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Use of a chlorophyll meter and plant visual aspect for nitrogen management in tomato fertigation

Paulo Cezar Rezende Fontes and Charles de Araujo

Departamento de Fitotecnia, Universidade Federal, 36570-000, Viçosa-MG. Brazil. Bolsistas do CNPq. Apoio FAPEMIG, e-mail: pacerefo@ufv.br.

Abstract

This study evaluated the feasibility of using SPAD-502 chlorophyll meter and plant visual aspect for N management in drip fertirrigated tomato plants (*Lycopersicon esculentum* Mill.) under unheated greenhouse. Two separate experiments were carried out at Universidade Federal de Viçosa - MG – Brazil in leached and non-leached soils under greenhouse. Six treatments were evaluated in a randomised complete-block design with four replicates. In treatment 1, N was applied at the time SPAD reading in leaf dropped below a critical value previously established for the specific plant physiological stage (SPAD-1). In treatments 2 and 3, SPAD critical values were increased 20 % (SPAD-2) and decreased 10% (SPAD-3), respectively. In treatment 4, the visual aspect of tomato plant (PVA) was utilized as a criterion of N management. In treatments 5 and 6 (check), N rates were 280 and 0 kg N ha^{-1}, respectively. Total applied N rates ranged from 0 to 594 kg N ha^{-1}. In both the experiments, total and marketable fruit yields were highest in SPAD-1 treatment which only differed from the check plot. All five criteria allowed high total tomato fruit yields but, as experiments average, N use efficiency was highest with the PVA treatment. The highest net income was obtained with SPAD-1 treatment and was associated with the highest yield. The results indicate that a SPAD meter can provide a quantitative measure of the N requirement of the tomato plants as long as appropriate SPAD critical values are established. Visual ratings of plant canopy needs to be more evaluated and improved.

Key words: *Lycopersicon esculentum* Mill, unheated greenhouse, drip irrigation, SPAD, plant nutrition

Introduction

Usually, nitrogen (N) fertilizer recommendation to tomato crop are derived from analysis of yield response to different N rates from a group of experiments (Fontes and Guimarães, 1999). In intensive vegetable cropping systems, as greenhouse tomato production (Fayad *et al.*, 2000), growers tend to add excessive N fertilizer. However, economic, environmental and safety considerations demand that N fertilizer should be applied only in quantities which are strictly justified. Matching agreement between crop demand and supply is one of the prerequisites for efficient N use.

Approaches based on N contents in leaves have been used to increase N fertilizer use efficiency. N management program in tomato production can be attained by suitable evaluation of plant N status (Coltman, 1988; Smith and Loneragan, 1997) which is usually accomplished by a quantitative analysis of the N concentration in the plant dry matter. Alternatively, quick procedures had been proposed as the tomato leaf greenness determination by a hand-held device– Minolta SPAD-502 meter (Sandoval-Villa *et al.*, 1999; Guimarães *et al.*, 1999)

The chlorophyll meter SPAD-502 is for simple, rapid, and non destructive estimation of chlorophyll contents in tomato leaves (Guimarães *et al.*, 1999). As several authors have shown a relationship between chlorophyll and N contents in plant leaves (Scheepers *et al.*, 1992; Sexton and Carol, 2002; Wang *et. al*, 2004), chlorophyll contents can be used as an alternative measure of plant N status (Fontes, 2001). Timely and nondestructive leaf N status detection could allow real time decision and improvement in N management.

Chlorophyll meter utilization to evaluate plant N status at real time is suitable for precision agriculture and canopy greenness might serve as a useful diagnostic tool to assess plant N demand (Wiesler *et al.,* 2002). This is also valid for plant visual aspect as long as evaluation criterion could be established. Very few papers deal with the theme (Ronchi *et al.*, 2001).

The objective of this study was to evaluate the feasibility of using SPAD-502 chlorophyll meter and plant visual aspect for N management in drip fertirrigated tomato plant under unheated greenhouse conditions.

Materials and methods

Two experiments were carried out in unheated greenhouse at the Federal University of Viçosa – MG – Brazil. One experiment was set in a previously leached area (experiment 1) and the other one was set in a non-leached area (experiment 2), in the same greenhouse conditions. Leaching was accomplished by applying excessive water in the soil during 15 days immediately before tomato plant transplantation. Six treatments were evaluated in a randomised complete-block design with four replicates.

