Assessing Physiological Contributions of the First True Leaf to Seedling Vigor for Cotton Under Field Conditions

UGA Cotton

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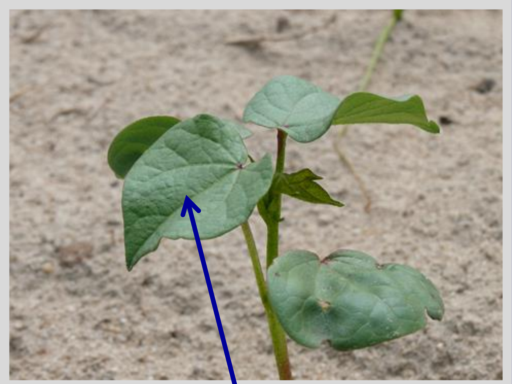
Introduction

Previous research has indicated that seed characteristics such as seed mass and composition can influence seedling vigor and possibly seedling growth response to temperature. In particular, high seed mass and total calorie content per seed are positively associated with seedling vigor (Snider et al., 2014, 2016).

While the differences in seedling vigor due to seed mass could be associated with greater nutritive reserves in the cotyledons to drive post-germinative growth, larger seeds may produce larger cotyledons as well, which could promote seedling vigor (Liu et al., 2015) and rapid vegetative development by intercepting more incoming solar radiation.



Rapid development of the first true leaf has been suggested as an important determinant of seedling vigor in cotton (Pilon et al., 2016), yet studies addressing the impact of first true leaf growth and physiology on early seedling and whole-crop growth are limited.

Objective

- **Quantify early season growth and physiological processes on multiple planting dates for Upland and Pima cotton known to differ in planting seed mass.**

Hypothesis

- **Large-seeded cotton would produce vigorous seedling and whole crop growth due to greater photosynthetic activity of the first true leaf.**

Materials and Methods

Plant Material and Planting Dates

- **Three Cultivars (Table 1 below)**

ID	Cultivar	Cotton Type	Seed Mass (mg seed^{-1})
1	DP 348	Pima	138
2	DP 1612	Upland	94
3	DP 1614	Upland	72

- **Three Planting Dates**
  - ✓ **April 18, 2017**
  - ✓ **May 11, 2017**
  - ✓ **June 8, 2017**
- **Experimental Design**
  - ✓ **Completely randomized design within each planting date**
  - ✓ **Five replications**

Sampling Procedures and Measurements

- **Two Sample Dates**
  - ✓ **21 Days After Planting (21 DAP)**
  - ✓ **35 Days After Planting (35 DAP)**
- **Growth Analysis Measurements (Seedling)**
  - ✓ **Mainstem true leaf nodes (# of Nodes)**
  - ✓ **Plant Height (cm)**
  - ✓ **Dry Weight (DW) per plant (g)**
  - ✓ **Leaf Area (LA) per plant (cm^2)**
  - ✓ **First True Leaf Area (cm^2)**
- **Crop Growth Indices***
  - ✓ **Crop Growth Rate (g m^{-2} land area d^{-1})**
  - ✓ **Net Assimilation Rate (g m^{-2} leaf area d^{-1})**
  - ✓ **Average Leaf Area Index**

***From destructively sampling 1.82 m length of row @ 0.91 m inter-row spacing.**

Materials and Methods

- **Gas Exchange and Fluorescence Measurements (Using LI-6400 XT)**
  - ✓ **Net Photosynthesis (A_n; µmol CO_2 m^{-2} s^{-1})**
  - ✓ **Actual quantum yield of Photosystem II (Φ_{PSII})**
  - ✓ **Photosynthetic Electron Transport Rate (ETR; µmol electrons m^{-2} s^{-1})**
  - ✓ **Midday Respiration (R_D; µmol CO_2 m^{-2} s^{-1})**
  - ✓ **Gross Photosynthesis ($A_g = A_n + R_D$ in µmol CO_2 m^{-2} s^{-1})**

LI-6400 XT portable photosynthesis system

Statistical Analysis

- ***Model*** **→ One-Way Analysis of Variance (ANOVA) with three levels of the main effect (cultivar) within planting and sample date.**
- ***Post Hoc Analysis*** **→ Fisher's LSD at α = 0.05**

