NITROGEN FERTILIZER APPLICATION AND DEPTH OF MOIST SOIL AT PLANTING AFFECTED GRAIN SORGHUM YIELD

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ABSTRACT

The depth of moist soil before planting is critical for grain crop production in intensified dryland cropping systems. We investigated depth of moist soil at planting and nitrogen (N) fertilizer application rate effects on continuous grain sorghum yields on a Crete silt loam soil over 32-years in western Kansas. Treatments were four N rates (0, 20, 40 and 60 lb ac^{-1}) in a randomized complete blocks design with four replication and depth of moist soil at planting determined with Paul Brown moisture probe. Grain sorghum yield response to N application was -0.10, 14.4, 29.3, and 36.5 lb grain ac^{-1} for every lb N applied in very low yielding (VLY), low yielding (LY), high yielding (HY), and very high yielding (VHY) environments, respectively. Grain yield increased with depth of moist soil at planting for each N rate, with yield increases of 217 to 461 lb ac^{-1} per inch increase in depth of moist soil at planting for the unfertilized control through 60 lb N ac^{-1}. Regardless of yield environment, net returns were negative when depth of moist soil at planting was below 30 inches. This suggest continuous grain sorghum should not be planted when depth of moist soil is < 30 inches. Results of this 32-year study showed depth of moist soil at planting could be used to fine-tune sorghum N application rates.

INTRODUCTION

The increase in soil water storage due to adoption of conservation tillage has allowed cropping intensification (including continuous grain sorghum) in dryland systems in the central Great (Rosenzweig et al., 2018). Over 5.2 million acres of grain sorghum was produced annually from 2016 to 2020 in the United States, >50% of which was grown in Kansas (USDA NASS, 2021). Storage of moisture is critical to ensure profitable grain sorghum production in water-limited environments. In addition to moisture stress, soil nutrients particularly N availability affect sorghum production. Too much fertilizer could provide good vegetative growth, but, because of limited soil moisture, yield levels could be low. However, too little fertilizer may not use the stored moisture effectively and thus, would not optimize profitable yields. There are limited studies that have attempted to address effect of available soil water at planting and N fertilizer application on grain sorghum production in the semi-arid Great Plains. In dryland systems, measuring the depth to moist soil could provide a measure of water stored at crop planting. The depth of moist soil could be determined using the Paul Brown Moisture probe (Brown, 1960).

The amount of force required to push the Brown moisture probe into the soil is directly related to soil moisture content, with resistance increasing as the soil moisture content decreases. The objective of the current research was to determine if the depth of moist soil at planting measured with the Paul Brown probe could be used to make fertilizer application decisions.

MATERIALS AND METHODS

This study was conducted at Kansas State University Agricultural Research Center near Hays, KS between 1970 and 2002 under dryland reduced tillage operation system with annual cropping of sorghum. Treatments were four N rates (0, 20, 40 and 60 lb ac^{-1}) arranged in a randomized complete block design with four replications. Individual plot size was 40 ft. long × 12 ft wide. Tillage operations were accomplished with a V-blade or sweep plow to about 15 cm depth. Approximately two tillage operations were performed, one in the fall and another in late spring before sorghum planting. Nitrogen, as ammonium nitrate fertilizer was broadcast applied in the fall each year just prior to fall tillage to incorporate fertilizer. Soil test levels for available P were medium to high over the study period and exchangeable potassium (K) are inherently high in this soil, therefore, N was the only fertilizer applied over the 32-year study period. An objective of this study was to determine the influenced of depth of moist soil at planting on grain sorghum response to N fertilizer. The depth of moist soil was determined prior to sorghum planting in each year of the study using the Paul Brown probe (Brown, 1960). Briefly, depth of moist soil was determined by pushing a 0.4 inch diameter rod with a 0.5 inch ball bearing on the end into the soil. The depth to which the rod could be pushed was marked as the depth of moist soil **(**Brown, 1960). Six probe measurements were taken and averaged per plot and the depth of moist soil were converted to plant available water at planting (ASW) using conversion tables based on soil texture.

Grain sorghum was planted in late May through the second week in June and harvested in October. Grain sorghum was planted in 30-inch row spacing at 35,000 plants ac^{-1}. Grain sorghum hybrids used changed occasionally over the course of the study as seed company's replaced discontinued hybrids with newer, better-adapted hybrids. Weed control in grain sorghum was done with a pre-mixture of 25.3% of [alachlor, 2-chloro-2',6'-diethyl-N-(methoxymethyl) acetanilide] and 15.3% of [atrazine, 2-chloro-4-(ethylamino)-6-(isopropylamino) s-triazine]. Grain yields were determined by harvesting 5 ft × 40 ft long area of each plot with a plot combine harvester (Massey Ferguson, Duluth, GA). The net returns from N fertilizer were computed for each N application rate treatment as the difference between total revenue from grain sales and cost of production (including planting, harvesting, trucking and fertilizer application costs). The total revenue was calculated as the product of grain yield and grain price. Nitrogen fertilization costs included in the calculations were price of fertilizer and spreading costs taken from the Kansas Agricultural Statistics custom rates (https://www.nass.usda.gov/Statistics_by_State/Kansas/). The economic analysis was done excluding government payments and crop insurance.

