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Cover Page Footnote

The authors appreciate and acknowledge the Kansas Wheat Commission for providing funds necessary to perform this research, and the Kansas State University Wheat Production Team for the help collecting and processing field data.

Wheat Development and Yield as Affected by Era of Variety Release and In-Furrow Fertilizer

R.E. Maeoka and R.P. Lollato

Summary

Nutrients play a major role in wheat yield determination; however, limited information exists on the differential responses of historical and modern varieties to in-furrow fertilizer. Our objectives were to estimate grain yield and differences in agronomic traits of historical and modern winter wheat varieties as affected by different fertilization programs. Two field trials were established during the growing season 2016–2017 (i.e., Ashland Bottoms and Belleville, KS). Seven winter wheat varieties released between 1920 and 2016–Kharkof (1920), Scout 66 (1966), Karl 92 (1988), Jagalene (2001), Fuller (2006), KanMark (2014), and Larry (2016)–were sown using one of two different fertilizer practices: either the university recommendation or a treatment where 100 lb/a MESZ were applied in-furrow. At both locations, historical varieties were taller and had thinner stems than modern ones. In-furrow fertilizer increased yield of modern varieties relative to no fertilizer treatment in a sandier soil in Ashland Bottoms, while historical varieties showed neutral to negative yield response. In the silt loam soil near Belleville, there was only a significant variety effect but no fertilizer effect, likely due to a greater cation exchange capacity of the studied soil. More site-years of this study are needed to determine whether there is a need for re-evaluation of current fertility recommendations for modern wheat varieties.

Introduction

Kansas is the largest hard red winter wheat producer in the United States. Wheat yield improved over the last few decades due to progress in plant breeding, especially led by the successful introduction of dwarfing genes by breeders that allowed the development of shorter plants and higher yield. Agronomic practices, such as the advent of nitrogen (N) fertilizer, also contributed to increased yields in the state. However, the increased grain yield potential of modern wheat varieties may have had the hidden consequence of a shift in the nutrient requirements of the modern wheat plants. Therefore, current fertilizer recommendations need to be tested to determine whether an update is needed to match nutrient necessities of modern varieties and increase the return over investment. The objectives of this project were to evaluate whether historical and modern winter wheat varieties respond differently to in-furrow fertilizer in high P-level soils and to determine the partial contribution from genetic and agronomic management to wheat yield gain.

Procedures

One field experiment was conducted at two Kansas State University research locations: the Research Farm in Ashland Bottoms, KS; and at the North Central Kansas Experiment Field in Belleville, KS. Both sites were characterized to have more than 40 ppm extractable phosphorus (P), which is double the minimum required by a wheat crop (about 20 ppm). A two-way factorial treatment structure was established in split plot design with four replications, with main plots arranged as randomized complete block design and subplots completely randomized within main plots. Main plots were varieties released in different historical eras and the subplots were two different nutrient fertilization programs. Seven varieties released between 1920 and 2016, were tested, grouped by eras: historical, Kharkof (1920) and Scout 66 (1966); and modern, Karl 92 (1988), Jagalene (2001), Fuller (2006), KanMark (2014), and Larry (2016). Fertilization programs were i) Kansas State University soil fertility recommendation for P and potassium (K), using the nutrient "sufficiency" approach, therefore, no fertilizer was applied; and ii) in-furrow 100 lb/a applied as 12-40-0-10-1.

