)       Lindain     1958     II     PH548582     Lincoln (2) × Hichland       Ford     1958     III     PH548576     Monree × Lincoln       Ford     1958     II     PH548576     Harosvy (B) × Biochlawk       Ford     1963     II     PH548576     Harosvy (B) × Biochlawk       Hardwaye (B)     1964     II     PH548508     Adams × Haroscy       Adaphia     1964     II     PH548508     Adams × Haroscy       Mancy     1965     II     PH548508     Adams × Haroscy       Conscy'     1965     II     PH548508     Adams × Haroscy       Conscy'     1965     II     PH548503<	Mandell	1934	 	PI548381	Selection from Manchu in 1926
Mingo     1840     III     PE54838     Selector from Marchu in 1824.       Lincohi     1943     III     PE54857     Makdar × Richland       Hawkeye <sup>T</sup> 1947     II     PE548577     Makdar × Richland       Herosoy <sup>T</sup> 1951     II     PE548573     Mardarin (Ottawaki) × Lincoln       Lindarin     1958     III     PE548573     Mardarin (Ottawaki) × Lincoln       Shelby     1958     III     PE548573     Mardarin (Ottawaki) × Lincoln       Ford     1985     III     PE548572     Hawlaye (I) × Bickhand       Ford     1985     II     PE548572     Hawlaye (I) × Bickhand       Hawlaye (S)     1963     II     PE548578     Hawlaye (I) × Bickhand       Variant     1964     II     PE548578     Hawlaye (I) × Bickhand       Variant     1964     II     PE548578     Hawlaye (I) × Bickhand       Variant     1966     II     PE54857     Hawlaye (I) × Adams       Artexy     1966     II     PE54850     C1223 (Isoki hawk       Variant     PE548510<	Richland	1938	II	PI548406	P.I. 70502-2 (NE China)
Lincoln'     1943     III     PH54852     Mandam x Manchu       Adams     1943     III     PH54857     Mudden x Kinchland       Adams     1943     III     PH548522     Illini x Dunfeld       Harasoy1     1953     III     PH548589     Mandam (Ditawa)(2) x A.K. (Harrow)       Lindarin     1953     II     PH548589     Mandam (Ditawa) x Lincoln       Ford     1983     III     PH548575     Herosoy (B) x Blochhawk       Ford     1983     II     PH548575     Herosoy (B) x Blochhawk       Harosoy (G)     1963     II     PH548575     Herosoy (B) x Blochhawk       Hawkaye (G)     1964     III     PH548576     Hawkaye (G) x Blochhawk       Wayel     1964     III     PH548560     Harasoy (C) x Captal       Bescon     1965     III     PH548510     C1203 (Blachhawk + Harasoy) x Kont       Carsoy (I)     1977     III     PH548513     Waye x L57-0024 (Clark x Adam)       Walls     1972     III     PH548513     Waye x L57-0024 (Clark x Adam)       Walls	Mingo	1940	III 	PI548388	Selection from Manchu in 1924
Hawkeys <sup>1</sup> 1947     II     PESAB07     Mukdam × Richland       Harcasy <sup>1</sup> 1951     II     PESAB02     Mandami (Ottawa) × Lincoln       Lindarin     1958     II     PESAB08     Mandami (Ottawa) × Lincoln       Shelby     1958     III     PESAB08     Mandami (Ottawa) × Lincoln       Shelby     1958     III     PESAB07     Lincoln (2) × Richland       Bosa     1960     III     PESAB075     Hawkaye (7) × Blackhawk       Harvasy (8)     1963     II     PESAB075     Harvasy (7) × Blackhawk       Mayne'     1964     III     PESAB075     Harvasy (7) × Blackhawk       Mayne'     1964     III     PESAB06     Adams × Harcasy × Capital       Corscy     1967     II     PESAB06     Adams × Harcasy × Capital       Beeson     1968     III     PESAB07     Amasy × Capital       Beeson     1968     III     PESAB07     Amasy × Capital       Milliane 1     1970     II     PESAB07     Amasy × Capital       Marcasy 11     1970     I	Lincoln <sup>T</sup>	1943	 	PI548362	Mandarin × Manchu
Adams     1948     III     PI548573     Mandarin (Ditawaj): X AK. (Harrow)       Lindarin     1958     III     PI548573     Mandarin (Ditawaj): X AK. (Harrow)       Lindarin     1958     III     PI548574     Mandarin (Ditawaj): X Incoln       Sheby     1958     III     PI548574     Lincoln (2): A Richland       Ford     1958     III     PI548575     Harosoy (B): Blackhawk       Bass     1963     II     PI548575     Harosoy (B): Blackhawk       Harwskye (G)     1964     III     PI548503     Clark       Adams     1964     II     PI548503     Clark       Alasoy     1965     II     PI548503     Clark     Adams       Ansoy     1967     II     PI548507     Cl233 X Kant     Ansoy (X Kent       Callandt     1968     II     PI548507     Cl233 X Kant     Ansoy (X Cl23)       Mandarin (Clark x Adams)     III     PI548507     Cl233 X Kant     Adams + Harosoy (X Cl23)       Viellan     1974     II     PI548510     Crasoy (X Cl23) X Cl23)	Hawkeye <sup>⊤</sup>	1947	II	PI548577	Mukden × Richland
Harcesor <sup>1</sup> 1951     II     PF548573     Mandam (Dtawa)(2 × Anc)       Shelby     1958     II     PF54858     Mandam (Dtawa) × Lincoln       Shelby     1958     III     PF548562     Lincoln (2) × Richland       Brossy 05     1963     III     PF548575     Lincoln (2) × Richland       Brossy 05     1963     III     PF548575     Harvesy (7) × Blackhawak       Harvesy 05     1963     III     PF548575     Harvesy (7) × Blackhawak       Harvesy 05     1963     III     PF548563     L99-001 × Cakr       Adalphia     1964     III     PF548560     C1070 × Adams       Amsay     1965     II     PF548560     C1023 × Blackhawk × Harceoy) × Kent       Calland*     1968     III     PF548501     C1263 × Kent       Amsay 71*     1970     II     PF548503     C1263 × Kent       Millians*     1972     II     PF54853     Veyne × L57-0034       Wells     1977     II     PF54853     Veyne × L57-0034       Wadovorh*     1978     II	Adams	1948		PI548502	Illini × Dunfield
Lindam     1988     II     Pf548594     Lincoh (2) x Richland       Ford     1958     III     Pf548574     Lincoh (2) x Richland       Ford     1958     III     Pf548575     Harcsoy (8) x Bickhawk       Bass     1960     III     Pf548575     Harcsoy (8) x Bickhawk       Harcsoy (63     1963     II     Pf548575     Harcsoy (7) x Bickhawk       Mayene     1964     III     Pf548568     L40-4091 x Clark       Adelphia     1964     III     Pf548568     L40-4091 x Clark       Adelphia     1965     II     Pf548508     C1203 (Bickhawk x Harcsoy) x Kent       Carsoy (1)     1967     II     Pf548507     C1233 x Kent       Amsoy 711     1970     II     Pf548507     C1233 x Kent       Amsoy 711     1970     II     Pf548530     C1263 (Hachawk x Adams)       Wells     1972     II     Pf548530     C1263 (Hachawk x Adams)       Wells     1977     II     Pf548530     Carsoy x OX383 (Corsoy x Harcsoy x Cl73) x Cl233       Wells     1977	Harosoy <sup>†</sup>	1951		PI548573	Mandarin (Ottawa)(2) × A.K. (Harrow)
Shelby     1968     III     P15486574     Lincoln ( $\beta \times$ Richland       Pord     1960     III     P1548652     Lincoln ( $\beta \times$ Richland       Ross     1960     II     P15486575     Haroscy ( $\beta \times$ Blackhawk       Harwsky 63     1963     II     P15486576     Harwsky ( $\beta \times$ Blackhawk       Vaynet     1964     III     P15486206     C1070 × Adams       Addepnia     1964     III     P1548606     Adams × Haroscy ( $\beta \times$ Stackhawk       Corsey. <sup>7</sup> 1967     II     P1548506     Adams × Haroscy ( $\beta \times$ Stackhawk       Corsey. <sup>7</sup> 1967     II     P1548507     Amsoy ( $\beta \times$ C1253 (Blackhawk × Haroscy) × Kent       Calland <sup>1</sup> 1968     II     P1548507     Amsoy ( $\beta \times$ C1253 ( $\beta \times$ Adams)       Wella     1972     II     P1548630     C1266R (Haroscy × C1079) × C1253       Warge × L57-0034     Harsor × L57-0034     Haroscy × C1379     C1253       Warge × L57-0034     Haroscy × C1379     C1266R (Haroscy × L57-0034)     Haroscy × L57-0034)       Haroscy + 1977     II     n/a     r/a     Haroscy × L57-0034) <td>Lindarin</td> <td>1958</td> <td>II</td> <td>PI548589</td> <td>Mandarin (Ottawa) × Lincoln</td>	Lindarin	1958	II	PI548589	Mandarin (Ottawa) × Lincoln