Data analysis for grain yield and net returns from N fertilizer for the 32-years were done using the PROC MIXED procedure of SAS (SAS Institute, 2012). Descriptive statistics was conducted and based on the results, the data was group into very low yielding environments (VLY), low yielding environments (LY), high yielding environments (HY), and very high yielding environments (VHY). Yield response to N in these environments were regressed using PROC REG procedure of SAS. Nitrogen application rate, depth of moist soil, and their interaction effects on yield and net return was conducted using PROC MIXED procedure. Mean separation of treatment effect was conducted using Tukey's honest significant difference.

RESULTS AND DISCUSSION

Precipitation and Grain Yield

Growing season precipitation (May through September) varied significantly over the study period (data not show). Total average growing season precipitation over 32-years of the study was 15.5 inches. In general, the 1993, 1996 and 2001 growing seasons recorded the highest growing season precipitation amounts. The driest growing season was 1983, with total seasonal precipitation amount of 6.8 inches. In 15 of the 32-year study, the amount of precipitation received was equal or above the 30-year average.

Sorghum grain yield varied significantly over the 32-yr study for each N rate. In five of the 32-years, average yield was below 1133 lb ac^{-1}, significantly smaller than the average yield (VLY). Average yields in twelve years of the study were below the overall average but within the lower portion of the standard deviation (LY). In eleven of the 32-years, annual average yields were above the overall average but within the standard deviation (HY). In four of the 32-years, yields were significantly above the overall mean (VHY). Sorghum grain yield did not respond to N fertilizer in VLY environments. In the LY, HY, and VHY environments, sorghum yields responded positively to fertilizer application rate (Fig.1a). In the LY environment, grain yield increased by 14 lb ac^{-1} for each additional lb ac^{-1} N fertilizer applied. In the HY environment, yield increased by 29 lb ac^{-1} for each lb increase in N fertilizer. Similarly, in the VHY environment, yield increased by 37 lb ac^{-1} for a one lb ac^{-1} increase in N fertilizer (Fig. 1a). Available soil water at planting and in-season precipitation amounts differed significantly among yield environments (Fig.1b & c).

In-season precipitation was generally weak at explaining grain yield response to N fertilizer application rate. However, sorghum gain yields responded positively to ASW at planting, and explained 86 - 98 % of the variation in yield within each N application rate (Fig. 2). Sorghum grain yield increased by 217 lb ac^{-1} for an inch increase in ASW for the unfertilized control. Applying N fertilizer at 20 lb ac^{-1}, grain yield increased by 318 lb ac^{-1} for an inch increase in ASW at planting. Likewise, grain yield increased 317 and

461 lb ac^{-1} with the application of 40 and 60 lb N ac^{-1}, respectively, for an inch increase in ASW at planting (Fig. 2).

