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Formulation and Testing of Site Specific Fertilizer Recommendation for Bitter Gourd *(Momordica charantia* L.)

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***ABSTRACT**. The average production of bitter gourd (Momordica charantia L.) in Sri Lanka had remained stagnant during the last decade despite the introduction of high yielding varieties. Farmers in general, use blanket fertilizer recommendations supplying only N, P, and K for bitter gourd. This study was conducted to evaluate the site specific approach in fertilizer recommendation for bitter gourd grown in a Reddish Brown Earth soil (Rhodustalfs) at CIC farm, Pelvehera, Sri Lanka.*

The systematic approach tested involved soil sampling, chemical analysis, nutrient sorption studies, greenhouse and field experiments. Soil analysis indicated deficient levels of N, P, K, Cu and Mo of 14, 28, 122, 3.6 and 1.4 mg/kg of soil, respectively. The nutrient levels for an optimum fertilizer treatment were formulated based on the results of routine analysis and a sorption study. Result from the greenhouse experiment indicated that out of the deficient nutrients, only addition of the N, P and K significantly increased the yield. A Significantly higher yield was recorded in the field experiment with the optimum treatment compared to other tested treatments. Yield reduction over the time was observed in all the treatments, but least yield reduction was observed in the optimum treatment. The optimum treatment obtained from the systematic approach was superior in terms of yield and profit to all other treatments. The optimum treatment with 50% less of P and K seems to be an attractive option giving high yield and net income, with about 50% less fertilizer cost. Therefore, the site-specific approach which formulated nutrient requirements based on soil analysis and greenhouse study could be used successfully in fertilizer recommendation for a particular soil.

INTRODUCTION

Bitter gourd (*Momordica charantia* L) is one of the nutritious vegetables cultivated in the low country of Sri Lanka, having a high demand in both local and export markets. The average production of bitter gourd remained stagnant during the last ten years despite the introduction of high yielding varieties. Identification of nutrient limitations in soils and

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supplying them at optimum level are the principal factors in fertilizer recommendations (Dowdle and Portch, 1988). Most of the fertilizer recommendations in Sri Lanka, especially for annual crops, are blanket recommendations that do not consider the inherent variability in soil fertility. Generally, these recommendations are limited to supplying major nutrients (N, P and K) with no emphasis on secondary and micronutrients. Application of fertilizers continuously without considering the fertility level of a soil may result in low production due to nutrient imbalances as well as lead to environmental pollution in soil and water bodies (Juang *et al*., 2002). Soil test based fertilizer recommendation method introduced by the Department of Agriculture in 1993, currently considers only the major nutrients, *i.e*., N, P and K. This method could be further improved by including secondary and micronutrients.

Adequate supply of nutrients is a principal factor to optimize the productivity of any cropping system. There are sixteen elements identified as essential nutrients for plant growth and development. All these nutrients are equally essential regardless of the amount required by the crop. In Sri Lanka, deficiencies of secondary and micronutrients have been reported in agricultural soils in various parts of the country (Kumaragamage and Indraratne, 2002; Deb, 1992; Nagarajah *et al*., 1983). The benefits of added N, P and K could be fully realized only if such nutrient deficiencies are corrected.

When nutrients are added to the soil, they undergo numerous physical, chemical and biological changes. Some of these result in the reduction of availability of certain nutrients for utilization by plants, referred to as nutrient immobilization in soil (Tisdale *et al.*, 1999). Therefore, when supplementing deficient nutrients, the rates should be adjusted on the basis of the degree of immobilization.

Application of fertilizers on a site-specific basis is beneficial in terms of farmer’s economy and environmental sustainability. A systematic procedure combining routine soil analysis, sorption or fixation studies and greenhouse experiments were proposed by Portch and Hunter (2002) to formulate complete and balanced fertilizer recommendation son a site-specific basis. In this approach, a representative soil sample from a particular location is used to determine physical and chemical properties including of available nutrients (status). A subsequent sorption study for plant nutrients is used to adjust the amounts to be added, depending on the nutrient sorption capacity of the soil. Based on these results of routine analysis and fixation study, an optimum treatment is formulated by adding deficient nutrients to the soil in balanced quantities.

