Nitrogen Use Efficiency of Grain Sorghum Genotypes

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Introduction

- Grain sorghum [*Sorghum bicolor* (L.) Moench] is an important crop in the semi-arid regions of Africa, Asia and United States. Productivity of grain sorghum is limited by soil fertility, especially nitrogen fertilizer. Nitrogen is an expensive input both in developed and developing countries. Genotypes vary in response to nitrogen fertilizer. Grain yield of sorghum can be dependent on nitrogen response. However, the information on nitrogen use efficiency (NUE) of genotypes is limited.

Objectives

- To determine the response of sorghum genotypes (hybrids and inbred lines) to nitrogen fertilizer; and
- Quantify genotypic difference in NUE.

Materials and Methods

- Field experiments were conducted in three locations (Hays, Ottawa and Manhattan, Kansas) in 2010.
- The experimental design was a randomized complete block design in a split plot arrangement with four replications. The main plots were assigned to three N regimes: control (no inorganic N), half recommended rate (45 kg N ha^{-1}) and optimum recommended rate (90 kg N ha^{-1}).The subplots were assigned to six hybrids and six inbred lines. Plot size was 6.1 m x 3.0 m. There were 4 rows per plot spaced at 76 cm.
- Soil samples at a depth of 0-15 cm and 0-60 cm were taken before planting. Planting was done in May and June across all the locations and nitrogen fertilizer (urea ,46%) was applied at emergence.
- Data on biomass was measured at three growth stages (vegetative, flowering and maturity) and grain yield was measured at maturity.
- Nitrogen concentration in the grain and components of NUE (uptake, utilization, N recovery, nitrogen harvest index (NHI) and total NUE) were determined at Ottawa and Manhattan.
- N Uptake efficiency = N uptake / Total N supply
- N Utilization efficiency = Grain weight / Total N uptake
- Percent N recovery = [uptake (fertilized plot) – N uptake (un-fertilized plot)] / [N applied] * 100
- N efficiency of use = Grain weight / Total N supply
- Nitrogen harvest index (NHI) = Grain N / N uptake
- Data was analyzed using SAS version 9.1 with GLM at an alpha level of 0.05.For significant variables, mean separation was accomplished using LSD test

Table1: Chemical characteristics of soils at experimental sites.

Location	pH	Mehlich3 P	k	OM	Cl$^-$	S	NH_4^+ N	NO_3^- N
		ppm	ppm	%	ppm	ppm	ppm	ppm
Hays	6.0	61.4	663.5	1.8	3.4	3.9	2.3	7.6
Ottawa	6.2	11.2	122.3	2.8	14.4	5.0	3.7	2.2
Manhattan (Unit 1)	6.2	42.1	270.3	1.2	10.0	4.2	1.9	6.0
Manhattan (Unit 7)	6.4	52.3	387.3	2.6	6.2	5.8	3.0	13.8

Table 2: Monthly maximum temperature (º C) and precipitation (mm) during crop growing season.

Location	May	June	July	August	September	October	November	Average
				Maximum temperature (º C)				
Manhattan	22.8	31.2	32.4	34.0	28.8	23.7	13.2	26.6
Ottawa	24.1	31.8	32.6	34.1	27.6	23.2	14.9	26.9
Hays	22.4	32.1	33.3	33.7	28.0	22.9	11.5	26.3
				Precipitation (mm)				
Manhattan	92.2	168.1	106.4	81.2	76.2	27.1	31.7	83.3
Ottawa	115.8	162.0	139.4	52.0	148.8	48.5	39.1	100.8
Hays	45.9	103.6	40.64	82.8	54.6	4.8	6.6	48.4

Table 3: Sources and characteristics of grain sorghum genotypes

Genotype	Type	Characteristics	Source
23012	Hybrid	PreDFR, PostFDR	Crosbyton
26056	Hybrid	PreFDS, PostFDR	Crosbyton
95207	Hybrid	PreFDR, PostFDS	Crosbyton
99480	Hybrid	PreFDS, PostFDR	Crosbyton
CSR1114/R45	Hybrid	PostFDR	Experimental hybrid
TX 3042xTX2737	Hybrid	PostFDS	Experimental hybrid
B35	Lines	Stay green (charcoal rot resistant)	Public inbred
SC35	Lines	Stay green (charcoal rot resistant)	Breeding material
SC599	Lines	Stay green (Stalk rot resistant)	Breeding material
TX 2783	Lines	Non stay green	Public inbred
TX 430	Lines	Non stay green	Public inbred
TX 7000	Lines	Non stay green (charcoal rot resistant)	Public inbred

Results and Discussion

- Ottawa had the highest mean rainfall, but maximum temperature was similar for all locations during the growing season (Table 2).
- There were significant effects of genotypes on biomass and grain yield across all locations (Figs 1 and 2A).
- At Manhattan (Unit 7) where NO3-N was high, inbred lines TX2783 and TX 7000 both non stay green, produced grain yield comparative to hybrids (Tables 1, 2 and Fig 1).

