

Upland and Pima Cotton Response to Soil and Foliar Potassium at Three Arizona Locations

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Abstract

Due to a limited information describing the response of cotton (*Gossypium* spp.) in Arizona to K fertilization, three studies were conducted in 1992 with the objective of evaluating the response of cotton crop growth and lint yield to soil and/or foliar applications of K fertilizer. The locations of the trials included the Safford Agriculture Center (Pima clay loam), Maricopa Agriculture Center (Casa Grande sandy loam), and a site located near Coolidge, AZ on a Mohall sandy loam soil. All irrigation, pest management, and fertilization inputs (other than K) were provided on an as-needed basis throughout the season. Routine plant measurements and plant mapping analyses were carried out at each location on regular intervals throughout the season. At the Safford location both Upland (*G. hirsutum* L., var DPL 90) and Pima (*G. barbadense* L., var S-6) cotton were planted with treatments including soil and foliar K applications imposed in a factorial arrangement. All soil K applications were broadcast and preplant incorporated using K_2SO_4 as the K source at rates of 0, 200, and 400 lbs. $K_2O/acre$. Four 4.6 lbs $K_2O/acre$ foliar applications of KNO_3 were applied at 1626, 2016, 2326, and 2510 heat units after planting (HUAP). The trial at the Maricopa Agriculture Center included four foliar K applications over the growing season applied to Pima cotton (S-6) at 2427, 2762, 3200, and 3515 HUAP. The six foliar treatments included rates which ranged from 0 to 37 lbs. $K_2O/acre$ using KNO_3 as the K source. Treatments were arranged over the experimental area in a randomized complete block design with five replications. At Coolidge all K treatments were band-applied to the soil at a depth of 8 in. using two shanks per row, preplant. The treatments were 0, 218, 436, and 654 lbs. $K_2O/acre$ using K_2SO_4 as the fertilizer source. Upland cotton (STV KC311) was planted and treatments were arranged in a randomized complete block design with four replications. Results from all three trials indicated no differences among any of the treatments (including soil versus foliar and unfertilized treatments). All of the plant measurements taken for all the locations reveal crop growth resulting in excellent fruit retention without vegetative growth (i.e. height-to-node ratios within the long-term 95% confidence intervals for both Upland and Pima cotton. This indicates ample nutrient demand so that if available soil K is inadequate to meet crop needs, deficiency symptoms and reduced yields should occur. No visual deficiency symptoms were detected for any treatment in the experiments (all locations). All plots experienced vigorous and well-balanced growth and development throughout the growing season. The results of these K fertility experiments supports current University of Arizona recommendations that unless exchangeable K is less than 150 ppm, crop response is not likely, although an exact critical level for exchangeable K is still lacking.

Introduction

Potassium (K) is commonly recognized as an essential nutrient for plant growth and development, and is considered a macronutrient similar to nitrogen and phosphorus in terms of total amounts required by plants. Total K in many soils is often between 0.5 to 2.5%, and commonly is about 1.2% (Tisdale et al., 1985). Soil K is commonly classified as being part of four general fractions 1) mineral, 2) nonexchangeable, 3) exchangeable, and 4) soil solution K. In terms of the K that is available to a plant over the period of a crop production season, the mineral and nonexchangeable forms of K are generally not included as an immediately available form of K, but are brought into the exchangeable and soil solution phases over time through soil mineral weathering (Tisdale et al., 1985). The actual mineral composition of a soil is known to dictate to a large degree the actual K fertility status that a soil realizes (Rich, 1968 and Tisdale et al., 1985). For example, mica is known to be a relatively K rich soil mineral and can render a large K supplying power to plants over time. Vermiculite is another important K mineral, in that it has a strong K - fixing capacity. The fixation of soil K often refers to the placement of K within the actual lattice structure of soil clay minerals, which renders the K so fixed in a form that it is not directly available to plant roots. Feldspars are also considered as soil minerals which harbor a high natural reserve supply of K. Agricultural soils of the Sonoran Desert regions of Arizona commonly have parent materials originating from igneous rocks, which upon weathering and soil forming processes often produce soil minerals such as mica and biotite, that are K bearing soil minerals (Hendricks, 1985).