Wheat was sown October 18, 2016 at Ashland Bottoms and October 3, 2016, at Belleville at a seeding rate of 60 lb/a (approximately 1.28 million seeds/a); all the locations were planted under the conventional tillage method following wheat. Plots were 30-ft long × 4.38-ft wide, with seven 7.5-in. spaced rows. In Ashland Bottoms, 50 lb/a of pre-plant N fertilizer in the form of urea (46-0-0) was applied, and 50 lb/a of N in the form of urea ammonium-nitrate (UAN) (32-0-0) was applied before winter dormancy. In Belleville, high levels (18.47 lb N/a) of inherent soil N was available so no fall N fertilization was necessary. In both locations, topdress N (46-0-0) was applied early spring (Feekes 5-6) with a yield goal of 90 bu/a, and two foliar fungicide applications were performed (Feekes 6-7, Feekes 10.5) to avoid foliar diseases and consequently yield losses. Similarly, commercially available herbicide products were sprayed to ensure weeds were not a limiting factor. No significant insect pressure was observed; therefore, insecticide applications were not warranted. Plots were harvested for grain using a self-propelled small-plot combine. Grain moisture was measured at harvest and grain yield was corrected for 13.5% moisture content. Measurements included percent canopy closure measured at bi-weekly intervals throughout the growing season, stem diameter was measured at Feekes growth stage 11.2 (soft dough stage of kernel development), and plant height was measured at the Feekes growth stage 11.4 (ripening). Analyses of variance considered varieties and fertilization practice as fixed effects, and orthogonal contrasts were developed to evaluate historical varieties versus modern varieties across fertilization programs. Dynamics of canopy cover were modeled by fertilization program and location as a sigmoidal function of growing degree days (GDD) using non-linear regression model:

$$Y = \frac{a}{1+e^{-\left(\frac{t-to}{b}\right)}} \qquad [1]$$

where a is the asymptotic maximum percent canopy cover, t is time (GDD), t_o is the inflection point at which the rate in percent canopy cover increase is maximized (GDD), and b is a parameter determining the shape of the curve.

Results

Growing Season Weather

The weather in both locations was similar, a fall characterized by warm temperatures and cumulative precipitation below normal, followed by a mild and dry winter during January through the third week of March, and cool and above-average well-distributed precipitation during the spring. Cumulative precipitation of 16.5 in. at Ashland Bottoms and 16.8 in. at Belleville occurred during the growing season, and mostly concentrated during the spring (more than ½ of the total precipitation).

Canopy Cover

The sigmoidal model in Equation 1 explained dynamics of canopy cover development and indicated that in-furrow fertilizer increased the asymptotic maximum canopy cover *(a)* from 90.2 to 94.5% at Ashland Bottoms (Figure 1A) and from 89.7 to 91.5% at Belleville (Figure 1B), compared to no fertilizer added. Furthermore, in-furrow fertilizer led to a quicker achievement of maximum rate of canopy cover (t_o) from 1099 GDD to 535 GDD at Ashland Bottoms (Figure 1A) and from 1310 GDD to 1257 GDD at Belleville (Figure 1B), irrespective of era of variety release as both historical and modern varieties presented the same pattern of development.

Plant Height

Variety was the only significant factor affecting plant height at both locations. Overall, plant height was negatively correlated with release year of the varieties, showing a reduction over time. The plant height ranged from 44.88 to 34.98 inches for historical and modern varieties, respectively. Modern varieties had approximately 78% of the plant height of historical varieties (Figures 2A), mainly due to the successful introduction of the dwarfing genes.

Stem Diameter

Similarly, to our measurements of plant height, variety was the only significant factor affecting wheat stem diameter at both locations; however, this followed the opposite trend and was positively correlated with year of release of the varieties, and we measured an increase over time. The stem diameter ranged from 0.113 to 0.121 inches for historical and modern varieties, respectively. Modern varieties had approximately 7% thicker stems relative to historical varieties (Figure 2B). Straw strength is important to avoid lodging, which can be associated with reduced yield.

Grain Yield

Ashland Bottoms

At the Ashland Bottoms field experiment, there was significant interaction between variety and fertilization program on wheat grain yield. Historical varieties showed negative responses to in-furrow fertilizer, on average decreased 5.88 bu/a, and obtained the lowest wheat yields regardless of fertilization practice (Figure 3). On average, modern varieties increased wheat yield under in-furrow fertilizer in 8 bu/a, with the exception of Karl 92 and Fuller in which fertilizer effect was non-significant. The increased grain yield on the other three modern wheat varieties nonetheless was significant. At this field experiment, barley yellow dwarf (BYD) decreased overall location yield.

Belleville

At the Belleville field experiment, there was no significant interaction between variety and fertilization program on wheat grain yield, and statistical difference was obtained only for variety factor. Grain yield ranged from 32.52 to 89.88 bu/a, increasing from Kharkof to KanMark, respectively (Figure 4). The historical varieties averaged 40.62 bu/a, while modern ones averaged 83.76 bu/a. Relative to Kharkof, all modern wheat varieties yielded more than 200%. At this location, bacterial streak was observed late in the growing season and could possibly have affected grain yields.

