Response of potatoes (cv. Russet Burbank) to supplemental calcium applications: Tuber yield, internal quality and tuber calcium concentration

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In the 1998 and 1999 seasons, we evaluated the response of potatoes (cv. Russet Burbank) to supplemental calcium application by using three soluble products: calcium nitrate, calcium chloride and N-Plus. In addition we also evaluated these products in combination with calsol. A combination of urea, calcium chloride and calcium nitrate was also evaluated. In 1998 we analyzed yield, internal quality and calcium contents of tubers. In 1999 yield and internal quality data have been analyzed but tuber calcium contents data are not yet available.

Experimental Plan

Each plot consisted of two 30 foot rows in 1998 and two 20 foot rows in 1999 and plots were separated by guard rows. Soil analyses of CEC (meq/100g), organic matter (%), and nutrients (mg/kg soil) P, K, Ca and Mg produced values 2, 0.6, 142, 93, 380 and 120, respectively. All seed pieces were planted by hand in 1998 and by machine in 1999. Starter fertilizer (6-20-19) pretreated with admire was applied at rate of 500 lbs/acre. At emergence 224 lbs/acre ammonium nitrate (33.5-0-0) was given. Total nitrogen given to each plot was 228 lbs/acre in 1998 and 269 lbs/acre in 1999 to all treatments. The additional 41 lbs nitrogen applied in 1999 was due to a 5″ rain right after last scheduled application (hilling+6weeks). The balance of 123 lbs of nitrogen was split equally into four application starting at hilling, using combinations of calcium nitrate, N-Plus, ammonium nitrate, calcium chloride+urea+calcium nitrate, calcium nitrate+liquid nitrogen in both years. The details on treatments and nutrient application are given in **Tables 1** and **2**. All treatments were replicated five times.

Tubers were harvested in both years at maturity and held at about 40F until they were analyzed and sampled for calcium six to eight weeks later. For internal defect analyses tubers were cut in half along longitudinal axis and visually inspected (Table 3). For this purpose, 100 tubers were evaluated in 1998 and between 50-100 tubers evaluated in 1999 from each plot. For calcium analyses in 1998 a longitudinal slice was taken from the middle of the tuber. Slices from 10 individual tubers were bulked for each calcium sample. Six bulk samples (includes 10 slices) were taken from each plot for calcium analyses. Total 300 tubers were analyzed for calcium data.

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Results

1998 Tuber Calcium Concentration

(Refer to **Table 3**, **Figure 1** and **2**)

In 1998 application of calcium as calcium nitrate or N-Plus or a mixture of calcium nitrate+urea+calcium chloride dramatically improved tuber calcium level. Result showed a significant shift in the frequency distribution of tubers toward higher calcium following treatment with calcium amendments. This effect was seen both in the presence and absence of calsol. For example in ammonium nitrate treatment nearly 25% of tubers had calcium contents less than 200 $\mu g.g^{-1}$ (ppm) dry weight. Furthermore there were less than 30% of the tubers in ammonium nitrate treatment that had calcium level greater than 250 $\mu g.g^{-1}$ (ppm) dry weights. Whereas in the N-Plus, calcium nitrate and calcium nitrate+N-Plus treatments more than 85% of the tubers had calcium level greater than 250 $\mu g.g^{-1}$ (ppm) dry weight. Split application of ammonium nitrate also raised some calcium levels in the tubers as compare to non split application.

In 1999, calcium samples were taken and oven dried however these data are not yet completed.

Tuber Yield (Refer to **Table 4**)

Overall 1999 was a good season for potato production in central Wisconsin. We generally do not see treatment effects on tuber yield under good (ideal) growing conditions, since calcium is expected to have more influence on tuber yield under less than ideal (heat stress etc.) conditions. In general our yield were good and there were no significant differences compare to non split nitrogen treatment to other treatments. However it is interesting to note that some treatments containing calcium chloride, N-Plus and/or calcium nitrate tended to produce slightly higher total tuber yield compare to non split nitrogen. Furthermore as compared to split nitrogen treatment some treatments containing calcium (N-Plus, calcium chloride+urea) produced significantly higher total tuber yield.