Results

Qualitative Observations

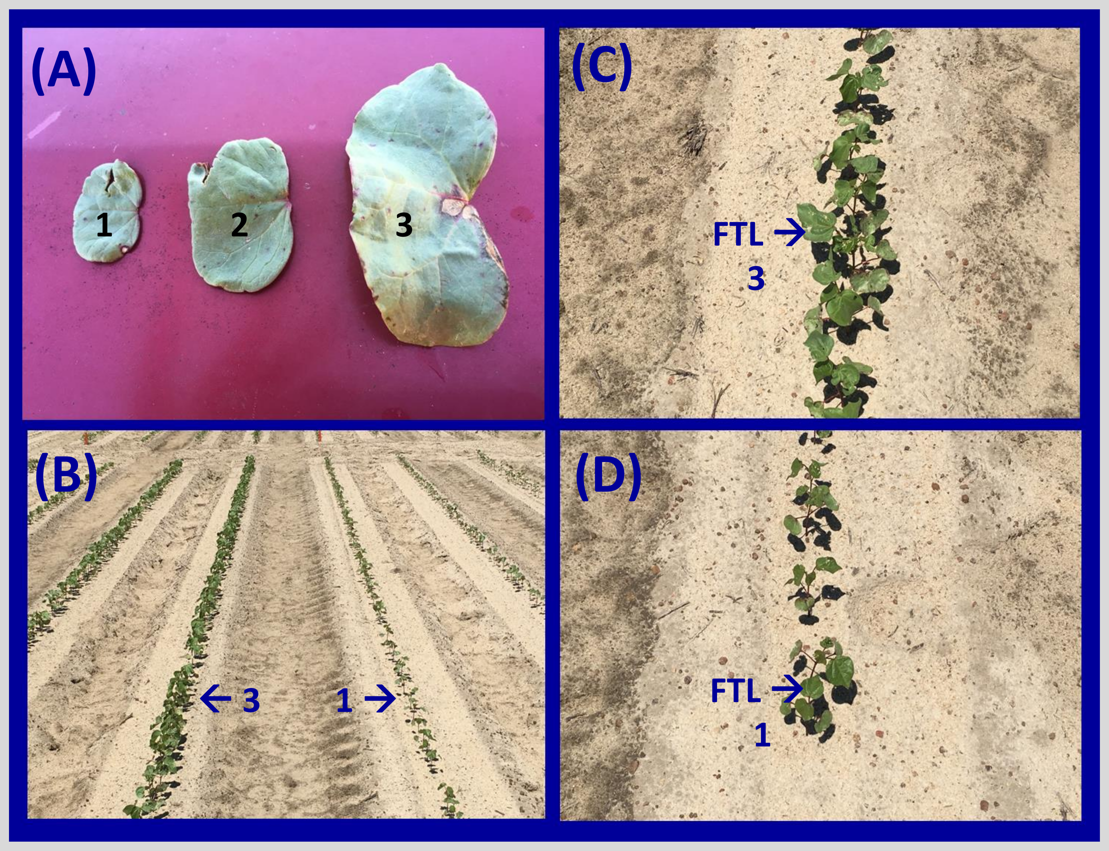


Fig. 1. Cotyledon (A), whole-crop (B,C), and first true leaf observations for early planted (April or May) cotton. No. **1** to **3** represent successively greater planting seed mass.

- Qualitative differences in growth characteristics were conspicuous for April or May planted cotton (**Fig. 1**).
- Though not quantified, cotyledon size was noticeably impacted by cultivar on the early planting dates (April planting date, 21 DAP shown in Fig. 1A), where cotyledon size increased with planting seed mass. **1** = lightest seed (Upland); **2** = intermediate weight seed (Upland); **3** = heaviest seed (Pima).
- Differences in whole-crop growth between cultivars was apparent as the early crop canopy was substantially leafier at 21 DAP for the largest seeded cotton (**3**) than for the smallest seeded cotton (**1**).
- When differences in first true leaf (FTL) area were observed, the heaviest planting seed (C) produced the greatest first true leaf area (FTLA).

