A Site-Specific Nutrient Management Approach for Maize

By Tasnee Attanandana and R.S. Yost

Extension workers in Thailand are being trained to use handheld computers for calculating nitrogen (N), phosphorus (P), and potassium (K) fertilizer requirements for maize. A simplified soil test kit was developed for rapid NPK measurement in the field. A farmer network has been established to exchange information, equipment, and labor.

Fertilizer recommendations in Thailand are obtained from simple experiments and extrapolated on generalized soil properties. Recent research using the Decision Support Systems for Agrotechnology Transfer (DSSAT-CERES-Maize) and the Phosphorus Decision Support System (PDSS) together with simplified soil test kits resulted in higher yields, greater economic return, and balanced fertilization. This technology was developed and tested in the maize belt area of four provinces in Thailand. More than 200 farmers and about 1,000 extension workers and academic officers have been trained in the approach. And more than 10,000 kits are being used by extension workers, academic officers, and farmer leaders.

Maize is an important crop in Thailand, with about 1.7 million hectares (M ha) in production, mainly for use in animal feed. The government of Thailand wishes to increase productivity and total production of maize as part of its efforts to improve food security and farmer incomes, particularly in the maize belt (Lop Buri, Nakhon Sawan, Petchaboon, and Nakhon Ratchasima provinces) where about 0.5 M ha or 30% of the total crop is cultivated. The average maize farm size in Thailand is about 10 ha and the national average yield is presently about 3.7 t/ha (Agricultural Statistics, 2001), but larger yields of >6.0 t/ha have been obtained in experimental plots (Attanandana et al., 2000).

Application of adequate quantities of plant nutrients is a key aspect of increasing maize productivity and production, particularly where farmers use hybrid maize with high yield potential. At present, recommendations supplied to farmers are very general (and often constrained by the nutrient content of particular fertilizer compounds available on local markets) rather than related to site-specific crop nutrient requirements. In addition, most existing fertilizer spreaders were not adjustable (Attanandana, et al., 2002a). These factors result in unbalanced and inefficient fertilizer use that results in poor economic returns to the farmer and inefficient use of costly imported fertilizer materials. Furthermore, when N and P are used in unbalanced nutrient programs, they may be in excess of crop demand and result in losses from the soil-crop system, contributing to the nutrient load in streams, rivers, and other water bodies. Unbalanced fertilizer use also causes soil degradation, particularly when N fertilizer use drives the removal of P and K that are not replenished by the addition of fertilizer nutrients.

Thus, there is an urgent need for more site–specific nutrient recommendations that can be readily transferred to farmers by extension officers or farmer leaders and which meet farmers' production goals and resources. Soil testing is an important tool for preparing site–specific fertilizer recommendations, but is little used by farmers due to the lack of supportive research, the cost of soil analysis, and the limited capacity for soil testing at province level which results in an unacceptable delay between the time of soil sampling and the delivery of recommendations to farmers. Also, farmers not skilled in the selection of suitable fertilizer materials often fall prey to poor advice. To address these needs and problems, a program of revising fertilizer recommendations was begun in Thailand in 1998 with the first Thailand Research Fund project. The following steps were undertaken to revise the fertilizer recommendation program.

Photo 1.

Photo 2.

A Step-Wise Approach to Fertilizer Recommendations

Step 1. Soil test kit development. A simple test kit (**photos 1 and 2**) was developed for rapid analysis of soil pH, N, P, and K. The kit uses colorimetric tests with droppers to apply indicator solutions, calibrated scoops to measure the sample, and plastic bottles to prepare samples for analysis. Comparisons of the kit's rapid soil test methods (**Table 1**) with conventional methods indicated strong agreement in all tests for analysis of nitrate (NO_3^-), 80% of tests for P, 90% of tests for K (Attanandana et al., 2002b).

Step 2. Simplified method to identify the soil series. Soil chemical and physical properties not measured by the soil test kit were estimated based on the local soil series. Extension workers and farmer leaders were trained to identify the soil series by using a simple key contained in a pocket guide. Thus, soil characteristics such as pH, texture, color, presence or absence of gravel at particular depth, free calcium carbonate, and soil depth were based on information contained in the key. Soil series identification and the comparison of different soil series were performed by reference to illustrations of the soil profiles for each soil series contained in the pocket guide (**photos 3a and 3b**).

Photo 3a, left.
Photo 3b, right.

Table 1. Comparison of soil test data by test kit and laboratory determination.

