Journal of Applied Horticulture, 9(1): 41-45, January-June, 2007

$N\text{-}NO_3$ from cellular extract as an indicator of nutritional status of cantaloupe muskmelon in fertigation

Maria Remedios Cigales Rivero[1] and Octavio Perez Zamora[2]

Centro Universitario de Investigacion y Desarrollo Agropecuario Universidad de Colima. Km 40 Autopista Colima-Manzanillo Tecomán, Col. 28100 Mexico. E-mail: mcigales@col.mx; [2]Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias. Campo Experimental Tecomán. Km 35 Autopista Colima- Manzanillo. Tecoman. Col. 28100 México.

Abstract

In cantaloupe farming (*Cucumis melo* L.), the production of export quality fruit require nutritional indicators that allow an adequate management of nitrogen fertilization and irrigation water supply. This study with cantaloupe muskmelon was carried out to test four nitrogen fertilization treatments and three levels of soil moisture tension under field conditions. Nitrate content ($N\text{-}NO_3$) in the cellular extract was evaluated as an indicator of nutritional status. Significant correlation was found between the lowest nitrate concentrations in the petiole sap and the N fertilization doses in three different sample periods. The effect of soil moisture tension on nitrate concentration varied in both years; this was attributed to soil temperature differences. Results showed that it is feasible to establish outcome predictions of yield and quality of the fruit based on the nitrate concentration in petiole sap, concluding that this is an adequate indicator of the nutritional status of the cantaloupe plant. However, its use as a guide for managing fertilization and irrigation must include a permanent follow up of the crop that evaluates the effects of environmental factors in plant growth and uptake of the nutrients.

Key words: *Cucumis melo* L., nitrogen fertilization, petiole sap, export product, soil moisture

Introduction

Cantaloupe muskmelon (*Cucumis melo* L.) is the main produce cultivated in the state of Colima, Mexico where 75% of its production is destined to the export market. An adequate crop management is required to obtain optimum yield with excellent fruit quality, to satisfy market demand and maintain crop profitability without environmental detriment, avoiding unnecessary waste of resources such as water, fertilizers and energy.

In different crops, it has been proved that yield and production quality are greatly related to an appropriate nutrition during the plant growth cycle (Locascio *et al.*, 1997; Williams, 1996). MacKerron *et al.* (1995) found a close relationship between the crop yield, days of active plant growth and the amount of required nutrients.

Studies have shown that variations in temperature between years and crop seasons, affect the development and duration of the tomato growth cycle, consequently, the uptake rate, and the utilization of nutrients (He *et al.*, 1999). On the other hand, using adequate nutrients doses during the early stage of the crop and even before pollination, an excellent yield is obtained. In contrast, with excessive doses of nitrogen, during low nutritional requirement period, toxins can be produced in plants and increase nitrate concentrations in fruit, which has been shown in muskmelon and other crops (Jang and Nukaya, 1997; Forlani *et al.*, 1997). Some authors point out that the $N\text{-}NO_3$ concentration in different crops is an indicator of the relation between nitrogen fertilization doses and yield, therefore this indicator has been utilized to evaluate the necessity for applying fertilizers during the plant growth cycle (Porter and Sisson, 1991). Nitsch and Varis (1991) observed that modern instruments for $N\text{-}NO_3$ determination in cellular extract, facilitates the use of this type of determinations as a guide in fertilization management. However, some authors propose a critical revision of this indicator because $N\text{-}NO_3$ concentration is not uniform the different parts of the plant (MacKerron *et al.*, 1995).

The availability of nutrients for the plant that come from the fertilizer depends greatly on soil moisture. The effect of the level of soil moisture on the quality and yield of cantaloupe was shown in a study for improving the irrigation management, particularly at the final stage of the crop, but little research has been done on its interaction with the nutrients (Hartz, 1997).

The objective of this study was to evaluate the usefulness of the determination of $N\text{-}NO_3$ concentration in the cellular extract of cantaloupe petioles as a reliable indicator of the nutritional status of the crop in relation to nitrogen fertilization and in combination with soil moisture levels.

Materials and methods

Experimental site: The study was conducted in a commercial plantation, located at 17 km south east of the city of Colima, Mexico during the winter seasons of 1998 and 1999. The soil is classified as Haplic phaeozem, pH 7.9, lightly calcareous, poor in organic matter, electric conductivity of 1.08 dS m^{-1}, high contents of exchangeable bases (>95 %), and a loamy to sandy loam texture.

