Final-Year Report

Balanced Nutrition and Crop Production Practices for Closing Sorghum Yield Gaps

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Summary

In order to study how diverse cropping system approaches influence grain sorghum productivity, field experiments were conducted in Topeka, KS at the Kansas River Valley Experiment Field, and in Ottawa, KS at the East Central Kansas Experiment Field. The primary objective of this study is to understand how to close yield gaps between the current on-farm yields and the maximum attainable yields. The factors that were tested include narrow row spacing; high and low plant population; balanced nutrition practices, including various timings of nitrogen, phosphorus, and potassium (N-P-K) and micronutrient applications of iron and zinc (Fe, and Zn); crop protection with fungicide and insecticide applications; plant growth regulator effects; and the use of precision Ag technology for maximizing yields, including a GreenSeeker meter (Trimble Navigation, Westminster, CO) for more precisely determining N needs for sorghum. Grain sorghum yields ranged from 149 to 166 bu/a in Topeka, KS under irrigation, and from 78 to 100 bu/a in Ottawa, KS under dryland conditions. At Ottawa, yield potential was limited by precipitation, 10.8 inch. Still, sorghum yield gap between the highest (treatment #2, "kitchen sink" but with low seeding rate) and lowest (treatment #10, "standard practice") was 22 bushels per acre. The production practices that produced the highest yields varied between the two locations.

Keywords: sorghum, nutrient uptake, production practices

Introduction

Low productivity is one of the biggest problems in grain sorghum production in Kansas. This productivity issue stems from a combination of management practices, genetics and varied environmental conditions. Understanding best management practices and using better genotypes are essential to closing yield gaps between current on-farm yields and maximum attainable yield. This project seeks to take into account the multitude of factors that influence farmers' decisions in an effort to achieve higher yields through best management practices.

Procedures

At both locations, Topeka, KS (irrigated), and Ottawa, KS (dryland), the plots were set up in a randomized complete block design with 5 replications and 11 treatments in each replication (Table 1). In Topeka, KS the plots were 10 ft x 70 ft. In Ottawa, KS the plots were 10 ft x 50 ft, or 0.01 acres. The hybrids used were DKS 53-67 for Topeka, and DKS 44-20 for Ottawa, these were chosen based on the Kansas Performance Tests for their suitability to each specific site.

Table 1. Description of sorghum treatments for all sites.

	Treatments										
	1	2	3	4	5	6	7	8	9	10	11
Seeding rate	Optimum	Normal	Optimum	Optimum	Optimum	Optimum	Optimum	Optimum	Optimum	Normal	Optimum
Row Spacing	15 in.	15 in.	30 in.	15 in.	15 in.	15 in.	15 in.	15 in.	15 in.	30 in.	15 in.
N Program	GS	GS	GS	Standard	GS	GS	GS	GS	GS	Standard	GS
Fungicide/ insecticide	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes
Micronutrients	Fe, Zn	Fe, Zn	Fe, Zn	Fe, Zn	Fe, Zn	None	Fe, Zn	Fe, Zn	Fe, Zn	None	Fe, Zn
Plant growth regulator	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes
Starter fertilizer	NPKSZn	NPKSZn	NPKSZn	NPKSZn	NPKSZn	NPKSZn	NPKSZn	NP	NPKSZn	NP	NPKSZn
Chloride	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes
GreenSeeker + N	No	No	No	No	No	No	No	No	No	No	Yes

Optimum seeding rate = 90,000 plants/acre; Normal = 45,000 plants/acre; 15 in. = narrow row spacing; 30 in. = wide row spacing; GS = GreenSeeker meter (Trimble Navigation, Westminster, CO); Standard = conventional N application (without precision ag technology); Fe = Iron; Zn = Zinc; N = Nitrogen; P = Phosphorous; K = Potassium; S = Sulfer.

Soil Characterization and Phenological Information for Both Sites

Soil samples were collected prior to planting and fertilization. The Ottawa site had low values of P, but a slightly higher organic matter content than Topeka. Both sites were planted the same date with hybrids of similar maturity groups.

