Relationship between Plant Nitrogen and NDVI of Cotton on the Texas High Plains

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Introduction

- Nitrogen (N) is a limiting factor for plant growth due to its involvement in both vegetative and reproductive growth (Li et al., 2001)
- Plant available N in the soil is very limited and can be lost easily due to environmental conditions (IPNI, 2012)
- Normalized difference vegetation index (NDVI) is a tool used to manage water use, N status, crop development and to predict yield at peak bloom (Li et al., 2001; Zhou and Yin 2014)
- According to Zhao et al. (2010) it is uncertain if in-season N uptake by cotton corresponds with canopy reflectance

Objective

- Evaluate the interaction of N rates with irrigation level and cultivar on plant health and cotton productivity to increase nitrogen use efficiency (NUE)

Materials and Methods

- Location: Texas A&M AgriLife Research Center- Lubbock, Tx (2019 & 2020)
- Soil type: Acuff loam
- Cotton cultivars: DP 1820 B3XF & DP 1823 NR B2XF
- Irrigation levels: 70% ET & 30% ET
- Fertilizer source: Urea ammonium nitrate (UAN; 32-0-0)
- Measurements:
  - Soil sampled at three depths prior to N application
    - 0-6", 6-12", 12-24"
  - N uptake: Plant N x biomass
  - Internal NUE (iNUE): Lint yield/total N uptake (Bronson, 2021)
  - Agronomic N use efficiency (ANUE): $(Y-Y^0)/F$
  - NDVI
    - Holland Scientific GeoScoutX data logger
    - Holland Scientific Crop Circle Sensors ACS-211 & ACS-435
  - Lint yield
- Treatments:
  1) 15 lb acre[-1] N pre (15-0-0)
  2) 15 lb acre[-1] N pre + 60 lb acre[-1] N (75-0-0)
  3) 15 lb acre[-1] N pre + 120 lb acre[-1] N (135-0-0)
- Analysis:
  - ArcGIS 10.5.1
  - SAS 9.4- GLIMMIX, Proc REG

Soil Characterization

Table 1. Characteristics of soil samples collected at three depths (0-6", 6-12" and 12-24") prior to fertilizer application for all four years

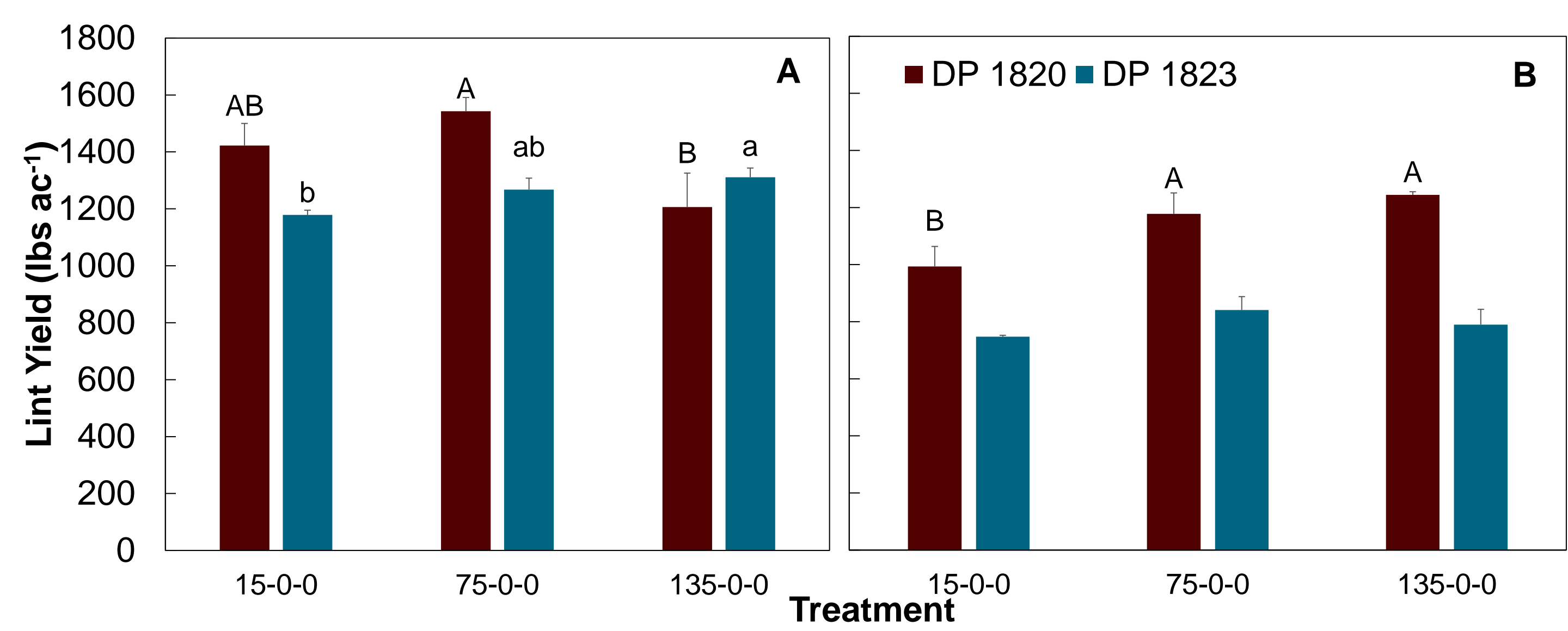| Year	Soil Depth	pH	EC	NO_3^--N	K
	in		umhos cm^{-1}	ppm	
	0-6	7.6	171	14	456
2019	6-12	7.9	134	11	299
	12-24	7.9	207	21	282
	0-6	7.6	223	23	385
2020	6-12	7.7	239	27	251
	12-24	7.6	395	48	236

