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J. A. Romero Soler
Kansas State University, jorgeromero@k-state.edu

L. O. Pradella
Kansas State University, pradella@k-state.edu

N. Giordano
Kansas State University, ngiordano@k-state.edu

See next page for additional authors

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Authors

J. A. Romero Soler, L. O. Pradella, N. Giordano, G. Cruppe, and R. P. Lollato

Does Winter Wheat Yield Response to Fungicide Application Depend on Nitrogen Management?

J.A. Romero Soler, L.O. Pradella, N. Giordano, G. Cruppe,[1] and R.P. Lollato

Summary

Nitrogen and fungicide are among the more important management tools to increase wheat (*Triticum aestivum* L.) grain yield in Kansas. However, there is limited information on whether hard red winter wheat grain yield is impacted by the interaction of nitrogen rates and foliar fungicide application. Thus, our objective was to evaluate the effects of different N rates with or without a fungicide application at Feekes 10.5 on grain yield of two winter wheat genotypes with contrasting disease resistances to leaf and stripe rust. Eleven field experiments were established across Kansas using a factorial structure of two fungicide management options (either no fungicide or 13 fl oz of Nexicor per acre), five N rates (0, 30, 60, 90, and 120 pounds of N per acre), and two genotypes (Larry and Zenda) in a split-split plot design during the 2021–2022 growing season. There was a significant interaction between genotype and environment where Larry out-yielded Zenda in anywhere from 3.1 to 15 bu/a. There was a significant interaction between N rate and environment, likely due to the initial soil NO_3-N and yield potential, as grain yield ranged from less than 34 to more than 81 bu/a. Increases in fractions of canopy cover in response to N fertilization and fungicide application explained about 29% and 15% of the increases in grain yield, respectively. There was a slightly greater crop yield response to foliar fungicide application as the N supply increased, from a nearly null difference at low N supply to as much as 5.9% for total N supply greater than 160.7 lb of N/a. In dry conditions with minimal disease incidence, winter wheat response to N availability differed in each environment, but there was only a marginal response to foliar fungicide.

Introduction

There is a large yield gap for winter wheat in Kansas, where the current farmer yields are considerably lower than their attainable potential (Patrignani et al., 2014; Lollato et al, 2017). Within this context, in-season management decisions can largely improve grain yields, narrowing the yield gap (Jaenisch et al., 2019, 2022; de Oliveira Silva et al., 2021, 2022). Among the many practices that growers can manage, nitrogen management and foliar fungicide applications seem to be the largest drivers of wheat yield in this region (Cruppe et al., 2017, 2022; Jaenisch et al., 2021; Lollato et al., 2019a; Munaro et al., 2020). Thus, more research is needed on agronomic management of nitrogen, fungicide, and potentially of their interaction to increase winter wheat yield in the region.

[1] Department of Plant Pathology, College of Agriculture, Kansas State University.

Some evidence suggested an interaction between N management and foliar fungicide application in other regions and for other wheat classes (Brinkman et al., 2014). Nitrogen can increase disease pressure by promoting lush growth, which creates a moist microclimate within the canopy and keeps leaves green longer. (Salgado et al., 2017). Likewise, with applications of foliar fungicide, the crop may have higher yield potential, and N requirements are linked to the crop's yield potential (Salgado et al., 2017; Lollato et al., 2019b, 2021).

Although this information on N × fungicide interactions is available in other regions, there is limited information on whether hard red winter wheat yield is impacted by this interaction in the U.S. central Great Plains region. Therefore, our objectives were to evaluate the effects of different N rates with or without a foliar fungicide application at heading on the grain yield of two winter wheat genotypes with contrasting disease resistances to leaf and stripe rust.

Procedures

This study was conducted at eleven rainfed locations across the state of Kansas during the 2021-2022 winter wheat growing season (Ashland Bottoms, Belleville after fallow; Belleville after soybeans; Great Bend, Hays, and Hutchinson with sowing dates around the early, optimum, and late side of the sowing window; and Leoti, Manhattan, and Solomon). Sowing dates for these locations are provided in Table 1.

The field experiment was established using a factorial structure arranged in a split-split plot design, where the fungicide application constituted the whole plot, N rates the sub-plot, and the genotype constituted the sub-sub-plot. The fungicide management was either no fungicide or 13 oz of Nexicor per acre at heading; the five nitrogen rates were 0, 30, 60, 90, and 120 pounds of N per acre; and the two winter wheat varieties used across locations were Larry (susceptible to leaf rust) and Zenda (susceptible to stripe rust).