Soil preparation: Soil preparation was conducted in the month of January following the practices followed by the farmers. Before planting ,150 kg ha^{-1} of each P (P_2O_5) and K (K_2O) were applied to the soil as additional fertilization to all treatments. The soil moisture was maintained by controlling the irrigation application with tensiometers installed at the soil depth of 0.30 and 0.60 m.

The soil temperature was registered daily.

Experimental design: A divided blocks experimental design was implemented in the field. Three sub-plots at soil moisture tensions of 10, 20, and 45 kPa constituted each block or main plot. Each main plot was divided into four small plots (Latin arrangement) for the application of nitrogen treatments: 0, 80, 120, and 160 kg N ha^{-1}. Each treatment was replicated four times.

The variety of cantaloupe evaluated was the hybrid Ovation. The cellular sap extractions to evaluate the N-NO$_3$ concentrations were carried out at the following phenological stages: blossom, fruiting and ripening stages. The samples were collected according to the Warncke's methodology (Warncke,1997). In order to have a representative sample of each treatment, 8 or 10 petioles were collected in each of the 12 small plots and were stored immediately at 4ºC temperature until the laboratory analysis.

The total fruit yields were registered in each treatment. Fruit quality was evaluated using the sugar content (ºBrix) and the fruit size as indicators. In this last indicator, five groups were considered according to the market criteria. Results were analyzed using ANOVA procedures and linear regression with the statistics software STATISTIX (1998)

Results and discussion

Effect of nitrogen applied to soil: The statistical analysis showed that the effect of nitrogen fertilization treatments was not similar in the two years of study. For 1998, only in the first stage of the cycle (43 days after sowing), significant differences were registered among treatments while, in 1999, significant differences were registered at all three crop stages (28, 49 and 63 days after planting) (Table 1).

The values of correlation between the N quantities applied to the soil and the N-N0$_3$ concentrations in the cellular extract varied in the crop stages. In 1998, only at blooming stage, a high correlation coefficient was observed (r=0.88). In contrast, during 1999, at all three sampling stages, correlation coefficients were significant (r = 0.90, 0.92, and 0.95, respectively). Similar variations have been reported in other horticultural crops when these variables correlate as function of time. (Andersen *et al.*,1999; Kubota *et al.,* 1997; Rhoads *et al.*, 1996; Waterer, 1997). These results indicate that variations of correlation values depend on the age of the crop (sampling date).

The differences in correlation values found in our study between 1998 and 1999 were related to the N-N0$_3$ level in the petiole sap. During 1998, the average of N-NO$_3$ concentrations was 1919 mg L^{-1} and for 1999 was 1316 mg L^{-1} (Table 2). In the first year, the lowest N-N0$_3$ level occurred at the harvest stage (6 days after sowing). At this date, high correlation was observed.

Some authors have observed that increase and decrease of N-NO$_3$ concentration in the first and final crop stages, are characteristic of species (MacKerron *et al.,* 1995). The age intervals in which applied doses of N and N-N0$_3$ concentration in the petiole sap correlated, depends on this characteristic that explains variations in correlation values for different ages and crops. Besides this, other factors like the space variability for N-N0$_3$ concentrations among plant parts necessitate a critical revision of the use of N-N0$_3$ concentration in the petiole sap as a guide to optimize fertilization (Mackerron *et al.*, 1995; Meyer and Marcus, 1998).

Applied water effect: Even though the effect attributed to the soil moisture treatments on the N-N0$_3$ concentration proved to be significant (P< 0.01) for every crop stage during the first year of study, in the second year the effect was significant only in the earliest stage of the crop, which is the most important stage for N deficits correction of the plant (Pérez-Zamora e*t al.*, 2004).

The increase of N-N0$_3$ related to the applied N varied with the soil moisture tension. In 1998, this increase was observed for 45 kPa treatment (Table 2). These results were attributed to the differences in soil temperature between both crop cycles: in 1998, a low level of soil moisture tension caused high concentration of N-N0$_3$. Considering that the humidity levels in treatments were kept within the adequate humidity range for cantaloupe, the high concentration of N-N0$_3$ in the petioles of the highest humidity treatment (10kPa) is explained by the effect the soil temperature registered in 1999 over the uptake rate and because the N0$_3$ moves in the soil mainly due to mass flow.

Reports are available that low humidity levels contribute to accumulation of nitrogen in the petioles of potato plants (Middleton *et al.*, 1975), also a lack of consistency in the correlation between humidity and concentration of nitrates is reported (Kubota *et al.*,

Table1. Analysis of variance summary for the N-N0$_3$ concentrations (mg L^{-1}) in cantaloupe petioles for N doses and soil moisture tension levels.

