Better Crops with plant food

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Soybeans & Biological Nitrogen Fixation: What Should You Expect?

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Better Crops with plant food

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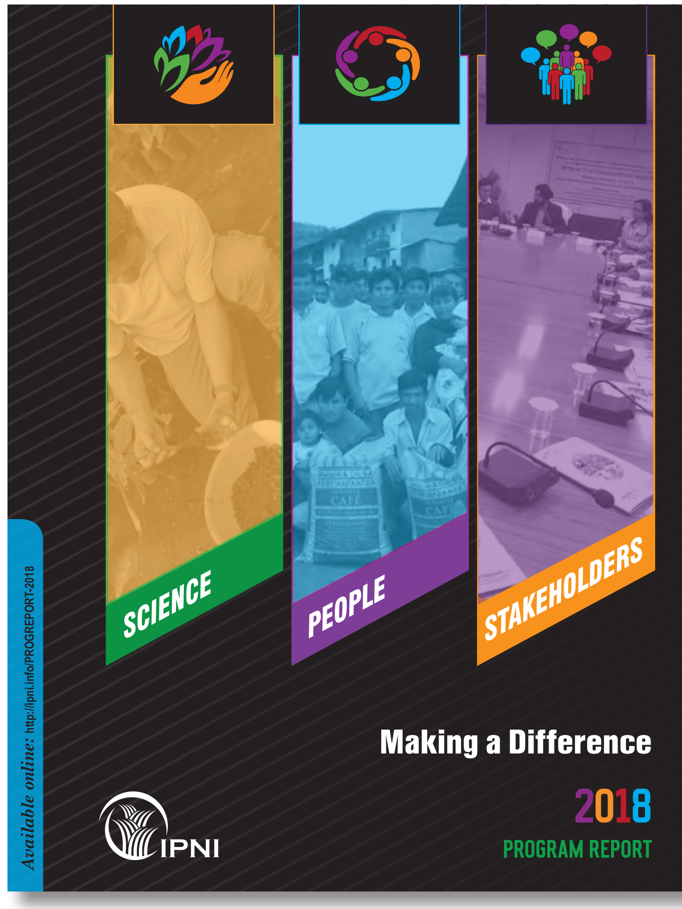
IPNI Annual Program Report: Making A Difference for Science, People, and Stakeholders

When IPNI was first established in 2007, environmental challenges associated with fertilizer use were the primary issues of concern for society and the fertilizer industry. We spent a lot of time and energy debunking false information and alleviating public concerns about nutrient use. Soon after our launch the global food crisis started and by 2008 fertilizers were being viewed in a new light ... as a solution to the problem, rather than a problem. It was under that atmosphere that IPNI scientists introduced the idea of 4Rs; that applying the right nutrient source, at the right rate, right time, and in the right place was the ideal way to scientifically address the need to produce more food and feed while protecting our environment. The foundation of 4Rs was science-based, site-specific best practices intended to accomplish stake holder goals of food security and environmental sustainability.

4Rs have and are making a difference in how nutrients are managed around the world and how regulators perceive nutrient management. What started in North America has spread to a global movement that has taken on a life of its own. 4Rs are being adopted in Australia, China, India, Pakistan, South East Asia, the Middle East, Sub-Saharan Africa, Russia, North and South America. In the developing world, 4Rs provide much needed nutrient management tools to increase basic food and feed production, while in the developed world 4Rs provide an environmental



Available at http://ipni.info/PROGREPORT-2018

tool to help ensure nutrients are being used efficiently and effectively.

One of the difference-making tools that IPNI has developed is Nutrient Expert®. This decision support software is changing how fertilizer recommendations are made in the developing world while integrating the prin-

Participants of Training Workshop on Innovative Nutrient Stewardship at North Bengal Agricultural University.

To better disseminate recent research results on 4R Nutrient Stewardship, IPNI and North Bengal Agricultural University organized a training workshop for 50 invited scientists, extension professionals and industry agronomists. The course, entitled "Innovative Nutrient Stewardship: Concepts, Principles and Applications" was organized to present case studies that would build capacity and problem-solving skills for making field-oriented decisions. A concept note was prepared and a training website was developed. This is the first event of its kind and the first of a series of 4R-themed events planned with additional partners.

