

Determination of Optimum Nitrogen Concentrations in Hydroponics for Tomato Grown in Coir Medium in Tropical Greenhouse

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ABSTRACT: Protected culture is a production technology for growing high-value horticultural crops. Fertigation in soilless culture is a major determinant of the quality and quantity of the greenhouse crop yields. Nitrogen is the widely used plant nutrient in fertigation and also the major potential environmental contaminant. Mismanagement of nitrogen in different growth stages has been reported in literature. Therefore, increasing of nitrogen use efficiency is vitally important for ensuring economic and environmental sustainability of protected culture. This study was conducted to determine optimum rates of nitrogen application for tomato addressing the plant nutrient status and total marketable yield. Tomato plants were fertigated with a progressive array of ten N treatments covering vegetative and reproductive stages. Plant analysis, growth parameters and total harvest were measured to find out the optimum nitrogen requirement. The treatment, supplied with N rates of 50, 60, 90 and 140 mg/plant/day at vegetative, early, middle and late reproductive stages, respectively showed the highest plant response. Thus it was selected as the most appropriate fertigation schedule for tomato grown soilless culture which comparatively increases tomato yield while reducing the cost of fertilizer and environmental hazards associated with excessive use of N fertilizer.

Keywords: Optimum nitrogen, fertigation, coir medium, tomato, green house

INTRODUCTION

Protected culture; growing perishable crops in environment controlled greenhouses, is a move on technology of global horticulture for last many decades. Since its introduction to Sri Lanka in 1997 protected agriculture techniques are being practiced for cultivation of high-value vegetables. Crops grown commercially, particularly those grown hydroponically, are provided with high levels of inorganic nutrients. Fertigation in soilless culture is a major determinant of the quality and quantity of the greenhouse crop yields (Wijesekara, 2013).

Nitrogen (N) is the most important and widely used plant nutrient and also the major potential environmental contaminant. In greenhouse tomatoes, excess N supplies have been found to be contributive to poor fruit set, reduced soluble sugars, off-flavor and fruit taste. Several studies have pointed out that N wastage from soilless cultures is in the range of 1 ton of N ha⁻¹ year⁻¹ in the absence of drainage recycling (Van Noordwijk, 1990). Albert's fertilizer mixture is the most commonly used fertilizer mixture and coir dust medium is the main crop growing

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medium of greenhouse farmers in Sri Lanka which contains all the essential nutrients (Wijesekara, 2013).

In Sri Lanka, hydroponics growers mainly use Albert's mixture without specific recommendation and also without considering crop growth stages. Tomato plants absorb nutrients at different rates at different stages of growth. This is especially true for nitrogen and potassium (Ministry of Agriculture, Canada, 2010). Plant tissue analysis is a useful diagnostic tool for developing nutrient management programs that predict when crops need additional nutrients while avoiding negative impacts on the environment (Silveira *et al.*, 2007). Therefore the aim of this work was to find out the optimum level of nitrogen application at different growth stages of tomato grown in soilless culture, in order to maintain optimum yields.

METHODOLOGY

The experiment was conducted in a semi-intensive greenhouse (100 m²) at the Meewathura Experimental Station in the Department of Crop Science of the Faculty of Agriculture, University of Peradeniya (agro-ecological zone, WM2) during 2017. The experiment was laid out as a RCB design. Plantlets of tomato (*Solanum lycopersicum*) variety, *Larisa F1* hybrid were transplanted in 18 L standard grow bags filled with sterilized coir medium when the plants had five to six true leaves. Grow bags were placed on plastic trays to collect the leachate separately. Plant density was maintained as 3 plants/m². The medium was fertilized with a progressive array of a soluble fertilizer with ten fertigation treatments, keeping three replicates and a plot size of 10 plants. Crop management practices were done according to the standard practices for the tomato crop (Wijesekara, 2013).

Application of nitrogen treatments

In each treatment, except nitrogen, other essential nutrients were provided equally according to the widely accepted proportion and dosages using Albert's solution (Saparamadu *et al.*, 2011); whereas the nitrogen level varied in the treatments according to each growth stages as shown in Table 1. Fertigation was done starting from 500 ml to 1200 ml of solution per day as plant growth was progressed. The volume of irrigation water applied was decided based on the evapo-transpiration rate at different growth stages (Mawalagedera, 2011). Nutrient solutions of each treatment were applied manually on daily basis and the drainage collection (excess nutrient solution) to the plates kept under the pots were circulated to each pot. The pH and EC could be maintained at around 5.8 - 6.5 and 2-3 dS/m respectively.