Source of variation	Degree of freedom	1998			1999		
		DAS[1]			DAP[2]		
		43	50	63	28	49	63
Main Plots							
Rows	3	NS	NS	NS	NS	NS	NS
Columns	3	NS	NS	NS	NS	NS	NS
Nitrogen	3	**	NS	NS	**	***	***
Error a	6						
Soil moisture	2	**	***	***	**	NS	NS
Error b	6						
Nitrogen x Soil moisture	6	NS	NS	NS	*	**	NS
Error	18						
C. V. (%)		9.39	8.63	8.87	9.37	12.82	14.22

*, ** and *** are significant at P=0.05, 0.01, and 0.001, respectively; NS=not significant; [1]DAS= day after sowing; [2]DAP= days after planting

Table 2. Concentrations of $N-NO_3$ ($mg\ L^{-1}$) in the cellular extract from cantaloupe petioles under four nitrogen doses and three soil moisture tensions at three crop stages

Treatments		Crop Stages					
N ($kg\ ha^{-1}$)	Soil moisture tension (k Pa)	1998			1999		
		Blooming	Fruiting	Ripening	Blooming	Fruiting	Ripening
0	10	1944	1944	1469	1763	1017	678
	25	2260	1808	1310	1831	1130	678
	45	2011	2290	1898	1492	859	746
80	10	2034	2035	1672	1893	1198	927
	25	2260	1695	1536	1863	1288	881
	45	2290	2215	2011	1559	927	859
120	10	2011	1853	1582	2237	1537	1175
	25	2280	1831	1401	1695	1220	1107
	45	2300	2214	2124	1695	1356	1041
160	10	1763	1808	1536	2057	1175	1153
	25	1831	1831	1469	1763	1424	1006
	45	2300	2011	2260	1695	1288	1107
LSD (*P*=0.05)		262	275	311	238	240	223

1997). In the case of cantaloupe muskmelon such report that the humidity effect on the $N-N0_3$ concentration in the petiole sap, does not exist.

Interaction of nitrogen fertilization and soil moisture: The effect of the nitrogen interaction with mositure was significant for samples at blooming and fructification in 1998, but it was not consistent under the different doses of fertilization in both crop cycles (Table 2). This contrasts with the results obtained in studies with potato crop, in which it is observed that an optimum combination of nitrogen and soil moisture during the plant growth cycle results in a high correlation with the $N-N0_3$ concentrations in the petioles during the whole plant growth cycle (Porter and Sisson, 1991).

Soil temperature and $N-NO_3$ concentrations: The pattern of soil temperature was different between the study years. In 1998, temperature average was 27.5ºC and showed a tendency to increase from the beginning of the crop cycle, in the month of February, until the end of the crop in the month of May. In 1999, temperature average was 25.5ºC and registered a decline during the first crop stage which was strongest during the blooming and fructification stages in the months of March and April. In the first year the $N-N0_3$ concentrations in the cellular extract of all treatments were superior to those of the second year, which showed the relation between temperature pattern and $N-NO_3$ concentration level.

Although the effect of the soil temperature on the utilization ability of N available from the cantaloupe crop has not been studied in detail. However, in other horticultural crops, the season effect has been observed on the $N-N0_3$ cellular extract levels, and the yield and quality of the fruit (Meyer and Marcus, 1998; He *et al.*, 1999).

In this study, the differences between soil temperature patterns for study years, were related with the nitrate level in the cellular extract.

Effect of $N-N0_3$ concentration on the yield and fruit quality: The effect of the $N-N0_3$ concentrations on the total production and fruit size was estimated indirectly through response functions of N applied to the soil and the production, and from applied N to the soil and concentration of $N-N0_3$. Maximum $N-NO_3$ concentration in the petiole sap, was obtained with 70 kg N ha^{-1} and 17 kPa, while the maximum yield and fruit size was also obtained with the same N and soil moisture tension indicated for the $N-NO_3$ concentration; this means that $N-NO_3$ concentration in the petiole sap is an indicator of yield and fruit size.

The results show that it is possible to establish predictions with r = 90% or higher. The production function (total yield of export fruit) for the average of two crop cycles was as following:

$$Yield\ (Mg\ ha^{-1}) = 60.92 - 0.126x - 1.124y + 0.00039x^2 + 0.0144y^2 + 0.00128xy;\ with\ r = 0.90$$

The response surface that considers the production of fruit size 9 and 12 (export size) is shown in Fig. 1.

These results coincide with reported values in other crops by authors when yield was correlated with the $N-N0_3$ concentration in the petiole sap. They showed that the harvest stage has an effect over the correlation value, in general high “r” values (0.74 to 0.89) were reported (Andersen, 1999; Dow and Roberts, 1982; Meyer and Marcus, 1998; Rhoads *et al.*, 1996; Williams, 1996).

