Research - Strawberry Nutrition

The Effect of Increased Nitrogen and Potassium Levels within the Sap of Strawberry Leaf Petioles on Overall Yield and Quality of Strawberry Fruit as Affected by Cultivar

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Justification:

Among the recent techniques for N and K management in vegetable and small fruit has been the use of petiole sap analysis to determine supplemental fertilizer needs. Sap tests to determine nutrient status of crops have been used to a limited degree since the 1920s. Until recently, however, these tests have been considered semi-quantitative at best. Within the last 20 years, advances have been made in determining sap NO_3 and K in various crops using Merck EM Quant test strips. More recently, the introduction of the electrode by Horiba Instruments called a "Cardy meter" has a flat membrane capable of providing a reading for NO_3 or K concentration in a non diluted sap. Researchers using the Cardy NO_3 electrode with non diluted sap have also shown that sap NO_3 is correlated to petiole NO_3 expressed on a dry weight basis. The Cardy K meter has been used to establish sufficient levels of K in petiole sap for eggplant. Plant sap analysis can help achieve optimum fertilization of strawberries. Petiole sap testing is not intended to replace standardized laboratory analytical procedures for whole leaves or dried petioles. However, analyzing fresh plant sap for N and K concentrations is a quick procedure to determine the N and K levels in plants, the results of which can be used in guiding N and K applications to strawberry plants. However, proper use of the equipment and sample techniques is vital to a reliable reading.

Work by investigators in California provides evidence of the benefits derived from strategically spaced nitrogen applications in the spring. Higher fruit yields in their studies were associated with nitrogen applied during vegetative growth and fruiting. During this period, petiole nitrate nitrogen values were 3000 – 4000 ppm nitrogen, which appears to be adequate. In general nitrate nitrogen should never drop below 500 ppm. Exceptions to this general rule would be during early winter and after fruiting. During plant establishment (fall) petiole nitrate nitrogen should approach 1500 – 2000 ppm. This work concurs with work in North Carolina as well. However, these numbers reflect the response of only one cultivar, Chandler.

Objectives:

1. Examine the effectiveness of the use of the Cardy Meter as a reliable source to be used by growers to monitor the Nitrogen and Potassium levels within the petiole sap throughout the production season.

2. Examine the levels of both nitrogen and potassium to maximize yield, yet maintain fruit quality as it is affected by cultivar selection.

Methods and Materials

Field experiments were conducted during the 2003-2004 growing seasons. The experimental site was located at the Clemson Coastal Research and Education Center (CREC), Charleston, South Carolina. The soil was Younges fine loamy sand. Strawberry cultivars chosen for this study were: 'Chandler', 'Gaviota' and 'Camarosa'. 'Chlandler', 'Gaviota' and 'Gaviota' transplants were obtained from commercial nursery sources. These transplants were grown for five weeks usng the NC Strawberry Transplant Growing Recommendations (Poling and Monks, 1994). Plug plants were field planted on October 9. A randomized complete block design was used with six replications of each of the four fertilizer treatments using each of the three cultivars. All plots received sixty units of nitrogen and potassium prior to transplanting. The fertilizer was broadcast and incorporated once bed formation had occurred but prior to fumigation and the black plastic mulch operation. Plugs were transplanted in 3 feet (.9m) wide fumigated, black plastic mulched beds, 8 inches (20 cm) high with 6 feet (1.8 m) between centers of each bed. Plots consisted of a single mulched bed, 5 feet long (1.5 m) long, with a double row of plants staggered 12 inches (30 cm) apart within row and 14 inches (36 cm) between rows. Each plot contained 10 plants. Irrigation and fertigation began the following March. Fertilizer treatments consisted of: (1) 2.5 lb/week, totaling 30 lb of N and K; (2) 5.0 lb/week, totaling 60 lb N and K; (3) 7.5 lb/week, totaling 90 lbs of N and K, and (4)10 lb/week, totaling 120 lbs of N and K. Fertigation started on a weekly basis beginning February 27 and ending May 14, twelve week total. Fertilizer was a liquid (8-0-8) with minors purchased from a local distribution center. It was applied using four Dosmatic A-40 injectors, one for each treatment. Stantard pesticide practices were used for the growing season following the NC Strawberry Growing Recommendations (Poling and Monks, 1994). Mature fruit was harvested by hand twice weekly (Monday and Thursday) beginning at the end of March and continuing through the last week of May, nine weeks. Berries were harvested by hand and graded according to the USDA grading standards (USDA, 1997). Berries were individually counted, graded and weighed and divided into US No. 1, defects (small and misshapen berries), and rots (*Botrytis criteria*). Differences in yields and fruit quality were detected on a weekly basis using analysis of variance (ANOVA).