Soil series	NO_3^- content: Spectro (Mehlich) mg N/kg	Level	Soil test kit	P content: Spectro (Mehlich) mg P/kg	Level	Soil test kit	K content: Atomic absorption mg K/kg	Level	Soil test kit
Lb1	2.00	VL	VL	4.50	M	H*	80	M	M
Lb2	18.00	L	L	0.25	VL	VL	130	H	H
Lb3	3.47	VL	VL	3.50	M	M	82	M	M
Ln1	4.38	VL	L	6.75	M	H*	89	M	M
Ln2	4.37	VL	VL	1.00	L	L	71	M	M
Tk1	2.67	VL	L	3.25	L	L	277	H	H
Tk2	12.92	L	L	0.56	L	VL	174	H	H
Pc	7.00	VL	L	6.00	M	M	39	L	L
Ct	3.00	VL	VL	2.00	L	L	266	H	M*
Lb	18.00	L	L	19.60	VH	H	628	H	H

* Indicates a significant difference between conventional and soil test kit methods.

Step 3. Simplification of crop modeling software for NP estimation. After the soil series has been identified, and the appropriate soil and weather data loaded, the DSSAT–CERES–Maize software (version 3.0) (Tsuji et al., 1994) can be used to predict maximum economic yield and maize N requirements. The PDSS was used to estimate P fertilizer requirements based on buffer coefficients, which are a simple function of soil clay percentage (Cox, 1994). These coefficients, together with estimates of field soil test P levels, were used to estimate fertilizer P requirements (Yost et al., 1992). Recommendations for N and P (type of fertilizer, amount required, and application timing) were printed in a manual for use by extension workers and farmer leaders.

Predicted and measured yield of Suwan 3601 hybrid maize was compared on important soils in four provinces of the maize belt area with NPK fertilizer recommendations based on the procedure described above. Relative yield was used to compare measured yield with the yield predicted by the model (Willmott, 1982). In eight experiments, the agreement index ranged from 0.90 to 0.99, indicating a close agreement between the predicted and actual yield for seven soil series (Attanandana et al., 2002b). The test kit results indicated very low soil N and P levels and the decision-aids predicted that larger amounts of fertilizer N and P were needed than in farmer practice. Field results indicated that the decision-aids fertilizer predictions resulted in higher

Table 2. Comparison of NPK fertilizer recommendation, yield of maize using decision aids and farmer's practice, and predicted economically optimal yields estimated by DSSAT 3.0.

Soil series	pH	Soil texture	Nutrient level, N–P–K	Recommendation N–P–K: Farmer practice	CERES maize PDSS	Yield, t/ha: Farmer practice	CERES maize PDSS	Predicted optimal yields
Lampayaklang	7.5	Clay	VL–VL–H	25–25–0	94–44–0	2.78	6.06	5.5
Chatturat	7.0	Loam	VL–VL–H	19–25–0	94–50–0	2.93	4.47	7.0
Lop Buri	8.0	Clay	VL–VL–H	69–38–0	125–69–0	2.71	3.43	6.9

Table 3. Economic analysis of maize production using decision-aids and farmer practice.

Treatment	Profit, US$/ha[1]
Farmer practice	261.3 a*
CERES- MB[2]	316.1 b
CERES-PDSS-MB	319.6 b

[1]US$1 = 43 baht
*Numbers followed by the same letter are not significantly different at p=0.05.
[2]MB=Mitscherlich-Bray

yields when compared with the farmer practice (**Table 2**). Farm profit was increased when the soil test kit and decision aids were used to prepare fertilizer recommendations despite increased fertilizer costs (**Table 3**).

Step 4. Farmer learning. A Participatory Learning Forum (PLF) was a successful method to identify and select farmer leaders. Farmers were asked to identify the leaders in the community, identify the best and most knowledgeable maize farmers, estimate the area and yield of maize in the local community, and determine price of maize, cost of fertilizer, and investment opportunities in the local community.

Photo 4.

Those who completed this work were selected for further contact. Farmers responded very favorably by taking the initiative to form their own network, with extension workers. **Photo 4** shows farmers discussing and solving their problems.

Step 5. Refining the N simulation. The CERES-Maize version 3.0, was initally simplified to estimate N fertilizer requirements based on the amounts of soil organic carbon from the laboratory data for each reference soil profile. This simplification was modified for DSSAT 3.5 to directly use the soil NO_3^- test results from the test kit. Other parameters used by the model were also adjusted: rooting depth of maize was reduced to 50 cm, allowance was made for the addition of 3 t/ha of crop residues, and the increment of N fertilizer was reduced to 10 kg/ha. An N response curve was developed on the farmers' fields by including a check and several levels of applied N that were greater and smaller than the amount recommended by the decision-aids. This response is being used to evaluate current predictions by DSSAT version 3.5 and plan for further revisions. There were relatively large differences between the N fertilizer recommendations produced by DSSAT version 3.0 and version 3.5 (**Table 4**).