Potassium is important to cotton plants for many physiological processes, but it has received considerable attention in its relation to fiber development. The development of individual fiber cells are dependent upon the maintenance of adequate turgor pressure within the cell (in the vacuole), which is controlled by a K^+ malate solute system (Dhindsa et al., 1975). Over the years many experiments have been conducted which have studied the effects of K fertilizers on cotton (Kerby and Adams, 1985). In the San Joaquin Valley (SJV) of California, Cassman and his colleagues have documented positive responses of Acala cottons grown on vermiculitic soils to K fertilization with regard to yield and fiber quality (Cassman et al., 1990). In this work they have shown the relationship in the cotton response pattern to the soil mineralogy and the vermiculitic nature of the soils in question which have a high K fixation capacity (Cassman et al., 1989b), the distribution of the root systems of two varieties of Acala cotton (Gulick et al., 1989), and then of the differential response of the two Acala varieties to K fertilization (Cassman et al., 1989a). This recent work done in the SJV has also documented the anomalies earlier described concerning K deficiency symptoms by Stromberg (1960); in that the foliar symptoms of K deficiency on cotton are not typical of other common crop plants, where symptoms on cotton commonly occur on young rather than older leaves and often appear at a time when sink demand (boll load) becomes great. Another interesting feature from this work is that no consistent relationships between lint yield and soil K availability indices have been developed for affected soils in the SJV (Cassman, 1986).

Further east in the U.S. Cotton Belt, recent research on K fertility of cotton have shown responses in Alabama (Mullins et al., 1991), Mississippi (Tupper et al., 1991a and Tupper et al., 1991b), and Arkansas (Oosterhuis et al., 1991). Most of the responses to K fertilization were found with soil applied treatments (Mullins et al., 1991 and Tupper et al., 1991a). However, responses to foliar applications of potassium nitrate (KNO_3) have also been reported (Oosterhuis et al., 1991).

Due to the increasing importance and interest in cotton lint quality, and therefore in fiber development, there has been increased interest in K fertility of cotton grown in Arizona. This interest has also been propelled by the positive responses found elsewhere, as noted by the aforementioned research in various parts of the U.S.. Agricultural soils of the Sonoran Desert regions of Arizona are commonly high in available K (as determined by soil extractions such as ammonium acetate) and in total K based upon common soil mineralogy. The soil conditions in other parts of the country where cotton responses to K fertilization are found usually differ significantly from those soils found in cotton producing areas of Arizona. However, due to a limited amount of information describing the responses of cotton in Arizona to K fertilization, a project was initiated in 1990 to evaluate cotton producing soils and their potential K fertility provisions. The first part of this project includes a survey of 10 common agricultural soils of southern Arizona and a complete characterization of the chemical and physical composition of the soils relative to K fertility (Unruh et al., 1993). The second part of this project

involves field experimentation to measure the response of cotton to K fertilization. The initial field experimentation component of this project, was a single field experiment was initiated in 1991 (Silvertooth et al., 1992). In 1992 three different K fertility studies were begun with the objective of evaluating the response of cotton crop growth, in-season fertility status, lint yield and lint quality to soil and/or foliar applications of K fertilizer.

Materials and Methods

Three K fertility trials were initiated in 1992. The locations of the trials included the Safford Agriculture Center (Pima clay loam), Maricopa Agriculture Center (Casa Grande sandy loam), and a cooperater site located near Coolidge, AZ on a Mohall sandy loam soil series. Initial soil test results are given for each location in Table 1. The exchangeable cations including Ca, Mg, Na, and K were extracted using 1 M ammonium acetate (pH 7), and exchangeable Zn was extracted with DTPA. Phosphate (P) was extracted with sodium bicarbonate, and nitrate ($\text{NO}_3\text{-N}$) was determined using an ion-specific electrode. Soil pH was determined using a glass electrode (1:1 soil-to-water ratio).

All irrigation, pest management, and fertilization inputs (other than K) were provided on an as-needed basis throughout the season. Routine plant measurements consisting of plant height, number of mainstem nodes, bloom counts per unit area (75 ft^2), number of nodes from the top white bloom to the terminal (NAWB), percent canopy closure, and plant mapping analyses were carried out at each location on regular intervals throughout the season. All fertilization and plant mapping was carried out on a heat unit (HU) basis using $86/55^\circ \text{ F}$ thresholds, and expressed commonly as HU accumulated after planting (HUAP).