Winter wheat varieties were sown at 90 pounds of seeds per acre, in combination with 50 pounds of diammonium phosphate applied in furrow at sowing. Nitrogen was applied as urea (46-0-0) by hand broadcast at Feekes 3, and fungicide was applied using flat fan nozzles mounted on a CO_2 backpack sprayer at Feekes 10.5. The fields had adequate weed control using commercially available herbicides to ensure weeds were not a limiting factor. Plots were harvested using a Massey Ferguson 8 XP small plot combine.

Soil samples were collected at each location before sowing from 0 to 6 in. and from 6 to 18 in., depths (Table 1). For each depth, soil fertility and texture were analyzed. Downward facing images were collected at a height of 5 feet above the ground through the season at Feekes 3, 6, 10.5, 11, and 11.4, and the fraction of green canopy cover was estimated with the Canopeo app (Pratignani and Ochsner, 2015). Delta (changes) in yield and delta in canopy cover were calculated based on all possible comparisons between genotype, environment, and fungicide management. The associations were analyzed with linear and non-linear regressions. Plots were 6 × 30 ft, and yield was measured by combine harvesting the entire experimental unit at maturity. Four-way ANOVA evaluated the main effects of N rate, fungicide, genotype, and environment, as well as their interactions.

Results

Genotype by Location Interaction

A significant interaction between genotype and environment suggested that the yield differences among genotypes depended on the environment (Table 2). Grain yield ranged from 30.75 to 90.31 bu/a, and the variety Larry out-yielded Zenda from 1.64 to 12.64 bu/a in seven locations. There was no difference between genotypes in the remaining four locations.

Nitrogen Rate by Location

There was a significant interaction between N rate and environment, likely due to the different initial soil NO_3-N contents and yield potential (Figure 1). Mean grain yield ranged from less than 34.1 bu/a in Manhattan to more than 83 bu/a in Belleville. Grain yield increased with increases in N rate in Hays, Ashland Bottoms, Belleville, and Manhattan. It was neutral in Hutchinson (with an early, optimum, and late planting date), Leoti, Great Bend, and Solomon. Grain yield also decreased with increases of N rate in Belleville with an optimum planting date.

Nitrogen by Fungicide

There was a trend of slightly greater crop yield response to foliar fungicide application as N supply increased (Figure 2), from a nearly null difference at low N supply to as much as 5.9% for total N supply greater than 160.7 lb/a.

Simultaneous Modulation of Green Canopy Cover and Grain Yield

Increases in green canopy coverage in response to N fertilization explained about 29% of the increases in grain yield, with steeper increases at low levels (Figure 3a). Differences in green canopy cover due to foliar fungicide application explained about 15% of the differences in grain yield (Figure 3b). Negative values in Figure 3b may be functions of the dry environments evaluated, and may reflect the environment-specific impacts of foliar fungicides.

Preliminary Conclusions

In a dry growing season, with minimal disease incidence, winter wheat grain yield responded to genotype and to N availability differently in each environment, and showed a global response to foliar fungicide. Grain yield responses to nitrogen and fungicide additions were partially explained by greater canopy cover at anthesis and the soft dough stage of grain development, respectively. We note, however, that foliar fungicide decreased grain yield in some of these dry environments. A continuation of this research should explore responses in more moist years where increased disease pressure may result in interaction among the studied factors.

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Table 1. Initial soil fertility measured at winter wheat sowing during the 2021–2022 growing season for eleven environments in Kansas

