Response of Atlantic to supplemental calcium applications during 1998 and 1999 Seasons: Tuber yield, internal quality, bruising and tuber calcium concentrations

Björn Karlsson, Jiwan Palta, Senay Özgen and Chris Gunter

The University of Wisconsin-Madison, Department of Horticulture, 1575 Linden Dr.. Madison, WI 53706

The potential benefits of supplemental calcium nutrition to potato have been demonstrated over several years in both field conditions and in controlled growth environments. During this time we have found that, in most seasons, enhanced tuber tissue calcium content leads to reduced incidence of internal defects, and in some seasons increased yield and grade. For the 1999 season, we found for Atlantic not only a dramatic reduction of internal defects, but also reduced bruising. Treatments applied in 1998 were non split ammonium nitrate, split ammonium nitrate, split calcium nitrate, split liquid nitrogen+calcium nitrate (UCAN), split urea + calcium chloride + calcium nitrate (CUC). For tubers harvested in 1998, we found a significant increase in the proportion of tubers containing higher calcium with treatments including calcium from both calcium nitrate and calcium chloride sources. For the 1999 field season we determined tuber yield, tuber grade, internal defects and incidence of bruising. These tubers are currently being analyzed for calcium content and data are not available at this time. In general, yield results from 1999 showed no statistically significant differences in yield among various treatments. However, 1999 treatments containing a combination of calcium nitrate + calcium chloride and urea demonstrated half the incidence of hollow heart, internal brown spot and brown center as compared to control split ammonium nitrate. Similarly, the incidence of bruising in the calcium nitrate + calcium chloride + urea treatment was reduced by more than half.

Our results demonstrate that by the application of calcium we can dramatically improve tuber calcium level in Atlantic potatoes. Furthermore these results show that even under good

---

For additional information contact Jiwan Palta:

Phone: 608-262-5782, Fax: 608-262-4743, E-mail: jppalta@facstaff.wisc.edu

(ideal) growing seasons like 1999, Atlantic tubers respond to supplemental calcium application in terms of reduced defects. Our results also suggest that the combination of different sources of calcium and nitrogen may be superior in terms of improving tuber quality. We plan to investigate this further in future studies.

Experimental Plan

Individual plots consisted of two 30 foot rows in 1998 and two 20 foot rows in 1999 separated by a guard row. All seed pieces were hand planted in 1998 and machine planted in 1999 with one seed piece per foot. Starter fertilizer (6-20-19) pretreated with admire was applied at a rate of (500 lbs/acre). At emergence 224 lbs/acre of ammonium nitrate (33.5-0-0) was given. Total nitrogen was 228 lbs/acre to all treatments in 1998 and 269 in 1999. The additional 41 lbs nitrogen plus calcium sources applied in 1999 was due to a 5 inch rain just after the last nutrient application (hilling + 8 weeks). The balance of nitrogen was split equally into applications starting at hilling which are presented in
Table 1. All treatments were replicated five times.

Tubers were harvested at maturity and held at about 40 °F until they were analyzed and sampled for calcium six to eight weeks later. For defect analysis tubers were cut in half along longitudinal axis and visually inspected for defects. Table 2 defines the defects encountered and analyzed.

Table 1: Summary of potato (cv. Atlantic) nutrient applications.

NUTRIENT APPLICATION SCHEDULE **1998**

Application of Nutrients				
Treatment	Source	Amount (lbs/acre)		Application
		Nitrogen	Calcium	Timing[1]
Nonsplit nitrogen	NH_4NO_3	123	0	H
Split nitrogen	NH_4NO_3	41	0	H,H+3,H+6
Split Cal Nit	Cal Nit	41	50	H,H+3,H+6
UCAN 75 lb calcium	UAN	20.5	0	H,H+3,H+6
	Cal Nit	20.5	25	
CUC 75 lb calcium	Cal Nit	20.5	25	H,H+3,H+6
	Urea	20.5	0	
CUC 150 lb calcium	Cal Nit	20.5	25	H,H+3,H+6
	Urea	20.5	0	
	$CaCl_2$	0	25	

[1] H = hilling; H + 3-6 = number of weeks after hilling

NUTRIENT APPLICATION SCHEDULE **1999**

Application of Nutrients				
Treatment	Source	Amount (lbs/acre)		Application
		Nitrogen	Calcium	Timing[1]
Nonsplit nitrogen	NH_4NO_3	123	0	H
Split nitrogen	NH_4NO_3	41	0	H,H+3,6,8
Split Cal Nit	Cal Nit	41	50	H,H+3,6,8
UCAN 75 lb calcium	Liquid N	20.5	0	H,H+3,6,8
	Cal Nit	20.5	25	
CUC 75 lb calcium	Cal Nit	20.5	25	H,H+3,6,8
	Urea	20.5	0	
CUC 150 lb calcium	Cal Nit	20.5	25	H,H+3,6,8
	Urea	20.5	0	
	$CaCl_2$	0	25	
UAN	Urea	20.5	0	H,H+3,6,8
	NH_4NO_3	20.5	0	
Urea	Urea	41	0	H,H+3,6,8

[1] H = hilling; H + 3,H+6 and H+8 = number of weeks after hilling

Planting Date: April 26, 1999
Emergence Date:May 18, 1999
Hilling Date: June 4, 1999

Vine kill: August 25, 1999
Harvest Date: September 11, 1999
Soil calcium: 380 ppm

Table 2: Definition of specific defects and terms used in analysis presentation.

Defect category	Definition for Defective Tuber
Hollow Heart	**Cavity of any perceptible size** in center of medullary tissue with or without discoloration.
Brown Center	**Any brown discoloration** in the **center** of the potato. Very faint, or small, but discernible browning was rated as a defect.
Internal Brown Spot	**Any spot 3 mm or greater** contained inside of the vascular ring in the medullary tissue but **not in the center**.
Multiple	Any tuber containing **two or more** of the above defects.
Total	**Sum** of all incidences of defect.
Bruise	Discolored, hollow or starch filled anomaly **external to the vacular ring** and with longitudinal axis parallel to tuber epidermis.

Results

1998 Tuber Calcium Concentrations (Refer to **Figure 1**)

Application of soluble calcium (either Cal Nit or Cal Chloride) dramatically increased tuber calcium concentration. As reported in Figure 1, the 1998 mean calcium concentrations were 112.6 and 118.0 ppm for ammonium nitrate nonsplit and split, respectively. For split calcium nitrate a mean value of 142.9 ppm was observed while UCAN 75 was 135.2 ppm. Finally, CUC 75 and CUC 150 treatments resulted in means 126.9 and 145.0 ppm, respectively.

