Response of Norland, Snowden and Superior potato cultivars to supplemental calcium applications during 1998 and 1999 seasons: Tuber yield, internal quality, bruising and tuber calcium concentration

Björn Karlsson, Jiwan Palta, Senay Özgen and Chris Gunter

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

In the 1998 and 1999 seasons, we continued our evaluation of the response of three potato cultivars (cvs. Dark Red Norland, Snowden and Superior) to supplemental calcium applications. During this time we have established that, in most seasons, enhanced tuber tissue calcium content leads to reduced incidence of internal defects, and in some seasons increased yield and grade. In 1998, treatments applied were nonsplit ammonium nitrate, split ammonium nitrate, split calcium nitrate, and, in 1999, we added a combination treatment of calcium nitrate, calcium chloride and urea (CUC150) (see **Table 1**). For the 1999 season we have collected and analyzed yield and internal quality data but tuber calcium content data are not yet available.

For tubers harvested in 1998, we found a significant increase in the proportion of tubers with higher calcium with treatment containing 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. Yield results from 1999 showed some significant grade differences but no general statistically significant differences. In general, treatments with either split or nonsplit nitrogen gave as good or better yield and grade as the calcium treatments. In general, quality of potato tubers was very good during the 1998 and 1999 seasons. Consequently, the incidences of physiological defects were very low in the 6-10 ounce tubers for these three cultivars during the 1997 and 1998 Seasons. However, in all three cultivars, some of the internal defects

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For additional information contact Jiwan Palta:

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

were reduced with supplemental application of calcium nitrate or a mixture of calcium nitrate, calcium chloride and urea. Only internal brown spot had a significant rate and only for cultivars Norland and Superior. In contrast, for tubers over 10 ounces, the rate of defects for all three cultivars was significantly higher than in the 6-10 ounce tubers. There were interesting differences among different cultivars in terms of incidences of bruising.

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 3 potato of cultivars (Dark Red Norland, Snowden, Superior) to nutrient applications.

NUTRIENT APPLICATION SCHEDULE 1998

Application of Nutrients

Treatment	Source	Amount (lbs./acre)		Application Timing[1]
		Nitrogen	Calcium	
Nonsplit nitrogen	NH_4NO_3	123	0	H
Split nitrogen	NH_4NO_3	41	0	H,H+3,H+6
Split Cal Nit	Cal Nitrate	41	50	H,H+3,H+6

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

NUTRIENT APPLICATION SCHEDULE 1999

Application of Nutrients

Treatment	Source	Amount (lbs./acre)		Application Timing[1]
		Nitrogen	Calcium	
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
CUC 150 LB	Cal Nit	20.5	25	H,H+3,6,8
calcium	Urea	20.5	0	
	$CaCl_2$	0	25	

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

Planting Date: April 26, 1999

Vine kill: August 25, 1999

Emergence Date:May 18, 1999

Harvest Date: September 11, 1999

Hilling Date: June 4, 1999

Soil calcium: 380 ppm

Table 2: Definition of specific defects and terms used in analysis presentation. Please note that some tubers rated with physiological evidence of defects will not be deemed defective by industry standards.

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 light 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.

Results

<u>1998 Tuber Calcium Concentrations</u> (Refer to **Figures 1,2,3**)

The 1998 results showed for all three cultivars a dramatic increase in the proportion of tubers containing higher calcium with supplemental application of calcium nitrate.

The details follow:

I. For Norland (**Figure 1**), nonsplit ammonium nitrate treatments yielded approximately 4 % of tubers with calcium concentration greater than 200 ppm concentration while in calcium nitrate treatment, 89% of tubers exceeded this calcium concentration. Thus calcium nitrate application dramatically increased the proportion of tubers with high calcium level. Interestingly, split application of ammonium nitrate also raised some calcium level in the tubers as compared to nonsplit application.

II. For Snowden (**Figure 2**), nonsplit ammonium nitrate treatments yielded no tubers with calcium concentration greater than 150 ppm concentration while in calcium nitrate treatment, 32% of tubers exceeded this calcium concentration. Thus calcium nitrate application dramatically increased the proportion of tubers with high calcium level. Again, split application of ammonium nitrate also raised some calcium level in the tubers as compared to nonsplit application.

III. For Superior (**Figure 3**), nonsplit ammonium nitrate treatments yielded approximately 40 % of tubers with calcium concentration greater than 200 ppm concentration while in calcium nitrate treatment, 79% of tubers exceeded this calcium concentration. Thus calcium nitrate application dramatically increased the proportion of tubers with high calcium level. Again, split application of ammonium nitrate also raised some calcium level in the tubers as compared to nonsplit application.

<u>1999 Tuber yield and grade data</u> (Refer to **Table 3**):

IV. The last several years, including 1999, were good years for tuber production in central Wisconsin. Notable for the 1999 yields include a lower rate of culls with CUC 150 treatment in Superior, though not statistically lower. Also, calcium treatments reduced the yield of Superior tubers in the size range > 16 ounces. More generally, reduced total and grade A yield with calcium treatments was found for Norland with the greatest reduction in the 6-10 ounce category. In Snowden, split calcium nitrate resulted in statistically significant reduced total yield as compared to split ammonium nitrate. In Superior, the trend for reduced total and grade A yields was present though not statistically significant.

In general, our yields were good and there were some significant differences among treatments in tuber grade but not in total or grade A yield. 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.

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

(Please refer to **Table 4**)

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:

Internal Defects:

V. 6-10 ounce tubers (**Table 4** and **Figure 4**): In general, the incidence of hollow heart, brown center and hollow heart was very low for all three cultivars in this tuber grade range. In Norland and Superior, internal brown spot ranged from 2-4% and 0-5%, respectively, and the incidence was significantly lower for calcium treatments. In

In Superior, brown center incidence was 1-4% and was significantly reduced by CUC 150 treatment.