Internal Tuber Quality (Refer to **Table 5**)

In general there were no dramatic differences in tuber quality among the treatments. Analyses from 1999 season showed that split nitrogen+calsol application decreased the incidence of internal brown center. Application of split calcium nitrate+N-Plus, split N-Plus (100lbs/a Ca), split CU, split UCAN (83.7lbs/a Ca) decreased the hollow heart compare to split calcium nitrate. Lowest brown center was seen in split nitrogen, split calcium nitrate+N-Plus, N-Plus (100lbs/a Ca) and there was a reduction in total defects in the tubers by these treatments. Multiple defects were very low for all the treatments.

Interesting Observations from the 1999 Season

i) The 1999 growing season was much longer than average, 158 days as compared to 120 days in average growing season.

ii) Record total yields were obtained. In some treatments total yield was greater than 600 cwt

iii) In a longer season, like 1999, Russet Burbank continues to respond to late fertilization which might induce late season tuber growth resulting in more culls.

iv) As compared to non split control, plants given late season nutrients maintained greater health and kept growing whereas the control plants shut down tuber growth.

Table 1: Nutrient application schedule in 1998.

Treatment	Source	Application of Nutrients Amount (lbs/acre) Nitrogen	Calcium	Application Timing[1]	Total Number of Applications
Non split Nitrogen	NH_4NO_3	123	0	H	1
Split Nitrogen	$NH4NO_3$	30.75	0	H, H+2, H+4, H+6	4
Cal Nit	$Ca(NO_3)_2$	30.75	37.5	H	1
N-plus	N-Plus	30.75	15.3	H+2, H+4, H+6	3
N-plus	N-Plus	30.75	15.3	H, H+2, H+4, H+6	4
CUC	Urea	15.37	0	H, H+2, H+4, H+6	4
	$CaCl_2$	0	18.8	H, H+2, H+4, H+6	4
	$Ca(NO_3)_2$	15.37	18.8	H, H+2, H+4, H+6	4
Cal Nit	$Ca(NO_3)_2$	30.75	37.5	H, H+2, H+4, H+6	4
CU	$CaCl_2$	0	15.3	H, H+2, H+4, H+6	4
	Urea	30.75	0	H, H+2, H+4, H+6	4
CU	$CaCl_2$	0	20.6	H, H+2, H+4, H+6	4
	Urea	30.75	0	H, H+2, H+4, H+6	4
UAN	Liquid N	30.75	0	H, H+2, H+4, H+6	4
UCAN	Liquid N	18.5	0	H, H+2, H+4, H+6	4
	$Ca(NO_3)_2$	12.3	15	H, H+2, H+4, H+6	4
UCAN	Liquid N	13.8	0	H, H+2, H+4, H+6	4
	$Ca(NO_3)_2$	16.9	20.6	H, H+2, H+4, H+6	4

Note: All treatments received equal amount of total nitrogen, which was 228 lbs/acre
[1]H: Hilling; H+2-6: number of week after hilling.

Table 2: Nutrient application schedule in 1999.

Treatment	Source	Application of Nutrients Amount (lbs/acre) Nitrogen	Calcium	Application Timing[1]	Total Number of Applications
Non split Nitrogen	NH_4NO_3	123	0	H	1
Split Nitrogen	$NH4NO_3$	30.75	0	H, H+2, H+4, H+6	4
Cal Nit+	$Ca(NO_3)_2$	30.75	37.5	H	1
N-plus	N-Plus	30.75	15.3	H+2, H+4, H+6	3
N-plus	N-Plus	30.75	15.3	H, H+2, H+4, H+6	4
N-plus	N-Plus	30.75	25	H, H+2, H+4, H+6	4
CUC	Urea	15.37	0	H, H+2, H+4, H+6	4
	$CaCl_2$	0	18.8	H, H+2, H+4, H+6	4
	$Ca(NO_3)_2$	15.37	18.8	H, H+2, H+4, H+6	4
Cal Nit	$Ca(NO_3)_2$	30.75	37.5	H, H+2, H+4, H+6	4
CU	$CaCl_2$	0	15.3	H, H+2, H+4, H+6	4
	Urea	30.75	0	H, H+2, H+4, H+6	4
CU	$CaCl_2$	0	21	H, H+2, H+4, H+6	4
	Urea	30.75	0	H, H+2, H+4, H+6	4
UAN	Liquid N	30.75	0	H, H+2, H+4, H+6	4
UCAN	Liquid N	18.5	0	H, H+2, H+4, H+6	4
	$Ca(NO_3)_2$	12.3	15.3	H, H+2, H+4, H+6	4
UCAN	Liquid N	13.8	0	H, H+2, H+4, H+6	4
	$Ca(NO_3)_2$	16.9	21	H, H+2, H+4, H+6	4

Note: All treatments received equal amount of total nitrogen which was 269 lbs/acre
[1]H: Hilling; H+2-6: number of week after hilling.

