Improving Cotton Production Efficiency With Phosphorus and Potassium Placement At Multiple Depths in Strip Tillage Systems

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Introduction and Justification

- The primary preplant fertilization system in Virginia cotton (*Gossypium hirusutum*) production is a broadcast application prior to planting
- Limited data exists for using banded starter fertilizers in Virginia upland cotton
- Crozier et al. (2012) observed an average increase of 60 lbs lint per acre in North Carolina with the use of starters in soils testing high in soil phosphorus
  - Study indicated 2 x 2 placement was more consistent than surface banding over seed
- New high yielding and earlier maturing cotton varieties have created a greater demand for nutrients during bloom and boll set
  - Phosphorus and potassium must be available >6 weeks after application to maximize yields

Research Objectives

1. Determine the impact on early season development of upland cotton through first square, nutrient status throughout the bloom period, and lint yield and quality of placing a fluid P & K fertilizer at multiple depths below the seed during strip-till cultivation.

2. Evaluate selected combinations of P and K placed at multiple depths in the strip-till process in combination with 2x2 banding of P and K solutions at planting on early season development through first square, nutrient status throughout the bloom period, and lint yield and quality.

Materials and Methods

- Two Locations:
  - Suffolk, VA (TAREC)
    - Unfertilized checks received no side-dress N
    - Side-dress N source was 24-0-0-3S
  - Lewiston, NC
    - Unfertilized checks received side-dress N
    - Side-dress N source was UAN30
- Fertilizer Placement
  - Deep Placement with Strip-tillage
    - 6, 9, and 12 in. below the row
    - 1-2 weeks prior to planting
  - 2 X 2 Band at Planting


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Materials and Methods

- Fluid Fertilizer Sources
  - Ammonium Polyphosphate (10-34-0)
  - Potassium thiosulfate (0-0-25-17S)
  - Soil Test Recommendations (100%):
    - 40 lbs. P_2O_5 ac^{-1}
    - 40 lbs. K_2O ac^{-1}
- Granular Fertilizer Sources
  - Diammonium phosphate (18-46-0)
  - Potassium Chloride (0-0-60)
- All preplant nitrogen and sulfur were balanced among treatments
  - Urea Ammonium nitrate (30-0-0)
  - Ammonium thiosulfate (12-0-0-26S)
  - 35 lbs N ac^{-1} and 41 lbs. S ac^{-1}

Treatment List

Trt	Placement	Description
1	Unfertilized Control	No P or K Fertilization
2	Broadcast Agronomic Control	P + K Broadcast – Soil test recommendation
3	Liquid Starter Agronomic Control	112 kg /ha of 10-34-0 in 2X2 band + K broadcast
4	2 X 2 Band	50%P + 50%K
5	2 X 2 Band	100%P + 100%K¶
6	2 X 2 Band	150%P + 150%K
7	Deep Placement	50%P + 50%K
8	Deep Placement	100%P + 100%K
9	Deep Placement	150%P + 150%K
10	2 X 2 + Deep Placement	(80%P + 80% K) + (20%P + 20%K)
11	2 X 2 + Deep Placement	(60%P + 60% K) + (40%P + 40%K)
12	2 X 2 + Deep Placement	(40%P + 40% K) + (60%P + 60%K)
13	2 X 2 + Deep Placement	(20%P + 20% K) + (80%P + 80%K)

¶ 100% rate equals 40 lbs. P_2O_5 and 40 lbs. K_2O per hectare based on soil test recommendations for producing cotton in Virginia

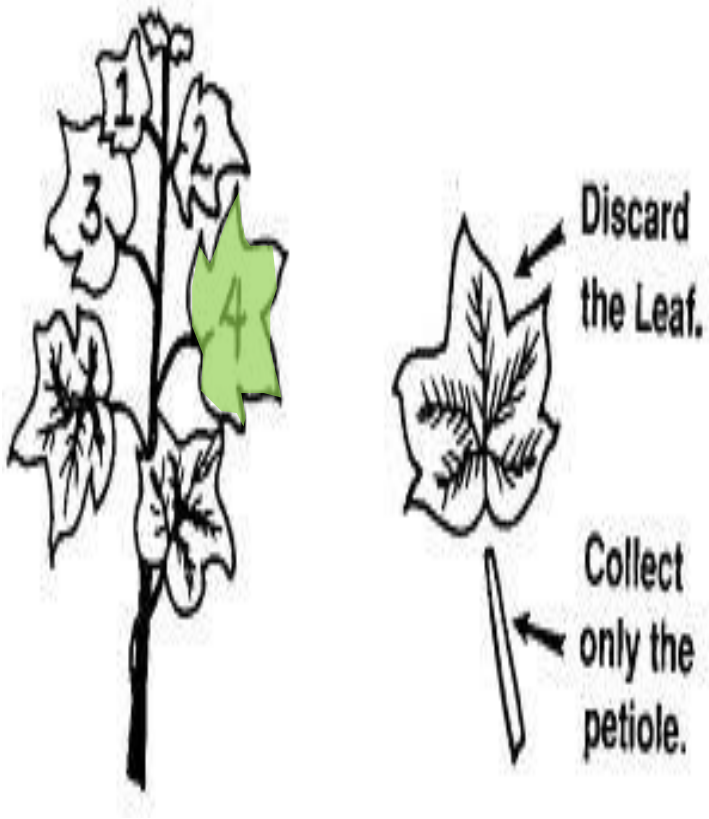
Materials and Methods

- Treatment were applied to 4 row plots
  - Row spacing = 3 ft.
  - Plot length = 40 ft

- In-season Plant Measurements
  - Plant Population
  - Plant Height (until 1st flower)
  - Total Nodes (from 1st square)
  - Nodes Above White Flower (NAWF)

Materials and Methods

- Petiole and Tissue Sampling
  - 1st through 5th week of bloom petiole sampling
  - 4th leaf down the main stem
  - 24 petioles per plot from the 1st and 4th rows
  - Petioles immediately detached from leaf
  - Petioles analyzed for nitrate-N, phosphorus, potassium, and sulfur
  - Leaf samples taken during 1st and 5th week of bloom
    - Complete nutrient analysis for leaf samples



Materials and Methods

- Lint Yield and Quality
  - Cotton harvested with two row cotton picker from center two rows
  - Lint was ginned on 10 saw micro-gin for % lint
  - Lint was sent to USDA for HVI analyses on lint quality

Unfertilized Check

40 lbs. P_2O_5 ac^{-1}

40 lbs. K_2O ac^{-1}

Statistical Design and Analysis

- Randomized Complete Block Design
  - 4 replications of each treatment
  - Analysis of variance was conducted at the $\alpha = 0.05$
    - Nutrient management systems tested at 40 lbs P_2O_5 and 40 lbs K_2O per acre as single factors
    - Placement and rate analyzed as 2 X 3 factorial
    - Combination placement treatments tested as single factors (Data not shown)
    - Tukey-Kramer HSD used for mean separation at $\alpha = 0.05$

Mehlich I Soil Test Results for 2015 Locations

Depth	TAREC	Lewiston	TAREC		Lewiston	
inches	Est. CEC		P	K	P	K
	meq. / 100g soil		ppm			
0-3	2.7	4.4	46 (H+)¶	80 (M+)	21 (H-)	81 (M+)
3-6	2.6	4.7	50 (H+)	83 (M+)	19 (H-)	58 (M)
6-9	2.2	4.3	35 (H)	66 (M)	13 (M)	43 (M-)
9-12	1.9	3.9	25 (H-)	59 (M)	8 (M-)	44 (M-)

¶ Indicates the soil test level based on Virginia's soil test calibration

Mehlich I Soil Test Results for 2013-2015 Locations

Depth	TAREC		Lewiston	
inches	P	K	P	K
	ppm			
0-3	45 (H+)¶	95 (H-)	22 (H-)	96 (H-)
3-6	36 (H)	89 (H-)	16 (M+)	59 (M)
6-9	24 (H-)	72 (M)	12 (M)	43 (M-)
9-12	17 (M+)	76 (M+)	6 (L+)	40 (M-)

¶ Indicates the soil test level based on Virginia's soil test calibration

Nutrient Management Systems and Early Season Growth in 2015

TAREC

Nutrient Systems	Plant Height					
	3rd‡	4th	5th	6th	7th	8th
	in.					
Unfertilized Control	4.3 b*	7.8 b	13.5 c	19.5 c	24.3 b	26.4 b
Broadcast Agronomic Control	4.6 ab	7.7 b	14.9 bc	21.5 b	28.1 a	32.8 a
Liquid Starter Control	5.0 a	9.2 a	17.1 a	24.1 a	29.7 a	34.9 a
100% 2X2 N-P-K-S	4.4 b	7.6 b	14.6 bc	21.8 b	27.8 a	32.8 a
100% Deep Placement N-P-K-S	4.4 b	8.0 ab	15.2 b	22.5 ab	29.1 a	33.1 a