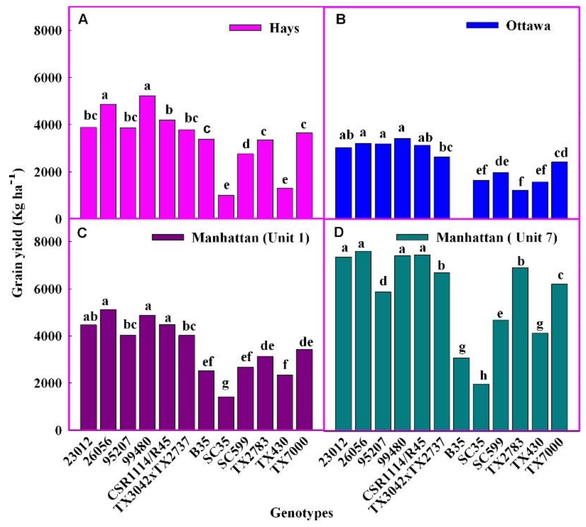

Fig 1: Grain yield of sorghum genotypes grown in Kansas.

- Hybrids 26056, 99480 produced maximum grain yield at all locations. While inbred line SC35 produced the lowest grain yield.
- There were significant effects of N on biomass (Fig 2A) at all stages of development and grain yield (Fig 2B) at all locations.
- Maximum biomass and grain yield was obtained at 90 kg ha^{-1} followed by 45 kg ha^{-1} and lowest yield in no fertilizer controls (Fig 2A).

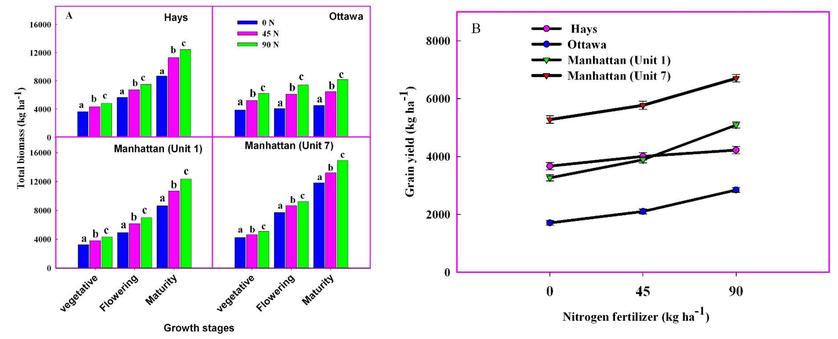

Fig 2: (A) Total biomass of grain sorghum at three different growth stages (B) Grain yield of grain sorghum at three N rates in Kansas.

- There were significant difference among genotypes for all NUE traits at Ottawa and Manhattan (Table 4 and 5).
- Across locations and genotypes, N uptakes efficiency ranged from 56 to 82, N utilization efficiency from 31 to 55, percent N recovery from 2 to 52%, NHI from 43 to 71% and NUE from 18 to 53 (Table 4 and 5).
- There were significant (P<0.05) genotype by nitrogen interaction for uptake efficiency, utilization efficiency NHI and NUE at Ottawa (Table 4).
- There were no significant interaction for components NUE at Manhattan (Table 5).
- At Ottawa genotype, 99480,26506,95207,CSR1114/R45 and 23012 had NUE >30 and genotypes SC599, SC35, TX430, TX7000, TX3042xTX2737 and TX2783 had NUE < 30 (Table 4).

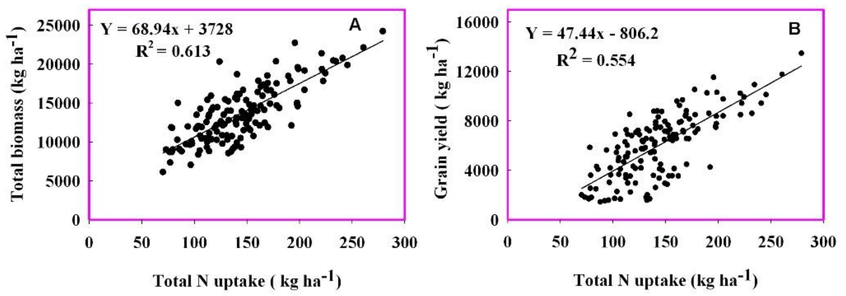

Fig 3:Total biomass (A) and grain yield (B) as a function of total N uptake.

