BETTER CROPS
WITH PLANT FOOD

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2009 Number 1

Nutrient Deficiency
Photo Contest Winners

In This Issue...

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BETTER CROPS
WITH PLANT FOOD

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Our cover: Winners of IPNI crop nutrient deficiency photo contest. For names of photographers and more information, see page 9.

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IPNI Science Award Goes to Dr. John Ryan of ICARDA

The International Plant Nutrition Institute (IPNI) has named Dr. John Ryan of the International Center for Agricultural Research in Dry Areas (ICARDA) as the winner of the 2008 IPNI Science Award. Dr. Ryan is Soil Fertility Specialist/Principal Scientist/Consultant, located at Aleppo, Syria. He receives a special plaque plus a monetary award of US$5,000.00 (five thousand dollars).

"We are honored to announce John Ryan as the recipient of the IPNI Science Award. He is a truly outstanding scientist and most deserving of this recognition. His distinguished career has included teaching, research, extension, and service. And Dr. Ryan has been prolific in the number of quality publications he has authored, co-authored, contributed to, or edited," said Dr. Terry L. Roberts, President of IPNI. "Dr. Ryan has worked in diverse countries during his career and has bridged the gap between the developed and undeveloped world."

Dr. Roberts also acknowledged the other outstanding nominees for the award, and encouraged future nominations of qualified scientists. Private or public sector agronomists, soil scientists, and crop scientists from all countries are eligible for nomination. This is only the second year the IPNI Science Award has been presented. The previous recipient in 2007 was Dr. M.S. Aulakh of India.

Born in Tipperary, Ireland, from a farming background, Dr. Ryan earned his B.Agr.Sc. in 1967 at University College Dublin. Dr. Ryan subsequently received his Ph.D. in Soil Science at University College Dublin/National University of Ireland, in 1971. Later, while serving as a post-doctoral researcher in soil science in the Soil and Water Science Department as a Fulbright Scholar at the University of Arizona, he earned his M.S. in Agricultural Education. In 1999, he was awarded the Doctor of Science (D.Sc.) degree by University College Dublin based on significant published work.

Before joining ICARDA, Dr. Ryan was Soil Fertility Specialist/Professor of Agronomy with the University of Nebraska, working with the USAID/MIAC-Maroc Project based at Aridoculture Center, Settat, Morocco, from 1987 to 1992. From 1975 to 1986, he was Professor of Soil Science at the Faculty of Agricultural and Food Sciences, American University of Beirut, in Beirut, Lebanon.

At ICARDA, Dr. Ryan's innovative strategic research (soil fertility/ agronomy/ crop nutrition) has involved wheat, barley, chickpea, lentil, vetch, and medics, focusing on sustainability in long-term cropping systems in rotation trials. Other crop-focused concerns include water and nutrient use efficiency, supplemental irrigation, wastewater use, and conservation tillage. His work on efficient fertilizer use for the past three decades has been a factor in the 10- to 20-fold increases in regional fertilizer use.

Dr. Ryan's other significant contributions include increasing awareness of micronutrients for crop growth and nutritional quality in Middle Eastern soils and demonstration of the potential of legume-based, cereal rotations to sequester carbon and improve soil quality and crop water use efficiency. While his work is directly related to the Mediterranean, it has implications outside the region. His innovative research has led to publication of more than 165 journal articles, 16 books, 25 chapters, 24 internal articles, 48 conference proceedings, 170 abstracts, and 30 reports.

Dr. John Ryan

During his career, Dr. Ryan has served on editorial boards of three international journals and four regional journals. He is a member of the American Society of Agronomy (serving as Chair of its International Division), the Soil Science Society of America, the Crop Science Society of America, the International Union of Soil Scientists (serving as Chair of its Soil Fertility and Plant Nutrition Division, 2002-2010), and the Soil and Plant Analysis Council. He served on the World Phosphate Industry's Scientific Advisory Committee (1997-2007) and is involved in several scientific networks.

Dr. Ryan is a Fellow of the American Society of Agronomy (1998) and the Soil Science of America (1999). He received the International Soil Science Award (1997), the International Service in Agronomy Award (2004), and the International Service in Crop Science Award (2008), being the only scientist from the CGIAR to receive all three international awards from the Tri-Societies. In 2007, he received the Soil Science Distinguished Service Award from Soil Science Society of America, and the Benton Jones Award from the Soil and Plant Analysis Council from North America. He was also the recipient of the prestigious International Crop Nutrition Award from the International Fertilizer Industry Association (IFA) in 2006, and was accorded the "Distinguished Citizen Award" from the University of Arizona (2000). In recognition of his lifetime services to international soil science, Dr. Ryan was recently announced as Honorary Member of the International Union of Soil Scientists (2008); the Award will be presented at the IUSS World Congress in Brisbane, Australia, in 2010.

The IPNI Science Award is intended to recognize outstanding achievements in research, extension, or education, with focus on efficient and effective management of plant nutrients and their positive interaction in fully integrated crop production that enhances yield potential. Such systems improve net returns, lower unit costs of production, and maintain or improve environmental quality. The recipient is selected by a committee of noted international authorities.

More information and nomination forms for the 2009 IPNI Science Award are available from the headquarters or regional offices of the organization, or from the website: www.ipni.net/awards. BC

Effect of Balanced Fertilization on Rice Nutrient Uptake, Yield, and Profit

By YueHua Xing, Ren Wang, Wentao Sun, JingWen An, CongXiang Wang, HongJing Bao, Liang Gong, and Xiang Zhen Wang

Balanced fertilization is important in optimizing both rice yield and profit. In this study, balanced fertilization also accelerated rice nutrient uptake and maintained soil nutrient balance at the site.

Rice covers about 20% of the total cultivated area in the north central province of Liaoning in China. And rice contributes over 25% of the province's total grain production per year. Traditionally, N and P fertilizers have been the only nutrients applied in these crops, but they are applied without any real understanding of yield potential or the required amounts and ratios of fertilizer nutrients.

In recent years, with various new high yield varieties being developed and introduced to Liaoning, soil nutrient deficiency has become more severe than ever. Previous investigation and experiments agree that while K deficiency exists in many regions, this deficiency has been alleviated after sustained K application, and yields have been shown to increase (Lei, et al., 2002).

Thus balanced fertilization can play a significant role in sustained development of grain production in Liaoning. The objective of this study was to investigate the effect of balanced fertilization technology on rice nutrient uptake, yield, and profit. A field experiment was conducted in the northern rice production area of Changgouyan Village, in Tieling County, Liaoning. This is a temperate region that is influenced by a monsoon season. The annual rainfall is 700 mm, and the average annual temperature is 7.6 °C, with a frost-free period of about 150 days annually.

The site was located on a paddy soil whose properties are listed in **Table 1**. A randomized complete block design was used with six treatments and three replications (**Table 2**). Plot area was 20 m^2 (2.5m x 8m). An initial soil test-based 'optimum' (OPT) nutrient application was recommended in 2006 based on the ASI method (Portch and Hunter, 2002) used by the National Laboratory of Soil Testing and Fertilizer Recommendations in Beijing (Yang, et al., 2001). In 2007, application rates for N and K were adjusted according to 2007 soil test results and profits obtained in 2006. Treatments received a basal fertilizer application including one-quarter of the total N as urea plus all of the P as diammonium phosphate (DAP) and K as potassium chloride (KCl). The remaining urea-N was topdressed and split between the seedling, tillering, and boot stages. The rice variety was '265-11-1' planted at a density of 225,000 hills/ha in 2006. The rice seedlings were transplanted on May 27 and harvested on September 29, 2006. In 2007, the rice variety was 'Liaojing 9' planted at 225,000 hills/ha. Rice seedlings were transplanted on June 6 and harvested on October 11, 2007.

In both 2006 and 2007, the OPT supported the highest nutrient uptake in rice, followed by a group including farmer practice (FP), OPT-P, OPT-K, and then the check (CK) and

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; OM = organic matter.

Northern Liaoning has extensive tracts of large-scale rice production.

Table 1. Soil OM, available nutrients, and pH of tested soil.

Item	2006	2007	Critical value
pH	5.65	5.69	–
OM, %	1.65	1.57	–
NH_4^+-N,mg/l	19.66	20.8	50
P, mg/l	12.15	25.7	12
K, mg/l	54.75	54.5	78

Table 2. Nutrient rates of different fertilizer treatments.

	Rates of N- P_2O_5- K_2O, kg/ha	
Treatments	2006	2007
OPT	300-90-150	210-90-135
OPT-N	0-90-150	0-90-135
OPT-P	300-0-150	210-0-135
OPT-K	300-90-0	210-90-0
CK	0-0-0	0-0-0
FP	210-105-105	210-105-105

Table 3. Treatment effect on nutrient uptake of rice, kg/ha.

	2006			2007		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
OPT	191	87	262	183	84	197
OPT-N	153	69	217	70	46	81
OPT-P	155	73	240	163	79	161
OPT-K	164	77	228	143	68	118
CK	110	52	151	102	51	101
FP	166	79	238	152	72	171

Balanced fertilization research sites are valuable extension tools used to promote improved nutrient management.

Optimum fertilization and farmer practice plots in Liaoning.

OPT-N treatments (**Table 3**).

Trends for soil nutrient balance were similar between the 2 years of study (**Table 4**). All treatments, including the OPT, showed a severe K deficit. With the exception of the OPT-N and CK, all other treatments expressed an N surplus and indicates that N was being applied in excess of crop requirements. Lowering the N rate in 2007 helped to minimize this N surplus. Only the OPT-P and CK treatments demonstrated a P deficit in either year, while the all other treatments provided sufficient P or a minor P surplus. It is important to note that the P balance was closest to zero for the OPT treatment. A nutrient imbalance due to lack of N or K produced an even greater P surplus.

Table 4. Effect of balanced fertilization on nutrient balance, kg/ha.

	2006			2007		
Treatments	N	P_2O_5	K_2O	N	P_2O_5	K_2O
OPT	199	3	-112	27	6	-62
OPT-N	-153	21	-67	-70	44	54
OPT-P	145	-73	-90	47	-79	-26
OPT-K	136	13	-228	67	22	-118
CK	-110	-52	-151	-102	-51	-101
FP	44	26	-133	58	33	-66

The OPT treatment supported the highest yields in both years of study (**Table 5**). Compared to plots receiving CK, FP, and nutrient omission treatments, the balanced OPT returned 6 to 42% more grain yield in 2006 and 8 to 40% more grain in 2007.

Table 5. Effect of balanced fertilization on rice yield.

	2006		2007	
Treatments	Yield†, kg/ha	Decrease, %	Yield, kg/ha	Decrease, %
OPT	8,667a	–	8,700a	–
OPT-N	6,333d	27	5,267e	40
OPT-P	7,100c	18	8,000b	8
OPT-K	6,467d	25	6,633c	24
CK	5,067e	42	6,000d	31
FP	8,133b	6	7,567b	13

†Dried rice yields followed by a different letter are significantly different (p=0.05).

Table 6. Effect of balanced fertilization on profit, US$/ha.

	2006			2007		
Treatments	Output	Fertilizer input	Net income	Output	Fertilizer input	Net income
OPT	2,374	316	2,059	2,384	248	2,135
OPT-N	1,735	146	1,498	1,443	111	1,332
OPT-P	1,945	248	1,697	2,192	191	2,001
OPT-K	1,772	238	1,626	1,817	178	1,639
CK	1,388	0	1,388	1,644	0	1,644
FP	2,228	253	1,976	2,073	242	1,831

2006 Prices (US$): 0.61/kg N, 0.81/kg P_2O_5, 0.56/kg K_2O, 0.29/kg rice grain.
2007 Prices (US$): 0.62/kg N, 0.92/kg P_2O_5, 0.56/kg K_2O, 0.29/kg rice grain.

The significant yield gains did translate into high returns as the economic analysis of net income over fertilizer costs determined the OPT to be the most desirable option, followed by the FP, and then the OPT-P treatments (**Table 6**). Net income derived from the OPT was US$83/ha and US$305/ha above common farmer practice in 2006 and 2007, respectively.

Balanced fertilization not only accelerates rice nutrient uptake and maintain soil nutrient balance, but also increases grain yield and farmer income. It was demonstrated that N was the first nutrient limiting factor for yield, followed by K, and then P. The continued K deficit observed in this study, even when K was applied, indicates that K deficiencies will continue to limit rice yields in the future. Application of K fertilizer should be increased beyond the level prescribed in the 'optimum' treatment of this study, so that soil K balance can be maintained under high yields. The importance of balanced fertilization in maintaining soil fertility for sustainable yield production is highly evident. BC

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Phosphorus Balance Trends on Agricultural Soils of the Lake Erie Drainage Basin

By Laura Bast, Robert Mullen, Ivan O'Halloran, Darryl Warncke, and Tom Bruulsema

Only a few decades ago, optimum plant nutrition involved applying more P than crops removed. In recent years, applications have come much closer to balancing removals. This trend has positive implications for both crop productivity and water quality.

Agriculture is one of the sources of P that feeds into Lake Erie. Reductions in total P loading since the 1960s have improved water quality in the lake, but in the past 10 years a rebound in loading of dissolved reactive P has raised new concerns (Baker, 2008).

The purpose of this article is to examine the trends in the balance of the major inputs and outputs of P on the agricultural soils of Ontario, Michigan, and Ohio. Much of the lake's watershed is within these three jurisdictions. While significant agricultural areas within each also drain elsewhere, accurate data representing agricultural activities is easier to obtain for political rather than watershed boundaries. In addition, since agricultural trends are driven by many external factors (markets, technology, etc.) it is not likely they would differ greatly among watersheds. Just under half of Ohio's and about 40% of Ontario's cropland drains into Lake Erie. Approximately 67% of the Lake Erie drainage basin is in agricultural land use (USEPA, 1995).

Agricultural producers apply P inputs to soils in the form of fertilizer and manure to support optimum growth of crops, and to replace the P removed with harvest. The balance between the amounts applied and removed determine whether soils are being built up or depleted in P. Enrichment of soils in P is one of several factors influencing loss of P to surface waters. Other factors include tillage and crop residue management through their influence on surface runoff and soil erosion.

The balance between amounts applied and removed serves as a performance indicator for P management. Attaining a proper nutrient balance while producing optimum crop yields can only be done by adopting best management practices (BMPs) for soils, crops, and nutrients.

Manure Inputs

Producers with livestock generally apply manures to their soils to capture the value of the nutrients they contain. However, not all manure is recovered, since not all animals are raised in confinement, and some manure (although a relatively minor amount) is lost in storage and handling. While total soil P includes all of the manure P applied to and remaining in the soil, manures vary in the degree of availability of the P they contain, and thus their immediate and long-term impact on soil test P levels and plant-available P may differ.

We estimated the total amount of manure P, "as excreted," and "as applied" to land, by applying coefficients from Kellogg et al. (2000) to inventory statistics for cattle, swine, and poultry from Statistics Canada and USDA-NASS. The figures for "as excreted" include all the P in all manure excreted, while those for "as applied" include only the plant-available P fraction in the recoverable manure. These coefficients result in amounts of P "as applied" similar to those calculated using values for manure nutrient content found in extension publications (e.g., OSU, 2006) based on animal type and size.

Over time, livestock have become more productive, partly by increasing feed conversion efficiency, and partly by increasing the output of meat, milk, and eggs per head. Some animals are now raised to higher weights than in the past; others are raised to market weight more quickly (e.g. more cycles per year for broilers). Feed conversion efficiency improvements lead to less manure excretion per unit of production, but other sources of productivity improvement increase manure excretion per unit of inventory.

Ohio, Michigan, and Ontario have the largest agricultural areas in the Lake Erie drainage basin, which is part of the larger Great Lakes watershed. Source: U.S. Army Corps of Engineers, Detroit District.

Abbreviations and notes for this article: P = phosphorus; tonnes = metric tons.

The coefficients in Kellogg et al. (2000) are based on animal performance in 1998. Comparing inventories and production statistics over the past 10 to 20 years, it is apparent that the livestock industry has been improving per-head productivity by roughly 10% each decade. Assuming that half of this productivity increase arose from improved feed conversion efficiency, we incremented the manure excretion coefficients by 0.5% of the 1998 value for each year after 1998, and likewise decreased the coefficients by the same amount for each year prior to 1998.

This productivity adjustment results in a linear 26% increase in the coefficients from 1955 to 2007. It can be argued that the amount of the adjustment should be higher or lower, but this adjustment is likely to be more accurate than assuming no change in manure output per unit of inventory over the period. Even though we assume an increase in the amount of manure excreted per unit of inventory, the total amount of manure available to spread on land has essentially remained the same–increasing by only 6%–over the past 50 years.

Cattle numbers were stable from 1955 to the mid-1970s, but have declined steadily since then. The number of swine followed the trend of cattle in Ohio, but in Michigan and Ontario swine numbers increased from the mid-1970s to the mid-1980s. In Ontario, numbers increased again in the last 10 years. Poultry populations increased sharply 20 years ago in Ohio and 10 years ago in Michigan, but in Ontario they have been increasing slowly and steadily since 1965.

