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Association of Grain Yield with Identifiable Plant Characteristics of Corn Hybrids in the West-Central Great Plains

Brian J. Frank, Alan J. Schlegel, Loyd R. Stone,* and Mary Beth Kirkham

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B.J. Frank, L.R. Stone, and M.B. Kirkham, Dep. of Agronomy, Throckmorton Hall, Kansas State Univ., Manhattan, KS 66506-5501; A.J. Schlegel, Tribune Unit, Kansas State Univ. SW Res. Ext. Ctr., 1474 State Hwy. 96, Tribune, KS 67879-9774. Contrib. 13-025-J, Kansas Agric. Exp. Stn. Received x xxxx 2012.

*Corresponding author (stoner@ksu.edu).

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ABSTRACT

Water supply for crop use is the primary factor controlling corn (*Zea mays* L.) grain yield in the west-central Great Plains. With water supply varying as production systems range from dryland through irrigated, selecting hybrids for optimum yield in the anticipated water environment is vital for success. Our objective was to analyze a group of corn hybrids and determine: a) are there significant differences in identifiable plant characteristics among the hybrids and b) are there significant associations between identifiable plant characteristics and grain yield. Corn was grown near Tribune, KS, in 3 yr in two fields; one dryland and one irrigated. Hybrids (18) replicated in four blocks were grown at each field, with dryland and irrigated results analyzed separately. From linear regression, no significant correlation existed between irrigated grain yield and days to initial silking of hybrids in any of the 3 yr. The correlation between dryland grain yield and days to initial silking of hybrids was significant ($P<0.05$) in all 3 yr, with grain yield decreasing as days to initial silking increased. Dryland grain yield was also significantly and negatively correlated with dry stover mass in all 3 yr and with tiller population in 2 of 3 yr. Hybrids selected for dryland in the west-central Great Plains should be from the earlier 1/3 or 1/2 of the 98- to 118-d relative maturity (RM) range of our study. In addition, hybrids selected for dryland should have characteristics of smaller stature (less stover) and non-tillering plants.

Abbreviations: ANOVA, analysis of variance; ASW, available soil water; AWC, available water capacity; CEC, cation exchange capacity; ET, evapotranspiration; PAR, photosynthetically active radiation; RM, relative maturity; T_a, ambient air temperature; T_c, canopy temperature.

Corn is prominent in both irrigated and dryland cropping systems of the west-central Great Plains. With mean annual precipitation ranging from 35 to 55 cm across the region (HPRCC, 2010), which is only 57 to 89% of the seasonal water requirement (evapotranspiration [ET]) of full-production corn (Stone et al., 2006), there is considerable use of supplemental irrigation. Of the 0.70 million ha of irrigated corn, grain sorghum [*Sorghum bicolor* (L.) Moench], soybean [*Glycine max* (L.) Merr.], and winter wheat (*Triticum aestivum* L.) harvested for grain in 2009 from western Kansas (west of 100° W long), 60% was corn (USDA-NASS, 2010). And as dryland producers in the region seek rotations that are more crop intensive than the traditional winter wheat–fallow, they often select a winter wheat–summer crop–fallow rotation, with grain sorghum or corn the summer crop. From 2007 through 2009, 0.32 million ha yr^{-1} of dryland corn was planted in Kansas west of 100° W long (USDA-NASS, 2010).

Water supply for irrigation in the region largely depends on groundwater, with the Ogallala formation of the High Plains aquifer being the primary source

(McGuire et al., 2003). Water-level declines of the Ogallala from predevelopment (~1950) to 2003 of 15 m or more are widespread in the west-central Great Plains, with some declines >45 m (McGuire, 2004). With water-level declines, well yields are reduced and pumping costs are increased by the additional lift and greater pump operation time (McGuire et al., 2003). With decreased water capacity of wells, growers face difficulty meeting crop water needs during the growing season, especially in corn, their preferred irrigated crop.

The favorable potential for corn as a component of dryland rotations was shown by Anderson et al. (1999) and Norwood (2001), where residue is maintained and tillage minimized to increase crop use of precipitation. Loomis (1983) stated that efficient use of water in semiarid regions is always a problem and cropping practices are adjusted accordingly, with farming risk increasing as one pushes toward maximum use of water. The high risk and yield variability over years with dryland corn in the region are illustrated by recent yield data. In 2000 through 2009, mean reported dryland corn grain yield in western Kansas (west of 100° W long) ranged from 1.8 Mg ha^{-1} in 2002 to 6.5 Mg ha^{-1} in 2009 (USDA-NASS, 2010). And in 2002, only 28% of planted dryland corn was harvested for grain, compared with 93% in 2009. Nielsen et al.'s (2009) analysis involving grain yield, soil water at planting, and in-season precipitation for northeastern Colorado confirmed the high-risk nature of dryland corn production.

Although several factors (e.g., plant population, fertility level, hail, wind, frost, insects, diseases, and weeds) can affect corn production, the primary factor controlling corn grain yield is water supply available for crop use (Nielsen et al., 2009). Unger et al. (2010) stated, “Probably the most important choice a producer of rainfed crops must make is crop (or crop cultivar) selection based on the amount and timeliness of water availability.” In selecting a cultivar for the diverse and variable western Great Plains environments, farmers should consider stability of performance in addition to mean or maximum performance (Guillen-Portal et al., 2003). Because of the importance of water in corn production and the wide range of water supply conditions that exist in the west-central Great Plains, the selection of hybrids that are appropriate for optimum yield in the anticipated water environment is a vital management decision.

Selection of corn cultivars for drought tolerance was evaluated by Bolaños et al. (1993) by considering plant traits involved with leaf expansion, leaf senescence, stem extension, canopy temperature, anthesis-silking interval, leaf number, and chlorophyll concentration. Rasmussen (1991) reported that plant breeders can modify traits that appear to affect yield, such as maturity, height, leaf area, leaf angle, kernel weight, and kernel number. A reasonable question is whether the consideration of these identifiable traits that appear to affect yield aids producers as they select corn hybrids? Knowledge of significant relationships between identifiable traits and grain yield in dryland or irrigated environments could be used in conjunction with, and as a supplement to, state crop performance test results by producers in the selection of corn hybrids. Our objective was to analyze a group of corn hybrids and determine: a) are there significant differences in identifiable plant characteristics among the hybrids and

b) are there significant associations between identifiable plant characteristics and grain yield of the hybrids.

MATERIALS AND METHODS

This field study was at the Southwest Research-Extension Center near Tribune, KS, in 2005, 2006, and 2007. Corn was grown dryland (Dryland Field; 38°28′ N, 101°46′ W; 1107 m) in a no-till winter wheat–corn–fallow cropping system and irrigated (Irrigation Field; 38°32′ N, 101°40′ W; 1095 m). The fields are separated by 11.5 km. Soils of both fields formed on upland plains in loess and are deep and well drained with 0 to 1% slope. Soil types were Richfield silt loam (fine, smectitic, mesic Aridic Argiustolls) on the Dryland Field and Ulysses silt loam (fine-silty, mixed, superactive, mesic Aridic Haplustolls) on the Irrigation Field (Gwin et al., 1974). Weather data means for Tribune (~100 yr) are annual precipitation of 422 mm, daily mean ([max. + min.]/2) air temperature of 11.2°C, and a 50% probability of 156 d between the last (early May) and first (early October) occurrence of 0°C (HPRCC, 2010).

Experimental design was randomized complete block with 18 treatments (hybrids) and four blocks at each of the dryland and irrigation fields. Hybrids were selected to cover the maturity range of those commercially available and recommended for producer use in the region, and were not selected based on any additional plant growth or developmental characteristic. The 18 hybrids ranged in RM rating from 98 to 118 d, with 11 from Pioneer Hi-Bred International, Inc., Johnston, IA; four from Croplan Genetics, St. Paul, MN; and three from Triumph Seed Co., Inc., Ralls, TX. Dryland plots were each 15.2 m long in 2005 and 2006, and 12.2 m long in 2007. Irrigated plots were each 15.2 m long in 2005, and 12.2 m long in 2006 and 2007. All plots were 3.05 m wide (four rows spaced 0.76 m apart). Dryland plots were no-till and followed wheat harvested the previous June. Irrigated plots were conventionally tilled with irrigation water applied through a linear-move sprinkler system to replace approximate ET minus rainfall. Irrigated corn in 2005 followed wheat harvested in June 2004; and in 2006 and 2007 followed soybean harvested the previous fall.

Liquid urea-ammonium nitrate was applied in early spring, with 112 kg ha^{-1} N to dryland each year, and 269, 135, and 269 kg ha^{-1} N to irrigated in 2005, 2006, and 2007, respectively. Starter fertilizer was dribbled beside the row at planting, with 8 kg ha^{-1} N and 12 kg ha^{-1} P to dryland each year, and 4, 4, and 7 kg ha^{-1} N and 6, 6, and 10 kg ha^{-1} P to irrigated in 2005, 2006, and 2007, respectively. Corn was planted 5, 9, and 14 May (dryland), and 10, 2, and 11 May (irrigated), in 2005, 2006, and 2007, respectively. Target planting rate was 44,000 and 88,000 seeds ha^{-1} for dryland and irrigated, respectively. Weeds were controlled as needed before and during growing seasons using herbicides at recommended rates.

Disturbed soil samples (~1.5 kg) and soil cores (66-mm diam.) were collected from 0.3-m depth increments of the 0- to 2.44-m soil profile by hydraulic probe at six dispersed locations in each of the six field areas (two water levels by 3 yr, i.e., 6 site-yr). Disturbed samples were air dried, and cores oven dried. Dry bulk density was calculated from oven-dried mass and core volume (Grossman and Reinsch, 2002). Portions of the air-dried disturbed soil were ground to pass through a sieve with 2-mm screen openings and used to determine texture and water retention. Particle size distribution was determined by hydrometer and sieving (Gee and Or, 2002). Sample mass was 50 g, the dispersing chemical was Na hexametaphosphate, and the corrected hydrometer reading at 8-h settling time represented clay content. Sediment and suspension were poured through a sieve with 0.053-mm openings, and oven-dried mass of material retained on the screen represented sand content. Oven-dried sample mass minus clay and sand represented silt content. Water content at -1.5 MPa matric potential was determined with the cellulose acetate membrane system (Klute, 1986).