In three treatments, Minolta SPAD-502 meter was utilized for measurements on five leaflets of the leaf closest to each specific cluster, at the same day time, from 7:00 to 9:00 a.m., immediately after drip irrigation. A mean SPAD value was calculated for each plot at 28, 42, 56, 70 and 98 days after transplantation (DAT) coinciding to the flowering time of the first, second, third, fourth, fifth, and sixth cluster, respectively. Each SPAD value was the mean of the measurement in 10 leaflets. In treatment 1, (SPAD-1), N was applied at the time SPAD reading dropped below a

Table 1. Previously established SPAD critical values (CV) and SPAD readings at selected tomato plant physiological stages[1] (days after transplantation-DAT) in experiments (Experiment 1 & 2)

DAT[1]	Treatments								
	SPAD-1			SPAD-2			SPAD-3		
	CV	Exp. 1	Exp. 2	CV	Exp. 1	Exp. 2	CV	Exp. 1	Exp. 2
28	45.9	49.0	49.6	55.2	48.0	51.3	41.5	47.1	46.7
42	43.6	49.3	52.1	52.4	51.8	54.2	39.4	48.8	50.5
56	41.2	43.3	48.5	49.6	56.2	51.5	37.3	44.3	45.9
70	38.8	32.8	37.1	46.8	57.6	56.8	35.2	32.6	38.1
84	36.4	55.3	57.5	44.0	61.2	60.2	33.1	53.0	51.9
98	34.0	57.5	50.7	41.2	57.8	57.4	31.0	56.0	54.2

[1] From the first to the sixth cluster.

critical value previously established for the specific physiological stage of the plant. In treatments 2 and 3, SPAD critical values were increased 20% (SPAD-2) and decreased 10% (SPAD-3), respectively (Table 1). SPAD critical values (Y) utilized in the experiment were previously established from the equation $\hat{Y}$ = 50.7179 - 0.170527 x, derived from Guimarães (1998), where x values were 28, 42, 56, 70, 84, and 98 DAT (Table 1). Plants in all three SPAD treatments received 50 kg N ha^{-1} at transplanting and the remaining N was applied as necessary set by SPAD critical values (Table 1) at the rates calculated by equations given in Table 2.

Table 2. Equations utilized to calculate nitrogen fertilizer rate in SPAD treatments[1]

Treatment	Equation
SPAD-1	$F=\{[50.7-(d \times 0.17)]-C\} \times 70$
SPAD-2	$F=\{[60.8-(d \times 0.20)]-C\} \times 70$
SPAD-3	$F=\{[45.7-(d \times 0.15)]-C\} \times 70$

[1] F = N rate (kg N ha^{-1}); d = plant age (days after transplantation) at the moment of SPAD reading; C = SPAD critical values at selected physiological stage; 0.17, 0.20, and 0.15 = daily decreases in the SPAD critical value with tomato plant aging; 70 = N rate (kg N ha^{-1}) to increase 1 SPAD unit.

In treatment 4, tomato plant visual aspect (PVA) was utilized as a criterion for N management. The severity of leaf chlorosis was characterized using a visual rating index (Table 3). Every 14 days, depending on the plant visual rating index it was decided on N sidedress application. Nitrogen rate of 30, 22.5, 15 or 7.5 kg N ha^{-1} was added whenever PVA where bad, regular, good or very good, respectively. A pre-planting 50 kg N ha^{-1}, at the transplanting time, was applied.

In treatment 5 (REFE), N was added @ 280 kg N ha^{-1} following recommendation supported by local experimental results (Fontes and Guimarães, 1999). In the treatment 6 (Check), plants were not fertilized with N.

At the transplanting time, N fertilizer (ammonium sulphate) was placed in open furrows, under the tomato plant. In sidedress, N fertilizer was applied by drip irrigation. N rates applied during the experiment are given in Table 4.

The experiments were conducted using recommended cultural practices (Fontes and Silva, 2002) which includes 25 days old seedlings (hybrid Carmen), plant stems vertically trained with plastic twine, stand of 1.66 plants m^{-2}, drip irrigation, stem tip pruned at 9 cluster, 10 harvests (during 65 days) and 143 days after transplantation cycle, from 10 September to 30 January.

Harvested fruits were separated as marketable and non-marketable; the marketable ones were graded according to Brazilian grade standards for big, medium, and small fruit. Based on different market prices for these three tomato fruit classes, yield was also expressed as "weighted yield" taking into account the big, medium and small fruits being 1, 0.658, and 0.396, respectively. Data were statistically evaluated by analysis of variance and treatment averages were compared with Tukey test (P=0.05).