Fertilizer Inputs

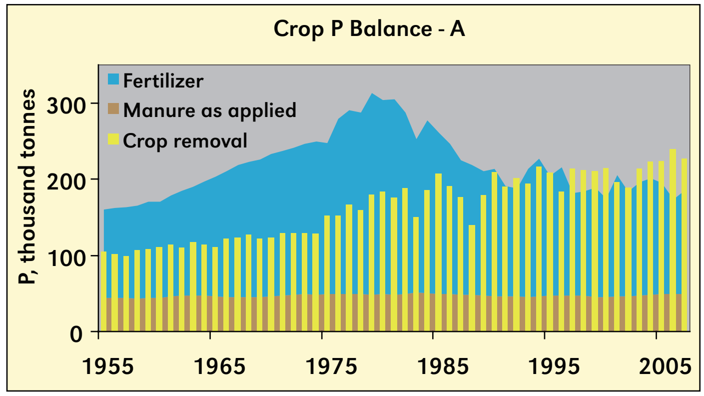
The publication Commercial Fertilizers (Terry, 2006) supplied sales data on an annual basis going back to 1975, and in 5-year intervals as far back as 1955, for Ohio and Michigan. Fertilizer sales in Ontario were reported by The Fertilizer Institute of Ontario for the period 1955 to 1965, by Agriculture Canada from 1966 through 2002, by the Canadian Fertilizer Institute from 2003 through 2006, and most recently by Statistics Canada for 2007.

We included fertilizer for non-farm uses, since data were not available for consistent estimates of the proportion used for non-farm purposes, including home lawns and gardens, recreational fields, golf courses, etc. Estimates of the proportion of fertilizer P used for non-farm purposes range from a few percent in Ohio (USGS) to 10% in Michigan in 1996 (USEPA).

Use of fertilizer P increased steadily from 1955 to about 1980, but decreased rapidly in the 1980s and has remained relatively stable since then. Prices for P fertilizer spiked upward in 2008. Crop prices also increased sharply, but not enough to prevent the price ratio for P relative to crops from attaining the highest levels seen in the past 30 years.

Crop Removal Outputs

We estimated the removal of nutrients harvested using crop production statistics from USDA-NASS and Statistics Canada for hay, corn, oats, barley, wheat, rye, soybeans, dry beans, and potatoes. The total area of these crops has changed little since 1955, though the soybean area has increased at the expense of hay and some of the cereals. These crops accounted for about 95%, 93%, and 99% of the total cropland in Ontario, Michigan, and Ohio, respectively, in the most recent agricultural census. We assumed that the crops on the remaining area removed P at the average rate of the listed crops.



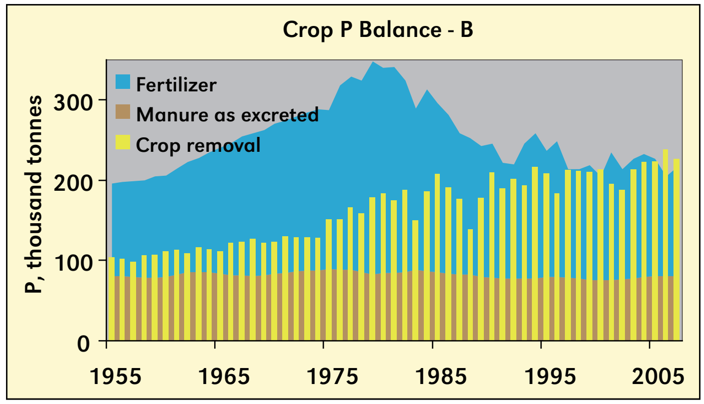


Figure 1. Crop P balance for Michigan, Ohio, and Ontario, based on manure P as applied (A) and as excreted (B).

We used coefficients for P content of the harvested crops from extension publications (OSU, 2006; OMAFRA, 2006) as much as possible, using IPNI (2001) coefficients for crops with no regional data.

Trends

We show the sum of fertilizer and manure inputs as a stacked area chart in **Figure 1**, with crop removal superimposed as a bar chart. The amounts represent the total cropland area of Ontario, Michigan, and Ohio. Units are metric tons (tonnes) of the element P. To convert these figures to P_2O_5, the standard unit of measure for fertilizer, multiply by 2.29.

Owing mostly to increases in crop yields, crop P removal has more than doubled since 1955. Year-to-year variations in weather cause considerable fluctuation in the amount removed, even when averaged across this rather large geographical area. Continued price increases for crops, crop breeding efforts, and refinement of best management practices are likely to spawn continued growth in crop P removal.

Current crops remove on average about 220 thousand tonnes of P. Relative to the loading levels estimated for Lake Erie from its drainage basin, this is a large quantity. Crop producers balance the removal by applying fertilizer and manure in order to maintain the productivity of crops. The large quantity underscores the importance and high sensitivity of managing nutrients appropriately to prevent avoidable losses impacting water quality.

The balance between inputs and removals changes considerably depending on whether manure P inputs are estimated as applied or as excreted. Compare **Figure 1A** with **1B**. With manure P as applied, there was a deficit for 9 of the past 11 years. On the as-excreted basis, there was a deficit for only

Balancing between the extremes of excess algae in drainage water and crop P deficiency requires careful attention to BMPs.

2 of the past 11 years. Estimated either way, P inputs greatly surpassed removals prior to 1990. Since P is strongly retained in soils, much of the surplus P has likely contributed to a buildup in soil P fertility. The improved P fertility has benefited crops. When soils are low in P, recommended rates of application often exceed the removal rate. At somewhat higher soil test levels, applications that do not exceed crop removal suffice for optimum crop yields, while soils with even higher soil test P levels can produce optimum crop yields with little or no P inputs.

The proportion of soils on which crops were limited by P availability in 2005 was estimated at 28, 30, and 42% for Ontario, Michigan, and Ohio, respectively (PPI, 2006). Comparison to historical soil test levels is confounded by changes in sampling distributions, but there has likely been a decreasing trend in this proportion over the past 50 years. Rising levels of soil test P would be consistent with expectations based on the historical P surplus. Considering that inputs and removals have recently become more closely balanced, it is unlikely that soil P fertility in general will continue to increase. Further increase in the P balance deficit could raise the risk of P deficiencies limiting crop yields.

The estimated fraction of manure P applied has increased over time. Comparing **Figure 1A** with **1B**, the as-applied fraction increased from 55% in 1955 to 61% in 2007, mostly owing to fewer cattle and more poultry, since the proportion of manure collected and land-applied is greater for poultry than for cattle. Much of the fraction not applied to land is directly deposited on pastures. The fate of the remainder is important to the issue of water quality, but is beyond the scope of this article. The accuracy of the estimates of the applied fraction can be questioned, since the past decade or two has seen considerable change in nutrient management on livestock farms.

We have ignored land application of sewage biosolids, owing to lack of historical data. Calculating from figures in Schroder et al. (2008), we estimate that the total amount of biosolids P applied in 2002 amounts to less than 5% of crop removal for this region.

The agricultural P balance trend is a useful performance indicator for crop management practices, since it reflects changes in crop productivity as well as surplus P potentially liable to contaminate water. On the other hand, the P balance does not indicate uniformity of distribution. It is possible that soil P levels in some areas have increased to the point of elevated risk of water contamination, while in other areas soils receive suboptimal amounts of P. Nutrient management plans encourage the use of best management practices (BMPs) to ensure that manure nutrients are directed to soils with lower nutrient levels and with lower risk of P loss to surface waters. Surveys of soil test P are a useful complement to the nutrient balance indicator.

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Winners Announced in IPNI 2008 Nutrient Deficiency Photo Contest

The scope and diversity of this annual contest continues to grow as the 2008 version has assembled a number of outstanding examples of nutrient deficiency in the field and lab. Our judges have selected three prize winners for each category which are highlighted here. Entries were evaluated on the overall quality of the image as well as the supporting data provided by entrants. All entries will be posted for viewing on the IPNI website at www.ipni.net/2008photocontest. Congratulations to these winners and sincere thanks to everyone who participated.

We encourage readers to watch for other opportunities to capture digital photos and document crop nutrient deficiencies in 2009. Also, further details of the 2009 IPNI contest will appear in upcoming issues of *Better Crops with Plant Food* and at the website.

Nitrogen

1st Prize: Chris Gunter, José Garzón, and Brian Whipker of North Carolina State University, Raleigh, North Carolina, USA, are credited with entering this example of N deficiency in immature lettuce. As part of their background description, they state: "These two plants are the same age, planted on the same day. Nutrient deficiency was induced by withholding nitrogen during growth. The other plant received complete nutrition."

2nd Prize: Muthukumar Bagavathiannan, Department of Plant Science, University of Manitoba, Winnipeg, Canada; **3rd Prize**: Cacciavillani Juan Ignacio, Demeter Laboratorio, Ordoñez, Cordoba, Argentina.

Nitrogen Category...N-Deficient Lettuce

Phosphorus

1st Prize: Tiequan Zhang, Agriculture & Agri-Food Canada, Harrow, Ontario, Canada, captured this dramatic case of P deficiency in a mid-summer corn crop. Soil test P (Olsen) at the site was 5.2 mg P/kg. The crop is obviously stunted and displaying the characteristic purplish-colored lower leaf edges.

2nd Prize: S. Srinivasan, Agricultural College, Tamil Nadu Agricultural University, Killikulam, Vallanad, India; **3rd Prize**: Ch. Srinivasarao, Central Research Institute for Dry Land Agriculture, Hyderabad, Andhra Pradesh, India.

Phosphorus Category...P-Deficient Corn

Potassium

1st Prize: Terry Wyciskalla, Wyciskalla Consulting, Inc., Nashville, Illinois, USA, submitted this example which contrasts side-by-side rows of soybean with adequate and deficient soil K supply. According to Mr. Wyciskalla, "Poor" areas had 89 lb/A (44.5 ppm) and "Good" areas had 281 lb/A (140.5 ppm). Whole-plant tissue analysis from the poor area equaled 0.58 ppm and 1.19 ppm in the good area. "According to the *Plant Analysis Handbook II* by Mills and Jones, critical K level in soybean is 1.70 to 2.50 ppm K. Results show a definite deficiency in the poor area, while results from the good area are borderline deficient, but may be adequate enough to not show deficiency symptoms."

2nd Prize: S. Srinivasan, Agricultural College, Tamil Nadu Agricultural University, Killikulam, Vallanad, India; **3rd Prize**: Nolver Atanacio Arias, Cenipalma, Barrancabermeja, Santander, Colombia.

Potassium Category...K-Deficient Soybeans

Other Category

1st Prize: Shahar Dayan, Haifa Chemicals Ltd., Yoqneam Elit, Israel, shot this close-up view of Zn deficiency in 2-month old cassava (tapioca) planted in Thailand. "It's a common phenomenon (for the region); this appearance is a typical zinc shortage, causing leaf curling, interveinal chlorosis, and auxin hormone flux disruptions."

2nd Prize: Leandro Marciano Marra, Universidade Federal De Lavaras, Minas Gerais, Brazil; **3rd Prize**: S. Srinivasan, Agricultural College, Tamil Nadu Agricultural University, Killikulam, Vallanad, India. BC

Other Category...Zn-Deficient Cassava

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; ppm = parts per million.

Optimal Fertilization of Banana for High Yield, Quality, and Nutrient Use Efficiency

By Lixian Yao, Guoliang Li, Baomei Yang, and Shihua Tu

Prescribed fertilizer application in first season banana crops (mother plants) uncovered a situation of oversupply due to seasonal differences in yield potential. This finding is of great importance in helping farmers adjust fertilizer inputs and improve fertilizer use efficiency, while maintaining high banana yield and quality.

Banana yield and quality improvement due to balanced fertilization has been well documented in China and elsewhere (Moreira et al., 1986; Hegde and Srinivas, 1991; McIntyre et al., 2000; Yao et al., 2005). However, adequate information on agronomic efficiency (AE - expressed as kg fruit per kg of nutrient) in China's banana crops is generally lacking, which identifies an important knowledge gap for these economically important and nutrient-demanding systems. Information on improving fruit storage quality and the storage properties of banana fruit through proper nutrient use is also very crucial since large quantities of fruit are sold to far-away markets.

Banana is widely grown in southern China and among the southern provinces, Guangdong is the number one producer. It has a planting area of 126,000 ha and a production (2006) of 3.35 million metric tons (M t), or about half of the banana production in China. It is reported that more than 20% of yield losses occur during transportation (Hu et al., 2003). This field study was designed to identify fruit yield and storage trait responses under improved NPK fertilization and to document AE data within two successive banana crops grown in southern China.

The experiment was located in Dongfu Village, Fusha Town, Zhongshan City of Guangdong Province, during 2006-2007 on an alluvial soil that is typical of the Pearl River Delta. The soil, analyzed using the ASI method used by the Sino-Canada Lab in Beijing and described by Portch and Hunter (2002), was determined to be deficient in N (10.5 mg/L), P (4.6 mg/L), and K (39.1 mg/L), and medium to high in Ca, Mg, S, Mn, Zn, Fe, and B. The soil test for N is often considered an unreliable indicator of soil N status under banana, as close relationships between soil N test and banana response to applied N are difficult to obtain (López and Espinosa, 2000). As a result, soil test information was combined with regional knowledge to construct an optimal (OPT) treatment of 900-270-1,080 kg N-P_2O_5-K_2O/ha for mother plant fertilization and 825-248-990 kg N-P_2O_5-K_2O/ha for the crop of daughter plants. A randomized plot design was used with four treatments and three replications. Three deletion plots individually omitted N, P, and K based on rates used in the OPT treatment. Urea, single superphosphate, and potassium chloride were used as sources for N, P, and K, respectively. The total N, P, and K fertilizers were split into eight dressings amounting to 35% of N, P, and K application during vegetative growth after planting and before flower differentiation, 40% before flower emergence, and the remaining 25% after flower emergence. The banana variety Baxi was planted at 1,620 seedlings/ha with 10 plants per plot. Mother plants were planted in early March 2006 and were harvested in late December 2006 to early March 2007. Daughter plants were selected in mid-August 2006 and harvested in early October to early November 2007.

Abbreviations and notes for this article: N = nitrogen, P = phosphorus, K = potassium, Ca = calcium, Mg = magnesium, S = sulfur, Mn = manganese, Zn = zinc, Fe = iron, B = boron; FW = fresh weight.

In both mother and daughter crops, K was the most limiting macronutrient for banana production.

Yield, Profits, and Nutrient Use Efficiency

Banana fruit yields for each treatment are shown in **Table 1**. As is typical to the Pearl River Delta, mother plant yields were generally lower than those obtained by daughter plants. This is a climatic effect caused by a shorter growth period and lower temperatures during the growth of mother plants. Though these mother plant yields were lower than usual, the yields under the OPT were still about 20% higher than those commonly obtained under traditional farm practice. The OPT-K and OPT-P treatments produced significantly lower mother plant fruit yields than the OPT treatment. However, yield under OPT-N was only 4% less than that produced by

Table 1. Banana fruit yields in different treatments at Dongfu.

	Mother plant		Daughter plant	
Treatment	Yield, t/ha	Yield reduction, %	Yield, t/ha	Yield reduction, %
OPT	40.5 a	-	58.2 a	-
OPT-N	38.9 ab	4.0	52.7 b	9.5
OPT-P	37.7 b	6.8	53.5 b	8.1
OPT-K	34.8 c	14.0	51.0 b	12.3

Means within a column followed by the same letter are not significantly different at p = 0.05.

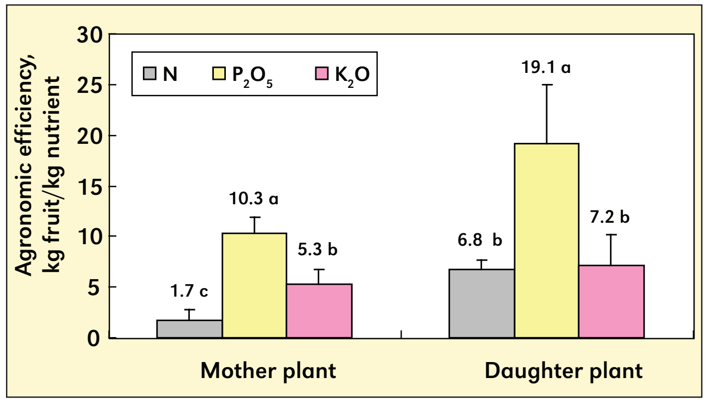


Figure 1. Agronomic efficiency of N, P, and K fertilizer in the respective OPT treatments applied to banana at Dongfu. Means within a bar group followed by the same letter are not significantly different at p = 0.05.

the OPT. In the subsequent crop of daughter plants, the set of omission treatments all led to significant yield declines, which were greatest in the OPT-K treatment followed by the OPT-N and OPT-P treatments. Thus, K was the most limiting macronutrient in both crops – a result which is in good agreement with the crop's large demand for K and the characteristically inadequate K supply capacity of the region's banana soils (Yao et al., 2005).

