A Complete Balanced Fertilizer Recommendation for Tomato grown in Sri Lanka

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Abstract
An integrated approach of formulating a complete and a balanced fertilizer recommendation was tested in the field with tomato as the test crop. A representative soil sample was analyzed for available nutrient status for 11 nutrients and acidity using a three-step extraction technique. Fertilizers were recommended based on the soil nutrient status and the results of a series of fixation experiments for P, K, Cu, Mn, Fe, Zn, S and B. A greenhouse nutrient survey using a modified missing element technique confirmed the deficiencies of nutrients identified through soil analysis. Treatments that provided one nutrient at a deficient level had significantly low dry mater yields (p<0.05) compared to the optimum, which provided all nutrients at adequate levels. In the field, the highest tomato yields and the highest net profits were obtained with the treatment providing the highest level of N, P and K (150 % N, 75 % P and 75 % K), while providing B and S at an adjusted optimum level. Providing nutrients based on the systematic approach was beneficial in terms of tomato yield and profit.

Key Words
Fertilizer recommendation, tomato, site-specific, balanced nutrition.

Introduction
Tomato is a popular vegetable crop in Sri Lanka, which is well adapted for different climatic conditions, soil types and altitude. Though farmers use high yielding crop varieties in the country, they rarely reach the potential yield of the crop due to poor fertilizer management and inherent low fertility of Sri Lankan soils. A systematic procedure to diagnose nutrient deficiencies and other soil related problems (Hunter 1984; Portch 1998) had been effectively used to determine yield-limiting nutrients in soils from different locations in Sri Lanka (Kumaragamage and Indraratne 2002). The results revealed that most soils were deficient in N, P, K, B and S while few soils were deficient in Ca, Mg and other micronutrients (Kumaragamage and Indraratne 2002). The present fertilizer recommendation for annual short-term crops in Sri Lanka often does not include secondary nutrients and micronutrients. The main objective of this study was to investigate the potential of adapting this systematic approach to formulate a fertilizer recommendation on site-specific basis for tomato and to test this recommendation in the field.

Methods
The experimental site selected for this study was a well-drained upland field with nearly 8% slope at the University Research Farm, Dodangolla (Mid Country Intermediate Zone), Sri Lanka. The soils belong to Immature Brown Loam great soil group (Typic Eutropepts Coarse, Non Calcareous Isohyperthemic). The annual rainfall in the region was 1400 mm while the average annual temperature was 29-32^{o} C. A representative composite soil sample (0-30 cm) was analyzed for physical and chemical properties using standard methods. Available nutrient status was determined by a three step extraction method; extraction with ASI solution (0.25 M $NaHCO_3$+ 0.01 M EDTA+0.01 M NH_4F) for P, K, Cu, Fe, Mn and Zn, 1 M KCl extraction for NH_4-N, Ca, Mg and Na, and 0.08 M $CaH_2(H_2PO_4)_2.H_2O$ extraction for B and S (Hunter 1984; Portch 1998). A fixation study was conducted to identify the fixation capacity of the soil for P, K, Cu, Zn. Fe. Mn, S and B. The amount of fertilizer to be supplemented was calculated based on the initial nutrient values and adjusted based on the fixation capacity. An optimum fertilizer recommendation was formulated and tested in the greenhouse using a modified missing element technique using sorghum as the indicator plant. The greenhouse nutrient survey was conducted with 14 treatments, one optimum treatment and 13 individual nutrient treatments (plus or minus). All the 13 nutrient treatments were identical to the optimum with the exception of one nutrient (or lime), which is either not supplemented (a minus treatment) or supplemented (a plus treatment) based on

the results of routine analysis. The nutrients, which were in sufficient amounts were not given in the optimum treatment, but supplied to the respective nutrient treatment (a plus treatment), to examine the effect of supplying an extra amount of the nutrient on yield even though soil analysis indicated supplementing was not required. If the soil analysis indicated a deficiency, the nutrient was supplied to the optimum treatment, but not in the nutrient treatment (a minus treatment), to see the effect of not supplying the nutrient when soil analysis indicates supplementing was required.