Results

Figure 1. Cotton lint yield in 2019 with the 70% ET (A) and 30% ET (B) irrigation levels. Uppercase letters within DP 1820 and lowercase letters within DP 1823 are not different at α<0.05 by Fisher's protected LSD. The vertical bars represent standard error of the mean
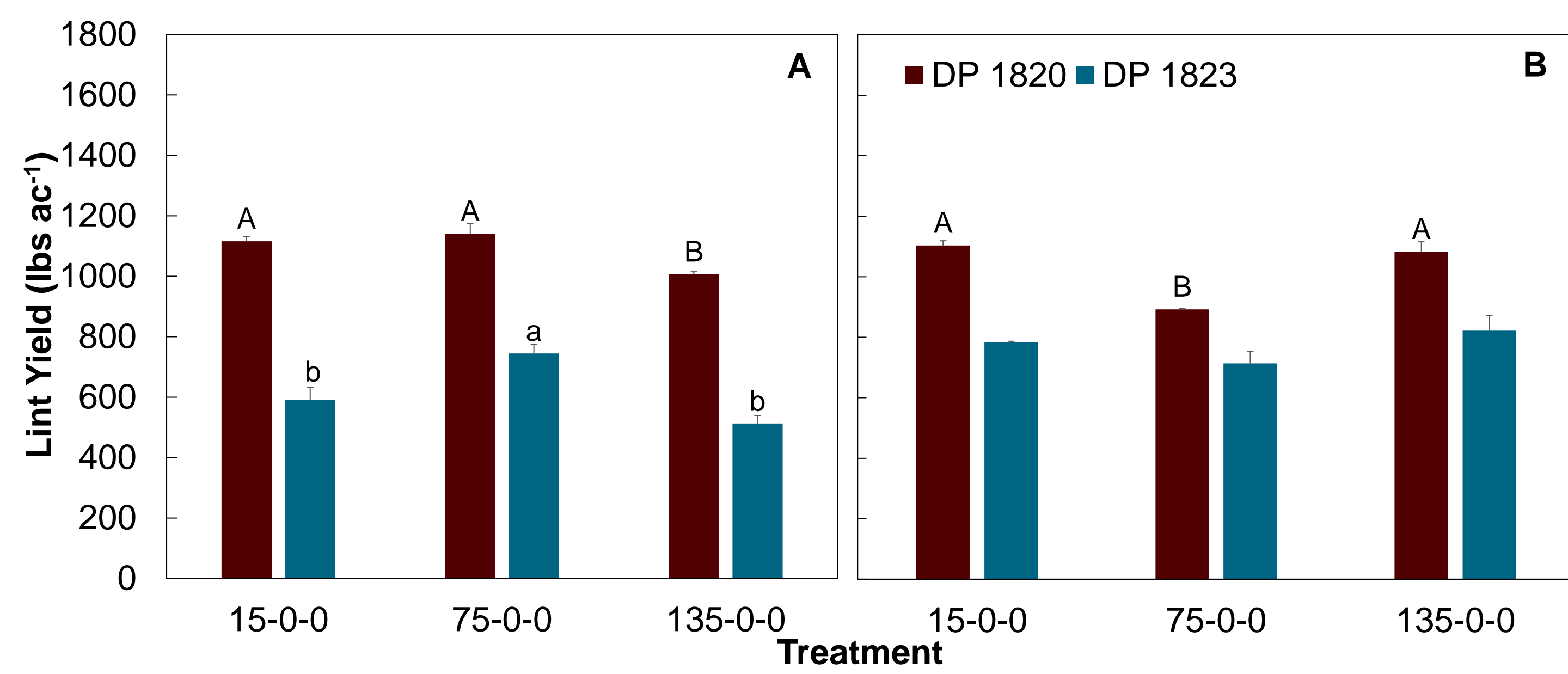