Over 10 ounce tubers (**Table 5** and **Figures 5,6,7**): The incidence of defect in this grade was significantly higher than the 6-10 ounce grade. For Norland, hollow heart, brown center and internal brown spot were half the rate for split ammonium nitrate, however, these reductions were not statistically significant. For Snowden, defect rates were greatest for nonsplit ammonium nitrate, and a slight trend toward reduction could be seen with calcium applications, especially for brown center. For Superior, a higher rate of defect was seen for internal brown spot which were reduced by inclusion of calcium treatment, though this trend was not statistically significant.

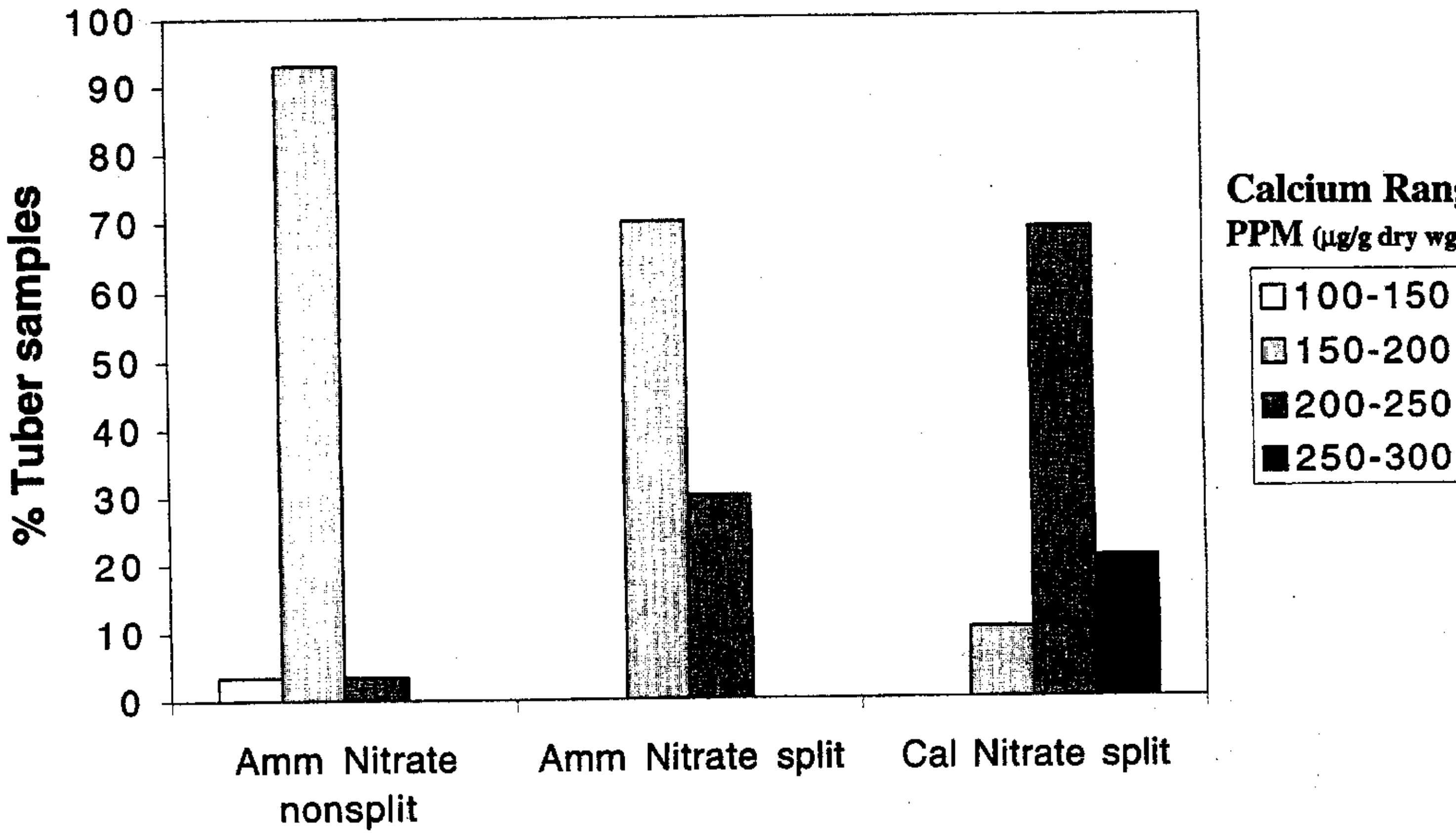
Bruising: (**Table 6** and **Figures 8,9,10**)

VI. For Norland, split calcium nitrate had a slightly lower incidence of bruising in the 6 – 10 ounce range, and a large, though statistically insignificant, reduction in bruising with the use of CUC 150 as compared to split ammonium nitrate. For Snowden, a substantial reduction in bruising was witnessed in both tuber grades, but again these reductions were not statistically significant. Finally, in Superior, the same nonstatistical trend was seen with a reduction of bruising for CUC 150 as compared with the split ammonium nitrate.

This is the first year we have investigated the influence of supplemental calcium application on bruising. Our results suggest that calcium application can influence the incidence of bruising and we plan to investigate this further next year.

Figure 1 :
Norland: 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).

