Reasons for and Impacts of Excessive Fertilizer Usage for Potato Farming in the Nuwara Eliya District

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ABSTRACT. *Excessive use of chemicals was common in upcountry farming systems. A comprehensive survey was conducted with selected potato farmers in the Nuwara Eliya district to gather information on agronomic and cultural practices, yield and environmental problems associated with potato farming; to estimate soil nutrient status, identify the causes and end effects of over fertilization, and to estimate economic losses.*

Soil pH and phosphorus levels were significantly affected by the previously cultivated crop. Fields to which dry cow dung was applied have lower phosphorus levels compared with the application of other types of organic manure combinations. Analysis also revealed that 4, 40, 25 and 15% of sampled farmer fields with >15, 11-15, 6-10, and 3-5 fold higher soil phosphorus contents, respectively than the optimum level required (40 ppm) for the potato crop. Similarly, 30% of farmer fields had almost double the amount of soil potassium than the optimum level of 160-400 ppm. Application of nitrogenous fertilizers as a basal-dressing showed no relationship with potato yield probably due to high accumulation of soil nitrogen. Application of nitrogen as top-dressing has even reduced the potato yield. Application of phosphorus as top-dressing to fields with high category of phosphorus availability also reduced potato yields. Potassium fertilizers as top-dressing increased the potato yield. In terms of soil phosphorus contents, most of the farmer fields' have very high phosphorus contents. Due attention has not been given to the existing soil nutrient status during the formulation of fertilizer mixtures. Farmers continue to apply optimum recommended quantities of fertilizer, or even higher every season. None of the farmers used straight fertilizers. Instead, they apply expensive, but sub-standard fertilizer mixtures. Soil test based fertilizer formulation and use of straight fertilizers could definitely reduce the fertilizer cost (by about 41%) and minimize the environmental hazards.

INTRODUCTION

Potato is the fourth most important food crop in the world, after wheat, rice and maize. Potato production in Sri Lanka is about 81,274 mt and covers a land area of 5,495 ha (Department of Census and Statistics, 2004). Potato in Sri Lanka is mainly grown in three districts namely Nuwara Eliya, Badulla and Jaffna. Potato crop needs adequate supplies of essential plant nutrients, particularly nitrogen (N), phosphorus (P) and potassium (K), which are removed by plants in large quantities. The application of the optimum level of fertilizer

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can maximize the tuber production. Although, fertilizer recommendations are available for the potato crop in Sri Lanka, farmers do not adhere to these recommendations (Wijewardena and Amarasiri, 1997). The reasons for non-practicing these fertilizer recommondations are still not understood fully.

Recommended fertilizer quantities for Potato cultivation are 75 kg/ha N, 125 kg/ha P_2O_5 and 75 kg/ha K_2O at basal dressing stage and 75 kg/ha N, and 75 kg/ha K_2O at top dressing stage (Department of Agriculture, 2004). Soil nutrient levels of K and P are considered as low, medium and high when soil K contents are lower than 160 ppm, between 160-400 ppm, and more than 400 ppm and soil P contents lower than 20 ppm, between 20-30 ppm and more than 30 ppm, respectively (Department of Agriculture, 1993). In the upcountry, especially in Nuwara Eliya, farmers use large quantities of fertilizer for their vegetable cultivation. Levels of fertilizer applied in upcountry were higher than the recommended rates (Wijewardena and Amarasiri, 1990; 1997; Marikar *et al.,* 1996). Continuous application of excessive amount of fertilizer increase the cost of production while causing many environmental problems such as desertification of lands, loss of soil biodiversity and eutrophication of water bodies. In introducing correct management practices, it is very important to investigate the severity of the over fertilization problem, and the economical and ecological impacts. Therefore, this study was initiated; (i) to estimate soil nutrient status in potato growing areas in the Nuwara Eliya district, (ii) to identify causal factors for overuse of fertilizer, and (iii) to analyze economic losses and the impacts of over fertilization on the environment.

MATERIALS AND METHODS

Study site

The study area was the Nuwara Eliya district and sampling sites include Seetha Eliya, Blackpool, Bambarakelle, Santhipura, Lindula, Nanu Oya, Meepilimana, Kuda Oya and Magoda.

Questionnaire survey

A survey was carried among 56 potato farmers from the Nuwara Eliya district to obtain information on history of the cropping pattern, levels of different fertilizers used and to gather other related information on production, management, environmental and social aspects with respect to potato cultivation. Farmers were selected using a systematic random sampling technique and more than four farmers were selected from each village listed above. The survey was carried out during the year 2005. Farmers were interviewed and relevant information was collected using a structured questionnaire.