The 1998 results showed a significant shift in the frequency distribution of tubers toward higher calcium following treatment with calcium amendments (see **Figure 1**). Nonsplit and split ammonium nitrate treatments yielded no tubers with calcium concentration greater than 150 ppm concentration while in calcium nitrate treatment, 33% of tubers exceeded this calcium concentration. CUC 150 treatment demonstrated approximately 27% of tubers over the 150 µg/g concentration threshold. Both CUC 75 and UCAN 75 treatments also resulted in improved tuber tissue calcium concentration. Thus calcium nitrate application significantly increased the proportion of tubers with higher calcium level. Interestingly, as witnessed for several years, split application of ammonium nitrate also raised some calcium levels in the tubers as compared to nonsplit ammonium nitrate application.

1999 Tuber yield (Refer to **Table 3**):

The last several years, including 1999, were good years for tuber production in central Wisconsin. In general our yields were good and there were no significant differences in either total yield or grade among treatments. This is expected since calcium influences yields primarily during season when some heat stress is present. The lack of yield response is not unusual based on previous seasons results as we generally do not see treatment effects on tuber yield in a good (ideal) growing season.

1999 Internal Tuber Quality (Hollow Heart, Brown Center and Internal Brown Spot)

(Refer to **Figures 2,3,4,5,6,7,8,9** and **Tables 4,5**):]

Tubers were cut and rated for internal defects between five to eight weeks following harvest. In 1999, for each treatment, 500 tubers (6 – 10 ounces) were analyzed (100 from each replication/ five replications per treatment). An additional 100-200 tubers with size over 10 ounces, depending on yield, were analyzed. At the same time three samples of ten tubers (30 tubers total) were collected for calcium analyses. For this purpose, a slice (about 1/8") was removed from the middle part of the tuber. Periderm and vascular ring was removed and the rest

of the internal tissue was taken and oven dried for calcium analyses. These data are not yet completed for 1999. A general summary of results are presented below:

1999 Internal defects (**Table 4,5 and Figure 2,3,4,5,6,7,8,9**):

The 1999 mean incidence of brown center and hollow heart for CUC150 was nearly half the rate of split ammonium nitrate for tubers 6-10 ounces (see **Figs. 2,3**). The incidence of internal brown spot (**Fig. 4**) for CUC150 was also lower, though this decrease was not statistically significant. In calcium treatments other than CUC 150, internal defects were not lower as compared to split ammonium nitrate. For tubers over 10 ounces (see **Table 5**), hollow heart (**Fig. 7**), brown center (**Fig. 6**) and internal brown spot (**Fig. 8**) was lower in CUC 150 as compared to split ammonium nitrate, though these trends are not statistically significant. Interestingly, hollow heart and brown center were statistically higher (20-70%) in UCAN75, Urea and UAN treatments as compared to split ammonium nitrate. Total defects (internal brown spot, brown center and hollow heart) and multiple defect rates (tubers having more than one of the above defects) are reported in **Figure 5** for tubers 6-10 ounces and in **Figure 9** for tubers greater than 10 ounces.

In general, it appears that a combination of calcium nitrate and calcium chloride along with urea was most effective at reducing internal defects. We plan to investigate this further next year.

Bruising:

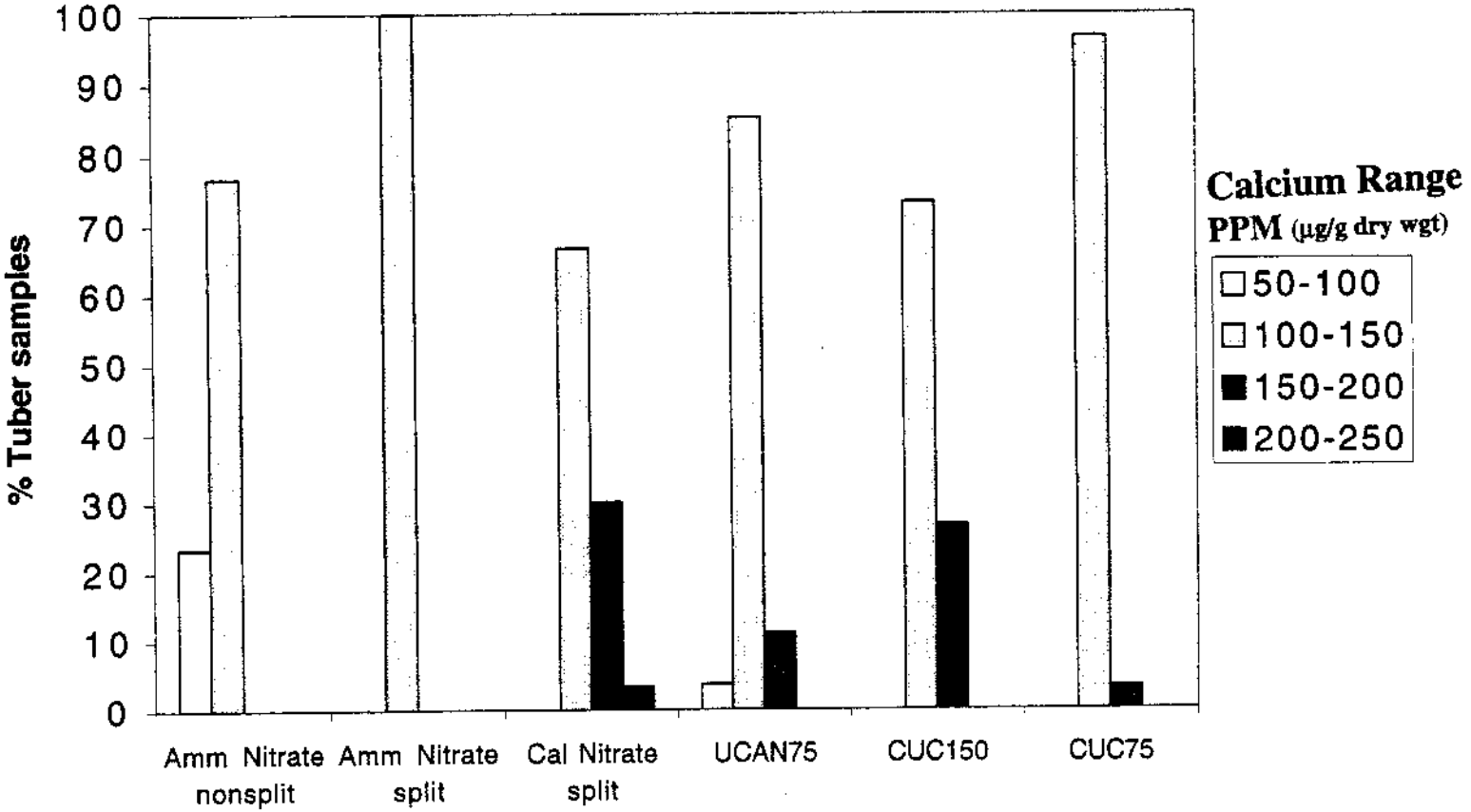
In 1999, (**Table 6 and Figure 10**) treatments containing calcium nitrate or calcium nitrate + calcium chloride (CUC150) resulted in half the incidence of bruise as compared to grower control split ammonium nitrate, urea, UAN and other calcium rates and treatments. This reduction was statistically significant for tubers in the 6 – 10 ounce range though not significant in the over 10 ounce range.