Results and discussion

In both experiments, treatments led to different N sidedress rates and application dates (Table 4). Total N rates ranged from 0 to 594 kg N ha^{-1}. N requirement for high-yielding tomato fruit (> 80 t ha^{-1}), at field conditions, ranged from 125 to 351 kg N ha^{-1} (Scholberg *et al.,* 2000). In both experiments, increasing (SPAD-2) or decreasing (SPAD-3) SPAD critical values in relation to SPAD-1, led to higher or lower N fertilizer applications rates, respectively (Table 4).

In experiments 1 and 2 (Tables 5 and 6), total and marketable fruit yields were highest at SPAD-1 treatment which only differed significantly from the check plot. Total, marketable, and weighted yield values in this treatment were higher than 97, 75, and 45 previously obtained in the same place (Guimarães *et al.*, 1999). Weighted yield indicates the production cash value as it takes into account the price relationships between each fruit size grade (Fontes, 1997).

All five criteria allowed high total tomato fruit yields but with the PVA treatment, as experiments average, due to lower N addition, the nitrogen use efficiency (NUE) was highest (Table 7). NUE was expressed as: (total fruit yield at each treatment - total fruit yield at check plot)/(N rate in the treatment). Adjusting N rate in association with visual aspect and eliminating evaluator bias may turn the PVA approach useful.

The highest net income was obtained with SPAD-1 treatment (Exp. 2) and was associated with both the highest yield and the highest NUE (Table 7). SPAD-1 treatment led to apply N at 70 days after transplantation (DAT), at almost mid tomato plant cycle, at the beginning of fruit harvest which started at 77 DAT. This was probability due to high N demand by the tomato fruit enlargement. At this time, N demand increases (Tapia and Gutierrez, 1997; Fayad *et al.*, 2000) and soil N contents plus 50 kg N ha^{-1} added at transplantation time were not sufficient to maintain SPAD reading above the critical value. N rate applied in function of SPAD treatment was calculated based upon the criterion to apply 70 kg N ha^{-1} to increase 1 SPAD unit. To increase 1 SPAD

Table 3. Tomato plant visual aspect (PVA) utilized as a criterion for N management in the treatment number 4 and associated characteristics determined during plant cycle

PVA	Characteristic	Days after transplantating					
		14	28	42	56	70	84
Bad	Canopy greenness	YE	YE	YE	YE	YE	YE
	Leaf number	5	11	14	22	25	23
	Plant height (cm)	10	20	25	35	45	50
Regular	Canopy greenness	YG	YG	YG	YG	YG	YG
	Leaf number	6	15	24	26	28	25
	Plant height (cm)	15	30	50	95	105	110
Good	Canopy greenness	LG	LG	LG	LG	LG	LG
	Leaf number	7	18	30	35	34	33
	Plant height (cm)	15	45	90	155	165	170
Very good	Canopy greenness	DG	DG	DG	DG	DG	DG
	Leaf number	8	20	32	38	36	34
	Plant height (cm)	20	50	100	165	170	185

[1] YE = yellow; YG = yellow green; LG = light green; DG = dark green.

Table 4. Sidedress N rates (kg N ha^{-1}) applied during the tomato plant growth cycle in experiments 1 and 2

Treatment	Experiment	Days after transplanting							Total
		14	28	42	56	70	84	98	
SPAD-1	1	0	0	0	0	420	0	0	420
	2	0	0	0	0	116	0	0	116
SPAD-2	1	0	502	42	0	0	0	0	544
	2	0	270	0	0	0	0	0	270
SPAD-3	1	0	0	0	0	180	0	0	180
	2	0	0	0	0	0	0	0	0
PVA	1	22	15	15	15	15	15	0	97
	2	15	15	15	15	15	15	0	90
REFE	1	28	42	42	42	42	42	42	280
	2	28	42	42	42	42	42	42	280
CHECK	1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0

Table 5. Total, marketable and weighted yields of tomato as a function of treatments in experiment 1

Treatment	Yield (t ha^{-1})		
	Total	Marketable	Weighted
SPAD-1	99.1 a	97.0 a	52.2
SPAD-2	83.4 ab	77.3 ab	45.4
SPAD-3	82.8 ab	78.7 ab	43.4
PVA	84.5 ab	81.0 ab	44.5
REFE	93.7 ab	91.5 ab	53.7
CHECK	68.3 b	64.5 b	37.5

Table 6. Total, marketable and weighted yields of tomato as a function of treatments in experiment 2

Treatment	Yield (t ha^{-1})		
	Total	Marketable	Weighted
SPAD-1	101.9a	99.7a	61.7a
SPAD-2	86.4ab	82.3ab	49.2ab
SPAD-3	77.7ab	74.9ab	40.9ab
PVA	93.1ab	88.5ab	50.3ab
REFE	94.3ab	89.8ab	55.5ab
CHECK	71.7b	68.2b	40.3b

In each column, means followed by the same letter were not different by Tukey test (P=0.05)

unit in cotton and potato plants it was necessary 25 or 61 kg N ha^{-1}, respectively (Feibo *et al.*, 1998; Gil *et al.*, 2002). Varvel *et al.* (1997) utilized 30 kg N ha^{-1} when SPAD reading was below the critical level to obtain the highest corn yield.