Ford     1958     III     PI548512     Morros of Lincoln ( $\lambda$ × Richland       Harosoy 63     1963     II     PI548517     Harosoy (I)     Stackhawk       Waynef     1964     III     PI548518     L49-4091 × Clark       Adelphia     1964     III     PI548628     L49-4091 × Clark       Adelphia     1964     III     PI548600     Adams × Harosoy       Corsoy 7     1965     II     PI548600     Adams × Harosoy       Corsoy 7     1967     II     PI548610     C1253 (Rackhawk × Harosoy) × Kent       Caland 1     1968     II     PI548610     C1253 (Rackhawk × Harosoy) × Kent       Caland 1     1968     II     PI548610     C1253 (Rackhawk × Harosoy) × Kent       Caland 1     1970     II     PI648631     Wayne × L57-0034 (Clark × Adams)       Wells     1971     II     PI648631     Wayne × L57-0034       Wordworth*     1974     II     PI648517     Corsoy × OX333 (Corsoy × Harosoy K3)       Wordworth*     1975     II     PI648517     Corsoy V	Shelby	1958	III	PI548574	Lincoln (2) × Richland
Ress     1960     III     PI548575     Harosoy (8) × Blachhawk       Harwsey 63     1963     II     PI548575     Harosoy (8) × Blachhawk       Hawkey 63     1964     III     PI548282     L494-601 × Clark       Adalphia     1964     III     PI548283     Cl370 × Adams       Antsoy     1965     II     PI548260     Adams × Harosoy       Corsoy     1967     II     PI548260     Adams × Harosoy     Kent       Corsoy     1968     III     PI54857     Cl253 (Blackhawk × Haroso) × Kent     Calland1       Beeson     1968     III     PI54857     Cl253 × Kent     Adams × Harosoy × Kent       Amsoy 71*     1970     II     PI548637     Wayno × L57-0034 (Clark × Adams)       Wells     1972     II     PI548632     Wayno × L57-0034     Cl253 (Plackhawk × Adams)       Woodworth*     1976     II     PI548632     Wayno × L57-0034     PI34       Wells     1977     II     n/a     n/a     N/a       Volcary     1976     II     PI5485	Ford	1958	III	PI548562	Lincoln (2) × Richland
Harosoy 65     1963     II     PI548575     Harosoy (8) × Blackhawk       Wayne <sup>1</sup> 1964     II     PI548528     L49-4091 × Clank       Adalphia     1964     II     PI548528     L49-4091 × Clank       Adalphia     1965     II     PI548506     Adams × Harosoy       Corsoy <sup>1</sup> 1967     II     PI548506     Adams × Harosoy       Corsoy <sup>1</sup> 1967     II     PI548506     C1253 (Slackhawk × Adams)       Caland <sup>1</sup> 1968     II     PI548517     C1253 × Kant       Caland <sup>1</sup> 1968     II     PI548517     C1253 × Kant       Millams <sup>2</sup> 1971     II     PI548531     Wayne × L57-0034       Wells     1972     II     PI548532     Wayne × L57-0034       Woodworth <sup>1</sup> 1974     II     PI548533     Wells (B) × Arksoy       Wells     1977     II     n/a     N/a       Private 2-3     1977     II     n/a     N/a       Vickery     1978     II     PI548573     Wells (B) × Arksoy	Ross	1960	III	PI548612	Monroe × Lincoln
Hawkeye (5.3     1963     II     P1548578     Hawkeye (7. × Blackhawk       Waynel     1964     III     P1548508     L (4)-4001 × Clark       Adelphia     1964     III     P1548508     L (4)-4001 × Clark       Amsoy     1965     II     P1548500     C1253 (Blachawk × Harosoy) × Kent       Calland!     1968     III     P1548507     C1253 (Blachawk × Harosoy) × Kent       Calland!     1968     III     P1548507     C1253 (Blachawk × Harosoy) × Kent       Calland!     1970     II     P1548507     Carsoy × L57-0034 (Clark × Adams)       Williams!     1971     III     P1548507     Carsoy × NX383 (Corsoy × Harosoy 63)       Woodworth*     1974     II     P1548570     Corsoy × NX383 (Corsoy × Harosoy 63)       Private 2-7     1977     II     n/a     n/a       Wells     1978     II     P1548513     Wells (8) × Arkasoy       Vickery     1978     III     n/a     n/a       Vickery     1978     III     n/a     I       Carsoy 799     1979	Harosoy 63	1963	II	PI548575	Harosoy (8) × Blackhawk
Waynel     1964     III     P1648628     L 49-4091 × Clark       Adelphia     1965     II     P1648508     C1070 × Adams       Amsoy     1965     II     P1648506     Adams × Hanosoy       Corsoy <sup>1</sup> 1967     II     P1648510     C1253 (Slackhawk × Harosoy) × Kent       Calland <sup>1</sup> 1968     III     P1648527     C1253 × Kent       Calland <sup>1</sup> 1968     III     P1648527     C1253 × Kent       Amsoy 71 <sup>1</sup> 1970     II     P1648630     C12050 (Harcsoxy × C1079) × C1233       Williams <sup>1</sup> 1971     III     P1648632     Wayne × L57-0034 (Clark × Adams)       Welks     1972     II     P1648570     Corsoy × OX383 (Corsoy × Harosoy 63)       Private 2-8     1977     II     n/a     n/a       Private 2-8     1977     II     n/a     n/a       Velkery     1978     III     P1648513     Wells (B) × Arksoy       Velkery     1978     III     P1648513     Wells (B) × Arksoy       Velkery     1978     III     P16	Hawkeye 63	1963	II	PI548578	Hawkeye (7) × Blackhawk
Adelphia   1964   11   P1548503   C1070 x Adams     Amsoy   1965   11   P1548506   Adams x Harosoy     Corsoy <sup>1</sup> 1967   11   P1548506   Adams x Harosoy     Beeson   1968   11   P1548507   C1253 (Blackhawk x Harosoy) × Kent     Caland <sup>1</sup> 1988   11   P1548507   C1253 x Kent     Amsoy 71 <sup>1</sup> 1970   11   P1548507   C1253 x Kent     Milliams <sup>1</sup> 1971   11   P1548630   C1263 (Carsoy × C1079) × C1253     Woodworth <sup>1</sup> 1974   11   P1548632   Wayne × L57-0034 (Cark × Adams)     Weils   1977   11   n/a   r/a     Private 2-7   1977   11   n/a   r/a     Vickery   1978   11   n/a   r/a     Vickery   1978   11   n/a   n/a     Vickery   1978   11   n/a   n/a     Corsoy 79   1978   11   n/a   n/a     Corsoy 79   1979   11   P1548651   Becson (8) × Arksoy     Corsoy 79	Wayne <sup>†</sup>	1964	III	PI548628	L49-4091 × Clark
Amsoy   1985   II   P1548506   Adams × Harosoy     Corsoy <sup>1</sup> 1967   II   P1548500   Adams × Harosoy   Xent     Beeson   1968   II   P1548507   C1253 x Kent   Xent     Amsoy 71 <sup>+</sup> 1970   II   P1548527   C1253 x Kent   Xent     Amsoy 71 <sup>+</sup> 1971   III   P1548630   C12681 (Harosoy × C1034) (Clark × Adams)     Wells   1972   II   P1548632   Wayne × L57-0034 (Clark × Adams)     Woodworth <sup>1</sup> 1974   III   P15486570   Corsoy × O1039 × C1253     Woodworth <sup>1</sup> 1977   II   n/a   n/a     Private 2-7   1977   II   n/a   n/a     Vickery   1978   II   P1548513   Wells (8) × Arksoy     Vickery   1978   II   P1548513   USE-13742 and Anoka × Mack)     Private 3-1 <sup>+</sup> 1978   II   n/a   n/a     Calland × Boros   1979   II   P1548651   Corsoy (8) × Le56 (342 and Anoka × Mack)     Orsoy 79   1979   II   P1548651   Beeson (8) × Arksoy   Centur <td>Adelphia</td> <td>1964</td> <td>III</td> <td>PI548503</td> <td>C1070 × Adams</td>	Adelphia	1964	III	PI548503	C1070 × Adams