Soil analysis

Composite soil samples were collected from all farmer fields to a depth of 25 cm to determine the soil nutrient contents just before planting of seed potato. Soil pH, Organic Carbon (OC) percentage, and soil P and K contents were measured using standard techniques. Soil analysis was done at the Tea Research Institute, Talawakele.

Data analysis

ANOVA, multiple linear regression and correlation analysis were used.

RESULTS AND DISCUSSION

Effect of previous crop cultivated on soil chemical properties

Farmers in the Nuwara Eliya district normally practice crop rotation and potato is cultivated mainly in two seasons, from August to September and January to February. Other vegetable crops are grown during the off-season. Some newly converted tea fields were also cultivated with potato. Results revealed that the soil pH and soil P levels are significantly varied based on the previous crop cultivated. The pH value of soils were high where leeks crop was grown in the previous season (p=0.0093) than when tea or radish was grown (Table 1). Tea lands are being converted for potato cultivation and the low pH observed in recently converted tea field may be due to low pH (4.5-5.5) levels maintained for the tea crop. Radish is cultivated as an inter-seasonal crop and farmers pay less attention to this crop and do not apply lime to correct the soil pH before cultivation. Soil P is high where radish, carrot and leeks are cultivated (p=0.0003) than the soils in which cauliflower and tea are cultivated (Table 1). The reason probably due to residual accumulation of P in soils due to the continuous application of highly soluble P fertilizers in vegetable cultivation than in tea cultivation where partially soluble rock phosphate is being applied. The demand for P for root vegetables is higher. Results revealed that the type of crop cultivated and the amount of fertilizer applied greatly influence the residual fertility status of soil.

Although, no significant difference was found for exchangeable K and OC in soils where different crops were cultivated, the K contents of soils under tea tend to be lower than in soils under vegetable crops. The reason might be the application of low level of K fertilizer in tea cultivation (Anon, 2000).

Table 1. Effect of cultivated crops on selected soil chemical properties.

Previous Crop	Mean			
	pH	P (ppm)	K (ppm)	OC (%)
Leeks	6.07^{a}	389.6^{a}	473.0^{a}	2.99^{a}
Beet	5.82^{ab}	373.3^{ab}	427.8^{a}	3.21^{a}
Cabbage	5.44^{ab}	333.1^{ab}	372.2^{a}	2.07^{a}
Potato	5.30^{ab}	286.5^{ab}	352.4^{a}	2.44^{a}
Carrot	5.20^{ab}	396.4^{a}	373.1^{a}	3.11^{a}
Cauliflower	5.19^{ab}	33.4^{c}	271.7^{a}	3.61^{a}
Tea	4.72^{b}	136.4^{bc}	250.0^{a}	2.88^{a}
Radish	4.68^{b}	518.8^{a}	333.3^{a}	4.04^{a}

Note: Means with same letters in a column are not significantly different at 5% probability.

Effect of organic manure application on soil chemical properties

Amount of organic manure applied vary from field to field. However, as a rough approximation, farmers applied wet cow dung 30 mt/ha, dry cow dung or poultry manure with wet cow dung 12-15 mt/ha, dry cow dung or poultry manure without wet cow dung 8-10 mt/ha, and ash 750 kg/ha. Fields in which dry cow dung was applied alone or with ash had significantly lower (p=0.0001) P level when compared with all other organic manure combinations applied (Table 2). It could be due to the application of relatively small quantities of dry cow dung, since it is more expensive than other organic manures. The pH value of wet cow dung was very high and when drying, most of nutrients in cow dung are converted into unavailable forms and some are volatilized. Wet cow dung + poultry manure + ash combination has significantly higher soil P content. The possible reason is that the most nutrients in these three organic fertilizers are in readily available forms. The humus fraction of organic matter, along with certain cations, is able to retain significant amount of P. Organic matter can reduces phosphorus fixation under acid soil conditions (Snyder and Bruulsema, 2002).

Table 2. Effect of different organic manure combinations on soil P contents.

Organic manure types	Mean Soil P contents (ppm)
Wet cow dung (Wc)	429.2 [abc]
Dry cow dung (Dc)	23.1 [e]
Poultry manure (Pm)	421.3 [abc]
Wc and Pm	341.9 [abc]
Dc and Pm	169.0 [cd]
Wc and Dc	441.9 [ab]
Wc and Paddy husk ash (Ash)	289.6 [abc]
Dc and Ash	37.5 [e]
Wc, Pm and Ash	518.8 [a]
Wc, Dc and Ash	418.8 [abc]
Dc, Pm and Ash	393.1 [abc]
Wc, Dc and Pm	315.0 [abc]
Wc, Dc, Pm and Ash	316.3 [abc]
No organic manure	111.9 [d]

Note: Means with same letters in a column are not significantly different at 5% probability.