Table 2. Soil characterization before planting

Soil Parameters	**Topeka**		**Ottawa**	
	0-6”	**6-24”**	**0-6”**	**6-24”**
pH (units)	6.9	6.9	6.3	6.5
Mehlich P (ppm)	67.1	40.2	12.1	4.6
K (ppm)	395	287.9	128.1	248.9
CEC (meq/100 g)	17.9	19.4	20.5	28.4
OM (%)	2.86	2.26	3.15	2.71

Table 3. Grain sorghum phenology at Ottawa and Topeka sites

Plant Phenology	**Topeka**	**Ottawa**
Planting date	June 9	June 9
V-5 Growth stage	July 7	July 7
Flowering	August 10	August 12
Harvest	September 30	October 12

Stand Counts

The plant population after emergence was measured for all the plots at both sites. The target population for the treatments at "Normal" seeding rate was 45,000 plants per acre (commonly used by producers). For the "Optimum" seeding rate, the target population was 90,000 plants per acre.

Table 4. Stand counts at each treatment and for each site

Treatments	Topeka	Ottawa
	Plants in 17.5 ft row-length	
1	92	88
2	48	46
3	88	90
4	92	90
5	95	90
6	92	89
7	91	90
8	92	91
9	92	91
10	49	47
11	92	88
C.V.	3.1	3.7

C.V. = Coefficient of Variation (%)

Seasonal precipitation and irrigation for all sites

At the Kansas River Valley Experiment Field in Topeka, KS the seasonal rainfall totaled 16.2 inches with an additional 4.2 inches of irrigation applied. At the East Central Kansas Experiment Field in Ottawa, KS there was a total of 10.9 inches of rainfall during the growing season.