Portions of the disturbed, sieved (2 mm) samples (0- to 0.3-m profile depth) were analyzed by the Kansas State University Soil Testing Laboratory for pH, available P, exchangeable K, organic matter content, and cation exchange capacity (CEC) following standard soil testing procedures for the North Central Region. Soil pH was measured with a 1:1 soil/deionized water slurry (Watson and Brown, 1998). Available P was determined by the Mehlich-3 test (Frank et al., 1998). Exchangeable K was extracted by 1 *M* NH_4OAc and measured by flame emission (Warncke and Brown, 1998). Organic matter content was determined by a modified Walkley-Black procedure (Combs and Nathan, 1998). Soil CEC was determined by saturating soil samples with NH_4^+, then replacing NH_4^+ by K^+ ions. The replaced NH_4^+ concentration was measured colorimetrically (Technicon Industrial Systems, Tarrytown, NY).

Daily precipitation was measured with standard rain gauges from 1 April through 30 September at the Irrigation Field and throughout the year at the Dryland Field, with snow recorded as liquid equivalent. Daily maximum and minimum air temperatures were recorded at the Dryland Field with mercury-in-glass MAX-MIN thermometers. Volumetric water content of soil was determined with a neutron probe (Model 503DR, CPN International, Inc., Martinez, CA). The probe was calibrated at each of the two fields using gravimetric water content and dry bulk density data. An Al access tube (38-mm diam. and 3.6-m length) was installed in the center of each of eight plots (the four plots of a 98-d and the four plots of a 118-d RM hybrid) in dryland and irrigated fields. Water content was determined with probe activity centered at 0.3-m depth increments from 0.15- through 2.29-m soil depths. Total water content of the 1.52- (to assess crop water stress at mid season) and 2.44-m (to determine total profile water depletion) soil profiles was calculated as 305 mm × volumetric water content of individual depths and summed over the respective total depth.

Plots were monitored for dates of plant emergence and initial silking (recorded as the date when 20% of a hybrid’s population had emerged, visible silks). Within-season variables of canopy cover and temperature, leaf P and N concentrations, leaf color, total and green leaf numbers, ear-leaf angle and area, plant height, and number of internodes were measured in 2005 and 2006. At-harvest variables of grain yield, kernel mass, and populations of plants, tillers, and ears with grain were measured in 2005, 2006, and 2007. Aboveground biomass was determined in dryland plots each year.

Canopy cover was estimated by measuring fraction of photosynthetically active radiation (PAR) intercepted by crop [1 – (PAR measured at groundlevel in corn/PAR measured in alleys)]. The PAR was determined with a linear PAR ceptometer (Model LP-80, Decagon Devices Inc., Pullman, WA) consisting of an 86.5-cm-long probe with 80 sensors sensitive to the PAR waveband. The probe was placed at a 45° angle between the two center rows of a plot on clear days within 2 h of solar noon. Two readings were taken per plot, and the mean was used with PAR measured in adjacent alleys to calculate the fraction of PAR intercepted by the canopy. Canopy cover was estimated at ~10-d intervals until the fraction of PAR intercepted reached ~0.8.

Canopy temperature (T_c) conditions were assessed through determination of T_c and ambient air temperature (T_a). Mid day T_a was taken with a shaded mercury-in-glass thermometer located above the canopy. Mid day T_c was measured with a handheld infrared thermometer (Model 112, Everest Interscience, Inc., Tucson, AZ) directed at sunlit leaves within 2 h of solar noon on clear days. Measurements were taken at a 20° angle from horizontal, 20° angle to the row, and 1 m above canopy surface. Field of view of the infrared thermometer was 4°, and care was taken to view only leaves, with no tassels or soil in the background. Four T_c measurements were made per plot, and the mean used in calculation of the temperature difference ($T_c – T_a$).

Leaf color conditions were measured using a contact-type leaf chlorophyll meter (SPAD 502, Minolta Corp., Ramsey, NJ). Measurements were taken on the leaf immediately below the ear leaf halfway between midrib and leaf margin and halfway between stalk and leaf tip. Measurements (SPAD) were made on six plants plot^{-1} on sunny days after silking and before leaf senescence. Nitrogen and P concentrations of the leaf immediately below the ear leaf, collected after silking, were determined by the Kansas State University Soil Testing Laboratory. Six leaves were clipped from each plot, dried at 60°C for 1 wk, and ground into a composite sample that passed a screen with 1-mm openings. Samples were digested using a sulfuric acid and hydrogen peroxide digest (Isaac, 1977). Total N and P were determined with a Technicon Autoanalyzer (Technicon Industrial Systems, Tarrytown, NY).

Angle of ear leaf in relation to the stalk of six plants plot^{-1} was measured after silking with a protractor (Maddonni et al., 2001). Area of the ear leaf of six plants plot^{-1} was determined after silking: length measured from ligule to leaf tip, width measured at the widest location on the leaf, and area calculated as length × width × 0.75 (Maddonni et al., 2001). Total leaf number of six plants plot^{-1} was determined on several dates through tasseling by counting leaves in accordance with Ritchie et al. (1997). Green leaf number of six plants plot^{-1} was determined ~3 wk after initial silking by counting green leaves, excluding senesced leaves (those with >50% chlorosis). Plant height from soil surface to the top leaf collar was measured, and number of internodes from first visible through highest node was counted, after tasseling on six plants plot^{-1}.

Aboveground biomass in dryland plots was determined by hand harvesting five plants plot^{-1} at groundlevel after the appearance of kernel milkline in all hybrids. Biomass samples were dried for 2 wk in forced air ovens at 60°C.

Dry mass plant^{-1} was multiplied by plant population ha^{-1} of plots measured at harvest, and reported as dry biomass yield.

Plots were hand harvested after hybrids reached physiological maturity (kernel black layer). Ears with grain (any grain) were counted and collected, and plants and tillers were counted, from 6-m lengths of the two center rows (12 m total) of plots. Ears were dried in forced air ovens at 60°C for 1 wk and shelled by hand. Water content of the grain was determined by oven drying at 60°C until reaching constant mass. Kernel mass was determined by hand counting and oven drying 300 kernels. Grain yield and kernel mass were adjusted to a water content of 155 g kg^{-1} (moist mass basis) for reporting. Dry stover yield for each plot was calculated as dry biomass yield minus dry grain yield.

Statistical analyses of data were performed using procedures provided by SAS (version 9.1, SAS Institute Inc., Cary, NC). Analysis of variance (ANOVA) was performed using PROC GLM for a randomized complete block design with 18 treatments (hybrids) and four blocks. Dryland and irrigated results were analyzed separately. Associations between selected plant variables were examined through linear regression analyses performed using PROC REG. Means and standard errors of the mean for data sets were calculated using PROC MEANS. Statistical significance of the treatment effect in ANOVA and correlation in linear regression was indicated by calculated *P* values of $\leq$0.05.

RESULTS AND DISCUSSION

Selected chemical and physical properties of the surface 0.3-m soil layer for each of the 3 yr (2005, 2006, and 2007) and two fields (dryland and irrigated) are summarized in Table 1. Mean soil pH ranged from 6.8 to 7.5 at the dryland sites and from 7.9 to 8.2 at the irrigated sites. Organic matter content of the surface 0.3 m of soil ranged from 14 to 17 g kg^{-1} across the six sites. Water content at -1.5 MPa matric potential and CEC were less and dry bulk density was greater at dryland sites than at irrigated sites. Clay content varied from 264 g kg^{-1} at the 2005 dryland site to 331 g kg^{-1} at the 2007 irrigated site. Dry bulk density, particle size distribution, and water held at -1.5 MPa matric potential for the additional seven 0.3-m depth increments of the 2.44 m soil profiles are presented by Frank (2010).

Rainfall, irrigation, and mean daily minimum and maximum air temperatures are listed by month for the three growing seasons and two sites in Table 2. May through July rainfall for all 6 site-yr was less than the long-term (~100 yr) mean of 201 mm, ranging from 96% (2005 irrigated site) to 38% of mean (2007 dryland site). In the 6 mo prior to planting in 2006, total precipitation was 51 mm compared with the ~100-yr mean of 105 mm. This resulted in dry surface soil at both the dryland and irrigated fields. At the dryland site, appreciable germination/emergence did not occur until 36 mm of rain was received the last week of May 2006. At the irrigated site, 74 mm of irrigation was applied in April to assist germination/emergence. Emergence date was 11 May, 3 June, and 20 May in dryland and 16, 8, and 17 May in irrigated for 2005, 2006, and 2007, respectively.

Soil water content is presented by depth on three dates in 3 yr in dryland (Fig. 1) and irrigated fields (Fig. 2). Data are means from eight neutron access tubes (one $plot^{-1}$ of two hybrids). We conducted two-treatment (hybrids), four-block ANOVAs for each depth, date, year, and water environment to determine if soil water contents of the two hybrids were different at P=0.05 significance level. Of the 144 ANOVA tests for data of Fig. 1 and 2 (eight depths, three dates, 3 yr, and two water environments), only 13 interspersed comparisons showed a significant difference between the two hybrids. Because water content data were to show relative water status of the 3 yr and two water environments, and because of the few instances of significant difference between the two hybrids, soil water data were combined across the two hybrids in each water environment.

Of the three measurement dates for each site-year, the first (in May) shows soil water near planting/emergence. The second date shows soil water in mid-season at about the time of initial silking (15–27 July 2005, 24 July–9 Aug. 2006, and 14–28 July 2007 under dryland and 16–28 July 2005, 7–17 July 2006, and 14–21 July 2007 under irrigation). The third measurement date gives soil water shortly after all hybrids had reached physiological maturity.

Field-measured drained upper-limit water content for 1.52-m profiles of Richfield and Ulysses silt loam soils was 53 and 54 cm, respectively (Stone et al., 2011). Laboratory-determined water content at -1.5 MPa matric potential for our 1.52-m soil profiles was 29, 28, and 30 cm for dryland sites (Richfield) and 26, 27, and 27 cm for irrigated sites (Ulysses) in 2005, 2006, and 2007, respectively. Because soil water data at dryland sites showed depletion below water contents at -1.5 MPa, we adjusted the dryland lower limit of available soil water (ASW) downward to 28, 25, and 25 cm for the 1.52-m soil profiles of 2005, 2006, and 2007, respectively. Other researchers (e.g., Haise et al., 1955; Musick et al., 1976) also observed depletion to water contents below those at -1.5 MPa. Ratliff et al. (1983) stated, “laboratory-estimated soil water limits should be used with caution and field-measured limits, if available, would be preferred.”