Corsoy <sup>1</sup> 1967     II     PI548540     Harosoy × Capital       Beeson     1968     II     PI548510     C1253 (Blackhawk × Harosoy) × Kent       Calland <sup>1</sup> 1968     III     PI548507     C1253 × Kent       Amsoy 71 <sup>1</sup> 1970     II     PI548507     C1253 × Kent       Millams <sup>1</sup> 1971     III     PI548631     Wayne × L57-0034 (Clark × Adams)       Wells     1972     II     PI548632     Wayne × L57-0034       Harcor     1975     II     PI548570     Corsoy × OX333 (Corsoy × Harosoy eG3)       Private 2-7     1977     II     n/a     n/a       Velst 2-7     1977     II     n/a     n/a       Velst 2-7     1978     II     PI548513     Wells (B) × Arksoy       Vickery     1978     II     PI548642     Corsoy × OX334 (Corsoy + Larosoy 4) Calland       Cumberland     1978     III     PI548542     Corsoy × OX343 (Corsoy + Larosoy       Corsoy 79     1979     II     PI548542     Corsoy × OX343 (Corsoy + Larosoy       Contherland <t< td=""><td>Amsoy</td><td>1965</td><td>II</td><td>PI548506</td><td>Adams × Harosoy</td></t<>	Amsoy	1965	II	PI548506	Adams × Harosoy
Beeson     1968     II     PI548510     C1253 (Bachkawk × Harosoy) × Kent       Calland1     1968     III     PI548507     Amsoy (8) × C1253       Williams1     1970     II     PI548630     C1253 (Kant × Adams)       Wells     1972     II     PI548630     C1266R (Harosoy × C1079) × C1253       Woodworth1     1974     III     PI548632     Wayne × L57-0034       Haroor     1975     II     PI548632     Wayne × L57-0034       Vickery     1977     II     n/a     n/a       Private 2-7     1977     II     n/a     n/a       Vickery     1978     II     PI648513     Wells (8) × Arksoy       Vickery     1978     III     PI548513     Wells (8) × Arksoy       Candand     1978     III     PI548513     Wells (8) × Arksoy       Carsor 79     1979     II     PI548514     L661-137 (Wayne × L57-0034) × Calland       Carsor 79     1979     II     PI548514     L661-137 × Calland       Milams 82*     1989     III     PI548511	Corsoy <sup>†</sup>	1967	II	PI548540	Harosoy × Capital
Calland <sup>†</sup> 1968     III     PI548527     C1253     Kent       Amsoy 71 <sup>+</sup> 1970     II     PI548631     Warpa × L57-0034 (Clark × Adams)       Williams <sup>†</sup> 1971     III     PI548632     Wayna × L57-0034 (Clark × Adams)       Woodworth <sup>*</sup> 1974     II     PI548632     Wayna × L57-0034       Harcor     1975     II     PI548570     Corsoy × OX383 (Corsoy × Harosoy 63)       Private 2-7     1977     II     n/a     n'a       Vickery     1978     II     PI648513     Wells (h) × Arksoy       Vickery     1978     II     n/a     n'a       Vickery     1978     III     n/a     n'a       Cumberland     1978     III     n/a     n'a       Corsoy 79     1979     II     PI548542     Corsoy (h) × Lee 68       Beeson 80     1979     II     PI548543     L66L-137 (Wayna × L57-0034) × Calland       Amoor     1979     II     PI548563     Amsoy 71 × Corsoy       Pila     1979     II     PI548512	Beeson	1968	II	PI548510	C1253 (Blackhawk × Harosoy) × Kent
Amsory 71*1970IIPI648507Amsory (8) < C1253Williams*1971IIIPI548631Wayne x L57-0034 (Clark x Adams)Wolds1972IIPI548632Wayne x L57-0034 (Clark x Adams)Woodworth*1974IIIPI648632Wayne x L57-0034Harcor1975IIPI648670Corsory x OX383 (Corsor x Harosory 63)Private 2-71977IIn/an/aPrivate 2-81977IIn/an/aVickery1978IIPI648513Weils (8) x ArksoryVickery1978IIIPI648617Corsory (5) x (L65-1342 and Anoka x Mack)Ourberland1978IIIPI648542Corsory w WilliamsOakland1978IIIPI648542Corsory w WilliamsOakland1978IIIPI648542Corsory (6) k Lee 68Corsory 791979IIPI648513Weils (8) k ArksoryCentury11979IIPI648512Calland x BonusAmcor1979IIPI648513Weils (8) k ArksoryCentury11979IIPI648514Beeson (8) x ArksoryCentury11979IIPI648513Weils (8) krksoryCentury11979IIPI648514Weils (8) krksoryCentury11979IIPI648514Corsory (6) krksoryPilate 3-151983IIn/an/aCentury 841984IIPI648523Cectury (6) krksoryPirkate 2-151985 <td>Calland<sup>†</sup></td> <td>1968</td> <td>III</td> <td>PI548527</td> <td>C1253 × Kent</td>	Calland <sup>†</sup>	1968	III	PI548527	C1253 × Kent
Willams <sup>1</sup> 1971   III   P1648631   Wayne x L57-0034 (Clark x Adams)     Wells   1972   II   P1648630   C1266R (Harosoy x C1079) x C1253     Woodworth <sup>1</sup> 1974   II   P1648632   Wayne x L57-0034     Harcor   1975   II   P1648570   Corsoy x OX383 (Corsoy x Harosoy 63)     Private 2-8   1977   II   n/a   n/a     Private 2-8   1977   II   n/a   n/a     Vickery   1978   II   P1648613   Wells (8) x Arksoy     Vickery   1978   II   P1648613   Wells (8) x Arksoy     Vickery   1978   III   P1648613   Corsoy x Williams     Oakland   1978   III   P1648651   Clebs - 137 (Wayne x L57-0034) x Calland     Corsoy 79   1979   II   P1648650   Corsoy (6) x Lee 68     Beeson 80   1979   II   P1648651   Beeson (8) x Arksoy     Century1   1979   II   P1648550   Amsoy 11 x Corsoy     Piela   1979   II   P1648550   Amsoy 11 x Corsoy     Piela   1979 <t< td=""><td>Amsoy 71<sup>†</sup></td><td>1970</td><td>II</td><td>PI548507</td><td>Amsoy (8) × C1253</td></t<>	Amsoy 71 <sup>†</sup>	1970	II	PI548507	Amsoy (8) × C1253
Wels   1972   II   P1548630   C1266R (Harcsory × C1079) × C1253     Woodworth <sup>1</sup> 1974   II   P1548632   Wayne × L57-0034     Harcor   1975   II   n/a   Corsoy × OX383 (Corsoy × Harosoy 63)     Private 2-7   1977   II   n/a   n/a     Private 2-8   1977   II   n/a   n/a     Wells II   1978   II   P1548613   Wells (8) × Arksoy     Vickery   1978   II   P1548617   Corsoy (5) × (L65-1342 and Anoka × Mack)     Private 3-11   1978   III   P1548617   Corsoy × Williams     Cumberland   1978   III   P1548542   Corsoy × Williams     Corsoy 79   1979   II   P1548542   Corsoy (6) × Le 68     Beeson 80   1979   II   P1548512   Calland k Borus     Amcor   1979   II   P1548512   Calland k Borus     Williams 82 <sup>+</sup> 1981   III   P1548512   Calland     Williams 82 <sup>+</sup> 1981   III   P1548512   Calland     Williams 82 <sup>+</sup> 1981   III   <	Williams <sup>†</sup>	1971		PI548631	Wayne × L57-0034 (Clark × Adams)
Woodworth*     1974     III     PI648632     Wayne x L57-0034       Harcor     1975     II     PI648570     Corsoy x OX383 (Corsoy x Harosoy 63)       Private 2-7     1977     II     n/a'     n/a       Private 2-8     1977     II     n/a     n/a       Wells II     1978     II     PI548513     Wells (8) x Arksoy       Vickery     1978     II     PI548517     Corsoy (5) x (L65-1342 and Anoka x Mack)       Private 3-1*     1978     III     PI548643     Corsoy Villiams       Oakland     1978     III     PI548543     L66L-137 (Wayne x L57-0034) x Calland       Corsoy 79     1979     II     PI548543     L66L-137 (Wayne x L57-0034) x Calland       Corsoy 79     1979     II     PI548542     Calland x Bonus       Amcor     1979     II     PI548513     Beoson (8) x Arksoy       Century*     1979     II     PI54852     Calland x Bonus       Amcor     1979     II     PI54852     Calland x Bonus       Privata 2-11     1982     II	Wells	1972	II	PI548630	C1266R (Harosoy × C1079) × C1253
Harcor1975IIPI648570Corsoy × X383 (Corsoy × Harosoy 63)Private 2-71977II $n/a^4$ $n/a$ Private 2-81977II $n/a$ $n/a$ Wells II1978IIPI548513Wells (8) × ArksoyVickery1978IIPI548517Corsoy (5) × (L65-1342 and Anoka × Mack)Private 3-1 <sup>+1</sup> 1978III $n/a$ $n/a$ Cumberland1978III $n/a$ $n/a$ Cumberland1978IIIPI548542Corsoy WilliamsOakland1978IIIPI548543L66L-137 (Wanya × L57-0034) × CallandCorsoy 791979IIPI548511Beeson (8) × ArksoyCentury <sup>1</sup> 1979IIPI548512Calland × BonusAmcor1979IIPI548523L66L-137 × CallandWilliams 82?1981IIIPI548523L66L-137 × CallandWilliams 82?1983III $n/a$ $n/a$ Private 3-151983III $n/a$ $n/a$ Private 3-151984IIPI548529Combertand × PellaElgin1984IIPI548529Combertand × PellaHarper1984IIPI54853Arsoy 1/a × Carland × Corso populationPrivate 2-151985II $n/a$ $n/a$ Private 2-151985IIPI648558F <sub>a</sub> selection from APE populationPrivate 2-151985II $n/a$ $n/a$ Private 2-151985II $n/a$	Woodworth <sup>†</sup>	1974	III	PI548632	Wayne × L57-0034
