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Monitoring Nitrogen Status of Organically-grown Strawberry Cultivars by Using Chlorophyll Meter Reading

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Abstract: In this study utilization of chlorophyll (CHL) meter to monitor nitrogen (N) status of five organically grown strawberry (*Fragaria* × *ananassa* Duch) cultivars including Sweet Charlie, Redlans Hope, Kabarla, Festival and Camarosa was investigated during 2003-2004 growing season. Leaf CHL was measured by using SPAD 502 chlorophyll meter. There was significant correlation (r = +0.434) between leaf N and CHL reading regardless of cultivar. Also there were significant differences in leaf N and CHL content among cultivars. Kabarla, Camarosa and R. Hope cultivars had the highest leaf N, followed by Festival and Sweet Charlie. The highest CHL reading value was recorded in Kabarla and R. Hope cultivars, followed by Festival, Sweet Charlie and Camarosa. The leaf N status of the cultivars used this experiment can be estimated using the regression equations belong to each cultivar. Therefore we recommend that standard value for CHL reading value should be determined for each cultivar before using CHL reading value for sound nitrogen management.

Key words: Strawberry (*Fragaria* × *ananassa* Duch), leaf nitrogen, chlorophyll, organic production

INTRODUCTION

Total conventionally-grown strawberry production of the world in 2005 was 3.5 million tons at the 250.751 ha area (FAO, 2005). Organically-grown strawberry production accounts for only small portion of the world total production. It is expected that owing to increasing demand for organically-grown strawberry, the share of it in the world total production will increase. Fertilizer management is of vital importance for high quality yield of not only conventionally grown but also organically grown strawberry. June-bearing or short-day varieties set buds for the following year's fruit in the fall. Therefore, after finishing harvest plants have to be fertilized regularly. Day-neutral strawberry varieties set fruit buds throughout the growing season and therefore need to have adequate nutrition provided for the entire period. To get a good bud set plants must not be nutritionally stressed (Ames *et al*., 2003). Of the fertilizer, nitrogen is the most important nutrient effecting strawberry yield and quality (May and Pritts, 1990). Because its lower or excessive application reduce yield and quality, cause some fruit disorders and increase insect and pest invasion (Johanson and Walker, 1963; Ulrich *et al*., 1980; Voth *et al*., 1967; May and Pritts, 1990; Miner *et al*., 1997). Leaf N content has been used as a tool to monitor N status of the strawberry plant (Hochmuth *et al*., 1991; Pritts and Handley, 1998). But it necessitates too much time and money. In fertigated strawberry, plant N status should be monitored in frequent intervals. For such frequent monitoring, non-destructive N determination is of vital importance. Chlorophyll meter have been used for determination of N requirements of many crops including corn (Schepers *et al*., 1992; Blackmer and Schepers, 1995; Piekielek and Fox, 1992; Piekielek *et al*., 1995; Varvel *et al*., 1997), wheat (Singh *et al*., 2002), rice (Turner and Jund, 1991; Singh *et al*., 2002) and potato (Shaaban and El-Bendary, 1999; Minotti *et al*., 1994; Gianquinto *et al*., 2003). Yadava (1986) working with 22 species representing 14 plant families including strawberry found significant correlation between CHL reading and CHL concentration determined by conventional technique. However there is no adequate information on relationships between leaf N and CHL reading value for organically-grown strawberry and utilization of CHL meter. With this study it was aimed at investigating the relationship between leaf N and CHL reading value and evaluating the cultivars used in terms of leaf N and CHL content.

MATERIALS AND METHODS

Experiment was conducted at the experiment field of The Black Sea Agricultural Research Institute, Samsun, Turkey (41° 21' N Latitude, 36° 15' E Longitude, 4 m elevation). Meteorological data of the experimental site were given in Table 1. Five short-day strawberry

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Table 1: Meteorological data of experimental site