After subtracting all the production costs for mother plants, the OPT treatment obtained the highest plantation profit of 73,507 Yuan/ha (**Table 2**). The OPT-N treatment was slightly less profitable (-407 Yuan/ha), and the OPT-P and OPT-K treatments generated considerably less income. In daughter plants, the three omission treatments resulted in significant profit reductions which were greatest in the OPT-K, followed by the OPT-P and OPT-N.

The prescribed OPT treatments led to AE values for applied P of 10.3 kg fruit/kg P_2O_5 for mother plants and 19.1 kg fruit/kg P_2O_5 for daughter plants. The AE values for N and K were considerably lower (**Figure 1**). Higher AE values from daughter plants are a reflection of higher yields compared to the preceding mother plants. Yield generated by daughter plants was considerably higher than that from mother plants, even when N, P, or K was omitted over both crops. It is apparent that the NPK recommendation prescribed for mother plants, although being more balanced than the region's common practice, failed to prevent nutrient oversupply under the specific conditions experienced in this study.

Fruit Quality and Storage

Nutrient supply to banana plants affected not only yield, but also fruit storage properties. Storage quality can be evaluated by pigment content in the fruit peel (Leshem et al., 1986). Fruits from the OPT treatment had higher contents of chlorophyll and the lowest cyanin and flavonoid contents, all of which contributed to delayed post-harvest ripening and longer shelf life (**Table 3**). In contrast, the OPT-N, OPT-P, and OPT-K treatments prompted the degradation of chlorophyll and formation of cyanin and flavonoid in the peels of fruits.

Table 3. Pigment content in banana fruit peel for different treatments at Dongfu, Guangdong.

Treatment	Chlorophyll, mg/g FW	Cyanin, △A530- A600 = 0.1[1]	Flavonoid, A325/g[2]
OPT	0.038 a	0.097 b	0.384 b
OPT-N	0.037 a	0.137 b	0.490 a
OPT-P	0.029 a	0.255 a	0.492 a
OPT-K	0.038 a	0.287 a	0.469 ab

Means within a column followed by the same letter are not significantly different at p = 0.05.
[1]Absorbance difference between 530 and 600 nm
[2]Absorbance at 325 nm

The post-maturation of banana fruit is due to climatic respiration caused by ethylene. The rate of ethylene released from fruit is also a reflection of storage conditions. The key during banana storage is to limit ethylene formation and prevent the occurrence of a respiratory peak during banana storage (Hu et al, 2003). It was found that the ethylene release rates from fruits 0 to 16 days after harvest were greatest in the OPT-K treatment, followed in order by the OPT-N > OPT-P > OPT (**Figure 2**). Furthermore, ethylene release from banana in the three omission treatments, especially in the OPT-K treatment, increased with time, while there was only a slight increase in the rate of ethylene release in fruits harvested from the OPT treatment. This evidence suggests that balanced fertilization can slow down the process of post harvest ripening and help reduce weight loss during banana storage and transportation. Additional advantages also exist from keeping fruits free from possible contamination caused by the utilization of chemical anti-staling agents.

(Continued on page 15)

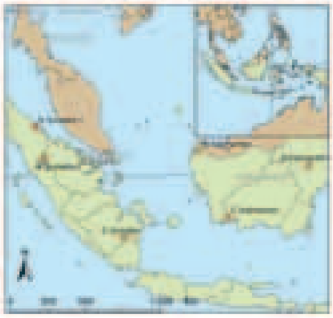
Table 2. Banana plantation profit in different treatments at Dongfu, Guangdong.

	Mother plant, Yuan/ha				Daughter plant, Yuan/ha			
Treatment	Output	Fertilizer cost	Profit	Profit reduction	Output	Fertilizer cost	Profit	Profit reduction
OPT	111,650	8,781	73,507	–	116,276	8,050	84,226	–
OPT-N	107,331	4,869	73,100	407	105,132	4,463	76,669	7,557
OPT-P	103,955	7,656	66,937	6,570	106,842	7,019	75,823	8,403
OPT-K	95,946	5,038	61,546	11,961	102,060	4,618	73,442	10,784

Notes: 1) Fertilizer price (Yuan/t): urea 2,000, SSP 500, KCl 2,080.
2) All the other costs totaled 29,362 Yuan/ha for mother plants, including land rent (16,500), seedlings (2,362), bamboo (3,000), labor (6,000), and pesticides (1,500). Those for daughter plants totaled 24,000 Yuan/ha, including land rent (16,500), labor (6,000), and pesticides (1,500).
3) Mean purchasing prices are 2.76 and 2.0 Yuan/kg for mother and daughter plant fruit, respectively. US$1 = 6.88 Yuan.

Yield Intensification in Oil Palm Plantations through Best Management Practice

By C.R. Donough, C. Witt, and T.H. Fairhurst



By comparison with the other major vegetable oil crops, oil palm occupies a small area but contributes about one-third of the global vegetable oil supply. Production has increased exponentially in the last 30 years, mainly through an expansion of the area planted. Meanwhile average yields have remained far below the economic yield potential. IPNI and its partners have developed a management concept to close existing yield gaps through best management practices (BMPs).

Planted area and production of palm oil have increased exponentially in Southeast Asia since the 1970s **(Figure 1)**. Indonesia and Malaysia, the largest producers, account for a combined share of 85% of global palm oil production. The potential productivity of oil palm is several times greater than that of other oil producing crops so that, provided the crop is managed properly, much less land is required to produce a quantum of vegetable oil compared with other vegetable oil crops.

Potential oil yield of oil palms planted on a commercial scale has been estimated at 10 to 11 t/ha (Breure, 2003). The largest reported oil yield at an estate scale (c. 2,000 ha) in Malaysia was more than 8 t/ha and leading plantation groups in Indonesia and Malaysia have achieved average oil yields of 6 t/ha at a larger scale (Donough et al., 2006). At an oil extraction rate of 22%, this would be equivalent to a bunch yield of about 27 t/ha. However, average bunch yield, even in the favorable environment in Southeast Asia, remains at less than 20 t/ha **(Figure 1)**.

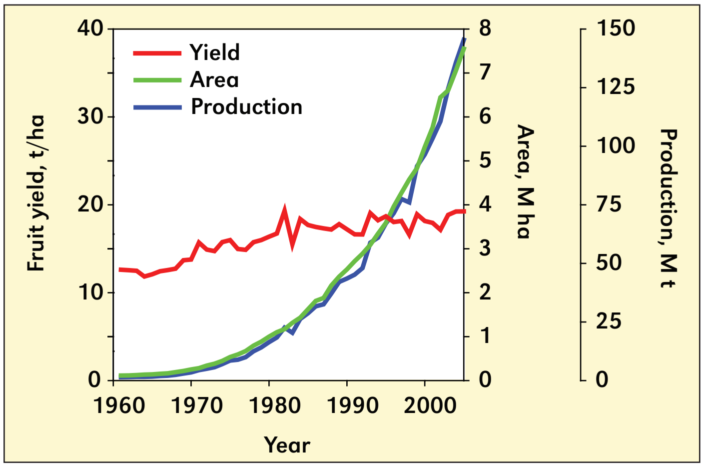


Figure 1. Yield, area, and production of palm oil fruits from 1961 to 2006. Source: FAOSTAT 2008.

Rationale for Yield Intensification

Oil palm responds rapidly to improvements in agronomic management with short term increases in bunch weight and longer term increases in bunch number both contributing to increased yield. There is a time lag of 3 to 4 years (i.e., the time interval between floral initiation and the production of a ripe bunch) between the removal of agronomic constraints and full impact on yield. For producers, the financial returns from investments in yield intensification in existing plantations are clearly more rapid and larger than returns on the development of new plantings for these reasons: 1) production starts to increase as soon as agronomic constraints are removed, and 2) yield intensification does not require capital outlay on new plantings and plantation infrastructure.

In addition, and provided BMPs are used, increasing yield on existing plantings has environmental benefits because production is increased while sparing wilderness land from agricultural development. A further impetus for yield intensification is the dwindling availability of suitable land for further expansion of oil palm plantings. With controls on land development tightening in Southeast Asia, future expansion is likely to focus on degraded land where development costs must allow for the amelioration of low fertility status soils.

For oil palm plantations, inputs are usually both available and affordable and estates obtain seed with high yield potential from certified seed producers. Thus, the key to improved yields is in better agronomic management and estate organization and planning. Yield improvement efforts in existing plantations must focus on identifying and rectifying management practices that contribute to the emergence of a gap between the maximum economic yield and actual yield **(Figure 2)**.

BMPs are well established and described. For example, note the series of handbooks and pocket guides published

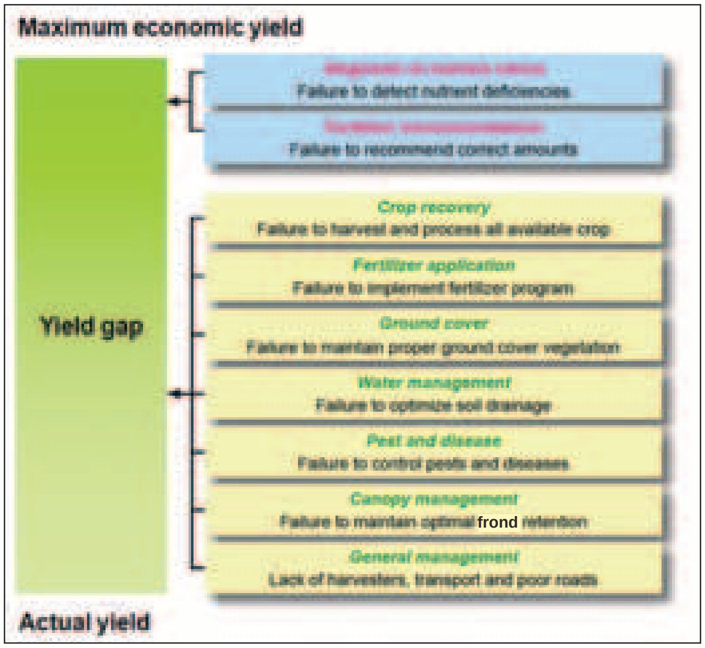


Figure 2. Management factors contributing to the gap between actual and maximum economic yield in existing oil palm plantations (after Fairhurst et al., 2006).

Abbreviations and notes for this article: M t = million metric tons.

by IPNI, available at: >**www.ipni.net/seasia**<. However, plantations often lack suitable methods to identify practices that could contribute most to yield improvement. The BMP concept promoted by IPNI is more than a description of the actual practices, it is a management tool to collect the necessary evidence on the potential for yield improvement before time and costly resources are allocated to expand practices within an estate (Fairhurst et al., 2009). In this article, we integrate yield intensification with environmental goals and define BMPs as follows:

BMPs are agronomic methods and techniques found to be the most cost effective and practical means to reduce the gap between actual and site yield potential and minimize the impact of the production system on the environment by using external inputs and production resources efficiently.

BMP as a Management Tool

IPNI has been instrumental in developing a BMP concept for yield intensification in existing mature plantings **(Figure 3)**. In this approach, a set of site-specific BMPs are identified and implemented in a representative number of full-size management blocks in each estate to achieve crop management objectives related to productivity, profitability, sustainability, and the environment. Through this process, estates identify better ways to implement BMPs for yield intensification, and decisions on larger investments in BMPs are based on practical, commercial-scale evidence. Performance indicators are selected to describe the complete impact of a combination of BMPs on all four crop management objectives while adhering to sustainable development goals.

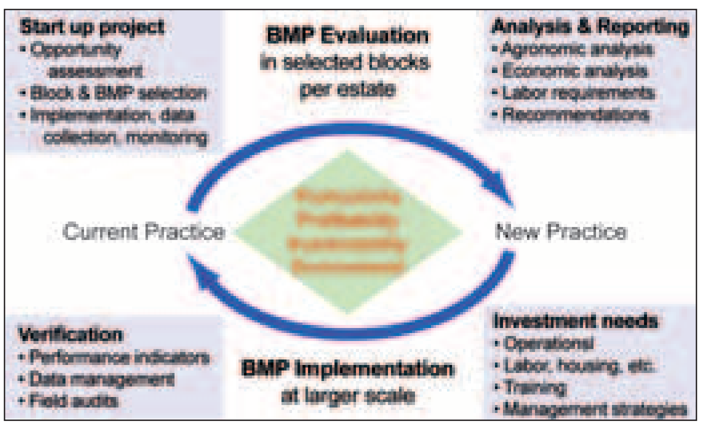


Figure 3. Conceptual framework for the evaluation of BMPs in mature oil palm plantations (after Witt and Donough, 2007).

The evaluation of BMPs is implemented by the estate management staff, and we emphasize the importance of involving key decision makers and resource persons in the local management team.

Once a new practice is successfully implemented at larger scale, it becomes current practice and the cycle of evaluation and implementation starts over again.

Evaluation of the BMP Concept

The BMP concept was first developed and successfully introduced in an oil palm rehabilitation project at PT Asiatic Persada in Jambi Province in Indonesia in 2001 (Griffiths and Fairhurst, 2003) before being implemented at larger scale in several other estates of CTP Holdings in Indonesia and Papua New Guinea (Fairhurst et al., 2006). In 2006, IPNI launched a new initiative to promote yield intensification based on generic principles of its BMP concept by setting up 30 commercial BMP blocks in partnership with collaborating plantations in Sumatra (North, South) and Kalimantan (West, Central, and East). Collaborating partners include Bakrie Sumatera Plantations (Site 1), Permata Hijau Group (Site 2), Wilmar International Limited (Sites 3 & 4), Sampoerna Agro Group (Site 5), and REA Kaltim Plantations (Site 6).

At each site, five pairs of blocks sized at least 25 ha were selected to represent the estate. One block was designated as the block for BMP implementation; the other became the reference (REF) block where current standard practices were maintained. BMPs were implemented based on the following priorities:

Priority 1 – Crop recovery
- Adopt a 7-day harvesting interval
- Maintain clean palm circles and clear access paths
- Construct harvesting platforms and harvesters' bridges
- Collect loose fruit in bags

Priority 2 – Canopy management
- Maintain proper pruning
- Remove abnormal and diseased palms
- Supply vacant planting points

Priority 3 – Soil, moisture, and nutrient management
- Maintain frond placement in inter-rows and between palms
- Apply empty fruit bunches
- Maintain fertilizer management to support large, profitable yields
- Construct adequate drainage

Projects at Site 5 and Site 6 have now completed at least one year of BMP implementation, while data for longer time periods is available from other sites (16 months for Sites 3 and 4; 22 months for Sites 1 and 2). Preliminary results are calculated on an annual basis **(Figure 4)**.

Prior to project implementation, fruit bunch (FB) yield was on average 1 t/ha greater in REF compared with candidate BMP blocks (data not shown). After 12 to 22 months of BMP implementation, yield was the same or greater in BMP compared with REF blocks at all six sites **(Figure 4a)**. On an individual block basis, higher FB yield was recorded post-implementation in 24 of 25 blocks with available pre-implementation records. There was no difference in yield between BMP and REF blocks at Site 1 where average yields were greatest amongst all project sites. It remains to be seen whether yields greater than 30 t/ha can be achieved with BMPs at Site 1 during the 4-year evaluation period. If not, attainable yield has been reached for the current palm stand.

The net added value with BMPs was significant at four out of six sites ranging from US$260 to 680/year **(Figure 4b)** based on actual cost and an assumed value of US$115/t fruit bunch yield. It is expected that BMP will become profitable at Site 6 once the full impact of BMP is expressed in yield and investments in drainage and other practices made in the first year are recovered in increased productivity.