Private 2-71977II $n/a$ $n/a$ $n/a$ Private 2-81977II $n/a$ $n/a$ Private 2-81978IIPI548513Wells (8) × ArksoyVickery1978IIPI548617Corsoy (5) × (L65-1342 and Anoka × Mack)Private 3-1*1978III $n/a$ $n/a$ Cumberland1978IIIPI548542Corsoy (5) × (L65-1342 and Anoka × Mack)Oakland1978IIIPI548514Corsoy (6) × Lee 68Gaeson 801979IIPI548511Beeson (8) × ArksoyCentury11979IIPI548512Calland × BonusAmcor1979IIPI548512Calland × BonusAmcor1979IIPI548514Masoy 71 × CorsoyPella1979IIPI548514Wells (B-137 × CallandWilliams 82*1981IIIn/aPrivate 2-111982IIn/aPrivate 2-111982IIn/aPrivate 2-111983IIIn/aPrivate 2-111984IIPI548577Private 2-111984IIPI548578Private 2-111984IIPI548512Century 841984IIPI548520Century 841984IIPI548520Century 841985IIn/aPrivate 2-151985IIn/aPrivate 2-151985IIn/aPrivate 3-21986IIn/aPrivat	Harcor	1975	II	PI548570	Corsoy × OX383 (Corsoy × Harosoy 63)
Private 2-81977IIn/an/aWells II1978IIP1548513Wells (8) × ArksoyVickery1978IIP1548517Corsoy (5) × (L65-1342 and Anoka × Mack)Private 3-1*1978IIIn/an/aCumberland1978IIIP1548542Corsoy × WilliamsOakland1978IIIP1548543L66L-137 (Wayne x L57-0034) × CallandCorsoy 791979IIP1548650ArksoyCentury*1979IIP1548511Beeson (8) × ArksoyCentury*1979IIP1548505Armsoy 71 × Corsoy 74Pella1979IIP1548523L66L-137 × CallandAmcor1979IIIP1548523L66L-137 × CallandPella1979IIIP1548523L66L-137 × CallandWilliams 82*1981IIIn/an/aPrivate 3-151983IIIn/an/aPrivate 3-151983IIIn/an/aCentury 841984IIP1548529Century (5) × Williams 82Elgin1984IIP1548520Schechinger S48 × Land O'Lakes MaxPrivate 2-151985IIn/an/aPrivate 3-21986IIn/an/aPrivate 3-21986IIP1548520Schechinger S48 × Land O'Lakes MaxPrivate 3-21986IIn/an/aPrivate 3-21986IIn/an/aPrivate 3-21986II<	Private 2-7	1977	II	n/a‡	n/a
Wells1978IIPI548513Wells (8) × ArksoyVickery1978IIPI548617Corsoy (6) × (L65-1342 and Anoka × Mack)Private 3-111978IIIPI548642Corsoy × WilliamsCumberland1978IIIPI548542Corsoy (6) × Le6 - 8Corsoy 791979IIPI548569Corsoy (6) × Lee 68Beeson 801979IIPI548511Beeson (8) × ArksoyCentury <sup>1</sup> 1979IIPI548512Calland × BonusAmcor1979IIPI548512Calland × BonusAmcor1979IIPI548512Calland × BonusAmcor1979IIPI548512Calland × BonusAmcor1979IIPI548512Calland × BonusAmcor1979IIPI548512Calland × BonusVilliams 8211981IIIPI54852Le6L-137 × CallandWilliams 8211984IIIPI54852Century (5) × Williams 82Elgin1984IIPI54852Century (5) × Williams 82Elgin1984IIPI548556F <sub>1</sub> selection from APC populationZane1984IIPI548557F <sub>2</sub> selection from an unknown dialel-cross populationPrivate 3-21986IIn/an/aPrivate 3-21986IIn/an/aPrivate 3-21986IIn/an/aPrivate 3-21986IIn/an/aPrivate 3-21986IIPI534645 <td< td=""><td>Private 2-8</td><td>1977</td><td>II</td><td>n/a</td><td>n/a</td></td<>	Private 2-8	1977	II	n/a	n/a
Vickery1978IIPI548617Corsoy (5) × (L65-1342 and Anoka × Mack)Private 3-1*1978IIIn/an/aCumberland1978IIIPI548542Corsoy × WilliamsOakland1978IIIPI548543L66L-137 (Wayne × L57-0034) × CallandCorsoy 791979IIPI548511Beeson (8) × ArksoyCentury11979IIPI548512Calland × BonusAmcor1979IIPI548512Calland × BonusAmcor1979IIPI548512Calland × BonusPella1979IIPI548512Calland × BonusPrivate 3-151981IIIPI54857KangwaPrivate 3-151983IIIn/an/aPrivate 3-151983IIIn/an/aCarnury 841984IIPI54857F <sub>a</sub> selection from AP6 populationZane1984IIPI54858F <sub>a</sub> selection from An unknown diallel-cross populationPrivate 3-151985IIn/an/aCarnury 841984IIPI54858F <sub>a</sub> selection from an unknown diallel-cross populationZane1984IIPI54855A76-304020 × Land O'Lakes MaxPrivate 3-21986IIn/an/aChamberlain*1986IIn/an/aPrivate 3-21986IIn/an/aPrivate 3-21986IIn/an/aPrivate 3-21986IIn/an/a <t< td=""><td>Wells II</td><td>1978</td><td>II</td><td>PI548513</td><td>Wells (8) × Arksoy</td></t<>	Wells II	1978	II	PI548513	Wells (8) × Arksoy
Private 3-111978IIIn/an/aCumberland1978IIIPI548542Corsoy × WilliamsOakland1978IIIPI548543L66L-137 (Wayne x L57-0034) × CallandOakland1979IIPI548569Corsoy (6) × Lee 68Beeson 801979IIPI548511Beeson (8) × ArksoyCentury11979IIPI548512Calland × BonusAmcor1979IIPI548553L66L-137 × CallandPella1979IIIPI548523L66L-137 × CallandWilliams 8211981IIIPI518671Williams (7) × KingwaPrivate 2-111982IIn/an/aPrivate 3-151983IIn/an/aCentury 841984IIPI548529Century (5) × Williams 82Elgin1984IIPI548557F <sub>a</sub> selection from AP6 populationZane1984IIPI548520Schechinger S48 × Land O'Lakes MaxPrivate 3-151985IIn/an/aChamberlain <sup>1</sup> 1986IIIn/an/aPrivate 3-21986IIn/an/aPrivate 3-21986IIn/an/aPrivate 3-21986IIn/an/aPrivate 3-21986IIn/an/aPrivate 3-21986IIn/an/aPrivate 3-21986IIn/an/aPrivate 3-21986IIn/an/aPriva	Vickery	1978	II	PI548617	Corsoy (5) × (L65-1342 and Anoka × Mack)
Cumberland1978IIIPI548542Corsoy × WilliamsOakland1978IIIPI548543L6BL137 (Wayne × L57-0034) × CallandCorsoy 791979IIPI548510Corsoy (6) × Lee 68Beeson 801979IIPI548512Calland × BonusCentury*1979IIPI548512Calland × BonusAmcor1979IIPI548512Calland × BonusPella1979IIPI548512Calland × BonusWilliams 82*1981IIIPI548523L66L137 × CallandVilliams 82*1983IIIn/an/aPrivate 3-151983IIIn/an/aCentury 841984IIPI548529Century (5) × Williams 82Elgin1984IIPI548529Century (5) × Williams 82Elgin1984IIPI548550F4 selection from AP6 populationZane1984IIIPI548520Schechinger S48 × Land O'Lakes MaxPrivate 2-151985IIn/an/aPrivate 2-151986IIIPI548550ArG-304020 × Land O'Lakes MaxPrivate 3-21986IIIn/an/aResnik1987IIIPI534645Asgrow 33127(4) × L24Pella 861987IIIPI53655F4 selection from K74-113-76-486 × CenturyPrivate 2-91988IIn/an/aBesnik1988IIN/an/aElgin 871988IIPI536655F4 selecti	Private 3-1 <sup>+</sup>	1978	III	n/a	n/a
Oakland     1978     III     PI548543     L66L-137 (Wayne x L57-0034) x Calland       Corsoy 79     1979     II     PI518669     Corsoy (6) x Lee 68       Beeson 80     1979     II     PI548512     Calland x Bonus       Century <sup>1</sup> 1979     II     PI548512     Calland x Bonus       Amcor     1979     II     PI548512     Calland x Bonus       Amcor     1979     II     PI548512     Calland X Bonus       Pella     1979     II     PI548523     L66L-137 x Calland       Williams 82*     1981     III     PI548523     L66L-137 x Calland       Private 3-15     1983     III     n/a     n/a       Private 3-15     1983     III     n/a     n/a       Century 84     1984     II     PI548529     Century (5) x Williams 82     Egin       Zane     1984     II     PI548536     F <sub>a</sub> selection from AP6 population     Eros population       Preston     1985     II     n/a     n/a     Eros population       Private 2-15	Cumberland	1978	III	PI548542	Corsoy × Williams
Corsoy 791979IIPI518669Corsoy (6) × Lee 68Beeson 801979IIPI548511Beeson (8) × ArksoyCentury*1979IIPI548512Calland × BonusAmcor1979IIPI548523L66L-137 × CallandWilliams 82*1981IIIPI548523L66L-137 × CallandWilliams 82*1981IIIPI518671Williams (7) × KingwaPrivate 2-111982IIn/an/aPrivate 3-151983IIIn/an/aCentury 841984IIPI548579Century (5) × Williams 82Elgin1984IIPI548577F <sub>a</sub> selection from AP6 populationZane1984IIPI548558F <sub>a</sub> selection from an unknown diallel-cross populationPrivate 2-151985IIn/an/aChamberlain*1986IIIn/an/aChamberlain*1986IIIn/an/aPrivate 3-21986IIIn/an/aPrivate 3-21986IIIn/an/aPrivate 3-21986IIIn/an/aPrivate 3-21986IIIPI536655Asgrow A3127(4) × L24Pella 861987IIIPI536656F <sub>4</sub> selection from K74-113-76-486 × CenturyPrivate 2-91988IIn/an/aElgin 871988IIPI5186666Elgin (5) × Williams 82Conrad*1988IIPI58656F <sub>4</sub> selection from K74-113-76-486	Oakland	1978	III	PI548543	L66L-137 (Wayne × L57-0034) × Calland