Numerous scientific articles and peer-reviewed publications were produced on 4R Nutrient Stewardship and balanced nutritional requirements of major crops like pulses, maize, and potato. For example, in commemoration of the U.N. International Year of Pulses, an invited article on 4R Nutrient Stewardship Guidelines for Sustainable Pulse Production was published.

IPNI supports research that explores the relationships among 4R practices, fertilizer recovery, and impacts on multiple nitrogen loss pathways.

Our Nitrogen Program is currently focused on improving the scientific understanding of how 4R Nutrient Stewardship reduces nitrogen losses from cropping systems.

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"IPNI continues to lead regional initiatives to develop standardized protocols for field research, data analysis, and models for interpreting soil and crop information…"

Dr. Shamie Zingore
Director, sub-Saharan Africa Program

Satisfying the Need for Speed

IPNI has made a major contribution in the development of innovative research methods for improved nutrient management recommendations for smallholder farming systems in sub-Saharan Africa. This is a priority due to the urgent need to increase crop productivity and fertilizer use to address human nutrition and food security in a region where farmers face complex challenges. IPNI continues to lead regional initiatives to develop standardized protocols for field research, data analysis, and models for interpreting soil and crop information leading to improved nutrient management recommendations. A systematic research framework that enables accurate, rapid and cost-effective development and dissemination of improved nutrient management recommendations has been developed and used by wide-ranging cooperating institutions. The framework addresses existing soil and crop data, any soil-based yield constraints, and then suggests practical options for overcoming yield barriers. By leading a network of private, NGO, and research/ extension institutions, IPNI is working to achieve adoption of practices for improving nutrient management recommendations by many thousands of smallholder farmers.

Maize Variety Selector application

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Strategic Recommendations

In many regions in the world, cassava is grown by farmers who traditionally do not apply fertilizer to this crop. When cassava is grown on the same area for many years without adequate fertilization, the soil becomes depleted and degraded. Where cassava is grown continuously for at least 8 years, potassium often becomes the most yield-limiting nutrient. The IPNI Southeast Asia Program initiated research to apply 4R concepts of nutrient management using Nutrient Expert® to predict cassava response to applied fertilizer. During the early years of research, yield response was greatest to additions of nitrogen followed by potassium, and then phosphorus. Improved fertilizer recommendations based on Nutrient Expert® result in 6 t/ha of additional cassava roots, compared with the standard government recommendation. This new data will be used to further refine the Nutrient Expert® tool for making improved fertilizer recommendations for cassava to boost farmer productivity and minimize soil degradation.

Our Southeast Asia Program has also developed the Plantation Intelligence (PI) tool to apply the concepts of strategic and tactical business intelligence to the palm oil industry. The process starts with acquiring data, preliminary analysis, and discussion with management to identify the most significant factors. PI then provides input to the plantation business plan by clarifying the fertilizer performance in an operation. This allows quantification of the opportunities provided by management changes of key input resources and agronomic activities. The PI tool clarifies how linked factors such as variable block productivity, cost of fertilizer, soil, and weather impact economic performance. Managers can then make rational decisions how to implement optimal fertilizer strategies.

Fertilizer recommendations based on Nutrient Expert® resulted in 6 t/ha of additional cassava roots, compared with the standard Philippine government recommendation.

Dr. Thomas Oberthür,
Director, Southeast Asia Program
with a smallholder farmer.

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ciples of 4R Nutrient Stewardship. Nutrient Expert makes site-specific fertilizer recommendations based on target yields using locally available fertilizers, with or without soil test results. It accounts for straw management, manure use, previous crops, tillage, soil type, residual nutrients, and climatic conditions. In partnership with governments, extension services, and research organizations, Nutrient Expert is being scaled up in China, South Asia, Southeast Asia, North Africa, and Sub-Saharan Africa.

IPNI's interaction with the International Nitrogen Initiative (INI) has made a great impact on the direction and outcomes of this group of influential scientists. Their stated objectives are "to optimize nitrogen's beneficial role in sustainable food production and minimize nitrogen's negative effects on human health and the environment resulting from food and energy production." Working together with The Fertilizer Institute, we became involved with INI in 2001 at the 2nd International N Conference held in the USA and have been working with them ever since. We have been represented on their Advisory Committee for more than 10 years and assisted in the organization of each of the subsequent International N Conferences held in China (2004), Brazil (2007), India (2010), Uganda (2013), and most recently in Australia (2016). Our participation has resulted in each conference reporting on and recognizing the beneficial role of N in food production. We have collaborated with the International Fertilizer Association in review of the "Declaration" outcomes of these conferences to ensure that fertilizers are accurately portrayed, which is critical to how N is perceived by the international community including the United Nations and Organization for Economic Co-operation and Development. Our Phosphorus Program, initiated in July 2015, is beginning to assume a similar role with the emerging Sustainable Phosphorus initiatives.