The additional cost associated with the implementation of BMPs was relatively small, ranging from US$15 to 30/ha after 10 months (sites A, B). Yield advantages with BMP were

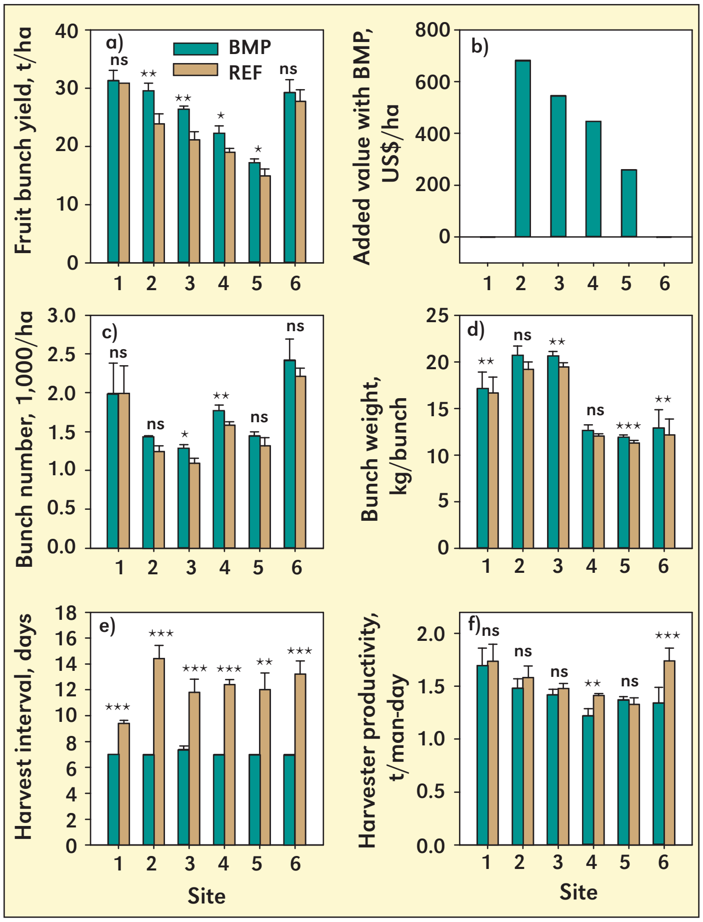


Figure 4. Performance of BMP in comparison to reference blocks (REF) at six project sites in Indonesia. Data represent a 12-month average, but the period of measurements ranged from 12 to 22 months.

generally due to improvements in both bunch number and bunch weight **(Figure 4c and 4d)**. Yield improvement in the first year of BMP implementation was largely attributed to improved crop recovery following the implementation of 7-day harvesting intervals, i.e., every palm is visited by harvesters once each week. The average harvesting interval in REF blocks was 12 days **(Figure 4e)**. Because of the short harvest intervals with less bunches to harvest per round, the daily area covered by harvesters was 15 to 35% greater within BMP blocks compared to the standard practice in REF blocks. However, because of the greater yield within BMP blocks, average harvester productivity based on the weight of the harvested fruit bunches per man-day was only 4 to 15% lower with BMP than REF **(Figure 4f)** while the number of harvested bunches was 10 to 20% lower in BMP (data not shown). As harvesters are paid based on the number of bunches harvested, productivity targets and payments will need to be reviewed so that harvesters benefit from the higher yield under BMPs. More harvesters are needed when following the BMP scheme, but the increased demand is not in direct proportion to the increased frequency of harvesting because each harvester covers a larger area per day when shorter harvesting intervals are maintained.

The project will continue until all sites have completed a 4-year cycle of yield improvement. Now that all BMP blocks have entered 'maintenance' mode, cost differences between the BMP and REF blocks will decrease, while the effects of other non-harvesting BMPs such as nutrient management are expected to provide further yield improvements compared to standard practices.

Conclusions

Encouraging yield improvements achieved through the implementation of BMPs at sites broadly representative of the oil palm industry underline the general applicability of the BMP concept. Clearly, a short harvesting interval and full crop recovery is a pre-requisite for closing current yield gaps at project sites. The next step in the yield intensification process will require a thorough analysis of the data at each site to determine the site-specific requirements for wider implementation of the selected BMPs. The BMP concept is consistent with Principle 4 (best practices) and Principle 8 (continuous improvement) of the Principles and Criteria for sustainable palm oil production of the Roundtable on Sustainable Palm Oil (RSPO, >**www.rspo.org**<). It should be noted that the success of a BMP project hinges on the commitment from senior management to provide direction as well as sufficient budget and resources, and from local estate management to implement the BMP(s) rigorously and on time. BC

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Banana…from page 11

Conclusions

This study is the first attempt in China to omit N, P, or K in banana based on prescribed OPT fertilizer treatment. Compared to the OPT, omission of P or K significantly decreased fruit yield in the mother plants while omission of N, P, or K all resulted in less yield from the following crop of daughter plants. Omission of K produced the largest reduction of yield and profit in both years.

In terms of storage traits, the content of chlorophyll in fruit peels decreased, while cyanin and flavonoid contents increased during storage. Ethylene release rates from banana fruits grown under -N, -P, or -K treatments increased over the time in storage compared with plants receiving the OPT treatment. Balanced fertilization with NPK could markedly improve fruit storage quality and extend storage life. Despite these yield and quality gains, large discrepancies in AE values were apparent between mother and daughter plants. More field experimentation is required regarding the balanced use of fertilizer application within these two successive crops. Results from this study suggest the need to address the nutrition of mother and daughter crops in a more distinct manner in order to address the differences in yield potential that are in part caused by differences in crop growth and development and environmental conditions. BC

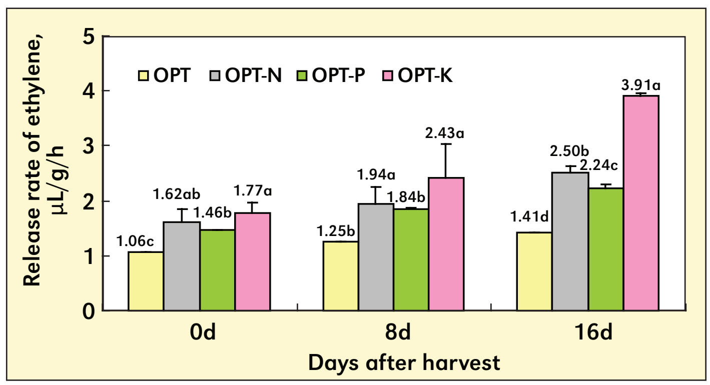

Figure 2. Variation in the release rate of ethylene from banana fruits from daughter plants receiving different fertilizer treatments at Dongfu, Guangdong, China.

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Nitrogen Rate and Source Effects on Nitrous Oxide Emissions from Irrigated Cropping Systems in Colorado

By Ardell D. Halvorson, Stephen J. Del Grosso, and Francesco Alluvione

Research shows that application of N fertilizer increases nitrous oxide (N_2O) emissions linearly from irrigated cropping systems in Colorado. Conventional-till continuous corn had a higher level of N_2O emissions than no-till continuous corn. Inclusion of soybean or dry bean in the no-till corn rotation increased the level of N_2O emissions during the corn year of the rotation. Use of controlled release and stabilized N sources reduced N_2O emissions under no-till when compared to urea and UAN fertilizer sources. Results of this work indicate that there are crop and fertilizer N management alternatives to reduce N_2O emissions from irrigated systems.

Nitrogen application generally increases N_2O emissions from irrigated cropping systems in the Central Great Plains (Mosier et al., 2006; Snyder et al., 2007; Halvorson et al., 2008a). Nitrous oxide is the principal non-carbon greenhouse gas emitted from soils and is produced through nitrification and denitrification processes in the soil. Agriculture contributes approximately 78% of the total N_2O emissions in the USA (Snyder et al., 2007). Snyder et al. (2007) presented an extensive review of greenhouse gas emissions from cropping systems, but little information was available on the effects of N fertilization on N_2O emissions from semi-arid, irrigated cropping systems in the western U.S.

The purpose of this article is to share our experiences with N_2O emissions from irrigated cropping systems located near Fort Collins, Colorado on a Fort Collins clay loam soil (Aridic Haplustalf). Studied cropping systems included conventional plow tillage continuous corn (CT-CC), no-till continuous corn (NT-CC), and no-till corn-soybean or dry bean (NT-CB) with N rates varying from 0 to 246 kg N/ha (0 to 220 lb N/A). From 2002 through 2006, N_2O emissions were measured from the CT-CC and NT-CC systems receiving N rates of 0, 67, 134, and 202+ kg N/ha. The highest N rate varied with year (202, 224, and 246 kg N/ha in 2002, 2003-2004, and 2005-2006, respectively). The N source was UAN (32%) from 2002 through 2005 which was subsurface band applied prior to crop planting with 33 cm (13 in.) band spacing parallel to the crop row. In 2005, the N was split applied with half the N rate applied as UAN prior to crop planting and the second half as a broadcast polymer-coated urea (ESN®, Agrium Advanced Technologies, Sylacauga, Alabama) in mid-June. In 2006, half the N rate was band-applied as ESN® near the corn row at corn emergence and the second half band applied in mid-June as dry granular urea followed the next day by irrigation. In the NT-CB rotation, N_2O fluxes were only measured in the 0 and high N rates each year. The high N rate applied to soybean and dry bean was 56 kg N/ha (50 lb N/A) in 2003 and 2005 with the entire N rate applied preplant as UAN. Nitrous oxide fluxes were measured during the growing seasons using vented static chambers (1 to 3 times per week; see photos) and an automated gas chromatograph analyzer. (See Mosier et al., 2006 and Halvorson et al., 2008a for more details on methodology).

The effects of N rate on growing season N_2O emissions from the irrigated CT-CC, NT-CC, and NT-CB rotations from 2002 through 2006 are shown in **Figure 1**. The average cumulative N_2O emissions across growing seasons were greater for CT-CC than for NT-CC, with N_2O emissions increasing with increasing N rate. For the NT-CB rotation in **Figure 1**, we assumed that a linear relationship existed between the low and high N rates. As shown in **Figure 1**, N_2O emissions with NT-CB rotation during the corn years were greater and parallel to the NT-CC cumulative emissions. During the bean years of the NT-CB rotation, N_2O emissions tended to be greater in the NT-CB rotation than in the continuous corn rotations at the 56 kg N/ha rate of N application. Thus, N rate, tillage, and crop rotation influence N_2O emissions from semi-arid, irrigated cropping systems in northern Colorado.

USDA-ARS technician Jessi Bishop collecting greenhouse gas samples from NT-CB plots for laboratory analysis on gas chromatograph.

During the 2005 and 2006 growing seasons when two N sources were used each year, it was noted (Halvorson et al., 2008a) that when ESN® was used, there were small N_2O emission peaks later in the growing season (July and August) that were not generally present when ESN® was not used (2002 – 2004). The normal response observed was for N_2O emission to increase within a few days of UAN application and then decline toward background levels in about 40 days. In 2005, N_2O emissions increased within a few days of UAN application, but small N_2O emission peaks continued to appear into the later part of the growing season (July-August) as a result

Abbreviations and notes for this article: N = nitrogen, 1.12 kg N/ha = 1 lb N/A; 1 Mg/ha = 15.9 bu corn/A.

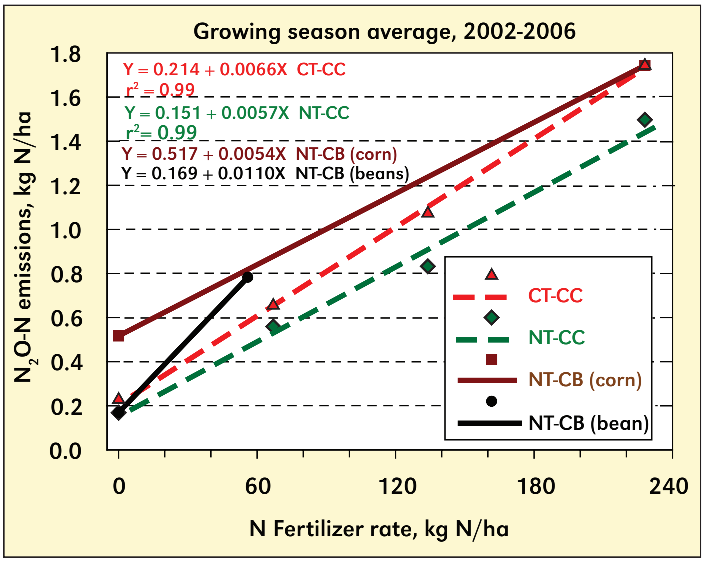

Figure 1. Average growing season N_2O emissions as a function of N fertilizer application rate from 2002 through 2006 near Fort Collins, Colorado (Mosier et al., 2006; Halvorson et al., 2008a).

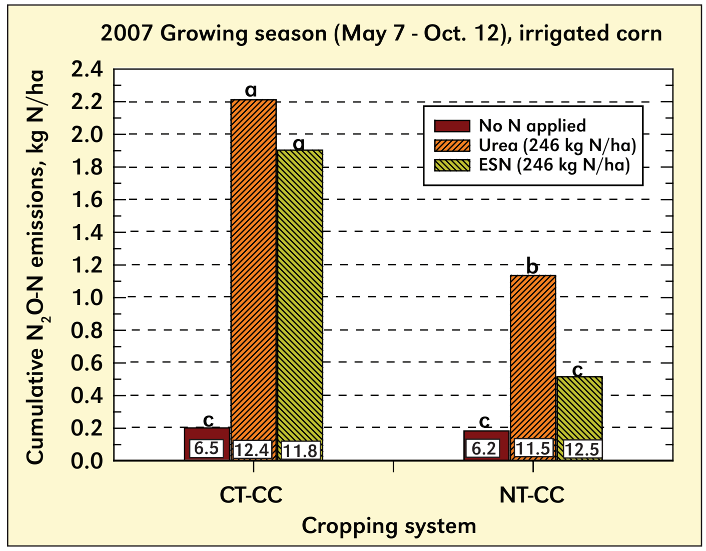

Figure 2. Growing season N_2O emissions in 2007 as a function of conventional-till (CT) and no-till (NT) production systems and N source near Fort Collins, Colorado (Halvorson et al., 2008b). Average grain yields (Mg/ha) are shown in a white box within each bar. (1 Mg/ha = 15.9 bu/A). Bars with same letters above are not significantly different at p = 0.05.

of the application of the polymer-coated urea (ESN®), which was applied in late June. In 2006, the ESN® was applied at corn emergence with no immediate increase in N_2O emissions, but with a large increase in N_2O emissions within days following application of dry granular urea in mid-June. Again in 2006, we observed small N_2O emission peaks in the later part of the growing season as a result of application of ESN®. As a result of these observations, in 2007 and 2008 we modified our treatments at the full N rate in the NT-CC and CT-CC systems to separate the N sources. Dry granular urea (246 kg N/ha or 220 lb N/A) was applied to plots formerly receiving 34 kg N/ha (30 lb N/A). The polymer-coated urea (ESN®) was applied to plots formerly receiving 246 kg N/ha. The entire N rate was mechanically band applied (see photo on next page) near the corn row at emergence.

Results from the 2007 study comparing N_2O emissions from plots receiving separate urea and ESN® applications in the NT-CC and CT-CC systems are shown in **Figure 2**. As was the case in 2006 (Halvorson et al., 2008a), N_2O emissions were greater in the CT-CC than in NT-CC plots in 2007. Cumulative growing season N_2O emissions from plots treated with dry granular urea and ESN® were not different in the CT-CC system, but were different in the NT-CC system. Under NT-CC, ESN® reduced N_2O emissions 55% compared with urea. Similar results were obtained in 2008 (data not shown). Reasons for the differences in N_2O emissions from ESN® between the two tillage systems are not clear. In the CT-CC system, the ESN® granules became covered with soil due to soil splash during rainfall and irrigation events and were partially buried in the soil, which may result in more rapid decomposition of the polymer coating of the ESN® granules with faster and earlier release of urea-N from the granules than in the NT-CC system. The ESN® granules remained on the soil surface underneath the crop residue in the NT-CC system throughout the growing season. In the CT-CC system, the ESN® granules tended to move (float) with water out of the fertilizer band, compared with little movement of the granules from the band in the NT-CC system, increasing the chance for the creation of microsites favorable to N_2O production through granule accumulation in depressed areas and coverage with soil. These factors may contribute to the differences in N_2O emissions from ESN® between tillage systems. These data suggest that tillage system may have a great effect on how N sources influence N_2O emissions from irrigated corn fields.

USDA-ARS technician Sadie Skiles collecting greenhouse gas samples from NT-CC plots in 2008 from N source study for laboratory analysis on gas chromatograph.

In addition to the 2007 study reported above, another N source comparison study was initiated in 2007 and continued in 2008 to compare N_2O emissions from plots receiving UAN and urea with controlled release N and stabilized N sources under irrigated NT-CC on a new set of plots at the same location. The controlled release sources were two polymer-coated ureas, ESN® and Duration III®, produced by Agrium Advanced Technologies, Sylacauga, Alabama. The stabilized N sources were SuperU® which is a granulated urea impregnated with a urease and nitrification inhibitor, and UAN treated with AgrotainPlus® (UAN+AP). Both materials were obtained from Agrotain International, St. Louis, Missouri. The SuperU® and AgrotainPlus® contain urease (N-(n-butyl)-thiophosphoric triamide) and nitrification (dicyandiamide) inhibitors. Each N source was hand banded next to the row at corn emergence followed by the application of 12 mm (0.5 in.) of water through the sprinkler irrigation system. The N rate used was 246 kg N/ha (220 lb N/A) in 2007 and 202 kg N/ha (180 lb N/A) in 2008. The N rate was reduced in 2008 to more closely bracket the economic N rate for the NT-CC system (Archer and Halvorson, 2008). In 2008, we also removed part of the corn residue…about 6,000 kg/ha (5,346 lb/A) of the 9,100 kg/ha (8,109 lb/A) produced in 2007) from the NT-CC plots used in this study in an attempt to increase soil temperatures and improve early corn development.