In the above context, this study was conducted with the following objectives; (a) to formulate and test a site specific, balanced fertilizer recommendation for bitter gourd in a Reddish Brown Earth soil (Rhodustalfs) and (b) to compare the yield and gross returns in relation to the fertilizer cost of the optimum treatment formulated using the systematic approach.

MATERIALS AND METHODS

Soil sampling and pretreatments

Soil samples for routine analysis, sorption study and greenhouse experiment were collected from an agricultural farm field at *Pelvehera* (CIC farms, Agro Ecological Zone

DL1b) where the soil type was Reddish Brown Earth or Rhodustalfs. The field was a well drained flat land, which had been cultivated previously, having a land area of about 2,000 m^2. Twenty sub samples were collected randomly from 0 - 30 cm depth, using a clean steel shovel. Soil samples were air dried and passed through a 2 mm mesh sieve prior to laboratory analysis.

Soil analysis

Soil pH was measured in a soil water suspension (1:2.5) using a pH meter after stirring occasionally over a 20 min period. Soil organic matter content was determined by digestion with an acid dichromate solution and titrating with ferrous ammonium sulphate by the Walkley - Black procedure (Nelson and Sommers, 1982). The Cation Exchange Capacity (CEC) of the soil was measured using NH_4OAC solution buffered at pH 7.0, trapping NH_3 released by treating with boric acid and determining the NH_4^+ content by titrating against a standard acid (Roades, 1982). Soil texture was assessed by the pipette method (Gee and Bauder, 1986).

Determination of available nutrients

Available nutrient status of soil samples were determined using a three-step extraction method proposed by Portch and Hunter (2002). Available P, K, Cu, Fe, Mn and Zn were extracted by shaking 2.5 g soil with a 25 mL solution consisting of 0.25 M $NaHCO_3$, 0.01 M di-sodium EDTA and 0.01 M NH_4F. Ammonium -N, Ca and Mg were extracted by shaking 2.5 g soil with 25 mL of 1 M KCl solution while S and B were extracted by shaking 5 g soil with 25 mL of 0.08 M $CaH_4(PO_4)_2.H_2O$ solution. For all the methods, the shaking time was 10 min and the extracts were filtered through Whatman No. 1 filter paper.The extractable K, Cu, Fe, Mn, Zn, Ca and Mg were determined with an atomic absorption spectrophotometer (Buck Scientific Model 210 *VGP*). The extractable P was determined by the molybdenum blue method (Murphy and Riley, 2002) measuring the absorbance using a spectrophotometer (Buck Scientific model 6300 visible range) at 880 nm wavelength. Ammonium-N, B and S were determined using colorimetric methods (Portch and Hunter, 2002) and absorbance was measured using a spectrophotometer (Buck Scientific model 6300). Molybdenum and chloride in soils were not analyzed even though they are essential plant nutrients, since a method of analysis, providing sufficient confidence in predicting its status had not been reported (Portch and Hunter, 2002). Since availability of Mo is pH dependent, Mo was supplemented when the soil pH was less than 6.5.

Sorption study

Retention of P and K by soil constituents were documented (Tisdale *et al*., 1999). Therefore, sorption studies were conducted separately for P and K to determine their requirements for the soil. Six concentration levels of P and K were used with two replicates for this study. Nutrient solutions were added to the soils and incubated for 72 hrs. Soils were extracted using a solution of 0.25 M $NaHCO_3$, 0.01 M di-sodium EDTA and 0.01 M NH_4F and analyzed for P and K (Portch and Hunter, 2002). The amounts of P and K to be applied to the soil were calculated using the curves generated by plotting the amount of nutrient extracted against the nutrient added to the soil.