	Precipitation (mm)			Temperature (°C)			Relative humidity (%)		
Month	Long term	2003	2004	Long term	2003	2004	Long term	2003	2004
January	58.4	28.1	84.2	6.90	9.30	8.1	68.0	72.2	61.3
February	48.8	77.8	43.9	6.60	4.80	7.5	70.4	74.0	66.3
March	52.7	73.5	66.2	7.80	5.00	8.5	75.8	75.4	75.4
April	58.3	45.0	101.1	11.10	8.70	11.4	79.5	79.6	77.5
May	50.6	54.7	68.6	15.30	16.20	14.9	80.6	78.4	82.4
June	47.9	3.3	53.4	20.00	20.70	19.8	76.3	68.8	81.5
July	31.3	37.2	68.1	23.10	23.70	21.7	73.4	72.5	80.4
August	50.9	94.0	14.6	23.20	24.10	22.9	73.7	72.9	76.5
September	87.4	194.7	66.2	19.80	19.50	18.9	74.7	75.5	78.8
October	78.6	64.0	83.4	15.90	17.50	15.6	75.8	69.3	81.2
November	73.3	104.0	233.4	11.90	11.50	11.1	70.4	79.7	71.3
December	55.7	61.2	109.8	9.30	9.30	7.6	66.8	64.6	68.8
Total	694.0	838.0	993.0	-	-	-	-	-	-
Mean	-	-	-	14.19	14.19	14.0	73.8	73.6	75.1

(*Fragaria* × *ananassa* Duch) cultivars (Sweet Charlie, Redlans Hope, Kabarla, Festival and Camarosa) were grown organically in a raised bed on clay soil in 2003-2004 growing season. The physical and chemical properties of the soil were as follows: pH 7.65 (1:5 soil: water), total salinity 0.11% (1:5 soil:water), $CaCO_3$ 6.55%, organic matter 4.07%, available P 62.0 kg ha^{-1}, exchangeable K 1000 kg ha^{-1}. Experimental design was Randomized Complete Block Design with four replications. Each plot had 20 plants. Before planting, each plot received 40 ton ha^{-1} farmyard manure (0.84% N, 0.17% P and 0.30% K, 2.94 dS m^{-1} EC). Also, wood ash containing 1.65% P was incorporated into the soil at a rate of equal to 100 kg ha^{-1} P. Green manure (*Vicia sativa* L.) sown in 2002 autumn was incorporated into the soil at the flowering stage in the spring of 2003. Frigo plants were sown in July 18, 2003. Straw was used as mulch material. After planting, aqueous solution of poultry manure was supplied with irrigation water through drip irrigation system at once per week application, beginning third week of April 2004, terminating at the end of September 2004. Chemical composition of poultry manure used was: 1.19% N, 2.31% P and 4.55% K, 3.27 dS m^{-1} EC, 6.98 pH. Leaf samples were taken for total N determination and CHL reading in June 01, 2004. The leaf chlorophyll was measured using minolta SPAD-502 chlorophyll-meter. A total of thirty chlorophyll meter reading was made on ten newly matured leaves in each plot, 3 reading on each leaf. Readings were taken from the same point of the leaves as much as possible. The same leaves were dried at 70° for 48 h for N determination. Leaf N was determined by micro-Kjeldahl method.

Analysis of variance (ANOVA), LSD test and regression analysis were performed on each variable using MSTAT program.

RESULTS AND DISCUSSION

There were statistically significant differences among cultivars in terms of leaf N ($p<0.001$) and CHL reading value ($p<0.001$) (Table 2). The mean leaf N content was 2.09% and mean leaf CHL reading was 29.86 unit irrespective of strawberry cultivars. When the cultivars were taken into account, Kabarla and Redlans Hope had the highest leaf N (2.42 and 2.31%N, respectively) and the highest CHL reading value (32.3 and 32.2 unit, respectively). Sweet Charlie cultivar had the lowest leaf N (1.58% N). While Camarosa had the higher leaf N (above 2%) than those of the Sweet Charlie and Festival, its CHL reading value was lower than those of these cultivars. Muramoto *et al.* (2003) compared five strawberry cultivars (Aromas, Chandler, Seascape, Pajaro and Diamante) under organic conditions and found great differences among cultivars in relation to leaf N. Seascape and Aromas, which had the highest leaf N, gave the highest marketable yield. In our studies, the cultivars having the highest leaf N produced the highest yield (data not given). They were ranked as Kabarla > Camarosa > Festival > Sweet Charlie > Redlans Hope. These results showed again the importance of monitoring N level of strawberry plant throughout the growing season. Muramoto *et al.* (2003) also suggested that total N in leaf blades rather than NO_3-N in petioles should be used as an indicator for N status in organic strawberries, which supports present results.