At the Safford Agriculture Center both Upland (DPL 90) and Pima (S-6) cotton were planted 21 April and watered-up on 23 April 1992. Plots consisted of eight 40 in. rows, each 34 ft. in length. Treatments included both soil and foliar K applications. All soil K application were broadcast and preplant incorporated using K_2SO_4 as the K source. Four foliar applications of KNO_3 were applied over the growing season, the date, HUAP, and rate of each foliar application is given in Table 2. All foliar applications were made using a ground-rig applicator with 25 gal./acre carrier. The soil and foliar K applications were combined to form a factorial arrangement of treatments with five replications as shown in Table 3. The Upland and Pima cotton had a final irrigation on 29 September and yield estimates were made by mechanically picking the center four rows of each plot on 18 November

The fertility trial at the Maricopa Agriculture Center included only foliar K applications over the growing season applied to Pima cotton (S-6). Cotton was planted on 19 April (HU after 1 January) in plots consisting of four 40 in. rows which were 40 ft. long. Foliar treatment rates and dates (HUAP) are given in Table 4. The six foliar treatments were arranged over the experimental area in a randomized complete block design with five replications. The experimental area had a final irrigation on 28 August and plots were mechanically picked on 19 November.

At Coolidge all K treatments were band-applied to a depth of 8 in. using two shanks per row, preplant. Plots were eight 40 in. rows wide and extended the full length of the irrigation run (1200 ft.). The K source was K_2SO_4 and the rate of application is shown in Table 5. Upland cotton (STV KC311) was planted on 14 April (512 HU after 1 January) and treatments were applied in a randomized complete block design with four replications. The last irrigation was 10 September prior to mechanical picking of the center eight rows on 29 October.

Results and Discussion

The height-to-node ratios (HNR) and fruit retention for both Upland and Pima cotton at the Safford Agriculture Center are shown for 1992 in Fig. 1 to 4. All the treatments resulted in measured parameters (HNR and fruit retention) falling between the long-term 95% confidence intervals for both Upland and Pima. This indicates normal growth and development and good fruit retention, and thus a strong sink for K nutrition. The yield data reported in Table 3 shows no differences among any treatments (including the unfertilized check). The treatments were separated into groups of "Soil" and "Foliar" and a single degree of freedom orthogonal contrast was

computed for the groups. There was no significant difference between the "Soil" and "Foliar" groups for either Upland or Pima cotton (the observed significance level (OSL), or probability of a greater F from the analysis of variance, was 0.2 in both cases).

Table 4 lists the six foliar treatments applied, and the associated lint yield at the Maricopa Agriculture Center. Figures 5 and 6 show the HNR and fruit retention, respectively. Statistical analysis revealed no differences among any of the treatments.

At Coolidge the HNR (Fig. 7) and fruit retention (Fig. 8) parameters show that the crop progressed normally over the growing season. In Table 5 the treatments and associated lint yield are listed. The overall comparison of treatments from the analysis of variance indicates no treatment differences (Table 5 OSL = 0.3).

Summary

It seems reasonable that circumstances which may result in potential responses to K fertilization on cotton would include low soil test K (< 150 ppm K), a coarse soil texture, and the development of a strong nutrient sink (boll load). All of the plant measurements taken for all the locations reveal crop growth resulting in excellent fruit retention (Fig. 2, 4, 6, 8) without vegetative growth (i.e. HNRs within the long-term 95% confidence intervals, Fig. 1, 3, 5, 7). This indicates ample nutrient demand so that if available soil K is not adequate to meet crop needs, deficiency symptoms and reduced yields should occur. No visual deficiency symptoms were detected for any treatment in any of the experiments. All plots experienced vigorous and well-balanced growth and development throughout the growing season. A good boll load was developed and maintained through harvest, as was evidenced by high fruit retention levels recorded from all plots at several dates of sampling.

At all locations there was a trend of decreasing extractable K with increasing soil depth, this being most pronounced at the Safford and Maricopa locations (Table 1). However, from the initial levels of K found at each experimental site, response to K fertilization is not likely (i.e., extractable K > 150 ppm at all depths). The results of these three K fertility experiments supports this conclusion, although an exact critical level for exchangeable K is still lacking.

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Table 1. Preseason soil test results for three Arizona K fertility experiments in 1992.

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Soil	Exchangeable							pH	EC	ESP†
Depth	Ca	Mg	Na	K	Zn	NO ₃ -N	P			
ft.	mg/kg								ds/m	%
Safford Agriculture Center										
1	8000	840	1840	726	1.5	10	10	8.4	2.8	14.1
2	5800	500	1550	405	1.8	6	5	8.6	2.4	16.5
3	2200	221	850	214	1.6	6	10	9.0	1.9	21.6
4	1450	184	810	198	1.4	4	10	9.2	1.9	27.5
Maricopa Agriculture Center										
1	3220	340	206	566	NA‡	18.0	18.0	8.4	1.4	4.2
2	6800	430	211	520	NA	8.0	9.2	8.4	1.4	2.3
3	7400	400	209	352	NA	4.4	3.7	8.4	1.4	2.2
4	7400	382	211	280	NA	5.2	4.5	8.4	1.4	2.2
Coolidge, AZ										
1	6650	412	202	320	NA	10.4	4.1	8.5	1.9	2.3
2	6880	445	307	300	NA	8.0	5.5	8.5	1.6	3.3
3	7100	547	610	311	NA	4.4	3.0	8.4	2.5	6.1
4	6900	475	377	232	NA	7.6	2.2	8.6	2.1	4.0

† Computed - exchangeable sodium percentage.