Beeson 80     1979     II     PI548511     Beeson (8) × Arksoy       Century <sup>1</sup> 1979     II     PI548512     Calland × Bonus       Amcor     1979     II     PI548512     Calland × Bonus       Amcor     1979     II     PI548523     L66L-137 × Calland       Williams 82 <sup>1</sup> 1981     III     PI548523     L66L-137 × Calland       Williams 82 <sup>1</sup> 1981     III     n/a     n/a       Private 2-11     1982     II     n/a     n/a       Century 84     1983     III     n/a     n/a       Century 84     1984     II     PI548529     Century (5) × Williams 82       Elgin     1984     II     PI548557     F <sub>4</sub> selection from AP6 population       Zane     1984     III     PI548558     F <sub>4</sub> selection from an unknown diallel-cross population       Private 2-15     1985     II     n/a     n/a       Private 2-25     1986     II     n/a     n/a       Private 3-2     1986     II     n/a     n/a <td>Corsoy 79</td> <td>1979</td> <td>II</td> <td>PI518669</td> <td>Corsoy (6) × Lee 68</td>	Corsoy 79	1979	II	PI518669	Corsoy (6) × Lee 68
Century11979IIPI548512Calland × BonusAmcor1979IIPI548505Amsoy 71 × CorsoyPella1979IIIPI548503L66L-137 × CallandWilliams 82*1981IIIPI518671Williams (7) × KingwaPrivate 2-111982IIn/an/aPrivate 3-151983IIIn/an/aCentury 841984IIPI548529Century (5) × Williams 82Elgin1984IIPI548557F <sub>4</sub> selection from AP6 populationZane1984IIIPI548658F <sub>4</sub> selection from an unknown diallel-cross populationPrivate 3-151985IIn/an/aHarper1984IIIPI548658F <sub>4</sub> selection from an unknown diallel-cross populationPrivate 2-151985IIn/an/aChamberlain*1986IIIPI548655A76-304020 × Land O'Lakes MaxPrivate 3-21986IIIn/an/aResnik1987IIIPI534645Asgrow A3127(4) × L24Pella 861987IIIPI533655F <sub>4</sub> selection from from K74-113-76-486 × CenturyPrivate 2-91988IIn/an/aElgin 871988IIPI518666Elgin (5) × Williams 82Conrad*1988IIPI518666Elgin (5) × Williams 82Conrad*1988IIPI518666Elgin (5) × Williams 82Conrad*1988IIPI518666Elgin (5) × Williams 82<	Beeson 80	1979	II	PI548511	Beeson (8) × Arksoy
Amcor1979IIPI548505Amsoy 71 × CorsoyPella1979IIIPI548523L66L-137 × CallandWilliams 82†1981IIIPI548523L66L-137 × CallandPrivate 2-111982IIn/an/aPrivate 3-151983IIIn/an/aCentury 841984IIPI548529Century (5) × Williams 82Elgin1984IIPI548557F4 selection from AP6 populationZane1984IIIPI548558F4 selection from an unknown dialel-cross populationPreston1984IIIPI548558F4 selection from an unknown dialel-cross populationPrivate 2-151985IIn/an/aChamberlain†1986IIIn/an/aPrivate 3-21986IIIn/an/aPrivate 3-21986IIIn/an/aPisa4655A56-304020 × Land O'Lakes MaxPisa4645Asgrow A3127(4) × L24Pella 861987IIIPI534645Asgrow A3127(4) × L24Pella 861987IIIPI533655F4 selection from K74-113-76-486 × CenturyPrivate 2-91988IIn/an/aElgin 871988IIPI518666Elgin (5) × Williams 82Conrad¹1988IIPI525453A3127 × Tri-Valley ChargerJack†1989IIPI50565Fayette × Hardin	Century <sup>†</sup>	1979	II	PI548512	Calland × Bonus
Pella   1979   III   P1548523   L66L-137 × Calland     Williams 82 <sup>†</sup> 1981   III   P1518671   Williams (7) × Kingwa     Private 2-11   1982   II   n/a   n/a     Private 3-15   1983   III   n/a   n/a     Century 84   1984   II   P1548529   Century (5) × Williams 82     Elgin   1984   II   P1548557   F <sub>4</sub> selection from AP6 population     Zane   1984   II   P1548558   F <sub>4</sub> selection from an unknown diallel-cross population     Zane   1985   II   P1548558   F <sub>4</sub> selection from an unknown diallel-cross population     Preston   1985   II   P1548520   Schechinger S48 × Land O'Lakes Max     Private 2-15   1985   II   n/a   n/a     Chamberlain <sup>†</sup> 1986   III   n/a   n/a     Resnik   1987   III   P1534635   Asgrow A3127(4) × L24     Private 2-9   1988   II   n/a   n/a     Burlison   1988   II   n/a   n/a     Private 2-9   1988   II <td>Amcor</td> <td>1979</td> <td>II</td> <td>PI548505</td> <td>Amsoy 71 × Corsoy</td>	Amcor	1979	II	PI548505	Amsoy 71 × Corsoy
Williams $82^{\dagger}$ 1981   III   PI518671   Williams (7) × Kingwa     Private 2-11   1982   II   n/a   n/a     Private 3-15   1983   III   n/a   n/a     Century 84   1984   II   PI548529   Century (5) × Williams 82     Elgin   1984   II   PI548557   F <sub>4</sub> selection from AP6 population     Zane   1984   III   PI548557   F <sub>4</sub> selection from a unknown diallel-cross population     Harper   1984   III   PI548558   F <sub>4</sub> selection from an unknown diallel-cross population     Preston   1985   II   PI548550   Schechinger S48 × Land O'Lakes Max     Private 2-15   1985   II   n/a   n/a     Chamberlain <sup>†</sup> 1986   III   n/a   n/a     Resnik   1987   III   PI534645   Asgrow A3127(4) × L24     Pella 86   1987   III   PI530655   F <sub>4</sub> selection from K74-113-76-486 × Century     Private 2-9   1988   II   n/a   n/a     Elgin 87   1988   II   PI518666   Elgin (5) × Williams 82	Pella	1979	III	PI548523	L66L-137 × Calland
Private 2-11   1982   II   n/a   n/a     Private 3-15   1983   III   n/a   n/a     Century 84   1984   II   Pl548529   Century (5) × Williams 82     Elgin   1984   II   Pl548557 $F_4$ selection from AP6 population     Zane   1984   II   Pl548634   Cumberland × Pella     Harper   1984   III   Pl548526   Schechinger S48 × Land O'Lakes Max     Preston   1985   II   Pl548520   Schechinger S48 × Land O'Lakes Max     Private 2-15   1985   II   n/a   n/a     Chamberlain†   1986   III   n/a   n/a     Resnik   1987   III   Pl548650   Af6-304020 × Land O'Lakes Max     Private 3-2   1986   III   n/a   n/a     Resnik   1987   III   Pl534645   Asgrow A3127(4) × L24     Pella 86   1987   III   Pl509044   From backcross of Pella(5) × Williams 82     Burlison   1988   II   n/a   n/a     Elgin 87   1988   II   n/a	Williams 82 <sup>†</sup>	1981	III	PI518671	Williams (7) × Kingwa
Private 3-15   1983   III   n/a   n/a     Century 84   1984   II   PI548529   Century (5) × Williams 82     Elgin   1984   II   PI548557 $F_4$ selection from AP6 population     Zane   1984   III   PI548634   Cumberland × Pella     Harper   1984   III   PI548558 $F_4$ selection from an unknown diallel-cross population     Preston   1985   II   PI548520   Schechinger S48 × Land O'Lakes Max     Private 2-15   1985   II   n/a   n/a     Chamberlain <sup>†</sup> 1986   III   PI548635   A76-304020 × Land O'Lakes Max     Private 3-2   1986   III   n/a   n/a     Resnik   1987   III   PI534645   Asgrow A3127(4) × L24     Pella 86   1987   III   PI533655 $F_4$ selection from K74-113-76-486 × Century     Private 2-9   1988   II   n/a   n/a     Elgin 87   1988   II   N/a   N/a     Elgin 87   1988   II   N/a   N/a     Conrad <sup>†</sup> 1988   II	Private 2-11	1982	II	n/a	n/a
Century 84   1984   II   PI548529   Century (5) × Williams 82     Elgin   1984   II   PI548557 $F_4$ selection from AP6 population     Zane   1984   III   PI548634   Cumberland × Pella     Harper   1984   III   PI548558 $F_4$ selection from an unknown diallel-cross population     Preston   1985   II   PI548520   Schechinger S48 × Land O'Lakes Max     Private 2-15   1985   II   n/a   n/a     Chamberlain <sup>†</sup> 1986   II   PI548635   A76-304020 × Land O'Lakes Max     Private 3-2   1986   III   n/a   n/a     Resnik   1987   III   PI534645   Asgrow A3127(4) × L24     Pella 86   1987   III   PI533655 $F_4$ selection from K74-113-76-486 × Century     Private 2-9   1988   I   PI533655 $F_4$ selection from K74-113-76-486 × Century     Private 2-9   1988   II   PI518666   Elgin (5) × Williams 82     Conrad <sup>†</sup> 1988   II   PI525453   A3127 × Tri-Valley Charger     Jack <sup>†</sup> 1989   II   PI50506	Private 3-15	1983	III	n/a	n/a