In SPAD-1 treatment, commercial average yield was 688 kg ha^{-1} day^{-1}. Usually, tomato plant cycle in the field is 120 -160 days. But, it can be grown for in the field for longer time and in such cases the fruit productivity will be higher. So, expressing fruit productivity per day plant stay in the field, allow appropriate comparison among research results (Fontes, 1997). Values ranging from 700 (Vooren *et al.*, 1986) to 1.200 kg ha^{-1} day^{-1} (Fontes *et al.*, 1997, Papodopoulos and Hao, 1997) have been reported.

Finally, the result suggests a SPAD meter can provide a quantitative measure of the requirement of tomato plants as long as appropriate SPAD critical value are established. To establish precise and universal critical SPAD index is complex process due to the narrow values separating N deficiency from surplus and great number of variables affecting the index, as changes in leaf irradiance and water status (Martinez and Guiamet, 2004), environmental conditions and statistical procedures (Fontes and Ronchi, 2002). Caution is needed regarding the universality of SPAD and N calibrations across geographical

Table 7. Total nitrogen fertilizer rate and cost, net income, nitrogen use efficiency (NUE), agronomic nitrogen efficiency (ANE) for each treatment in experiments 1 and 2[1]

Treatment	Experiment	Total N (kg N ha^{-1})	N cost (US$ ha^{-1})	NPI[2] (US$ ha^{-1})	NUE[3] (kg kg^{-1})	ANE[4] (kg kg^{-1})
SPAD-1	1	470	588	15,072	66	211
	2	166	208	18,302	182	614
SPAD-2	1	594	745	12,875	25	140
	2	320	400	14,360	46	270
SPAD-3	1	230	288	12,732	63	360
	2	50	63	12,207	122	1556
PVA	1	153	191	13,159	106	552
	2	146	183	14,907	147	638
REFE	1	280	350	15,760	91	335
	2	280	350	16,300	81	337
CHECK	1	0	0	11,250	-	-
	2	0	0	12,090	-	-

[1]N price: US$ 1.25 kg^{-1}; selling price of high graded fruit (weighted yield): US$ 0.30 kg^{-1}

[2]Net partial income: (weighted yield x 0.30) – (N fertilizer cost). [3]NUE: (total fruit yield at each treatment - total fruit yield at check plot)/(N rate at treatment).[4]NE: (total fruit yield at each treatment)/(N rate at each treatment).

locations and seasons. To counter these potential problems, users should establish the SPAD critical values for specific environmental condition. Visual ratings of plant canopy needs to be more evaluated. This may facilitate more precise N fertilizer recommendations and thereby help to minimize nitrate contents in the soil.

References

Coltman, R.R. 1988. Yield of greenhouse tomatoes managed to maintain specific petiole sap nitrate. *HortScience*, 23(1): 148-151.

Fayad, J.A., P.C.R Fontes, A.A. Cardoso, F.L. Finger and F.A. Ferreira, 2000. Absorção de nutrientes pelo tomateiro cultivado em condições de campo e de estufa. *Horticultura Brasileira*, 20(1): 90-94.

Feibo, W., W. Lianghuan and X. Fuhua, 1998. Chlorophyll meter to predict nitrogen sidedress requirements for short-season cotton (*Gossypium hirsutum* L.). *Field Crops Res.,* 56: 309-314.

Fontes, P.C.R. 1997. Produtividade do tomateiro: kg/ha ou kg/ha/dia?. *Horticultura Brasileira*, 15(2): 83-84.

Fontes, P.C.R. 2001. *Diagnóstico do estado nutricional das plantas*. Viçosa: UFV, 122p.

Fontes, P.C.R., E.N. Dias, S.R. Zanin and F.L. Finger, 1997. Produção de cultivares de tomate em estufa coberta com plástico. *Revista Ceres*, 44(252): 152-160.