The recommendation was tested in the field using tomato (variety *Thilina*) for four seasons. Seventeen treatments (Table 1) were tested in the field using a Randomized Complete Block design with four replicates. Tomato yield and the net profit for each treatment were determined. Analysis of variance (ANOVA) of tomato yield data was performed with mean separation by Duncan New Multiple Range Test. For all statistical analyses, significance was set at $p \leq 0.05$.

Table 1. Description of the seventeen fertility treatments tested I the field experiment

Treatment	Description	Nutrients added (kg /ha)			
		N	P	K	S
1	Low N treatment	110	160	250	50
2	**Optimum**	220	160	250	50
3	High N treatment	330	160	250	50
4	No P treatment	220	0	250	50
5	Low P treatment	220	80	250	50
6	High P treatment	220	240	250	50
7	No K treatment	220	160	0	50
8	Low K treatment	220	160	125	50
9	High K treatment	220	160	375	50
10	No S treatment	220	160	250	0
11	No B treatment	220	160	250	50
12	High PK treatment	220	240	375	50
13	High NPK treatment	330	240	375	50
14	No PK treatment	220	0	0	50
15	50% of optimum N,P, K	110	80	125	50
16	Department of Agriculture recommendation	135	40	75	0
17	Control	0	0	0	0

Results

The soil had a sandy clay loam texture with an organic matter content of 0.6%. The soil is slightly acidic in reaction with a pH of 6.3 but had no detectable active acidity. Cation exchange capacity of the tested soil was 12.7 $cmol_c\ kg^{-1}$.The amounts of available nutrients extracted using the 3-step extraction method were interpreted using the interpretive guide of Hunter and Portch (2002). The soil was extremely deficient in N, P, K, S and B and marginally deficient in Zn (Table 2). The levels of Ca, Mg, Fe and Mn were sufficient without reaching toxic levels, while the level of Cu is slightly above the toxic level (Table 2).

The soil had high fixing capacity for P, K, S and B, reflecting the need to use higher rates of P, K, S and B to reach up to respective critical level for the nutrient. The greenhouse nutrient survey confirmed the deficiencies of nutrients identified through soil analysis. The mean dry matter yield in ranged from 0.42 – 2.60 g/pot, with the lowest dry matter yield in the minus treatments of N, P and S while the highest were observed in the optimum, plus Cu and minus Zn treatment. Relative yields calculated in comparison to the optimum treatment varied from 17.69 to 107.07% (Table 3).

Table 2. Nutrient status of the experimental soils

Nutrient	The amount available mg/kg soils	Optimum*	Above*	Interpretation*
Ca	1820	1202	4810	Sufficient
Mg	398.8	304	1458	Sufficient
K	58.5	196	1173	Deficient
Ca/Mg	4.56	4.1	11.9	Close to optimum
Mg/K	6.8	1.5	4.5	Too high
P	7	48	150	Deficient
S	17	40	150	Deficient
B	0.28	0.8	6.0	Deficient
Cu	6.7	3.0	6.0	Sufficient
Fe	65	30	300	Sufficient
Mn	34.5	12	125	Sufficient
Zn	3	4.0	25.0	Deficient
N**	5	100		Deficient

*According to the interpretive guide (Hunter and Portch, 2002)
** Critical level for N according to Hunter (2000)

Table 3. Mean dry matter yield (g/pot) and relative yield (%) in the greenhouse study

Treatments	Status	Mean (g/pot)	Relative yield (%)
Zn	Negative	2.60a	107.07
Cu	positive	2.44a	100.82
Optimum		2.43a	100
Mg	positive	2.39a	98.76
Mo	Negative	2.33a	96.29
Mn	positive	2.32a	95.88
B	Negative	2.24a	92.59
Fe	positive	2.13a	88.06
Ca	Positive	2.07a	85.59
K	Negative	2.01a	83.12
S	Negative	**0.72b**	30.04
P	Negative	**0.46b**	19.03
N	Negative	**0.42b**	17.69

Means with the same letters are not significantly different (P = 0.05)