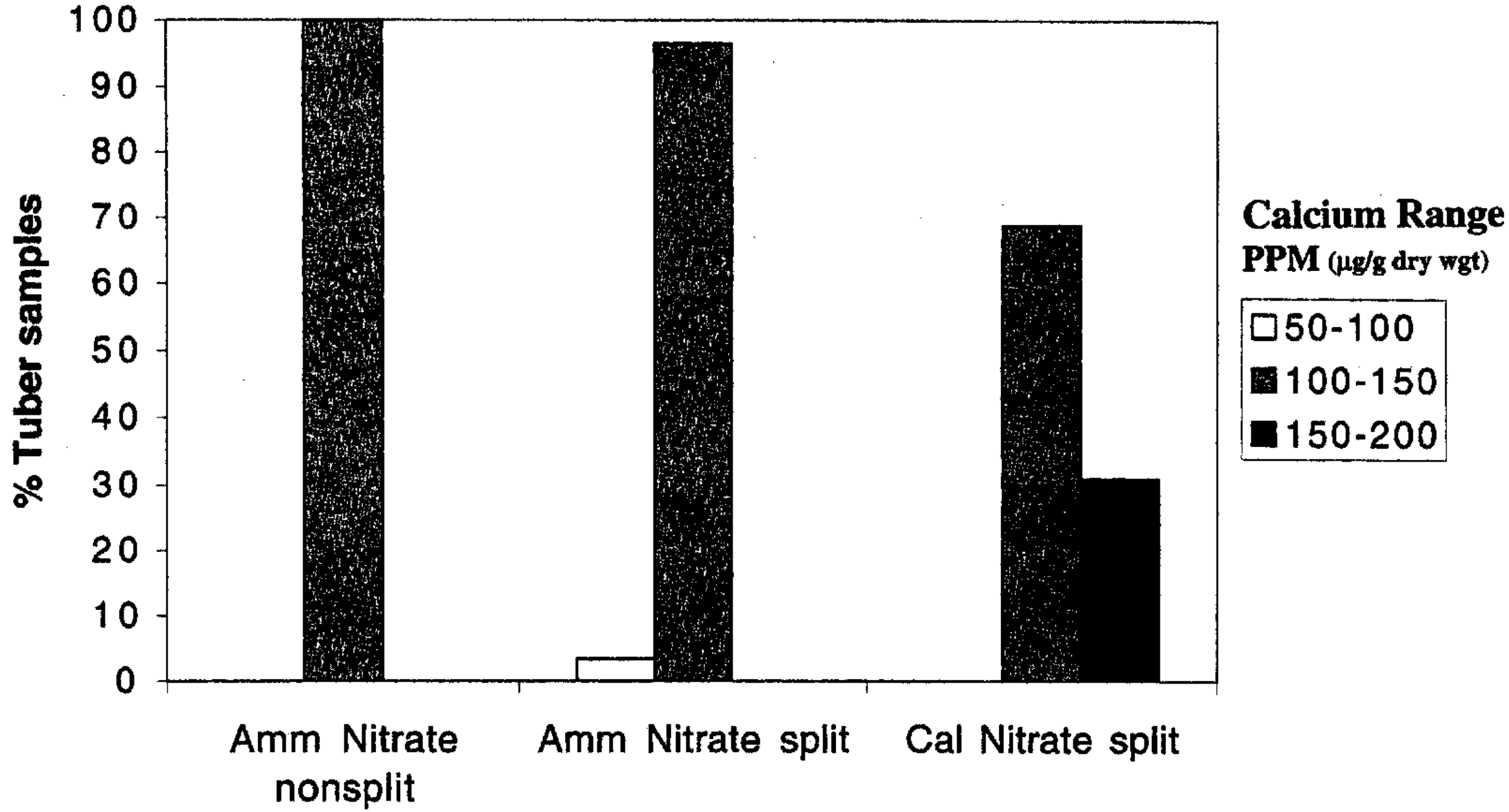


Average calcium Concentration **167.0c** **197.1b** **228.2a**

Figure 2:

Snowden: Frequency distribution of tuber calcium concentration

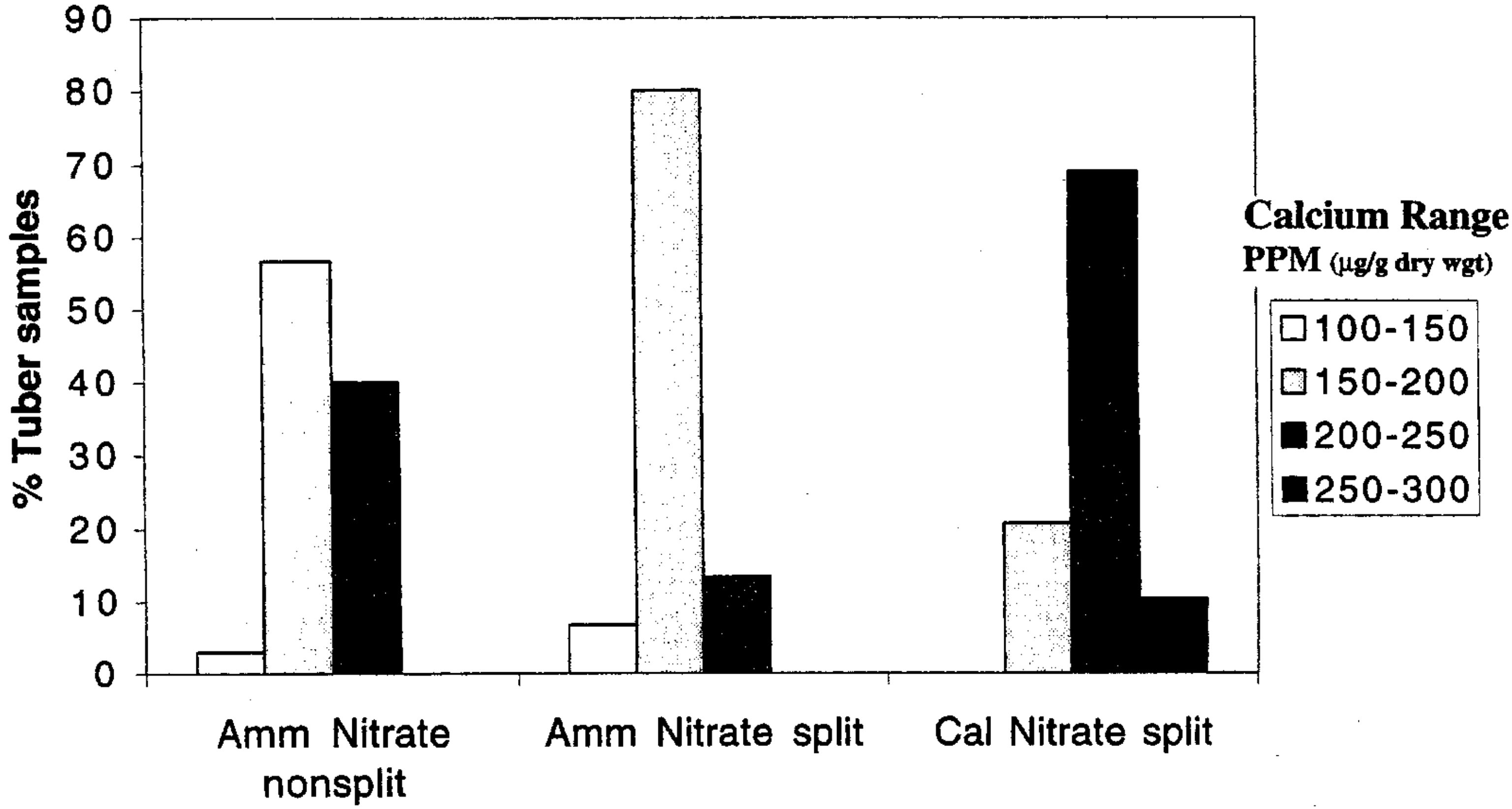
Presented are the proportion (percentage) of 1998 season tubers within various ranges of tuber calcium concetration. For each treatment 30 samples of ten tubers each (total of 300 tubers) were analyzed for tuber calcium concentration. The comparison of means between treatments having the same letter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