Elgin1984IIPI548557 $F_4$ selection from AP6 populationZane1984IIIPI548634Cumberland × PellaHarper1984IIIPI548558 $F_4$ selection from an unknown diallel-cross populationPreston1985IIPI548520Schechinger S48 × Land O'Lakes MaxPrivate 2-151985IIn/aChamberlain†1986IIIPI548635A76-304020 × Land O'Lakes MaxPrivate 3-21986IIIn/an/aResnik1987IIIPI534645Asgrow A3127(4) × L24Pella 861987IIIPI533655F_4 selection from K74-113-76-486 × CenturyPrivate 2-91988IIn/an/aElgin 871988IIPI518666Elgin (5) × Williams 82Conrad†1988IIPI525453A3127 × Tri-Valley ChargerJack†1989IIPI50556Fuert Hardin	Century 84	1984	II	PI548529	Century (5) × Williams 82
Zane1984IIIPI548634Cumberland × PellaHarper1984IIIPI548558 $F_4$ selection from an unknown diallel-cross populationPreston1985IIPI548520Schechinger S48 × Land O'Lakes MaxPrivate 2-151985IIn/an/aChamberlain <sup>†</sup> 1986IIIPI548635A76-304020 × Land O'Lakes MaxPrivate 3-21986IIIn/an/aResnik1987IIIPI534645Asgrow A3127(4) × L24Pella 861987IIIPI509044From backcross of Pella(5) × Williams 82Burlison1988IIPI533655 $F_4$ selection from K74-113-76-486 × CenturyPrivate 2-91988IIn/an/aElgin 871988IIPI518666Elgin (5) × Williams 82Conrad <sup>†</sup> 1988IIPI525453A3127 × Tri-Valley ChargerJack <sup>†</sup> 1989IIPI540556Fayette × Hardin	Elgin	1984	II	PI548557	F <sub>4</sub> selection from AP6 population
Harper1984IIIPI548558 $F_4$ selection from an unknown diallel-cross populationPreston1985IIPI548520Schechinger S48 × Land O'Lakes MaxPrivate 2-151985IIn/an/aChamberlain <sup>†</sup> 1986IIIPI548635A76-304020 × Land O'Lakes MaxPrivate 3-21986IIIn/an/aResnik1987IIIPI534645Asgrow A3127(4) × L24Pella 861987IIIPI509044From backcross of Pella(5) × Williams 82Burlison1988IIPI533655 $F_4$ selection from K74-113-76-486 × CenturyPrivate 2-91988IIn/an/aElgin 871988IIPI518666Elgin (5) × Williams 82Conrad <sup>†</sup> 1988IIPI525453A3127 × Tri-Valley ChargerJack <sup>†</sup> 1989IIPI540556Fayette × Hardin	Zane	1984	III	PI548634	Cumberland × Pella
Preston     1985     II     PI548520     Schechinger S48 × Land O'Lakes Max       Private 2-15     1985     II     n/a     n/a       Chamberlain <sup>†</sup> 1986     III     PI548635     A76-304020 × Land O'Lakes Max       Private 3-2     1986     III     n/a     n/a       Resnik     1987     III     PI534645     Asgrow A3127(4) × L24       Pella 86     1987     III     PI533655     F <sub>4</sub> selection from K74-113-76-486 × Century       Private 2-9     1988     II     n/a     n/a       Elgin 87     1988     II     PI518666     Elgin (5) × Williams 82       Conrad <sup>†</sup> 1988     II     PI525453     A3127 × Tri-Valley Charger       Jack <sup>†</sup> 1989     II     PI540556     Fayette × Hardin	Harper	1984	III	PI548558	F <sub>4</sub> selection from an unknown diallel-cross population
Private 2-15     1985     II     n/a     n/a       Chamberlain <sup>†</sup> 1986     III     Pl548635     A76-304020 × Land O'Lakes Max       Private 3-2     1986     III     n/a     n/a       Resnik     1987     III     Pl534645     Asgrow A3127(4) × L24       Pella 86     1987     III     Pl509044     From backcross of Pella(5) × Williams 82       Burlison     1988     II     Pl533655     F <sub>4</sub> selection from K74-113-76-486 × Century       Private 2-9     1988     II     n/a     n/a       Elgin 87     1988     II     Pl518666     Elgin (5) × Williams 82       Conrad <sup>†</sup> 1988     II     Pl525453     A3127 × Tri-Valley Charger       Jack <sup>†</sup> 1989     II     Pl540556     Fayette × Hardin	Preston	1985	II	PI548520	Schechinger S48 × Land O'Lakes Max
Chamberlain <sup>†</sup> 1986     III     PI548635     A76-304020 × Land O'Lakes Max       Private 3-2     1986     III     n/a     n/a       Resnik     1987     III     PI534645     Asgrow A3127(4) × L24       Pella 86     1987     III     PI509044     From backcross of Pella(5) × Williams 82       Burlison     1988     II     PI533655     F <sub>4</sub> selection from K74-113-76-486 × Century       Private 2-9     1988     II     n/a     n/a       Elgin 87     1988     II     PI518666     Elgin (5) × Williams 82       Conrad <sup>†</sup> 1988     II     PI525453     A3127 × Tri-Valley Charger       Jack <sup>†</sup> 1989     II     PI540556     Fayette × Hardin	Private 2-15	1985	II	n/a	n/a
Private 3-2     1986     III     n/a     n/a       Resnik     1987     III     PI534645     Asgrow A3127(4) × L24       Pella 86     1987     III     PI509044     From backcross of Pella(5) × Williams 82       Burlison     1988     II     PI533655 $F_4$ selection from K74-113-76-486 × Century       Private 2-9     1988     II     n/a     n/a       Elgin 87     1988     II     PI518666     Elgin (5) × Williams 82       Conrad <sup>+</sup> 1988     II     PI525453     A3127 × Tri-Valley Charger       Jack <sup>+</sup> 1989     II     PI540556     Fayette × Hardin	Chamberlain <sup>†</sup>	1986	III	PI548635	A76-304020 × Land O'Lakes Max
Resnik     1987     III     PI534645     Asgrow A3127(4) × L24       Pella 86     1987     III     PI509044     From backcross of Pella(5) × Williams 82       Burlison     1988     II     PI533655 $F_4$ selection from K74-113-76-486 × Century       Private 2-9     1988     II     n/a     n/a       Elgin 87     1988     II     PI518666     Elgin (5) × Williams 82       Conrad <sup>+</sup> 1988     II     PI525453     A3127 × Tri-Valley Charger       Jack <sup>+</sup> 1989     II     PI540556     Fayette × Hardin	Private 3-2	1986	III	n/a	n/a
Pella 86     1987     III     PI509044     From backcross of Pella(5) × Williams 82       Burlison     1988     II     PI533655 $F_4$ selection from K74-113-76-486 × Century       Private 2-9     1988     II     n/a     n/a       Elgin 87     1988     II     PI518666     Elgin (5) × Williams 82       Conrad <sup>+</sup> 1988     II     PI525453     A3127 × Tri-Valley Charger       Jack <sup>+</sup> 1989     II     PI540556     Fayette × Hardin	Resnik	1987	III	PI534645	Asgrow A3127(4) × L24
Burlison     1988     II     PI533655 $F_4$ selection from K74-113-76-486 × Century       Private 2-9     1988     II     n/a     n/a       Elgin 87     1988     II     PI518666     Elgin (5) × Williams 82       Conrad <sup>†</sup> 1988     II     PI525453     A3127 × Tri-Valley Charger       Jack <sup>†</sup> 1989     II     PI540556     Fayette × Hardin	Pella 86	1987	III	PI509044	From backcross of Pella(5) $\times$ Williams 82
Private 2-9     1988     II     n/a     n/a       Elgin 87     1988     II     PI518666     Elgin (5) × Williams 82       Conrad <sup>+</sup> 1988     II     PI525453     A3127 × Tri-Valley Charger       Jack <sup>+</sup> 1989     II     PI540556     Fayette × Hardin	Burlison	1988	II	PI533655	$F_4$ selection from K74-113-76-486 × Century
Elgin 87     1988     II     Pl518666     Elgin (5) × Williams 82       Conrad <sup>†</sup> 1988     II     Pl525453     A3127 × Tri-Valley Charger       Jack <sup>†</sup> 1989     II     Pl540556     Fayette × Hardin	Private 2-9	1988	Ш	n/a	n/a
Conrad <sup>†</sup> 1988     II     PI525453     A3127 × Tri-Valley Charger       Jack <sup>†</sup> 1989     II     PI540556     Fayette × Hardin	Elgin 87	1988	Ш	PI518666	Elgin (5) × Williams 82
Jack <sup>†</sup> 1989 II Pl540556 Fayette × Hardin	Conrad <sup>†</sup>	1988	Ш	PI525453	A3127 × Tri-Valley Charger
	Jack <sup>†</sup>	1989	Ш	PI540556	Fayette × Hardin
Kenwood 1989 II PI537094 Elgin × A1937	Kenwood	1989	II	PI537094	Elgin × A1937