This is the first year we have investigated the influence of supplemental calcium application on bruising. We feel the bruising incidence was high in our tubers. Our results

suggest that calcium application can influence the incidence of bruising. We plan to investigate this further next year.

Figure 1:
Atlantic: Frequency distribution of tuber calcium concentration

Presented are the proportion (percentage) of 1998 season tubers within various ranges of tuber calcium concetration. For each treatment 30 samples of ten tubers each (total of 300 tubers) were analyzed for tuber calcium concentration. The comparison of means between treatments having the same letter are not significantly different (based on SAS general Linear Model Procedure α = 0.05).



	Amm Nitrate nonsplit	Amm Nitrate split	Cal Nitrate split	UCAN75	CUC150	CUC75
Average calcium Concentration	**112.6d**	**118.0cd**	**142.9a**	**135.2ab**	**145.0a**	**126.9bc**

Table 3: 1999 Yield response of Atlantic to supplemental nutrient applications. 1999 Atlantic yields by nutrient treatment. All yields are expressed as mean of five replications. Each replication is an average yield (cwt/acre) of two combined 20 foot rows (one plot = 40 feet). Means within the same column having the same letter are not significantly different (based on SAS General Linear Model procedure).

Atlantic	Yield (cwt/acre)									
Treatment	Total	Grade A	B's	Culls	< 4 oz	4-6 oz	6-10 oz	10-13 oz	13-16 0z	>16 oz
	529.1a	472.5a	11.1b	45.4ab	61.7a	51.4ab	182.6a	80.4ab	51.4a	45.0a
Nonsplit nitrogen										
Split nitrogen	537.3a	492.6a	13.6ab	31.1b	74.7a	49.7b	197.1a	71.3abc	55.8a	43.9a
Split Cal Nit	517.0ab	464.2ab	10.7b	42.1ab	67.1a	47.3b	187.4a	77.2ab	47.7a	37.5a
CUC[1] 150 lb calcium	532.3ab	479.5a	10.9b	42.0ab	66.0a	46.1b	185.6a	81.9a	54.7a	45.2a
CUC 75 lb calcium	538.7a	474.4a	16.0a	48.3a	72.0a	67.0a	198.3a	57.7c	43.4a	36.0a
UCAN[2] 75 lb calcium	534.2a	475.4a	11.5b	47.3a	58.2a	54.3ab	192.5a	74.3abc	55.2a	40.9a
Urea	531.0ab	474.3a	17.0a	39.7ab	59.9a	67.4a	177.6a	83.2a	46.2a	40.0a
UAN[3]	554.4a	485.9a	16.9a	51.5a	65.2a	59.5ab	200.1a	81.5a	50.7a	29.0a
LSD (α=0.05)	37.4	34.2	4.1	16.0	20.0	16.9	24.7	18.8	20.0	19.1

[1] (see Table 1) Calcium nitrate, urea and calcium chloride
[2] Calcium nitrate and urea
[3] Urea and ammonium nitrate

Table 4: 1999 Incidence (%) of internal defects in Atlantic 6-10 ounce tubers as influenced by nutrient applications. 1999 tuber defects reported as percent of tubers evaluated. Means within the same column having the same letter are not significantly different (based on SAS General Linear Model procedure). **500** tubers were evaluated for each treatment.

Atlantic	Defects (%)				
Treatment	Total	Hollow Heart	Brown Center	Internal Brown Spot	Multiple
Nonsplit nitrogen	14.92ab	1.61bc	4.02ab	9.29a	2.01bc
Split nitrogen	16.60a	3.00abc	5.80 ab	7.80a	3.40abc
Split Cal Nit	13.73ab	3.22abc	4.84 ab	5.66ab	3.62abc
CUC[1] 150 lb calcium	9.10b	1.47c	2.48b	5.15ab	1.67c
CUC 75 lb calcium	14.03ab	4.80a	5.80 ab	3.44b	5.20a
UCAN[2] 75 lb calcium	13.31ab	3.27abc	5.73 ab	4.31b	3.27abc
Urea	18.36a	5.29a	6.12a	6.95a	5.29a
UAN[3]	17.40a	4.40ab	6.40a	6.60ab	4.60ab
LSD (α=0.05)	7.06	2.87	3.40	3.47	2.90

[1] (see Table 1) Calcium nitrate, urea and calcium chloride mixture
[2] Calcium nitrate and urea mixture
[3] Urea and ammonium nitrate mixture

Figure 2: Incidence of brown center in Atlantic 6-10 ounce tubers.

1999 tuber defects reported as a percentage of tubers evaluated. Means with statistical analyses are presented in **table 4**. 500 tubers were evaluated for each treatment (100 tubers per plot).