Seedling Vigor, First True Leaf Area & Physiological Processes

P.D.	DAP	Cultivar	# of Nodes	Height (cm)	DW (g)	LA/Pt (cm^2)	FTLA (cm^2)
April 18	21	DP1612	2.14^{a,b}	5.62^{a}	0.31^{a}	39.35^{a}	10.40^{a}
		DP1614	1.89^{b}	5.04^{a}	0.20^{a}	23.75^{a}	6.80^{a}
		DP348	2.49^{a}	5.79^{a}	0.34^{a}	36.97^{a}	9.74^{a}
			p= 0.0191	**p= 0.422**	**p= 0.2838**	**p= 0.2603**	**p= 0.3666**
	35	DP1612	5.42^{a}	6.03^{a}	1.35^{b}	155.28^{a,b}	13.85^{b}
		DP1614	4.87^{a}	5.99^{a}	0.99^{b}	114.24^{b}	13.50^{b}
		DP348	5.99^{a}	6.80^{a}	2.23^{a}	271.00^{a}	31.37^{a}
			p= 0.4101	**p= 0.462**	**p= 0.0262**	**p= 0.0379**	**p= 0.0134**
May 11	21	DP1612	3.40^{a}	9.47^{a}	0.87^{b}	88.87^{b}	26.86^{a}
		DP1614	2.46^{b}	6.99^{b}	0.51^{c}	54.74^{c}	20.40^{a}
		DP348	3.38^{a}	7.86^{b}	1.48^{a}	151.97^{a}	41.34^{a}
			p= 0.0031	**p= 0.0018**	**p< 0.0001**	**p< 0.0001**	**p= 0.0568**
	35	DP1612	7.84^{a}	11.21^{a}	5.23^{b}	573.88^{a}	34.75^{b}
		DP1614	6.45^{b}	8.27^{b}	3.55^{c}	370.86^{b}	29.64^{c}
		DP348	8.09^{a}	11.90^{a}	6.86^{a}	751.01^{a}	66.30^{a}
			p= 0.0001	**p= 0.0031**	**p= 0.0012**	**p= 0.0024**	**p< 0.0001**
June 8	21	DP1612	2.35^{a}	8.03^{a}	0.15^{b}	25.52^{b}	8.27^{b}
		DP1614	1.77^{b}	5.68^{c}	0.16^{b}	16.23^{b}	5.69^{b}
		DP348	2.07^{a}	6.71^{b}	0.35^{a}	55.64^{a}	20.89^{a}
			p= 0.0036	**p= .0005**	**p= 0.0142**	**p= 0.0001**	**p= 0.0002**
	35	DP1612	4.69^{a}	14.03^{a}	0.12^{a}	140.77^{a}	12.27^{b}
		DP1614	4.39^{a}	12.78^{a}	0.14^{a}	115.26^{a}	12.06^{b}
		DP348	4.27^{a}	12.51^{a}	0.17^{a}	164.28^{a}	28.39^{a}
			p= 0.6894	**p= 0.5677**	**p= 0.5331**	**p= 0.2424**	**p< 0.0001**

Table 2 (Left). Number of mainstem true leaf nodes, plant height, dry weight (DW), leaf area per plant (LA/Pt), and first true leaf area for three cultivars, planted on three dates (P.D) and sampled twice (21 and 35 DAP) during the early season. Values are means (n = 5) and those not sharing a common letter within a given P.D. and DAP are significantly different at P < 0.05.