In-Furrow Fertilizer vs. No Fertilizer, Yields

On average of both sites, an increase in yield was greater when in-furrow fertilizer was applied as compared to no fertilizer (Figure 5), which is indicated by the slope of the relationship between no-fertilizer and in-furrow fertilizer of 1.31, which is greater than one. This relationship also indicates that modern, higher yielding varieties responded more to the in-furrow fertilizer than older, lower yielding varieties, as the low-yielding points are positioned below the 1:1 line.

Acknowledgments

The authors appreciate and acknowledge the Kansas Wheat Commission for providing funds necessary to perform this research, and the Kansas State University Wheat Production Team for the help collecting and processing field data.

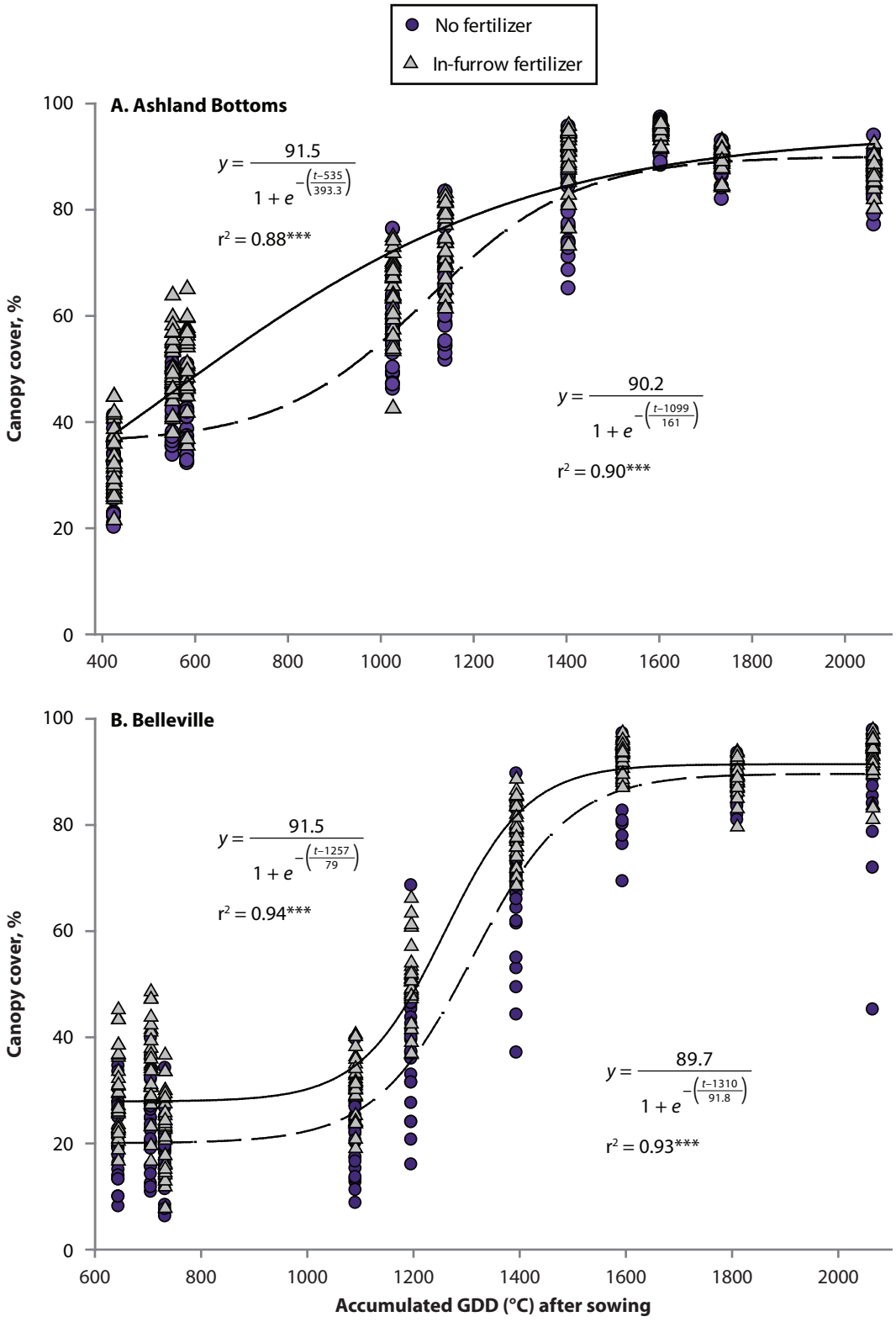

Figure 1. Dynamics of canopy cover development during the growing season 2016–2017 as function of accumulated growing degree days (GDD °C) after sowing, as affected by in-furrow fertilizer.

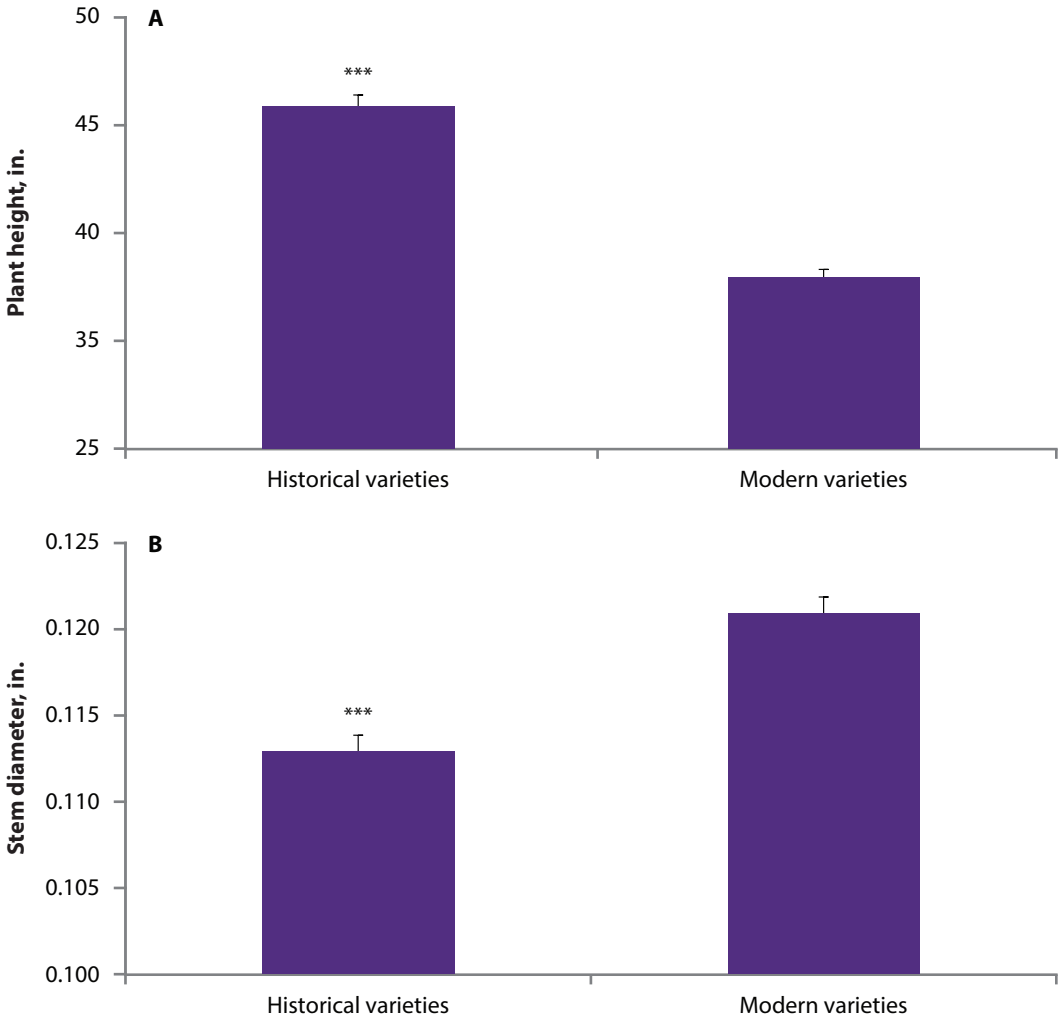

Figure 2. Plant height (A) and stem diameter (B) in historical versus modern varieties irrespective of fertilization program during the growing season 2016–2017. *,,*** = significant at $P < 0.05$, 0.01, and 0.001, respectively.**