Fontes, P.C.R. and T.G. Guimarães, 1999. Manejo dos fertilizantes nas culturas de hortaliças cultivadas em solo, em ambiente protegido. *Informe Agropecuário*, 20(200&201): 36-44.

Fontes, P.C.R. and C.P. Ronchi, 2002. Critical values of nitrogen indices in tomato plants grown in soil and nutrient solution determined by different statistical procedures. *Pesquisa Agropecuária Brasileira*, 37(10): 1421-1429.

Fontes, P.C.R. and D.J.H. Silva, 2002. *Produção de tomate de mesa*. Viçosa, MG: Aprenda Fácil, 195p.

Gil, P.T., P.C.R. Fontes, P.R. Cecon and F.A. Ferreira, 2002. Índice SPAD para o diagnóstico do estado de nitrogênio e para o prognóstico da produtividade de batata. *Horticultura Brasileira*, 20(4): 611-615.

Guimarães, T.G. 1998. *Nitrogênio no solo e na planta, teor de clorofila e produção do tomateiro, no campo e na estufa, influenciados por doses de nitrogênio*. Viçosa-MG: UFV, 184p. (DS Thesis).

Guimarães, T.G., P.C.R. Fontes, P.R.G. Pereira, V.H.V. Alvarez and P.H. Monnerat, 1999. Teores de clorofila determinados por medidor portátil e sua relação com formas de nitrogênio em folhas de tomateiro cultivados em dois tipos de solo. *Bragantia*, 58(1): 209-216.

Martinez, D.E. and J.J. Guiamet, 2004. Distortion of the SPAD 502 chlorophyll meter readings by changes in irradiance and leaf water status. *Agronomie*, 24(1): 41-46.

Papadopoulos, A.P. and X. Hao, 1997. Effects of three greenhouse cover materials on tomato growth, productivity, and energy use. *Scientia Hortic.*, 69: 1-29.

Ronchi, C.P., P.C.R. Fontes, P.R.G. Pereira, J.C.S. Nunes and H.E.P. Martinez, 2001. Índices de nitrogênio e de crescimento do tomateiro em solo e em solução nutritiva. *Revista Ceres*, 48: 469-484.

Sandoval-Villa, M., C.W. Wood and E.A. Guertal, 1999. Ammonium concentration in solution affects chlorophyll meter readings in tomato leaves. *J. Plant Nut.,* 22(11): 1717-1729.

Scheepers, J.S., D.D. Francis, M. Vigil and F.E. Below, 1992. Comparison of corn leaf-nitrogen concentration and chlorophyll meter readings. *Commun. Soil Sci. Plant Anal.,* 23(17&20): 2173-2187.

Scholberg, J., B.L. McNeal, K.J. Boote, J.W. Jones, S.J. Locascio and S.M. Olson, 2000. Nitrogen stress effects on growth and nitrogen accumulation by field-grown tomato. *Agronomy Journal,* 92: 159-167.

Sexton, P. and J. Carrol, 2002. Comparison of SPAD chlorophyll meter readings vs. petiole nitrate concentration in sugarbeet. *J. Plant Nut.*, 25(9): 1975-1986.

Smith, F.W. and J.E. Loneragan, 1997. Interpretation of plant analysis: concepts and principles. In: *Plant analysis - an interpretation manual.* Reuter, D.J., Robinson, J.B. (Eds). Collingwood: CSIRO Publishing, p.2-33.

Tapia, M.L. and V. Gutierrez, 1997. Distribution pattern of dry weight, nitrogen, phosphorus, and potassium thought tomato ontogenesis. *J. Plant Nut*., 20(6): 783-791.

Varvel, G.E., J.S. Schepers and D.D. Francis, 1997. Ability for in-season correction of nitrogen deficiency in corn using chlorophyll meters. *Soil Sci. Soc. Am. J*., 61: 1233-1239.

Vooren, J., G.W.H. Welles and G. Hayman, 1986. Glasshouse crop production. In: *The tomato crop a scientific basis for improvement*. Atherton, J.G., Rudich, J. (Eds.). London: Chapman and Hall, p. 581-623.

Wang, Q., J. Chen and Y. Li, 2004. Nondestructive and rapid estimation of leaf chlorophyll and nitrogen status of peace lily using a chlorophyll meter. *J. Plant. Nut.,* 27: 557-569.

Wiesler, F., M. Bauer, M. Kamh, T. Engels and S. Reusch, 2002. The crop as indicator for sidedress nitrogen demand in sugar beet production – limitations and perspectives. *J. Plant Nutr. Soil Sci.,* 165: 93-99.