Profitable tomato and tomato-maize nutrient management systems in an acid Soil

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ABSTRACT

The prevalence of highly weathered marginal soils in the tropics calls for the development of an integrated nutrient management system that will enhance tomato production at the same promote sustainable management of the soils under marginal upland. A study was conducted in an acid soil todevelop more productive nutrient management systems for tomato and to promote adoption of management practices best suited to local conditions in Claveria, Misamis Oriental, which is known as the tomato bowl of the Philippines. Three field trials were conducted with the first trial comprised of sole tomato crop, while the second trial had tomato-maize sequence and third trial had tomato-maize -maize sequence. In these cropping sequences, only the sole tomato trial received fertilizers while the second and third trials of maize made use of the residual fertilizers from the first trial. Results showed that profitable and sustainable vegetable production could be achieved through the development of a productive cropping scheme for vegetables. The highest GMB of P237,433 in the tomato-maize-maize cropping scheme was obtained in T_1 (with 154:91;64 kg/ha N-P_20_5-K_20) while the lowest was obtained in T_2 (with 93:30:150 kg/ha N-P_20_5-K_20)).

Key words: tomato production, acid soil, tomato-maize-maize cropping sequence.

INTRODUCTION

Providing higher economic returns per unit area and developing new export markets for high value crops in the Philippines has been identified as a priority by the Philippine Government and the Australian Centre for International Agricultural Research (ACIAR) as a means of increasing economic growth and improving the standard of living of people living in rural areas. In the southern Philippines, vegetables are grown extensively. The regions 8 (Leyte), 10 (Northern Mindanao/Cagayan de Oro) and 11 (Southern Mindanao/ Davao) have significant potential for expanding vegetable production. Moreover, they are seen as strategically important to the Australian Government, whereby efforts to improve the livelihoods of the populations in these areas could contribute to improving geo-political stability in the region. However, a number of barriers exist to achieving these objectives including: a lack of grower expertise in soil management and crop agronomy; high incidence of pests and diseases; lack of developed markets and value chains for horticultural produce; and political/ economic constraints, such as limited capital/ resources and insecurity of land tenure (Dorahy et al., 2010).

A scoping study in the Philippines conducted by ACIAR team in November 2007 had identified the following key issues with respect to soil and crop nutrient management in vegetable production systems in Northern and Eastern Mindanao and the Eastern Visayas (Leyte). These include declining soil fertility; high cost of inorganic fertilizers and a lack of grower capital; shift towards more "organic" production; availability of organic materials; lack of information and training; and the widespread prevalence of soil borne diseases. Most of the best quality farmlands are already utilized for agriculture, which implied that further area expansion would occur on marginal lands that are unlikely to sustain high yields and is vulnerable

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to degradation (Young, 1999). Common problems encountered by the vegetable farmers are inherent poor soil fertility and productivity, lack of appropriate technologies, improper water and soil conservation management and other production factors such as fertilizers and limited capital (Dorahy et al., 2010).This poses a major concern on minimizing cost at the same time increasing food production. To successfully achieve this, crop production must increase without an increase in the negative environmental impact associated with agriculture.

The inadequate knowledge in soil and crop nutrient management of vegetable leads to improper allocation of limited financial resources that could result to financial risk, poor soil fertility management and low productivity. This practice makes the soil less productive through time depending on the amount of fertilizer applied per cropping season. This implied large increases in the efficiency of nitrogen, phosphorus and water use, and integrated pest management that minimizes the need for toxic pesticides (Tilman et al., 2002). Fertilizer use is the obvious way to overcome soil-fertility depletion, and indeed it has been responsible for a large part of the sustained increases in per capita food production that have occurred in Asia, Latin America, and the temperate region, as well as in the commercial farm sector in Africa (Mokwunye & Hammond, 1992; Borlaug & Dowswell, 1994; Buol & Stokes, 1997, Sanchez et al., 1996). The usual recommended rates for fertilizers were set to assume that the soil fertility is low, so it is not appropriate to apply these to the continuously cultivated soils due to its increasing residual fertility (Yoo and Jung, 1991).