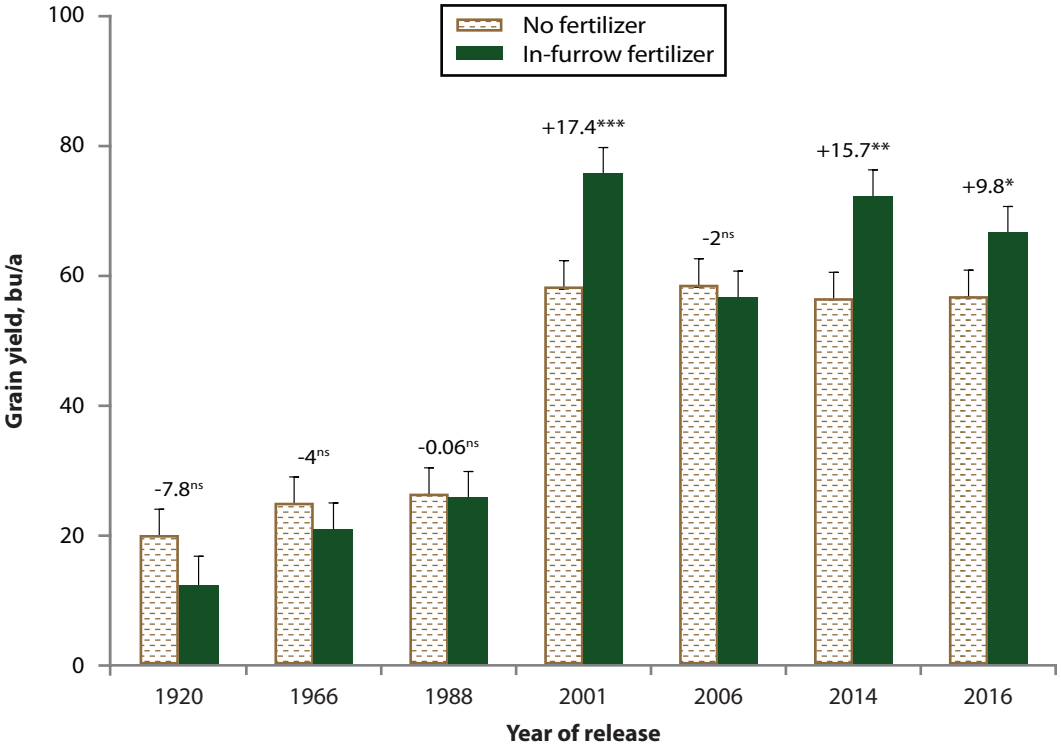

Figure 3. Grain yield of varieties released from 1920 to 2016 as affected by two fertilization programs during the growing season 2016–2017, at Kansas State University Ashland Bottoms Research Farm and the difference in yield from no fertilizer and in-furrow fertilizer. *,,*** = significant at $P < 0.05$, 0.01, and 0.001, respectively.**