Planting: 27 April 1999, 500lbs/a starter fertilizer (6-20-19) was applied.
Emergence: 18 May 1999, 224lbs/a ammonium nitrate(33.5-0-0) was applied.
Hilling: 4 June 1999, see table above for nutrient application.
Harvesting: 11 October 1999

Table 3: 1998. Average calcium concentration of bulk samples.

Treatments		Average calcium Concentration (µg.g-1 dry weight)
Non Split Nitrogen	+calsol	227.1h
Non Split Nitrogen	-calsol	238.3fgh
Split Nitrogen	+calsol	250.6cdefg
Split Nitrogen	-calsol	227.8gh
Split Cal Nit	+calsol	269.4bcd
Split Cal Nit	-calsol	278.1b
Split Cal Nit + N-Plus	+calsol	276.6b
Split Cal Nit + N-Plus	-calsol	248.4defgh
Split N-Plus (60 lb/a Ca)	+calsol	271.8bc
Split N-Plus (60 lb/a Ca)	-calsol	263.9bcde
Split CUC[1]	-	313.1a
Split CU[2] (60 lb/a ca)	-	268.5bcd
Split CU[2] (82.5 lb/a ca)	-	264.8bcde
Split UAN[3]	-	243.0efgh
Split UCAN[4] (60 lb/a Ca)	-	251.2cdef
Split UCAN[4] (82.5 lb/a Ca)	-	261.3bcde

CUC: Calcium chloride, calcium nitrate and urea
CU: Calcium chloride and urea
UAN: Urea and ammonium nitrate
UCAN: Calcium nitrate and urea

Table 4: 1999 yields by nutrient treatment. All yields are expressed mean of five replications. Each replication in an average yield (cwt/a) of combined two 20 foot rows.

Treatment		Total yield	US#1 (6-13 oz)	B's	Culls	<4 oz	4-6 oz	6-10 oz	10-13 oz	13-16 oz	>16 oz
Non Split Nitrogen	+calsol	586.3abc	168.98ab	37.6cd	140.5e	93.5bcde	130.1abcd	141.0a	28.0ab	11.1a	4.1ab
Non Split Nitrogen	-calsol	586.7abc	177.6a	32.3d	158.2cde	79.0e	124.8bcde	141.2a	36.4ab	8.3abc	0.8b
Split Nitrogen	+calsol	563.7bc	116.0c	51.3ab	156.8de	114.8abc	118.3bcdef	91.4bc	24.6ab	5.5abc	0.7b
Split Nitrogen	-calsol	568.6bc	128.5bc	45.5abc	163.5cde	107.9abcde	120.3bcdef	107.9bc	20.6b	2.1c	0.9ab
Split Cal Nit	+calsol	582.6abc	137.0abc	41.9bcd	168.9cde	104.1bcde	119.6bcdef	116.7abc	20.3b	7.7abc	2.6ab
Split Cal Nit	-calsol	543.6c	132.9bc	46.6abc	141.7e	88.8cde	126.8abcde	112.7abc	20.2b	4.5abc	2.2ab
Split Cal Nit + N-Plus	+calsol	559.1bc	110.4c	42.9bcd	199.9abc	94.7bcde	103.3f	95.1bc	15.3b	6.1abc	0.9ab
Split Cal Nit + N-Plus	-calsol	601.6abc	135.9abc	52.3ab	184.7bcd	107.3abcde	111.5def	111.7abc	24.2ab	8.4abc	1.6ab
Split N-Plus (61.2 lb/a Ca)	+calsol	635.3a	148.7abc	42.4bcd	219.9ab	98.2bcde	111.9def	116.4abc	32.2ab	9.2ab	5.0a
Split N-Plus (61.2 lb/a Ca)	-calsol	565.3bc	125.9bc	44.4abc	191.7abcd	83.8de	114.1cdef	107.0bc	18.8b	5.3abc	0.0b
Split N-Plus (100 lb/a Ca)	+calsol	583.0abc	147.7abc	46.5abc	164.5cde	94.9bcde	119.6bcdef	121.4ab	26.3ab	7.5abc	2.4ab
Split N-Plus (100 lb/a Ca)	-calsol	565.8bc	124.9bc	45.8abc	167.0cde	101.4bcde	118.8bcdef	103.2bc	21.7b	6.4abc	0.0b
Split CUC[1]	-	592.5abc	119.6c	54.2a	173.5cde	106.8abcde	130.4abcd	100.0bc	48.6a	8.0abc	0.0b
Split CU[2] (61.2 lb/a Ca)	-	637.5a	122.2c	45.1abc	227.8a	106.3abcde	127.7abcde	102.5bc	19.7b	7.6abc	0.0b
Split CU[2] (83.7 lb/a Ca)	-	563.7bc	108.6c	54.4a	175.4cde	110.2abcd	108.9ef	88.0c	20.5b	5.3abc	0.8b
Split UAN[3]	-	618.2ab	123.6c	55.3a	172.7cde	113.3abcd	146.3a	102.6bc	20.1b	4.3abc	2.7ab
Split UCAN[4] (61.2 lb/a Ca)	-	590.9abc	136.1abc	39.2cd	152.1de	121.1ab	135.0ab	115.4abc	20.7b	5.9abc	1.6ab
Split UCAN[4] (83.7 lb/a Ca)	-	593.1abc	115.5c	50.4ab	151.0de	135.5a	133.8abc	92.7bc	22.8ab	3.5bc	3.4ab