Therefore, a need exists to assess the current soil fertility status in soils used for vegetable production, quantify the rates of nutrient removal from these systems (mass balances) and develop strategies for matching nutrient inputs to crop and soil requirement through the judicious and integrated application of inorganic and organic fertilizers. When organic fertilizers are used, there is a need to quantify the availability and types of materials, evaluate the treatment and stabilization technologies (e. g. composting) and determine how they can be applied in conjunction with inorganic fertilizers to optimize productivity and profitability (Tulin et al., 2010 & 2014). Dissemination and training activities are also required to promote the outcomes and maximize benefits to growers.

In the Philippines, the main issue is that conventional inorganic fertilizers are expensive and growers are looking towards alternative inputs such as composts, manures and crop residues to improve/ maintain soil fertility. This paper will present the result of the project that was conducted in Claveria, Misamis Oriental that was planted with tomato. Claveria region is known as the “tomato bowl in the Philippines” (Mercado et al., 2010).

The objectives of the study were to:

- Develop more productive nutrient management systems for tomato grown in acid soil.
- Promote adoption of management practices best suited to local conditions.

MATERIALS AND METHODS

Soil Chemical Properties

Soil pH was determined using the potentiometric method at a soil-water ratio of 1:2.5 (ISRIC,1995).Total Nitrogen (%) was analyzed following the procedures of ISRIC, 1995. Organic carbon content was analyzed using the modified Walkley-Black method (Jackson, 1958). Available Phosphorus (mg/kg) was determined according to the Olsen and Bray No. 2 methods for calcareous and acidic soils, respectively (PCARRD, 1980; Murphy and Riley,1962). Exchangeable K, Ca, Mg, Na (mg/kg) were extracted using 1 N NH_4OAc adjusted to pH 7.0. Determination of bases was done by atomic absorption spectrophotometry (AAS). Exchangeable acidity and aluminum were analyzed by extracting the exchangeable acidity (H + Al) in the soil by unbuffered KCl solution and quantified by titration method (ISRIC, 1995). Cation exchange capacity (CEC) was determined using 1 N NH_4OAc at pH 7 as the extracting solution (USDA-NRCS, 1996).

In determining the critical levels of nutrients for vegetables based on the results of soil analysis, the criteria presented in Table 1 was used for soil pH and important soil nutrients such as N, P and K (AVRDC, 1990).

Table 1. Critical levels of nutrients for vegetables.

Parameters	Low	Moderate	High
Soil pH, water	5.5-6.0	6.0-7.5	>7.0
Organic C, %	2.0	4.0	>5.0
Total N	<0.2	0.2-0.3	>0.5
Bray No. 2 P (mg/kg)	<10	10-20	20-30
Exch. K (mg/kg)	40-80	80-120	120-160

Tissue sample collection, preparation and analysis

Leaf samples were collected 30 days after transplanting and at harvest period. Whole plants were also sampled for dry matter yield and plant nutrient uptake determination. Leaf samples were washed with deionised water, blotted dry with tissue paper and air-dried. The leaves were then oven-dried at 70˚C for at least 2 days. The dried leaves were then ground using Willey mill and placed in labeled paper bags for analysis. Total concentration of P and K in the plant samples was analyzed by first dry ashing them at 500^{o}C for a minimum of 5 hours (but not exceeding 16 hours) followed by the addition of 6 M hydrochloric acid. Quantification of K was done using an atomic absorption spectrophotometer while P was analyzed using a spectrophotometer. Total N was analyzed by Kjeldahl method involving sample digestion with concentrated H_2SO_4, distillation and titration (Mylavarapu and Kennelley, 2002).