The 2-year average growing-season cumulative N_2O fluxes are shown in **Figure 3** for each of these N sources. Dry granular urea had the greatest growing season N_2O emission followed by UAN, Duration III®, and ESN® with the SuperU® and UAN+AP treatments having the lowest N_2O emissions. When compared to urea, the controlled release (ESN®) and stabilized N (SuperU®) sources reduced N_2O emissions 33% and 48%, respectively, in this irrigated NT-CC production system. Addition of AgrotainPlus® to the UAN solution reduced N_2O emissions 35% when compared to UAN alone. Application of SuperU® resulted in a 29% reduction in N_2O emissions compared with UAN alone. The check (no N applied) treatment had the lowest level of N_2O emissions during the growing season. These data indicate that selection of N source can have an impact on N_2O emissions from irrigated, no-till production systems. Producers managing their cropping systems to reduce N_2O emissions need to consider using the controlled release and stabilized N sources along with no-till. No-till has been shown to reduce carbon dioxide (CO_2) emissions and increase soil organic matter. Reduction in N_2O and CO_2 emissions will have a positive effect on reducing global warming potential.

Nitrogen application to irrigated crops in the Central Great Plains is essential to attaining optimum yield potential and economic returns on most soils. Deciding how much N to apply, when and how to apply it, and what N source to use are important decisions for optimizing yield and economic returns, while protecting the environment from N pollution by leaching of NO_3-N into groundwater or N_2O emissions as explained above. In our study, N source had little impact on grain yield, but did impact N_2O emissions. Maintaining a low level of available N in the surface soil early in the growing season should contribute to reduced N_2O emissions (Snyder et al., 2007). Thus, the principle of applying the right N source, at the right rate, in the right place, at the right time becomes a key management decision for optimizing crop yields and economic returns while protecting the environment (Roberts, 2007). Soil testing for residual NO_3-N is a critical component in this semi-arid region for determining the right N rate to be used. Previous cropping history and crop management practices also play a key role in efficient use of N (Maddux and Halvorson, 2008). BC

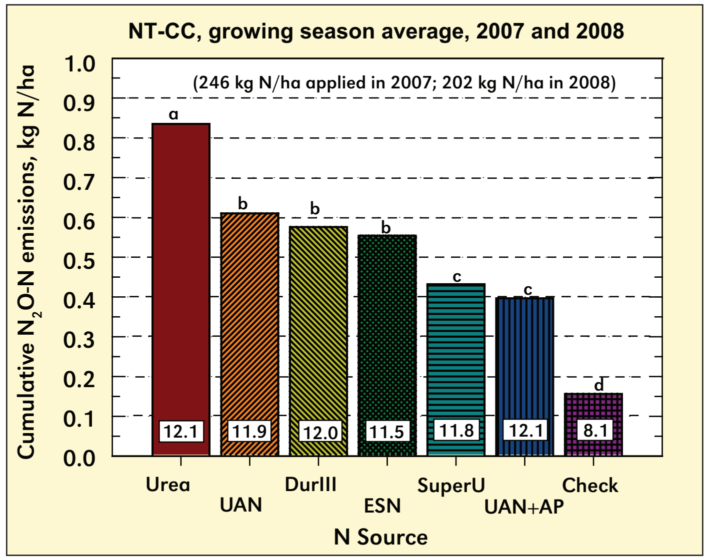

Figure 3. Average (2007 and 2008) growing season N_2O emissions as a function of N source in a no-till continuous corn irrigated cropping system near Fort Collins, Colorado. Each N source was surface banded near the corn row at emergence. Average grain yields (Mg/ha) are shown in a white box within each bar. Bars with same letters above are not significantly different at $p = 0.05$.

Band applying SuperU® fertilizer to NT-CB rotation in 2008 are, from left, Dr. Halvorson, Francesco Alluvione, Brad Floyd, and Robert D'Adamo.

Dr. Halvorson (e-mail: ardell.halvorson@ars.usda.gov) and Dr. Del Grosso are Soil Scientists with USDA-Agricultural Research Service (ARS) at Fort Collins, Colorado. Mr. Alluvione is with the University of Turin, Italy, and was a visiting scientist with USDA-ARS.

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Important Staff Changes for IPNI India Program

The International Plant Nutrition Institute (IPNI) has announced a series of significant changes to the India Program staff. The announcement came from IPNI President Dr. Terry L. Roberts and Dr. Adrian Johnston, IPNI Vice President, Asia and Oceania Group.

Effective January 1, 2009, **Dr. Kaushik Majumdar** was appointed to the position of Director of the India Program. Dr. Majumdar succeeds **Dr. K.N. Tiwari**, who served as Director of the India Program since 1998 and retired from IPNI effective December 31, 2008. IPNI leaders also announced the appointment of two new Deputy Directors in India. **Dr. Harmandeep Singh Khurana** will have responsibility in India-West Region, while **Dr. T. Satyanarayana** will work in India-South Region and Sri Lanka. **Dr. T. Nagendra Rao** resigned from the India Program staff in October 2008.


Dr. Majumdar

Dr. Majumdar is a native of West Bengal and served as IPNI Deputy Director, India-East Zone, since 1999. He received his B.Sc.(Ag) Hons. degree from Visva-Bharati University in 1984, M.Sc. (Ag) in Agriculture Chemistry and Soil Science from Bidhan Chandra Krishi Viswavidyalaya (BCKV) in 1987, and Ph.D. from Rutgers University in Soil Mineralogy and Soil Chemistry in 1993. Dr. Majumdar returned to BCKV as a research associate in 1994, and then joined the Potash Research Institute of India from 1995 to 1999 where he worked on K mineralogy and dynamics in Indian soils. Dr. Majumdar has been based in Kolkata. Beginning in 2009, he will work from an office in New Delhi and take responsibility for Northeast India and Bangladesh, in addition to his role as Director, India Program.


Dr. Khurana

Dr. Khurana officially joined the staff of IPNI as Deputy Director, India Program-West Region, effective July 1, 2008 and has established an office in Pune. He received his Ph.D. in 2005 in Soils at Punjab Agricultural University (PAU), in Ludhiana, India. He earlier earned his Masters degree in 2001 and B.S. in 1999 at the same university. From 2006 until 2008, Dr. Khurana was Postdoctoral Associate, Soil Fertility and Plant Nutrition, in the Department of Crop and Soil Environmental Sciences at Virginia Tech, Blacksburg. In that responsibility, he modified and tested a soil-water-plant-atmosphere simulation model related to site-specific management and analyzed the fate of excess N in soil and water. From 2005 to 2006, he served on the staff at PAU as an Assistant Professor, Soil Fertility and Plant Nutrition, with 100% research responsibility. Dr. Khurana has received numerous awards and recognition for academic and research achievements, and is the author or co-author of several research publications.


Dr. Satyanarayana

Dr. Satyanarayana joined the staff of IPNI as Deputy Director, India Program-South Region, effective November 1, 2008 and has established an office in Hyderabad. In 2005, Dr. Satyanarayana received his Ph.D. degree from the Indian Agricultural Research Institute (IARI) in New Delhi. He received his M.Sc. degree at Dr. Y.S.P.U.H. & F. in Himachal Pradesh in 2001, and his B.Sc. Ag. from Tamil Nadu Agricultural University in 1998. Most recently, Dr. Satyanarayana was Deputy Manager-Business Development & Agri Technical Services, with Shriram Fertilizers & Chemicals, DSCL. In that role, he was involved with identifying emerging trends in agriculture and other allied businesses, imparting training, developing publications and coordinating the functioning of 110 Shriram Krishi Vikas Kendras (SKVKs). From 2005 to 2007, he worked as Deputy Manager–Regulatory Affairs, with Coromandel Fertilisers Ltd. in Hyderabad. Dr. Satyanarayana was also a Senior Research Fellow at IARI from 2001 to 2002 and worked on projects related to the rice-wheat cropping system. He is author or co-author of several research publications.


Dr. Tiwari

Dr. Tiwari joined the staff of PPI/PPIC (now IPNI) India Program as Deputy Director in June 1998 and was named Director on July 1, 1998. During his 10 years with PPI/PPIC and IPNI, Dr. Tiwari provided leadership in developing information on fertilizer management practices in India which can be readily transferred to farmers to improve yield, quality, and profitability. He also provided training opportunities for scientists, extension workers, fertilizer industry personnel, agricultural students, farmers, and children. A prolific writer, Dr. Tiwari released a large number of scientific and extension publications on the impact of balanced fertilizer use on crop production, profitability, and food security in India. BC

Potassium Uptake by Kiwi Orchards in Shaanxi

By Yan'an Tong, Wang Jian, and Ma Wenjuan

Potassium concentration and accumulation in kiwi fruit trees showed that fall accumulated K was used to meet demand during fruit expansion in early July of the next year. When fruit production was 40 t/ha, the total K uptake was 170 kg/ha. Of that, 43 kg/ha was accumulated from September to the following May, and 125 kg/ha was taken up during the fruit formation period between May and September.

Potassium is usually regarded as a "quality element" in fruit production (Fvallhi, 1998). More specifically, the cycling and recycling of K in the plant plays an important role in maintaining cation-anion balance (Engels et al., 1996), providing dynamics for solute flow in the xylem and phloem (Mengel et al., 1973; Marschner, 1995; Hayashi et al., 1990; Mengel et al., 1977), a feedback signal regulating K uptake by the root (Drew et al.,1990; Engle et al., 1992), and provides the K required for proper functioning of phloem loading (Mengel et al., 1977; Huber et al., 1981; Giaquinta et al., 1979; Lohaus et al., 1995). Although much attention has been paid to the cycling and recycling mechanism of K in plants, information on biomass and K accumulation are still lacking due to the limited research in this area.

Latest statistics put the total area planted to kiwi fruit in China at 55,000 ha in 2005, while total production was 457,000 metric tons (t). In Shaanxi Province, 16,000 ha of kiwi is currently planted, representing 30% of planted area in China. This region produces 240,000 t of fruit, accounting for 53% of total production in China. Even though kiwi fruit orchards are located in loess soil areas rich in K (Institute of Soil Science, 1978), application of K fertilizer can still improve the yield and quality. The objective of this study was to determine the principles of K uptake by kiwi trees and provide guidelines for K application at the right amounts and the right time intervals.

A field trial was conducted in Maitun Village, Zhouzhi County, the main kiwi fruit production area in Shaanxi. The annual mean temperature is 13.2 °C, annual precipitation is 660 mm, and annual sunshine is 1,870 hrs. The orchard site was a 10-year old kiwi orchard (Qinmei variety). The trial was carried out during 2005 and 2006. Three trees were selected each time for sampling at six different stages. Sampling began on March 28 (sprouting and foliage growing), May 18 (young fruit), July 9 (fruit expansion), September 8 (fruit maturity), November 6 (defoliation) in 2005, and on January 11 in 2006 (dormancy). Samples of fruit, leaves, new tops, branches, trunks, and roots were collected separately at each sampling time. Root samples were collected within a radius of 100 cm around the trunk and from five successive 20 cm layers down to the 100 cm depth.

Results indicated that the biomass of kiwi fruit trees increased slowly at earlier growth stages from March 28 to May 18, then faster from May 18 to July 9, reaching the peak on September 8 (**Figure 1**). The root biomass increased slowly and steadily during this period.

Abbreviations and notes for this article: K = potassium.

Potassium accumulation in kiwi fruit trees followed similar patterns observed for biomass accumulation (**Figure 2**). Of the total K accumulated, 74% was accumulated during the fruit growing period between May 18 to September 8. Potassium removed in harvested fruit and fallen leaves represented 61% and 22% of total K accumulation, respectively. Potassium

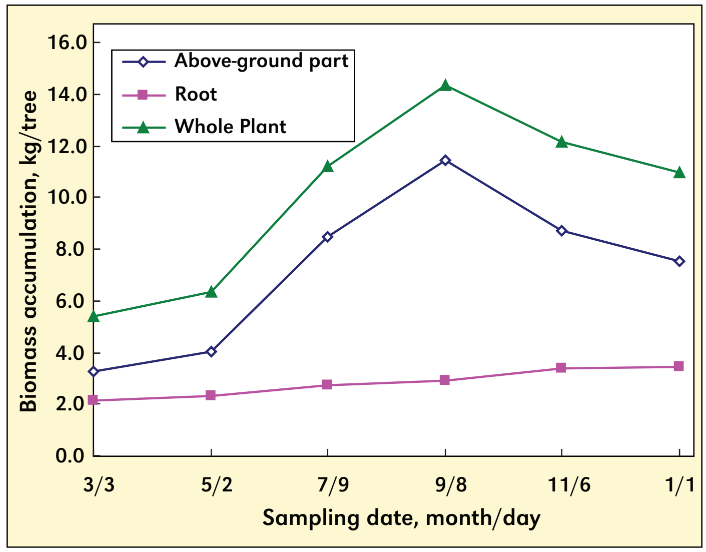


Figure 1. Annual changes of biomass in kiwi fruit trees, Zhouzhi County, Shaanxi.

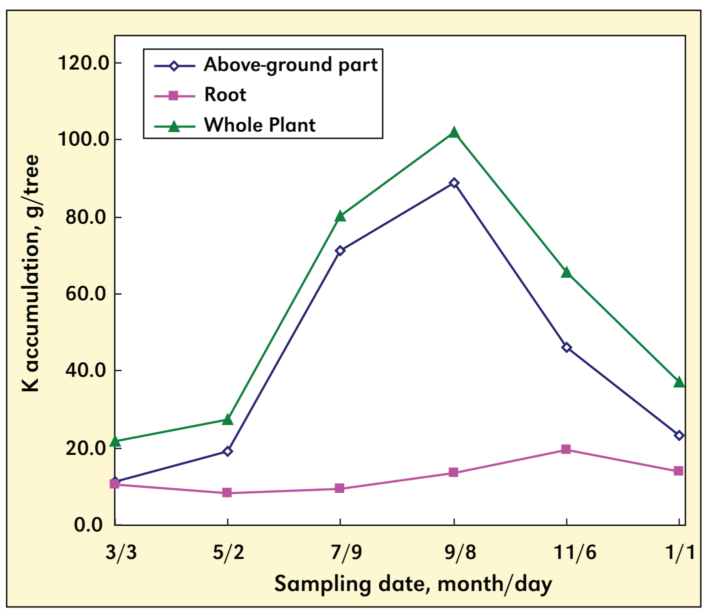


Figure 2. Annual changes of K accumulation in kiwi fruit trees, Zhouzhi County, Shaanxi.

Researchers sample below-ground plant parts for nutrient composition.

Researchers sample above-ground plant parts for nutrient composition.

accumulation in roots changed only slightly over the studied period.

Potassium concentrations in roots decreased slightly from March 28 to July 9, increased from July 9 to November 6, and then decreased after November 6. Potassium concentration in the stem was similar to that in the root. The leaves had the highest K concentration on May 18 and dropped to the lowest level in July 9. Potassium concentration in fruit declined from July 9 to September 8 (**Figure 3**).

Potassium within the xylem and stem or root cortex also decreased during the earlier growing stages (**Figure 4**). Potassium concentrations in xylem were much lower than those in the cortex. Potassium in the cortex dropped to its lowest levels on May 18, and then it increased and reached its highest level on November 6. As cited earlier, this cycling and recycling of K provided the sieve tubes with K nutrition necessary for functioning of phloem loading, so these changes of K concentrations may be the result of fruit growth and carbohydrate transportation in phloem. This trend in K concentrations is similar to results obtained by Qin (2004). Potassium concentrations in xylem changed only slightly during the period studied.

The period when fruit trees had the highest demand for K was between mid-May and early July (**Table 1**). Net K accumulation during this growth interval was 89 kg/ha. From May to July, K accumulation in roots, stems, and fruits increased by 1 kg/ha, 6 kg/ha, and 87 kg/ha, respectively. Leaves showed a net loss of 5 kg/ha during this time frame. Therefore, developing fruits received 98% of accumulated K from May to July.

By harvest time, on September 8, another 36 kg/ha distributed similarly between the roots (7 kg/ha), stems (7 kg/ha), and leaves (5 kg/ha), while 17 kg/ha was stored within the fruits.

Total annual net K accumulation in this established kiwi fruit tree orchard, with a yield of 40 t/ha, was 170 kg K/ha.

This research found two distinct periods when trees required more K. The first period was after fruit harvest in the

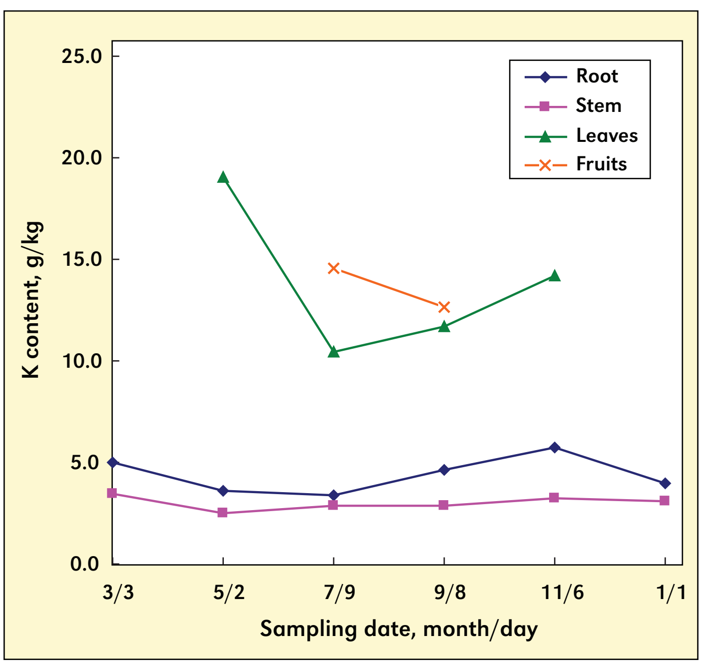


Figure 3. Dynamic changes of K concentration in root, stem, fruits and leaves of kiwi fruit tree, Zhouzhi County, Shaanxi.