Results

The majority of variation in the plant growth and yield of strawberry plants were attributed to cultivar effects (Tables 1a, 2a and 3a). However, there was an effect of petiole analysis in each of the fertility treatments (Table 2a). As the fertility treatments increased the amount of nitrate nitrogen in the petioles increased, up to the 7.5 pound application per week (Table 2). As the fertility rate increased beyond that point additional levels were not detected in the petiole analysis. Potassium results, although significant at some sampling dates, at this time cannot be explained with any degree of confidence. There were no interactions of cultivar by fertility treatments seen by either element. Cultivar yield differences were detected at each of the nine week of harvest (Table 3). ‘Camarosa’ seemed to out perform both‘ Chandler’ and ‘Gaviota’. Chandler seemed to lag behind during the first four weeks of harvest before equaling and in some weeks out yielding ‘Camarosa’. Final crown counts showed trends in fertilizer treatments among cultivars (Table 3). ‘Gaviota’ appears to show harmful effects with increased nitrogen and potassium levels. Keep in mind that this is the first year of this study. Plots were not as uniform and I would have liked to have had. There was period of heavy rain fall during the harvest period that made it difficult to evaluate the plots. Visually you could see difference in the fertilizer treatments but those difference were not detected in the data that was analyzed. Additional years are needed before fertility recommendations can be make.

Table 1a. Source of variation in the analysis of variance (ANOVA) for petiole sap analysis on five different dates of four fertilizer treatments and three cultivars.

		Percent of total sums of square[Z]				
		Petiole sampling dates for nitrate nitrogen				
Source of Variation	**Degree of Freedom**	March 25	April 8	April 22	May 6	May 20
Rep	**5**	20**	41**	20**	40**	62**
Cultivar (C)	**2**	22**	5*	26**	1 (.51)	7*
Fertility (F)	**3**	30**	7*	7*	3 (.36)	4*
C x F	**6**	3 (.69)[Y]	2 (.54)	3 (.69)	2 (.33)	2 (.83)
Error	**55**	25	45	44	54	25

		Percent of total sums of square[Z]				
		Petiole sampling dates for potassium				
Source of Variation	**Degrees of Freedom**	March 25	April 8	April 22	May 6	May 20
Rep	**5**	25**	35**	21**	20**	32**
Cultivar(C)	**2**	0 (.06) [Y]	4 (.13)	7*	5 (.13)	2 (.70)
Fertility(F)	**3**	14**	8*	26**	2 (.32)	4 (.26)
C x F	**6**	5 (.31)	6 (.37)	4 (.43)	3 (.45)	4 (.66)
Error	**55**	54	49	42	70	58

[Z] The sum of squares for each of the factors in the ANOVA converted to a percentage of the total sums of squares.
[Y]Number in parentheses in the probability at which F test would be significant
**,* F values significant at P = 0.01, 0.05 respectfully.

Table 1. Effect of four fertilizer rates on petiole nitrogen and potassium levels at five different dates pooled over three cultivars within the production cycle using petiole sap analysis using a portable Cardy Meters.[Z]

Nitrate Nitrogen ppm

Petiole Sampling Dates					
Fertilizer treatments[Y]	March 25	April 8	April 22	May 6	May 20
2.5 lb/acre/week (8-0-8)	2237 c[X]	2721 c	4020 b	2124	1645 b
5.0 lb/acre/week (8-0-8)	2782 b	3292 a	4508 a	2311	1908 a
7.5 lb/acre/week (8-0-8)	3158 a	3298 a	4766 a	2406	1824 a
10.0 lb/acre/week (8-0-8)	3101 a	2920 b	4354 a	2453	1999 a
				ns	

Potassium ppm

Petiole Sampling Dates					
Fertilizer treatments[Y]	March 25	April 8	April 22	May 6	May 20
2.5 lb/acre/week (8-0-8)	1867 a[X]	1889 a	2300 a	1828	1833
5.0 lb/acre/week (8-0-8)	1706 c	1706 b	2138 b	1783	1689
7.5 lb/acre/week (8-0-8)	1861 a	1856 a	1944 c	1850	1700
10.0 lb/acre/week (8-0-8)	1722 b	1928 a	1939 c	1794	1717
				ns	ns

[Z]Twelve random samples from the most recent fully developed petioles were takes from each plot. Sap was extracted using a lemon press.
[Y]Fertilizer treatments applied weekly using a Dosmatic A40 injected. All treatments were applied through the drip irrigation lines beginning Feb. 27 and ending May 14, twelve weeks.
[X]Least significant difference within columns at P = 0.05

Table 2a. Percentage of treatment sum of squares of the model[Z] partitions into main and interaction effects for strawberry yield variables in response to fertility by cultivar.