Establishment of on-farm trials

A. Site Description

Claveria, Misamis Oriental is located at 980 meters asl. The soil is derived from pyroclastic materials (Mts Mat-i, Balatukan, Sumagaya), deep and well drained. Claveria soils represent most of acid uplands in Southeast Asia physically (Mercado, 2007) and socio-economically (Bertomeu, 2005). Tomato farmers in Claveria tend to apply 3-5 times more more fertilizers than what are required affecting efficiency and income. Vegetable farmers tend to over-fertilize vegetables in order to secure optimum yield (Morris, 1996).

B, Farm trials

Three on-farm trials were established in Claveria, Misami Oriental to verify the validity of the results of soil tests on the growth of tomato. Then after the tomatoes were harvested, maize crop was planted on the same piece of land using the residual fertilizers from the first cropping of tomato as the source of nutrients. This was followed by another cropping of maize on the same area for another season thereby following a tomato-maize-maize cropping sequence. Since the tomato farmers of Claveria, Misamis Oriental tend to apply excessive amounts of NPK fertilizers in the first cropping of tomato, the above cropping sequence was adopted to find out if the first application of high amounts of NPK fertilizers will be sufficient to supply the needed nutrients for the subsequent cropping of maize.

For tomato field trial, the experiment was laid out in the field in a Randomized Complete Block Design with four treatments and five replications (Table 2). The levels of fertilizers in the treatments were established based on the soil test results. The sources of fertilizers were complete fertilizer (14-14-14), urea and muriate of potash.

Table 2. The different treatments used in the study indicating the levels of fertilizers applied for the first trial of tomato.

Treatment	Claveria		
(kg/ha)	N	P_2O_5	K_2O
T_1*	154	91	64
T_2	93	30	150
T_3	186	60	150
T_4	92	36	150

*Farmers practice

RESULTS AND DISCUSSION

Results of Field trials in the Claveria Site:

Plant height, yield and total dry matter yield

During the early stage of tomato growth at 30 (DAP), T_2 showed better except for T_3, while T_4 had lower plant height of 46 cm (Table 3). At 45 DAP, farmer's fertility level (T_1) had significantly higher plant height except for T_2. It is worth noting that the farmer's level applied a combination of both organic and mineral fertilizers as compared to the alternative treatments with only mineral fertilizers. At 60 DAP (days after planting), T_1had a plant height of 105 cm which is significantly higher than T_2.

Tomato yields were classified into marketable and non-marketable (Table 4). Farmer's fertility level (T_1) had significant marketable yield of 15.82 t/ha compared with other treatments. For non-marketable yield, T_1 still had significantly higher yield than other treatments except for T_2. For total yield, T_1 had the highest yield of 22.6 t/ha, significantly better than the alternative treatments. The treatment T_3, which had the highest nutrient load among the alternative treatments, yielded the 2nd highest total yield of 16.76 t/ha but not significantly better than T_2 and T_4. This results implied that the application of both organic and mineral fertilizers is more beneficial to the growth and yield of tomato as compared to the application of purely inorganic fertilizers.

Table 3. Agronomic results from field experiment on tomato during wet season (2009), Claveria, Philippines.

Treatment	Plant height (cm)			Dry matter at (t/ha)	Marketable yield (t/ha)	Non-Marketable yield (t/ha)	Total yield (t/ha)
	30 DAP	45 DAP	60 DAP	50 DAP			
T1(FP) (154:91:64)	48.26^{bc}	94.92^{a}	105.38^{a}	1.34^{a}	15.82^{a}	6.78^{a}	22.6^{a}
T2 (93:30:150)	53.07^{a}	89.90^{ab}	96.12^{b}	1.13^{ab}	11.72^{b}	4.76^{ab}	16.48^{b}
T3 (186:60:150)	50.97^{ab}	88.30^{b}	98.08^{ab}	1.22^{ab}	12.26^{b}	4.50^{b}	16.76^{b}
T4 (92:36:150)	46.00^{c}	87.18^{b}	97.26^{ab}	1.04^{b}	12.22^{b}	4.40^{b}	16.62^{b}
Mean	49.57	89.82	99.21	1.18	13.0	5.11	18.13
LSD (5%)	3.59	6.46	8.27	0.27	2.96	2.08	4.22