The ASW in 1.52-m dryland soil profiles was 44, 26, and 33% of available water capacity (AWC) in May 2005, 2006, and 2007, respectively, with AWC the difference between field-measured upper (Stone et al., 2011) and lower limits of ASW. At mid-season, ASW in the 1.52-m dryland profiles (Fig. 1) had decreased to 12, 1, and 10% of AWC in 2005, 2006, and 2007, respectively. Water depletion from the 2.44-m dryland profiles was 73, 66, and 58 mm in the first half, and 42, -10, and 32 mm in the second half, of 2005, 2006, and 2007 seasons, respectively (Fig. 1). Rainfall for the time span of Fig. 1 was 286, 259, and 159 mm for 2005, 2006, and 2007, respectively. Assuming negligible runoff and deep-profile water flux, mean annual ET for the 3 yr of dryland corn was 322 mm (profile water depletion plus rainfall).

At irrigated sites (Fig. 2), ASW in the 1.52-m profile was 57, 58, and 63% of AWC in May 2005, 2006, and 2007, respectively, with AWC the difference between field-measured upper limit water content (Stone et al., 2011) and laboratory-measured water content at -1.5 MPa matric potential. At mid-season, ASW in the 1.52-m irrigated profiles was 44, 56, and 49% of AWC in 2005, 2006, and 2007, respectively. Water depletion from the 2.44-m irrigated soil profiles was 10, -4, and 32 mm in the first half, and 46, 86, and 118 mm in the second half, of 2005, 2006, and 2007 seasons, respectively.

Plant variable data of corn grown dryland or irrigated in the 3 yr are summarized in Table 3. Field measurement date, treatment significance level (*P*>*F*) from ANOVA, and results from PROC MEANS analysis are presented for the group of 18 hybrids for each variable. Most plant variables were significantly different among hybrids, with noted exceptions. Temperature difference between canopy and air ($T_c - T_a$) was not significantly different among hybrids in any measured site-year (dryland 2005 and irrigated 2005 and 2006), with mean $T_c - T_a$ of 0.7, -2.7, and -3.3ºC in 2005 dryland, 2005 irrigated, and 2006 irrigated, respectively. In dryland, fraction of PAR intercepted in 2005 and 2006 and plant population of 2005 were not significantly different among hybrids. Tiller population was not significantly different among hybrids in the more highly-populated irrigated plots (≤200 tillers ha^{-1}), which is in agreement with Kapanigowda et al. (2010), who stated that tiller formation is normally not a significant factor when corn populations are in the range of 70,000 plants ha^{-1} or greater. Dry biomass measured in dryland was not significantly different among hybrids, which agrees with Alessi and Power (1974) and LeDrew et al. (1984), who found that in water-stressed environments, total dry matter of hybrids did not vary with maturity class because of restrictive water supplies.

Associations between corn grain yield summarized in Table 3 and days from plant emergence to initial silking of the 18 hybrids in the 3 yr are presented in Fig. 3 (dryland) and 4 (irrigated). Linear regression analyses found significant

($P<0.05$) correlation between grain yield and days to initial silking in all years of dryland (Fig. 3), with grain yield decreasing as days to initial silking increased. In water-limiting, dryland conditions, others also have reported a negative association between grain yield and maturity length. From dryland crop performance tests of western Kansas, higher grain yield was associated with early maturity more often than with late maturity, and the same was true in eastern Kansas in more water-limiting years (Roozeboom and Fjell, 2007). And in the two drier years of 3 yr of dryland in North Dakota, corn grain yield was greater for a shorter-season than for a longer-season hybrid (Alessi and Power, 1974).

With irrigation, the correlation between grain yield and days to initial silking was not significant in any of the 3 yr (Fig. 4). In our group of 18 hybrids (RM range of 98–118 d), we had no extremely early-season hybrids that likely would have produced a greater variation in irrigated grain yield vs. maturity response. Results from eastern Nebraska illustrated that well-adapted earlier-maturing corn hybrids (RM of 95–99 d) can produce grain yields comparable to those of later-maturing hybrids (RM of 114–118 d) (Larson and Clegg, 1999). Roozeboom and Fjell (2007) stated that many mid-maturity hybrids have excellent yield potential under favorable conditions, such that from correlation analyses of yield vs. measures of maturity, often no association of yield with hybrid maturity was detected.

Linear regression analyses relating plant variable data of Table 3 (X variables) and grain yield of the 18 hybrids (Y variable) grown dryland or irrigated in the 3 yr are summarized in Table 4. With irrigation, no plant variable was consistently and significantly correlated with grain yield; i.e., no variable was significant in more than 1 yr. Dryland grain yield was significantly correlated with hybrid maturity in 3 yr (Fig. 3), ears with grain in 3 yr (Table 4), dry stover in 3 yr (Table 4), and tiller population in 2 yr (Table 4). Of the variables measured and related with grain yield, the strongest and most consistent correlations were with the population of ears with grain in dryland (Table 4), which was >0.95 in each year as presented in Fig. 5.

A lack of ears with grain was prevalent in our water-stressed, dryland plots (mean of ears with grain plant^{-1} at 0.6, 0.4, and 0.4 in 2005, 2006, and 2007, respectively) and was a strong factor in limiting yields. In an analysis of grain yield components of dryland corn, ears ha^{-1} and kernels ear^{-1} accounted for the vast majority of variability in grain yield among hybrids (Norwood, 2001). Anderson et al. (2004) stated that reduced kernels ear^{-1} is the most consistent, irreversible component of yield reduction resulting from water stress. Karlen and Camp (1985) found that the number of barren plants was increased by water stress created by a lack of plant ASW, with the number of barren plants greater when drought occurred at anthesis. At mid-season, ASW of our 1.5-m dryland profiles was <15% of AWC in all years (Fig. 1). This dearth of ASW at mid-season and limited rainfall thereafter caused a lack of ears with grain, and the associated significant grain yield reduction in dryland.

Biomass yield has a positive, linear association with cumulative transpiration (Loomis, 1983). In water-limited, dryland environments, rapid and extensive early-season growth can exhaust stored ASW and leave insufficient soil water for pollination and grain filling growth stages (Ludlow and Muchow, 1990); therefore, dryland crop management must conserve water during the first half of the growing season for use later in the season. Dryland planting strategies such as reduced plant population, different spacing between rows, skip-row configurations, and planting in clumps have the goal of reducing early season vegetative growth and water use to conserve ASW for use during pollination and grain filling (Stewart et al., 2010). Longer-season hybrids accumulate more dry matter prior to pollination than shorter-season hybrids, so selecting shorter-season hybrids to limit extensive vegetative growth and water use is a way of matching growth and transpiration with anticipated water supply.

Because of the strong correlation between dryland grain yield and ears with grain (Fig. 5), we examined the association between ears with grain and hybrid maturity, dry stover mass, and tiller population. The correlation between dryland grain yield and hybrid maturity was significant and negative in each year (Fig. 3). With dryland, hybrids of greater RM have increasing tendency to run out of ASW during pollination and grain filling, leading to water stress,a lack of ears with grain, and decreased yield. The correlation between ears with grain and hybrid maturity, which was significant and negative each year, is presented in Fig. 6. From a study of dryland corn hybrid response in Kansas, ears plant^{-1} decreased as maturity of hybrids increased from RM of 99 to 114 d (Claassen, 2009), and from dryland in North Dakota, a longer-season hybrid had fewer ears plant^{-1} at all plant populations than a shorter-season hybrid (Alessi and Power, 1974). In our study, shorter-season hybrids had greater population of ears with grain and greater grain yield. Early maturing hybrids tend to have smaller-statured plants that give higher grain yields and greater yield stability than later-maturing hybrids in water-limited, dryland environments (Ludlow and Muchow, 1990).

The association between dryland grain yield and stover mass was significant in each year (Table 4). The correlation between ears with grain and dry stover mass was significant in all 3 yr and is presented in Fig. 7. The correlations of Table 4 and Fig. 7 show a decrease in population of ears with grain and grain yield associated with increasing stover mass. In the two drier of the 3 yr of dryland corn in North Dakota (Alessi and Power, 1974), total dry matter was not different by hybrid, but grain yield was greater for a shorter-season than for a longer-season hybrid, producing a significant negative correlation between grain and stover yields. Dryland corn in Montana had increased stover yield and decreased grain yield with increased plant population, creating a significant negative correlation between grain and stover yields (Allen, 2012). These significant negative associations between grain and stover yields from North Dakota and Montana are similar to our findings from water-stressed, dryland environments.

Tiller population is often a significant factor at the lower plant populations of dryland corn. In Montana, tillers plant^{-1} increased from 0.1 to 1.7 as dryland corn seeding rate decreased from 64 to 27 thousand seeds ha^{-1} (Allen, 2012). Mean tillers plant^{-1} were 1.0, 0.6, and 0.2 in 2005, 2006, and 2007, respectively

(Table 3). Tiller population was significantly influenced by hybrid in the 3 yr of dryland (Table 3), and the correlation between grain yield and tiller population was significant in 2005 and 2006, but not in 2007 (Table 4). The association between ears with grain and tiller population was significant ($P<0.05$) in 2005 and 2006, but not in 2007 (Fig. 8). The data in Fig. 8 indicate a decrease in ears with grain associated with an increase in tillering. Downey (1972) found that as tiller density of corn increased, barrenness increased and grain yield declined. A goal of dryland planting strategies such as planting in clumps (Bandaru et al., 2006; Kapanigowda et al., 2010) is to reduce tillering and early season vegetative growth so ASW will be conserved for later use during pollination and grain filling. The positive association between tillering and barrenness led Downey (1972) to conclude that breeding or selecting for non-tillering corn varieties is desirable.

Dryland plant populations for hybrids in our study ranged from 40 to 54 thousand plants ha^{-1} over the 3 yr. Norwood (2001) stated that corn grown dryland in southwest Kansas should not exceed 45,000 plants ha^{-1}, and Norwood and Currie (1996) stated populations should be reduced from that value in lower rainfall regions. Selecting an appropriate plant population for dryland corn is difficult, because a stand appropriate for water-stress, low-rainfall years will not fully utilize water resources in years with above-average rainfall (Miller et al., 1995). Some plant variables measured in dryland during these 3 yr likely would have been affected to a different degree had plant populations been higher or lower, but we believe corn hybrid responses measured in our dryland and irrigated environments provide information useful to the producer in considering hybrid selection. This information should be used in conjunction with, and as a supplement to, state corn hybrid performance test results.