Average calcium Concentration	**121.6b**	**128.5b**	**146.3a**

Figure 3:
Superior: 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).



Average calcium Concentration **192.2b** **180.4b** **218.7a**

Table 3: 1999 Yield response of cultivars (Norland, Snowden, Superior) to supplemental nutrient applications. 1999 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
Dark Red Norland										
Nonsplit nitrogen	574.3ab	500.0a	19.6ab	54.7b	60.0a	120.3ab	203.6a	72.8a	34.6a	8.8a
Split nitrogen	593.3a	476.6ab	24.4a	92.3a	74.5a	134.7a	204.8a	50.7b	9.9b	2.1b
Split Cal Nit	549.4bc	452.6bc	23.7a	73.1ab	74.7a	133.8a	196.0ab	32.3b	12.1b	3.6ab
CUC[1] 150 lb calcium	529.4c	422.2c	21.8ab	85.4ab	71.8a	105.3b	172.2b	49.7b	17.0b	6.3ab
LSD (α=0.05)	34.6	41.5	6.7	32.8	21.6	23.7	24.6	19.8	14.2	6.0
Snowden										
Nonsplit nitrogen	585.2a	542.1a	19.1a	24.1ab	150.5b	82.4a	226.9a	52.4a	20.3a	9.5a
Split nitrogen	582.7ab	536.7a	19.3a	26.6a	189.5a	81.4a	200.0bc	38.9a	18.2a	8.8a
Split Cal Nit	542.0bc	505.3ab	18.2a	18.5b	171.2ab	87.8a	183.3bc	39.3a	18.1a	5.5ab
CUC[1] 150 lb calcium	562.9ab	524.6a	18.6a	19.7b	161.6a	86.2a	205.0ab	44.4a	17.8a	9.6a
LSD (α=0.05)	41.1	42.8	5.4	5.9	22.7	24.1	24.8	20.8	17.1	5.4
Superior										
Nonsplit nitrogen	574.7a	507.7a	11.2a	55.8a	50.4a	100.2a	231.4a	64.5a	32.5a	28.7a
Split nitrogen	574.7a	518.9a	9.3a	46.5a	49.7a	90.4a	234.1a	81.7a	37.0a	26.0ab
Split Cal Nit	536.9a	482.8a	11.4a	42.7a	56.7a	77.9a	233.9a	65.0a	33.4a	16.0c
CUC[1] 150 lb calcium	541.7a	493.1a	9.5a	39.1a	48.8a	90.8a	224.1a	72.0a	38.6a	18.9bc
LSD (α=0.05)	45.4	17.3	3.1	16.0	19.3	25.6	38.0	19.2	16.0	9.5

[1] (see Table 1) Calcium nitrate, urea and calcium chloride mixture

Table 4: 1999 Incidence (%) of internal defects of 6-10 ounce tubers in cultivars (cvs. Norland, Snowden and Superior) 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.

Cultivar	Defects (%)				
Treatment	Total	Hollow Heart	Brown Center	Internal Brown Spot	Multiple
Dark Red Norland					
Nonsplit nitrogen	4.91a	0.60a	1.64a	2.67a	0.80a
Split nitrogen	5.49a	0.42a	0.82ab	4.24a	0.42a
Split Cal Nit	3.08a	0.00a	0.21b	2.87a	0.00a
CUC[1] 150 lb calcium	3.78a	0.20a	0.61ab	2.97a	0.20a
LSD (α=0.05)	2.76	0.77	1.38	1.74	0.82
Snowden					
Nonsplit nitrogen	6.00a	2.20a	2.20a	1.60a	2.00a
Split nitrogen	2.00b	0.60b	0.80a	0.60a	0.60b
Split Cal Nit	2.00b	0.40b	0.80a	0.80a	0.40b
CUC[1] 150 lb calcium	3.40ab	0.40b	1.80a	1.20a	1.20ab
LSD (α=0.05)	3.08	1.29	1.50	1.27	1.39
Superior					
Nonsplit nitrogen	7.12a	0.20a	1.47a	5.44a	0.20a
Split nitrogen	7.23a	0.00a	3.59a	3.64ab	0.20a
Split Cal Nit	4.25ab	0.00a	1.80a	2.45bc	0.00a
CUC[1] 150 lb calcium	2.00b	0.00a	1.20a	0.80c	0.00a
LSD (α=0.05)	3.70	0.61	2.50	2.62	0.67

[1] (see Table 1) Calcium nitrate, urea and calcium chloride

Table 5: 1999 Incidence (%) of internal defects of over 10 ounce tubers in cultivars (cvs. Norland, Snowden and Superior) 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.