Greenhouse experiment

A greenhouse experiment was conducted using 13 treatments including an optimum treatment and 12 individual treatments for each nutrient namely N, P, K, Ca, Mg, S, Fe, Zn, Cu, Mn, Mo and B. Treatments were designed based on the results of routine analysis and sorption study. The modified missing element technique described by Portch and Hunter (2002) was used to evaluate the status of individual elements. The optimum treatment had all nutrients at optimum levels, at the rates calculated based on the soil analysis and sorption study. Other 12 treatments were either plus or minus treatments depending on the status of the individual treatment. If a nutrient is deficient in soil, it was added to the optimum, but not to the treatment evaluating its status (- treatments). If a nutrient is sufficient in soils, that nutrient was not added to the optimum, but added only to the treatment, evaluating its status (+ treatments). Accordingly, the treatments were optimum (OPT), minus treatments each for N, P, K, Cu and Mo (-N, -P, -K, -Cu, -Mo), plus treatments for Ca, Mg, S, Fe Zn, Mn, and B (+Ca, +Mg, +S, +Fe, +Zn, +Mn, +B,) with 4 replications. Sorghum was used as the test crop in the greenhouse experiment because it showed a clear growth response to differences in availability of essential plant nutrients and is well adapted to wide variety of environmental and management conditions (Portch and Hunter, 2002). A capillary irrigation system was practiced throughout the growth period to keep the soil at field capacity. Plants in each pot were harvested at the ground level six weeks after planting and oven dried at $60^{o}C$ to a constant dry weight. Relative dry matter yield percentage of each treatment was calculated as a percentage by the following formula

$$\text{Relative yield (\%)} = \frac{\text{Mean yield of individual treatment}}{\text{Mean yield of optimum treatment}} \times 100$$

Field experiment

The field experiment was conducted at the CIC farm, *Pelvehera, Dambulla,* of the Low Country Dry Zone of Sri Lanka (Agro ecological zone: DL1b). The experimental design used was Randomized Complete Block Design (RCBD) with four replicates. Nine different treatments (Table 1) were tested in four consecutive seasons (*i.e*. 2003/2004 *maha*, 2004 *yala*, 2004/2005 *maha* and 2005 *yala*). Fertilizer combinations of treatments were formed based on the results of routine analysis of original soil sample, sorption study and greenhouse experiment. Even though N, P, K, Cu and Mo were reported as deficient nutrients in routine analysis, greenhouse study did not show any response for Cu and Mo. Therefore, only three nutrients (*i.e*., N, P, and K) were included into the fertilizer combination of the optimum and other treatments of the field study. The chemical fertilizer recommendation of the Department of Agriculture (DOA) for bitter gourd was also included as a treatment (Table 1). Even though DOA recommendation includes incorporation of organic manure along with the inorganic fertilizer for bitter gourd, the Dry Zone farmers generally do not apply organic manure due to scarcity. In this study, therefore organic matter was not added to any of the treatments (Table 1). The bitter gourd variety MC 43 was used in all four seasons and the crop was grown in raised beds (net plot size 4.5 m x 4 m) with perimeter bunds. Twelve bitter gourd plants were maintained in a plot with the spacing of 1 m x 1.5 m. A split fertilizer application was practiced at three different levels as basal at the time of planting (34% N, 100% P and 34% K), 1st top dressing at 4 weeks after planting (WAP) (33% N, 33% K) and 2nd top dressing at 8 WAP (33% N and 33% K). Urea, Triple Super Phosphate (TSP) and Murate of Potash (MOP) were used to supply N, P and K, respectively and apply to each planting hole of the treatment. All the cultural practices for crop protection were done according to the recommendations of DOA. Matured pods were harvested and the crop yields as fresh weights were determined. Crop yield of each treatment was taken as principal parameter for assessment of the treatments in the field trial. The data analysis was done using Statistical Analysis Software (SAS) package.

Table 1. Treatments used in the field experiment.

Treatments	Amount (kg/ha)		
	N	**P**	**K**
T1 100% N, 100% P, 100% K (optimum)	200	180	400
T2 50% N, 100% P, 100% K	100	180	400
T3 100% N, 50% P, 100% K	200	90	400
T4 100% N, 0% P, 100% K	200	0	400
T5 100% N, 100% P, 50% K	200	180	200
T6 100% N, 100% P, 0% K	200	180	0
T7 100% N, 50% P, 50% K	200	90	200
T8 DOA*	105	40	90
T9 0% N, 0% P, 0% K (Control)	0	0	0

Note: *DOA: Department of Agriculture chemical fertilizer recommendation.

RESULTS AND DISCUSSION

Basic soil properties and available nutrient contents

The soil used in this experiment was slightly acidic in reaction (pH 5.7) with a low CEC value (5.8 cmol (+)/ kg). Soil texture was sandy clay loam and organic matter content was 1.0%. Available nutrient contents in the soil are given in Table 2. All nutrients except N, P, K, Cu and Mo were sufficiently available in the experimental soil (Table 2).

Table 2. Mean available nutrient contents in the soil (mg/kg of soil).