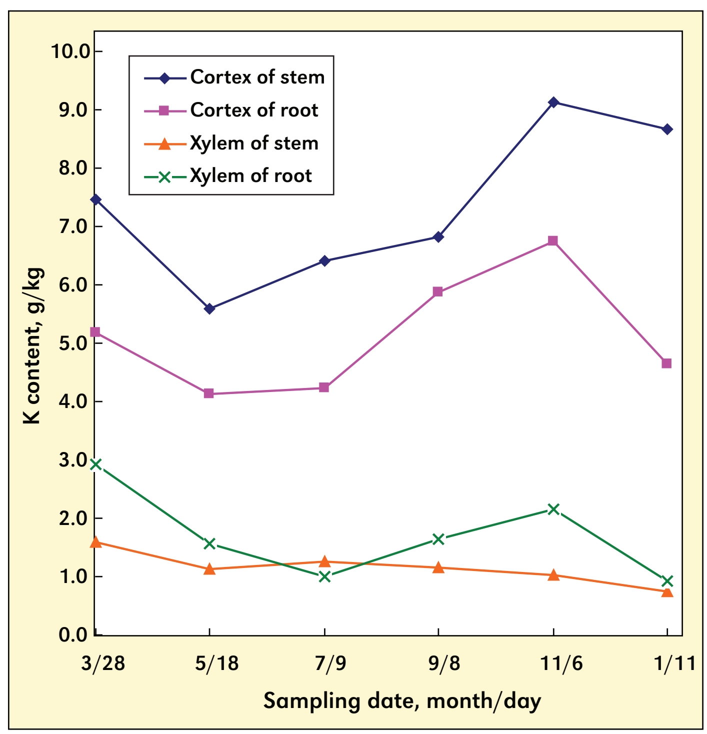


Figure 4. Dynamic changes of K concentration in xylem and cortex of kiwi fruit tree, Zhouzhi County, Shaanxi.

International Plant Nutrition Colloquium Set for August 2009

The 16th International Plant Nutrition Colloquium (XVI IPNC) will take place August 26-30, 2009 at the Sacramento Convention Center in California, sponsored by the University of California-Davis (UC-Davis). Since its inception in the 1950s, the IPNC has grown to become one of the most important international meetings on fundamental and applied plant nutrition, from both an agricultural and environmental context.

The theme for the 2009 Colloquium, "Plant Nutrition for Sustainable Development and Global Health", aims to highlight the importance of plant nutrition as a foundation science with impact on all aspects of cropping system and environmental sustainability, human health, and well being. Dr. Patrick Brown of the UC-Davis Department of Plant Sciences serves as President of the IPNC. Additional information is available at the website: http://ipnc.ucdavis.edu. BC

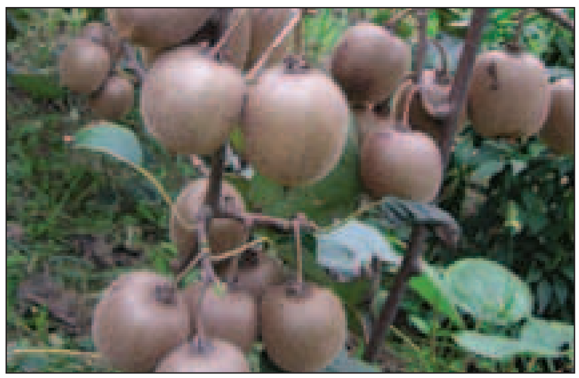
11th International Symposium on Soil and Plant Analysis July 2009

The Soil and Plant Analysis Council will present the "11th International Symposium on Soil and Plant Analysis" July 20-24, 2009, at Santa Rosa, California. The purpose of the symposium is to ensure a forum for research, practitioners, and experts working in agricultural laboratories, fertilizer consulting, or instrumentation industries to meet the challenges of the 21st century while meeting its needs for environmental sustainability (soil, water, air, biosphere). Main topics for the 2009 Symposium include water analysis, managing nutrients in a vineyard, petiole and soil testing in vineyards, turf analysis, precision agriculture, global warming, and management for biofuels. For more information, call the Soil and Plant Analysis Council at 970-686-5702, or visit the website at: >www.spcouncil.com/symposium.htm< BC

Kiwi…from page 21

Table 1. Potassium accumulation (kg K/ha) in various parts of kiwi fruit trees at different sampling periods (2005 to 2006), Zhouzhi County, Shaanxi.

	Sampling date					
Plant part	March 28	May 18	July 9	September 8	November 6	January 11
Root	18	14	15	22	33	23
Stem	18	14	20	27	38	39
Leaves	--	17	12	17	38	--
Fruits	--	--	87	104	--	--
Total Plant	36	45	134	170	109	62



fall and the second period was during fruit expansion in the following growing season.

Although it is difficult to quantify the nutrients required for kiwi fruit orchards by soil testing, it is necessary to consider the K balance in order to compensate for annual removal of K by harvested fruits, fallen leaves, and cut branches. Assuming K fertilizer use efficiency of 40%, and 50% of the total annual K accumulation was from indigenous soil sources, the initial recommendation for K application required to offset K removal in the orchard would be 210 kg/ha. Results from this study suggest that about 85 kg K/ha (40%) should be applied in the fall after fruit harvest and the remaining 125 kg K/ha (60%) be applied prior to fruit expansion in early May. BC

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Ion Exchange Resin for Assessing Phosphorus Availability in Soils

By Bernardo van Raij, H. Cantarella, J.A. Quaggio, and Luís Ignácio Prochnow

Soil testing is an important tool for modern agriculture. It represents a link between a remarkable amount of research information on one side and the possibility to solve many plant nutrition problems for specific farmer sites on the other. To be effective, a soil test should give adequate evaluation of soil nutrient bioavailability. In this paper, research data are used to demonstrate that the ion exchange resin procedure is superior to other widely used methods to determine P in routine soil testing. In Brazil, ion exchange resin has been used since 1983 and about 100 laboratories have adopted the method.

Phosphorus has received considerable attention in the research of methods of soil analysis, but agreement on best methodology is lacking. Resin extractable P seems to be a superior method, but its adoption in routine soil testing is still limited worldwide.

When there is a choice between several methods of analysis, if results are not comparable, greenhouse experiments under controlled conditions are used to select the soil test that is more closely related with nutrient uptake. This is done in pot experiments with soils representing a wide range of attributes that affect P reactions. A test plant is grown under conditions of proper nutrient supply except for P. The linear correlations between P uptake by plant and soil P determined by different procedures allow the ranking of methods based on the quality of prediction of P availability in soils.

An example of such research for a pot experiment with flooded rice is shown in **Figure 1**. In this case, resin extractable P is compared with the Mehlich 1 extraction. The results of resin P presented a much better correlation with P absorbed by the rice plants than Mehlich 1.

Several studies comparing soil P determination methods have been carried out. The literature review by Silva and Raij (1999) included papers published with soils of different countries, in which P determined by different methods was correlated with plant P uptake. The data in **Table 1** indicate that the ion exchange resin method is better correlated with P uptake than the other methods and that it is suitable for all types of soils, both acidic and alkaline.

The pH of the extractant solution is important for the ion-exchange resin procedure as shown in **Table 2**. Phosphorus extraction was poor when the suspension pH was low. For soil #2, where no response to P was observed, a high value of extractable P (36 mg/dm^3) was obtained when the suspension pH was 6.8 whereas at pH 5.6, soil P was only 5 mg/dm^3. This can be explained in part because the availability of Fe and Al phosphates increase when pH increases. It also explains why acid extractants fail to remove P from soils high in Fe and Al

Table 1. Effectiveness of soil P extraction methods in predicting plant uptake based on data from 70 experiments reported in world literature.

	Average coefficient of determination (100 r^2) for soils		
Method	Acid soils	Alkaline or neutral soils	Non specified soils
Resin	84	83	69
Olsen	47	52	58
Mehlich 1	56	39	41
Bray-1	53	25	48
Morgan	26	40	32

Source: Silva and Raij, 1999.

Table 2. Effect of pre-treatment[1] of the resin on pH of soil resin suspension and extractable P.

	Soil 1		Soil 2	
Resin saturation	Suspension pH	Soil-P, mg/dm^3	Suspension pH	Soil-P, mg/dm^3
Resin-HCl	3.3	2	3.4	3
Resin-NaCl	5.3	1	5.6	5
Resin-$NaHCO_3$	6.8	12	6.8	36

Soil 1- Cotton yield in kg/ha: control, 2,058; with P, 2,244.
Soil 2- Cotton yield in kg/ha: control, 3,678; with P, 3,673.
[1]Soils were shaken overnight in the soil-resin suspension.

Source: Raij et al.,1986.

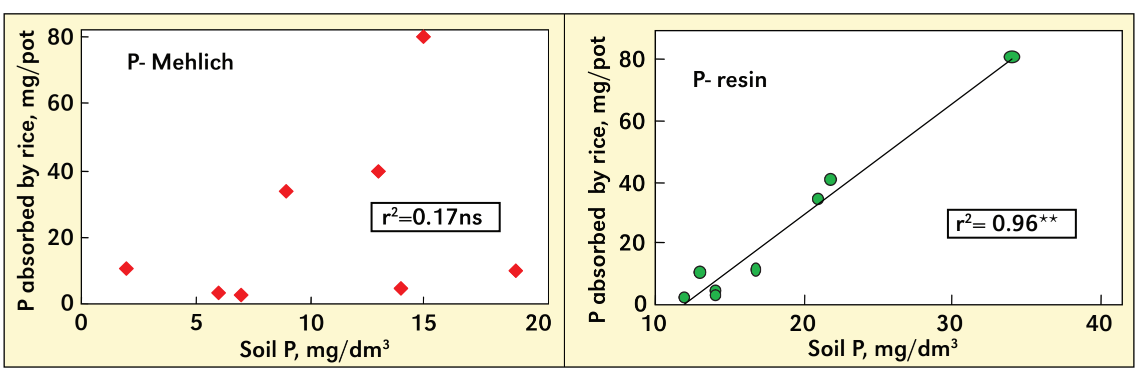

Figure 1. Relation of P uptake by flooded rice and P determined by resin and Mehlich 1 procedures. (Grande et al., 1986)

Abbreviations and notes for this article: P = phosphorus; HCl = hydrochloric acid; NaCl = sodium chloride; $NaHCO_3$ = sodium bicarbonate; Fe = iron; Al = aluminum; Ca = calcium; Mg = magnesium; K = potassium.

oxides containing sufficient available P. The presence of the bicarbonate ion saturating the resin is important because it buffers the medium, a factor that favors the stability of the results.

The equation below illustrates the system that has to be assessed by soil analysis. The method should extract P solution, which is very low, and obtain P labile from the labile forms. Non-labile P and undissolved fertilizer P should not be included in the results. Since resin extraction is done with a water suspension the ion exchange resin simulates more closely than the other methods the extraction by plant roots, acting as a sink for the elements absorbed from the solution. The negatively charged P ions in solution (mainly $H_2PO_4^-$) are absorbed by the positive charges of the ion exchange resin, also promoting the dissolution of the labile P of the solid phase.

$$P_{fertilizer} \rightarrow P_{solution} \leftrightarrow P_{labile} \rightarrow P_{non\text{-}labile}$$

Figure 2 shows a schematic representation on how the resin works, as compared with P uptake by plants. In this case, P moves through the soil solution to the roots creating a concentration gradient that promotes dissolution of the labile P in the solid phase and continuous movement to the roots by diffusion. Likewise, in the extraction procedure with the resin, P moves into solution, and is then adsorbed by the resin, a porous synthetic material with positive charges, mimicking what happens with roots. For soil extraction in the lab, the process is sped up by 16 hours of overnight shaking.

A soil test should extract mainly P solution and P labile. It should not remove slow release phosphates if they do not contribute for P uptake by plants. It should also not extract P from non-labile forms. The problem in practice is that most P extractants determine specific chemical forms of P, not necessarily bioavailable P. Thus, acid extracts, such as Mehlich 1, have preference for calcium phosphates and fluoride containing extractants, such as Bray 1, have specific action on Al phosphates.

In **Table 3** various aspects of the relationship between fertilizer P sources and methods for soil P determination are illustrated. Soils were treated with triple superphosphate (TSP), rock phosphate, and calcinated aluminum phosphate and cultivated with soybean in a pot experiment. Triple superphosphate was applied at seeding time and the three phosphates were applied 75 days prior to seeding. P uptake by soybean was measured and the soil samples were analyzed by resin, Mehlich 1, and Bray 1 methods.

The results presented in **Table 3** allow several observations. Comparing the results of superphosphate applied at seeding with those of the same fertilizer applied 75 days ahead, it can be seen that availability of P decreased with time of incubation, as shown by the reduction of P uptake by soybean from 4.3 mg/pot to 2.3 mg/pot. The decrease of P availability of water soluble phosphates with time is a well known effect; this tendency could be identified by resin, but not by Mehlich 1 or Bray 1.

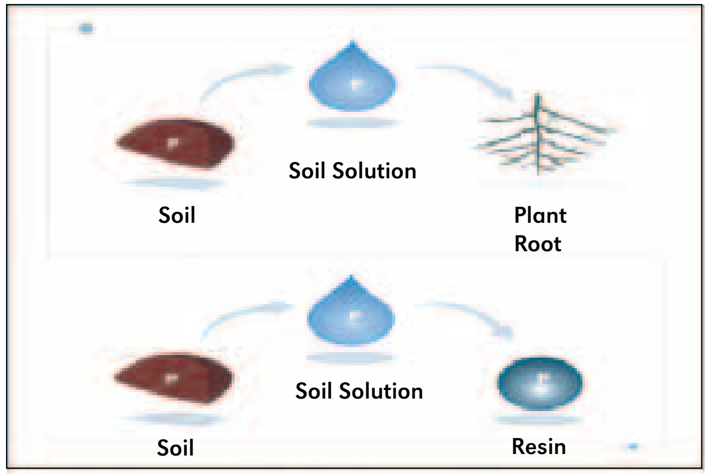

Figure 2. Schematic demonstration of P extracted from soils by ion exchange resin.

Alvorada rock phosphate had low agronomic efficiency, with an uptake of only 1.1 mg/pot of P in excess of that of the control treatment. Results of resin and Bray 1 methods indicated this tendency, but Mehlich 1 extracted far too much P, as expected, for an acid extractant acting on a soil treated with apatite.

The calcinated aluminum phosphate, also of low agronomic efficiency, had low extractable values for resin and Mehlich 1, but Bray 1 overestimated the results because the fluoride in the extractant solution released P from the Al bond.

These examples show some of the limitations of the chemical extractants in assessing available P in soils.

It is commonly accepted or well known that pH values around 6 enhance P availability. Accordingly, in four field experiments in the State of São Paulo, a significant increase of P concentration in beans, sunflower, and soybean leaves was observed following limestone application (columns 2 and 3 in **Table 4**). The soil samples, collected 2 years after liming, presented puzzling results. The results of Mehlich 1 and Bray extractable P were not affected by liming, as seen in columns 4 and 5 in **Table 4**. Odd results were observed for the Olsen method since as soil pH increased, soil P decreased, thus moving in the opposite direction. The results obtained with P resin increased in the same direction as P in leaves. In conclusion,

Table 3. Phosphorus uptake by soybean with the application of three P sources, three different methodologies, and index ratios using TSP before seeding as a standard. The values represent the difference from the control treatment.

			Fertilizers applied 75 days prior to seeding					
P evaluation	Triple superphosphate applied at seeding		Triple superphosphate		Alvorada rock phosphate		Calcinated aluminum phosphate	
	Value	Index	Value	Index	Value	Index	Value	Index
Soybean, mg/pot	4.3	100	2.3	53	1.1	27	1.7	40
Resin P, mg/dm^3	12.7	100	7.9	62	1.7	13	4.9	39
Bray 1 P, mg/dm^3	37.9	100	39.6	105	7.9	21	39.4	104
Mehlich 1 P, mg/dm^3	27.9	100	24.6	88	42.8	153	1.5	5

Source: Raij and Diest, 1980.

Table 4. Relation between soil pH in $CaCl_2$ 0.01 M, leaf P content, and soil P – determined by four methods.