*Values with the same letter are not significantly different at α=0.05

‡ Week after Planting

Lewiston

Nutrient Systems	Plant Height					
	3rd‡	4th	5th	6th	7th	8th
	in.					
Unfertilized Control	3.8	7.2	8.8	13.7	21.5	26.9
Broadcast Agronomic Control	3.7	7.1	9.1	14.6	21.5	27.9
Liquid Starter Control	3.7	7.5	9.6	16.3	23.2	28.5
100% 2X2 N-P-K-S	3.5	6.9	8.5	14.5	20.9	26.6
100% Deep Placement N-P-K-S	3.9	7.5	9.8	16.8	23.5	28.9

*Values with the same letter are not significantly different at α = 0.05

‡ Week after Planting

Normalized Difference Vegetative Index for Nutrient Management Systems in 2015

TAREC

Nutrient Systems	Normalized Difference Vegetative Index (NDVI)					
	4th‡	5th	6th	7th	8th	9th
Unfertilized Control	0.38 ab*	0.80	0.83 b	0.78 b	0.78 b	0.78 b
Broadcast Agronomic Control	0.41 ab	0.83	0.86 a	0.85 a	0.89 a	0.87 a
Liquid Starter Control	0.45 a	0.84	0.86 a	0.86 a	0.90 a	0.88 a
100% 2X2 N-P-K-S	0.35 b	0.82	0.85 a	0.84 a	0.88 a	0.87 a
100% Deep Placement N-P-K-S	0.40 ab	0.83	0.85 a	0.85 a	0.89 a	0.87 a

*Values with the same letter are not significantly different at α=0.05

‡ Week after Planting

Lewiston

Nutrient Systems	Normalized Difference Vegetative Index (NDVI)			
	7th‡	8th	9th	10th
Unfertilized Control	0.72	0.80	0.83	0.88
Broadcast Agronomic Control	0.75	0.79	0.83	0.88
Liquid Starter Control	0.74	0.81	0.81	0.87
100% 2X2 N-P-K-S	0.76	0.81	0.83	0.87
100% Deep Placement N-P-K-S	0.78	0.81	0.85	0.87

‡ Week after Planting

Normalized Difference Vegetative Index for Nutrient Management Systems in 2015

TAREC

Nutrient Systems	Normalized Difference Vegetative Index (NDVI)					
	4th‡	5th	6th	7th	8th	9th
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‡ Week after Planting

Lewiston

Nutrient Systems	Normalized Difference Vegetative Index (NDVI)			
	7th‡	8th	9th	10th
Unfertilized Control	0.72	0.80	0.83	0.88
Broadcast Agronomic Control	0.75	0.79	0.83	0.88
Liquid Starter Control	0.74	0.81	0.81	0.87
100% 2X2 N-P-K-S	0.76	0.81	0.83	0.87
100% Deep Placement N-P-K-S	0.78	0.81	0.85	0.87

‡ Week after Planting

Total Nodes and Node Above White Flower (NAWF)for Nutrient Management Systems in 2015

TAREC

Nutrient Systems	Total Nodes			NAWF	
	6th‡	7th	8th	9th	10th
Unfertilized Control	7.7	8.0	8.2	4.1 b*	2.2
Broadcast Agronomic Control	8.3	8.5	9.5	5.9 a	3.5
Liquid Starter Control	8.6	9.2	9.5	6.0 a	3.7
100% 2X2 N-P-K-S	8.5	8.9	9.1	5.4 a	4.3
100% Deep Placement N-P-K-S	8.2	8.8	9.9	5.8 a	3.6