Figure 2. Cotton lint yield in 2020 with the 70% ET (A) and 30% ET (B) irrigation levels. Uppercase letters within DP 1820 and lowercase letters within DP 1823 are not different at α<0.05 by Fisher's protected LSD. The vertical bars represent standard error of the mean
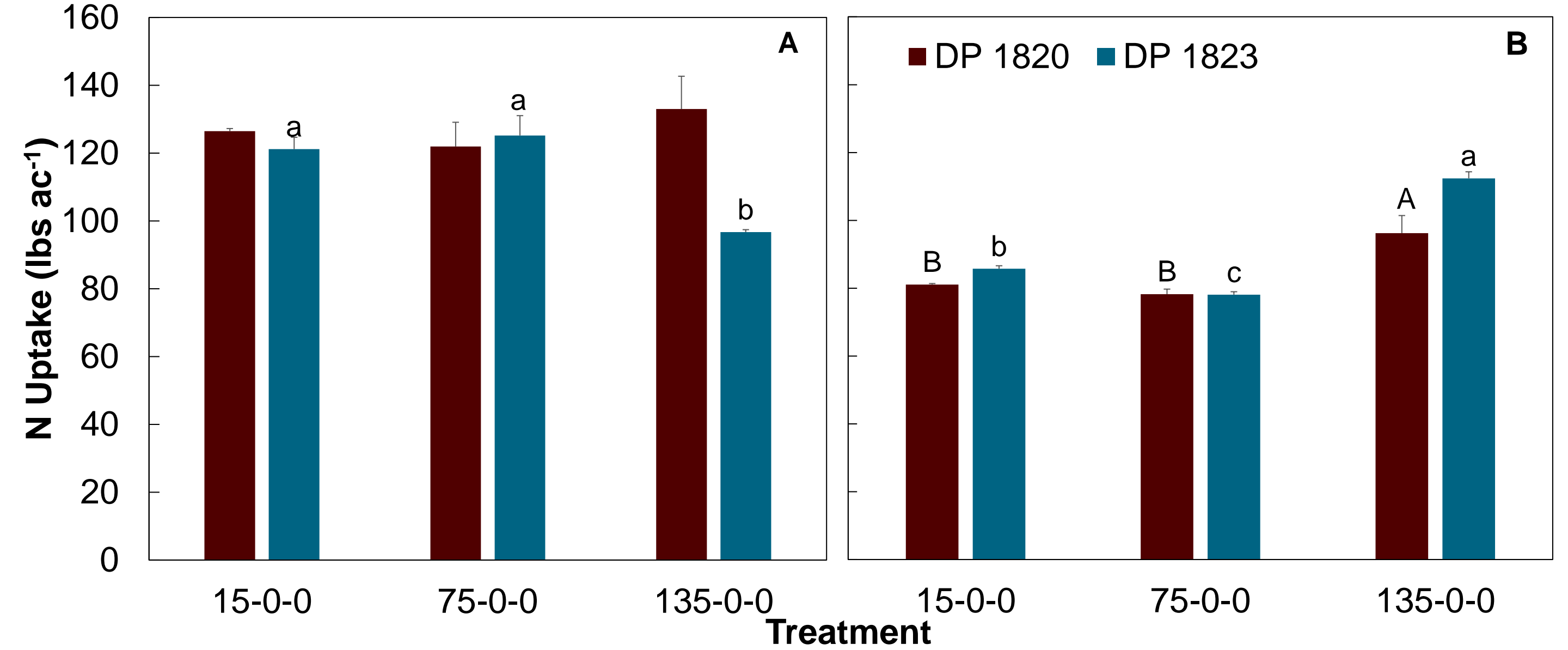

Figure 3. Nitrogen uptake in 2020 with the 70% ET (A) and 30% ET (B) irrigation levels. Uppercase letters within DP 1820 and lowercase letters within DP 1823 are not different at α<0.05 by Fisher's protected LSD. The vertical bars represent standard error of the mean

Table 2. Nitrogen use efficiencies in 2019 and 2020 with the DP 1820 and DP 1823 cultivars. Letters within irrigation levels are not different at α<0.05 by Fisher's protected LSD.