In column, means having the same letters are not significantly different by Tukeu's test at 5% level

Partial nutrient budget

Nutrient loading, uptake, removal and balance of N, P_2O_5 and K_2O are presented in Table 4. Total N loading was highest at $T_3$with 186 kg/ha N, followed by farmer's fertility level of 143 kg/ha N.T_2 and T_4 had 93 and 92 kg/ha N, respectively. The P loading was highest at farmer's fertility level (T_1) with 143 kg/ha P_2O_5followed by T_3 with 60 kg/ha P_2O_5, then by T_4 with 36 kg/ha $P_2O_5$and lastly by $T_2$with 30 kg/ha P_2O_5. The K nutrient loading was lowest in $T_1$with only 64 kg/ha K_2O and the other treatments have similar loading of 150 kg/ha K_2O.The N uptake was highest at T_1 and $T_3$with 44.68 and 44.28 kg/ha N, respectively, followed by T_4 and T_2, which were significantly lower. Treatment T_1 had significantly higher P uptake, followed by T_3. Treatment T_2 had the lowest P uptake of 4.93 kg/ha. Treatment T_1 had the highest K uptake followed by T_3 and T_4. T_2 had significantly lower K uptake of 45.05 kg/ha K_2O. Hedge (1996) found out a ton of fresh tomato fruits need to absorb 3:0.3:3.5 kgs NPK, respectively. These results suggest that the application of higher levels of NPK will results to very high positive nutrient balance, which suggests that the applied fertilizers is more than what the crop needs.

Table 4. Partial nutrient budget on tomato yield experiment, Claveria. Philippines (Wet Season, 2009)

Treatment	Nutrient loading			Nutrient uptake			Nutrient removal			Nutrient balance		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
		(kg/ha)			(kg/ha)			(kg/ha)			(kg/ha)	
T1 (FP)	143	91	64	44.68a	7.34a	88.22a	58.32 a	8.34^a	74.76^a	84.68b	82.86a	-10.56b
T2	93	30	150	28.77b	4.93c	45.05c	33.80 b	4.69^b	44.45^b	59.20c	25.31d	105.55a
T3	186	60	150	44.28a	6.21b	61.48b	44.12 b	6.06^b	56.46^b	141.88a	53.94b	93.54a
T4	92	36	150	29.46b	5.02c	56.11b	40.86 b	4.98^b	47.99^b	51.14c	31.02c	102.01a
Mean	129	67	151	36.80	5.58	62.72	44.28	6.02	55.91	84.22	48.28	95.92
LSD (5%)				4.87	0.78	8.45	11.62	1.75	24.75	11.61	1.75	16.72

In a column, means having the same letters are not significantly different by Tukey's test at 5% level

Nutrient removal for N was significantly higher in T_1 followed by T_3, T4 and T2 in descending order. Nutrient removal data for tomatoes were obtained at harvest while the nutrient uptake data were obtained at two months of tomato growth. P removal was significantly higher in T_1 with 8.34 P_2O_5 kg/ha, followed by T_3, which was significantly higher than T_4 and T_2. K removal was highest in T_1 of 74.76 K_2O kg/ha, followed by T_3, which was significantly lower. T_2 had the lowest K removal, but was not significantly different from T_4 and T_3. Hedge (1996) also found out that 38 t fruit/ha removes 104 kg N, 9.5 kg P and 116 kg K. Nutrients remaining in the soil including the ones in the tomato residues are presented in Table 5.

In terms of nutrient balance, it was very evident for K that the treatment which applied the lowest K (as in the case of T_1) showed a negative balance as compared to those treatments which applied higher amounts of K as in T_2, T_3, and T_4.