*Values with the same letter are not significantly different at α=0.05

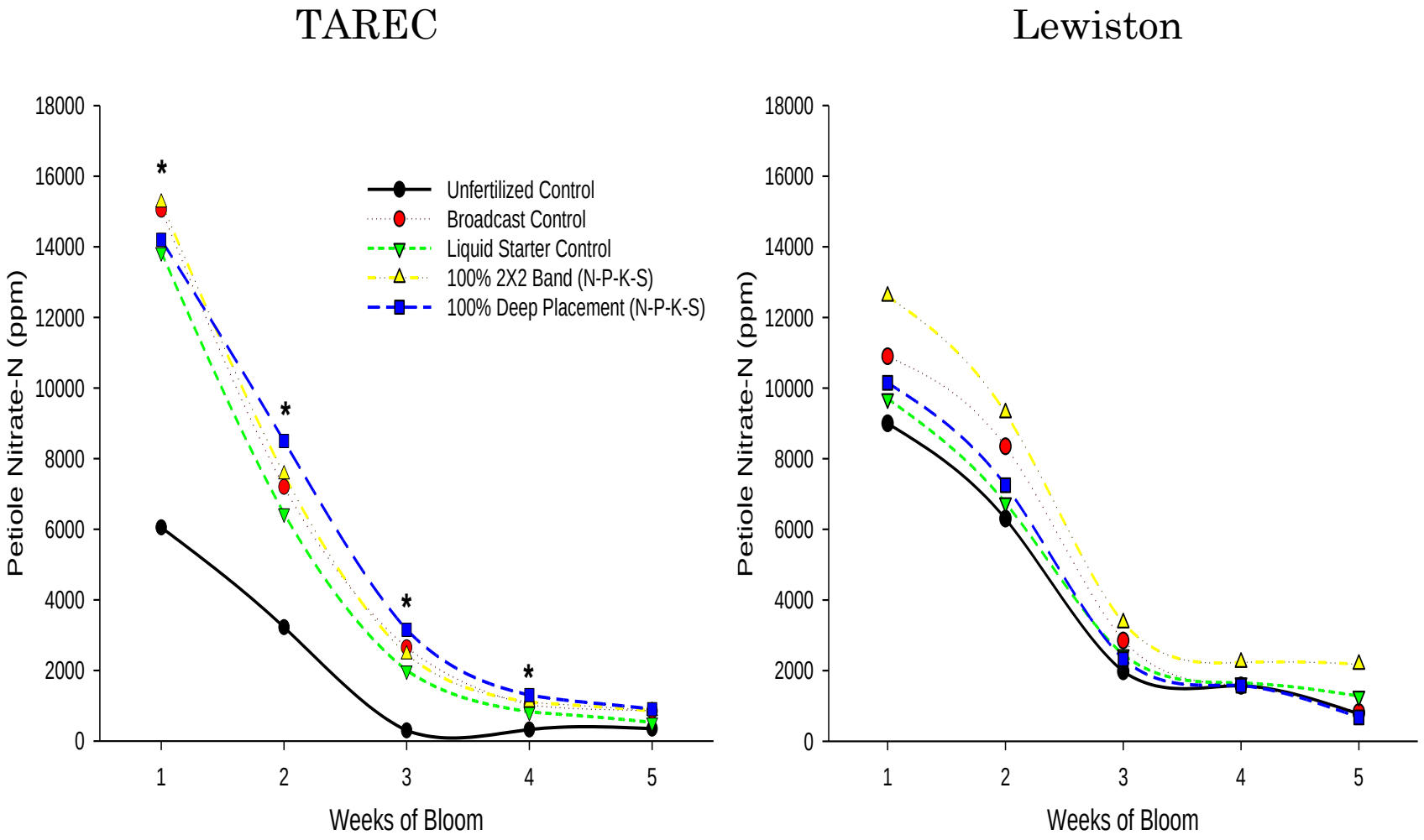
‡ Week after Planting

Lewiston

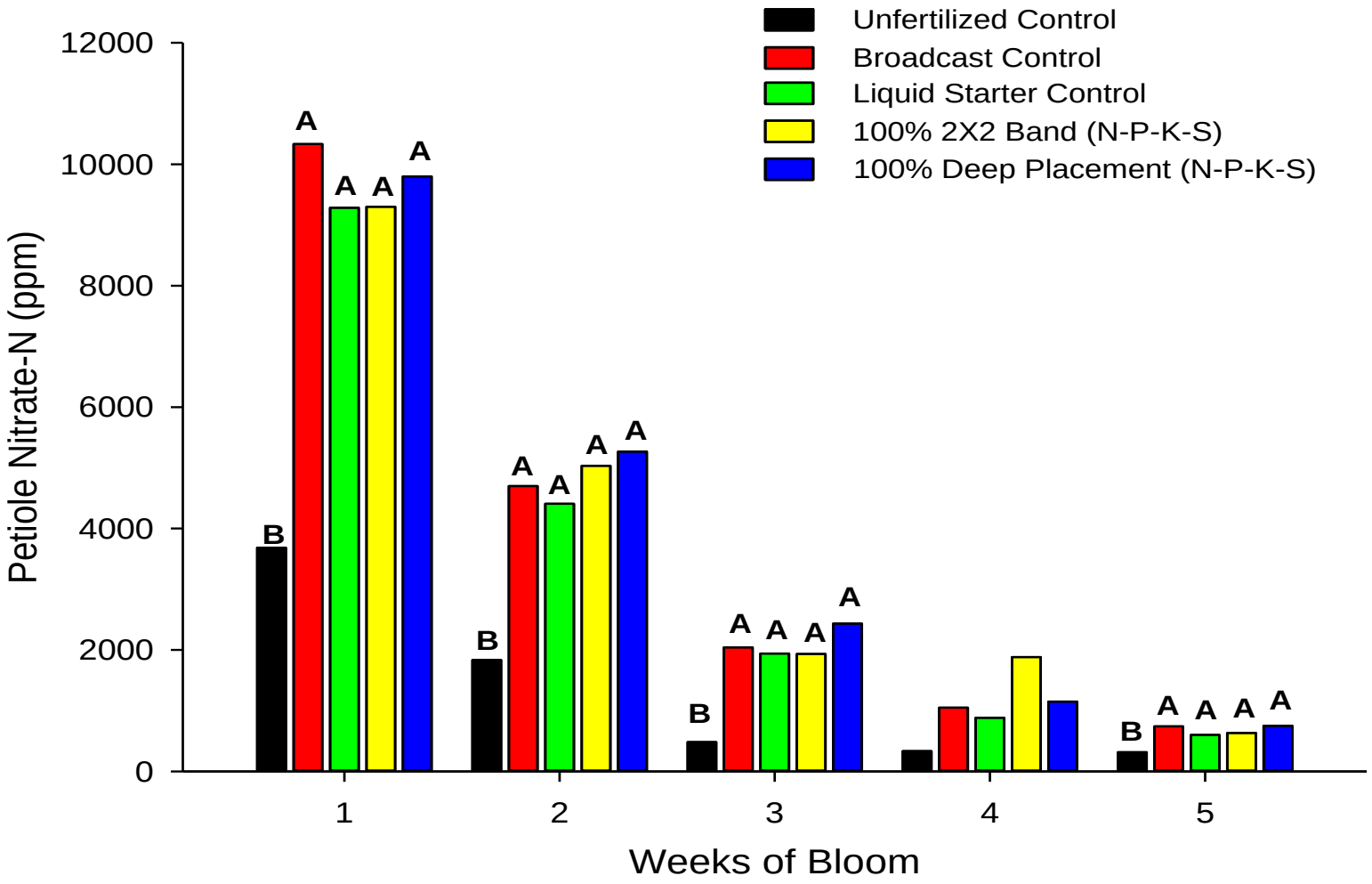
Nutrient Systems	Total Nodes				NAWF	
	5th‡	6th	7th	8th	9th	10th
Unfertilized Control	5.2	6.2	8.7	9.9	3.8	2.7
Broadcast Agronomic Control	5.1	6.4	7.8	9.9	4.1	2.6
Liquid Starter Control	5.3	6.5	8.3	9.7	3.4	2.9
100% 2X2 N-P-K-S	4.8	6.1	8.0	9.5	3.8	2.9
100% Deep Placement N-P-K-S	5.6	6.9	7.8	10.1	3.8	2.5

‡ Week after Planting

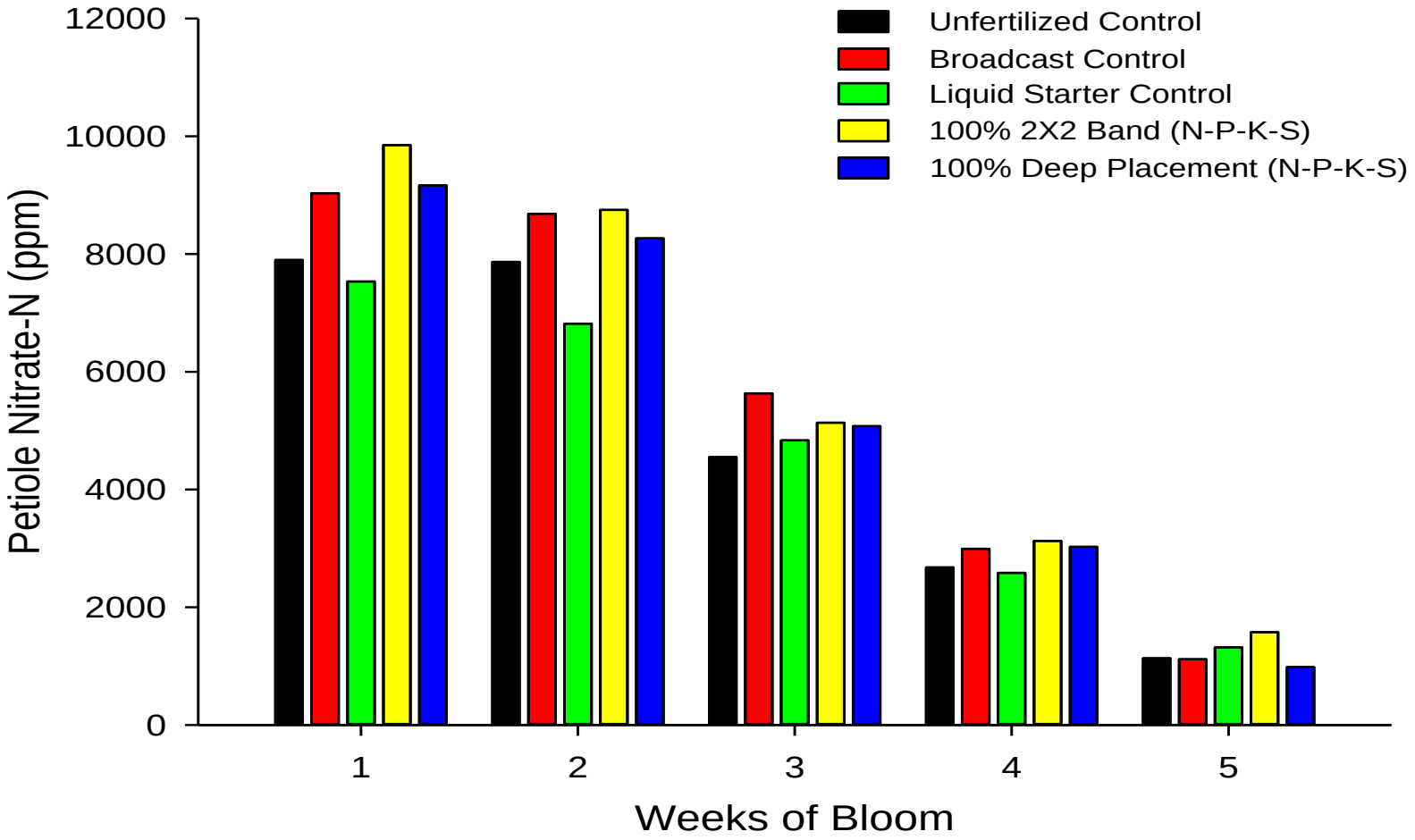
Petiole Nitrate-N Concentrations During Bloom Period in 2015