‡ Not available.

Table 2. Dates of foliar K applications, Safford Agricultural Center, AZ, 1992.

Date	HUAP†	Rate lbs. K ₂ O/acre
3 August	1626	4.6
19 August	2016	4.6
4 September	2326	4.6
14 September	2510	4.6

† HUAP, Heat Units (86/55°F thresholds) accumulated after planting on 19 May (978 HU after 1 January).

Table 3. Lint yield means for all soil and foliar K treatments at the Safford Agriculture Center, AZ, 1992.

Treatment		Lint Yield	
Soil†	Foliar‡	Upland (DPL 90)	Pima (S-6)
lbs. K ₂ O/acre		lbs./acre	
0	0	1109	515
0	18.4	1075	495
200	0	1052	464
200	18.4	1082	491
400	0	1035	447
400	18.4	1170	526
OSL§		0.3	0.3
LSD _{0.05}		NS¶	NS
CV (%)		10.7	17.6

† Broadcast-applied, preplant, and incorporated.

‡ Sum of four 4.6 lbs. K₂O/acre foliar applications as KNO₃.§ Observed significance level, or probability of a greater *F* value.

¶ Not significant.

Table 4. Foliar K applications which comprised each treatment and the associated plant mapping and lint yield of Pima cotton (S-6) at Maricopa Agriculture Center, AZ, 1992.

Trt†	Date (HUAP)‡				Measurements at 2999 HUAP		
	28 July (2427)	10 August (2762)	26 August (3200)	9 Sept. (3515)	Height/Node Ratio	Fruit Retention	Lint Yield
	lbs. K ₂ O/acre				in.	%	lbs./acre
1	0	0	0	0	1.6	56	1173
2	4.6	4.6	4.6	4.6	1.7	57	1170
3	9.2	9.2	9.2	9.2	1.7	55	1203
4	0	4.6	4.6	0	1.6	55	1217
5	0	9.2	9.2	0	1.6	52	1182
6	0	9.2	0	0	1.5	52	1169
OSL§							0.1
LSD _{0.05}							NS¶
CV (%)							5.7

† All foliar treatments were applied with a ground-rig applicator.

‡ Heat units (86/55°F thresholds) accumulated after planting (19 April, 604 HU after 1 January).

§ Observed significance level, or probability of a greater *F* value.

¶ Not significant.

Table 5. Lint yields for soil K treatments applied preplant to Upland cotton (STV KC311) at Coolidge, AZ, 1992.

Treatment	Rate	Lint Yield	
	lbs. K ₂ O/acre	lbs./acre	
1	0	1301	
2	218	1238	
3	436	1234	
4	654	1213	
		OSL†	0.3
		LSD _{0.05}	NS†
		CV (%)	4.4

† Observed significance level, or probability of a greater *F* value from the analysis of variance.

† Not significant.