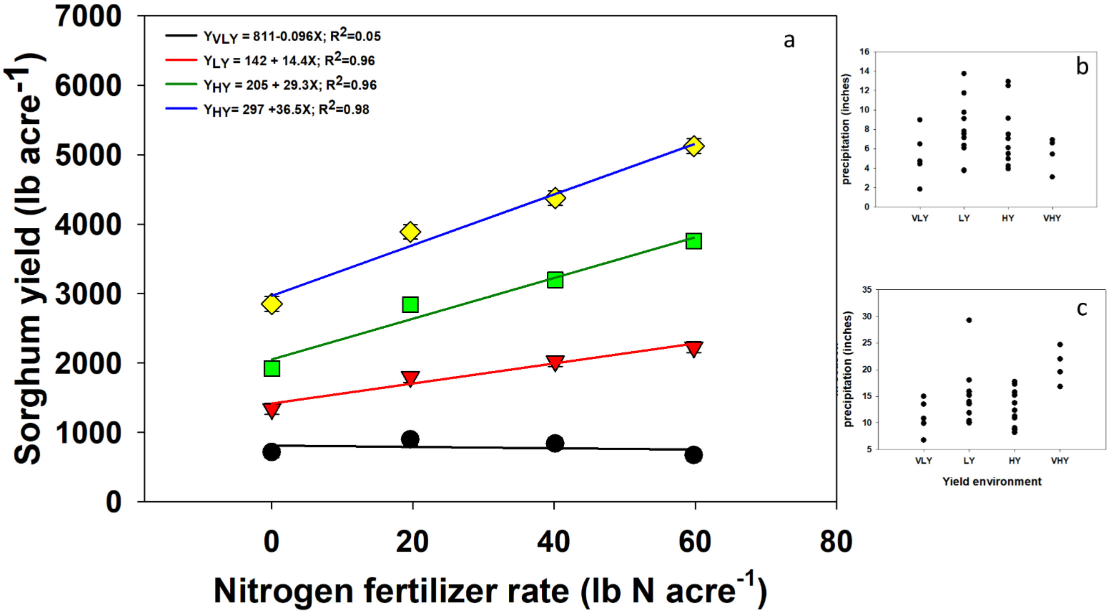

Fig.1. Nitrogen fertilizer rate and sorghum yield relations at four dryland yield environments [years with low yielding (VLY), low yielding (LY), high yielding (HY), and very high yielding (VHY)] and (b) off-season (fallow) precipitation, and (c) in-season precipitation amounts by yield environment from 1971-2002 near Hays, KS.

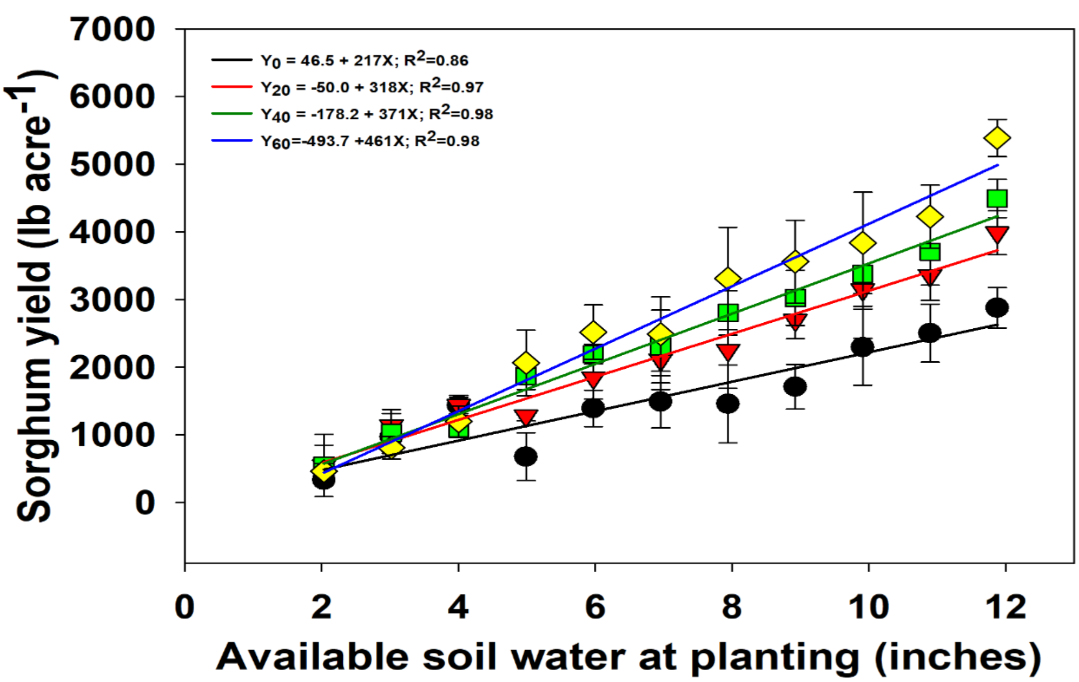

Fig. 2. Available soil water and sorghum yield relations in four N fertilizer amounts over the years from 1971-2002.

Net Return

Regardless of N fertilizer amount applied, net return for continuous sorghum production was negative for all environments when depth of moist soil at planting was below 30 inches. Irrespective of in-season precipitation, net return from N fertilizer application increased with depth of moist soil. For example, when in-season precipitation was < 16 inches, net return averaged $-200 to $-46 when depth of moist soil was ≤ 30 inches compared to net returns of $142 to $355 when depth of moist soil was 48 to 72 inches. In environments with > 16 inches in-season precipitation, net return to fertilizer application increased by $3.4 – $3.6 for each additional increase in depth of moist soil.

Conclusion

Grain sorghum response to N fertilizer application was highly dependent on yield environment. Available soil water at planting explained 86-98% of the variation in yield within N fertilizer rate. However, compared with only 4-18% with in-season precipitation explained only 4-18% of variability in yield with N rate. Net return with fertilizer application was negative for all environments when depth of moist soil at planting was less or equal to 30 inches. We concluded that the depth of moist soil at planting could be used to fine-tune continuous sorghum planting (do not plant sorghum when depth of moist soil < 30 inches) and N fertilizer requirements.

REFERENCES

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