Petiole Nitrate-N Concentrations During Bloom Period at TAREC 2013-2015

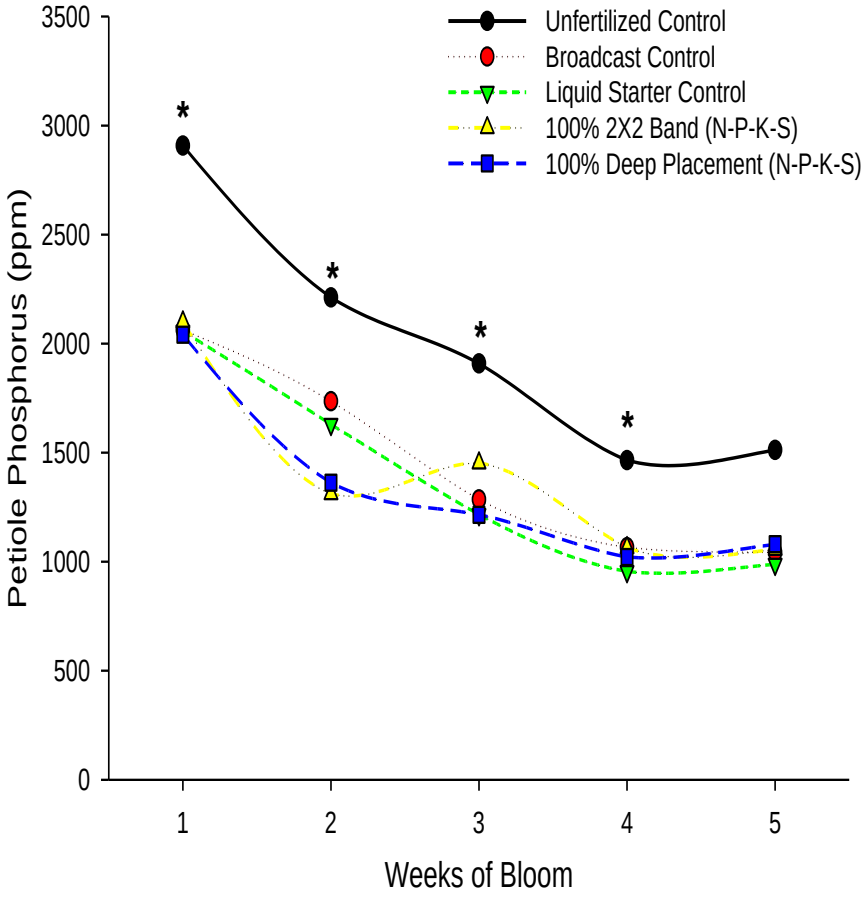


Petiole Nitrate-N Concentrations During Bloom Period at Lewiston 2013-2015

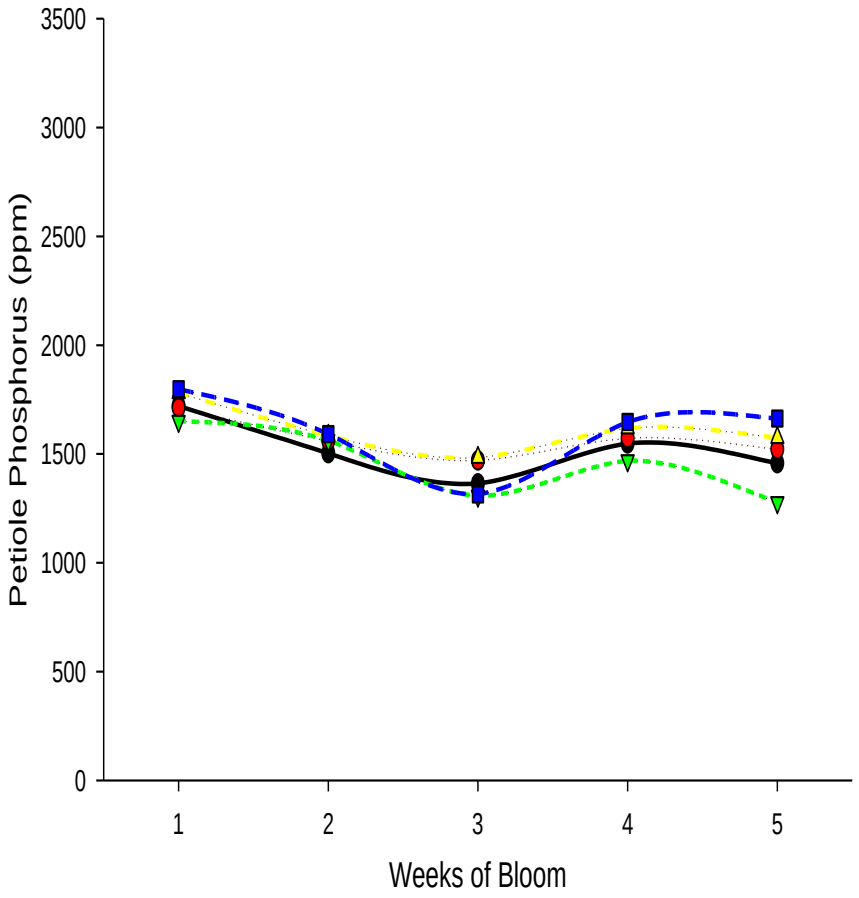


Petiole Phosphorus Concentrations During Bloom Period in 2015

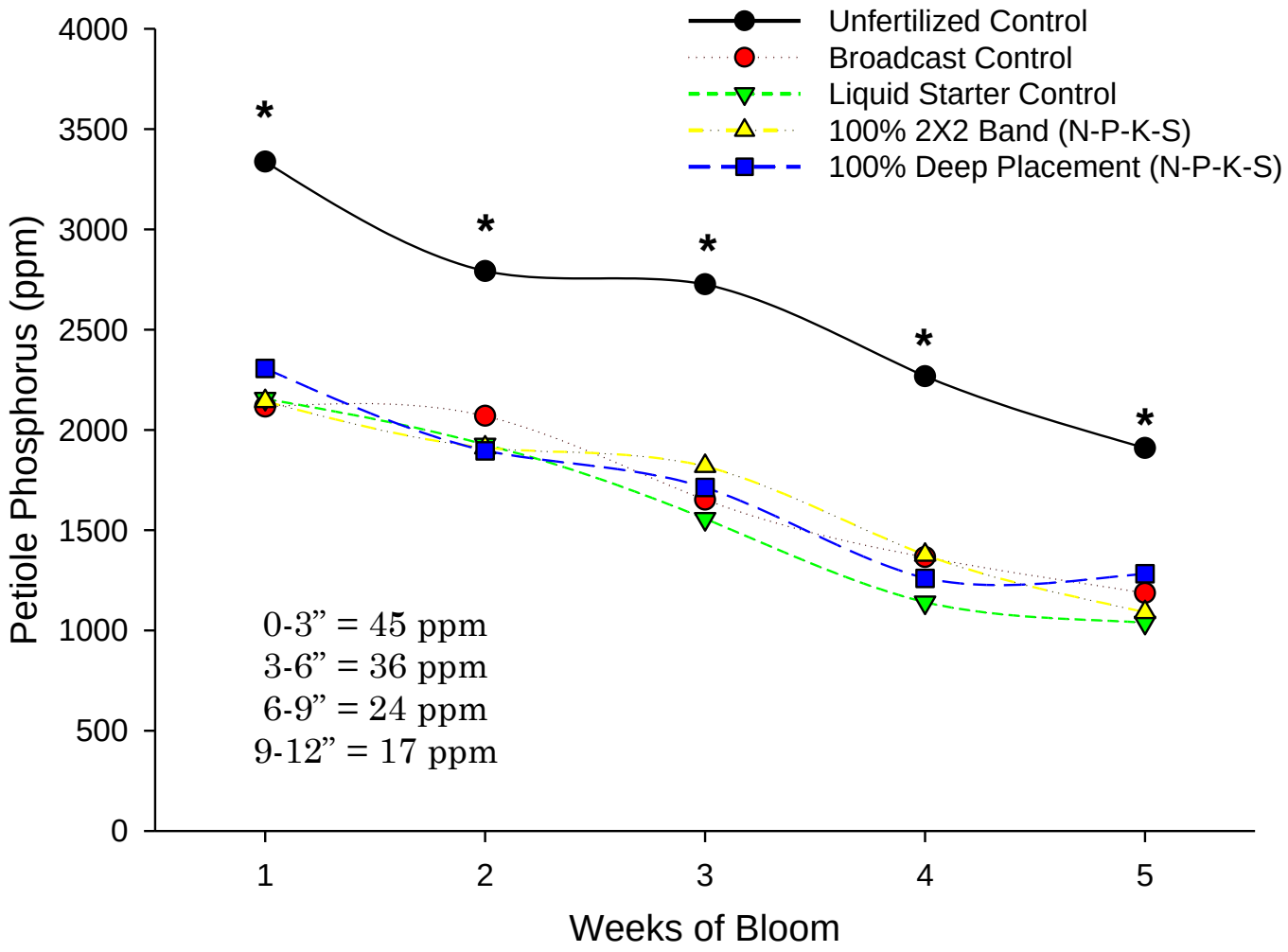
TAREC



Lewiston

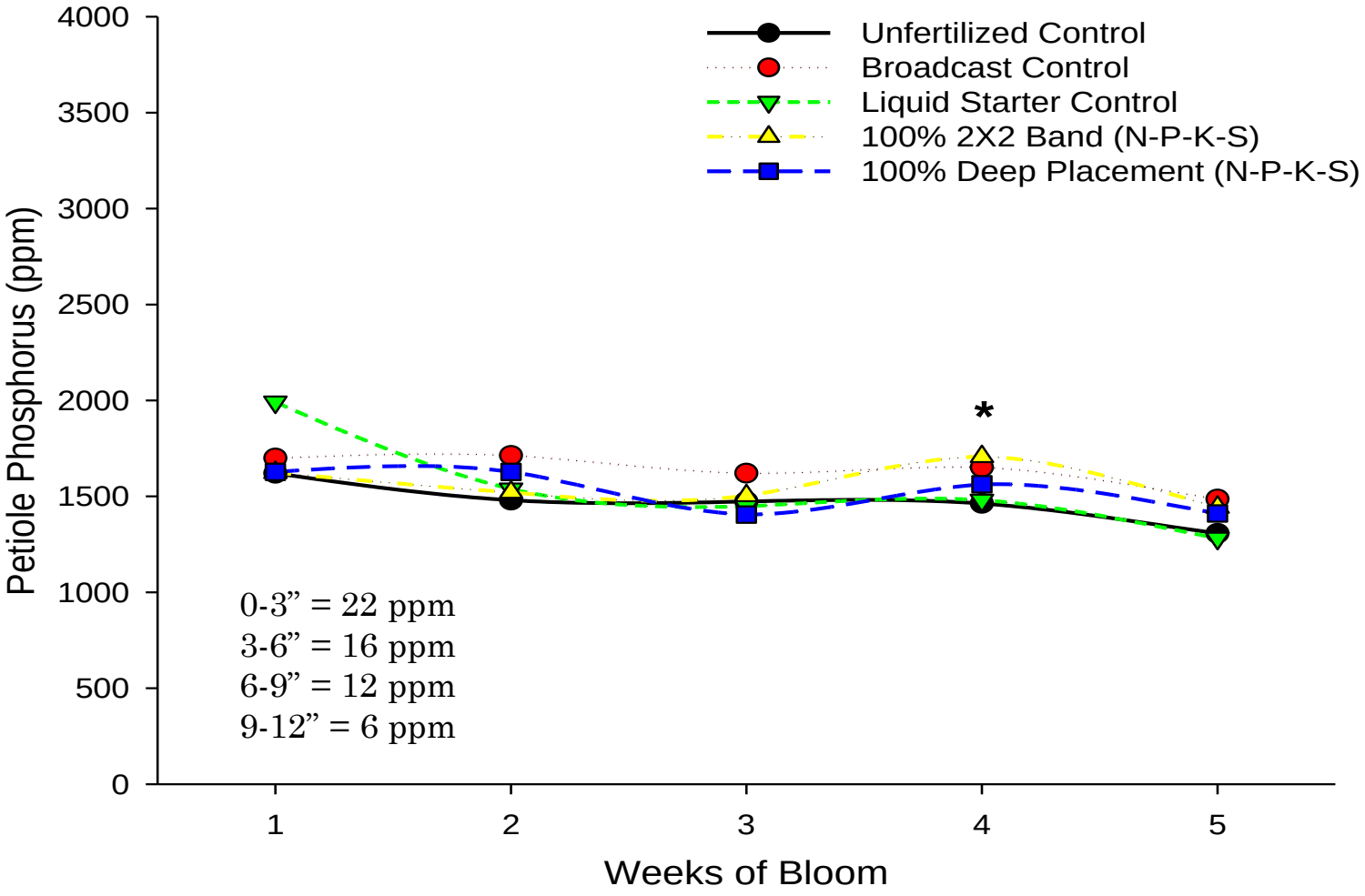


Petiole Phosphorus Concentrations During Bloom Period at TAREC from 2013-2015



* Atleast two treatments are significantly different at α = 0.1

Petiole Phosphorus Concentrations During Bloom Period at Lewiston from 2013-2015



* Atleast two treatments are significantly different at α = 0.05

Petiole Nitrate-N and Phosphorus Sufficiency Ranges during Bloom

"Arkansas" Interpretation (Benton and others 1979)

Time of sampling	*Nitrate nitrogen (ppm)*	*Phosphorus (ppm)*
Week of bloom	10,000–35,000	>800
Bloom + 1 week	9,000–30,000	*