Table 2: Leaf N content and CHL reading of organically-grown strawberry cultivars

Cultivars	Leaf N (%)	Chlorophyll reading
S.Charlie	1.58b*	29.03b*
R. Hope	2.31a	32.2a
Kabarla	2.42a	32.3a
Festival	1.88b	29.05b
Camarosa	2.24a	26.73c
Mean	2.09	29.86
LSD	0.305	2.11
CV (%)	6.80	3.27

* Significant at $p<0.001$

Leaf N in strawberry shows great variability depending on growing season and cultivars. It reaches its highest value at flowering and fruiting stages and its lowest value at the end of the harvest (Kwong and

Table 3: Regression equations, probabilities and standard errors for regression analysis

Cultivars	Regression equations	R^2	Probability	Standard error	Student's t-value
S.Charlie	Y = 0.3979+0.0408x	0.312	0.000	0.043	0.95
R. Hope	Y = 4.0584-0.0542x	0.0635	0.000	0.147	-0.37
Kabarla	Y = 0.0034+0.0749x	0.4577	0.323	0.058	1.30
Festival	Y = 1.7684-0.1256x	0.8617	0.073	0.037	3.49
Camarosa	Y = 8.7678-0.2444x	0.3305	0.000	0.246	-0.99
Mean	Y = 0.2176 + 0.0626x	0.1884	0.056	0.031	2.05

Table 4: Average leaf N, CHL reading value, covariance and correlation values of cultivars

Cultivars	Average CHL reading	Average leaf nitrogen (%)	Covariance	Correlation
S.Charlie	29.03 (2.89)	1.58 (0.02)	0.12	0.559
R. Hope	32.20 (1.03)	2.31 (0.05)	-0.06	-0.252
Kabarla	32.30 (1.61)	2.42 (0.02)	0.12	0.677
Festival	29.05 (2.12)	1.88 (0.04)	0.27	0.927
Camarosa	26.73 (0.14)	2.24 (0.03)	-0.03	-0.575
Mean	29.86 (5.99)	2.09 (0.12)	0.38	0.434

[Y] values in parenthesis show the variance of the variable

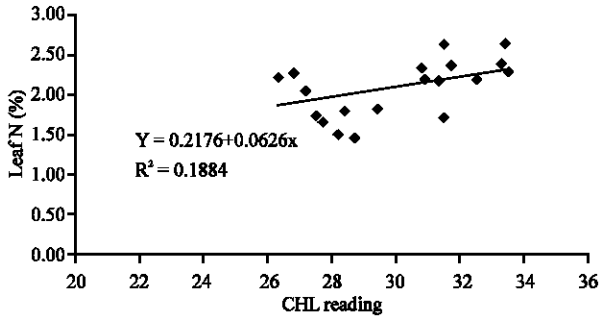

Fig. 1: Relationships between leaf N content and chlorophyll reading of strawberry irrespective of cultivar

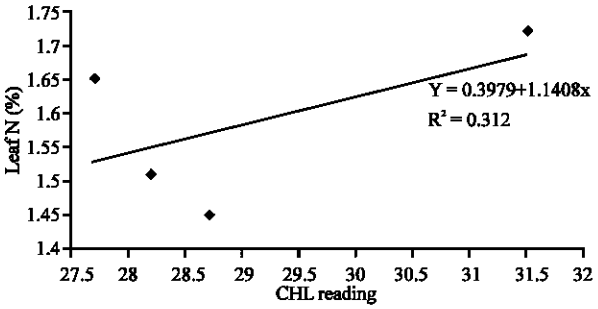

Fig. 2: Relationships between leaf N content and chlorophyll reading of Sweet Charlie cv

Boynton, 1959; Bould 1961; John *et al*., 1975; Stanisavljevic *et al*., 1997). In the literature, leaf N of strawberry ranged from 2.4 to 3.5% at the beginning of fruiting stage. In this study leaf sample was taken at the beginning of the fruiting stage (June 01, 2004). In present study, the leaf N varied from 1.58 (Sweet Charlie cv) to 2.42% (Kabarla cv). These values were close the values

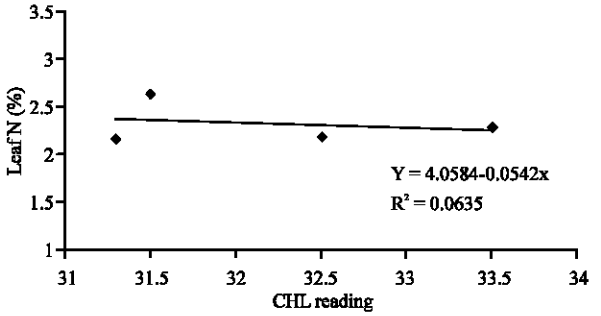

Fig. 3: Relationships between leaf N content and chlorophyll reading of Redlans Hope cv