Cultivar	Defects (%)				
Treatment	Total	Hollow Heart	Brown Center	Internal Brown Spot	Multiple
Dark Red Norland					
Nonsplit nitrogen	8.82a	1.03a	2.49a	5.29a	1.47a
Split nitrogen	14.40a	4.14a	5.28a	4.70a	4.41a
Split Cal Nit	10.81a	2.29a	2.29a	6.23a	2.29a
CUC[1] 150 lb calcium	7.31a	2.82a	2.82a	1.67a	2.82a
LSD (α=0.05)	12.26	5.34	5.61	6.06	5.33
Snowden					
Nonsplit nitrogen	10.76a	3.38a	5.23a	2.17ab	3.98a
Split nitrogen	5.16a	0.89a	1.58a	2.69a	0.89a
Split Cal Nit	3.50a	1.25a	2.25a	0.00b	0.63a
CUC[1] 150 lb calcium	2.85a	0.00a	0.80a	2.05ab	0.00a
LSD (α=0.05)	11.95	5.73	6.42	2.51	5.85
Superior					
Nonsplit nitrogen	9.608a	0.00a	1.03a	8.66a	0.40a
Split nitrogen	6.20a	0.00a	0.45a	5.74a	0.00a
Split Cal Nit	4.44a	0.00a	0.00a	4.44a	0.00a
CUC[1] 150 lb calcium	3.45a	0.00a	1.11a	2.34a	0.49a
LSD (α=0.05)	6.35	0.00	2.18	6.31	1.39

[1] (see Table 1) Calcium nitrate, urea and calcium chloride

Table 6: 1999 Incidence (%) of tuber bruising in cultivars (cvs. Norland, Snowden and Superior) 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 on approximately 200 tubers evaluated for each treatment.

Cultivar Treatment	6 – 10 ounce tubers % Bruised	> 10 ounce tubers % Bruised
Dark Red Norland		
Nonsplit nitrogen	6.1a	4.4a
Split nitrogen	3.4ab	13.6a
Split Cal Nit	2.2b	11.5a
CUC[1] 150 lb calcium	4.2ab	4.8a
LSD (α=0.05)	2.9	13.0
Snowden		
Nonsplit nitrogen	22.4a	28.1a
Split nitrogen	20.8a	26.9a
Split Cal Nit	21.4a	27.6a
CUC[1] 150 lb calcium	15.0a	17.1a
LSD (α=0.05)	7.4	13.3
Superior		
Nonsplit nitrogen	8.0a	9.2a
Split nitrogen	9.1a	17.3a
Split Cal Nit	8.4a	11.9a
CUC[1] 150 lb calcium	5.8a	9.9a
LSD (α=0.05)	3.7	10.6

[1] (see Table 1) Calcium nitrate, urea and calcium chloride

Figure 4: Incidence of internal defect in Superior 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.