Data collection and analysis

Data were collected at four different growth stages (Table 1) and vegetative growth was examined with growth parameters of plant height, 3rd leaf length, total leaf area and total dry matter per plants in each treatment. At the early reproductive stage plant height, total leaf area per plant, number of clusters and flowers per plants and total plant dry weight were measured. In the middle reproductive and late reproductive stages, mature ripened fruits were harvested weekly for determining the marketable yield and total yield. Most information used to interpret tissue analysis is based on the most-recently-matured whole leaf. For tomatoes, this leaf is usually the fifth or sixth leaf from the top (Hochmuth, 1988). Thus the 5th leaf of plants were sampled at four different growth stages (Table 1) and analysed for total N, P, K, Ca and Mg. Total nitrogen was determined using standard Kjeldahl procedure. P in plant tissue was determined using visible light spectrophotometer (880 nm) while Ca and Mg were determined

using flame photometer and atomic absorption spectrophotometer respectively (Van Ranst *et al.*, 1999). The parametric data processing and statistical analysis were carried out through ANOVA procedure and mean separation by Duncan's multiple range Test (DMRT) at the 0.05 probability level using Statistical Analysis System (SAS).

Table1. N levels applied at different growth stages of tomato in each treatment

Treatments (T)	Vegetative stage	Reproductive stages (N amount - mg/plant/day)		
		Early (5-8WAP)	Middle (9-12WAP)	Late (13-18 WAP)
1	10	20	50	90
2	20	30	60	100
3	25	40	70	110
4	30	45	75	120
5	40	50	80	130
6	50	60	90	140
7	60	70	100	150
8	70	80	110	160
9	75	90	120	170
10	80	100	130	180

WAP –Week after transplanting

RESULTS AND DISCUSSION

Vegetative Stage

The treatment effect on the plant growth during the vegetative stage was analysed with respect to several plant growth parameters/indices, as illustrated in Table 2. The means of plant height, total leaf area and total dry matter were not significantly different among nitrogen treatments at $p \leq 0.05$. The 3rd leaf length was also not significant. Previous studies on greenhouse tomato has reported a stem thickness of 1cm at the 15 cm below the tip as the standard stem thickness for a properly nourished tomato plant (Ministry of Agriculture-Canada, 2010) but the stem diameter of this experiment did not show significant treatment effect while the treatment means fall within the desirable plant vigour level as specified above. However, treatment 5 showed the highest diameter and treatment 2 showed the lowest (Table 2). Nutrient status of the 5th leaf of tomato plant were analysed at the end of the vegetative stage and nitrogen percentage of the 5th leaf was not significantly different among N treatments at ($p \leq 0.05$) and it was 4-5%, within adequate range for tomato (4-5.5%) (Hochmuth *et al.*, 2006). Plant tissue P, Ca and Mg content also did not show a significant treatment effect and they were in satisfactory levels. K percentage was also not significantly different among treatments and the range was below the required level (3.5-5%) (Hochmuth *et al.*, 2006) (Table 3). According to the above results, the least level of N supply, treatment 1 was also found to be satisfying the N requirement during this vegetative-stage (1-4 WAP) which was normal practices of farmers. Application of high dosage of fertilizer further increases the cost of production.

Table 2. Average values of each growth parameters in vegetative stage (1-4WAP)