	Major			**Secondary**			**Micro**					
	N	P	K	Ca	Mg	S	B	Cu	Zn	Fe	Mn	Mo
Nutrient Amount	14	28	122	1232	425	46	1.0	3.6	14	114	48	1.4
Critical level #	100	48	196	1202	304	40	0.8	4.0	6.0	40	15	2.0
Status	D	D	D	S	S	S	S	D	S	S	S	D

Note: # Source: Portch and Hunter (2002), D: Deficient, S: Sufficient.

Determination of nutrient requirement based on sorption study

The relationship between added and extracted amounts of P and K in the sorption study was used to calculate the required amounts for 1 kg of soil to attain the optimum level of P and K separately. The data showed that 90 mg of P kg^{-1} of soil and 200 mg of K/kg of soil should be added separately to achieve sufficient level of P and K (data not shown). The results indicated a high fixing capacity of K in the experimental soil. High K fixation in paddy soils (Low Humic, Gley) associated with Reddish Brown Earth soils had been previously reported in the same region (Weerasinghe and Keerthisinghe, 1986).

Greenhouse experiment

Mean dry matter yields of treatments and their relative yield as a percentage of optimum are presented in Table 3. The optimum treatment recorded the highest dry matter yield in comparison to all other 12 treatments. The yields of plus treatments of S, B, Ca ,Mg, Fe, Mn and Zn and the minus treatments of Cu and Mo were not significantly different from the optimum treatment (Table 3). Significantly lower dry matter yields were recorded in treatments without application of N, P, and K, (minus treatments) and the magnitudes of the yield reduction were 74% for N, 40% for K and 37% for P. Therefore, the greenhouse study showed only N, P and K should be applied for this soil as fertilizers.

Field experiment

Yield of bitter gourd in each season and the mean yield (of four seasons) are presented in Table 4. The treatment with 100% of recommended levels of N, P and K recorded the maximum yield in all four seasons. The yields obtain from the treatment ranged from 13.14 to 15.85 t/ha. Yields at the optimum treatment were significantly higher in three out of four cultivated seasons. It is reported that bitter gourd requires a fairly high quantity of N, P and K to produce good yield (AVRDC, 1990). In all treatments, the yield decreased from the first season to the fourth season. However, the reduction in yield of the optimum treatment over the four seasons was less compared to other treatments. Yield reduction over the time is more pronounced in 0% K which is T6, DOA recommendation which is T8 and control (T9) treatments. Depletion of nutrients over the time could be the possible reason. There was no significant difference among yields of the different treatments in the first season. But the second season onwards significant yield differences were observed among treatments and the optimum gave the highest yield. In the optimum treatment the nutrients removed by the crop were sufficiently supplemented, consequently giving comparable yields over the time. Treatment (100% N, 100% P and 50% K) recorded the second highest average yield, with only a 16% yield reduction compared to the optimum treatment, while the third highest average yield was shown by the treatment 7 with 100% N, 50% P and 50% K. It was noted however with no application of P in treatment 4 (100% N, 0% P, 100% K) and no application of K in treatment 6, showed average yields of 9.88 and 9.1 t/ha, respectively. The results reveal that bitter gourd is capable of producing a fairly high yield even under low P and K availability in soils, even though a significant yield response was observed with the supply of P and K. It was also noted that application of 50% of the optimum K and P was sufficient to obtain a significant yield response in some seasons. The DOA chemical fertilizer recommendation recorded an average yield of 8.91 t/ha, of yield. The reason for the lower yield could be low supply of N (almost ½ of the optimum N level) and low P and K (1/4 of the respective optimum levels) associated with DOA recommendation.

Table 3. Mean dry matter yields and relative yields of the tested treatments in the greenhouse experiment

Treatments	Status	Mean* (g)	Relative yield as a % of optimum
Optimum		4.57^{a}	100.00
S	Plus	4.54^{a}	99.30
B	Plus	4.2^{ab}	91.90
Ca	Plus	4.14^{ab}	90.59
Mo	Minus	4.10^{b}	89.71
Mg	Plus	4.10^{b}	89.71
Fe	Plus	4.09^{b}	89.49
Mn	Plus	4.05^{b}	88.62
Zn	Plus	4.04^{b}	88.40
Cu	Minus	4.08^{b}	89.27
P	Minus	2.87^{c}	62.80
K	Minus	2.76^{c}	60.28
N	Minus	1.04^{d}	26.25

Note: Means followed by the same letters along the column are not significantly different.