Crop and soil	pH $CaCl_2$	Leaf P g/kg	Soil P, mg/dm³ Mehlich 1	Bray 1	Olsen	Resin
Beans Organic soil	3.8 d[1]	2.44 b	17 a	20 a	41 a	33 b
	4.2 c	3.21 a	18 a	21 a	33 b	36 ab
	4.7 b	3.25 a	18 a	20 a	26 c	38 ab
	5.1 a	3.26 a	19 a	18 a	19 d	43 a
	5.2 a	3.25 a	20 a	19 a	21 d	43 a
Sunflower Ultisol	4.3 c	2.79 c	12 b	24 a	17 a	22 b
	4.6 c	3.27 b	12 b	22 a	17 a	26 ab
	5.3 b	3.81 a	16 a	25 a	16 a	33 ab
	5.5 ab	3.87 a	15 a	20 a	12 a	35 a
	5.7 a	3.80 a	16 a	20 a	12 a	37 a
Soybean Ultisol	4.3 a	1.85 c	6 a	15 a	10 a	13 c
	4.8 d	2.06 bc	7 a	16 a	11 a	16 c
	5.5 c	2.44 ab	5 a	13 a	7 a	17 bc
	6.1 b	2.26 a	7 a	17 a	8 a	22 ab
	6.4 a	2.55 a	7 a	15 a	8 a	27 a
Soybean Oxisol	4.5 d	2.35 b	9 a	20 a	18 a	16 c
	4.9 c	2.69 ab	8 a	22 a	15 ab	19 bc
	6.1 b	2.88 a	8 a	20 a	13 ab	23 b
	6.6 a	2.85 a	10 a	24 a	12 b	34 a

[1]Numbers followed by different letters in the same column are statically different at 5% level.
Source: Raij and Quaggio, 1990.

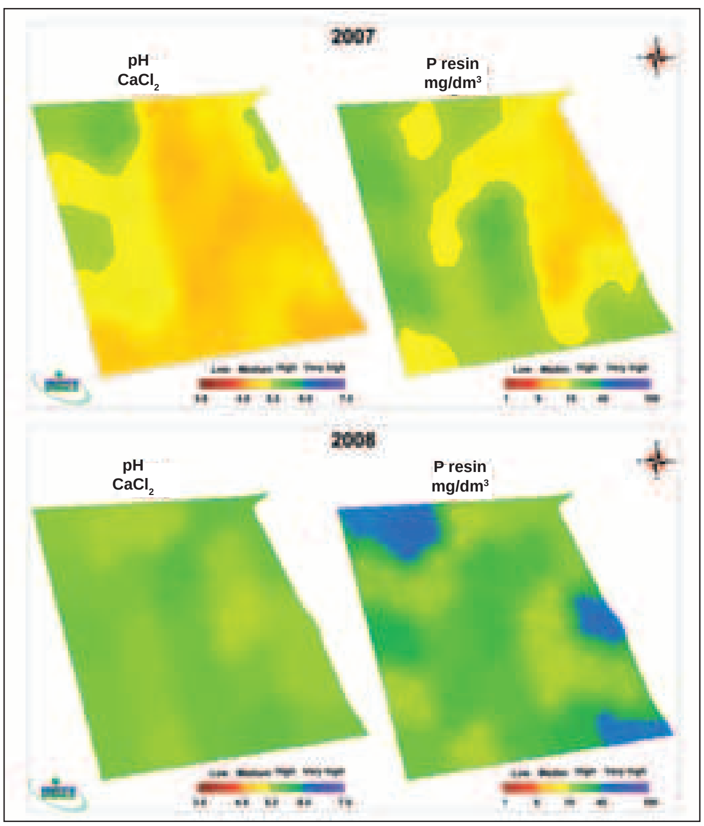

Figure 3. Images of precision agriculture showing pH in $CaCl_2$ and P resin before (2007) and after liming (2008).

the results showed that the resin procedure better evaluated the increase in P availability due to liming, while Mehlich 1 and Bray 1 were not sensitive to the changes caused by variation of soil pH. Olsen indicated a decrease in available P, which was inconsistent with leaf P concentration.

Another demonstration of the effect of liming on the increase of resin extractable P is shown in **Figure 3**, with maps prepared by precision agriculture technology, with pH and P resin values obtained before (2007) and after liming (2008). Reducing acidity by liming, as indicated by pH, resulted in increase of resin P. This is important because it has economical consequences, represented by a lower need to apply P fertilizers.

A soil test method is only good if it can be used in large scale soil testing. Although ion exchange resin has proven valid for the determination of available P in soils for more than 50 years, it was always considered a method not suitable for routine soil testing. However, the ion exchange resin has been used in Brazil since 1983 (Raij et al., 1986; Raij, 1999) and is now adopted by about 100 laboratories in that country. The ion-exchange resin procedure described by Raij et al. (1986) uses a mixture of cation and anion resins that enhances P extraction and also permits the determination of exchangeable Ca, Mg, and K in the same extract. Inexpensive time saving equipment was developed by the IAC team (Raij et al., 2001) and is commercially produced by third parties, one important step to assure the adoption of the method.

Phosphorus extracted by ion exchange resin has been shown to be a sensitive index of P availability in soils. Having such a good alternative for P determination in soils could improve P fertilizer recommendations and advance fertilization technologies, such as precision agriculture. BC

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Improving Mid-Season Nitrogen Recommendations for Winter Wheat Using Soil Moisture Data

By Olga Walsh, Yumiko Kanke, D.E. Edmonds, and W.R. Raun

Nitrogen sensor technology has significantly advanced the understanding of site-specific N management in crop production. Combining sensor information with other important yield affecting data has the potential to further improve the capabilities of this technology. Scientists at Oklahoma State University (OSU) are developing means of incorporating soil moisture into winter wheat yield potential determinations, and ultimately N management decisions.

Soil water availability and fertility status are among the major factors limiting crop production worldwide. Soil moisture (SM) is the amount of water that is contained within the soil pores, and it is a key factor affecting yield.

Establishment of automated, high-density SM networks offers effective technology to generate high-quality SM data sets. Recognizing the importance of SM for agriculture and other disciplines, numerous research institutions across the USA are dedicated to collecting and managing SM information. The Climate Prediction Center of the National Weather Center database (http://www.cpc.ncep.noaa.gov/), the Automated Weather Data Network of the High Plains Regional Climate Center in Nebraska (http://www.hprcc.unl.edu), and the Illinois State Water Survey (http://www.sws.uiuc.edu/warm/) are examples of such automated networks that offer climatological data on temperature, precipitation, and SM for the USA.

The Oklahoma Climatological Survey's Oklahoma Mesonet (OM) (Brock et al., 1995) is an automated statewide network designed to measure the environment at the size and duration of mesoscale weather events. Soil moisture data at four depths – 2 in., 10 in., 24 in., and 30 in. (5, 25, 60, and 75 cm) – are collected every 10 minutes at over 100 remote meteorological stations. Data are available at the OM website: >http://www.mesonet.org/<.

Many authors proposed that accurate SM information could be vital for estimating crop yield potential (YP) and making fertilizer recommendations. Carlson et al. (1995) noted that lack of homogeneity in soil water content is apparent and indicates the need for evaluation of factors affecting SM spatial and temporal variability. Gillies et al. (1997) also stated that knowing soil water content is important when evaluating crop YP mid-season. It is not unusual for SM levels to vary significantly both site-to-site and year-to-year. Thus, spatial and temporal variability in SM should be accounted for when estimating YP and making fertilizer recommendations. Results by Kumar et al. (2006) illustrated that YP estimates could be improved using Normalized Difference Vegetative Index (NDVI) data combined with SM data in a grain sorghum experiment.

Sensor-Based N Rate Calculator

The Sensor-Based Nitrogen Rate Calculator (SBNRC), developed at OSU, is an on-line tool available at the N use efficiency (NUE) website: >http://nue.okstate.edu/<. The SBNRC enables producers to estimate in-season YP, and to determine

Abbreviations and notes for this article: N = nitrogen; OM = organic matter.

On-line view of Sensor Based Nitrogen Rate Calculator (SBNRC) available at >www.nue.okstate.edu<.

optimum N fertilization application rates based on predicted YP and crop responsiveness. The SBNRC entails using GreenSeeker™ technology to measure crop canopy reflectance and calculate NDVI. Canopy reflectance readings are collected mid-season (Feekes 5 growth stage for winter wheat). The sensor is designed to illuminate the light in both red (650nm) and NIR (770nm) bands and to register the fraction of the emitted light returned from the canopy to the sensor. NDVI is highly correlated with plant vigor, leaf chlorophyll content, and plant N status. Response Index (RI) is determined by comparing the NDVI values from the representative area within a field to the NDVI values obtained from an N-rich strip (NRS) (Mullen et al., 2003). The NRS is simply a strip within a field to which N fertilizer was applied to create a non-limiting environment. Comparing the NDVI's from non-limiting NRS to the NDVI's from the rest of the field provides valuable information about the crop's N status and helps to make a decision about how much, if any, fertilizer N must be applied to satisfy crop needs. In-Season Estimated Yield (INSEY) is calculated as NDVI (Feekes 5) divided by growing degree days (GDD)>0 (Lukina et al., 2001; Raun et al., 2001). The INSEY index serves as an indicator of the rate of plant N uptake (Raun et al., 2002). Using NDVI allows accounting for spatial and temporal variability existing within the field.

Soil Moisture and SBNRC

The soil fertility group at OSU is currently striving to further refine the winter wheat algorithm for SBNRC by incorporating SM at the time of sensing into the algorithm. At-

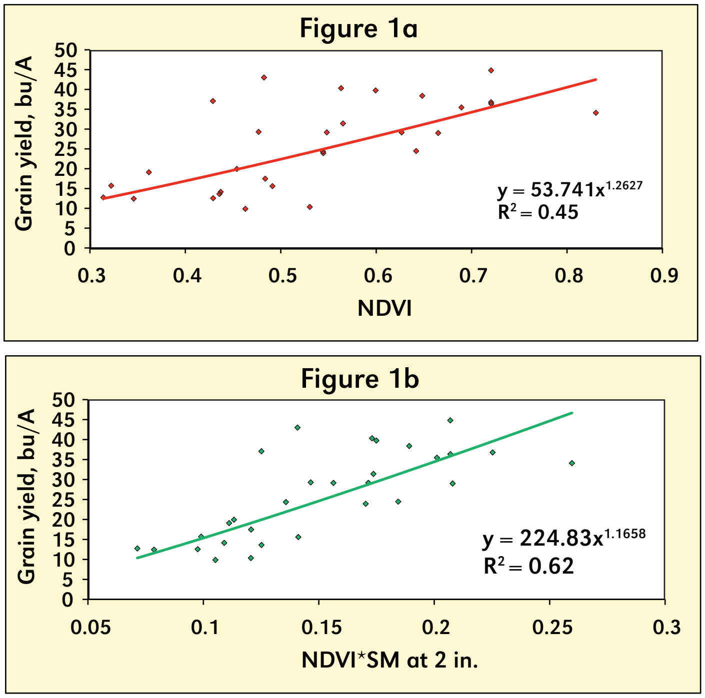

Figure 1. Normalized Difference Vegetative Index (NDVI) (a, top) and NDVI*SM at 2 in. (b, bottom) as a predictor of winter wheat grain yield at Stillwater, Oklahoma (2001-2006).

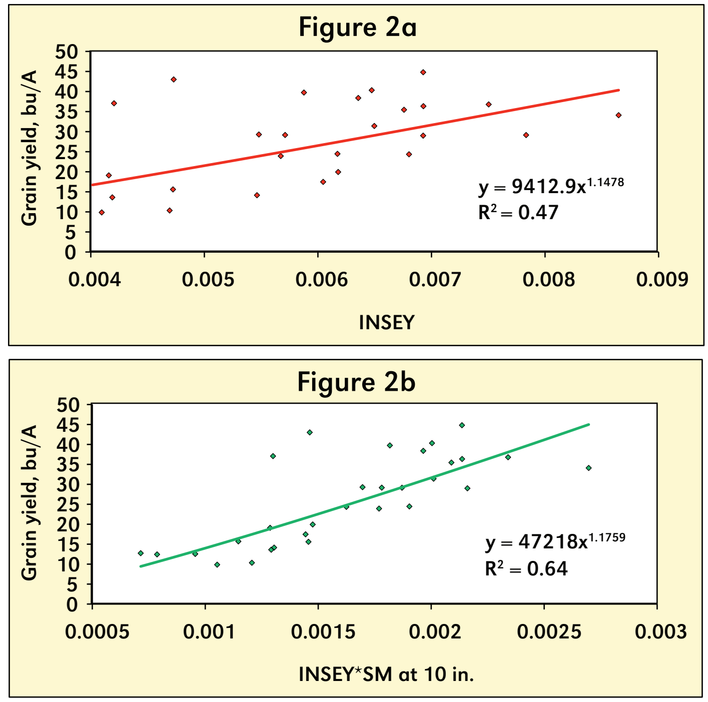

Figure 2. In-Season Estimated Yield (INSEY) (a, top) and INSEY*SM at 10 in. (b, bottom) as a predictor of winter wheat grain yield at Stillwater, Oklahoma (2001-2006).

sensing knowledge of the amount of water present in the soil profile will help to more accurately predict YP. This should in turn improve N recommendations.

Statistical analysis was carried out to assess the value of SM data in YP estimation. Simple correlation analysis between 24 variables, including SM, NDVI*SM, INSEY*SM, and wheat grain yield were performed using yield data from long-term OSU experiments near Lahoma and Stillwater, Oklahoma, and SM data provided by the OM. The SM values at sensing, and a month average SM around sensing date at four depths (2, 10, 24 and 30 in.) were used in the analysis.

Results showed that SM at sensing and a month average SM around sensing date were generally highly correlated ($p < 0.001$) with grain yield at both sites. At Lahoma, 17 of 24 variables (excluding SM at sensing at 10, 24, and 30 in., and a month average SM around sensing date at all four depths) were significantly correlated with grain yield ($p < 0.001$). While there was no relationship observed between grain yield and the variables reflecting only SM at this site, all the variables combining both vegetative and SM characteristics (NDVI*SM and INSEY*SM) were significantly correlated ($P < 0.001$) with yield. At Stillwater, 22 of total 24 variables (excluding a month average SM around sensing date at 24 and 30 in. depths) were significantly correlated with wheat yield ($p < 0.001$). Trend analysis showed that higher correlation values (R^2) were generally observed with combination of indices (NDVI*SM and INSEY*SM) compared to NDVI and INSEY alone (**Figures 1 and 2**), suggesting that indices that combine both SM and the vegetative crop characteristics could help to more accurately estimate winter wheat YP.

Our SBNRC approach makes fertilizer N recommendations based on crop YP, thus increasing the accuracy of the YP estimation. Using SM data has the potential to substantially improve N recommendations and management decisions. BC

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Ammonia Emissions from Agricultural Operations: Livestock

By Shabtai Bittman and Robert Mikkelsen

The global abundance of N fertilizer has dramatically increased agricultural productivity. However, when N escapes to the atmosphere as ammonia (NH_3) gas, NH_3 loss can cause undesirable effects. In addition to a loss of a valuable resource, it can have negative impacts on air quality, ecosystem productivity, and human health. Animal production is the largest source of NH_3 emission in North America. Improved manure and fertilizer management practices will help reduce volatile losses of this valuable resource.

The century-old Haber Bosch process for transforming atmospheric N_2 into valuable NH_3 has been one of the most important discoveries for the benefit of humanity. The synthesis of NH_3 and other N fertilizers has fed and improved the diet and living conditions for billions of people. However, when reactive N escapes into the environment, it can have unintended and sometimes undesirable consequences **(Figure 1)**.

Farmers are continually reexamining the impacts of their operations on the surrounding environment. Many practices have been implemented in recent years to reduce soil erosion and to avoid water quality degradation. More recently, air quality issues related to agricultural production have captured the attention of environmental agencies. Nitrous oxide (N_2O) is a concern due to its contribution as a global greenhouse gas. Ammonia has also emerged as an atmospheric gas of concern.

Farmers using anhydrous NH_3 or ammonium (NH_4^+)-based fertilizers (such as urea) for their crops are fully aware of the potential for volatile losses and take extra efforts to minimize the loss of this economically valuable resource. This article primarily reviews NH_3 losses from livestock operations. An article in the next issue of this magazine will cover NH_3 losses from fertilizer in more detail.