Table 4. Nitrogen fertilizer recommendations and predicted economically optimal yield (maize variety Suwan 3601) for three soil series using DSSAT V 3.0 and 3.5.

		DSSAT V 3.0		DSSAT V 3.5	
Soil series	Nitrate level	N requirement, kg/ha	Predicted yield, t/ha	N requirement, kg/ha	Predicted yield, t/ha
Cd	Very low	95	6.97	90	7.45
	Low	65	6.96	80	7.54
	Medium	35	6.92	40	7.51
Pc	Very low	95	7.21	70	7.28
	Low	35	6.93	30	7.24
	Medium	35	7.18	20	7.28
Suk	Very low	125	6.46	140	7.83
	Low	35	6.07	100	7.66
	Medium	35	6.51	90	7.73

Conclusions

After training and with guidance from extension workers, farmers were able to identify the soil series using a pocket guide and determined basic soil fertility with a simple soil test kit. Nitrogen and P fertilizer requirements for maize, predicted by DSSAT-CERES and PDSS, respectively, resulted in increased yields and farm profits. The DSSAT 3.5 software predicted N fertilizer requirements based on soil NO_3^- measured with the soil test kit before planting and the model allowed for the effect of rainfall on possible N losses due to leaching (based on historical rainfall distribution), and the supply of N from soil and crop residues.

The PLF proved to be a major success in stimulating the farmers to organize and think for themselves. Farmers were able to determine their fertilizer requirements and formed networks to share resources and information. **BCI**

Dr. Attanandana is Professor of Soil Science, Kasetsart University, Graduate School Dept. of Soil Science, Bangkok, Thailand, email: agrtna@nontri.ku.ac.th. Dr. Yost is Professor of Soil Science, University of Hawaii at Manoa, Dept. of Tropical Plant and Soil Sciences, 3190 Maile Way, Honolulu, HI 96822, email: rsyost@hawaii.edu.

Acknowledgments

The authors acknowledge the Thailand Research Fund for the initial support for this work and subsequent support by Food and Agriculture Organization (FAO) and Soil Management Collaborative Research Support Program (SM-CRSP-Hawaii) projects.

References

Agricultural Statistics. 2001. Agricultural Statistics of Thailand, crop year 2001/02. Center for Agricultural Statistics, Office of Agricultural Economics, Ministry of Agriculture and Cooperatives, Bangkok, Thailand.

Attanandana, T., C. Suwannarat, T. Vearasilp, S. Kongton, R. Meesawat, P. Bunampol, K. Soitong, C. Tipanuka, and R.S. Yost. 2000. NPK fertilizer management for maize: decision aids and test kits. Thai Journal of Soil and Fertilizer 22:174-186.

Attanandana, T., T. Vearasilp, and K. Soitong. 2002a. Decision support system for fertilizer application in maize production:phase III. Progress report

Attanandana, T., C. Suwannarat, T. Vearasilp, S. Kongton, R. Meesawat, P. Bunampol, K. Soitong, C. Tipanuka, and R.S. Yost. 2002b. Use of decision-aids in on-farm experiment in Thailand. Paper presented at the Regional Workshop on Decision-aids for Nutrient Management Support System (NuMaSS). PhilRice, January 21-24, 2002.

Cox, F.R. 1994. DSSAT 3, Vol. 1, 2 and 3. International Benchmark Sites Network for Agrotechnology Transfer, University of Hawaii, Honolulu, Hawaii.

Tsuji, G., G. Uehara, and S. Balas. 1994. DSSAT 3, vol. 1, 2 and 3. International Benchmark Sites Network for Agrotechnology Transfer, University of Hawaii, Honolulu, Hawaii.

Willmott, C.J. 1982. Some comments on the evaluation of model performance. American Meteorological Society 63:1309-1313.

Yost, R.S., F.R. Cox, A.B. Onken, and S. Reid. 1992. The Phosphorus Decision Support System. ***In*** Proceedings Phosphorus Decision Support System, Texas A&M University, College Station, Texas.

Workshop Set for August 2003

The use of soil test kits to improve fertilizer recommendations for maize growers will be the subject of a workshop at Kasetsart University, Bangkok, Thailand, in August 2003. More details are available at www.eseap.org.