Bloom + 2 weeks	7,000–25,000	*
Bloom + 3 weeks	5,000–20,000	*
Bloom + 4 weeks	3,000–13,000	*
Bloom + 5 weeks	2,000–8,000	
Bloom + 6 weeks	1,000–5,000	
Bloom + 7 weeks	0–5,000	
Bloom + 8 weeks	0–5,000	

* A decrease in P concentration of more than 300 ppm from the previous week usually indicates moisture stress

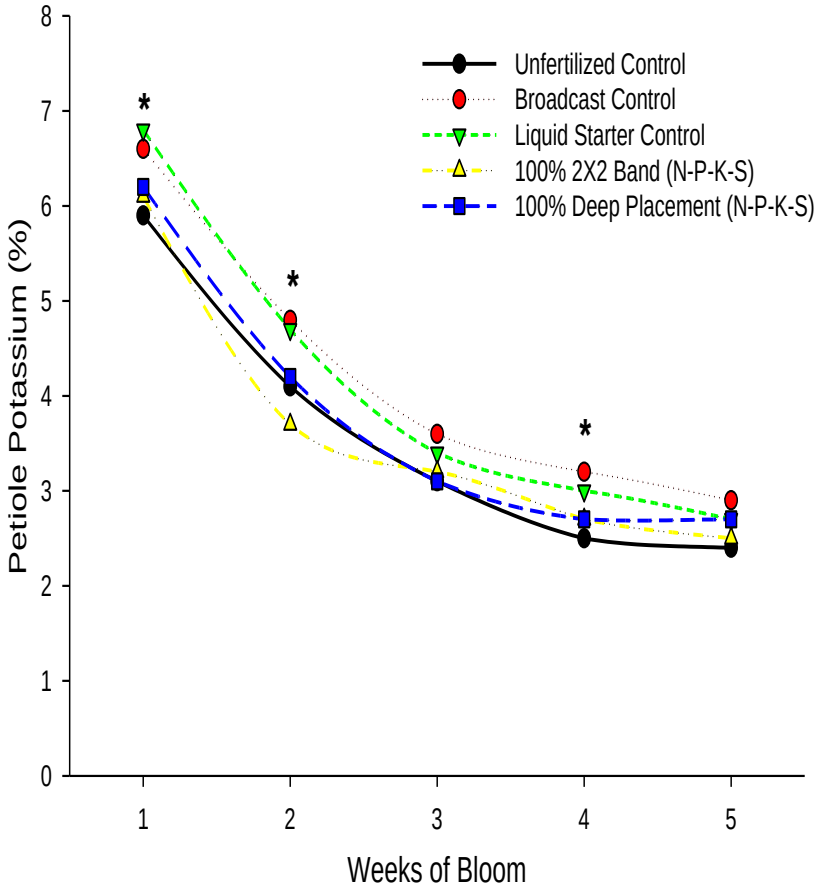
"Georgia" Interpretation (Lutrick and others 1986; Plank, personal communication)

Time of sampling	*Nitrate nitrogen (ppm)*	*Phosphorus (ppm)*
Week before first bloom	7,000–13,000	>800
Week of bloom	4,500–12,500	>800
Bloom + 1 week	3,500–11,000	*
Bloom + 2 weeks	2,500–9,500	*
Bloom + 3 weeks	1,500–7,500	*
Bloom + 4 weeks	1,000–7,000	*
Bloom + 5 weeks	1,000–6,000	*
Bloom + 6 weeks	500–4,000	
Bloom + 7 weeks	500–4,000	
Bloom + 8 weeks	500–4,000	

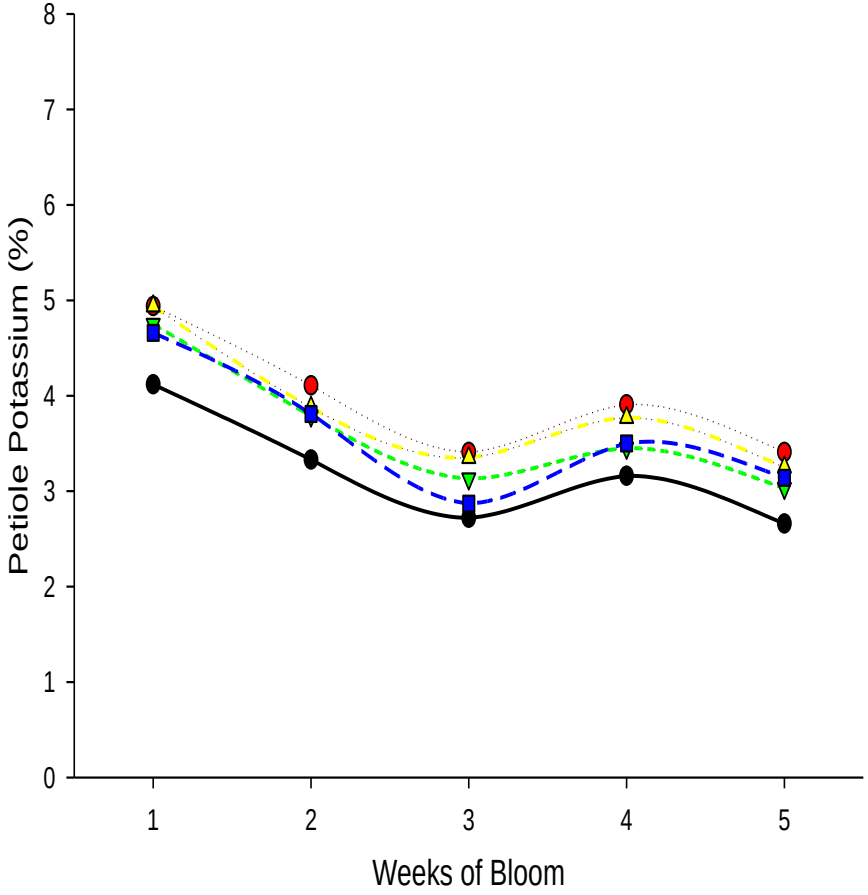
* A decrease in P concentration of more than 300 ppm from the previous week usually indicates moisture stress