Location	Sowing date	Depth	pH	NO_3-N	P-M	K	S	OM	Sand	Silt	Clay
		in.		ppm				%			
Ashland Bottoms	10/12/2021	0-6	5.80	26.7	54.6	256	8.2	1.7	38	54	8
		6-18	7.20	5.6	31.2	156	2.3	0.8	35	53	12
Belleville, O	10/7/2021	0-6	4.9	41.8	56.5	409	8.1	2.7	16	52	32
		6-18	6.1	25.1	15.8	484.8	5.4	2.3	18	42	40
Belleville	10/7/2021	0-6	5.1	17.5	75.5	571.9	6.8	2.7	20	56	24
		6-18	6	8.6	57.1	730	5.4	2.8	10	54	36
Great Bend	10/20/2021	0-6	5.7	21.9	164.1	618.9	8.6	1.9	20	54	26
		6-18	7.2	12.9	57	557.9	9.4	1.3	20	40	40
Hays		0-6	6	26.4	76.4	709.3	5.7	1.8	18	52	30
	9/28/2021	6-18	6.4	18.7	45.5	614.2	4.7	2	22	42	36
Hutchinson, E	9/21/2021	0-6	5.4	47	61.2	324.5	8.7	2.5	28	48	24
		6-18	7	43.5	36.1	295.9	8.4	2.7	34	39	27
Hutchinson, L	10/21/2021	0-6	5.6	34.5	84.6	434.7	8	3.3	34	38	28
		6-18	5.9	21.2	51.6	386	6.4	2.3	26	44	30
Hutchinson, O	8/8/2021	0-6	6.7	37.7	46.9	214	7.1	1.6	38	42	20
		6-18	7.5	34.4	24.4	216.6	5.7	1.7	36	40	24
Leoti	9/25/2021	0-6	6.8	28.8	74.7	692.3	6.8	1.7	26	46	28
		6-18	7.4	20.9	32.7	677.3	6.1	1.8	26	43	31
Manhattan	10/18/2021	0-6	6.6	10.4	23.1	243.2	3.5	2.3	22	50	28
		6-18	7.2	7.5	13.4	260.3	4	3	22	46	32
Solomon	10/21/2021	0-6	7.4	11.8	42.8	349.8	4.7	2.9	20	44	36
		6-18	7.2	9.8	18.5	325.5	4.5	2.5	20	41	39

O = optimum. E = early. L = late.

Table 2. Grain yield of two winter wheat genotypes at eleven locations in Kansas during the 2021–2022 growing season

	Genotype		
	Larry	Zenda	Mean
Location	Grain yield, bu/a		
Ashland Bottoms	57.04 a	55.4 a	56.22
Belleville, O	90.31 a	78.72 b	84.51
Belleville	84.66 a	72.04 b	78.35
Great Bend	38.77 a	34.61 b	36.69
Hays	56.89 a	50.06 b	53.47
Hutchinson, E	54.51 a	46.04 a	50.28
Hutchinson, L	34.31 a	30.75 b	32.53
Hutchinson, O	57.93 a	52.58 a	55.25
Leoti	59.56 a	44.56 b	52.06
Manhattan	58.22 a	45.9 b	52.06
Solomon	40.85 a	39.66 a	40.25

Means of each variety followed by the same letter are not statistically different at $P < 0.001$.
O = optimum. E = early. L = late.