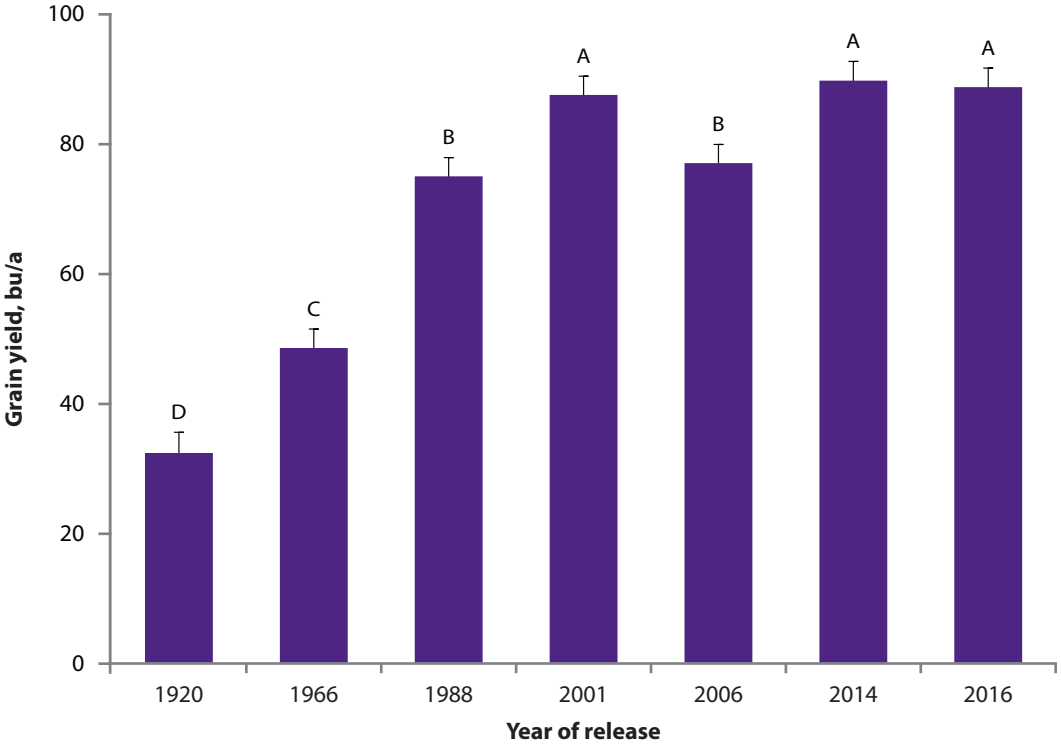

Figure 4. Grain yield of varieties released from 1920 to 2016 during the growing season 2016–2017, Kansas State University North Central Kansas Experiment Field, Belleville.

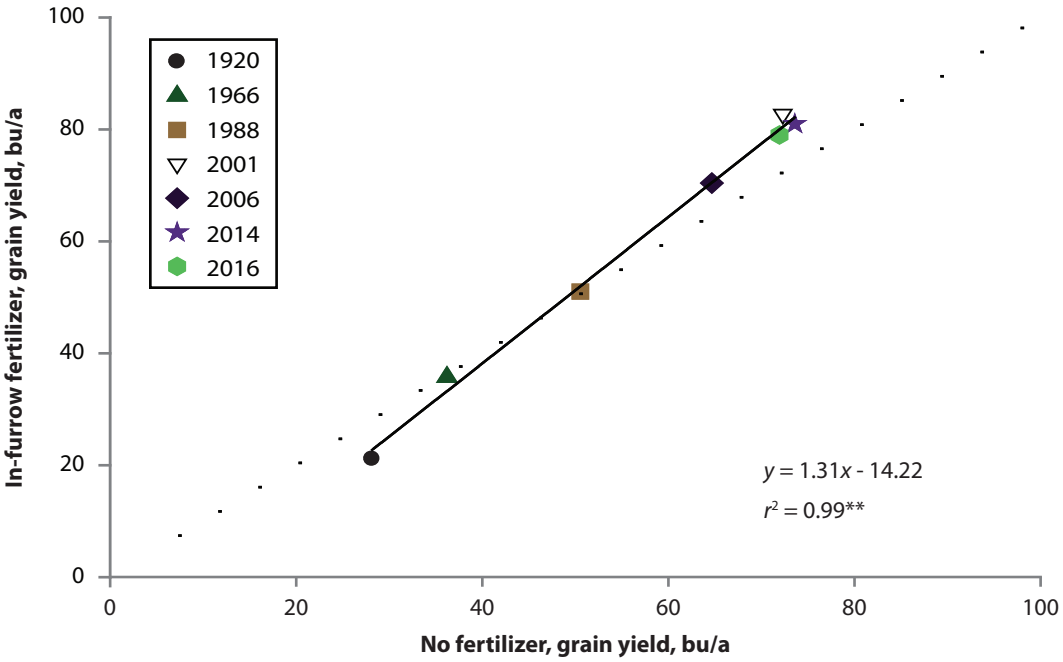

Figure 5. Correlations among grain yield and two fertilization programs during the growing season 2016–2017.