The fruit quality was evaluated taking the fruit size and the sugar content (ºBrix) as indicators. There were not any significant difference among treatments as far as sugar content is concerned. However, the tendency was to diminish from 10 to 9.2ºBrix when the soil moisture level rose to 10 kPa which is the moisture tension value in which maximum production (80 Mg ha^{-1}) of export fruit was obtained. The results of this research contrasted with the results of other authors who did not find moisture effect or N effect on the soluble solids concentration in watermelon (Singh and Naik, 1989; Pier and Doerge, 1995). The level of $N-N0_3$ in petiole sap was related to production and the size distribution was

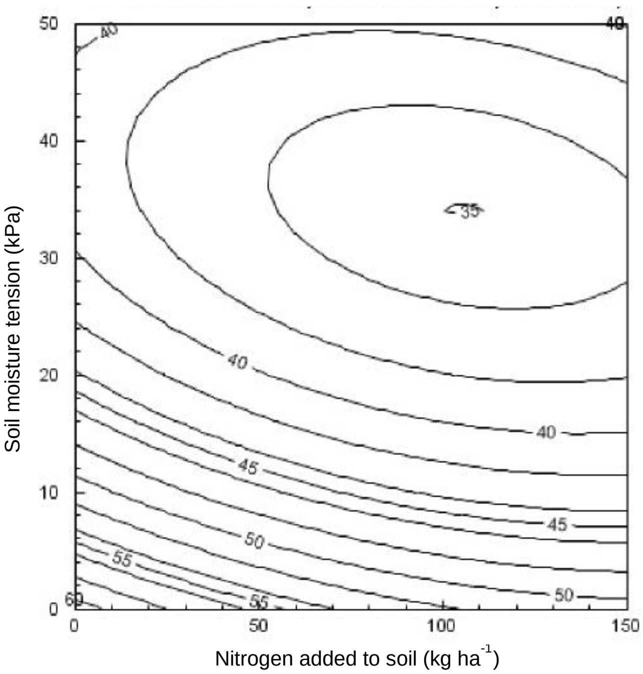

Fig.1. Response surface for cantaloupe melon, sizes 9 and 12. Lines contours are yields in Mg ha^{-1}.

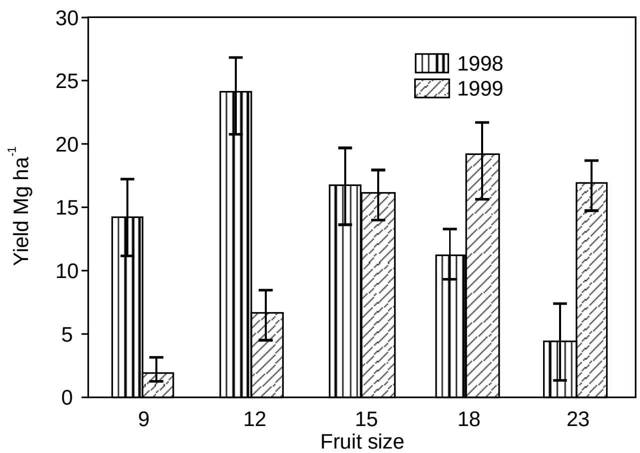

Fig. 2. Distribution by size of cantaloupe production, during two consecutive crop cycles under N fertilization and different soil moisture treatments.

strongly different for the extreme sizes, but not for intermediate size (No. 15), in both experimental cycles (Fig. 2).

The highest correlation values were obtained between the $N\text{-}NO_3$ concentration and the blossom stage, and the sizes 9 and 12 (r= 0.77 and r= 0.82, respectively). High correlation values between $N\text{-}NO_3$ concentration and the production quality (taken size as indicator) have been reported for tomato crop under field and greenhouse conditions (Anderson *et al.*, 1999; He *et al.*, 1999).

The results in this study showed that the $N\text{-}NO_3$ concentration in the sap petioles of the cantaloupe plant is an adequate indicator of the nutritional status of the plant and therefore constitute a useful instrument in the prediction of final yield and production quality.

The $N\text{-}NO_3$ analysis as a guide for management of the N fertilization and soil moisture requires a crop follow up at different stages and in different climatic conditions. It is necessary to consider the environmental conditions affecting the N absorption from soil.

The $N\text{-}NO_3$ concentrations reflect the effects of the interactions between N fertilization and soil moisture. An adjustment programme during the crop cycle must take in consideration both factors in order to maintain these concentrations in adequate ranges.