CONCLUSIONS

In irrigated environments, we found no consistent, significant association between measured plant variables and grain yield of our 18 corn hybrids (RM of 98–118 d). If water supply is subject to decrease or is not reliable, selecting hybrids from the earlier 1/3 or 1/2 of the 98- to 118-d RM range appears appropriate. These earlier-maturing hybrids would yield well with irrigation and would suffer less yield loss than later-maturing hybrids if rainfall and irrigation water supplies fall below anticipated values.

In dryland environments, grain yield of the 18 hybrids had consistent, significant, negative associations with maturity length, stover mass, and tiller population. The correlation of grain yield with maturity length was strongest of the three, followed by correlations with stover mass and tiller population. Our results agree with Sindelar et al. (2010), that with corn grown dryland in the central Great Plains where a high probability of season-long water stress (water shortage) condition exists, earlier-maturing hybrids provide the greatest grain yield potential and with Norwood (2001), that for corn grown dryland for grain in southwest Kansas, RM of hybrids should not exceed ~106 d. In addition to selecting earlier-maturing hybrids for dryland, our results illustrate that producers should select hybrids with the characteristics of smaller stature (less stover) and non-tillering plants.

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Fig. 1. Soil water content vs. soil profile depth in dryland corn on three dates in (A) 2005, (B) 2006, and (C) 2007 near Tribune, KS. Horizontal bars represent ± standard error of the mean (n = 8).

Fig. 2. Soil water content vs. soil profile depth in irrigated corn on three dates in (A) 2005, (B) 2006, and (C) 2007 near Tribune, KS. Horizontal bars represent ± standard error of the mean (n = 8).

Fig. 3. Association between dryland corn grain yield and days from plant emergence to initial silking of 18 hybrids in (A) 2005, (B) 2006, and (C) 2007 near Tribune, KS.

Fig. 4. Association between irrigated corn grain yield and days from plant emergence to initial silking of 18 hybrids in (A) 2005, (B) 2006, and (C) 2007 near Tribune, KS.

Fig. 5. Association between dryland corn grain yield and ears with grain of 18 hybrids in (A) 2005, (B) 2006, and (C) 2007 near Tribune, KS.

Fig. 6. Association between ears with grain and days from plant emergence to initial silking of 18 corn hybrids in dryland in (A) 2005, (B) 2006, and (C) 2007 near Tribune, KS.

Fig. 7. Association between ears with grain and dry stover mass of 18 corn hybrids in dryland in (A) 2005, (B) 2006, and (C) 2007 near Tribune, KS.

Fig. 8. Association between ears with grain and tiller population of 18 corn hybrids in dryland in (A) 2005, (B) 2006, and (C) 2007 near Tribune, KS.

Table 1. Soil properties of the 0- to 0.3-m depth zone of two sites (dryland and irrigated) per year during 3-yr study near Tribune, KS, presented as means and standard errors of the mean (SE with *n* = 6) in parentheses.

	Dryland sites			Irrigated sites		
	2005	2006	2007	2005	2006	2007
Property	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)
pH	7.2 (0.1)	7.5 (0.2)	6.8 (0.1)	8.2 (0.1)	8.0 (0.1)	7.9 (0.1)
Mehlich-3 available P, mg kg^{-1}	57 (3)	39 (6)	43 (2)	23 (3)	19 (4)	15 (3)
Exchangeable K, mg kg^{-1}	700 (29)	621 (12)	678 (20)	715 (19)	539 (18)	525 (18)
Organic matter, g kg^{-1}	15 (1)	15 (1)	14 (1)	17 (1)	16 (1)	16 (1)
Cation exch. cap., cmol$_c$ kg^{-1}	19.4 (1.4)	18.7 (1.0)	18.5 (0.6)	21.2 (1.2)	22.5 (1.0)	24.7 (3.4)
Sand (0.053-2.0 mm), g kg^{-1}	250 (15)	200 (3)	236 (6)	189 (2)	150 (3)	146 (8)
Silt (0.002-0.053 mm), g kg^{-1}	486 (12)	513 (6)	489 (14)	532 (5)	523 (7)	523 (5)
Clay (<0.002 mm), g kg^{-1}	264 (7)	288 (7)	276 (13)	279 (5)	327 (10)	331 (10)
Dry bulk density, g cm^{-3}	1.45 (0.03)	1.41 (0.03)	1.45 (0.02)	1.37 (0.02)	1.40 (0.03)	1.38 (0.03)
Water at -1.5 MPa, g kg^{-1}	127 (4)	126 (2)	118 (5)	146 (2)	151 (6)	157 (7)

Table 2. Air temperature (mean daily minimum and maximum), rainfall, and irrigation by month during growing seasons of 3-yr study near Tribune, KS.

Month	Air temperature: Mean daily minimum	Air temperature: Mean daily maximum	Monthly rainfall: Dryland site	Monthly rainfall: Irrigated site	Monthly irrigation
	°C	°C	mm	mm	mm
			2005		
April	1.6	18.6	46	79	0
May	7.2	24.3	42	54	44
June	13.4	30.1	114	121	38
July	16.0	34.6	31	19	186
Aug	15.1	31.8	98	116	132
Sept	12.3	29.9	9	39	0
			2006		
April	2.9	23.1	5	4	74
May	8.3	26.8	41	40	59
June	14.7	32.2	77	61	120
July	17.7	34.9	54	42	170
Aug	16.1	32.6	40	10	161
Sept	7.9	25.3	25	30	0
			2007		
April	0.9	15.5	84	97	0
May	8.4	24.4	28	29	0
June	12.9	29.5	36	74	24
July	15.9	33.9	13	52	161
Aug	17.9	34.4	84	68	149
Sept	11.5	30.4	19	8	0

Table 3. Plant variable data of corn grown dryland or irrigated in 3 yr near Tribune, KS. Displayed for variables are: field measurement date for reported results; treatment significance level (*P>F*) from analysis of variance; and the minimum, maximum, mean, and standard error of mean (SE) of data sets of the response of 18 hybrids (*n* = 18).

Plant variable	Date	*P>F*	Min.	Max.	Mean	SE	Date	*P>F*	Min.	Max.	Mean	SE
	Dryland 2005						Irrigated 2005					
Grain yield, Mg ha^{-1}	24 Sept	<0.001	0.24	5.77	2.82	0.36	2 Oct	<0.001	9.67	13.64	12.03	0.29
Temp. diff. (canopy-air), ^{o}C	27 July	0.070	0.2	1.2	0.7	0.07	28 July	0.503	-3.2	-2.4	-2.7	0.04
Fraction of PAR intercepted	5 July	0.265	0.58	0.76	0.67	0.01	6 July	<0.001	0.72	0.93	0.83	0.01
Leaf P, g kg^{-1}	3 Aug	<0.001	1.71	2.79	2.37	0.07	4 Aug	0.002	1.64	2.26	2.01	0.04
Leaf N, g kg^{-1}	3 Aug	<0.001	16.1	21.6	18.8	0.4	4 Aug	0.007	17.1	23.3	20.8	0.4
Leaf color, SPAD units	3 Aug	0.004	42.1	51.7	46.2	0.6	4 Aug	<0.001	48.3	58.1	53.4	0.7
Green leaves, leaves plant^{-1}	9 Aug	<0.001	6.1	12.3	10.0	0.4	17 Aug	<0.001	11.6	14.8	13.2	0.2
Total leaves, leaves plant^{-1}	27 July	<0.001	18.8	22.5	20.1	0.2	27 July	<0.001	18.7	22.0	20.0	0.2
Ear leaf angle, degrees	3 Aug	<0.001	11.5	25.1	18.7	0.8	4 Aug	<0.001	16.4	28.9	22.5	0.8
Ear leaf area, cm^{2}	28 July	<0.001	493	721	591	12.7	28 July	<0.001	601	769	683	11.0
Internodes, number plant^{-1}	24 Sept	<0.001	12.8	16.5	14.1	0.2	2 Oct	<0.001	12.7	16.0	14.0	0.2
Plant height, cm	10 Aug	<0.001	147	177	161	1.9	17 Aug	<0.001	196	230	213	2.5
Plant population, 1000s ha^{-1}	24 Sept	0.243	39.9	43.2	41.2	0.23	2 Oct	<0.001	71.9	88.9	79.3	1.03
Tiller population, 1000s ha^{-1}	24 Sept	<0.001	15.6	71.1	44.1	3.69	2 Oct	0.638	0	0.5	0.1	0.04
Ears with grain, 1000s ha^{-1}	24 Sept	<0.001	3.3	40.0	24.3	2.50	2 Oct	<0.001	67.0	88.0	76.8	1.29
Kernel mass, mg kernel^{-1}	24 Sept	<0.001	215	374	302	9.3	2 Oct	<0.001	238	368	323	7.4
Dry biomass, Mg ha^{-1}	3 Sept	0.060	10.1	14.1	12.0	0.25						
Dry stover, Mg ha^{-1}		<0.001	7.9	11.2	9.7	0.27						
	Dryland 2006						Irrigated 2006					
Grain yield, Mg ha^{-1}	14 Oct	<0.001	0.04	3.19	1.47	0.23	29 Sept	<0.001	13.56	16.74	14.94	0.26
Temp. diff. (canopy-air), ^{o}C							20 July	0.179	-3.8	-2.9	-3.3	0.06
Fraction of PAR intercepted	14 July	0.129	0.59	0.76	0.67	0.01	27 June	0.004	0.79	0.93	0.85	0.01
Leaf P, g kg^{-1}							27 July	<0.001	1.70	2.65	2.12	0.05
Leaf N, g kg^{-1}							27 July	0.001	17.7	24.1	21.8	0.4
Leaf color, SPAD units							27 July	<0.001	49.8	59.4	55.1	0.6
Green leaves, leaves plant^{-1}	14 Aug	<0.001	3.0	12.2	8.6	0.5	8 Aug	<0.001	11.2	14.4	12.6	0.2
Total leaves, leaves plant^{-1}	9 Aug	<0.001	18.7	22.1	20.1	0.2	26 July	<0.001	18.7	22.1	20.0	0.2
Ear leaf angle, degrees	14 Aug	<0.001	15.7	26.4	20.0	0.7	2 Aug	<0.001	18.8	32.0	25.1	0.9
Ear leaf area, cm^{2}							26 July	<0.001	603	803	680	12.8
Internodes, number plant^{-1}	15 Sept	<0.001	11.6	14.8	12.9	0.2	4 Sept	<0.001	11.8	14.4	12.9	0.2
Plant height, cm	14 Aug	<0.001	132	166	153	1.9	15 Aug	<0.001	205	262	235	3.5
Plant population, 1000s ha^{-1}	14 Oct	0.047	42.9	52.5	47.3	0.51	29 Sept	<0.001	79.6	94.6	88.0	0.93
Tiller population, 1000s ha^{-1}	14 Oct	<0.001	3.8	47.8	26.9	2.85	29 Sept	0.750	0	0.8	0.2	0.05
Ears with grain, 1000s ha^{-1}	14 Oct	<0.001	1.1	39.6	18.2	2.68	29 Sept	<0.001	66.7	92.4	83.7	1.72
Kernel mass, mg kernel^{-1}	14 Oct	<0.001	234	348	285	7.3	29 Sept	<0.001	291	373	340	6.0
Dry biomass, Mg ha^{-1}	23 Aug	0.119	9.2	13.0	10.8	0.25						
Dry stover, Mg ha^{-1}		0.004	7.4	12.3	9.6	0.32						