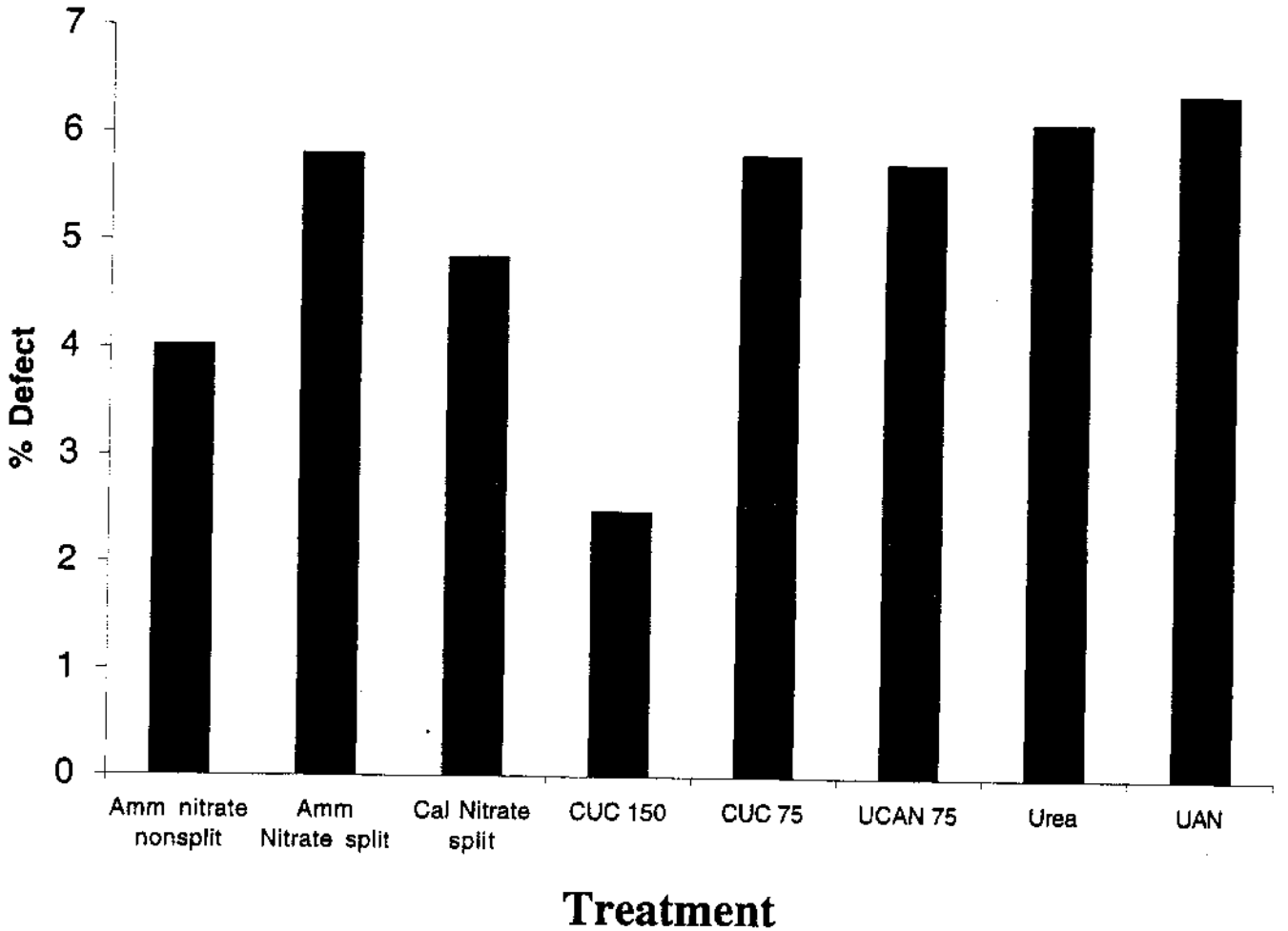


Figure 3: Incidence of hollow heart in Atlantic 6-10 ounce tubers.

1999 tuber defects reported as a percentage of tubers evaluated. Means with statistical analyses are presented in **table 4**. 500 tubers were evaluated for each treatment (100 tubers per plot).

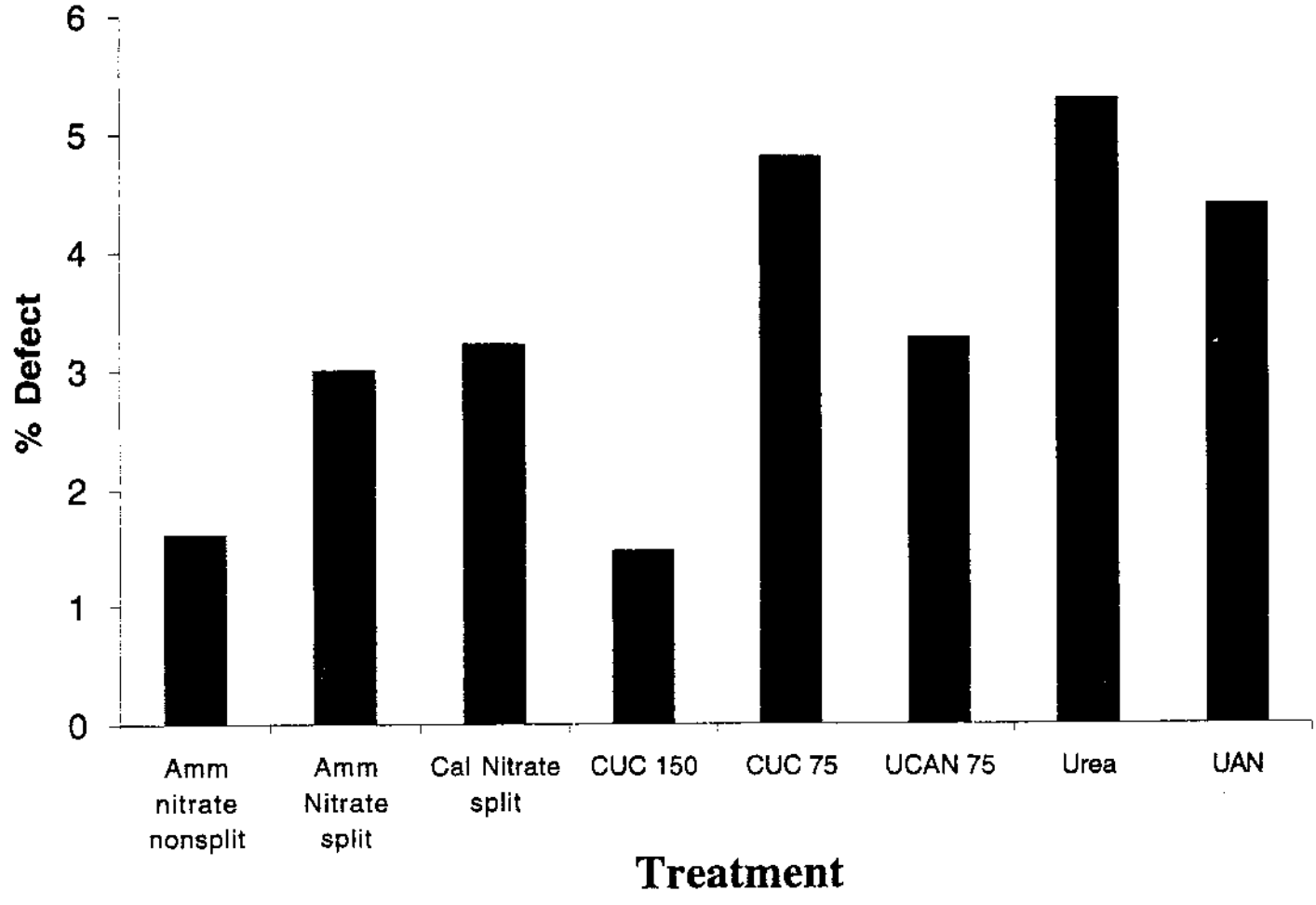


Figure 4: Incidence of internal brown spot in Atlantic 6-10 ounce tubers. 1999 tuber defects reported as a percentage of tubers evaluated. Means with statistical analyses are presented in **table 4**. 500 tubers were evaluated for each treatment (100 tubers per plot).