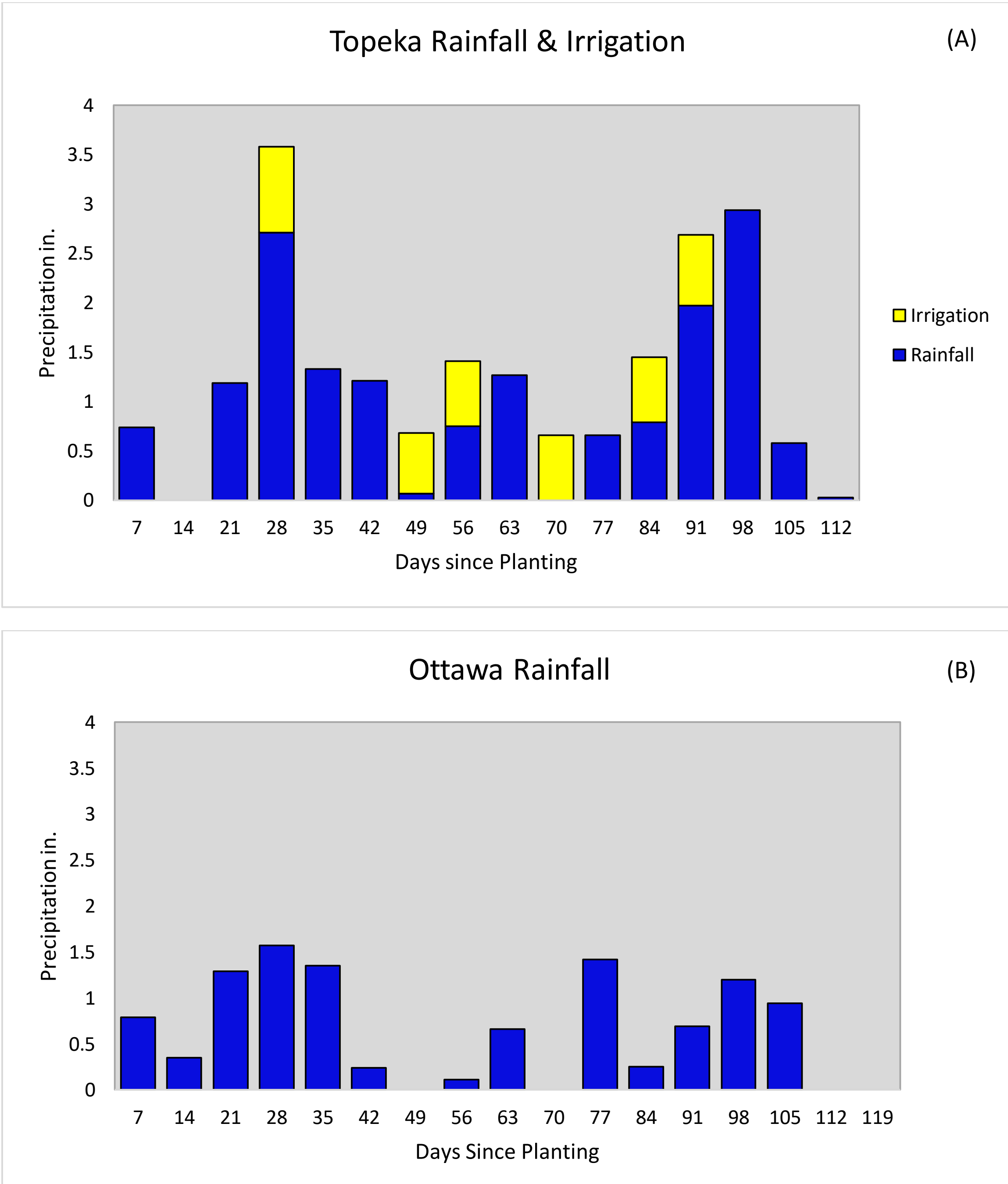

Figure 1. (a) Seasonal precipitation in Topeka, KS. (b) Seasonal precipitation in Ottawa, KS.

Results

Grain sorghum yields portrayed a contrasting picture at the evaluated sites. In Topeka under irrigation, sorghum yields ranged from 149 to 166 bu/a (Fig. 2). At Ottawa under dryland, sorghum yields ranged from 78 to 100 bu/a (Fig. 3). In Topeka, the higher yield potentials were related to the irrigation scheduling system, with the highest yields being achieved from treatments 4 and 10. The yield gaps between the highest yielding and the lowest was 17 bu/a, and the two highest yielding treatments were significantly different than the rest. This yield difference can be partially explained by the fertilizer N program employed. With the GreenSeeker technology and in-season N application there was damage done to the green leaves on the plants, which was counter-productive by inhibiting photosynthesis and limiting yields (producing rapid senescence). The yield gaps across all the other treatments were minimized with the addition of adequate irrigation.

The yields in Ottawa were quite different with the greatest yield gap being 22 bu/a between the highest, treatment #2, and the lowest, treatment #10 (Fig. 3). The yields were limited overall by the low precipitation of only 10.8 inches (Fig. 1) during the growing season. Treatment #2 included a high input, narrow row spacing except at a low seeding rate, and treatment #10 was a low input treatment with traditional 30 inch row spacing and low seeding rate. This site demonstrated how narrowing the row spacing and utilization of improved management practices can maximize the yields even in a low-yielding, water-limiting environment. Regardless of the treatment evaluated in both sites, the yield per plant was highly related to the grain number per head (Fig. 4). By focusing on this yield component, such as how management factors affect the grain number per head, the variation in yields across environments can be better explained.

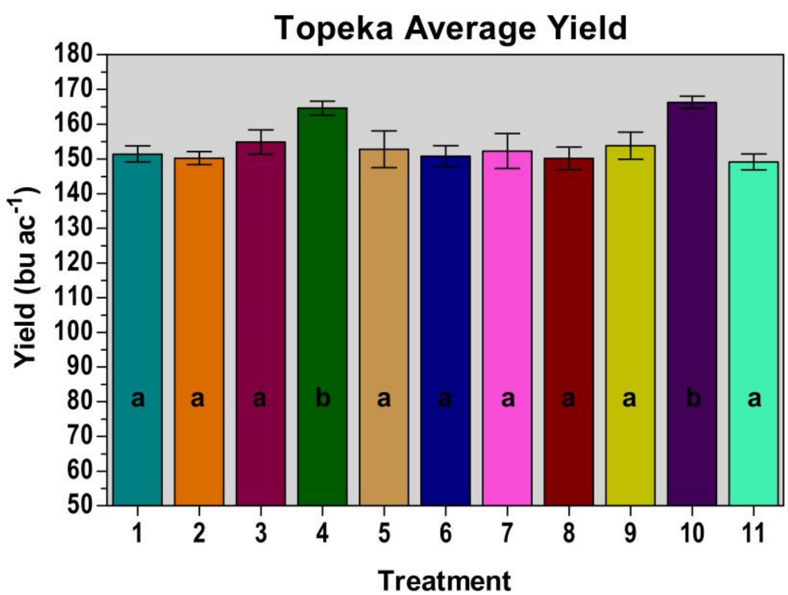

Figure 2. Sorghum grain yield under diverse crop production practices at the Topeka unit of the Kansas River Valley Experiment Field. See Table 1 for treatment details. Different letter shows statistical significance (P<0.05).