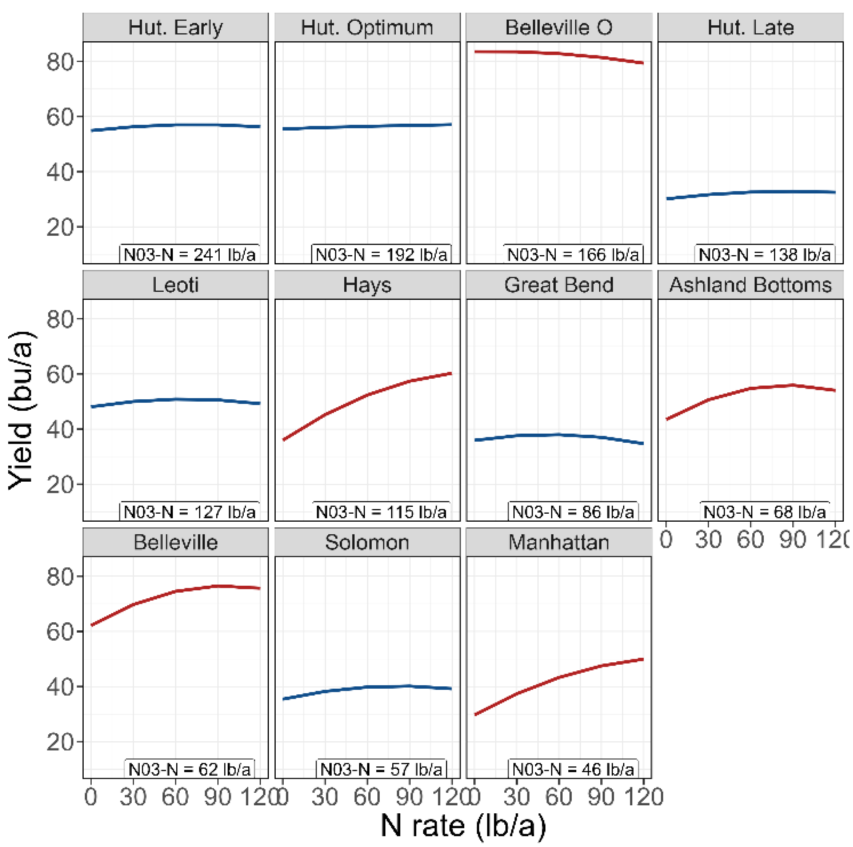

Figure 1. Winter wheat grain yield as function of nitrogen rate and its interactions with environment during the 2021–2022 growing season in 11 locations across Kansas. Initial soil NO_3-N contents for each location are presented in the lower panels. Red lines indicate significant relationship while blue lines indicate no significant relationship.

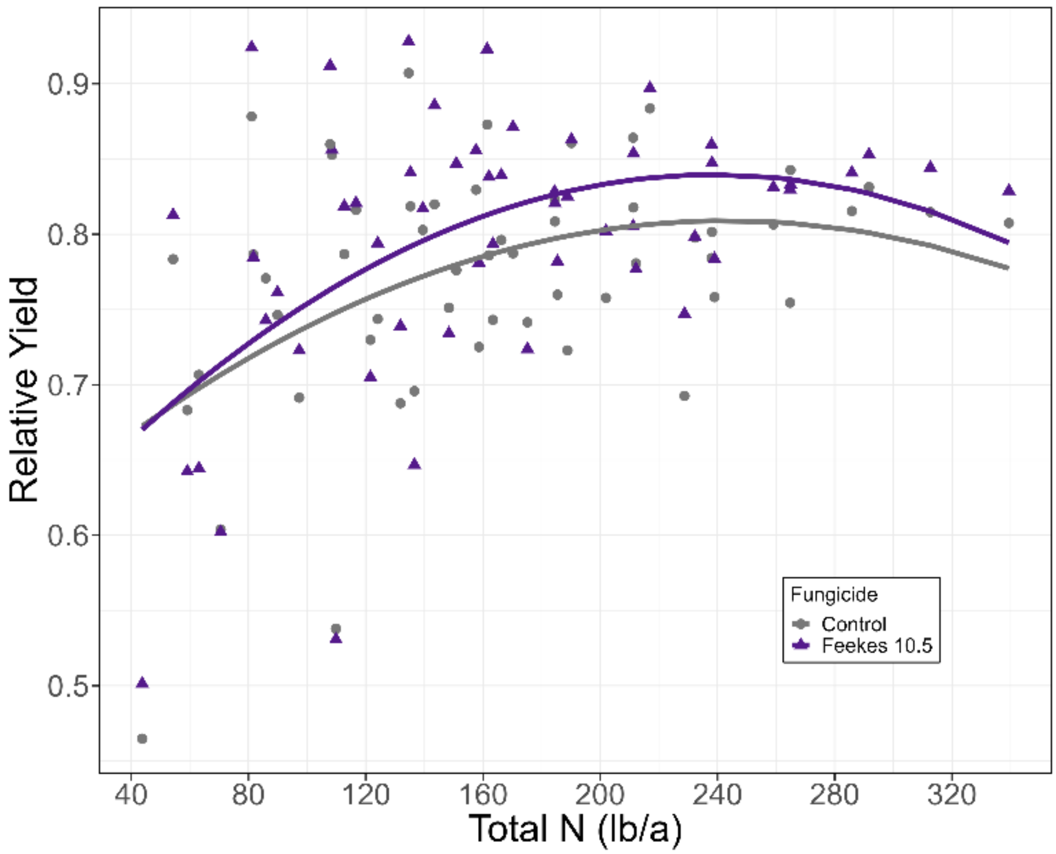

Figure 2. Relative wheat grain yield in response to total nitrogen available (soil NO_3-N at sowing in the top 18-in. profile plus applied N rate) for crops with (purple) and without (grey) foliar fungicide applied at Feekes 10.5 during the 2021–2022 growing season in Kansas.