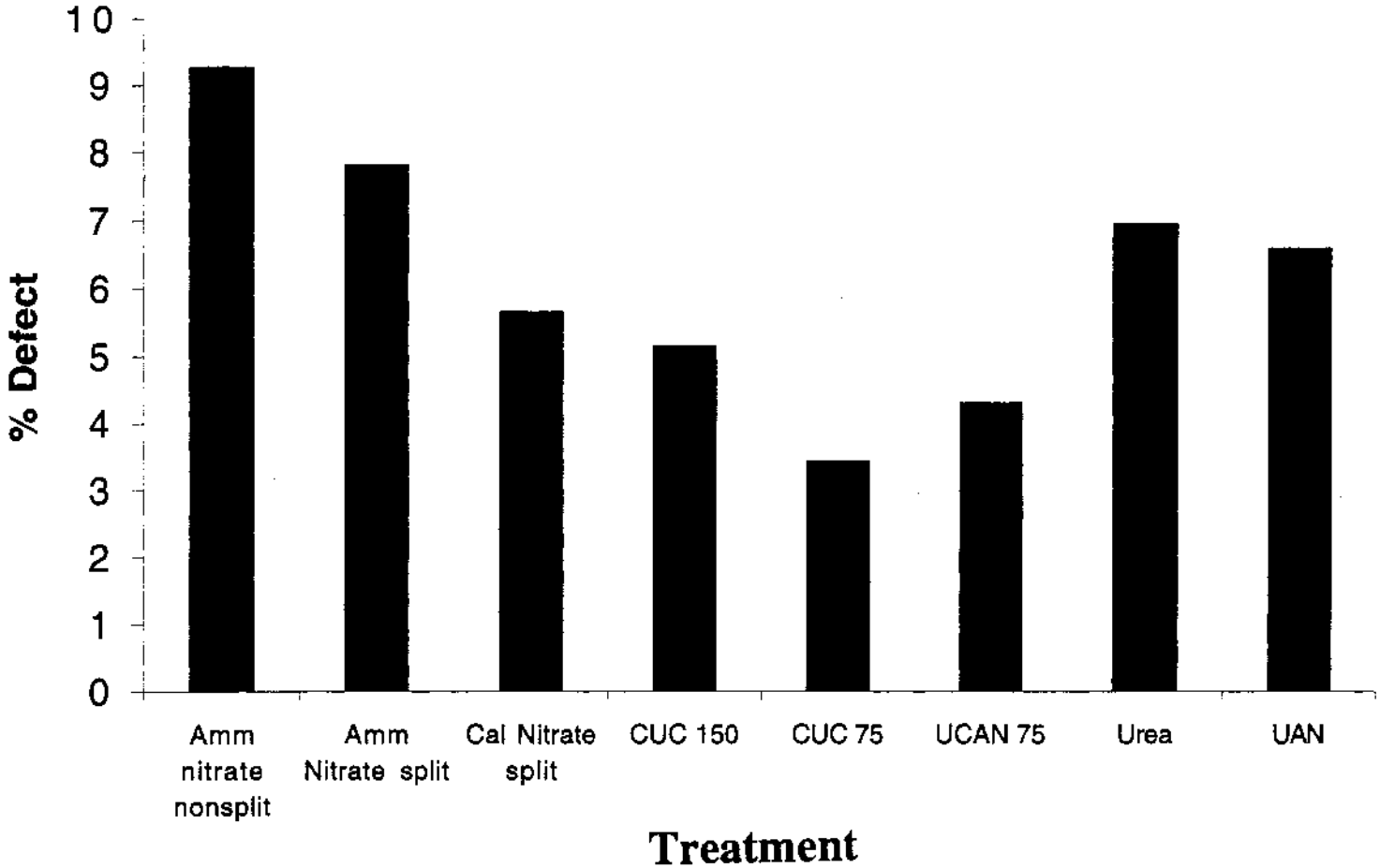


Figure 5: Incidence of multiple and total defect in Atlantic 6-10 ounce tubers. 1999 tuber defects reported as a percentage of tubers evaluated. Means with statistical analyses are presented in **table 4**. 500 tubers were evaluated for each treatment (100 tubers per plot).