LSD α=0.05

CUC: Calcium chloride, calcium nitrate and urea CU: Calcium chloride and urea UAN: Urea and ammonium nitrate

UCAN: Calcium nitrate and urea

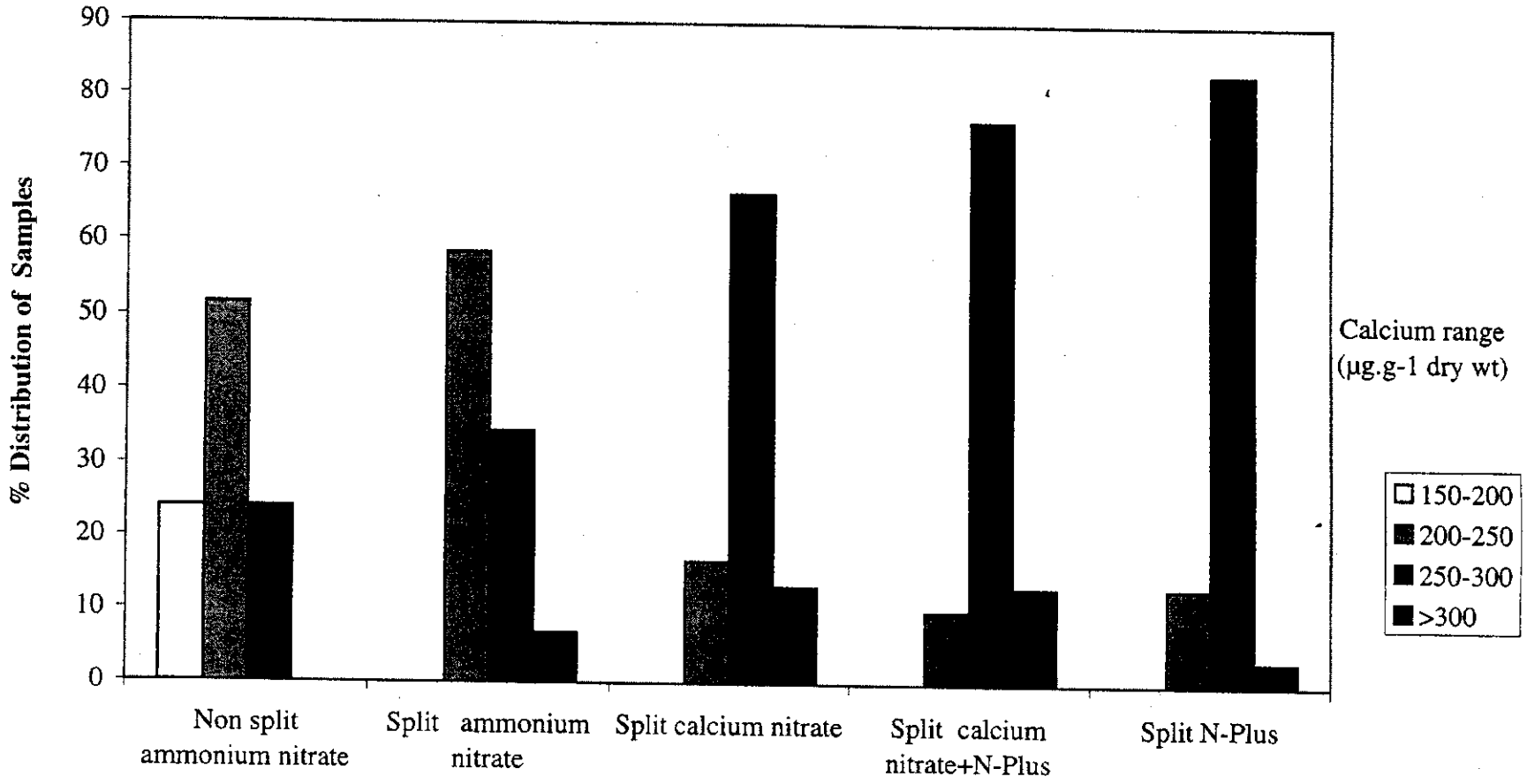
Table 5:1999 Tuber defects, hollow heart and brown center, total defect and multiple defects by nutrient treatment. 500 tubers were evaluated for each treatment.