Since the results of the tomato field trials indicated a high nutrient balance of nutrient left in the soil after crop uptake and removal, maize was planted in the next cropping without the application of fertilizers to check if the soil is still capable of sustaining the growth and yield of corn. From the results presented in Table 6 and 7, it was shown that the second cropping of maize is still profitable after tomato even without fertilization by just utilizing the residual fertilizers left on the soil after a high application of NPK fertilizers for tomato. The grain yield and other agronomic characteristics of maize as influenced by different fertility levels employed to the preceding tomato crop are presented in Table 5. The highest grain yield was obtained in T3 (186:60:150, NPK) with 4.34 tons per hectare, and followed by T1 (Farmer's fertility level with 154:91:64, NPK), and the lowest was T2 (93:30:150). For the total dry biomass yield, the trend was similar with that of grain yield that T3, T1, and T2 were having 14.07, 12.64, and 12.30 tons per hectare, respectively. The maize plant height at early stage (30DAE) did not follow the same trend, T4 had the highest plant height of 45.96 cm, followed by T1 with 44.62 cm and T2 was consistently the lowest. At 60 DAE and at harvest, T1 consistently had the highest plant height (Table 7), followed by T3 and T4, and the lowest was T2.

This results supported the practice of farmers in Claveria of applying higher levels of fertilizers for tomato and planting corn in their field after harvesting the tomato. This results provided solid scientific evidences on the importance of allocating the right amounts of fertilizers for the needs of specific vegetables. An added income of about P175,000 to P200,000/ha is still attainable for another crop after harvesting the first crop of tomato (Table 6). This results further show the profitability of establishing a good cropping sequence after vegetables in a heavily fertilized soil.

Table 5. Grain yield (t/ha) and other agronomic characteristics of first crop maize following the tomato as influences by different fertility levels employed to the preceding tomato crop. Claveria, Misamis Ori-

Treatment	Grain yield (t/ha)	Total dry matter yield (t/ha)	Plant height (cm)		
			30 DAE	60 DAE	Harvest
T1(FP) (154:91:64, NPK)	4.24	12.64	44.62	203.4	244.5
T2 (93:30:150, NPK)	4.04	12.30	43.42	188.7	235.7
T3 (186:60:150, NPK)	4.34	14.07	44.4	198.4	240.0
T4 (92:36:150, NPK)	3.92	12.43	45.96	195.9	237.5
Mean	4.13	12.8	44.6	196.59	239.43
LSD (5%)	0.56^{ns}	2.14^{ns}	5.18^{ns}	12.25^{ns}	10.43^{ns}
CV (%)	9.92	12.07	6.18	3.32	3.16

Table 6. Partial cost-benefit analysis of tomato-maize sequence. Claveria, Misamis Oriental, Philippines.

Treatment	Maize grain yield (kg/ha)	Total sales from maize (PHP)	Total sales from tomato (PHP)	Variable input costs (PHP)	Partial GMB (PHP)
T_1 (FP) (154:91:64, NPK)	4,240	53,000	189,840	24,666	218,174
T_2 (93:30:150,NPK)	4,040	50,500	140,120	14,800	175,820
T_3 (186:60:150,NPK)	4,340	54,250	147,120	20,350	181,020
T_4 (92:36:150,NPK)	3,920	49,000	146,640	15,830	179,810

Selling price of maize is at P12.50 at 14% MC

Partial cost-benefit analysis

Relying solely on the residual fertilizers from the preceding tomato crop, the first maize crop yields ranged from 3.92 to 4.34 tons per hectare (although not statistically different among treatments) were impressively high. Assuming the buying price of maize is at P12.50 kilo at 14% moisture content, T4, which had the highest yield, had a total sales of P54,250.00, followed by T1, P53,000.00, and the lowest was T4 of P49,000.00 (Table 7).

During the tomato cropping, the T1 had the highest total sales of P189,840.00, followed by T3 with P147,120.00 and the lowest was T2 with P140,000.00, and looking at the variable inputs (Table 7) T_1 had the highest investment costs of P24,666.00, followed by T_3 of P20,350.00 and the lowest was T_2 of P14,800.00. During the 2nd maize crop, T_3 had the highest grain yield of 1561 kg/ha with a gross sales of P21,074.00 at P13.50 per kilo (Table 7). This was followed by T_4 with 1536 kg/ha with a gross sales of P20,736.00, while T_1 (farmer's practice) had the lowest grain yield of 1427 kg/ha with a gross sales of P19,265.00. Summing up the partial gross marginal benefits (GMB) for both the tomato and two subsequent maize crops, T_1 (farmer's fertility level) still had the highest GMB of P237,433.00, followed by T_3 with P202,094.00 and the lowest was T_2 with P195,989.00.