Petiole Potassium Concentrations During Bloom Period in 2015

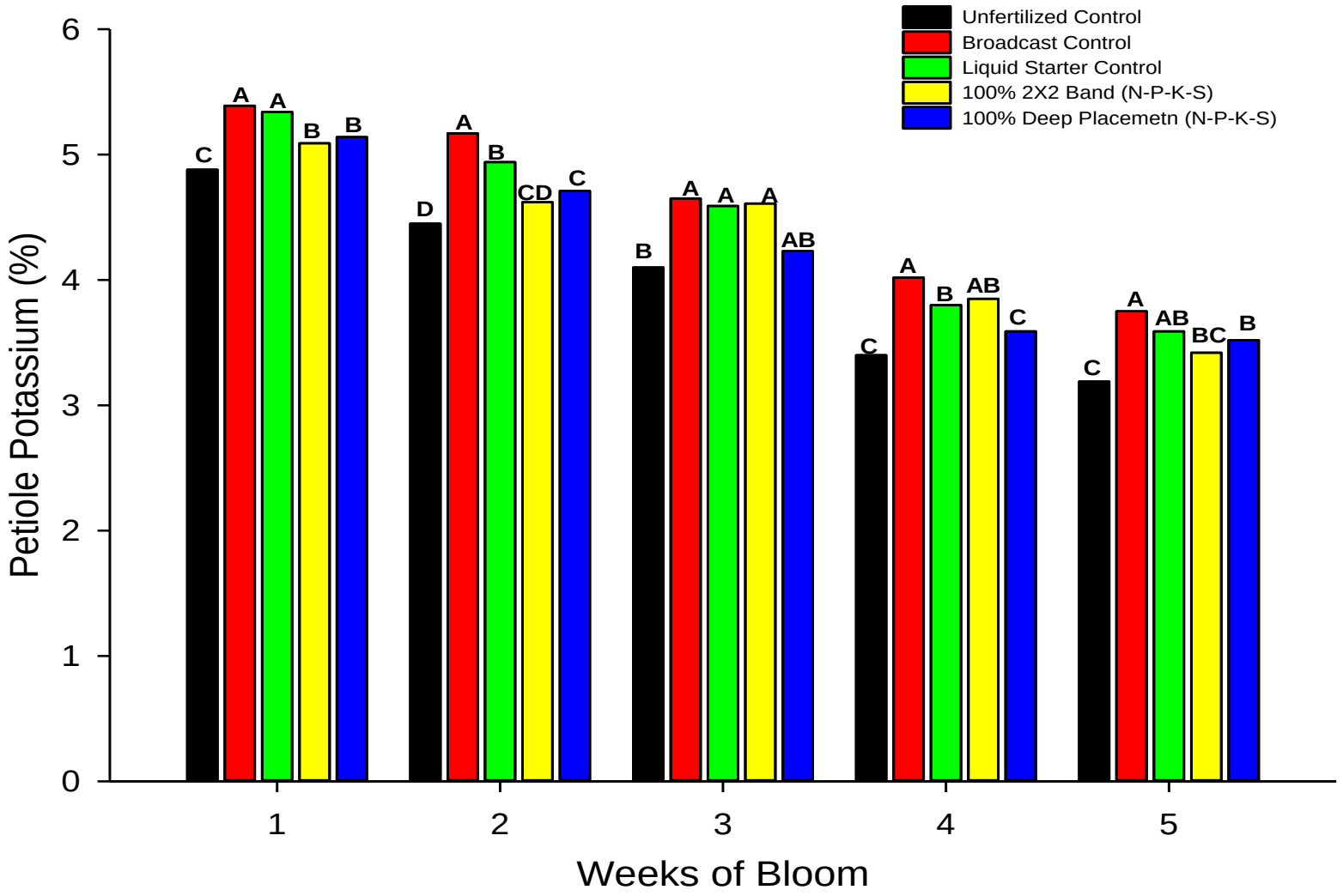
TAREC



Lewiston



Petiole Potassium Concentrations During Bloom Period for All Sites 2013-2015

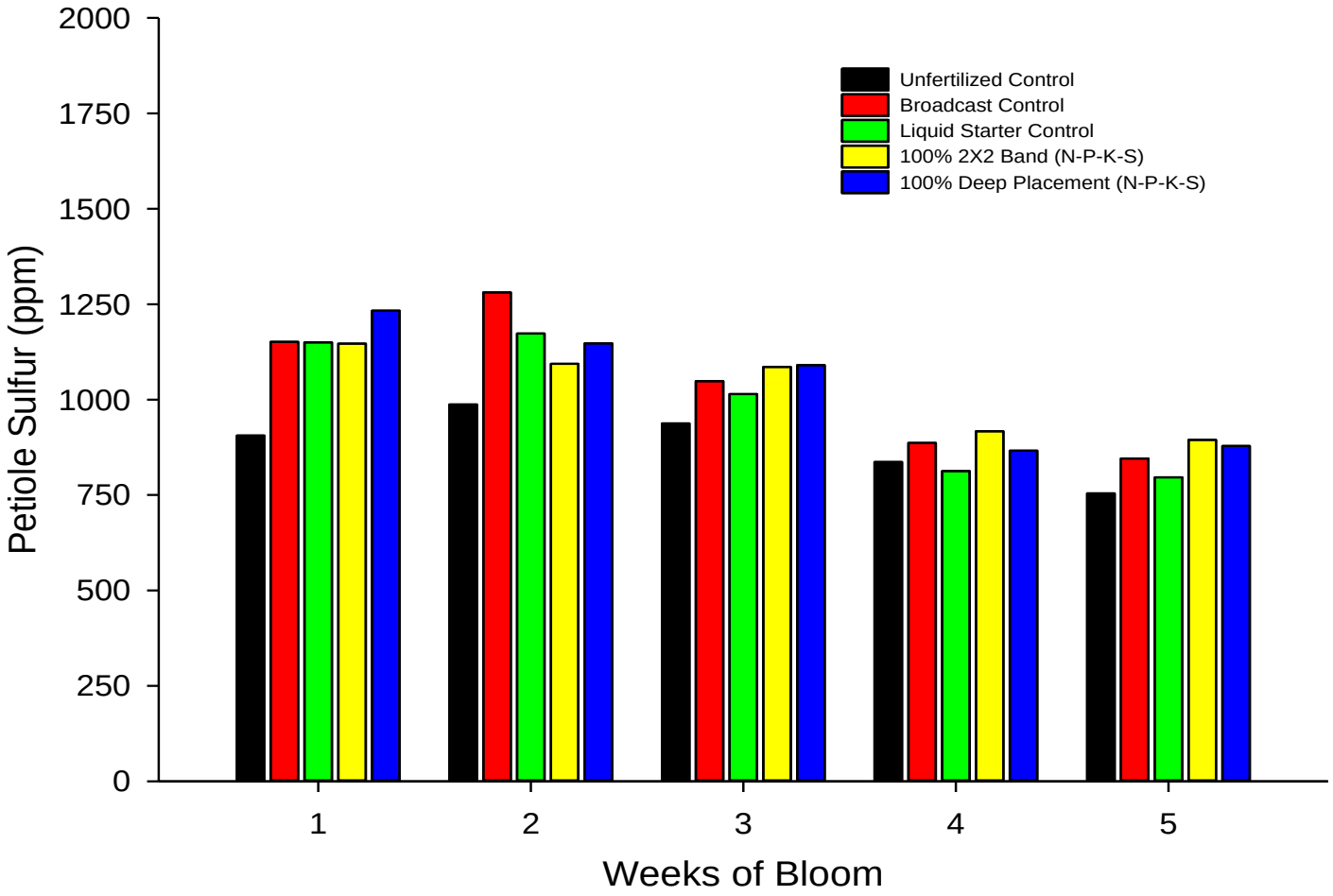


Petiole Potassium Sufficiency Range for Cotton

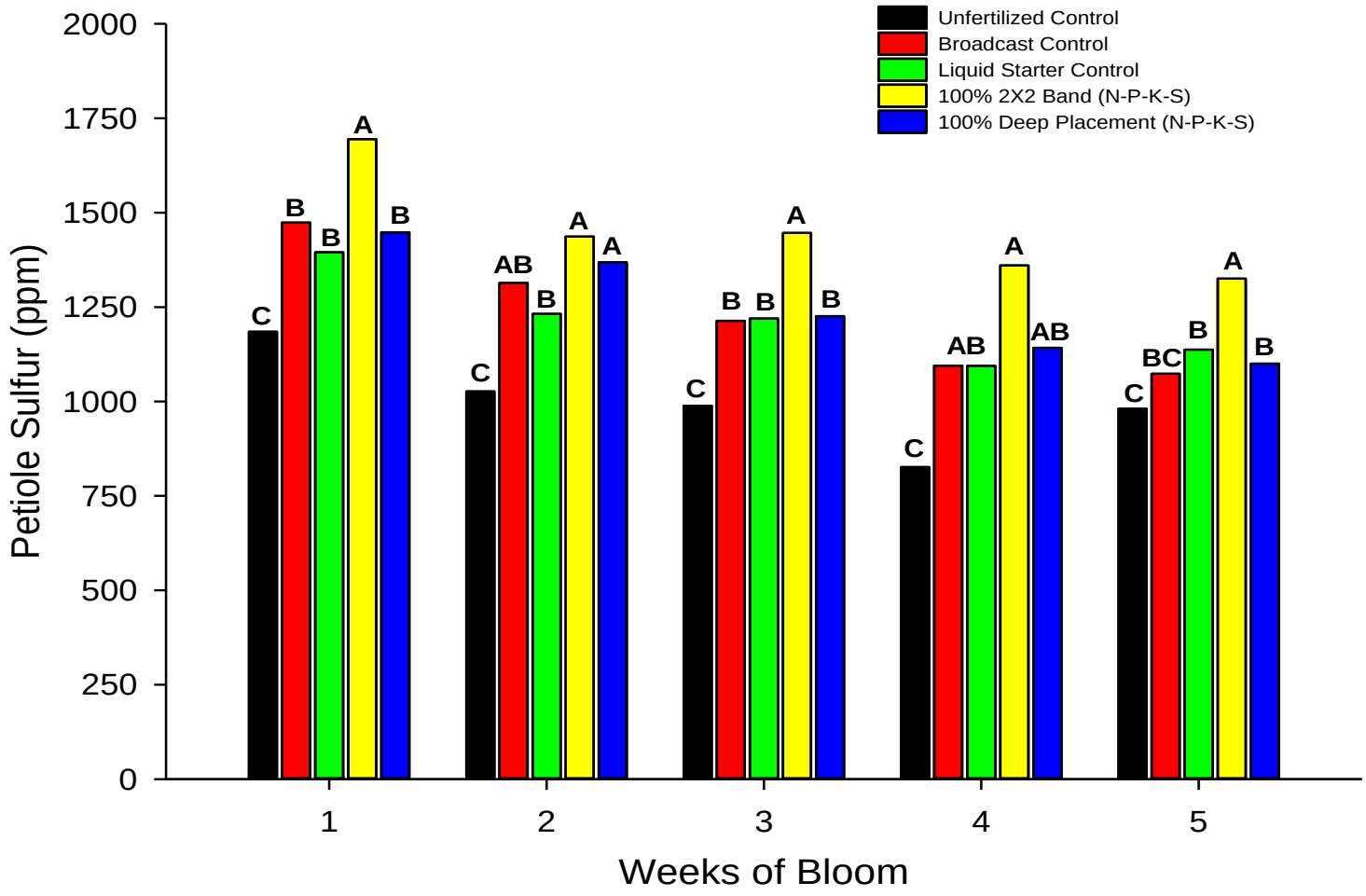
"California" Petiole K Interpretation (Bassett and MacKenzie 1976)

Time of sampling	*% Potassium (K)*
Week of first bloom	4.0–5.5
Bloom + 4 weeks	3.0–4.0
Bloom + 6 weeks	1.5–2.5
Bloom + 8 weeks	1.0–2.0

Petiole Sulfur Concentrations During Bloom Period for TAREC 2013-2015



Petiole Sulfur Concentrations During Bloom Period for Lewiston 2013-2015



Leaf Tissue Nutrient Concentrations at TAREC from 2013-2015

Nutrient Systems	Leaf Nutrient Concentrations							
	1st‡				5th			
	N	P	K	S	N	P	K	S
	%							
Unfertilized Control	3.41 c*	0.34	1.57	0.54 b	2.76 c	0.26	1.29	0.71
Broadcast Agronomic Control	4.32 a	0.32	1.77	0.76 a	3.49 ab	0.24	1.47	0.77
Liquid Starter Control	4.23 a	0.32	1.67	0.68 a	3.45 ab	0.23	1.44	0.75
100% 2X2 N-P-K-S	4.29 a	0.31	1.76	0.77 a	3.46 ab	0.23	1.44	0.78