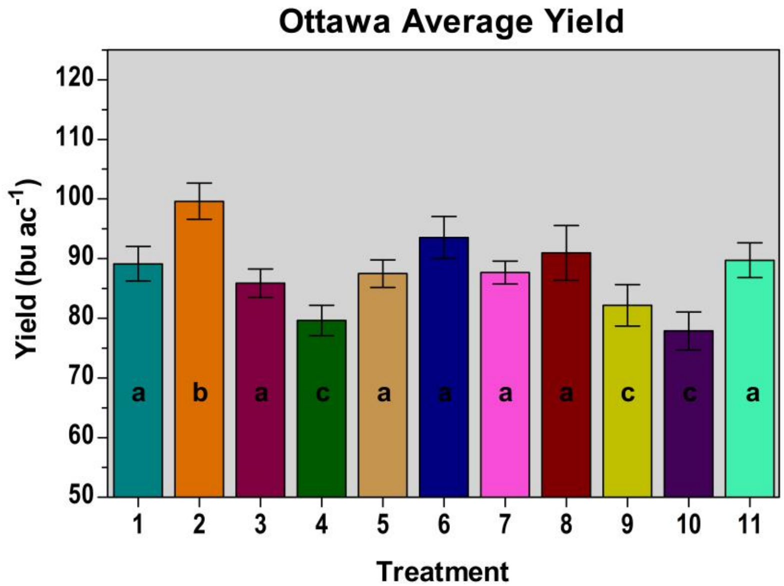

Figure 3. Sorghum grain yield under diverse crop production practices at the Ottawa site of East Central Kansas. See Table 1 for treatment details. Different letter shows statistical significance ($P<0.05$).

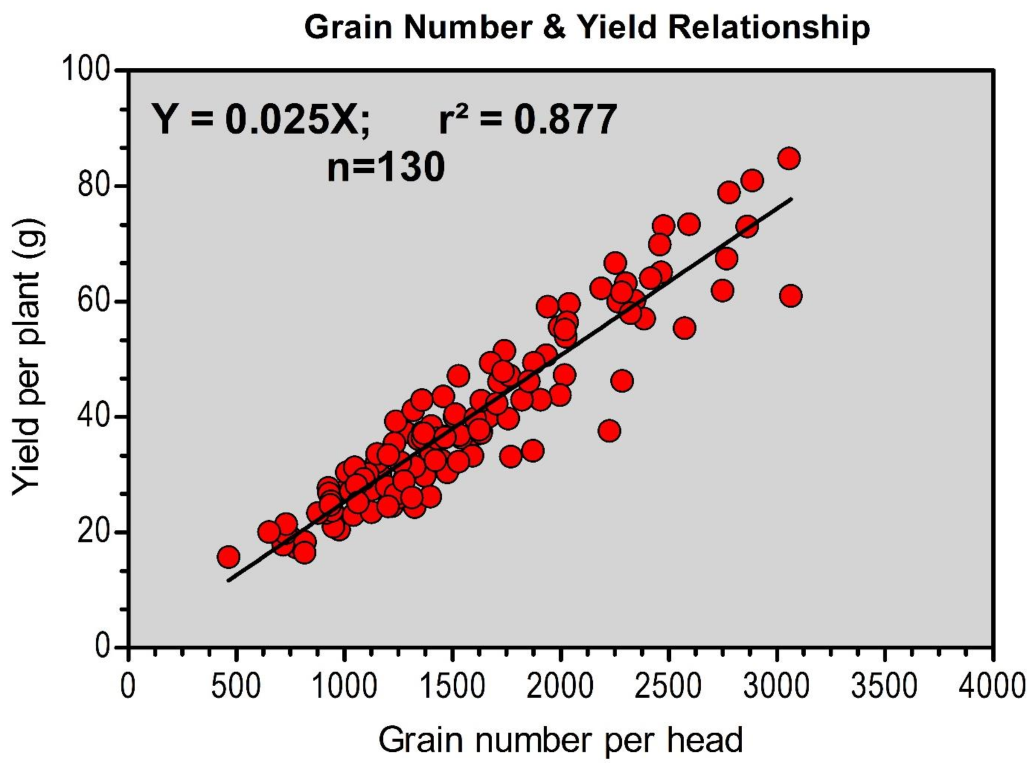

Figure 4. Grain number per head vs. yield per plant relationship for both sites for the 2014-15-16 growing seasons, regardless of treatment.