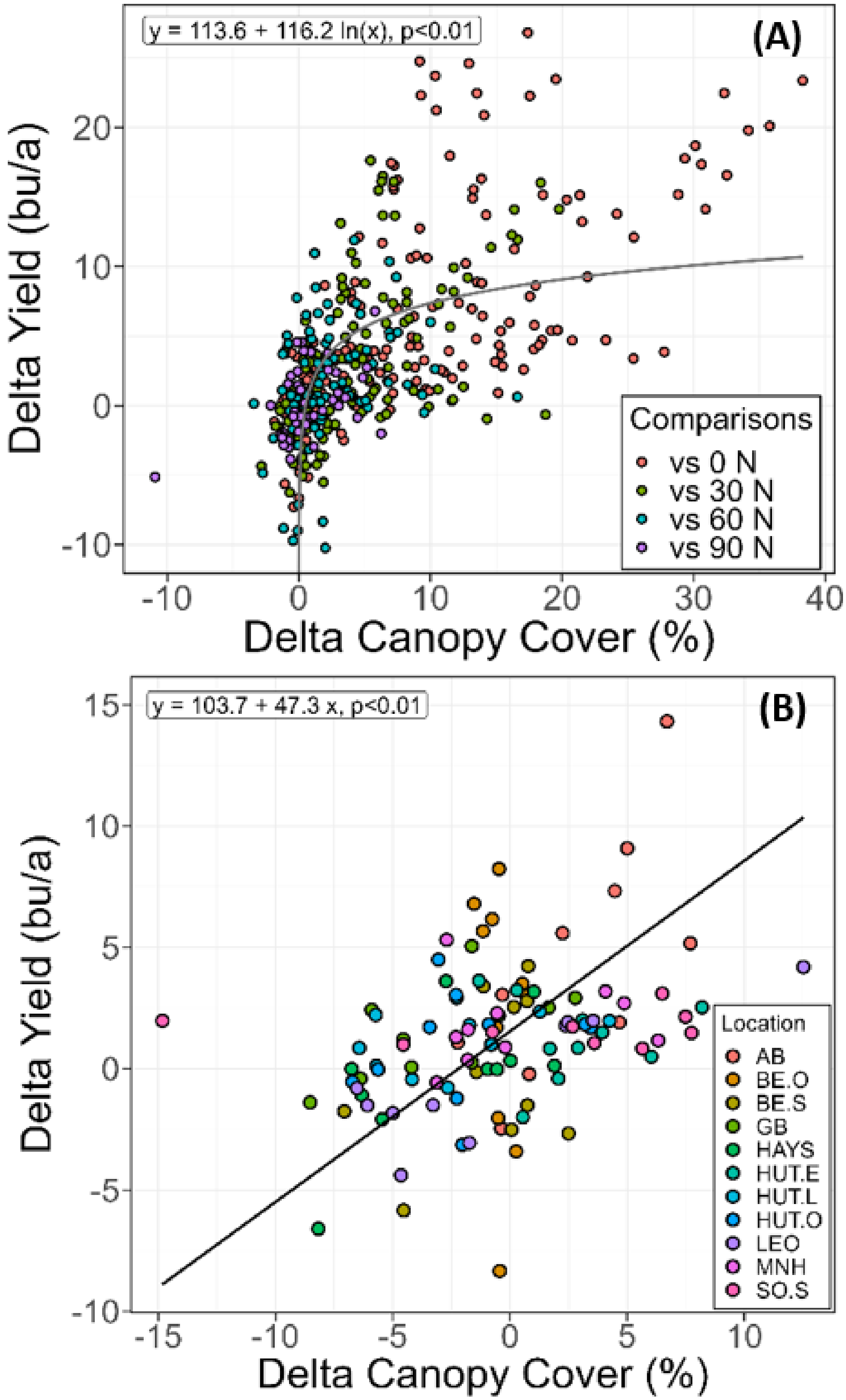

Figure 3. (a) Relation between winter wheat delta canopy cover at Feekes 10.5 and delta yield for all possible comparisons among location, fungicide management, and genotype as function of N addition. (b) Relation between delta canopy cover at Feekes 11 and delta grain yield for all possible comparisons within the location, nitrogen rate, and genotype as function of foliar fungicide application at Feekes 10.5 during the 2021–2022 growing season in Kansas.