Treatment		IBS[a]	HH[b]	BC[c]	TD[d]	MD[e]
			(%Tubers)			
Non Split Nitrogen	+calsol	10.9ab	5.9abc	3.5bc	20.3abc	0.0b
Non Split Nitrogen	-calsol	11.0ab	6.2abc	5.1abc	22.2abc	0.0b
Split Nitrogen	+calsol	4.3c	5.3bc	2.4c	12.3c	0.3ab
Split Nitrogen	-calsol	11.6a	5.8abc	7.3ab	24.7ab	0.0b
Split Cal Nit	+calsol	8.2abc	6.4abc	5.5abc	20.1abc	0.0b
Split Cal Nit	-calsol	10.0abc	10.0a	4.6abc	24.6ab	0.0b
Split Cal Nit + N-Plus	+calsol	5.0bc	3.0c	4.5abc	13.0c	0.6ab
Split Cal Nit + N-Plus	-calsol	6.0abc	5.2bc	2.1c	14.7bc	1.2a
Split N-Plus (61.2 lb/a Ca)	+calsol	7.8abc	8.1ab	4.0bc	20.1abc	0.2ab
Split N-Plus (61.2 lb/a Ca)	-calsol	5.4abc	5.9abc	4.9abc	16.4abc	0.4ab
Split N-Plus (100 lb/a Ca)	+calsol	7.3abc	3.2c	1.9c	12.3c	0.0b
Split N-Plus (100 lb/a Ca)	-calsol	6.5abc	6.7abc	3.0bc	16.6abc	0.4ab
Split CUC[1]	-	9.6abc	7.1abc	8.8a	25.9a	0.4ab
Split CU[2] (61.2 lb/a ca)	-	8.3abc	5.6abc	5.0abc	19.3abc	0.4ab
Split CU[2] (83.7 lb/a ca)	-	7.3abc	3.0c	4.9abc	15.3bc	0.0b
Split UAN[3]	-	9.0abc	6.0abc	4.7abc	20.4abc	0.8ab
Split UCAN[4] (61.2 lb/a Ca)	-	8.7abc	5.8abc	4.1bc	19.2abc	0.5ab
Split UCAN[4] (83.7 lb/a Ca)	-	8.2abc	3.4c	4.0bc	16.9abc	1.0ab

LSD (α=0.05)
CUC: Calcium chloride, calcium nitrate and urea
CU: Calcium chloride and urea
UAN: Urea and ammonium nitrate
UCAN: Calcium nitrate and urea
[a]Internal brown center: **Any spot 3mm or greater** contained inside of the vascular ring in the medullary tissue but **not in the center.**
[b]Hollow heart: **Cavity of any perceptible size** in center of medullary tissue with or without discoloration.
[c]Brown center: **Any brown discoloration** in the **center** of the potato. Very faint, or small, but discernible browning was rated as a defect.
[d]Total defect: **Sum** of all incidences of defect, except bruise.
[e]Multiple defect: Any tuber containing **two or more** of the above defects, except bruise.

Figure 1: Frequency distribution of tuber calcium concentration. Represented are the proportion (percentage) of 1998 season tubers within various ranges of tuber calcium concentration. For each treatment 6 bulk samples of ten tubers (total of 300 tubers) were analyzed. LSD Alpha=0.05.