Total Nutrient Uptake – Analysis by Yield Environment

End-season total nutrient uptake was similar at the plant-level but the total nutrient content was greater under the high-yielding sites (Rossville, KS and Topeka, KS). Overall environmental conditions for the classified as high-yielding and low-yielding environments is highlighted in Figure 5. Environments with final yield below 100 bu/acre were classified as low-yielding and with yields values above 100 bu/acre were identified as high-yielding sites.

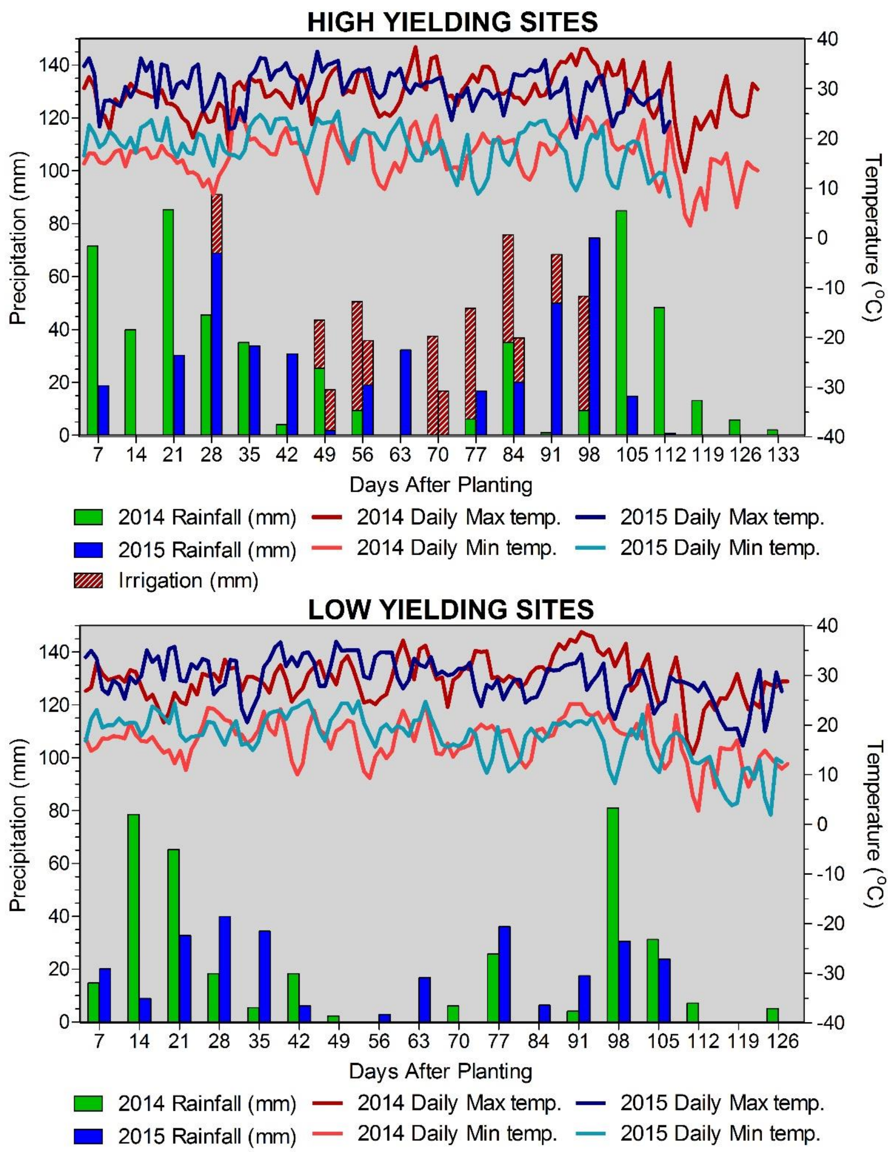

Figure 5. Measured weather from the Kansas Mesonet, including daily maximum and minimum temperatures (°C), and weekly precipitation and irrigation (mm) in the high and low yielding environments (high yielding sites include Rossville, KS and Topeka, and low yielding sites include Ottawa).