Table 3 (Continued)

	Dryland 2007						Irrigated 2007					
Grain yield, Mg ha^{-1}	22 Sept	0.022	0.03	3.46	1.57	0.27	13 Oct	<0.001	13.34	16.81	14.99	0.20
Plant population, 1000s ha^{-1}	22 Sept	0.005	46.5	53.9	49.5	0.46	13 Oct	<0.001	70.3	80.6	75.8	0.84
Tiller population, 1000s ha^{-1}	22 Sept	<0.001	0	46.2	11.5	3.24	13 Oct	0.686	0	0.5	0.1	0.04
Ears with grain, 1000s ha^{-1}	22 Sept	<0.001	1.1	39.9	20.7	2.87	13 Oct	<0.001	66.7	79.6	74.2	1.00
Kernel mass, mg kernel^{-1}	22 Sept	0.001	199	300	257	6.7	13 Oct	<0.001	302	410	361	6.5
Dry biomass, Mg ha^{-1}	8 Sept	0.988	7.4	10.4	9.3	0.18						
Dry stover, Mg ha^{-1}		0.822	5.5	9.4	7.9	0.29						

Table 4. Linear regression analyses relating plant variables (X variables) and grain yield in Mg ha^{-1} of 18 corn hybrids (Y variable) grown dryland or irrigated in 3 yr near Tribune, KS. Regression equations (n = 18) are listed with coefficient of determination (r^2), regression significance level ($P>F$), and standard error of estimate of Y on X ($S_{Y \bullet X}$).

Plant variable	Regression equation	r^2	$P>F$	$S_{Y \bullet X}$	Regression equation	r^2	$P>F$	$S_{Y \bullet X}$
	Dryland 2005				Irrigated 2005			
Temp. diff. (canopy-air), °C	$Y = 2.8 + 0.06X$	0.01	0.966	1.6	$Y = 19.9 + 2.93X$	0.16	0.100	1.2
Fraction of PAR intercepted	$Y = 7.8 - 7.42X$	0.05	0.387	1.5	$Y = 14.2 - 2.63X$	0.01	0.647	1.2
Leaf P, g kg^{-1}	$Y = 1.3 + 0.62X$	0.02	0.626	1.6	$Y = 8.5 + 1.78X$	0.07	0.309	1.2
Leaf N, g kg^{-1}	$Y = 0.3 + 0.135X$	0.02	0.552	1.6	$Y = 6.0 + 0.291X$	0.15	0.108	1.2
Leaf color, SPAD units	$Y = 1.3 + 0.034X$	0.01	0.824	1.6	$Y = 2.7 + 0.174X$	0.17	0.092	1.1
Green leaves, leaves plant^{-1}	$Y = 1.5 + 0.131X$	0.02	0.580	1.6	$Y = 10.5 + 0.113X$	0.01	0.758	1.3
Total leaves, leaves plant^{-1}	$Y = 14.1 - 0.559X$	0.10	0.199	1.5	$Y = 21.0 - 0.448X$	0.10	0.199	1.2
Ear leaf angle, degrees	$Y = 0.5 + 0.124X$	0.08	0.244	1.5	$Y = 11.9 + 0.007X$	0.01	0.944	1.2
Ear leaf area, cm^2	$Y = 4.7 - 0.0033X$	0.01	0.650	1.6	$Y = 9.4 + 0.0038X$	0.02	0.567	1.2
Internodes, number plant^{-1}	$Y = 10.9 - 0.572X$	0.11	0.180	1.5	$Y = 18.3 - 0.448X$	0.10	0.199	1.2
Plant height, cm	$Y = -8.5 + 0.0705X$	0.14	0.129	1.5	$Y = 9.6 + 0.0112X$	0.01	0.694	1.3
Plant population, 1000s ha^{-1}	$Y = -21.3 + 0.586X$	0.14	0.126	1.5	$Y = 7.2 + 0.061X$	0.05	0.382	1.2
Tiller population, 1000s ha^{-1}	$Y = 5.0 - 0.049X$	0.25	0.034	1.4	$Y = 12.2 - 2.002X$	0.07	0.299	1.2
Ears with grain, 1000s ha^{-1}	$Y = -0.6 + 0.140X$	0.93	<0.001	0.4	$Y = 3.8 + 0.107X$	0.23	0.042	1.1
Kernel mass, mg kernel^{-1}	$Y = -2.1 + 0.0163X$	0.18	0.082	1.4	$Y = 8.9 + 0.0097X$	0.06	0.321	1.2
Dry biomass, Mg ha^{-1}	$Y = -6.4 + 0.764X$	0.27	0.027	1.4				
Dry stover, Mg ha^{-1}	$Y = 11.0 - 0.850X$	0.42	0.004	1.2				
	Dryland 2006				Irrigated 2006			
Temp. diff. (canopy-air), °C					$Y = 12.8 - 0.64X$	0.03	0.531	1.1
Fraction of PAR intercepted	$Y = 5.6 - 6.10X$	0.1	0.208	1.0	$Y = 3.1 + 13.92X$	0.25	0.037	1.0
Leaf P, g kg^{-1}					$Y = 17.0 - 0.99X$	0.04	0.423	1.1
Leaf N, g kg^{-1}					$Y = 14.5 + 0.021X$	0.01	0.892	1.1
Leaf color, SPAD units					$Y = 4.8 + 0.184X$	0.20	0.063	1.0
Green leaves, leaves plant^{-1}	$Y = 1.1 + 0.037X$	0.01	0.737	1.0	$Y = 13.0 + 0.151X$	0.01	0.677	1.1
Total leaves, leaves plant^{-1}	$Y = 8.0 - 0.325X$	0.08	0.256	1.0	$Y = 15.7 - 0.040X$	0.01	0.909	1.1
Ear leaf angle, degrees	$Y = -1.6 + 0.154X$	0.23	0.047	0.9	$Y = 15.3 - 0.016X$	0.01	0.835	1.1
Ear leaf area, cm^2					$Y = 15.0 - 0.0002X$	0.01	0.977	1.1
Internodes, number plant^{-1}	$Y = 4.3 - 0.221X$	0.03	0.470	1.0	$Y = 13.3 + 0.127X$	0.01	0.775	1.1
Plant height, cm	$Y = -6.5 + 0.0518X$	0.17	0.085	0.9	$Y = 10.5 + 0.0188X$	0.07	0.304	1.1
Plant population, 1000s ha^{-1}	$Y = 0.4 + 0.022X$	0.01	0.850	1.0	$Y = 9.8 + 0.058X$	0.04	0.404	1.1
Tiller population, 1000s ha^{-1}	$Y = 2.6 - 0.043X$	0.28	0.024	0.9	$Y = 15.0 - 0.322X$	0.01	0.804	1.1
Ears with grain, 1000s ha^{-1}	$Y = 0.0 + 0.083X$	0.92	<0.001	0.3	$Y = 9.5 - 0.065X$	0.19	0.071	1.0
Kernel mass, mg kernel^{-1}	$Y = 2.9 - 0.0050X$	0.03	0.530	1.0	$Y = 14.8 + 0.0005X$	0.01	0.963	1.1
Dry biomass, Mg ha^{-1}	$Y = 2.0 - 0.049X$	0.01	0.838	1.0				
Dry stover, Mg ha^{-1}	$Y = 6.0 - 0.469X$	0.42	0.004	0.8				

Table 4 (Continued)

	Dryland 2007				Irrigated 2007			
Plant population, 1000s ha^{-1}	Y = 9.2 - 0.154X	0.07	0.289	1.1	Y = 8.6 + 0.084X	0.12	0.161	0.8
Tiller population, 1000s ha^{-1}	Y = 1.9 - 0.025X	0.09	0.227	1.1	Y = 15.1 - 0.451X	0.01	0.728	0.9
Ears with grain, 1000s ha^{-1}	Y = -0.3 + 0.091X	0.94	<0.001	0.3	Y = 10.7 - 0.058X	0.08	0.256	0.9
Kernel mass, mg kernel^{-1}	Y = 5.8 - 0.0164X	0.17	0.091	1.1	Y = 14.5 + 0.0014X	0.01	0.863	0.9
Dry biomass, Mg ha^{-1}	Y = 1.4 + 0.015X	0.01	0.969	1.2				
Dry stover, Mg ha^{-1}	Y = 7.4 - 0.734X	0.61	<0.001	0.7				