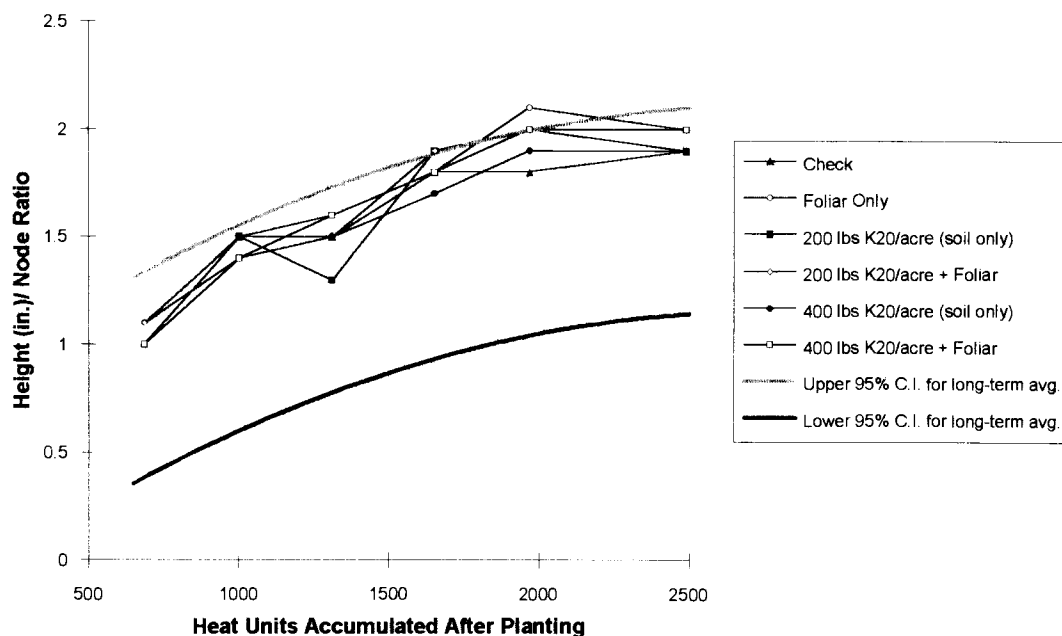


Fig. 1. Height-to-node ratio as function of HUAP for each K fertility treatment applied to Upland cotton (DPL 90) at the Safford Agriculture Center, AZ, 1992.

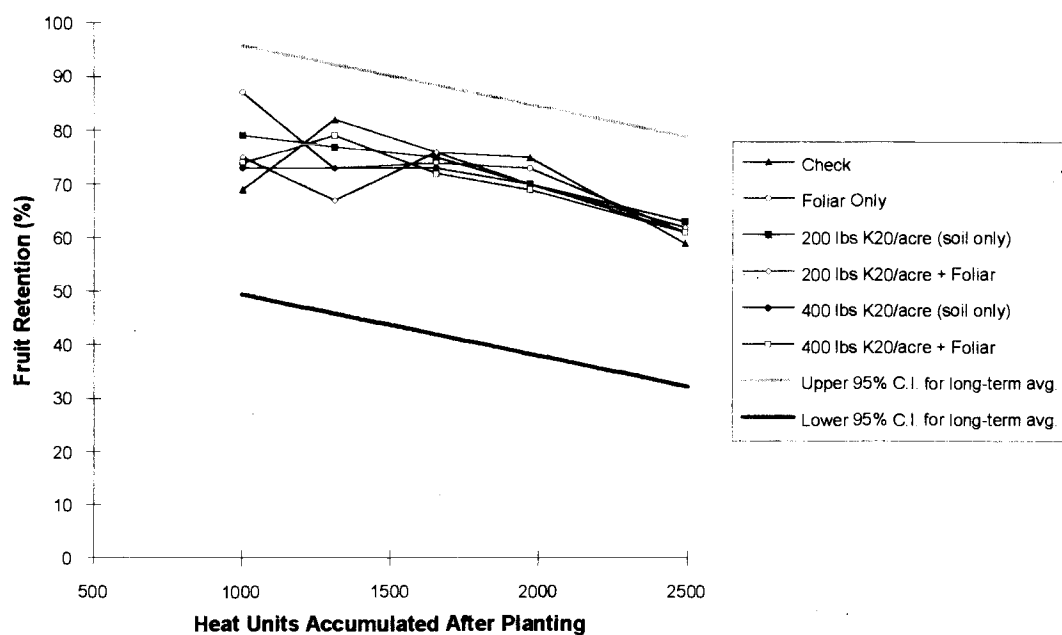


Fig. 2. Fruit retention as function of HUAP for each K fertility treatment applied to Upland cotton (DPL 90) at the Safford Agriculture Center, AZ, 1992.