Effect of time of fertilizer application on potato yield

Application of nitrogenous fertilizers as a basal dressing had no significant relationship (p=0.5904) (Table 3) with increasing potato yield. Application of nitrogenous fertilizer as a top dressing significantly reduced (p=0.0338) the potato yield. As far as potato crop is concerned, N is needed for vegetative growth, but not during the reproductive phase. Therefore, nitrogenous fertilizer is needed only at the initial stages (Vander Zaag, 1992).

Application of P at basal dressing stage did not show any significant relationship with increases in potato yield. Though, P is needed for root growth and tuber formation, the absence of a response to P fertilization may be due to the higher concentration of soil P yielded from residual effect of previously applied P fertilizers (Vander Zaag, 1992). Analysis revealed that only 16% of the potato fields had the soil phosphorus contents within the recommended range of 20-30 ppm. All the other fields had sometimes more than 15 fold higher soil P levels. This clearly indicates that there can be a nutrient imbalance for potato plants in these fields. This nutrient imbalance might be the reason for reduced (p=0.0267) potato yield when phosphorus was applied as a top dressing.

Table 3. Relationship of time of different nutrients application and potato yield.

Parameter	Estimate	Pr>(t)
Intercept	8128.50	<0.0001
Basal Nitrogen (BN)	14.25	0.5904
Basal Phosphorus (BP)	-6.77	0.7339
Basal Potassium (BK)	-21.18	0.4185
Top dressing Nitrogen (TN)	-42.79	0.0338
Top dressing (TP)	-41.61	0.0267
Top dressing Potassium (TK)	57.17	0.0048

Regression analysis revealed that the application of K as a basal dressing has negative impact on the potato yield. This may due to the very high residual soil K contents. Application of K during early stages when crop requirement is low may cause nutrient imbalance. Soil N levels may fluctuate due to many reasons such as high rainfall prevailed in this region, immobilization with high amount of organic matter added *etc*., indicating need for N fertilization at early stages. But application of N during tuber growing period where N demand is less causes negative impacts on yield. Application of K fertilizers as a top dressing significantly increased the potato yield (Table 3). K is needed for photo-assimilate translocation from source to sink and tuber enlargement (Mengel and Kirkby, 1987).

Effect of fertilizer application on environment

It was found that some plant nutrients like P in most farmers' fields were in very high category (>30 ppm). None of the field was in the low category (<20 ppm). In the higher category, 4, 40, 25 and 15% of farmer fields were having more than 15, 11-15, 6-10, and 3-5 folds high soil P content, respectively than the optimum level required for the potato crop. Overall, 45% of farmer fields are having ten fold higher P content. This is a very critical situation and it could cause numerous environmental problems. Danger is that the farmers continue to apply recommended rates or even more without considering the already accumulated P content. This may lead to waste of fertilizer and pollute most important natural resources (soil and water). In some areas, this may lead to develop eutrophication in water bodies. High concentration of some nutrient elements imposes nutrient imbalances and therefore, the total productivity could be reduced. This could be one reason for the productivity decline trends observed over the fast few years.

In terms of K, most of the fields were in the optimum category (160-400 ppm), 38% farmer fields were in high category (>400 ppm) and only 3% fields were in low category (<160 ppm) (Table 4). Overall, 30% of farmer fields had almost double the amount of soil K than the optimum level of 400 ppm. Farmers in Nuwara Eliya district cultivate three or four crops per year and for all these crops, they apply organic and inorganic fertilizers. As crops do not absorb all fertilizers applied, some nutrient could be leached into groundwater, thus polluting the environment. The farmers do not purchase straight fertilizers and mix *in-situ*. They purchase fertilizer mixtures available in the market and those mixtures do not compatible with the Department of Agriculture recommendations.

Table 4. Percentage of farmer fields in Nuwera Eliya with soil nutrient categories.

Nutrient category	Farmer fields (%)	
	P	**K**
Low	0	3
Optimum	9	59
High	91	38

The time gap between lime application and fertilizer application is about few days and most of the applied N could be lost to the environment as ammonia gas. Thus, farmers used to apply increasing quantities of fertilizer mixtures to supply more N to their fields. This could result in an excessive accumulation of P and K, increased fertilizer cost and pollution of soil and water sources.