Marketable number/plot										
		Percent of total sums of squares								
Source of variation	**Degrees of freedom**	**Harvest weeks[Y]**								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Rep	**5**	6	3	7**	8	10*	9*	14**	9	7
Cultivar (C)	**2**	18**	74**	65**	23**	46**	55**	48**	29**	40**
Fert (F)	**3**	6(.21) [X]	2(.15)	4**	2(0)	1(0)	0(0)	0(0)	2(0)	0(0)
C x F	**6**	5(0)	3(.11)	7**	6(0)	5(.28)	4(.36)	4(.38)	4(0)	7(.28)
Error	**55**	65	18	17	61	38	32	34	56	46

Marketable weight/plot										
		Percent of total sums of squares								
Source of variation	**Degrees of freedom**	**Harvest weeks[Y]**								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Rep	**5**	5	3	6	16**	20**	2**	14*	12	5
Cultivar (C)	**2**	21**	79**	64**	56**	10*	52**	31**	15**	45**
Fert (F)	**3**	4(.36)	2*	4*	1(0)	0(0) [X]	0(0)	0(0)	5(.28)	0(0)
C x F	**6**	3(0)	3(.07)	6*	1(0)	10(.22)	24(.39)	6(0)	3(0)	4(0)
Error	**55**	67	13	20	26	60	22	49	65	46

Defect number/plot										
		Percent of total sums of squares								
Source of variation	**Degrees of freedom**	**Harvest weeks[Y]**								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Rep	**5**	6	17	20**	10*	13*	18**	6**	5	5
Cultivar (C)	**2**	11*	2(0) [X]	14**	44**	32**	38**	75**	58**	36**
Fert (F)	**3**	6(.17)	8(.09)	1(0)	1(0)	6(.06)	1(0)	1(.27)	1(0)	3(0)
C x F	**6**	9(.34)	8(.35)	6(0)	4(0)	5(.37)	1(0)	1(0)	2(0)	6(0)
Error	**55**	68	65	59	41	44	42	17	34	50

Defect weight /plot										
		Percent of total sums of squares								
Source of variation	**Degrees of freedom**	**Harvest weeks[Y]**								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Rep	**5**	6	8	10	10*	20**	12**	7*	6	3
Cultivar (C)	**2**	12*	19**	38**	42*	8*	57**	61**	39**	34**
Fert (F)	**3**	7(.16) [X]	8(.07)	1(0)	2(0)	3(0)	1(0)	3(.14)	2(0)	4(.25)
C x F	**6**	5(0)	8(.30)	3(0)	5(.33)	6(0)	2(0)	2(0)	4(0)	6(.43)
Error	**55**	70	57	48	41	63	28	27	49	53

Rot number/plot										
		Percent of total sums of squares								
Source of variation	**Degrees of freedom**	**Harvest weeks[Y]**								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Rep	**5**	-	9	7	3	8	9*	25**	10	6

Cultivar (C)	**2**	-	0(0)[X]	8*	5(0)	30**	48**	13*	1(0)	0(0)
Fert (F)	**3**	-	4(.39)	8(.10)	15(.18)	3(.32)	2(0)	6(.12)	3(0)	5(.37)
C x F	**6**	-	4(0)	8(.43)	9(.31)	4(0)	3(0)	5(0)	2(0)	9(0)
Error	**55**	-	83	69	68	55	38	51	84	80
Rot weight /plot										
		Percent of total sums of squares								
Source of variation	**Degrees of freedom**	**Harvest weeks[Y]**								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Rep	**5**	-	7	9	6	10	8	17*	5	7
Cultivar (C)	**2**	-	5(.37) [X]	10*	5(.11)	23**	2(0)	4(.24)	3(.38)	3(.34)
Fert (F)	**3**	-	3(.20)	6(.19)	16**	11	4(0)	6(.18)	3(0)	5(.36)
C x F	**6**	-	7(0)	7(0)	8(.36)	2	8(.42)	8(.37)	2(0)	8(.43)
Error	**55**	-	78	68	65	54	78	65	87	77

*,** F test significant at P = 0.05 or 0.01.
[Z]Composed of only those sources of variation given in ANOVA tables. All sources within columns add up to 100%. Numbers given show relative importance to each factor in analysis.
[Y]Harvest weeks : 1 = 3/29 to 4/2; 1 = 4/5 to 4/9; 3 = 4/12 to 4/16; 4 = 4/19 to 4/23; 5 = 4/26 to 4/30; 6 = 5/3 to 5/7; 7 = 5/10 to 5/14; 8 = 5/17 to 5/21; 9 = 5/24 to5/28.
[X]Number in parentheses is the probality at which F test would be significant.

Table 2. Effect of cultivar selection on individual harvest characteristics (pooled over four fertility rates) at each end of each week for nine weeks.