100% Deep Placement N-P-K-S	4.16 b	0.31	1.66	0.76 a	3.56 a	0.23	1.47	0.77

*Values with the same letter are not significantly different at $\alpha = 0.05$

‡ Week of bloom

Macronutrients (%)						
	N	P	K	Ca	Mg	S
early bloom	3.0–4.5	0.2–0.65	1.5–3.0	2.0–3.5	0.3–0.9	0.25–0.8
late bloom / maturity	3.0–4.5	0.15–0.6	0.75–2.5	2.0–4.0	0.3–0.9	0.3–0.9

The following sufficiency ranges were compiled from several sources (Anderson and others 1971; Hodges and Hadden 1992; Mullins and Burmester 1990, 1992, 1993; Plank 1988; Reeves and Mullins 1993; Sabbe and Mackenzie 1973; Sabbe and others 1972).

Leaf Tissue Nutrient Concentrations at Lewiston from 2013-2015

Nutrient Systems	Leaf Nutrient Concentrations							
	1st‡				5th			
	N	P	K	S	N	P	K	S
	%							
Unfertilized Control	4.42	0.29 a*	1.09	0.60 c	3.95	0.28	1.26	0.71 c
Broadcast Agronomic Control	4.26	0.28 ab	1.12	0.69 b	3.92	0.29	1.29	0.79 b
Liquid Starter Control	4.31	0.26 c	1.09	0.67 bc	3.93	0.28	1.27	0.80 b
100% 2X2 N-P-K-S	4.40	0.27 bc	1.22	0.85 a	3.91	0.29	1.31	0.89 a
100% Deep Placement N-P-K-S	4.28	0.29 a	1.17	0.75 b	3.87	0.28	1.25	0.82 b