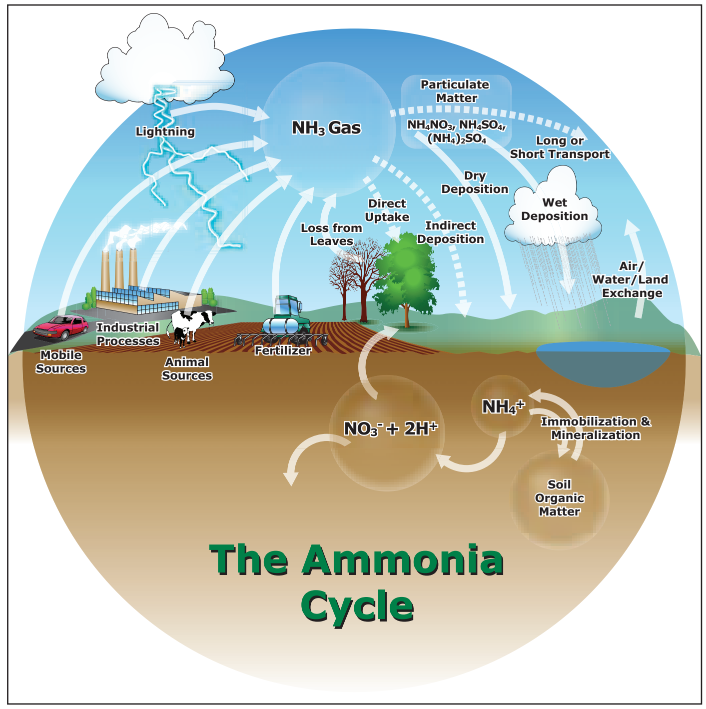

Figure 1. Ammonia emission, transport, and deposition from major sources.

Ammonia from Animals

Agriculture is responsible for over three-fourths of the NH_3 emissions in the USA and Canada, with animal production accounting for the major share **(Figure 2)**. Ammonia becomes a constituent of animal waste when N-rich protein in feed is not completely converted into animal products (such as meat, milk, wool, and eggs). For example, only 25 to 35% of the N fed to dairy cows is converted into milk, with the remainder excreted in urine and manure in a variety of simple and complex forms of N. Chemical and microbial processes release NH_3 into the air. Nitrogen in poultry manure is mainly in the form of uric acid, which also rapidly converts to urea and to NH_3.

The loss of volatile NH_3 occurs when NH_4^+ is converted to a gas in the reaction:

$$\underset{\text{Acid Conditions}}{NH_4^+} \longleftrightarrow \underset{\text{Alkaline Conditions}}{NH_3 + H^+}$$

Ammonia-containing materials are more prone to volatilization in alkaline conditions than under acidic conditions (pKa=9.2). This NH_3-emitting reaction accelerates when the temperature increases or when the concentration of NH_4^+ increases.

Abbreviations and notes for this article: N = nitrogen.

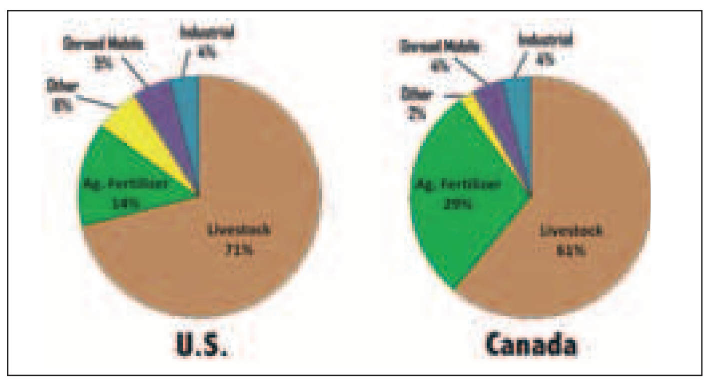

Figure 2. Primary sources of NH_3 emission from the USA and Canada. (USEPA, 2005; Environ. Canada 2006.)

The greatest NH_3 losses from animal production typically come from animal buildings and barns, and during land application of manure. Animal grazing and manure storage can also be important sources of NH_3. For example, a recent study from a cattle feedlot in Alberta found that daily emissions averaged 140 g NH_3/head (0.3 lb NH_3) throughout the summer. With a feedlot population of 22,500 cattle, a single facility can make an important regional impact on air quality (McGinn et al., 1977).

Across all livestock sectors in Canada, 50 to 63% of the excreted NH_4-N is lost from animal housing, during manure storage, or when applied to the land. Emission losses of the excreted NH_4^+ are approximately 50% for dairy, 50% for beef, 60% for poultry, and 60% for swine. Of these losses, typically 40 to 50% occurs in housing (and pasture), 5 to 15% from storage, and 40 to 55% during land application.

It is important to consider NH_3 loss from a whole-farm perspective, because some of the NH_3 conserved in barns may later be lost during manure application. Improved management to conserve NH_3 during manure application will only conserve NH_3 that has not already been lost from barns and storage. Thus to conserve NH_3, a whole-farm strategy is needed.

Various techniques can be used to minimize NH_3 loss during animal production. For example, acidic amendments (such as sodium bisulfate and aluminum sulfate) maintain much of the N in the non-volatile NH_4^+ form in poultry litter. Microbial and enzyme inhibitors that delay conversion of urea to NH_4^+ have been successfully used to reduce the release of NH_3 from animal facilities. Absorbing agents (such as bedding and zeolite minerals) can reduce volatile losses of NH_3, as do natural or artificial covers or other methods (such as deep storage) that reduce exposed manure surfaces. Increasing animal productivity, most notably milk production per cow, and reduction of excess protein in animal diets have major benefits for reducing emissions. Management practices during field application which reduce the exposure of applied manure to the atmosphere can help minimize NH_3 loss **(Table 1)**.

High concentrations of atmospheric NH_3 have a negative effect on animal production in confined buildings. Therefore, good ventilation of barns and buildings with fresh air is important for healthy animals. Farm workers should also avoid prolonged exposure to high concentrations of NH_3 in barns. Ammonia is lighter than air and is easily removed from livestock buildings with adequate ventilation.

There are many good methods used for measuring NH_3 emissions from agricultural sources, but no method is perfect for all studies. Wind tunnels on small plots are well suited for comparing treatments and for validating NH_3 loss models. Field measurements that utilize sophisticated micrometeorological methods are commonly used for measurements over larger areas (such as fields, manure stockpiles, and lagoons) and are thought to give more reliable values.

Ammonia Particle Formation and Deposition

Ammonia in the atmosphere has become a concern for environmental (EPA and Environment Canada) and health agencies for two primary reasons – the formation of fine particle matter and uncontrolled N deposition – both of which can have negative consequences.

When NH_3 (an alkaline compound) is released into the air, it rapidly adsorbs to surfaces and significant deposition (up to 20%) may occur within a few hundred meters of the source. The remaining atmospheric NH_3 can rapidly react with a number of acidic compounds (such as nitric acid or sulfuric acid) to form very small secondary aerosol particles. This fine particulate matter has a diameter of <2.5 microns (referred to as PM 2.5), which is about 30 times smaller than a human hair. Some of these very small particles can persist in the air for up to 2 weeks.

PM 2.5 particles are a health concern for their impacts on respiratory function. These extremely small particles are inhaled deeply into the lungs. Short-term exposure to PM 2.5 aerosols can cause eye, nose, throat, and lung irritation, plus coughing and sneezing, among other symptoms. Long-term exposure to PM 2.5 materials has been linked to a variety of respiratory and cardiovascular ailments. Children, elderly, and individuals with impaired respiratory capacity due to asthma or emphysema may be particularly sensitive to problems caused by PM 2.5.

The fine airborne PM 2.5 particles also contribute to atmospheric haze and low visibility **(Figure 3)**. Haze occurs when sunlight encounters particles in the air – thereby obscuring visual clarity and colors in the landscape. There are many sources of primary PM 2.5 into the air (including dust and smoke from fires), but the contribution of NH_3 in forming secondary PM 2.5 can be significant. For example, the adverse effects of PM in the Lower Fraser Valley of British Columbia and Southern Ontario have been well documented. In the USA, the overall trend is a steady decline in PM 2.5 since the year 2000. However, there are several notable exceptions to this national trend.

Ammonia in the atmosphere will be transported with the wind and may become redeposited in previously pristine regions, often hundreds of miles from the original source of NH_3. Ammonium deposited on the soil is generally converted rapidly to nitrate (NO_3^-), with an accompanying release of acidity (H^+) during nitrification. The NH_3 may enter the leaves of plants through the stomata or may enter the leaf as NH_4^+ after it is dissolved in water. The NH_4^+ may also be taken up from the soil by plant roots. Plants that primarily utilize NH_3 and NH_4^+ as the major N source will excrete H^+ from the roots, increasing the acidity of the rooting zone. Note that plant leaves can also serve as a source of NH_3 emissions, especially during plant maturation and senescence.

Widespread NH_3 fertilization through atmospheric deposition can cause enhanced plant growth in areas where N was previously limiting. Changes in plant species have been noted in undisturbed ecosystems where high NH_3 deposition occurs. In some ecosystems, the plant species that are

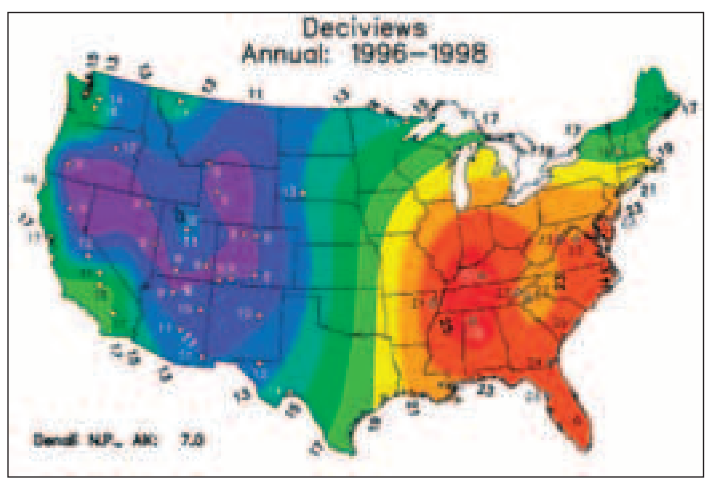

Figure 3. Map of haze distribution of the USA. Units are expressed as deciviews which measures haze and visibility. Higher deciview levels are hazier, while lower deciview levels are clearer. (IMPROVE, 2009).

Table 1. Factors affecting NH_3 loss from field-applied animal manure.

Climate	Soil Properties	Manure Properties	NH_3 Reduction Strategies
Volatilization losses increase as temperature and solar radiation rise. This results from a combination of factors such as atmospheric turbulence, faster drying, increased NH_3 concentration, and faster diffusion.	When manure slurries infiltrate into the soil, the potential for volatilization decreases. Sandy soils with a high infiltration rate commonly have less NH_3 loss than from slurries applied to finer-textured soils.	The dry matter content of the animal waste influences NH_3 loss. Effluents and slurries with a low solid fraction tend to infiltrate more quickly and have less NH_3 loss than high dry-matter materials that remain on the surface for a longer time.	Manure separators produce a liquid and solid material that allow more precise nutrient management and may also reduce the hauling costs. The liquid generally infiltrates more quickly than the whole manures.
Increased wind speed generally results in higher NH_3 losses by maintaining a large gradient between the manure and the air.	Since NH_4^+ is retained on soil cation exchange sites, increased exchange capacity is typically associated with less NH_3 loss.	Liquid manures have a very high initial NH_3 loss rate after application. Therefore, abatement measures such as incorporation or irrigation, must be done immediately after application. Ammonia loss rates from solid manures are slower, so there is more time to perform field practices. Waste water and effluents are not generally incorporated.	Cultivating the soil before application can improve the infiltration rate and reduce NH_3 loss. Cultivation after application reduces NH_3 loss by burying the majority of the manure.
Rainfall can dilute the NH_3 and help move it into the soil, thereby reducing volatilization losses. However, a light rainfall may have an opposite effect by stimulating biological processes that increase NH_3 losses after the manure dries again.	Saturated soils, compacted soils, and high-pH soils are more susceptible to NH_3 losses.	Manure that sticks to vegetation when applied will tend to have greater volatile loss than manure that makes direct contact with the soil. Surface banding the manure is a low-cost method of minimizing contact with vegetation and taking advantage of the protective effect of vegetation or crop stubble.	Soil incorporation should be done immediately after application for liquid manure, but may be delayed slightly for solid manures. A one-pass system for application and incorporation is preferred when applying liquid manures.
If possible, apply manure when conditions favor conservation of the NH_3. While application during cool weather or when rain is expected is desirable, it is not always feasible to wait until weather conditions are ideal. Remember that a heavy rainstorm after manure application may cause leaching and runoff of NH_4^+, NO_3^-, and pathogenic microbes.		Larger manure application rates are typically associated with a greater percentage NH_3 loss. However, there are circumstances where light application rates result in a greater percentage loss of the total applied N.	Injecting animal waste beneath the soil surface is very effective for minimizing NH_3 emissions. However, factors such as energy costs, crop and soil disturbance, potential soil compaction, and the NO_3^- leaching potential must also be considered. Where deep injection is not possible, consider shallow injection, surface banding, s-tine cultivators, sweep injectors, or other application methods that minimize NH_3 loss.
		High pH of manure increases NH_3 emissions. As the pH increases, a greater proportion of the N is in the volatile NH_3 form, compared with NH_4^+ favored at lower pH. Amendments that are added to reduce manure pH will generally reduce NH_3 losses.	Higher application rates generally result in greater NH_3 losses, especially on wet soils. If the manure is applied in excess of the soil's capacity to assimilate the material, more of the N may be subject to loss. The rate of application is typically determined by the field equipment and the desired rate of nutrient application to meet the crop requirement.
		Manure residue after anaerobic digestion for methane generation tends to have elevated pH and greater potential for NH_3 loss.	Have the manure regularly tested to determine the chemical content so application rates match the nutrient requirement of the crop.

naturally adapted to low-N conditions have been replaced by plant species with a higher N demand because of NH_3 deposition. Enrichment of surface water with additional N can lead to eutrophication, especially in coastal waters. Accelerated soil acidification following nitrification is also a potential impact from NH_3 deposition. Direct damage to sensitive vegetation (lichens and bryophytes) can occur even at very low NH_3 concentrations.

There are no current policies or regulations in the USA or Canada that require a reduction in NH_3 emissions from agriculture. However, there are restrictions on NH_3 loss in European countries under the U.N. Convention on Long-Range Transboundary Air Pollutants (Gothenburg Protocol). The Netherlands was the first country to set limits on NH_3 emissions. Ammonia emissions in that country have decreased by more than 40% since 1995. Both the USA and Canada are signatories of the Protocol and regularly submit NH_3 emission inventories.

With attention focused on environmental impacts of agriculture, awareness of the issues related to NH_3 emissions in North America is increasing. The loss of NH_3 not only presents a potential environmental problem, but the loss of a nutrient that could be conserved for beneficial plant nutrition.

Agricultural emissions of NH_3 are primarily associated with animal production. Additional research is needed to measure the extent and the location of these NH_3 losses on the farm. Implementing advanced management practices will assist the animal industry to effectively manage animal manures for their maximum benefit. BC

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Conversion Factors for U.S. System and Metric Units

Because of the diverse readership of *Better Crops with Plant Food*, units of measure are given in U.S. system standards in some articles and in metric units in others…depending on the method commonly used in the region where the information originates. For example, an article reporting on corn yields in Illinois would use units of pounds per acre (lb/A) for fertilizer rates and bushels (bu) for yields; an article on rice production in Southeast Asia would use kilograms (kg), hectares (ha), and other metric units.

Several factors are available to quickly convert units from either system to units more familiar to individual readers. Following are some examples which will be useful in relation to various articles in this issue of *Better Crops with Plant Food*.

To convert Col. 1 into Col. 2, multiply by:	Column 1	Column 2	To convert Col. 2 into Col. 1, multiply by:
	Length		
0.621	kilometer, km	mile, mi	1.609
1.094	meter, m	yard, yd	0.914
0.394	centimeter, cm	inch, in.	2.54
	Area		
2.471	hectare, ha	acre, A	0.405
	Volume		
1.057	liter, L	quart (liquid), qt	0.946
	Mass		
1.102	tonne[1] (metric, 1,000 kg)	short ton (U.S. 2,000 lb)	0.9072
0.035	gram, g	ounce	28.35
	Yield or Rate		
0.446	tonne/ha	ton/A	2.242
0.891	kg/ha	lb/A	1.12
0.159	kg/ha	bu/A, corn (grain)	62.7
0.149	kg/ha	bu/A, wheat or soybeans	67.2

[1]The spelling as "tonne" indicates metric ton (1,000 kg). Spelling as "ton" indicates the U.S. short ton (2,000 lb). When used as a unit of measure, tonne or ton may be abbreviated, as in 9 t/ha. A metric expression assumes t=tonne; a U.S. expression assumes t=ton.

Plants Don't Care about the Market Conditions

In recent months, economics of farming has been the dominant issue, even more so than in most years. Seed and fertilizer costs continue to be higher than farmers are accustomed to paying. So much money out the door means that a lot of return has to be guaranteed to come back in to ensure profitability.

Uncertainties in markets and yields put farmers at a greater risk of losing larger amounts of capital. This has led to questions about how costs can be trimmed and risks managed. The upshot is that there are no general, quick fixes. Individuals have to assess for themselves the risks they are willing to take.

The most important consideration in this economic environment is taking the time to make an informed decision. Knowing the fundamentals of crop nutrition is essential. Many tools – including soil testing, tissue testing, and university recommendations – provide good science and serve as guideposts for nutrient management decisions.

Remember that the plant, like a child, doesn't care about the markets. It just wants to be fed.

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