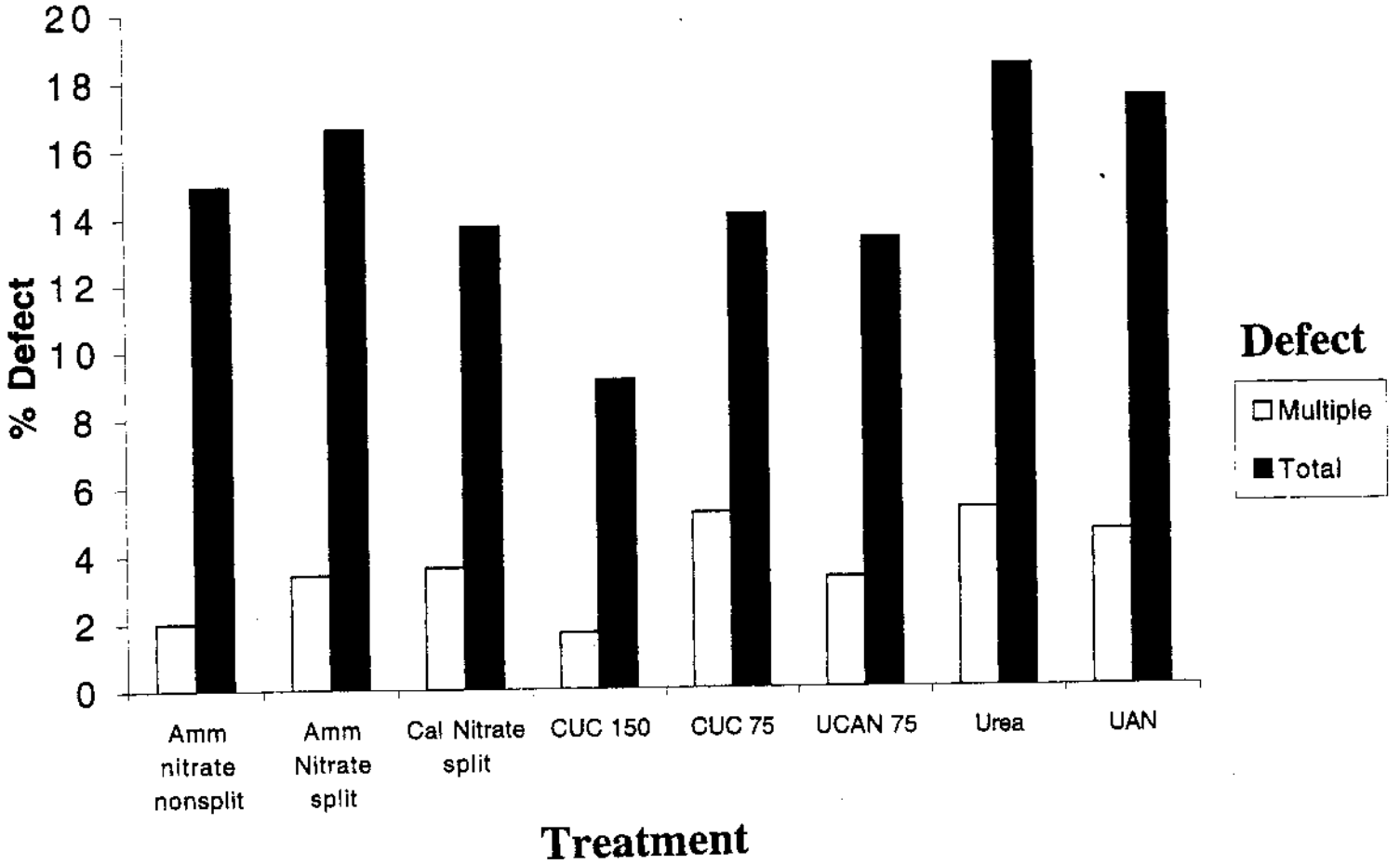


Table 5: 1999 Incidence (%) of internal defects in Atlantic >10 ounce tubers as influenced by nutrient applications. 1999 tuber defects reported as percent of tubers evaluated. Means within the same column having the same letter are not significantly different (based on SAS General Linear Model procedure). Approximately 200 tubers were evaluated for each treatment.

Atlantic	Defects (%)				
Treatment	Total	Hollow Heart	Brown Center	Internal Brown Spot	Multiple
Nonsplit nitrogen	50.50ab	16.58abc	19.26abc	14.67a	16.58ab
Split nitrogen	50.89ab	14.27bc	18.26abc	18.37a	15.90ab
Split Cal Nit	40.83ab	15.64abc	17.81c	7.38b	13.75b
CUC[1] 150 lb calcium	29.21b	8.25c	9.04c	11.92ab	8.60b
CUC 75 lb calcium	38.36ab	14.71bc	16.67c	6.99b	14.71b
UCAN[2] 75 lb calcium	69.88a	24.42a	30.94a	14.53a	25.66a
Urea	60.84a	21.25ab	26.06abc	13.53ab	23.39a
UAN[3]	54.62a	18.06ab	22.07abc	14.49a	15.26ab
LSD (α=0.05)	25.03	9.59	13.09	6.97	10.77

[1] (see Table 1) Calcium nitrate, urea and calcium chloride mixture
[2] Calcium nitrate and urea mixture
[3] Urea and ammonium nitrate mixture

Figure 6: Incidence of brown center in Atlantic > 10 ounce tubers.

1999 tuber defects reported as a percentage of tubers evaluated. Means with statistical analyses are presented in **table 5**. ~200 tubers were evaluated for each treatment.

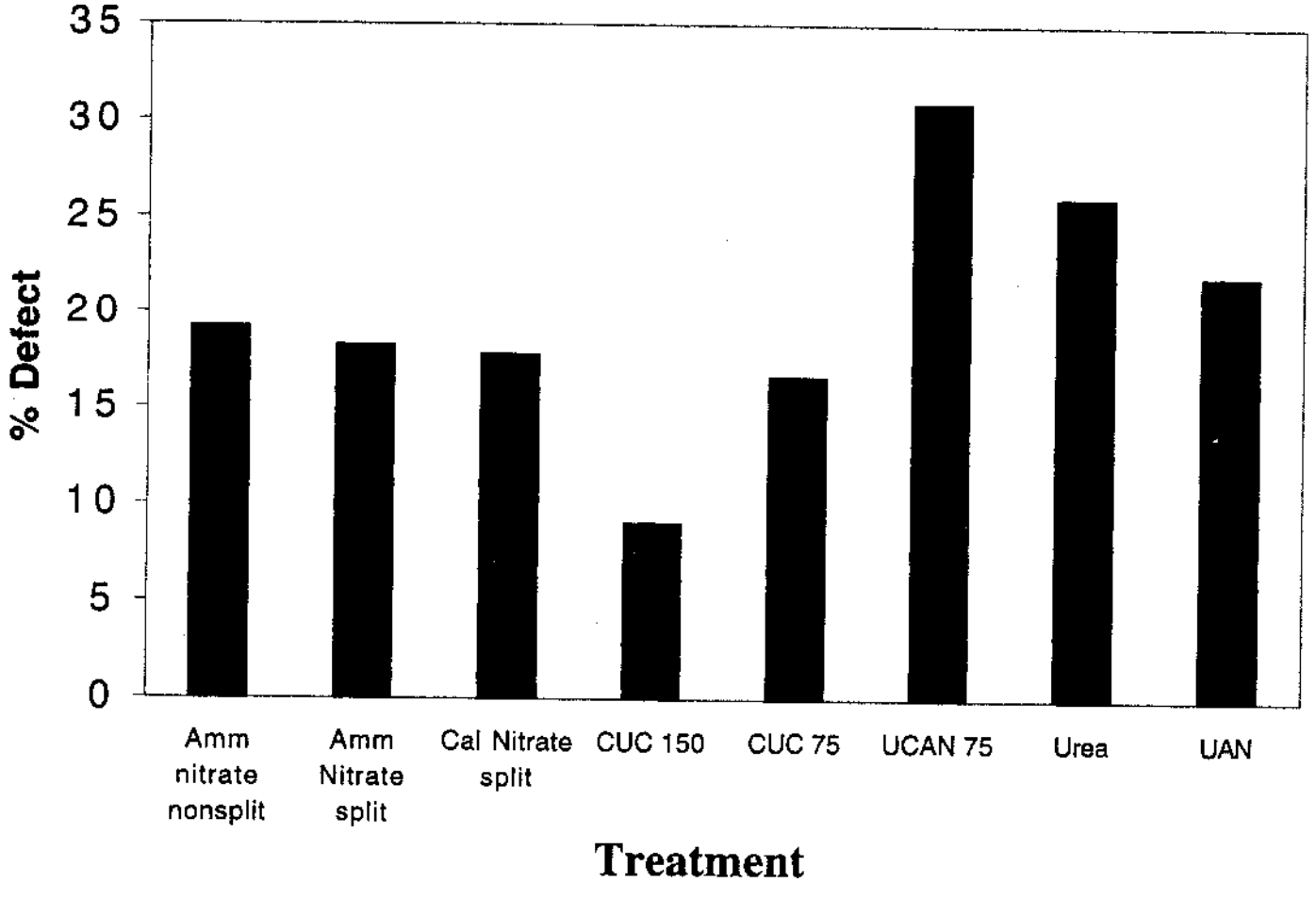


Figure 7: Incidence of hollow heart in Atlantic > 10 ounce tubers.