Cultivar	Marketable number/plot								
	Harvest weeks[Z]								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Chandler	2.0 a	6.7 b[Y]	19.5 b	90.8 b	165.3 a	168.2 a	45.3 a	24.9 a	1.1 b
Camarosa	2.4 a	25.2 a	49.6 a	118.5 a	162.0 a	90.7 b	43.6 a	21.3 a	3.8 a
Gaviota	0.3 b	3.5 b	19.4 b	48.6 b	110.7 b	80.8 b	19.5 b	11.4 b	0.5 b

Cultivar	Marketable weight (g)/plot								
	Harvest weeks[Z]								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Chandler	45.8 a	121.8 b[Y]	322.0 c	1412.7 b	2742.0 a	3592.8 a	562.0 b	261.0 a	12.2 b
Camarosa	56.2 a	552.5 a	1079.3 a	1804.5 a	2757.4 a	1395.4 b	605.6 a	283.6 a	49.9 a
Gaviota	4.2 b	62.4 c	413.3 b	976.0 c	2406.9 b	1253.2 b	343.5 c	181.2 b	7.5 c

Cultivar	Defect number/plot								
	Harvest weeks[Z]								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Chandler	0.6 ab	3.6 a[Y]	13.3 b	42.2 a	70.5 a	66.7 a	52.3 a	29.5 a	17.9 b
Camarosa	1.1 a	4.2 a	17.5 a	38.9 a	46.0 b	56.4 b	26.4 b	15.5 b	22.7 a
Gaviota	0.3 b	3.3 a	11.5 b	17.8 b	41.8 b	28.0 c	11.9 c	9.3 c	7.6 c

Cultivar	Defect weight (g)/plot								
	Harvest weeks[Y]								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Chandler	13.2 b	51.6 b[Y]	207.7 b	571.2 a	821.1 a	1123.7 a	431.2 a	178.8 a	88.8b
Camarosa	22.6 a	76.4 a	354.7 a	592.0 a	645.6 c	573.0 b	234.4 b	110.1 ab	149.3a
Gaviota	3.9 c	32.1 c	178.5 b	289.4 b	709.6 b	359.3 c	148.1 c	78.8 b	64.6b

Cultivar	Rot number/plot								
	Harvest weeks[Y]								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Chandler	0.0	0.3 a[Y]	1.3 ab	6.6 a	19.0 a	26.1 a	8.0 a	3.2 a	2.0 a
Camarosa	0.0	0.3 a	2.2 a	7.6 a	7.5 c	14.7 b	4.9 b	3.0 a	1.7 a
Gaviota	0.0	0.2 a	0.5 b	5.0 a	16.2 b	6.2 c	4.5 b	3.8 a	2.1 a

Cultivar	Rot weight (g)/plot								
	Harvest weeks[Y]								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Chandler	0	6.4 a[Y]	20.8 b	82.8 a	229.4 a	395.4 a	67.8 a	26.6 a	10.7 a
Camarosa	0	6.6 a	42.6 a	113.0 a	110.4 b	229.6 a	47.6 a	25.3 a	12.3 a
Gaviota	0	1.4 a	8.7 c	74.5 a	245.4 a	516.2 a	57.2 a	37.2 a	58.8 a

[Y]Harvest weeks : 1 = 3/29 to 4/2; 1 = 4/5 to 4/9; 3 = 4/12 to 4/16; 4 = 4/19 to 4/23; 5 = 4/26 to 4/30; 6 = 5/3 to 5/7; 7 = 5/10 to 5/14; 8 = 5/17 to 5/21; 9 = 5/24 to5/28.

[Y]Least significant difference within columns at P = 0.05

Table 3a. Source of variation in the analysis of variance (ANOVA) for final stand counts on three cultivars at four different fertility rates.

Source of variation	Degrees of freedom	Percent of the total sums of squares[Z]
		Final crown counts/Plant
Replication	5	12**
Cultivars (C)	2	16**
Fertility (F)	3	4 (30)[Y]
C x F	6	14(25)
Error	55	54

[Z] The sum of squares for each of the factors in the ANOVA converted to a percentage of the total sums of squares.
[Y]Number in parentheses in the probability at which F test would be significant
** F values significant at P = 0.01.

Table 3. Interaction of total fertility rates and cultivars on final crown counts per plant at the end of the production year.

Cultivar	Total N and P per acre	Final crowns per plant[Z]
Chandler	90 lb	6.2
	120 lb	6.6
	150 lb	6.5
	180 lb	5.8
Mean		**6.3 a**
Camerosa	90 lb	5.7
	120 lb	5.7
	150 lb	5.8
	180 lb	6.1
Mean		**5.8 b**
Gaviota	90 lb	4.9
	120 lb	3.5
	150 lb	3.5
	180 lb	3.1
Mean		**3.8 c**

[Z]Least significant difference at P = 0.05