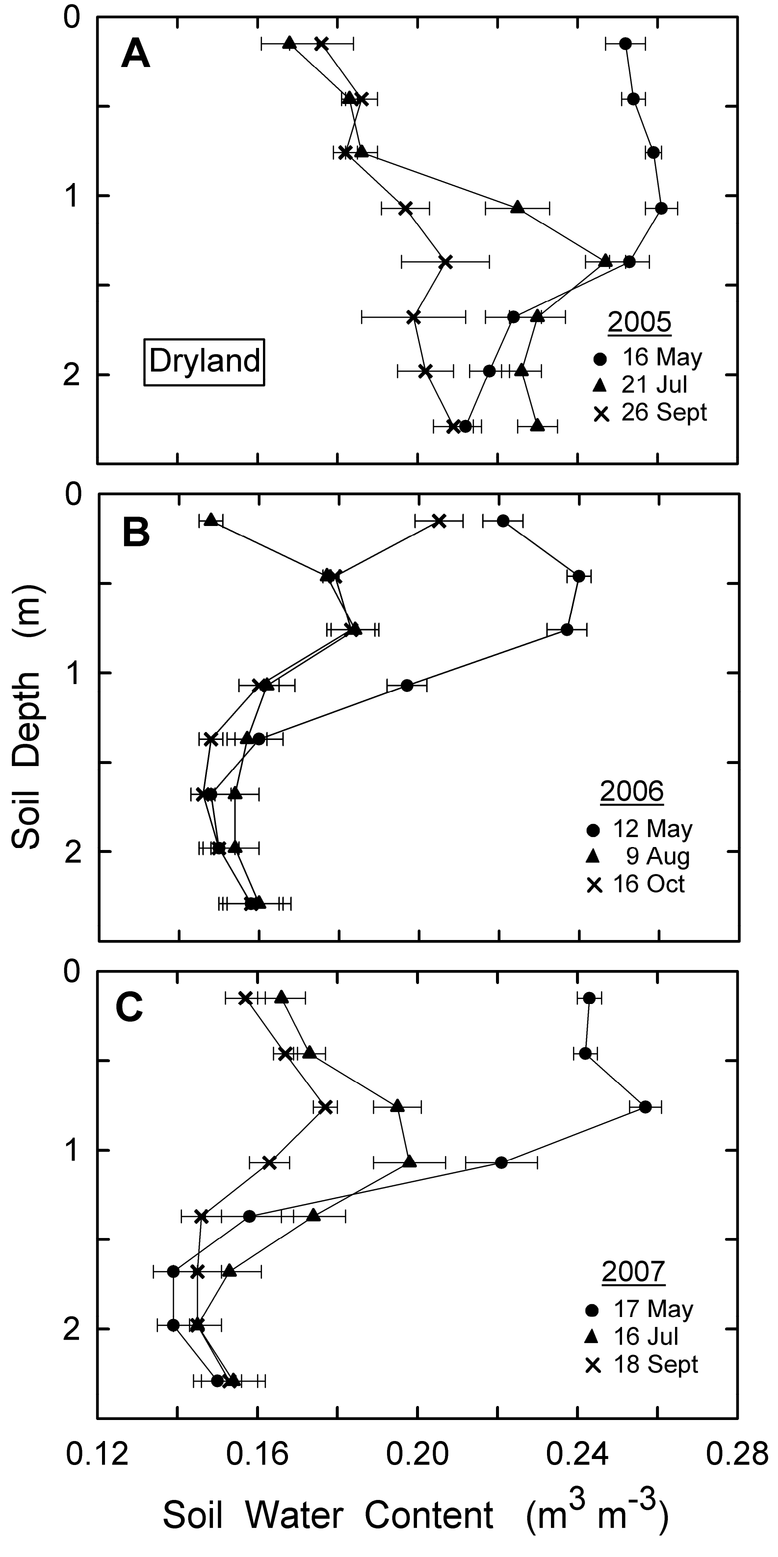

Fig. 1. Soil water content vs. soil profile depth in dryland corn on three dates in (A) 2005, (B) 2006, and (C) 2007 near Tribune, KS. Horizontal bars represent ± standard error of the mean (n = 8).

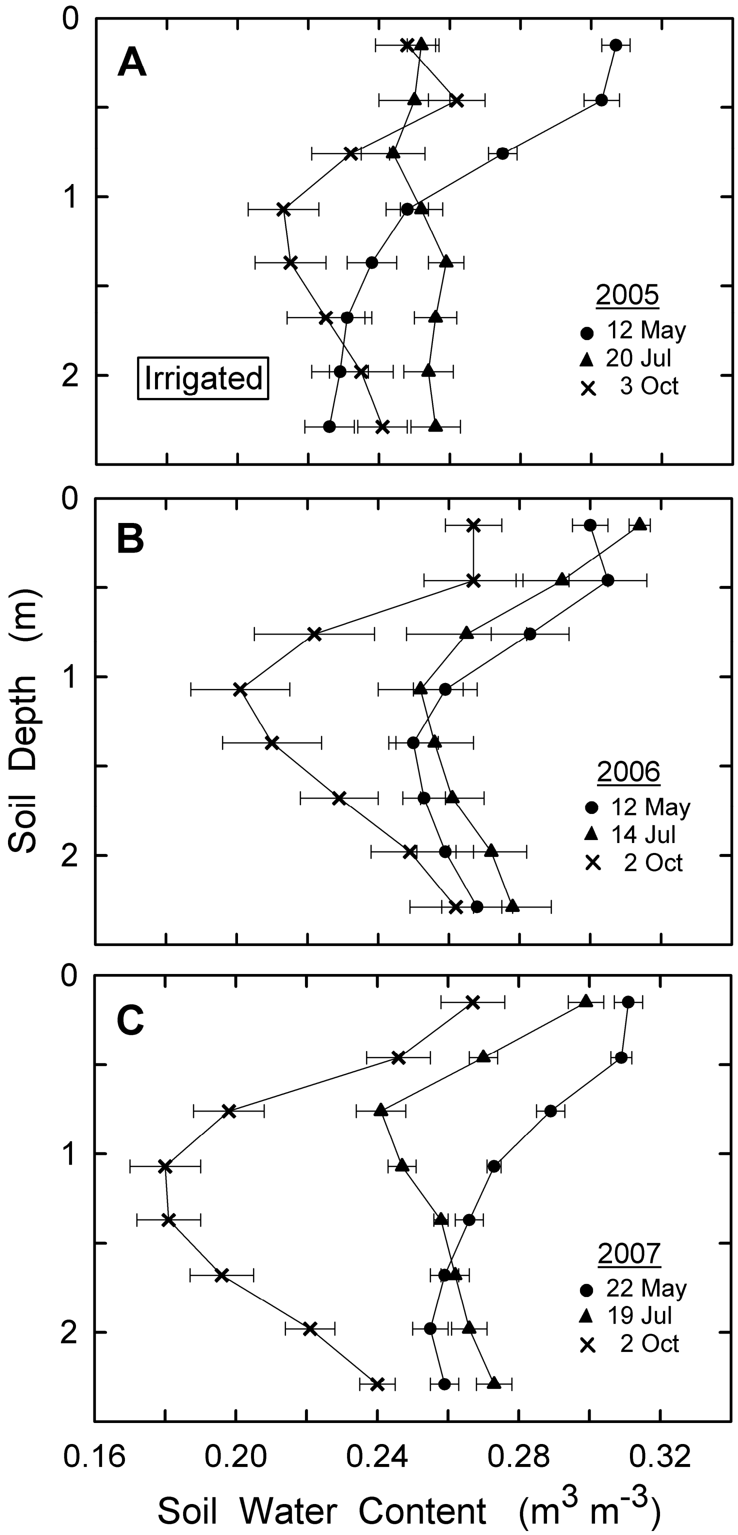

Fig. 2. Soil water content vs. soil profile depth in irrigated corn on three dates in (A) 2005, (B) 2006, and (C) 2007 near Tribune, KS. Horizontal bars represent ± standard error of the mean (n = 8).

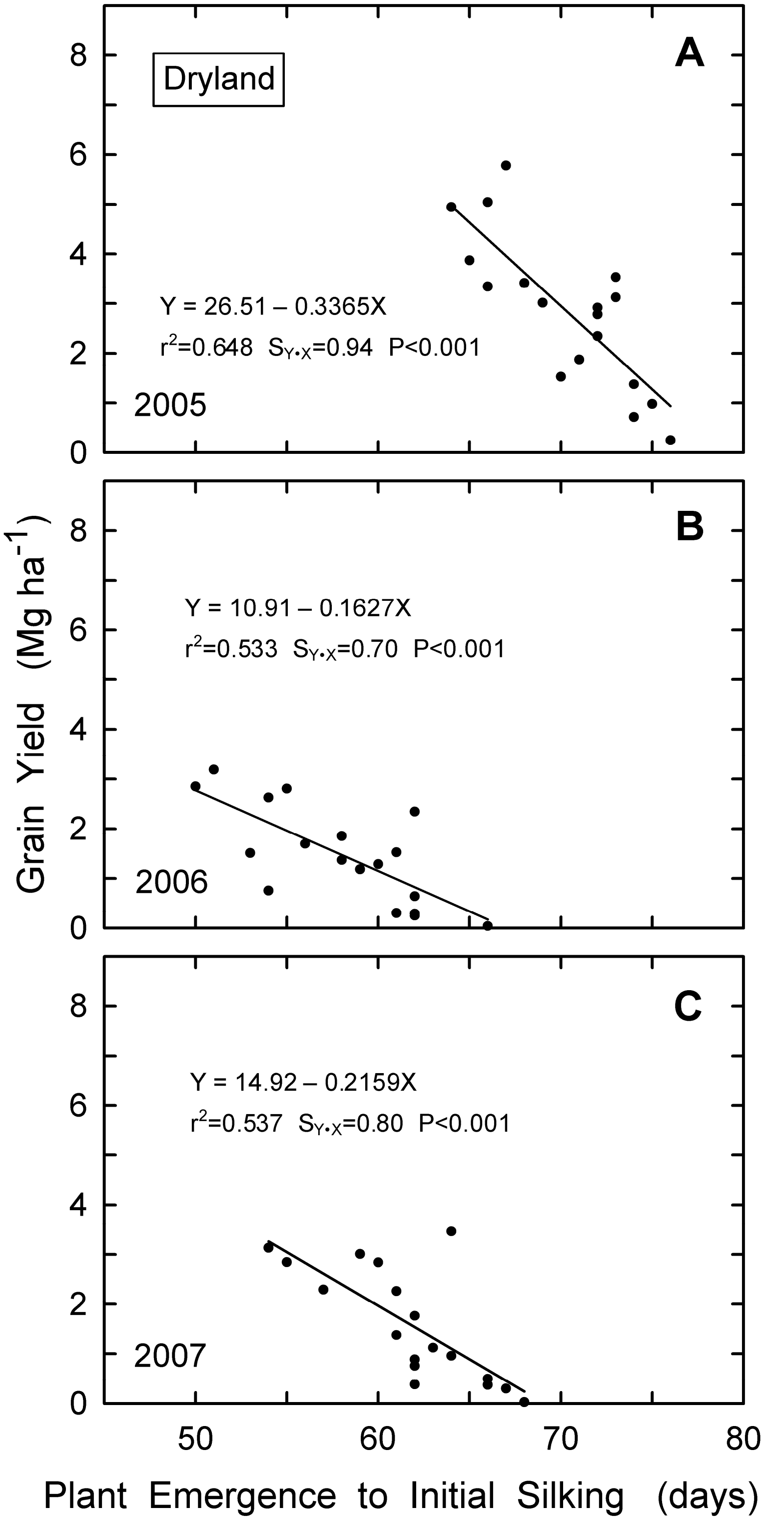

Fig. 3. Association between dryland corn grain yield and days from plant emergence to initial silking of 18 hybrids in (A) 2005, (B) 2006, and (C) 2007 near Tribune, KS.