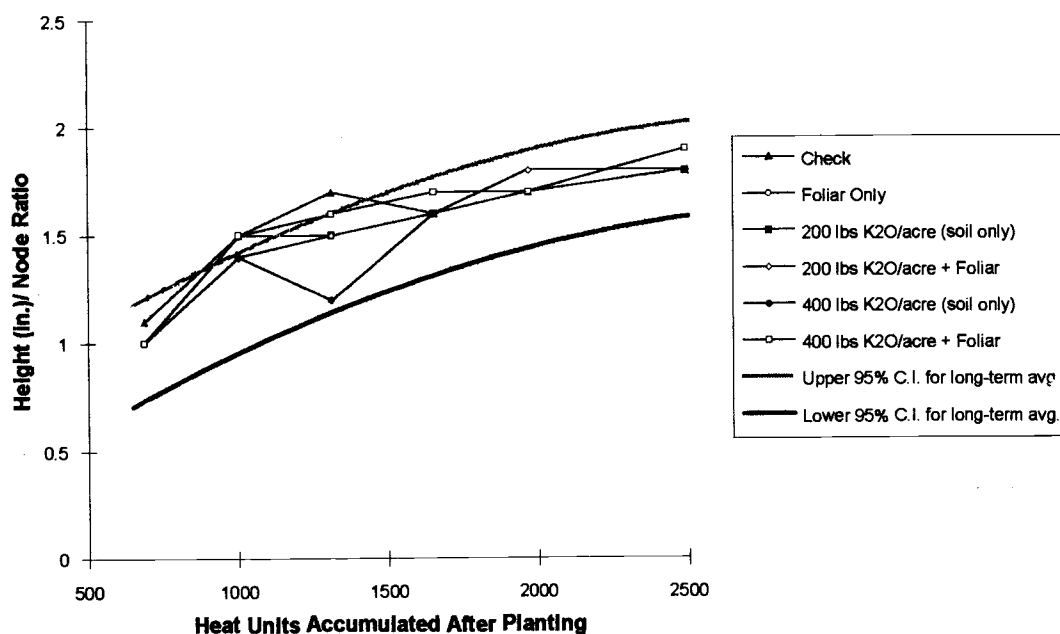


Fig. 3 Height-to-node ratio as function of HUAP for each K fertility treatment applied to Pima cotton (S-6) at the Safford Agriculture Center, AZ, 1992.

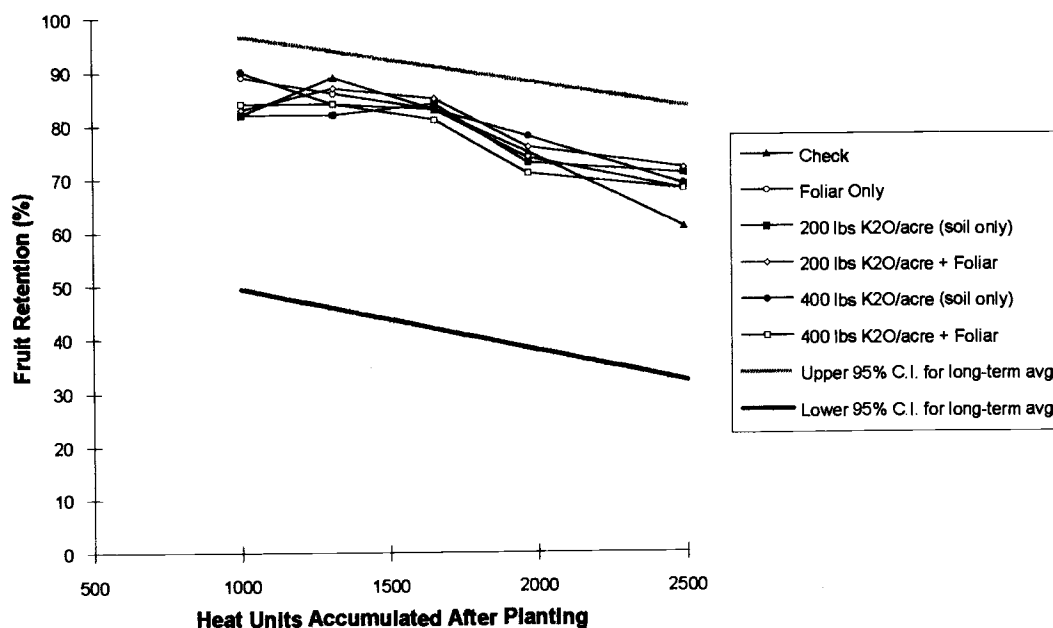


Fig. 4. Fruit retention as function of HUAP for each K fertility treatment applied to Pima cotton (S-6) at the Safford Agriculture Center, AZ, 1992.