1999 tuber defects reported as a percentage of tubers evaluated. Means with statistical analyses are presented in **table 5**. ~200 tubers were evaluated for each treatment.

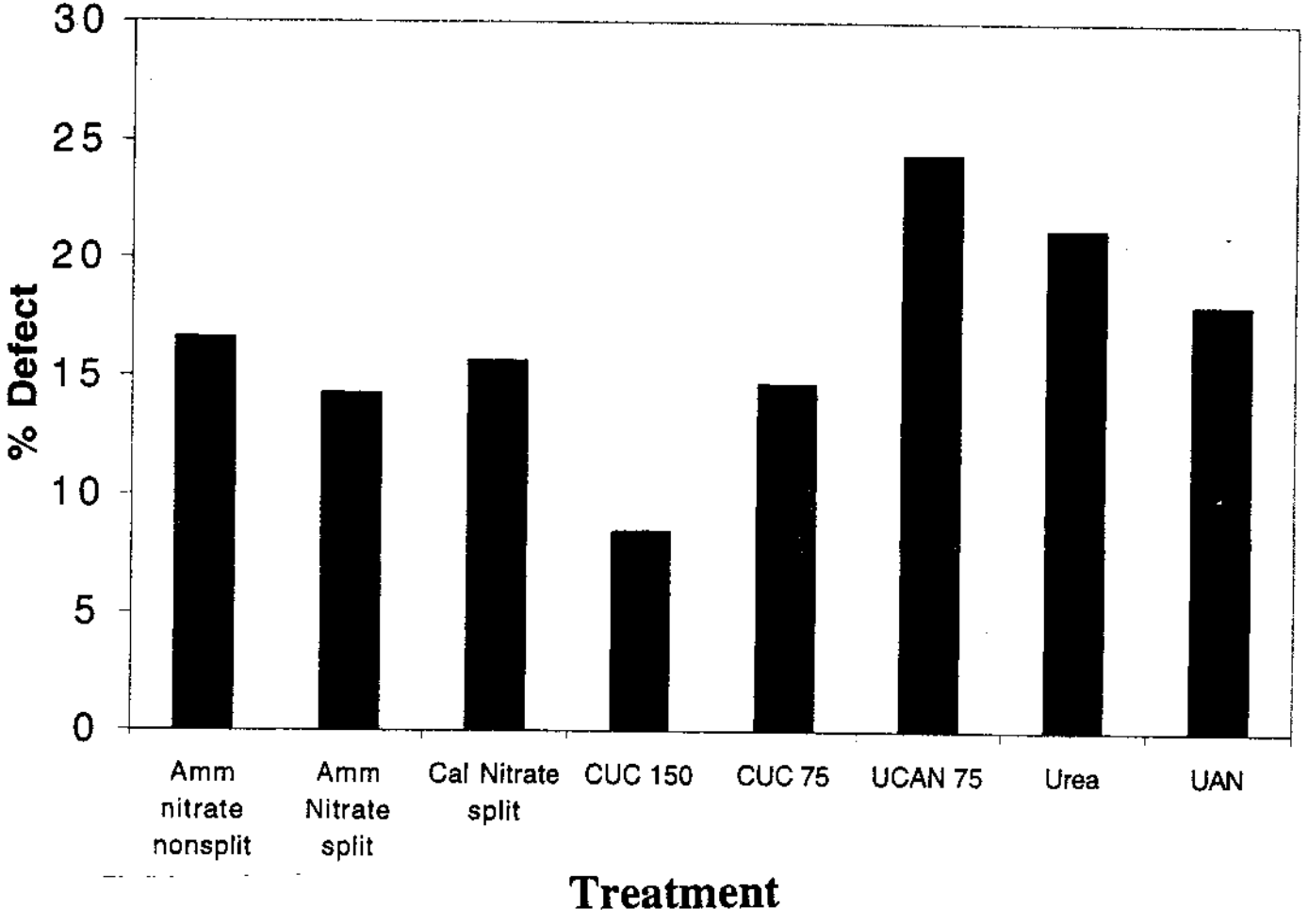


Figure 8: Incidence of internal brown spot in Atlantic > 10 ounce tubers. 1999 tuber defects reported as a percentage of tubers evaluated. Means with statistical analyses are presented in **table 5**. ~200 tubers were evaluated for each treatment.