(Treatment applied with calsol)

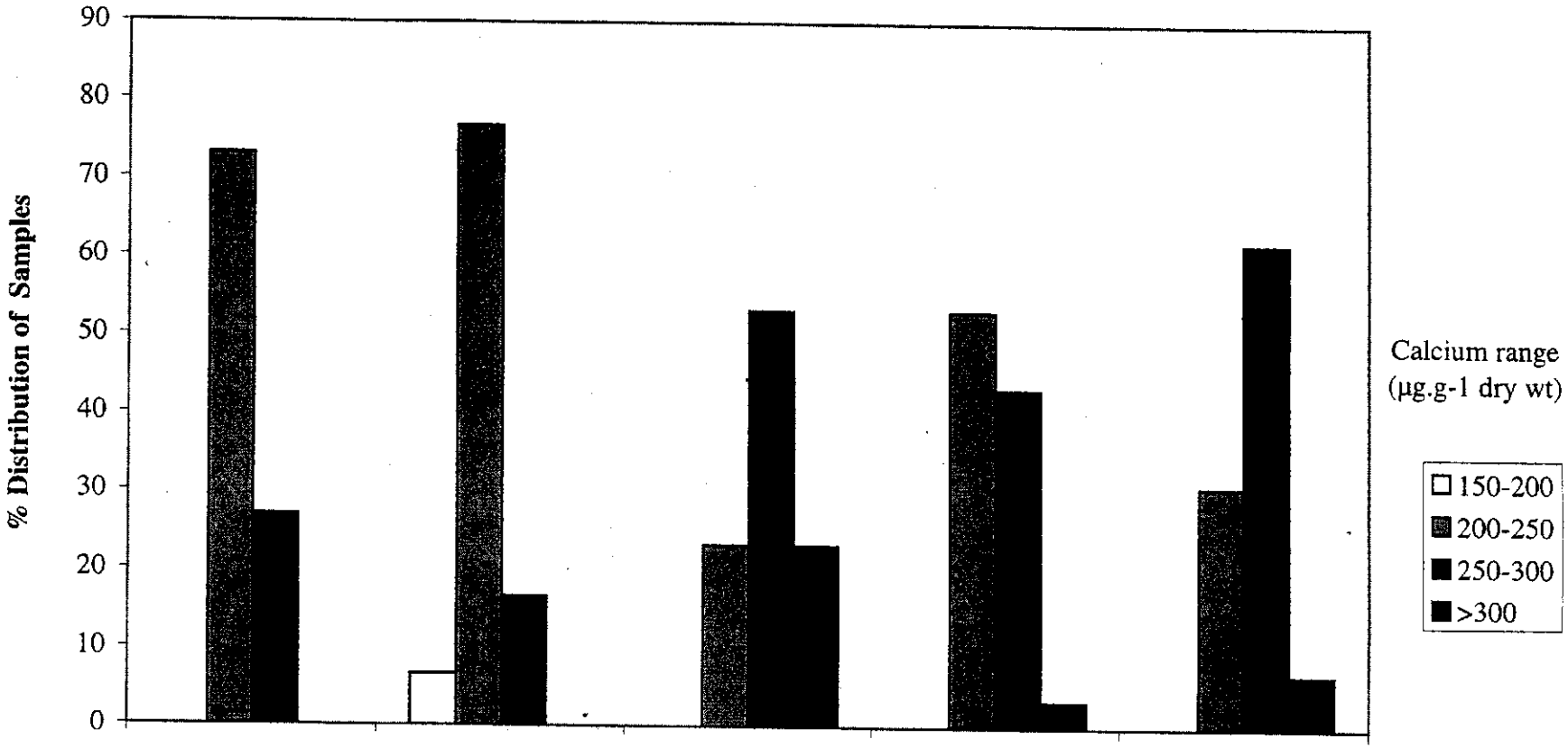


Average calcium concentration	227.1b	250.6ab	268.5a	278.0a	271.8a

All treatments in figure 1 analyzed together

Figure 2: Frequency distribution of tuber calcium concentration. Represented are the proportion (percentage) of 1998 season tubers within various ranges of tuber calcium concentration. For each treatment 6 bulk samples of ten tubers (total of 300 tubers) were analyzed. LSD Alpha=0.05.

(Treatment applied without calsol)



	Non split ammonium nitrate	Split ammonium nitrate	Split calcium nitrate	Split calcium nitrate+N-Plus	Split N-Plus
Average calcium concentration	238.3c	227.8c	264.8b	313.1a	263.9b

All treatments in figure 2 analyzed together