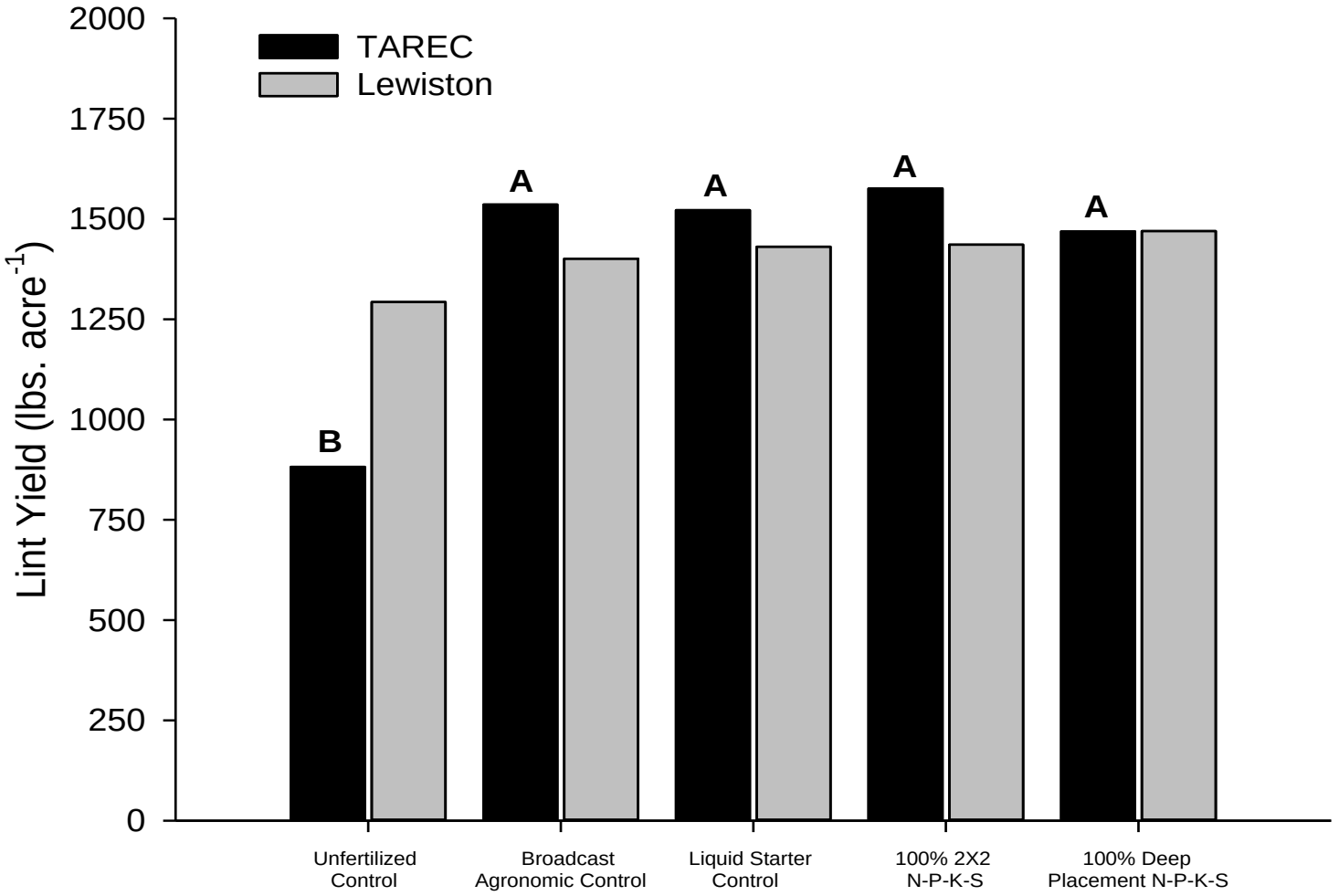
*Values with the same letter are not significantly different at α = 0.05

‡ Week of bloom

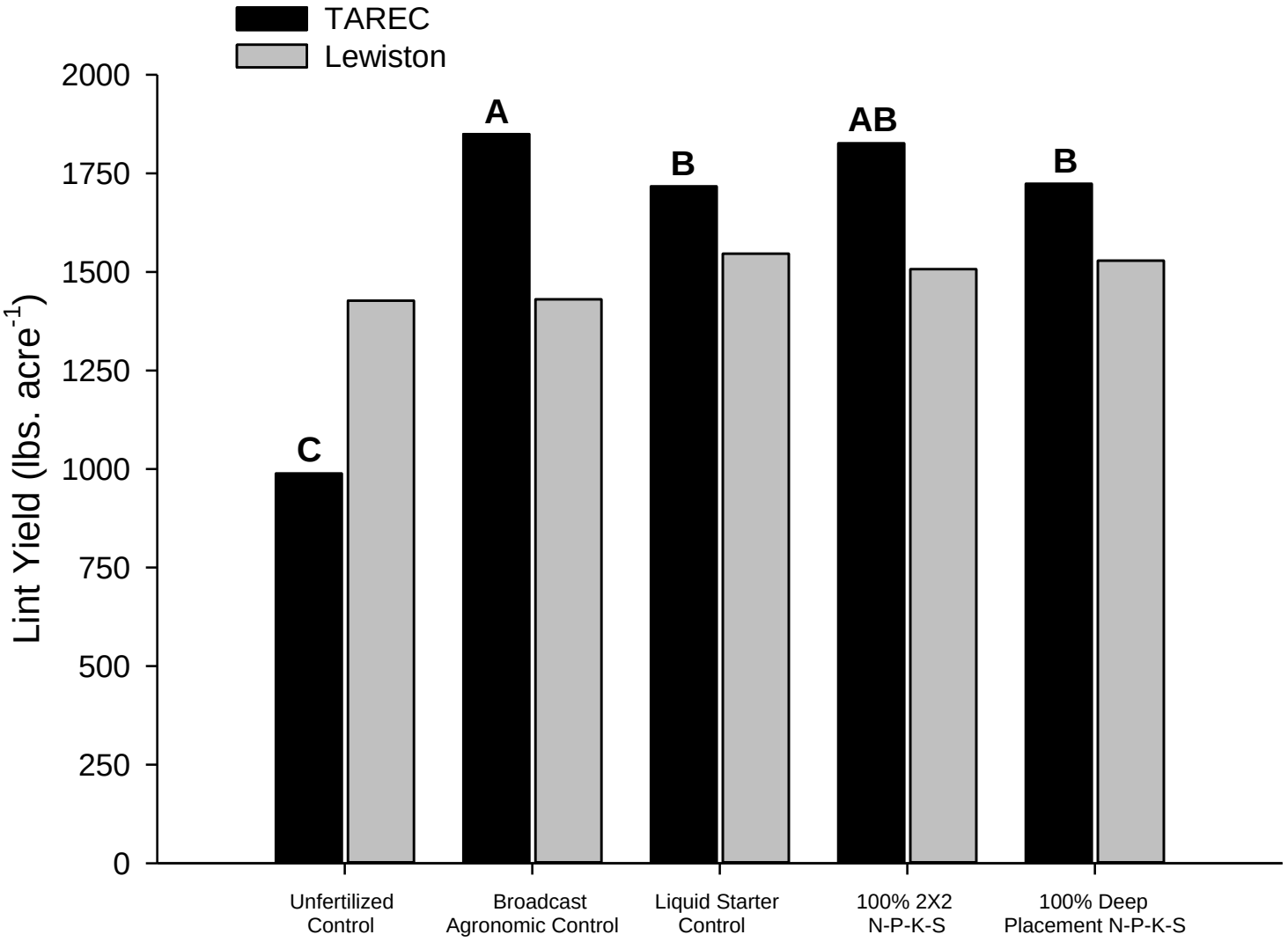
Macronutrients (%)						
	N	P	K	Ca	Mg	S
early bloom	3.0–4.5	0.2–0.65	1.5–3.0	2.0–3.5	0.3–0.9	0.25–0.8
late bloom / maturity	3.0–4.5	0.15–0.6	0.75–2.5	2.0–4.0	0.3–0.9	0.3–0.9

The following sufficiency ranges were compiled from several sources (Anderson and others 1971; Hodges and Hadden 1992; Mullins and Burmester 1990, 1992, 1993; Plank 1988; Reeves and Mullins 1993; Sabbe and Mackenzie 1973; Sabbe and others 1972).

Nutrient Management Systems and Lint Yield in 2015



Lint Yield and Nutrient Management Systems from 2013-2015



Conclusions

- Early season growth is very important in Virginia cotton production as weather can be variable during May
  - Cool temperatures
  - Heavy rainfall events
  - Little to no-rainfall
- Major response in plant heights, nodes, NAWF an yield can be mainly attributed to NITROGEN fertilization
- Nitrogen deficiency increased phosphorus concentrations in cotton petioles 1.5X
  - When petiole sampling is used in cotton, N status will be important when making decisions about in-season phosphorus management
- Petiole phosphorus and potassium concentrations decrease linearly throughout the bloom period regardless of fertilizer nutrient management systems
  - Rate of decrease (especially for phosphorus) seems to be related to soil test levels
- Petiole potassium significantly higher with the broadcast system than systems with banded potassium during 3 out of the 5 first weeks of bloom
  - Broadcast control had the highest petiole potassium levels every week.

Conclusions (cont.)

- Leaf tissue N, P, and K concentrations were less responsive than petiole nutrient levels during the study.
  - Sulfur was the one exception where leaf tissue concentrations were more consistent in differentiating differences among systems
  - Application of sulfur in the 2X2 band produced the highest leaf S concentrations in every sampling interval at Lewiston where no side-dress S was applied.
- Lint yields were higher with the broadcast agronomic control than the liquid starter control and deep placement systems at TAREC when all years were combined.
- At Lewiston, where side-dress N was applied no significant lint yield response was observed among nutrient management systems.
  - However when liquid banded phosphorus was applied average lint yields were 45 lbs. per acre higher than the broadcast agronomic control.
  - This response was similar to work conducted by Crozier with banded P applications
- Responses to P and K application rate, placement, and placement combinations were sparse during the study for every dependent variable measured
  - Relatively small rate differences (20 vs. 60 lbs. P_2O_5/K_2O)

Acknowledgements

- Fluid Fertilizer Foundation
- Water's Agricultural Laboratories, Inc.
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- Gail White, Research Specialist, VA Tech
- David Horton, Research Specialist, VA Tech


Questions?