Results and Discussion cont..

- The relationship between total biomass (kg ha^{-1}) and grain yield (kg ha^{-1}) as a function total N uptake fit to linear best with r^2 of 0.613 and 0.554 respectively (Fig 3 A and B).
- N uptake was greater in environment with greater grain yield and stover yield indicating that N uptake was largely a function of dry matter production rather than grain or stover N concentration.
- At Manhattan, genotypes 99840,26506,95207,CSR1114/R45,23012, TX3042xTX2737,TX430 and B35 had NUE > 30,while SC35 and SC599 had NUE < 30 (Table 5).

Table 4: Components of NUE of grain sorghum genotypes grown at Ottawa

Genotype	Uptake efficiency	Utilization efficiency	Nitrogen recovery	NHI	Efficiency of use
Hybrids	**(% N)**	**Kg kg^{-1}**	**(%)**	**(%)**	**Kg kg^{-1}**
23012	63.4a	51.0ab	30.8ab	60.1a	32.6a
26506	64.7a	55.8a	29.2ab	61.4a	35.4a
95207	63.9a	54.5a	16.3b	61.1a	33.3a
99480	64.5a	54.3a	12.1c	61.4a	33.9a
CSR1114/R45	63.7a	50.2ab	23.7ab	57.7a	32.2ab
TX3042xTX2737	58.1b	42.4cd	11.6c	51.6b	24.5cd
Inbred Lines					
SC35	62.6a	33.7e	23.4ab	50.3b	22.3de
SC599	56.1b	34.1e	20.4ab	43.6c	18.1e
TX2783	65.04a	42.7cd	31.3ab	62.1a	27.9bc
TX430	56.3b	39.5de	15.3b	50.1b	18.1e
TX7000	62.9a	46.2bc	37.5a	60.5a	26.2cd
P-value	*	**	*	**	**
N levels (kg ha^{-1})					
0	100a	41.4b	0	51.8b	41.4a
45	49.1b	46.8a	27.7a	57.2a	23.2b
90	36.8c	49.3a	22.7b	60.1a	18.4c
P-value	**	**	NS	**	**
Genotype x Nitrogen	**	**	NS	*	**

,**, statistically difference at P-value 0.05, 0.01 0.001. NS not significant**

Table 5: Components of NUE of grain sorghum genotypes grown at Manhattan.

Genotype	Uptake efficiency	Utilization efficiency	Nitrogen Recovery	NHI	Efficiency of use
Hybrids	**(% N)**	**Kg kg^{-1}**	**(%)**	**(%)**	**Kg kg^{-1}**
23012	72.3abc	46.1ab	48.0b	65.4ab	37.5ab
26506	68.3bcd	39.5cd	52.0a	61.9abc	32.2bcde
95207	64.83cd	38.8bcd	2.6	59.7bcd	31.6bcde
99480	82.5a	52.9a	7.4f	69.7a	42.6a
CSR1114/R45	71.4abc	41.6bc	35.2c	67.8ab	34.5bc
TX3042xTX2737	65.1bcd	45.5ab	16.6e	71.7a	36.2ab
Inbred Lines					
B35	74.9ab	46.7ab	2.1f	69.8a	37.2ab
SC35	58.2d	32.2d	24.1d	51.2d	25.2e
SC599	60.3dc	35.1cd	19.6e	54.5cd	28.9cde
TX2783	56.1de	31.6d	8.5f	65.2bcd	53.9cd
TX430	65.1bcd	42.3bc	29.1d	67.4ab	32.5bcd
TX7000	61.6cd	42.7bc	17.0e	68.6ab	34.0bc
P-value	*	**	*	**	**
N levels (kg ha^{-1})					
0	100.0a	50.2a	0	70.2a	50.2a
45	50.0b	32.8c	26.8a	52.9b	24.3b
90	52.5b	40.8b	13.7b	67.3a	25.1b
P-value	*	**	*	**	**
Genotype x Nitrogen	**NS**	**NS**	**NS**	**NS**	**NS**

,**, statistically difference at P-value 0.05, 0.01 0.001. NS not significant**

Conclusions

- Sorghum hybrids and inbred lines vary in response to nitrogen.
- There were significant differences in components of NUE in sorghum hybrids and inbred lines.
- There are opportunities to breed for higher NUE in grain sorghum.
- Studies are in progress to identify physiological bases for differences in NUE traits in grain sorghum.

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