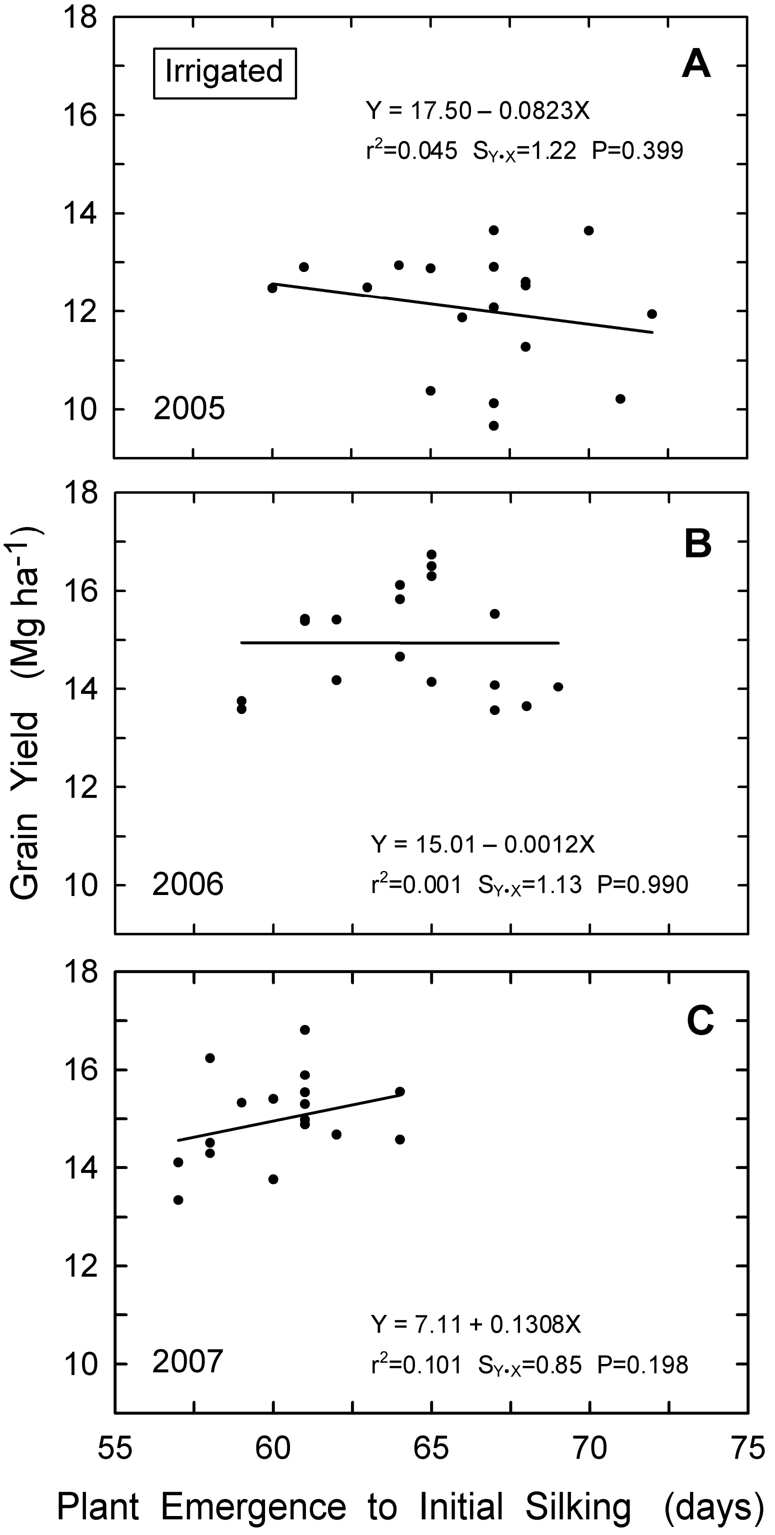

Fig. 4. Association between irrigated corn grain yield and days from plant emergence to initial silking of 18 hybrids in (A) 2005, (B) 2006, and (C) 2007 near Tribune, KS.

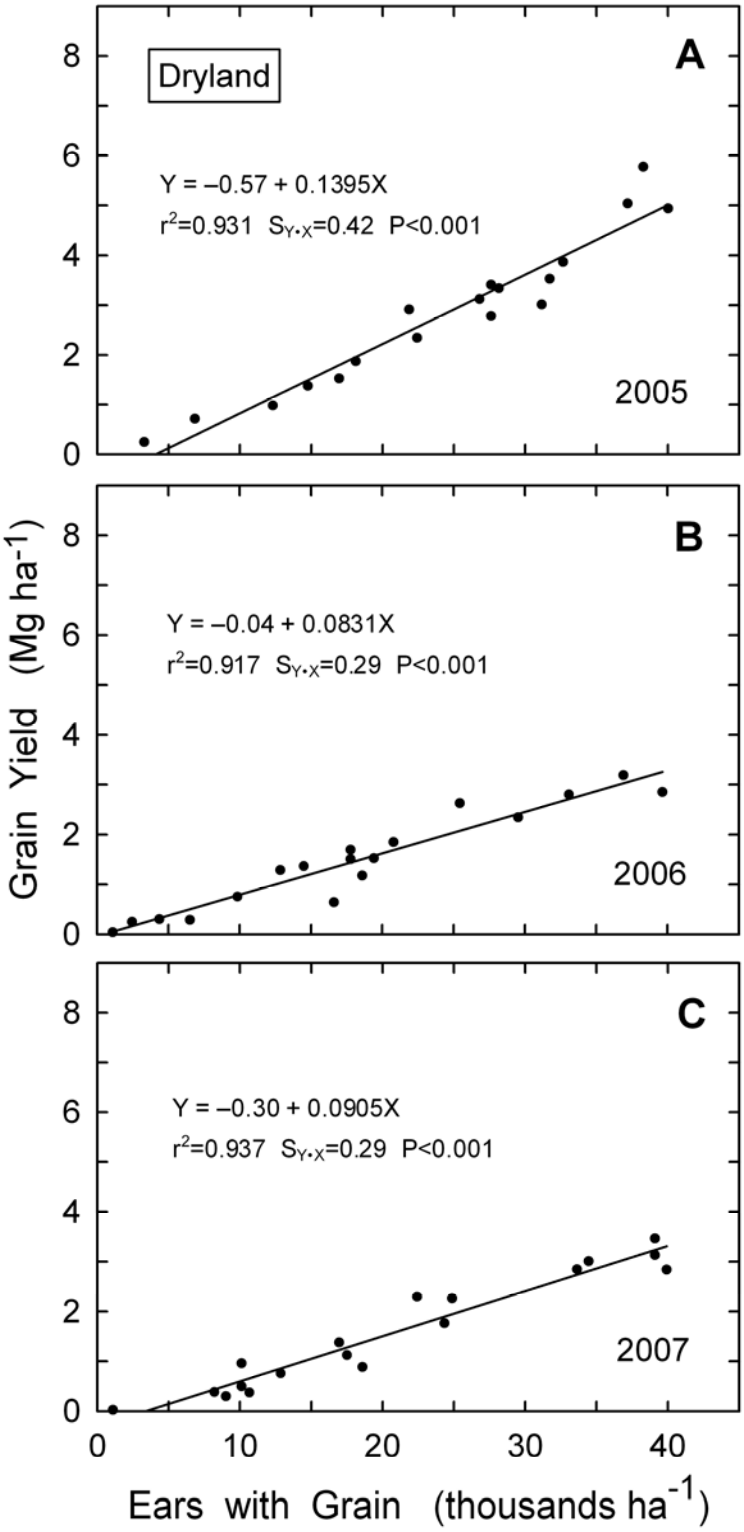

Fig. 5. Association between dryland corn grain yield and ears with grain of 18 hybrids in (A) 2005, (B) 2006, and (C) 2007 near Tribune, KS.