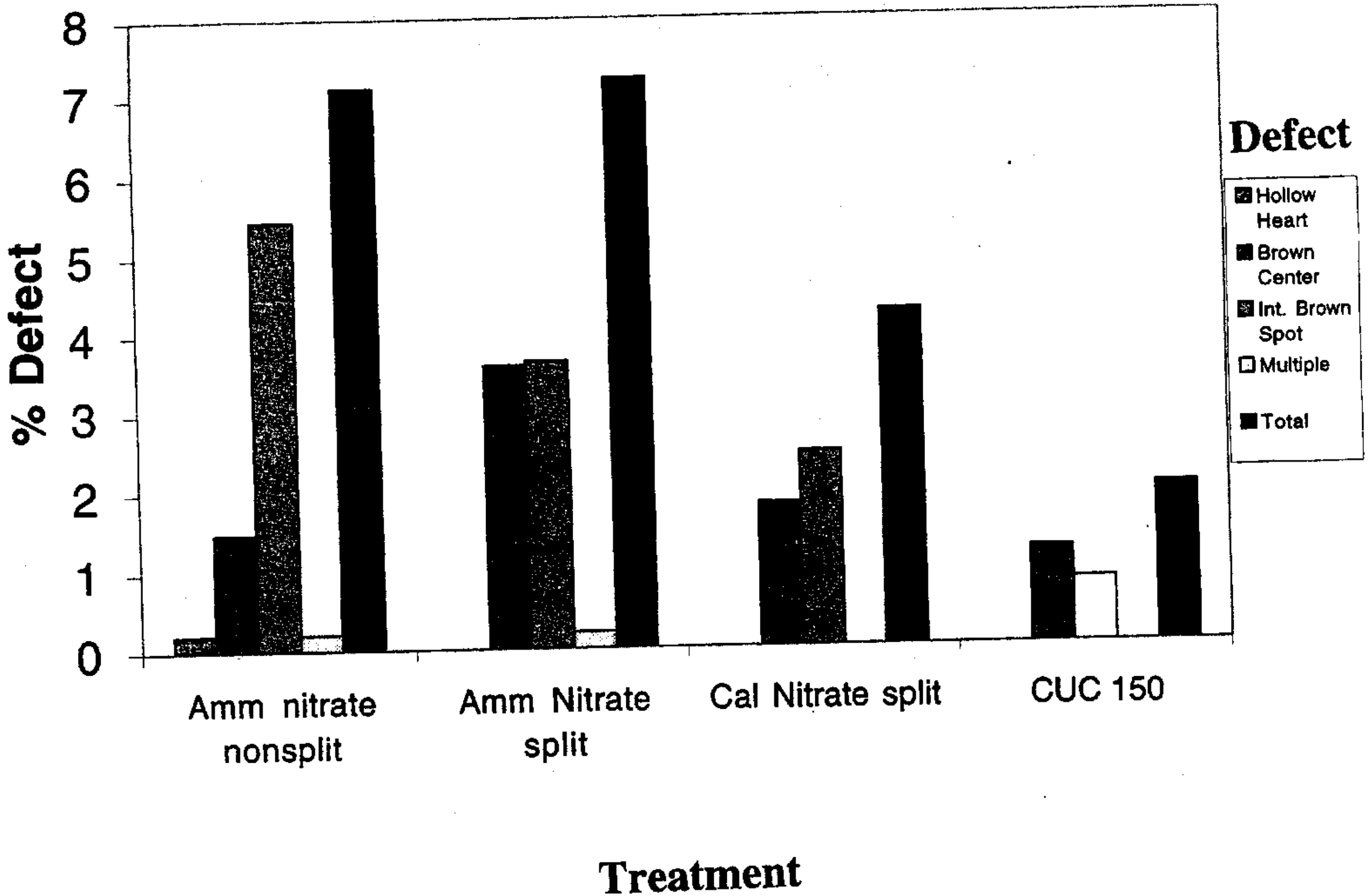


Figure 5: Incidence of internal brown spot in Norland > 10 ounce tubers. 1999 tuber defect reported as a percentage of tubers evaluated. Means with statistical analyses are presented in **table 5**. ~200 tubers were evaluated for each treatment.

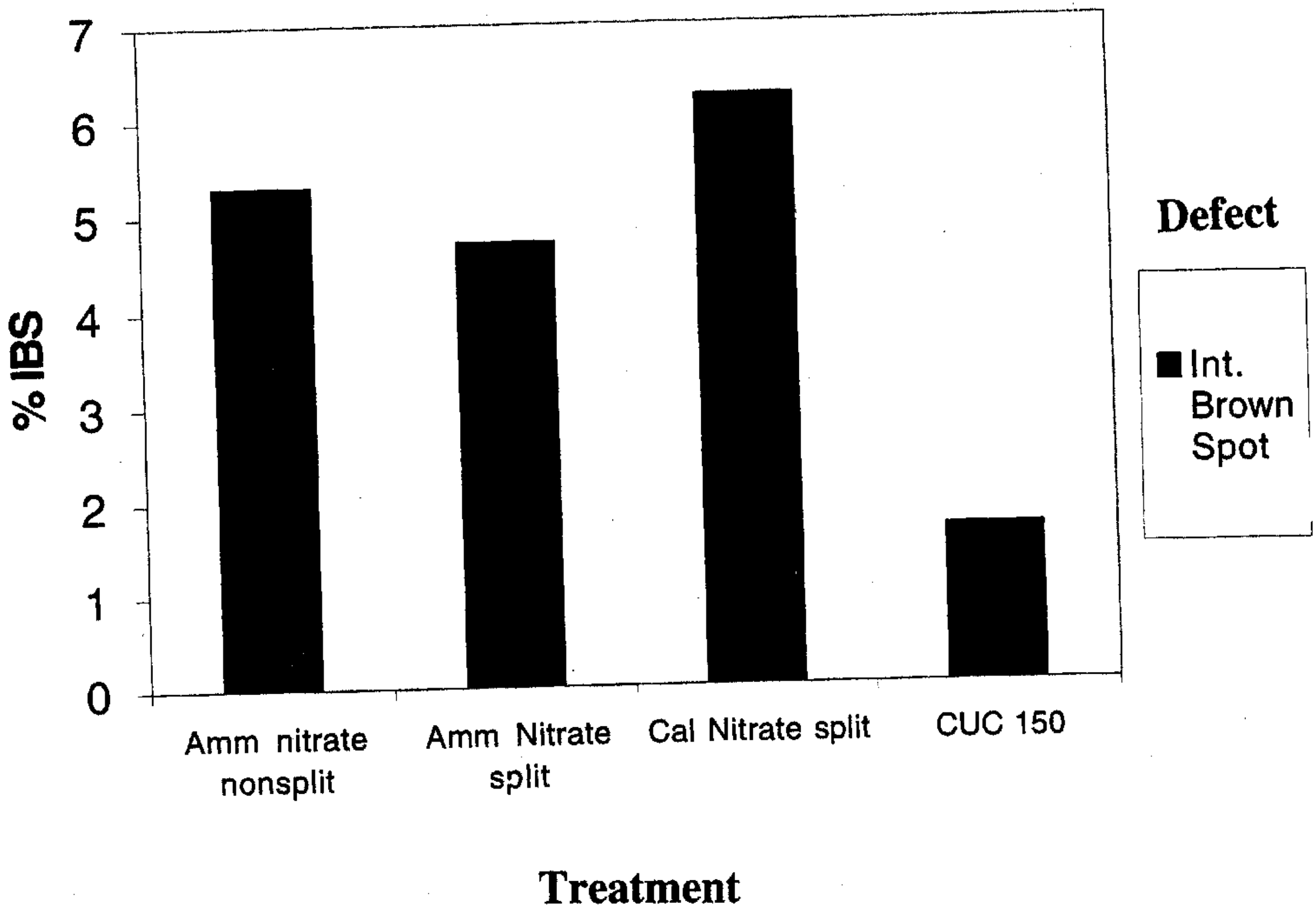


Figure 6: Incidence of internal defect in Snowden > 10 ounce tubers.

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.