Trt.	Plant height (cm)	3 rd leaf length (cm)	Stem diameter(cm)	Leaf Area (cm ² /plant)	Plant DM (g)
1	112.3 ^a	23.1 ^{ab}	2.94 ^{cd}	1250 ^a	79.1 ^a
2	116.1 ^a	23.4 ^{ab}	2.57 ^d	1260 ^a	78.2 ^a
3	114.0 ^a	26.7 ^a	2.82 ^{cd}	1151 ^a	80.0 ^a
4	113.3 ^a	23.8 ^{ab}	2.87 ^{cd}	1210 ^a	78.9 ^a
5	124.1 ^a	24.3 ^{ab}	3.52 ^a	1128 ^a	81.2 ^a
6	114.6 ^a	23.5 ^{ab}	3.47 ^{abc}	1114 ^a	83.1 ^a
7	114.5 ^a	25.0 ^{ab}	3.31 ^{abc}	1156 ^a	81.3 ^a
8	120.3 ^a	24.7 ^{ab}	3.57 ^{ab}	1154 ^a	81.8 ^a
9	116.3 ^a	26.5 ^a	3.44 ^{abc}	1165 ^a	82.1 ^a
10	126.6 ^a	24.5 ^{ab}	3.41 ^{abc}	1210 ^a	81.9 ^a

Trt. – Treatments, The treatment means denoted by the same letters within each column are not significantly different (DMRT/P<0.05)

Early Reproductive Stage (5-8 WAP)

Table 4 illustrates that mean plant height was significantly higher in the treatment 5, 8, 9 and 10 followed by treatment 2, 4, 6 and 7. Number of clusters and flowers per plants did not show a significant treatment differences while leaf area increases in response to increasing N (from treatment 1-10) and thus the highest total leaf area was resulted by the treatment 5-9. Similarly total dry matter in tomato plants significantly increased as N supply increased up to treatment 5 and then showed a slight decrease in response to further increase in N (Table 3).

Table 3. Main nutrient % of the 5th leaf of tomato at vegetative & early reproductive stages

Trt.	Vegetative stag (1-4WAP)					Early reproductive (5-8 WAP)				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg
1	5.26 ^a	0.81 ^a	2.19 ^b ^c	1.50 ^b ^c	0.08 ^a	2.09 ^c	0.48 ^a	1.76 ^{ab}	0.26 ^{ab}	0.15 ^a
2	5.20 ^a	0.78 ^a	2.19 ^c	1.43 ^b ^c	0.08 ^a	2.04 ^c	0.47 ^a	1.69 ^b	0.25 ^{ab}	0.12 ^{ab}
3	5.33 ^a	0.83 ^a	2.07 ^c	1.34 ^c	0.08 ^a	2.51 ^c	0.43 ^a	1.92 ^a	0.25 ^{ab}	0.11 ^{ab}
4	5.29 ^a	0.77 ^a	2.21 ^b ^c	1.55 ^{ab} ^c	0.09 ^a	3.37 ^b	0.42 ^a	1.88 ^{ab}	0.23 ^b	0.10 ^{ab}
5	5.24 ^a	0.80 ^a	2.24 ^b ^c	1.65 ^{ab}	0.08 ^a	3.41 ^b	0.42 ^a	1.79 ^{ab}	0.22 ^b	0.10 ^{ab}
6	5.25 ^a	0.77 ^a	2.55 ^a	1.79 ^a	0.09 ^a	3.58 ^{ab}	0.57 ^a	1.78 ^{ab}	0.32 ^a	0.10 ^{ab}
7	5.29 ^a	0.76 ^a	2.52 ^a	1.66 ^{ab}	0.09 ^a	4.02 ^{ab}	0.57 ^a	1.84 ^{ab}	0.27 ^{ab}	0.07 ^{bc}
8	5.30 ^a	0.75 ^a	2.42 ^{ab}	1.52 ^{ab} ^c	0.08 ^a	3.72 ^{ab}	0.56 ^a	1.77 ^{ab}	0.32 ^a	0.07 ^{bc}
9	5.37 ^a	0.81 ^a	2.16 ^c	1.53 ^{ab} ^c	0.08 ^a	3.98 ^{ab}	0.53 ^a	1.68 ^b	0.32 ^a	0.06 ^c
10	5.33 ^a	0.77 ^a	2.41 ^b ^c	1.65 ^{ab}	0.09 ^a	4.18 ^a	0.44 ^a	1.85 ^{ab}	0.23 ^b	0.05 ^c

Trt. – Treatments, The treatment means denoted by the same letters within each column are not significantly different (DMRT/P<0.05)

Table 4. Average values of each vegetative growth parameters of tomato in early reproductive stage (5-8WAP)