Yield levels were influenced largely by seasonal weather and precipitation. Rossville, KS in 2014 received 522 mm of rainfall plus 223 mm of applied irrigation, while Ottawa, KS during the same year received only 363 mm of rainfall. In Topeka, the rainfall amounted to 412 mm with 106 mm of applied irrigation, and in Ottawa, KS 276 mm of rainfall was received (Figure 5). In 2014, the low-yielding environment (Ottawa, KS) experienced drought-stress prior to and during flowering (around 70 days after planting), which impacted the yields to a great extent. The same low-yielding environment also experienced low rainfall, however the precipitation was received in a more uniform and timely manner, which improved the mean yields from the previous year. The mean yield levels attained in the two high-yielding environments were 118 bu/acre in 2014 and 143 bu/acre.

Final plant biomass accumulation by plant fraction for each yield environment is depicted in Figure 6. Total plant biomass accumulation was greater for the high-yielding sites as compared with the low-yielding environments. The low yielding environment shows a higher portion of the total biomass accumulating in the stem, and the head portion of the total biomass levels off much more quickly than in the high yielding environments, which display a trend of continued accumulation until the end of the growing season.

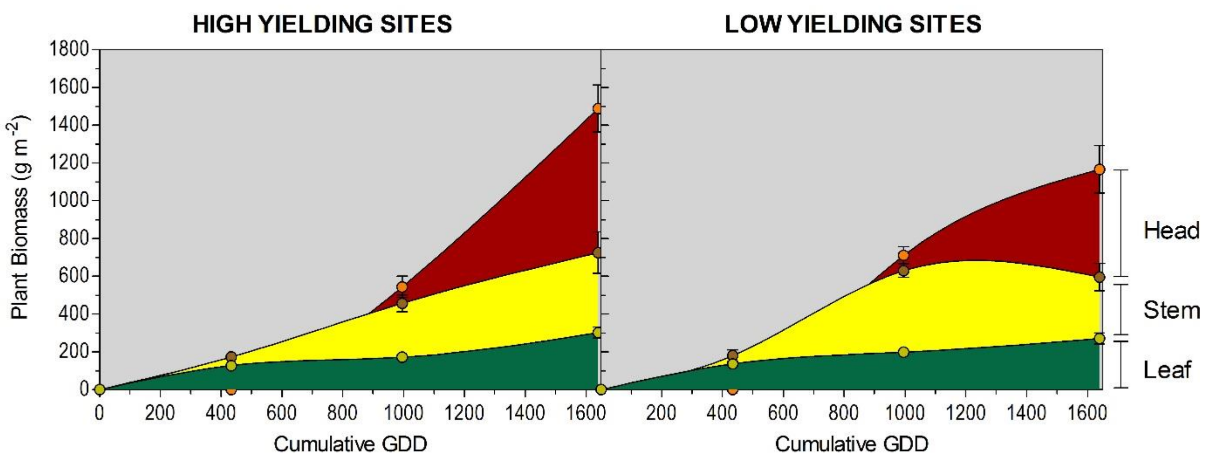

Figure 6. Plant biomass accumulation (g m^{-2}) by fraction (leaf- green, stem- yellow, head- red) for high yielding (>100 bu/acre) and low yielding (<100 bu/acre) environments (high yielding sites include Rossville, KS and Topeka, KS, and low yielding sites include Ottawa, KS).

In all the other nutrient uptake curves for N, P, K (Figure 7), and Fe, Zn (Figure 8), display greater differences between the high yielding and low yielding environments. The latter trend consistently shows that the plant nutrient content values for the high yielding environment were always higher than the averages from the low yielding environment. In Ottawa, KS during both years, the soil test P levels were extremely low, at or below the critical level, as defined by the Tri-State Fertilizer Recommendations. Due to these existing soil conditions, there is a striking difference in the P uptake curves (Figure 7 - middle panels) between the high yielding environments and the low yielding environments. This data indicates that the environment was always having a significant effect on the nutrient uptake processes and subsequently nutrient management practices. This also highlights the importance of soil testing regularly and applying adequate amounts of fertilizer according to the levels found in each particular soil region.