Table 4. Mean yield of bitter gourd in four consecutive seasons.

Treatments*	Quantity applied (kg/ha)			Mean seasonal yield (t/ha)				Average yield (t/ha)
	N	P	K	1	2	3	4	
T1	20	180	400	15.85^{a}	13.7^{a}	13.14^{a}	13.50^{a}	14.05
T2	10	180	400	15.18^{a}	9.82^{c}	10.01^{bc}	8.47^{b}	10.85
T3	20	90	400	13.61^{ab}	10.53^{bc}	10.9^{b}	7.82^{bc}	10.70
T4	20	0	400	12.35^{ab}	10.18^{c}	9.35^{bcd}	7.67^{bc}	9.88
T5	20	180	200	14.72^{a}	12.61^{ab}	11.53^{ab}	8.57^{b}	11.75
T6	20	180	0	12.87^{ab}	9.59^{c}	8.09^{cde}	5.8^{cd}	9.10
T7	20	90	200	14.84^{a}	12.63^{ab}	10.52^{b}	7.05^{bcd}	11.13
T8	10	45	100	14.11^{a}	8.76^{cd}	7.37^{de}	5.42^{d}	8.91
T9	0	0	0	10.16^{b}	3.75^{e}	3.91^{f}	2.9^{e}	5.18

Note: T1: 100% N, 100% P, 100% K (optimum), T2: 50% N, 100% P, 100% K, T3: 100% N, 50% P, 100% K, T4: 100% N, 0% P, 100% K, T5: 100% N, 100% P, 50% K, T6: 100% N, 100% P, 0% K, T7: 100% N, 50% P, 50% K, T8: Department of Agriculture (DOA*), T9: 0% N, 0% P, 0% K (Control). Means within a season followed by the same letters are not significantly different.

Cost benefit analysis

Even though the highest fertilizer cost was recorded from the optimum treatment (Table 5), it showed the highest gross return value (GRF) of Rs. 2,18,900.00/ha above fertilizer cost. Wollenhaupt and Buchholz (1993) reported that site specific fertilizer recommendations have potential of increasing profitability of crops especially in soils with low P and K. Application of 50% of the optimum P and K with 100% of the optimum N level is an attractive option giving the next highest gross return value of Rs. 1,92,250.00/ha with a fertilizer cost of 52% of that of the optimum. On the other hand, presently used fertilizer recommendation (DOA recommendation) recorded GRF value of Rs. 1,62,025.00/ha The optimum treatment recorded remarkably higher profit margin of Rs. 56875.00/ha compared to the GRF of DOA recommendation while the treatment with 50% of P and K of the optimum recorded a profit margin of Rs. 30,225.00/ha compared to the GRF of DOA recommendation.

Table 5. Total income (TI), total fertilizer cost (TFC) and gross return above fertilizer cost (GRF).

Treatments *	TI (Rs/ha) 00’	TFC (Rs/ha) 00’	GRF (Rs/ha) 00’
T1	2,810	621	2,189
T2	2,170	608	1,562
T3	2,140	4635	1,6765
T4	1,976	306	1670
T5	2,350	481	1,869
T6	1,820	341	1,479
T7	2,226	3235	1,9225
T8	1,782	16175	1,62025
T9	1,036	0	1,03600

Note: T1: 100% N, 100% P, 100% K (optimum), T2: 50% N, 100% P, 100% K, T3: 100% N, 50% P, 100% K, T4: 100% N, 0% P, 100% K, T5: 100% N, 100% P, 50% K, T6: 100% N, 100% P, 0% K, T7: 100% N, 50% P, 50% K, T8: Department of Agriculture (DOA*), T9: 0% N, 0% P, 0% K (Control).

CONCLUSIONS

The optimum fertilizer recommendation (N 200 kg/ha, P 180 kg/ha, K 400 kg/ha) developed through systematic approach for balanced fertilizer recommendation was superior in terms of yield and net income to all other treatments for bitter gourd grown in a Reddish Brown Earths soils (Rhodustalfs) at CIC farm, Pelvehera in Sri Lanka. Optimum treatment with 50% less of P and K seems to be an attractive option giving a reasonably high yield and net income by reducing fertilizer cost by 50%.

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