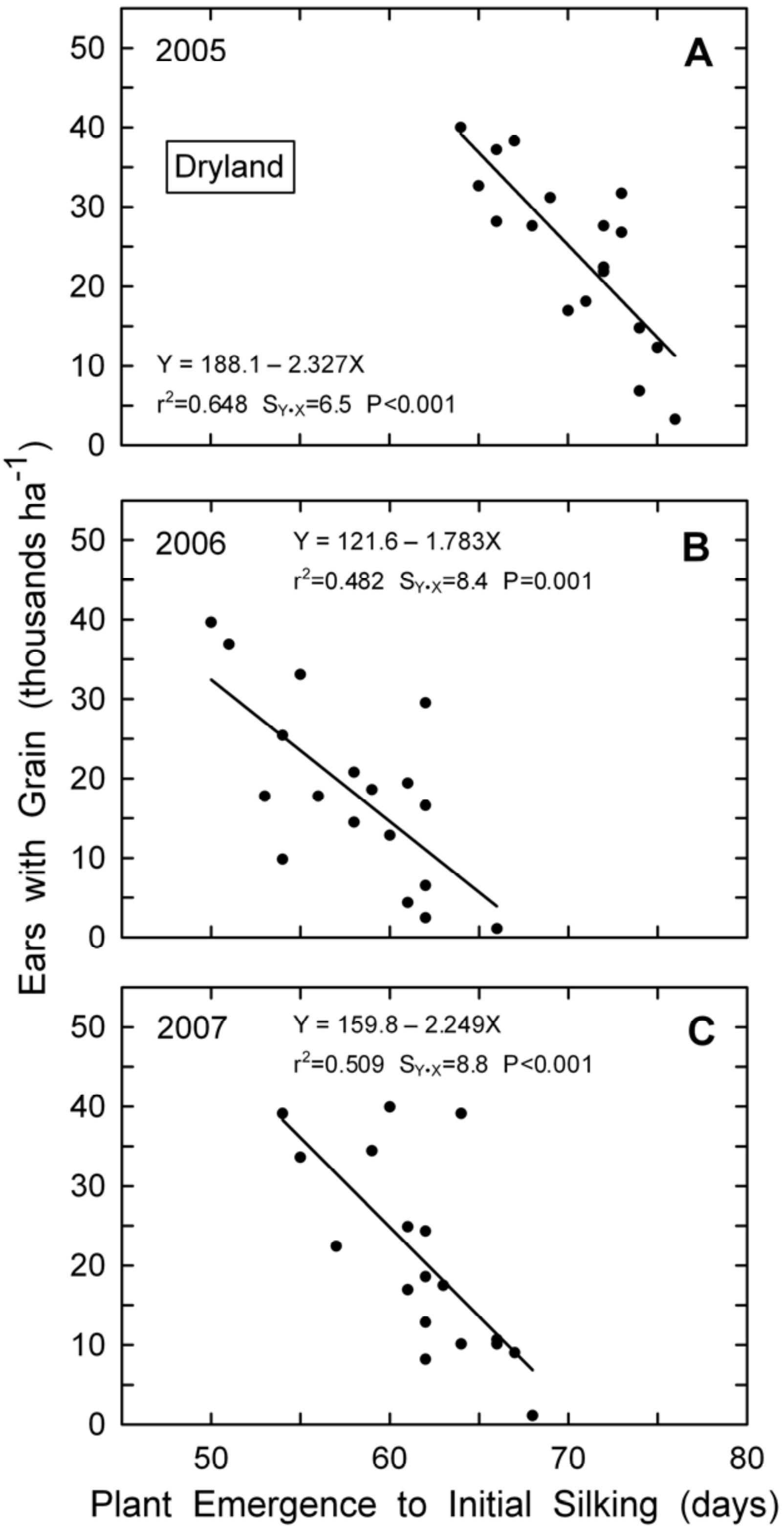

Fig. 6. Association between ears with grain and days from plant emergence to initial silking of 18 corn hybrids in dryland in (A) 2005, (B) 2006, and (C) 2007 near Tribune, KS.

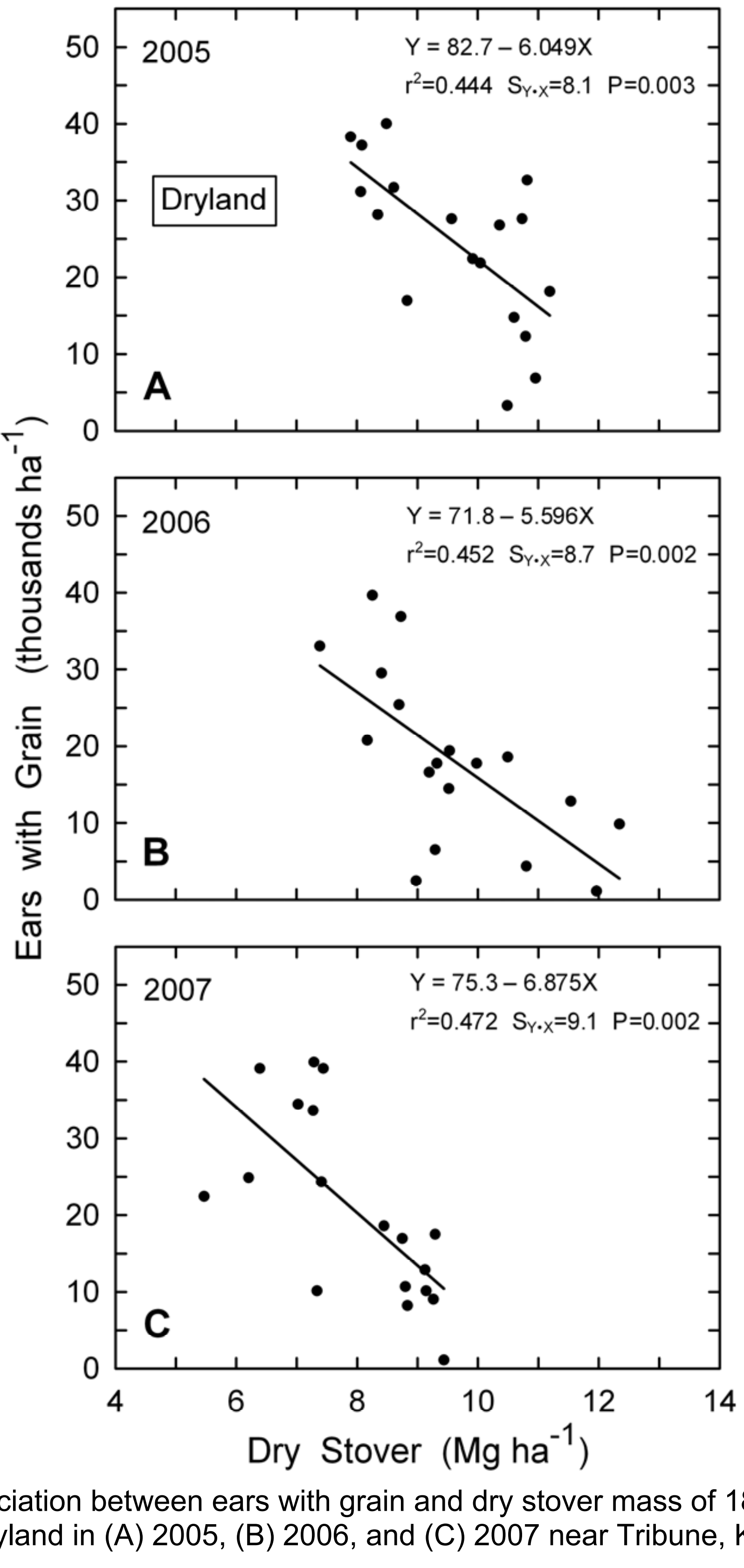

Fig. 7. Association between ears with grain and dry stover mass of 18 corn hybrids in dryland in (A) 2005, (B) 2006, and (C) 2007 near Tribune, KS.

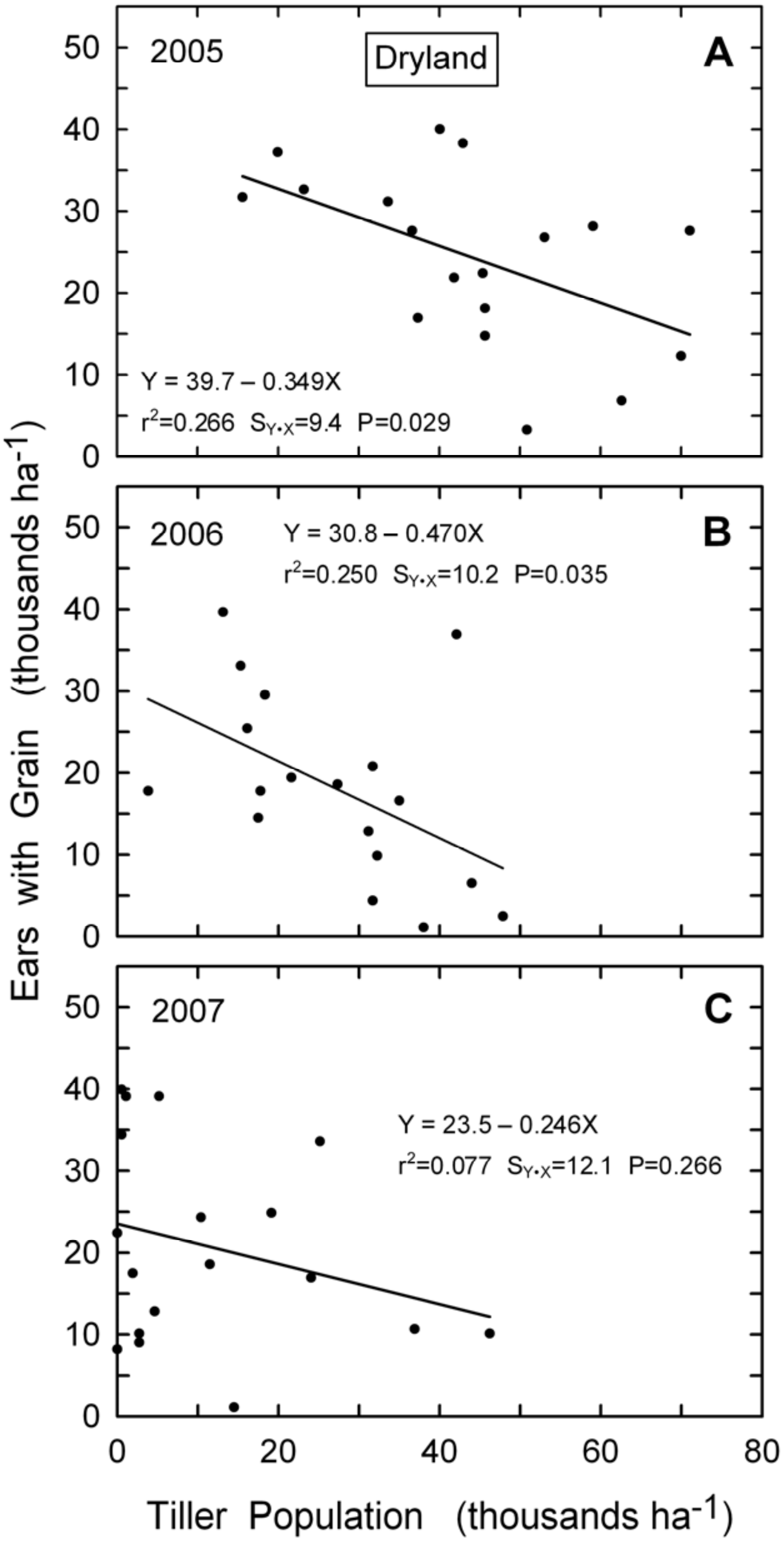

Fig. 8. Association between ears with grain and tiller population of 18 corn hybrids in dryland in (A) 2005, (B) 2006, and (C) 2007 near Tribune, KS.