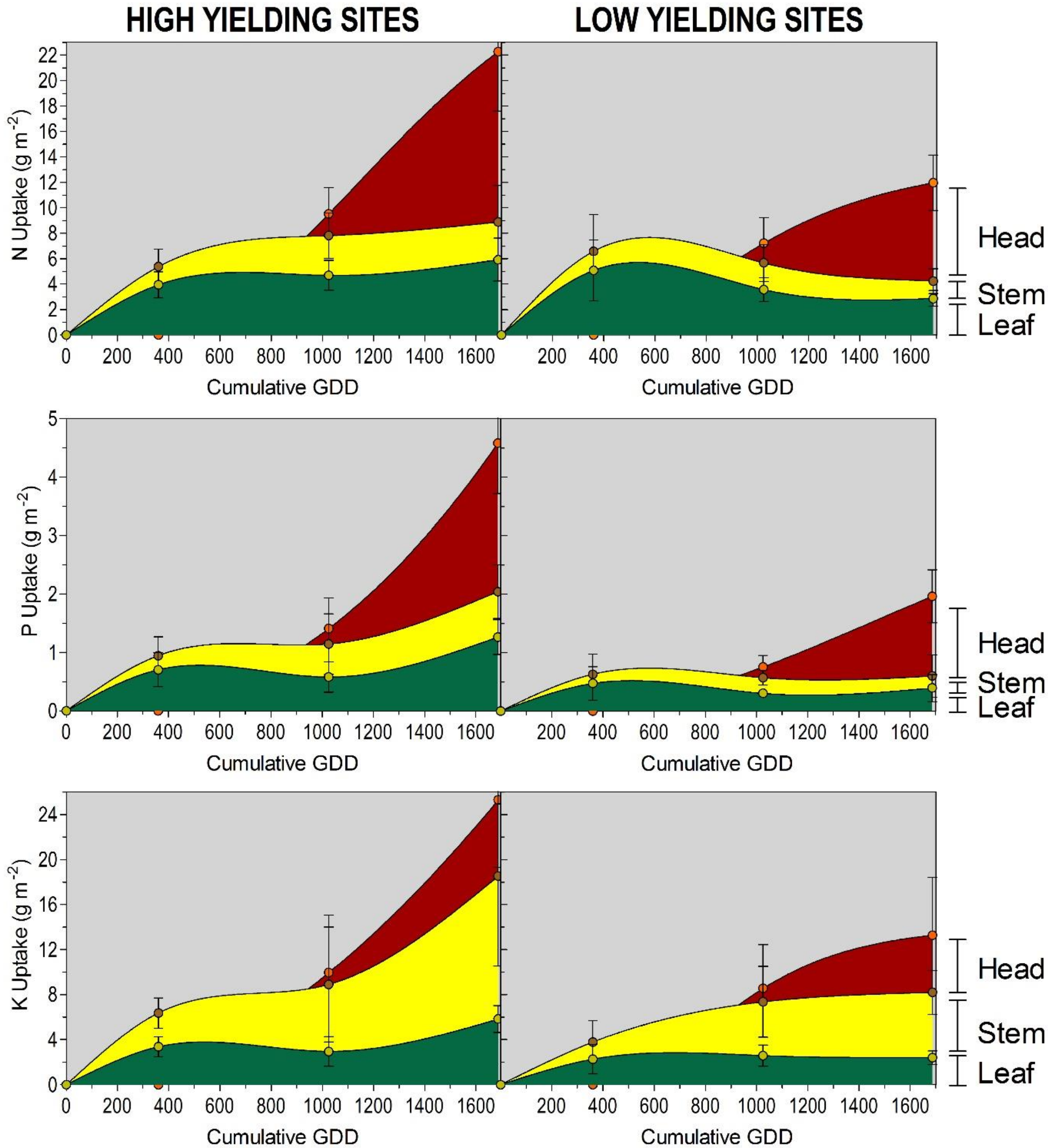

Figure 7. Grain sorghum nitrogen, phosphorous, and potassium nutrient accumulations (g m^{-2}) by fraction (leaf- green, stem- yellow, head- red) for high yielding (>100 bu/acre) and low yielding (<100 bu/acre) environments (high yielding sites include Rossville, KS and Topeka, KS, and low yielding sites include Ottawa, KS).