Trt.	Plant height(cm)	No. of flowers	No. of clusters	LA (m ² /plant)	Plant DM(g)
1	89.3 ^{abc}	5.43 ^{ab}	3.60 ^b	0.31 ^d	83.9 ^c
2	93.0 ^{ab}	5.63 ^{ab}	4.17 ^{ab}	0.33 ^d	75.6 ^c
3	90.0 ^{abc}	4.77 ^b	3.63 ^{ab}	0.37 ^{cd}	87.8 ^c
4	93.5 ^{ab}	10.33 ^{ab}	3.60 ^b	0.38 ^{cd}	126.2 ^b
5	97.7 ^a	11.2 ^a	3.63 ^{ab}	0.50 ^{abc}	164.7 ^a
6	95.4 ^{ab}	9.4 ^{ab}	3.87 ^{ab}	0.50 ^{abc}	159.6 ^a
7	92.0 ^{ab}	8.4 ^{ab}	4.00 ^{ab}	0.51 ^{abc}	134.1 ^b
8	100.1 ^a	7.5 ^{ab}	4.53 ^a	0.51 ^{abc}	134.7 ^b
9	102.4 ^a	8.2 ^{ab}	4.43 ^{ab}	0.52 ^{ab}	117.3 ^b
10	104.8 ^a	10.8 ^a	3.77 ^{ab}	0.54 ^a	112.1 ^b

Trt. – Treatments, The treatment means denoted by the same letters within each column are not significantly different (DMRT/P<0.05)

As shown in Table 3, leaf N level gradually increased in response to increase in N fertilizer, leading to apparently highest leaf N content at treatment 10 (4.2%). When consider the rate of increase, increasing N fertilizer up to treatment 4 was much higher, when the N fertilizer increased with the treatments and in treatment 10 showed the significantly highest N percentage. Meanwhile leaf P, K and Ca percentages were not influenced by the N treatments meanwhile the leaf magnesium percentage showed a gradual decrease from treatment 1 to 10 and significantly lower percentage of Mg was present in treatment 8-10 than other treatments (Table 3). Based on these evidences, N level in the nutrient solution applied for treatment 5 or 6 could be selected as the optimum N level in early reproductive stage because proper nutrient absorption may lead to have highest dry mater content, and also plant leaf N, P, Ca and Mg was within the adequate range according to the Hochmuth, *et al.*, (2006).

Middle (8-12WAP) and late (13-18WAP) reproductive stages

Harvesting was continued to the end of the late reproductive stage in order to determine the marketable yield. The marketable yield of treatments 5, 6 and 7 significantly higher than the other treatment (Figure 1). Marketable yield was almost similar to the total yield in all the treatments, indicating the quality of harvest. In Middle reproductive stage the mean nitrogen percentage of leaf tissue in treatment 6-10 was significantly higher than the lower N fertilizer dosages treatments. Percentage P, K and Ca levels in 5th leaf did not show treatment differences. There was an unusual drop in leaf K percentage in treatment 5 but treatment 6 onwards it came to the normal range (Table 5). Leaf K contents were not adequate in the middle reproductive stage, according to the Hochmuth *et al.* (2006). Leaf K content of treatments was inversely related with fruit formation (yield) data, indicating K partitioning into fruit sink. In late reproductive stage, mean leaf N, K and P percentages were statistically insignificant within treatments despite some apparent ups and downs found for some of the plant nutrients at some levels of N fertilizer supply (Table5). In middle and late reproductive stages, treatment 6 could be selected as the optimum N level in the fertigation solution because treatments 6 and 7 showed the highest yield while there was no significant difference in yield between treatments 6 and 7. With regard to previous studies (Hochmuth *et al.*, 2006; Ministry of Agriculture-Canada, 2010), plant leaf N, P and Mg contents were within the adequate range while K and Ca percentages were at sub-optimum in all the treatments.

In this study the highest N fertilizer applied treatments (treatments 8 to 10) showed a relatively lower yield as reported by several authors found negative effects of high N levels in soil and in nutrient solution on tomato shoot dry weight (SDW) and yield (Cezar, *et al.*, 2002). The low rate of N fertilization not only produced health-safe and environment-friendly tomato yield but also reduces the cost of fertilization. Hence further research is needed to examine whether the reduced rate of other nutrients use can also sustain the tomato yield and maintain the eco-system sustainably.