#### Table 2. Continued.

Cultivar	Year of	Maturity group	PI No.	Pedigree
Drivete 0.1	1000		FINO.	redigree
Private 2-1	1989	11	n/a	n/a
Private 3-9	1989		n/a	n/a
Private 2-2	1990	11	n/a	n/a
Private 3-10	1990	111	n/a	n/a D150 T0110
RCAT Angora	1991	11	PI572242	B152 × 18112
Private 2-6	1991	11	n/a	n/a
Private 3-16	1991	III 	n/a Dissosoo	
Dunbar	1992	III 	PI552538	
I horne	1992		PI564718	A80-344003 × A3127BC3F2-1
Private 3-17	1992		n/a	n/a
Private 2-5	1993	II 	n/a	n/a
Private 3-18	1993		n/a	n/a
Private 2-10	1994	II 	n/a	n/a
Private 2-16	1994	II 	n/a	n/a
Private 3-19	1994		n/a	n/a
IA 2021	1995		n/a	Elgin 87 × Marcus
Macon <sup>†</sup>	1995	III	PI593258	Sherman × Resnik
IA 3004	1995		n/a	Northrup King S23-03 × A86-301024
Savoy	1996	ll	PI597381	Burlison × Asgrow A3733
Private 2-12	1996	II	n/a	n/a
Maverick	1996		PI598124	LN86-4668 (Fayette × Hardin) × Resnik(3)
Private 3-4	1996	III	n/a	n/a
Private 3-11	1996		n/a	n/a
Dwight <sup>†</sup>	1997	II	PI597386	Jack × A86-303014
Private 2-18	1997	II	n/a	n/a
Pana	1997	III	PI597387	Jack × Asgrow A3205
Private 3-5	1997	III	n/a	n/a
Private 3-12	1997	III	n/a	n/a
IA 2038	1998	II	n/a	Pioneer 9301 × Kenwood
Private 3-6	1998	III	n/a	n/a
IA 3010	1998	III	n/a	Jaques J285 × Northrup King S29-39
Private 3-7 <sup>†</sup>	1999	III	n/a	n/a
IA 2050	2000	II	n/a	Northrup King S24-92 × A91-501002
IA 2052	2000	II	n/a	Northrup King S24-92 × Parker
Private 3-20	2000	III	n/a	n/a
Loda <sup>†</sup>	2001	II	PI614088	Jack × IA 3003
Private 2-4	2001	II	n/a	n/a
Private 2-17	2001	II	n/a	n/a
U98-311442	2001		n/a	A94-773014 × Bell
IA 3014	2001	III	n/a	LN90-4366 × IA3005
Private 3-8 <sup>†</sup>	2002	III	n/a	n/a
IA 2068	2003	II	n/a	AgriPro P1953 × LN94-10470
IA 3023	2003		n/a	Dairyland DSR-365 × Pioneer P9381
Private 2-3	2004	II	n/a	n/a
NE3001	2004		n/a	Colfax × A91-701035
Private 3-13 <sup>†</sup>	2004		n/a	n/a
IA 3024	2004		n/a	A97-553017 × Pioneer YB33A99
IA 2065	2005	II	n/a	n/a
Private 2-19	2005	II	n/a	n/a
Private 2-20	2005	II	n/a	n/a
IA 2094	2006	II	n/a	AgriPro X0121B74 × A00-711036
Private 3-22	2006		n/a	n/a
Private 3-23	2006		n/a	n/a
Private 3-14	2007	III	n/a	n/a
Private 2-13	2008	II	n/a	n/a
Private 2-14 <sup>†</sup>	2008	II	n/a	n/a

<sup>+</sup> Cultivars replicated within location.

<sup>‡</sup> n/a, not applicable.

Table 3. Mean monthly air temperature and total monthly precipitation at Arlington, WI, Urbana, IL, and Lafayette, IN, during the 2010 and 2011 growing seasons, and during the past 30 yr.

	Arlington, WI				Urbana, IL			Lafayette, IN		
	2010	2011	30 yr	2010	2011	30 yr	2010	2011	30 yr	
Air temperature (°C)										
April	10.4	6.2	7.1	15.1	11.9	11.1	14.9	11.6	10.7	
May	15.3	13.4	13.2	18.3	16.9	16.9	18.1	17.1	16.6	
June	19.7	19.6	18.7	23.8	22.8	22.3	23.3	22.6	21.8	
July	22.9	24.0	20.8	25.2	26.8	23.8	24.4	26.0	23.4	
August	22.2	21.0	19.6	25.1	24.1	23.0	24.3	22.7	22.4	
September	15.6	14.5	15.2	19.7	17.5	19.0	19.4	17.1	18.8	
Precipitation (mm)										
April	107.5	106.4	88.9	48.5	214.6	93.5	72.9	192.6	86.6	
May	88.9	55.4	93.7	78.5	121.9	124.2	72.6	113.4	117.9	
June	169.4	98.8	118.9	198.6	106.7	110.2	95.0	92.8	115.6	
July	222.8	64.3	105.7	90.7	39.9	119.4	66.3	45.5	103.6	
August	114.0	39.9	99.1	40.1	44.7	99.8	42.2	26.3	100.1	
September	50.5	96.5	89.9	76.7	70.9	79.5	24.1	82.8	71.2	

effect due to the fact that those selected for the experiment were chosen from a larger group of cultivars available over the eight decades. Fixed effects were tested for significance (P < 0.05) using the appropriate F test. Final models were a function of the model fit statistics (AIC, BIC, -2 Res Log Likelihood), as well as biological interpretation. Simple correlation coefficients were calculated using the PROC CORR procedure in SAS Version 9.2 (SAS Institute Inc., Cary, NC).

## RESULTS AND DISCUSSION Environment

Except for the month of July, average air temperatures were lower in 2011 than in 2010 at all locations (Table 3). At the Wisconsin location, 2010 could be characterized as an above-average rainfall year, whereas 2011 was a year with very low mid-season (July–August) rainfall and less than normal early- and late-season rainfall. In Wisconsin, the combination of above-average temperature and precipitation in 2010 led to record state soybean yields. At the Illinois and Indiana locations, early-season precipitation (April–May) was greater in 2011 than in 2010. Mid-season (July–August) precipitation at both Illinois and Indiana was well below the 30-yr average for both years, with drier conditions prevailing in 2011 than in 2010. Excess soil moisture was the most important factor resulting in actual planting dates not matching the targeted dates.

## Yield

A comparison of mixed-effect regression models indicated that a linear mixed model provided the most appropriate fit to the observed trends in yield over year of release. Previous studies evaluating genetic yield gain in soybean have regressed yields either linearly (Boerma, 1979; De Bruin and Pedersen, 2008b; Specht and Williams, 1984; Wilcox, 2001) or quadratically (Voldeng et al., 1997) over year of release. Specht and Williams (1984) used multiple linear regressions within a maturity group to represent genetic gain over shorter periods of time while assessing the influence of different breeding methods on genetic gain. There was not sufficient evidence in the present study of curvilinearity in the change in yield over time, so a linear model was fitted to the yield data for each planting date.

Within maturity groups, more recently released cultivars exhibited higher yields (P < 0.001) than earlier released cultivars (Fig. 1). Simple correlation coefficients for yield and cultivar year of release ranged from 0.62 to 0.72 (Table 4). For MG II (Fig. 1a), there was no evidence of an interaction between planting date and cultivar year of release (P > 0.05). The rate of gain for soybean yield over time was 18.5 ( $\pm$  1.57) kg ha<sup>-1</sup> yr<sup>-1</sup>. One possible explanation for the lack of an interaction between planting date and cultivar year of release in Wisconsin was that in both 2010 and 2011, record and above-average state soybean yields were documented.

For MG III (Fig. 1b), cultivar yield was influenced by planting date (P < 0.05); on average, cultivars planted in May provided superior yields. For the June planting, the rate of gain was 19.6 ( $\pm$  1.74) kg ha<sup>-1</sup> yr<sup>-1</sup>, whereas it was increased +3.10 ( $\pm$  1.41) kg ha<sup>-1</sup> yr<sup>-1</sup> for the May planting. A 3.10 kg ha<sup>-1</sup> yr<sup>-1</sup> greater rate of annual yield gain in cultivars planted in May vs. June indicates that newer cultivars responded more positively to earlier planting than cultivars released in earlier years. The synergistic interaction between planting date and year of release, along with significantly higher yields in May-planted soybean, provide evidence that trends toward earlier planting over time have contributed to soybean yield improvement and support the hypothesis that earlier planting over time by soybean growers in the midwestern United States has impacted on-farm yield gain in MG III soybean. Furthermore, the greater yield levels obtained with May planting in this study confirm recent planting date recommendations in



Figure 1. Regression of (a) Maturity Group (MG) II and (b) MG III seed yield (kg ha<sup>-1</sup>) over soybean cultivar year of release at May (solid) and June (dashed) planting dates (PD) in 2010 and 2011.

Table 4. Simple linear correlation coefficients (r) between yield, seed mass, seed protein concentration, seed oil concentration, and cultivar year of release for Maturity Group (MG) II and MG III cultivars at May and June planting dates (PD) during 2010 and 2011.

				Year of				Year of
	Seed mass	Protein	Oil	release	Seed mass	Protein	Oil	release
			MG II, J	une PD				
Yield	-0.08	-0.05	0.10	0.72***	-0.03	0.04	-0.21*	0.62***
Seed mass	-	0.14	-0.10	-0.04	-	0.26**	-0.24**	-0.19*
Protein	-	-	-0.78***	-0.26**	-	-	-0.77***	-0.31***
Oil	-	-	-	0.27***	-	-	-	0.27**
		MG III,	May PD			MG III, J	lune PD	
Yield	0.25***	0.12*	-0.08	0.67***	0.22***	-0.11	0.26***	0.68***
Seed mass	_	0.14*	0.00	0.22***	-	0.04	0.10	0.32***
Protein	_	_	-0.78***	-0.23***	-	-	-0.76***	-0.24***
Oil	_	_	-	0.23***	-	-	_	0.31***

\* Significant at the 0.05 probability level.

\*\* Significant at the 0.01 probability level.

\*\*\* Significant at the <0.001 probability level.

the midwestern United States, with maximization of yields realized when using early-May planting dates (De Bruin and Pedersen, 2008a; Robinson et al., 2009; Specht, 2010).