Since potato is a cash crop and the economic loss is very high if the crop is failed, farmers do not like to take any risk and therefore, they use large amount of fertilizers and other agrochemicals without considering the fertilizer requirement and pest and disease situations. As farmers in the Nuwara Eliya district cultivate three or four crops per year, fertilizers are applied several times. Ratios of fertilizer mixtures also do not match with the recommendations given, and farmers are very much unaware about the negative impact and have poor knowledge about the technical aspects of these subjects as well. These are the main reasons for overuse of fertilizers in the Nuwara Eliya district. Due to overuse of fertilizers, some plant nutrients can be accumulated and some other nutrients can be leached specially causing groundwater pollution. Due to accumulation of certain nutrients in greater quantities, some essential soil organisms could be destroyed. All above reasons cause imbalance of the ecosystem. Relative proportions of overuse of fertilizers by farmers in the Nuwara Eliya district are given in Table 5. No one had used the optimum quantity of fertilizer recommended by the Department of Agriculture for the Potato crop.

Economical analysis

As a result of improper application of fertilizer, the cost of potato production increases, and the soil, water and air get polluted. According to the soil test values, application of nutrients, which are already in excess, can be reduced. This will reduce the cost of production of potato significantly. For example, when farmers practice normal fertilizer recommendations without considering soil nutrient status, they have to spend Rs. 33,006.00/ha for fertilizers (assuming August 2006 prices of 1 kg of urea, ammonium sulphate, triple super phosphate and muriate of potash were as Rs. 36.00, Rs. 24.50, Rs. 29.00 and Rs. 30.50, respectively). For the fields containing high P levels, they can save money by cutting down half of the phosphate fertilizer requirement, reducing the total expenditure for fertilizer to Rs. 29,062.00/ha. Similarly, K fertilizer can also be reduced with a reduction of the total cost to be around Rs. 29,194.00/ha. Fields which are containing higher amount of both P and K, could be applied with half the recommended amount, thereby reducing the cost to be around Rs. 25,250.00/ha with a reduction of fertilizer cost by 24%. This could be even reduced if N fertilizer amounts are also adjusted based on the soil fertility status.

Table 5. Relative proportion of fertilizer usage by potato farmers in the Nuwara Eliya district.

Category of fertilizer use	Relative proportion (%)		
	Nitrogen	Phosphorus	Potassium
Underused	43	18	21
Optimum range	0	0	0
Overuse	57	82	79

Most of the farmers in the up-country area are using fertilizer mixtures, which contain ammonium sulphate as their N source, which is expensive, mainly due to availability in the market. If they use urea as the N source, the cost could further be reduced to Rs. 27,249.00, Rs. 23,305.00, Rs. 23,436.50 and to Rs. 19,492.50/ha, respectively (Table 6). It is evident that the total cost for fertilizer could be reduced by 41% for fields where K and P contents are high if straight fertilizers are used while protecting the environment.

Table 6. Cost of fertilizer application under recommended level, fields containing high amount of P only, K only and both P and K and the % reduction of fertilizer cost when urea is applied as straight fertilizer.

Fertilizer sources	Cost/ha (Rs.)			
	Recommended level	Fields containing higher P	Fields containing higher K	Fields containing higher P&K
N $(NH_4)_2SO4$	17,493.00	17,493.00	17,493.00	17,493.00
N (Urea)	11,736.00	11,736.00	11,736.00	11,736.00
P (TSP)	7,888.00	3,944.00	7,888.00	3,944.00
K (MOP)	7,625.00	7,625.00	3,812.50	3,812.50
Total cost with $(NH_4)_2SO_4$	33,006.00	29,062.00	29,193.50	25,249.50
Total cost with Urea	27,249.00	23,305.00	23,436.50	19,492.50
Fertilizer cost reduction (%), if urea is used	17.00	30.00	29.00	41.00

CONCLUSIONS

In Nuwara Eliya vegetable growing area, soil pH and soil phosphorus levels depend largely on the crop species cultivated in the previous season. The combinations of wet cow dung, poultry manure and ash produced significantly higher soil P content compared to other organic fertilizer combinations such as dry cow dung, dry cow dung and poultry manure, and dry cow dung and ash.

Application of nitrogenous fertilizers as a basal dressing has no effect on increasing potato yield when the residual fertility levels were at optimum to high category. Majority of the farmer fields were having high to very high levels of P and K contents in the soil. Application of potassium fertilizers at top dressing stage increases the potato yield. The relative proportion of overuse of fertilizers by potato farmers in Nuwara Eliya district were N 57%, P 82% and K 79%. No farm field came under the optimum range category. Over fertilization could cause serious environmental problems. Therefore, site-specific fertilizer recommendation based on soil analysis could reduce fertilizer cost and minimize environmental hazards due to over fertilization. Use of urea as a straight nitrogen fertilizer source instead of ammonium sulphate could reduce fertilizer costs significantly.

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