Irrigation	Cultivar	N	iNUE 2019	iNUE 2020	ANUE 2019	ANUE 2020
		(kg ha^{-1})	(lb lint lb N[-1])			
	DP 1820	15	9.757	8.824	---	---
		75	10.708	9.480	1.566 A	0.334
		135	9.780	7.700	-1.317 B	-0.808
70% ET	DP1823	15	11.824	4.859 B	---	---
		75	13.282	5.983 A	1.151	2.053 A
		135	13.958	5.304 AB	0.952	-0.575 B
	DP 1820	15	5.908 B	13.613 A	---	---
		75	8.300 A	11.411 B	2.391	-2.816 B
		135	9.533 A	11.317 B	1.806	-0.153 A
30% ET	DP1823	15	8.161	9.142 A	---	---
		75	8.436	9.144 A	1.511	-0.934 B
		135	7.991	7.311 B	0.462	0.286 A

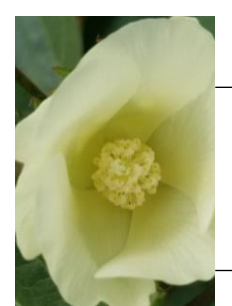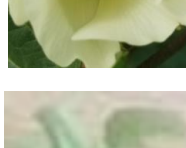Table 3. Regression R^2 and p-values for normalized difference vegetation index (NDVI) vs lint yield in 2019

	DAP	Irrigation	DP 1820 R^2	DP 1820 p-value	DP 1823 R^2	DP 1823 p-value
	26	70% ET	0.431	0.020	0.531	0.007
		30% ET	0.027	0.611	0.003	0.870
	42	70% ET	0.425	0.022	0.606	0.003
		30% ET	0.323	0.054	0.281	0.076
	56	70% ET	0.616[†]	0.003	0.134	0.242
		30% ET	0.163	0.194	0.163	0.193
	63	70% ET	0.546	0.006	0.461	0.015
		30% ET	0.048	0.492	0.193	0.153
	69	70% ET	0.393	0.029	0.027	0.610
		30% ET	0.569[†]	0.005	0.189	0.158

Table 4. Regression R^2 and p-values for normalized difference vegetation index (NDVI) vs lint yield in 2020

	DAP	Irrigation	DP 1820 R^2	DP 1820 p-value	DP 1823 R^2	DP 1823 p-value
	69	70% ET	0.326[†]	0.052	0.030	0.593
		30% ET	0.578	0.017	0.018	0.734
	92	70% ET	0.389	0.030	0.076	0.387
		30% ET	0.184	0.249	0.149	0.305
	99	70% ET	0.201	0.143	0.297	0.067
		30% ET	0.062	0.518	0.141	0.319
	127	70% ET	0.129	0.252	0.007	0.793
		30% ET	0.065	0.509	0.282	0.141

[†] Highlighted boxes indicate greatest R^2 values within irrigation level and cultivar

Discussion

- ANUE
  - DP 1820 within the 70% ET irrigation level was greater with the 75-0-0 treatment in 2019
  - DP 1823 within the 70% ET irrigation level was greater with the 75-0-0 treatment in 2020
  - DP 1820 and 1823 within the 30% ET irrigation level was greater with the 135-0-0 treatment in 2020
- iNUE
  - DP 1823 in 2019 had an iNUE of 13.96 lb lint lb N[-1] with the 135-0-0 treatment, which was considered deficient in N (Bronson, 2021)
  - In 2020, treatment 15-0-0 had the greatest iNUE of 13.61 lb lint lb N[-1] which was considered deficient in N, however N was mostly taken up in excess according to Bronson, 2021
- Lint Yield
  - 70% ET Irrigation- DP 1820 had the lowest lint yield with the 135-0-0 treatment for both years, while DP 1823 had the lowest lint yield with the 15-0-0 treatment in 2019 and 2020 had the lowest lint yield with the 15-0-0 and 135-0-0 treatments
  - 30% ET Irrigation- DP 1820 in 2019 had the lowest lint yield with the 15-0-0 treatment, while in 2020 the 75-0-0 treatment had the lowest lint yield.
- NDVI- DP 1820 had a better relationship with lint yield during flowering, while DP 1823 had a better relationship during squaring in 2019 and in 2020 had a better relationship during boll development
  - 70% ET
    - In 2019 NDVI had a greater relationship with lint yield 56 DAP (R^2=0.616) with the cultivar DP 1820 and 42 DAP (R^2=0.606) with the cultivar DP 1823
    - In 2020 NDVI had a greater relationship with lint yield 92 DAP (R^2=0.389) with the cultivar DP 1820
  - 30% ET
    - In 2019 NDVI had a greater relationship with lint yield 69 DAP (R^2=0.569) with the cultivar DP 1820
    - In 2020 NDVI had a greater relationship with lint yield 69 DAP (R^2=0.578) with the cultivar DP 1820

Summary

- The lack of yield response to the greatest N rate (135-0-0) when compared to the 75-0-0 treatment may be due to high levels of N in irrigation water
- The lack of a strong relationship between NDVI and lint yield may be due to the limited range in lint yield across N treatments. Hail damage to the test plots in 2019 is also acknowledged here as a possible confounding effect
- Similar results to Bronson et al. (2003 & 2005) were determined in which NDVI had a moderate to poor correlation to lint yield
- When N uptake was the greatest, iNUE was the lowest, which resulted in excess N uptake (Rochester, 2011; Bronson, 2021)

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