Table 7. Partial cost-benefit analysis of tomato-maize-maize sequence as influenced by different fertility levels applied to first tomato crop. Claveria, Misamis, Oriental, Philippines.

Treatments	Variable input costs (P)	Tomato		Maize (1st subsequent crop		Maize (2nd subsequent crop		Partial GMB (P)
		Marketable yield (kg/ha)	Sales (P)	Grain yield (kg/ha)	Sales (P)	Grain yield (kg/ha)	Sales (P)	
T1(FP) (154:91:64, NPK)	24666	15820a	189840	4240	53000	1427	19265	237433
T2 (93:30:150, NPK)	14800	11720b	140120	4040	50500	1494	20169	195989
T3 (186:60:150, NPK)	20350	12260 b	147120	4340	54250	1561	21074	202094
T4 (92:36:150, NPK)	15830	12220b	146640	3920	49000	1536	20736	200546

The growth of tomato was more influenced by the level of N when P and K were not limiting. This was partly influenced by the mobility of N during intense rainfall particularly if the organic matter was not applied. The better yield in farmer's fertility level was attributed to the addition of organic matter which reduced N losses during intense rainfall. Under intense rainfall, diseases severity was not influenced by the different fertility levels. Although farmer had intensive pesticides application, occurrence of diseases still persisted. Marketable and non-marketable yields were still superior under farmer's fertility level than the alternative treatments. Farmer's fertility level still provided the better income against alternative treatments, but not the highest return to investment (700%), than the lowest fertility level (T_2) which had 850%. Tomato fertility levels and management regimes should revolve around climatic conditions that would enhance better N-use efficiency. There is a need for better N management during high rainfall period in order to reduce N losses and better understanding on the role of organic matter in N management such will increase N use-efficiency (Saito, 1990).

The yields of two subsequent maize crops were high across all treatments suggesting that farmers can still gain substantially from maize production by solely relying on the residual fertilizers from previous tomato crop. The use of high level of fertilizer inputs during the first crop tomato espoused by the farmers in Claveria was not mandated by the sensible vegetable fertility management during the current tomato crop but rather an opportunistic approach to gain longer benefits of the current arrangement with the traders. There are vegetable farmers willing to lose during the current tomato crop minding of the windfall harvests during the subsequent maize crops. These current levels of fertilizer inputs are becoming a standard recommendation among tomato growers even those who do not have access to traders' credit. These farmers are at a losing end particularly in situation where fertilizer use efficiency is low due to soil erosion, volatilization or fixation. There are two ways to approach this issue: 1) identify optimum fertilizer rate of current crop vegetable, and 2) identify nutrient management that would reduce if not avoid fertilizer losses by using organic materials that would temporarily immobilize nutrients and synchronize nutrients release when the crop needs them particularly on N which is highly mobile in the soil.

CONCLUSION AND RECOMMENDATION

From the results of this research, the following conclusions can be drawn:

- This research critically evaluated the current management practices and proposed alternative forms and rates of fertilizer inputs based on the soil test results and the current farmer's practice that would increase the productivity and profitability of vegetable production in the southern Philippines.
- Implemented alternative management practices that are based on the philosophy of matching fertilizer application to the nutrient requirements of the crop and the fertility status of the soil based on soil test results and mass balance approaches.
- As shown in the Claveria site, profitable and sustainable vegetable production could be achieve through the development of a productive cropping scheme for vegetables such as the tomato-maize-maize cropping sequence wherein only the vegetable was fertilized and the two maize sequence benefited from the residual fertilizers.

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