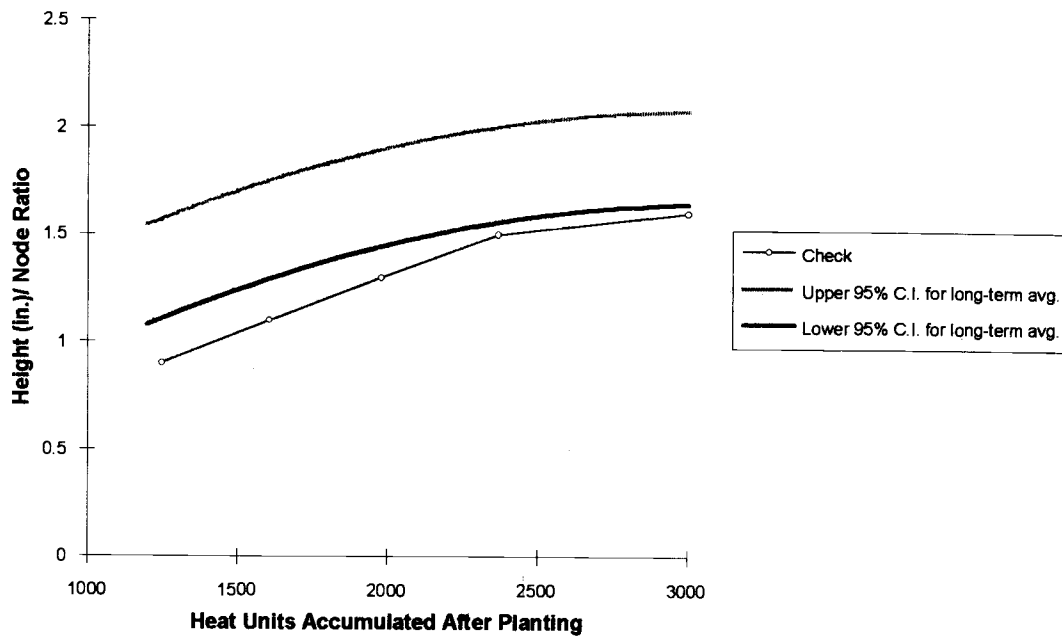


Fig. 5. Height-to-node ratio as function of HUAP for each K fertility treatment applied to Pima cotton (S-6) at the Maricopa Agriculture Center, AZ, 1992.

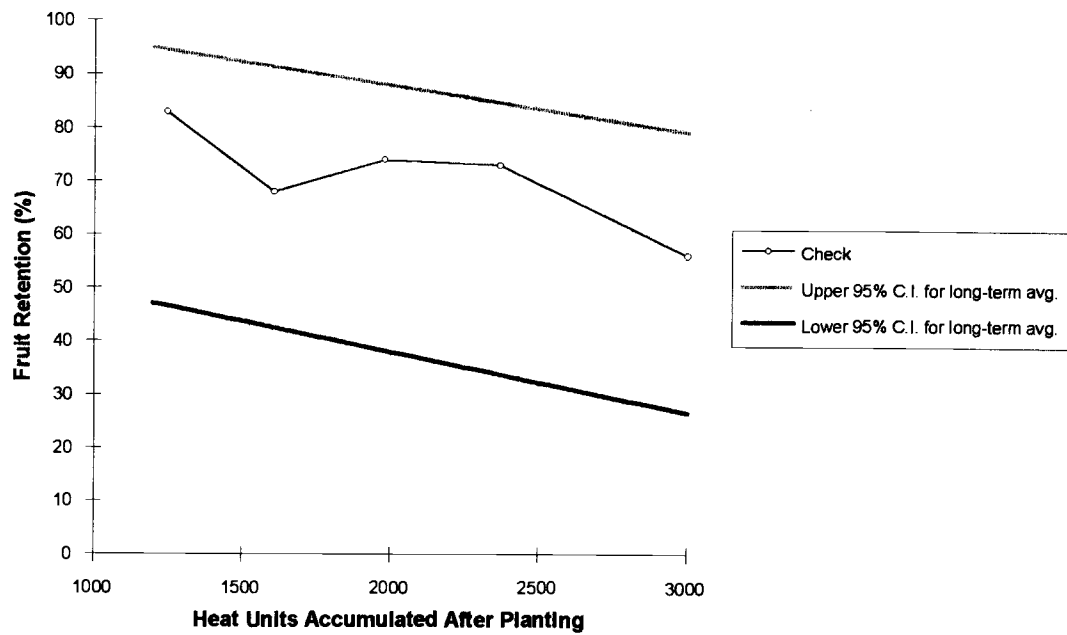


Fig. 6. Fruit retention as function of HUAP for each K fertility treatment applied to Pima cotton (S-6) at the Maricopa Agriculture Center, AZ, 1992.