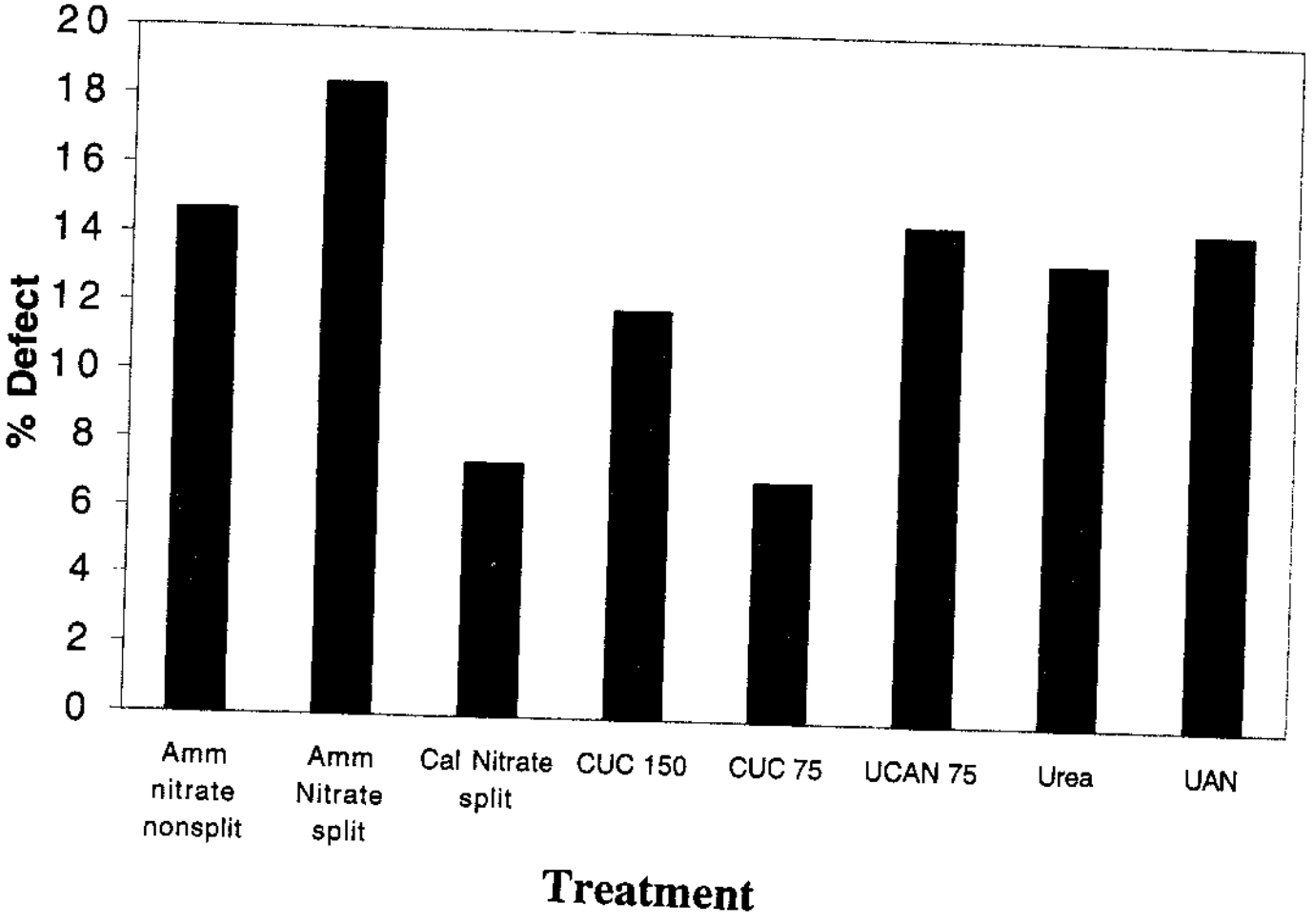


Figure 9: Incidence of multiple and total defect in Atlantic > 10 ounce tubers. 1999 tuber defects reported as a percentage of tubers evaluated. Means with statistical analyses are presented in **table 5**. ~200 tubers were evaluated for each treatment.

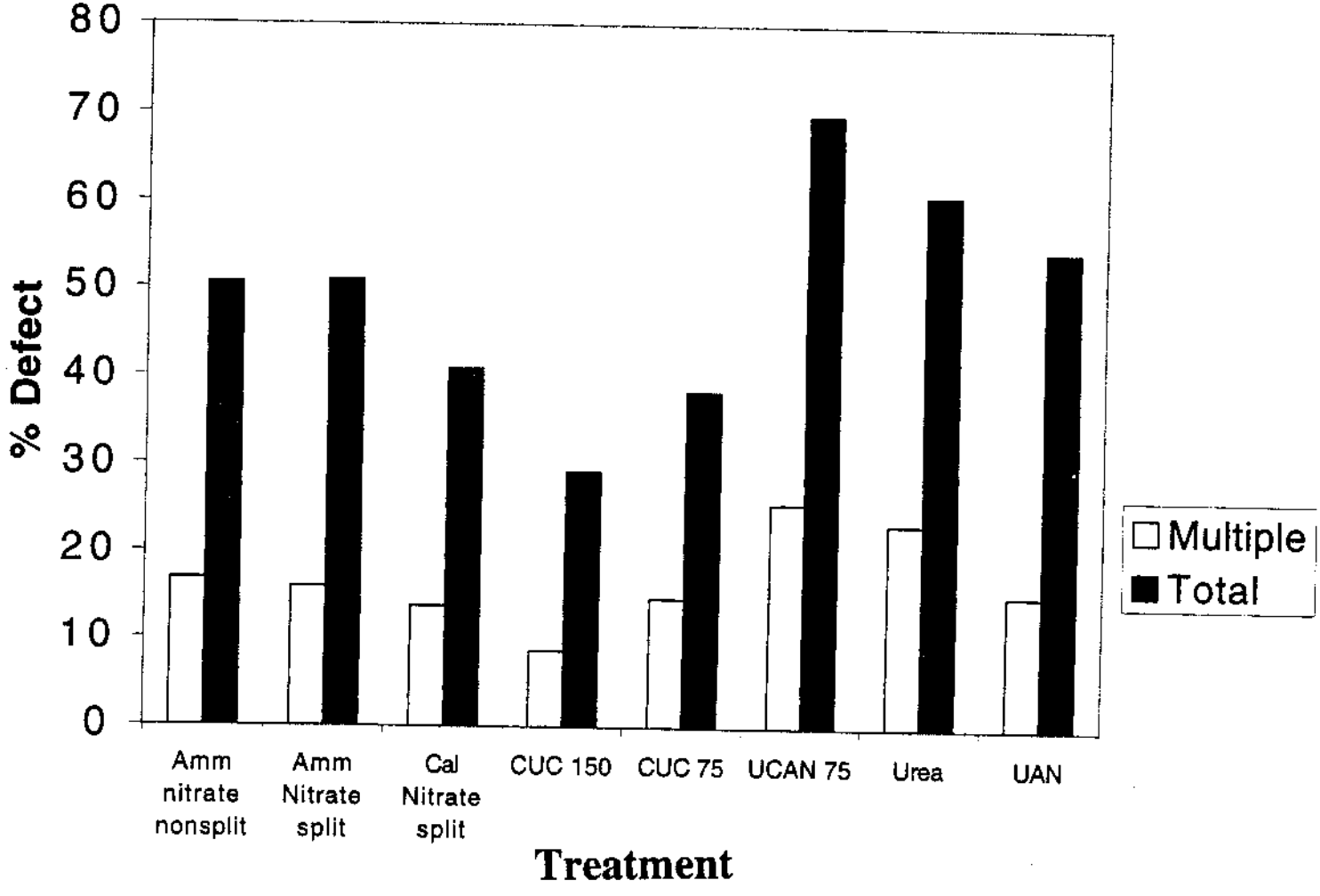


Table 6: 1999 Incidence (%) of tuber bruising in Atlantic as influenced by nutrient applications. 1999 tuber defects reported as percent of tubers evaluated. Means within the same column having the same letter are not significantly different (based on SAS General Linear Model procedure). 6 – 10 ounce tubers based on 500 tubers analyzed per treatment and > 10 ounce based on approximately 200 tubers evaluated per treatment.

Treatment	Tuber Size	
	6 – 10 ounce tubers	> 10 ounce tubers
	% Bruised	% Bruised
Nonsplit nitrogen	35.46a	36.66ab
Split nitrogen	32.60a	39.14ab
Split Cal Nit	24.83ab	28.75ab
CUC[1] 150 lb calcium	17.75b	21.65b
CUC 75 lb calcium	24.74ab	46.05a
UCAN[2] 75 lb calcium	28.42ab	44.32a
Urea	25.58ab	33.17ab
UAN[3]	30.40a	32.21ab
LSD (α=0.05)	12.47	20.36

[1] (see Table 1) Calcium nitrate, urea and calcium chloride mixture
[2] Calcium nitrate and urea mixture
[3] Urea and ammonium nitrate mixture

Figure 10: Incidence of bruising in Atlantic 1999. 1999 tuber bruising reported as a percentage of tubers evaluated. Means with statistical analyses are presented in **table 6**. About 200 tubers were evaluated for each treatment.