The MG III cultivars exhibited a greater positive mean yield response to earlier planting when compared to MG II cultivars. Although the number of days between the May and June planting dates was similar (~30 d) at the MG III sites vs. the MG II sites, the difference between the targeted and actual June planting dates was, on average, about 8.5 d later for the MG III sites vs. only 2.5 d for the MG II sites. The 6-d greater delay in June planting at the MG III sites was an artifact of our May planting date establishment issues at these locations. The additional delay at MG III sites may have lessened the yield levels obtained with June plantings, though yields in delayed May plantings at the same sites may also have been lessened, influencing the response to planting date. In any case, these data show that earlier planting is more imperative for MG III than MG II cultivars, as later planting appears to limit the expression of genetic yield potential and reduce yield to a greater degree in MG III cultivars. The magnitude of yield response to early planting is very location and year specific (De Bruin and Pedersen, 2008a), and the environmental differences across locations and years in this study may not only underlie mean yield differences between the maturity groups but also yield response to planting date between maturity groups.

Plant populations at establishment (V1) and harvest (R8) for the two planting dates were not statistically different from one another for both maturity groups and did not impact harvested yields (data not shown). The similarities in plant populations indicated that stand establishment was not compromised with early planting into cooler, wetter soils with untreated seed. Comparable results were reported by De Bruin and Pedersen (2008a), who also found no decrease in harvest plant populations



Figure 2. Regression of (a) Maturity Group (MG) II and (b) MG III seed mass (g 100 seeds<sup>-1</sup>) over soybean cultivar year of release at May (solid) and June (dashed) planting dates (PD) in 2010 and 2011.

with earlier planting, though a study conducted 20 yr ago by Oplinger and Philbrook (1992) found that plant populations decreased with earlier planting.

## Seed Mass

Mean seed mass was higher in MG II than MG III cultivars. There was no evidence of an effect of planting date or cultivar year of release on seed mass (i.e., 100-seed weight) for the MG II cultivars (Fig. 2a). However, there was an effect of cultivar year of release (P < 0.05) on seed mass for MG III cultivars (Fig. 2b), as seed mass increased 0.017 ( $\pm$  0.008) g yr<sup>-1</sup>.

Specht and Williams (1984) found an annual increase in 100-seed mass of 0.10 g yr<sup>-1</sup> across all maturity groups (MG 00-IV) studied, although regression slopes for seed mass over year of release were not significantly different from zero in MG II and MG III soybean. Previous studies have shown that no consistent relationship between seed mass and cultivar year of release exists (Boerma, 1979; Morrison et al., 2000; Voldeng et al., 1997). Morrison et al. (2000) reported that breeders have improved yield over time by increasing the number of seeds per plant, not by increasing seed mass. In the present study, seed mass response did not differ appreciably by planting date, with similar seed mass recorded in both May and June planting for MG II and MG III cultivars. These results are in agreement with previous research suggesting that delayed planting date has little or no effect on soybean seed mass (Pedersen and Lauer, 2004; Wilcox and Frankenberger, 1987), although other studies have exhibited both increased (Bastidas et al., 2008) and decreased (Anderson and Vasilas, 1985; Elmore, 1990) seed mass with delayed planting. The conflicting results of the effect of planting date on soybean seed mass can likely be attributed to the variability of seed mass among cultivars and maturity groups (Robinson et al., 2009; Specht and Williams, 1984; Voldeng et al., 1997)

and the influence of location-specific environmental conditions during the mid- to late seed fill period on seed mass (Ball et al., 2000; De Bruin and Pedersen, 2008a; Elmore, 1990). Both of these factors were observed in this study.

## **Seed Protein and Oil**

Seed protein concentration decreased (P < 0.05) linearly over cultivar year of release for both MG II and MG III (Fig. 3). For MG II (Fig. 3a), the rate of decrease was 0.191  $(\pm 0.069)$  g kg<sup>-1</sup> yr<sup>-1</sup> and for MG III (Fig. 3b.) it was 0.242  $(\pm 0.063)$  g kg<sup>-1</sup> yr<sup>-1</sup>. The annual decline in seed protein concentration coincided with an improvement in seed oil concentration within maturity groups. Seed oil concentration in our study increased (P < 0.01) over cultivar year of release (Fig. 4). Within MG II (Fig. 4a), the rate of increase was 0.142 ( $\pm$  0.037) g kg<sup>-1</sup> yr<sup>-1</sup>, whereas it was 0.127 ( $\pm$ (0.039) g kg<sup>-1</sup> yr<sup>-1</sup> in MG III (Fig. 4b). Trends in decreasing seed protein and increasing seed oil concentrations over time have been previously noted using a very small subset of MG II cultivars; however, no patterns in MG III protein and oil concentrations over time were documented in the same study (Wilcox et al., 1979). Subsequent evaluation of high-yielding, elite soybean lines from the Uniform Soybean Test produced no consistent trends over time in seed protein and oil concentrations among the MG II and MG III cultivars examined (Wilcox, 2001). Although patterns in seed protein and oil content over time have been unclear, the changes in soybean seed protein and oil over time across maturity groups in the current study agree favorably with the well-documented relationship of seed protein and oil concentration being negatively correlated (Hartwig and Kilen, 1991; Hymowitz et al., 1972; Panthee et al., 2005; Sebern and Lambert, 1984; Watanabe and Nagasawa, 1990; Wilcox and Guodong, 1997; Wilson, 2004; Yaklich et al., 2002). Simple correlation coefficients



Figure 3. Regression of (a) Maturity Group (MG) II and (b) MG III seed protein concentration (g kg<sup>-1</sup>) over soybean cultivar year of release at May (solid) and June (dashed) planting dates (PD) in 2010 and 2011.



Figure 4. Regression of (a) Maturity Group (MG) II and (b) MG III seed oil concentration (g kg<sup>-1</sup>) over soybean cultivar year of release at May (solid) and June (dashed) planting dates (PD) in 2010 and 2011.

ranged from -0.76 to -0.78 for seed protein and seed oil concentration in the present study (Table 4).

Within MG II, seed protein concentration was higher (P < 0.05) in June- than in May-planted soybean (Fig. 3), whereas seed protein concentration in MG III was unaffected by planting date. There was no evidence of an effect of planting date on seed oil concentration (Fig. 4). These results are in partial agreement with literature that has shown lower seed protein and higher seed oil concentrations with earlier planting (Heatherly and Elmore, 2004; Kane et al., 1997; Pendleton and Hartwig, 1973; Robinson et al., 2009). Delayed planting has occasionally produced no definitive response in the seed constituents of protein and oil in MG II (Pedersen and Lauer, 2003) and MG III (Bastidas et al., 2008) soybean. Seed oil and protein concentrations are primarily dictated by genetic factors such as cultivar selection and maturity group (Kane et al., 1997; Yaklich et al., 2002), and environmental factors

such as temperature (Robinson et al., 2009) and moisture availability (Dornbos and Mullen, 1992) during the reproductive phases of growth, particularly R5 to R6. It is likely that genotypic and environmental variability are the principal drivers behind the occasional absence of response to delayed planting observed in other research.

In the current study, the ratio of the slopes suggested that for each 1-unit increase in seed oil content there was a 1.35-unit decrease (MG II) or a 1.91-unit decrease (MG III) in seed protein content. These values agree favorably with published literature. Specht et al. (1999) established that in most cases, a 1-unit increase in oil content is accompanied by a 2-unit decrease in protein content across soybean maturity groups. A 1:1 relationship was documented in shorter-maturing Canadian cultivars (Voldeng et al., 1997), a ratio substantially more balanced than the 1:2 ratio noted by Specht et al. (1999) and our observed ratios. From the observed trends in seed protein and oil across MG II and MG III soybean, we speculate that breeders have unintentionally reduced seed protein concentration over time while focusing on the principal selection criterion, greater yield. It has been suggested that the increase in seed oil concentration and decrease in seed protein concentration over time are due to the positive and negative correlation of seed protein and oil with yield, respectively (Hartwig and Kilen, 1991; Wilcox and Guodong, 1997).

## CONCLUSIONS

Soybean breeders have effectively increased yield by continuing to release higher yielding cultivars over time. Earlier planting provided higher yields (+3.1 kg ha<sup>-1</sup> yr<sup>-1</sup>) than late planting for MG III soybean. The apparent synergistic interaction between earlier planting and cultivar year of release suggested that yields of more recently released cultivars respond more positively to the practice of earlier planting in MG III environments. We conclude that trends toward earlier planting in the midwestern United States, combined with genetic yield gain, have contributed to on-farm yield improvement in MG III soybean. Within maturity groups, mean seed mass levels were similar at early and late plantings and were resistant to change over time. Breeding efforts within maturity groups increased seed oil concentration and decreased seed protein concentration. We suspect that the changes in soybean seed protein and oil are primarily a by-product of breeders selecting for yield and not necessarily for seed protein and oil.

Considering the greater yield response of newer cultivars to early planting, it may be beneficial for breeders to employ strategies in their breeding programs to exploit this synergistic interaction. Incorporating early planting trials into breeding nurseries may provide soybean breeders with the opportunity to make valuable progress that would otherwise go unnoticed in breeding settings where later planting to avoid spring frost, among other environmental uncertainties, is a standard practice. Other synergistic agronomic  $\times$  genetic yield gain interactions conceivably exist. Successfully identifying and exploiting these synergies may provide soybean breeders and agronomists with tools that can facilitate greater yield improvement.

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