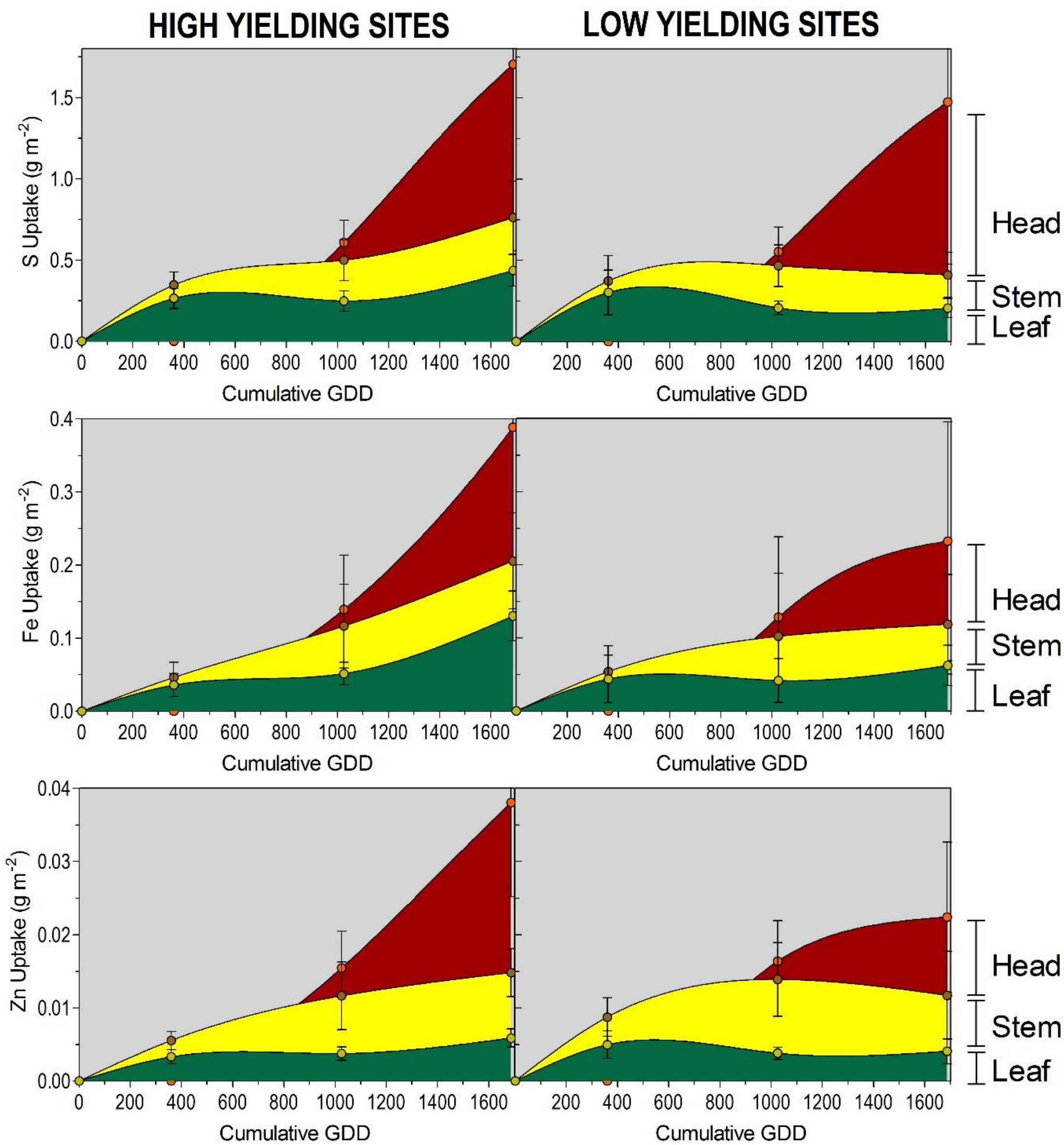

Figure 8. Grain sorghum sulfur, iron, and zinc nutrient accumulations (g m^{-2}) by fraction (leaf- green, stem- yellow, head- red) for high yielding (>100 bu/acre) and low yielding (<100 bu/acre) environments (high yielding sites include Rossville, KS and Topeka, KS, and low yielding sites include Ottawa, KS).

Conclusions

High yielding and low yielding environments displayed enormous differences between the nutrient uptake and partitioning levels in all nutrients examined (N, P, K, S, Fe, and Zn), except sulfur, in which no difference was seen in the uptake levels between different environments. Existing soil conditions, weather, and precipitation impacted the yields, and nutrients uptake values to a great extent, which highlights the need for crop production practices that are suited to a specific environment, rather than using standard practices for sorghum production across diverse environments.