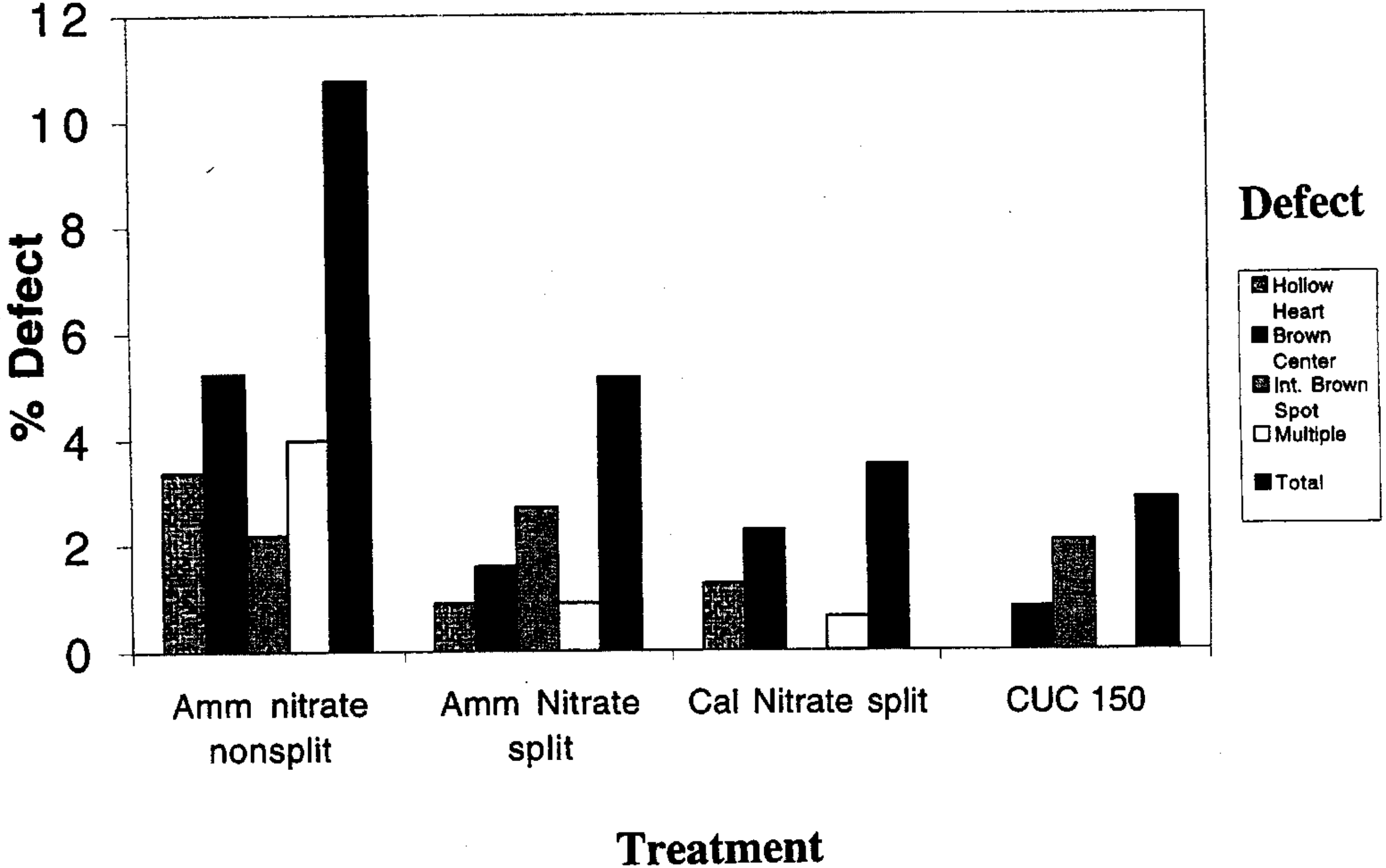


Figure 7: Incidence of internal brown spot in Superior > 10 ounce tubers. 1999 tuber defect reported as a percentage of tubers evaluated. Means with statistical analyses are presented in **table 5**. ~200 tubers were evaluated for each treatment.