References

Andersen, P.C., F.M. Rhoads, S.M. Olson and B.V. Brodbeck, 1999. Relationships of nitrogenous compounds in petiole sap of tomato to nitrogen fertilization and the value of these compounds as a predictor of yield. *HortScience*, 34(2): 254-258.

Dow, A.I. and S. Roberts, 1982. Proposal. Critical nutrients rangs for crop diagnosis. *Agronomy. Journal*, 74: 401-403.

Forlani, L., S. Grillenzoni, E. Ori and P. Resca, 1997. Nitrate levels in vegetables that may be eaten raw. *Italian Journal of Food Sciences*, 9(1): 65-69.

Hartz, T.K. 1997. Effect of drip irrigation scheduling on muskmelon yield and quality. *Scientia Horticulturae,* 69(2): 117- 122.

He, Y.Q., S. Terabayashi, T. Asaka and T. Namiki, 1999. Effect of restricted supply of nitrate on fruit growth and nutrient concentrations in the petiole sap of tomato cultured hydroponically. *Journal of Plant Nutrition,* 22(4-5): 799-811.

Jang, H.G. and A. Nukaya, 1997. Relationships between concentration of nutrient solution and uptake of nutrients in muskmelon grown in Rockwool. *Journal of the Japanese Society for Horticultural Science,* 66(2): 307-312.

Kubota, A., T.L. Thompson, T.A. Doerge and R.E. Godin, 1997. A petiole sap nitrate test for broccoli. *Journal of Plant Nutrition,* 20(6): 669-682.

Locascio, S.J., G.J. Hochmuth, F.M. Rhoads, S.M. Olson, A.G. Smajstrla and E.A. Hanlon, 1997. Nitrogen and potassium application scheduling effects on drip irrigated tomato yield and leaf tissue analysis. *HortScience*, 32(2): 230- 235.

Mackerron, D.K.L., M.W. Young and H.V. Davies, 1995. A critical assessment of the value of petiole sap analysis in optimizing the nitrogen nutrition of the potato crop. *Plant and Soil*, 172: 247-260.

Meyer, R.D. and D.B. Marcus, 1998. Potato yield, petiole nitrogen and soil nitrogen response to water and nitrogen. *Agronomy. Journal,* 90: 420-429.

Middleton, J.E., S. Roberts, D.W. James, T.A. Cline, B.L. McNeal and B.L. Carlile, 1975. Irrigation and fertilizer management for efficient crop production on a sandy soil. *Washington State Univ. Coll. of Agric. Res. Ctr. Bull*., 811.

Nitsch, A. and E. Varis, 1991. Nitrates estimates using the Nitrachek test for precise N fertilization during plant growth and, after harvest for quality testing potato tubers. *Potato Research*, 34: 95-105.

Pérez-Zamora, O., M.R. Cigales Rivero and M. Orozco Santos y Pérez-Castro K. 2004. Tensión de humedad del suelo y fertilización nitrogenada en melón cantaloupe: Part II. *Agrociencia*, 38(3): 261-271

Pier, J.W. and T.A. Doerge, 1995. Nitrogen and water interactions in trickle - irrigated watermelon. *Soil Sci. Soc. Am. J.,* 59: 145-150.

Porter, G.A. and J.A. Sisson, 1991. Response of Russet Burbank and Seepody potatoes for nitrogen fertilizer in two cropping systems. *American Potato Journal,* 68: 425-443.

Rhoads, F.M., S.M. Olson, G.J. Hochmuth and E.A. Hanlon, 1996. Yield and petiole-sap nitrate levels of tomato with N rates applied preplant or fertigated. *Soil and Crop Science Society of Florida Proceedings,* 55: 9-12.

Statistix, 1998. *User´s Manual.* Analytical Software. Florida, 333 p.

Singh, R.V. and L.B. Naik,1989. Response of watermelon (*Citrullus lanatus* (Thunb) *Monsf.*) to plant density, nitrogen and phosphorus fertilization. *Indian Journal of Horticulture,* 46(1): 80-83.

Warncke, D. 1997. Petiole sap nitrate guidelines for selected vegetable crops. Michigan State University Extension Vegetable. CAT Alerts 1994-1998.10p.

Waterer, D. 1997. Petiole sap NO_3-N testing as a method for monitoring nitrogen nutrition of potato crop. *Canadian Journal of Plant Science,* 77(2): 273-278.

Williams, C.M.J. 1996. Assessment of the nitrogen and potassium status of irrigated Brussels sprouts (*Brassica oleracea* L. var. *Genunifera*) by plant analysis. *Australian Journal of Experimental Agriculture,* 36(7): 887-895.