P.D.	DAP	Cultivar	A_n (µmol m^{-2} s^{-1})	Φ_{psII}	ETR (µmol m^{-2} s^{-1})	R_D (µmol m^{-2} s^{-1})	A_g (µmol m^{-2} s^{-1})
April 18	21	DP1612	26.14^{a}	0.35^{a}	226.02^{a}	6.68^{a}	32.41^{a}
		DP1614	22.33^{a,b}	0.32^{a,b}	204.71^{a,b}	7.23^{a}	29.86^{a,b}
		DP348	17.91^{b}	0.30^{b}	191.02^{b}	6.49^{a}	24.29^{b}
			p= 0.0164	**p= 0.0383**	**p= 0.0372**	**p= 0.7375**	**p= 0.0275**
	35	DP1612	22.22^{a}	0.27^{a}	174.03^{a}	2.31^{a}	26.01^{a}
		DP1614	19.15^{a}	0.24^{a,b}	154.15^{a,b}	1.78^{a}	20.93^{a}
		DP348	18.45^{a}	0.21^{b}	132.68^{b}	3.00^{a}	20.24^{a}
			p= 0.3375	**p= 0.0186**	**p= 0.0187**	**p= 0.6485**	**p= 0.1165**
June 8	21	DP1612	17.04^{a}	0.19^{a}	120.33^{a}	5.05^{b}	23.57^{a}
		DP1614	13.90^{a}	0.20^{a}	125.55^{a}	5.43^{b}	19.70^{a}
		DP348	14.76^{a}	0.16^{a}	103.05^{a}	8.21^{a}	19.95^{a}
			p= 0.3035	**p= 0.2487**	**p= 0.2477**	**p= 0.0054**	**p= 0.2095**
	35	DP1612	25.26^{a}	0.31^{a}	197.62^{a}	4.56^{a}	28.67^{a}
		DP1614	20.56^{a}	0.27^{a}	169.35^{a}	4.23^{a}	25.91^{a}
		DP348	19.87^{a}	0.26^{a}	168.03^{a}	3.82^{a}	24.05^{a}
			p= 0.2256	**p= 0.0893**	**p= 0.0892**	**p= 0.8822**	**p= 0.3358**

Table 3 (Left). Net photosynthesis (A_n), actual quantum yield (Φ_{PSII}), electron transport rate (ETR), midday respiration (R_D), and gross photosynthesis (A_g) for three cultivars, planted on two dates (P.D) and sampled twice (21 and 35 DAP) during the season. Values are means (n = 5) those not sharing a common letter within a given P.D. and DAP are significantly different at P < 0.05. Weather conditions prevented sampling for the May 11 P.D.

Results

Table 4. Crop Growth Rate (CGR; g m^{-2} land area d^{-1}), Net Assimilation Rate (NAR; g m^{-2} leaf area d^{-1}), and average Leaf Area Index (LAI) between 21 and 35 days after planting (DAP) for three cotton cultivars sown on three different planting dates (P.D.) during the 2017 growing season near Tifton, GA. values represent means (n = 5) and those not sharing a common letter within a given P.D. are significantly different (P < 0.05).

P.D.	Cultivar	CGR (g/m^2/d)	NAR (g/m^2/d)	LAI
April 18	DP1612	0.50^{b}	7.58^{a}	0.08^{b}
	DP1614	0.27^{b}	6.99^{a}	0.05^{b}
	DP348	0.87^{a}	8.33^{a}	0.13^{a}
		p= 0.0021	**p= 0.6347**	**p= 0.0004**
May 11	DP1612	3.25^{a}	11.56^{a}	0.35^{b}
	DP1614	1.87^{b}	12.01^{a}	0.46^{c}
	DP348	3.55^{a}	9.01^{b}	0.46^{a}
		p= 0.0017	**p= 0.0038**	**p= 0.001**
June 8	DP1612	0.43^{a}	5.86^{a}	0.08^{a}
	DP1614	0.40^{a}	8.20^{a}	0.06^{a}
	DP348	0.36^{a}	3.94^{a}	0.10^{a}
		p= 0.857	**p= 0.1023**	**p= 0.1288**

Discussion

- **Planting seed from cotton cultivars known to differ substantially in seed mass exhibited significant differences in first true leaf size, photosynthetic processes, seedling vigor (predominantly seedling dry weight), and whole-crop growth indices.**
- **First true leaf area is more important in determining seedling vigor than single leaf photosynthesis because the cultivar with the greatest plant DW and whole plant leaf area also had the largest first true leaves (Table 2). By comparison, first true leaf photosynthetic rates were either unaffected by cultivar or lowest in the most vigorous cultivar (Table 3).**
- **Similarly, whole crop leaf area development (LAI) was more important in determining crop growth rates than net assimilation rates, indicating that the total leaf area available to intercept incoming solar radiation is the dominant driver of early crop growth rather than photosynthetic efficiency of the canopy.**

Future Research

To verify the seedling vigor and crop growth responses of cultivars differing in seed mass and first true leaf characteristics, the study will be conducted again during the 2018 season.

Analyses of plant pigments, oxidative stress, and ROS scavenging enzyme activity are ongoing to determine what role these factors play in promoting vigor under different, early season conditions.

Citations

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