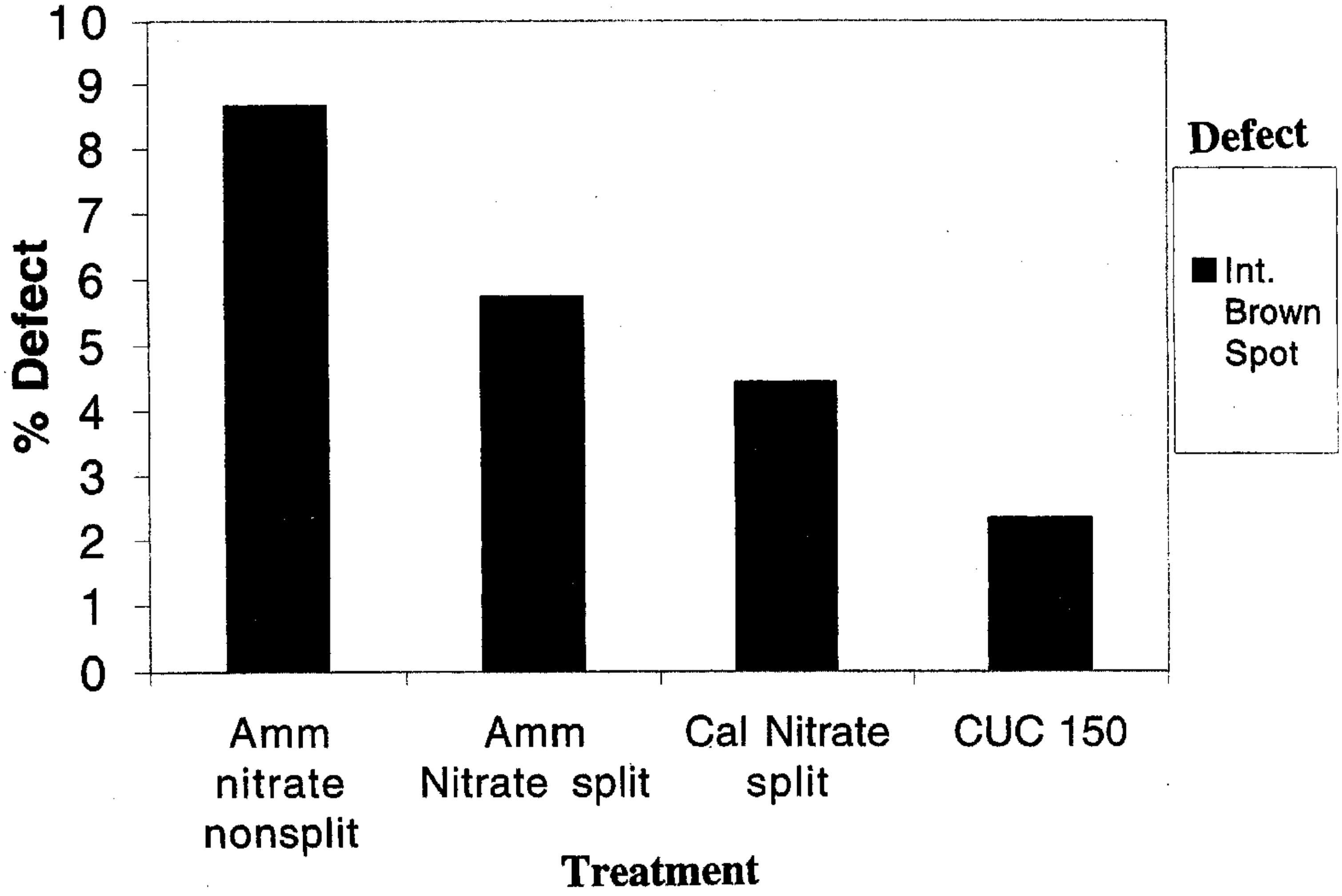


Figure 8: Incidence of bruising for two grades in Norland 1999. 1999 tuber bruising reported as a percentage of tubers evaluated. Means with statistical analyses are presented in **table 6**. 500 tubers were evaluated for each treatment for 6-10 ounce grade and ~200 tubers were evaluated for > 10 ounce grade in each treatment.

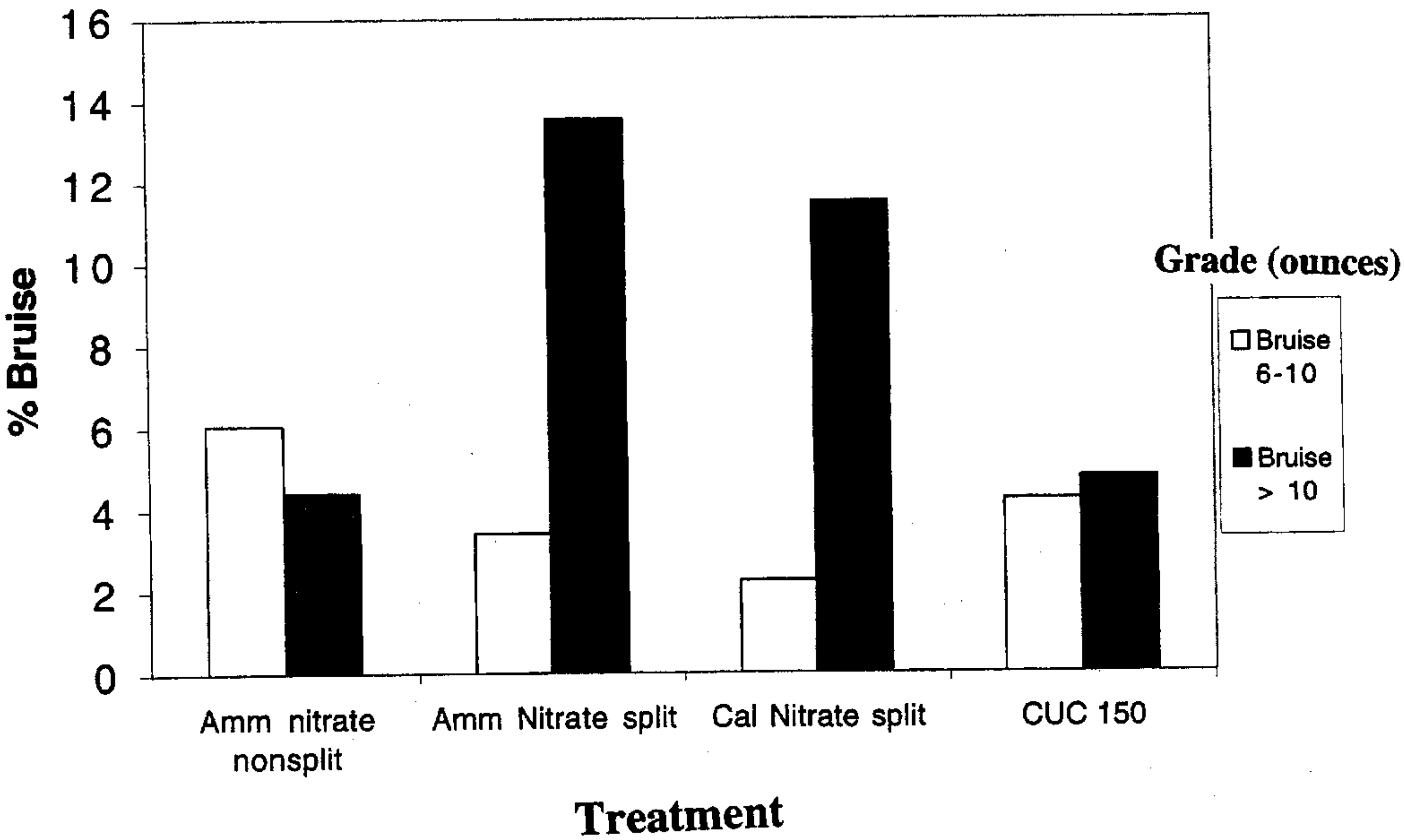


Figure 10: Incidence of bruising for two grades in Superior 1999. 1999 tuber bruising reported as a percentage of tubers evaluated. Means with statistical analyses are presented in **table 6**. 500 tubers were evaluated for each treatment for 6-10 ounce grade and ~200 tubers were evaluated for > 10 ounce grade in each treatment.