The mean tomato yields of the field trail varied over the treatment and the season (Table 4) and the statistical analysis indicated a significant treatment effect, seasonal effect as well as treatment and seasonal interaction (p<0.05). During the first season, high NPK treatment gave the highest yield of 60.8 t/ha, whereas the control treatment gave the lowest yield of 20.6 t/ha. The mean yield of the optimum treatment was 38.9 t/ha. The yield increment in treatment 13 over the optimum treatment was 21.8 t/ha, which was statistically significant (p<0.05). Continuous heavy rains and subsequent attacks of fungal diseases in the second season seriously affected the crop giving a very low mean yield compared to the first season. The treatment with no P gave the highest mean yield of 36.2 t/ha, while the control treatment gave the lowest mean yield of 19.4 t/ha. In the third season, high NPK treatment again showed the highest mean yield (49.9 t/ha) whereas the no PK treatment gave the lowest mean yield of 20.9 t/ha. In the fourth season, treatment with high K gave the highest mean yield of 48.5 t/ha followed by high N treatment with a mean yield of 47.4 t/ha. The treatment with no PK gave the lowest yield of 20.3 t/ha (Table 4).

Treatments with higher level of nutrients often showed statistically significant yield increases (p<0.05) over the treatment 16 (Department of Agriculture recommendation) and treatment 17 (control with no fertilizer), with few exceptions (Table 4). The results over the four seasons also indicated that with the depletion of nutrients by providing the same fertility treatment over many seasons to the same plot, the crop responses for major nutrients like N, P and K becomes more apparent. However, there was no response to sulfur even at the 4th season, whereas response to B was seen only in the 4th season. The high NPK treatment gave the highest net profit whereas the control treatment gave the lowest profit. Reasonably high net profits were recorded in treatments with high N, high P and high K treatments.

Table 4. Description of the seventeen fertility treatments tested I the field experiment

Treatment	Description	Nutrients added (kg /ha)			
		Season 1	Season 2	Season 3	Season 4
1	Low N treatment	43.9bcd	24.7ef	35.6abcdef	30.5def
2	**Optimum**	38.9bcde	28.8bcde	35.6abcdef	41.3abcd
3	High N treatment	49.3abc	31.4abcd	47.8ab	47.2ab
4	No P treatment	32.0defg	36.2a	24.3ef	36.6bcd
5	Low P treatment	28.5efg	26.4de	32.7bcdef	32.7cde
6	High P treatment	50.8ab	24.9ef	45.5abc	45.9ab
7	No K treatment	34.9cdef	33.3abcd	39.9abcd	32.0cde
8	Low K treatment	28.8efg	35.3ab	35.3abcdef	33.6cde
9	High K treatment	46.6bc	33.7abc	38.5abcde	48.5a
10	No S treatment	38.7bcde	31.4abcde	39.3abcde	42.6abc
11	No B treatment	41.5bcd	34.0abc	40.0abcd	30.2def
12	High P, K treatment	38.6bcde	34.0abc	32.9bcdef	42.1abcd
13	High N, P, K treatment	60.8a	30.4abcde	49.9a	22.5 ef
14	No P, K treatment	39.7bcde	26.9cde	20.9f	20.3f
15	50% of optimum N,P, K	28.5efg	30.1abcde	30.1def	30.6def
16	Department of Agriculture rec.	24.0fg	28.1cde	25.1def	30.6def
17	Control	20.6g	19.4f	22.3f	20.5f

Conclusions

Initial analysis of the soil at the experimental site indicated deficient levels of N,P,K,S and B, and marginal levels of Zn. The soil had high fixation capacities for P, K, S and B. Optimum fertilizer rates calculated based on initial soil analysis, fixation curves and established critical nutrients levels performed better in the greenhouse while the minus treatments for N, P, K and S gave significantly lower dry matter yields, thus confirming the deficiencies. In the field, the highest tomato yield and net profits were obtained with the treatment providing the highest level of N, P and K (higher than the adjusted optimum rate), while B and S were provided at the adjusted optimum level. The second highest yield was given by the optimum treatment providing all nutrients at the adjusted optimum rate (220 kg N, 160 kg P, 250 kg K, 50 kg S and 1 kg B per hectare). Thus providing nutrients based using this technique was beneficial in terms of tomato yield and profit and this technique can be adapted to formulate site-specific fertilizer recommendation for tomato. Since the treatment with the highest rates of nutrients was superior in terms of both yield and profit, further studies are needed to investigate the change in yield and profit with further increase in the level of nutrients.

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