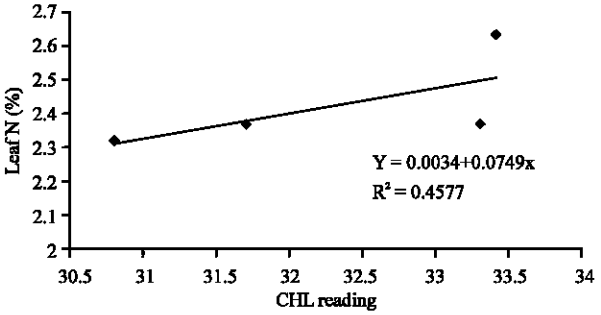

Fig. 4: Relationships between leaf N content and chlorophyll reading of Kabarla cv.

reported by Kwong and Boynton (1959), Bould (1961) and Stanisavljevic *et al*. (1997). In three cultivars, R. Hope, Kabarla and Camarosa, the leaf N were above 2% (Table 2).

Leaf CHL ranged from 26.73 and 32.30 unit, irrespective of cultivar (Table 2). Camarosa cv had the lowest CHL (26.73 unit), Kabarla cv had the highest CHL (32.30 unit). The low variability (3.27%) between the CHL measurements indicates good accuracy.

Regression analysis results were given in Table 3 and 4. There was significant correlation ($r = +0.434$, $p<0.05$) between leaf N and CHL reading value of strawberry irrespective of cultivars (Table 3, Fig. 1). There were positive and significant correlations between leaf N and CHL in Sweet Charlie ($r = +0.559$, $p<0.001$), negative and significant correlation in Redlans Hope ($r = -0.252$, $p<0.001$) and Camarosa ($r = -0.575$, $p<0.001$) cultivars. The relationships between leaf N and CHL reading value of strawberry cultivars used were presented in Fig. 2-6. These differences among cultivars may be attributed to organic growing conditions and cultivar differences. In this production system, plant was fed with organic inputs as poultry manure, farmyard manure, wood ash and green manure. The nutrient utilization power of the plant can change when the soil environment changed. Some cultivars show good adaptability, whereas others do not.

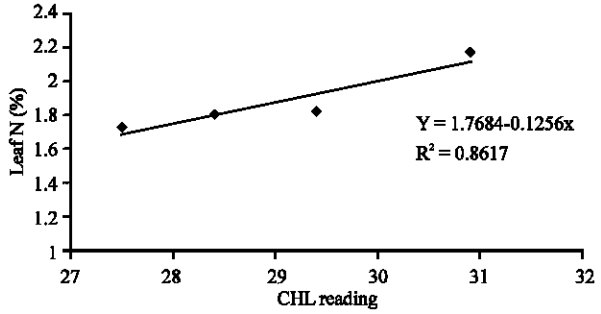

Fig. 5: Relationships between leaf N content and chlorophyll reading of festival cv

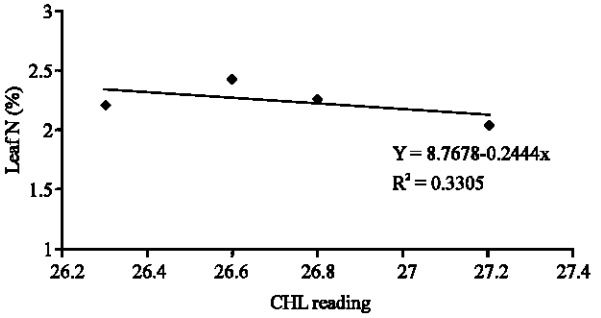

Fig. 6: Relationships between leaf N content and chlorophyll reading of Camarosa cv

Nutrient supply power of the organically fertilized soil is different from conventionally fertilized soil. Organically fertilized soils need a long time to reach the adequate level in relation to nutrient supply power (Stockdale *et al*., 2002; Watson *et al*., 2002). Therefore in organically grown strawberry plant N status should be monitored closely by measuring its leaf CHL as frequent intervals as possible.

In organic strawberry production, cultivars used showed great variability in relation to theirs leaf N and CHL reading value. Reference values determined for the cultivars used in this study can be used for the same cultivars. However, the reference value of leaf N and CHL reading for each cultivar need to be determined before using as a tool to monitor nitrogen status of organically grown strawberry.

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