Table 5. Main nutrient % of the 5th leaf of tomato at Middle and late reproductive stages

Trt.	Middle reproductive (9-13WAP)					Late reproductive (14-18WAP)				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg
1	2.64 ^c	0.53 ^a	1.88 ^a	1.51 ^c	0.56 ^a	3.96 ^a	0.63 ^a	2.98 ^{ab}	2.62 ^a	0.62 ^a
2	2.96 ^c	0.58 ^a	1.85 ^a	1.65 ^{abc}	0.50 ^a	3.80 ^a	0.69 ^a	3.08 ^a	2.88 ^a	0.46 ^a
3	3.63 ^b	0.75 ^a	1.63 ^{ab}	1.81 ^{abc}	0.46 ^{ab}	3.73 ^a	0.76 ^a	2.98 ^b	2.70 ^a	0.43 ^a
4	3.88 ^a	0.47 ^a	1.57 ^{ab}	2.07 ^{ab}	0.48 ^a	4.35 ^a	0.80 ^a	2.98 ^{ab}	2.83 ^a	0.38 ^{ab}
5	4.06 ^a	0.55 ^a	1.37 ^b	2.16 ^a	0.46 ^{ab}	3.80 ^a	0.88 ^a	2.88 ^{ab}	2.87 ^a	0.40 ^{ab}
6	4.21 ^a	0.68 ^a	1.66 ^{ab}	1.83 ^{abc}	0.47 ^{ab}	4.10 ^a	0.80 ^a	2.97 ^{ab}	1.95 ^b	0.39 ^{ab}
7	4.26 ^a	0.59 ^a	1.62 ^{ab}	1.66 ^{abc}	0.46 ^{ab}	4.19 ^a	0.90 ^a	2.80 ^{ab}	2.42 ^{ab}	0.30 ^{ab}
8	4.16 ^a	0.56 ^a	1.47 ^{ab}	1.46 ^c	0.36 ^{ab}	4.28 ^a	0.94 ^a	2.75 ^{ab}	2.35 ^{ab}	0.27 ^{ab}
9	4.36 ^a	0.67 ^a	1.63 ^{ab}	1.51 ^c	0.28 ^{bc}	4.05 ^a	0.82 ^a	2.72 ^{ab}	2.48 ^a	0.23 ^{bc}
10	4.29 ^a	0.64 ^a	1.66 ^{ab}	1.62 ^{bc}	0.26 ^c	4.11 ^a	0.81 ^a	2.98 ^{ab}	2.47 ^a	0.21 ^c

Trt. – Treatments, The treatment means denoted by the same letters within each column are not significantly different (DMRT/P<0.05)

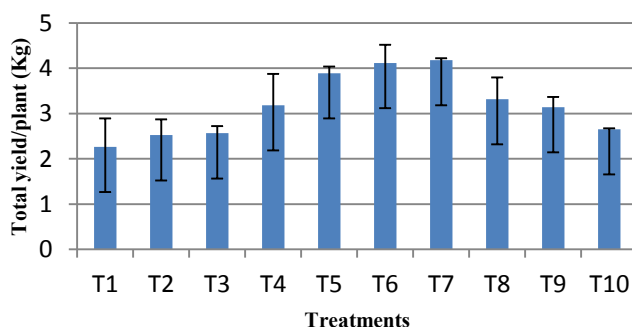


Figure1. Total tomato yield per plant, variation among the treatments

CONCLUSIONS

The optimum N levels needed for each growth stage of hydroponics tomato, grown in coir dust medium under greenhouse conditions in the mid country wet zone (MW2) in Sri Lanka could be identified. For the vegetative stage, N levels applied in the treatments 1 to 10 were in satisfactory levels while for the preceding growth stages the treatment levels 5-6 were

adequate. Based on the total and marketable yields, N level used in treatment 6 could be identified as the optimum for all growth stages of tomato plant, which were 50, 60, 90 and 140 mg/plant/day in vegetative, early, middle and late reproductive stages, respectively. Restricting into these optimum N levels definitely reduces possible yield losses, cost of fertilizer and environmental hazards associated with excessive N fertilizer use in hydroponics tomato cultivation.

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