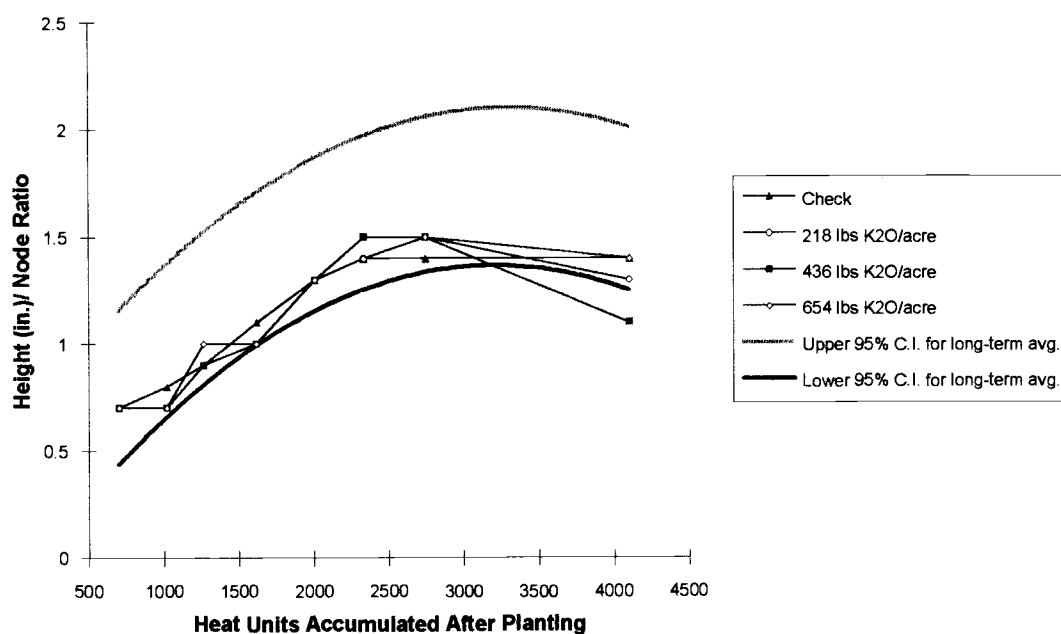


Fig. 7. Height-to-node ratio as function of HUAP for each K fertility treatment applied to Upland cotton (STV KC311) at the Maricopa Agriculture Center, AZ, 1992.

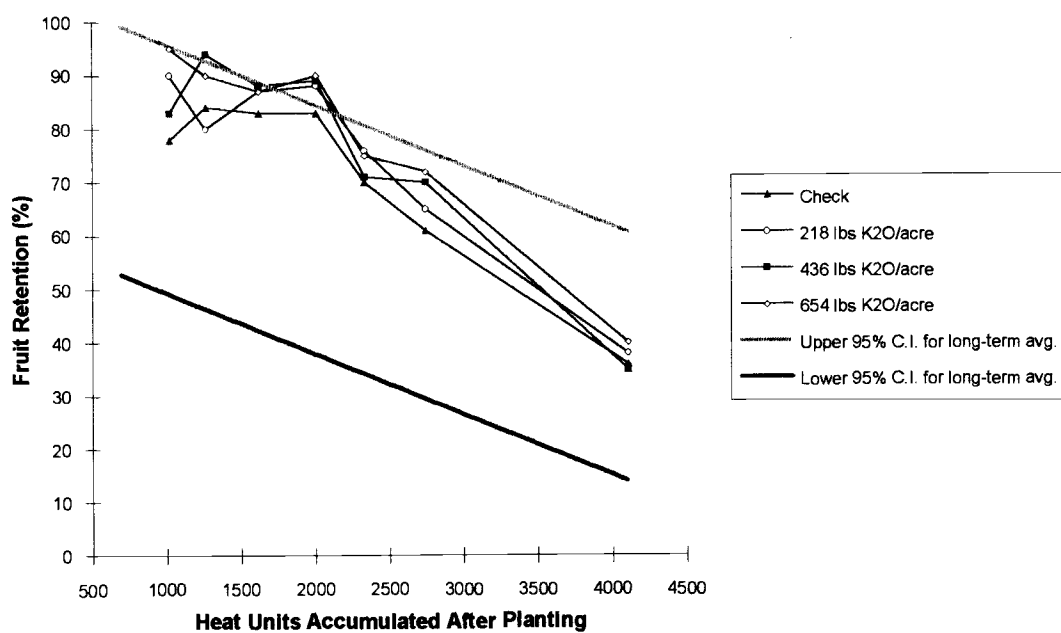


Fig. 8. Fruit retention as function of HUAP for each K fertility treatment applied to Upland cotton (STV KC311) at the Maricopa Agriculture Center, AZ, 1992.