Our work with Field to Market: The Alliance for Sustainable Agriculture has been instrumental in moving their Fieldprint®Calculator to consider all 4Rs, instead of just application rate, as it analyzes and benchmarks a farmer's sustainability performance against regional, state and national standards. Similarly, we have played important roles integrating 4R principles into certification programs, including the Lake Erie Watershed 4R Certification Program, and the American Society of Agronomy's Certified Crop Adviser 4R Nutrient Management Specialty.

IPNI's regional programs directly impact fertilizer markets—protecting nutrient use in mature markets and increasing fertilizer use in developing markets. We accomplish this through our research and demonstration programs and educational activities. Our efforts have led to improved fertilizer recommendations from the U.S. Corn Belt to the Gangetic Plains in India to the Cerrado in Brazil. Our work has improved livelihoods for smallholder subsistence farms in sub-Saharan Africa and the large agricultural holdings in Russia. IPNI scientists are respected by research and academic colleagues, government officials, extension workers, and NGOs, and are often sought after to serve in leadership roles, partner with in research projects, co-author papers, participate in advisory committees, to speak at meetings and a host of other activities which make a difference.

Our roots in the realities of science and agriculture enable us to apply the results of research to transform crop production. We appreciate the great support of our members and their long-term vision in striving to help feed the world. **BC**

Dr. Terry Roberts, IPNI President

Pedro Guglielmone-INTA Oliveros

Well nodulated soybean roots.

Soybeans and Biological Nitrogen Fixation: A review

By Ignacio A. Ciampitti and Fernando Salvagiotti

Soybean crops provide one of the world's most important sources of protein and oil. Historically, soybean yield improvements have occurred from biomass gains and increased partitioning to the seed, which all require large amounts of N (Balboa et al., 2018) supplied by BNF and/or the soil. In soybean, the contribution of N from BNF ranges from 0 to 98% depending on many factors, the most important being rhizobial activity. A past review on BNF documented an average contribution of 50 to 60% (Salvagiotti et al., 2008). Recent values recorded in Argentina (60%; Collino et al., 2015) fall within this range, but values of up to 80% have been noted in less fertile soils in Brazil (Alves et al., 2003).

The main question motivating this review is whether BNF can supply sufficient N for high-yielding soybean systems (>7 t/ha) while maintaining a neutral partial N balance. Our data comprised 733 observations from 60 studies conducted from 1955 until 2017, including data on seed yield (adjusted to 13% moisture), BNF, and plant N uptake. A partial N balance was calculated as:

Partial N balance = fixed N in aboveground biomass –
N in harvested seeds.

A negative partial N balance indicates that the amount of N exported in seeds is larger than N fixed, and thus a net "soil N depletion" occurs, which may affect the system N balance.

Seed Yield, Plant N Uptake, and N_2 Fixation

The overall mean seed yield was 3.1 t/ha, and the maximum value was 8.3 t/ha (**Figure 1**). Plant N uptake averaged 245 kg N/ha, with a maximum N uptake close to 560 kg N/ha. The slope of the middle regression line indicated that, on average, 81 kg plant N was required for every 1 t of soybean produced. However, **Figure 1** shows a four-fold

SUMMARY

A review of 60 studies reporting on biological N fixation (BNF) in soybean was done to study the limits to which BNF can satisfy plant N demand. This review confirmed that BNF could satisfy plant N demand up to 200 kg N/ha. The N-gap (plant N uptake minus fixed N) widened rapidly if plant N demand exceeded 370 kg N/ha, which suggested the need for additional N under conditions of high yield potential. The partial N balance (fixed N minus N removed in seeds) was negative on average but approached neutral or positive values when BNF contributed at least 58% of plant N uptake.

KEYWORDS:
biological fixation; partial balance; nitrogen gap; soybean credit; high yields.

ABBREVIATIONS AND NOTES:
N = nitrogen; BNF = biological nitrogen fixation.

https://doi.org/10.24047/BC10235

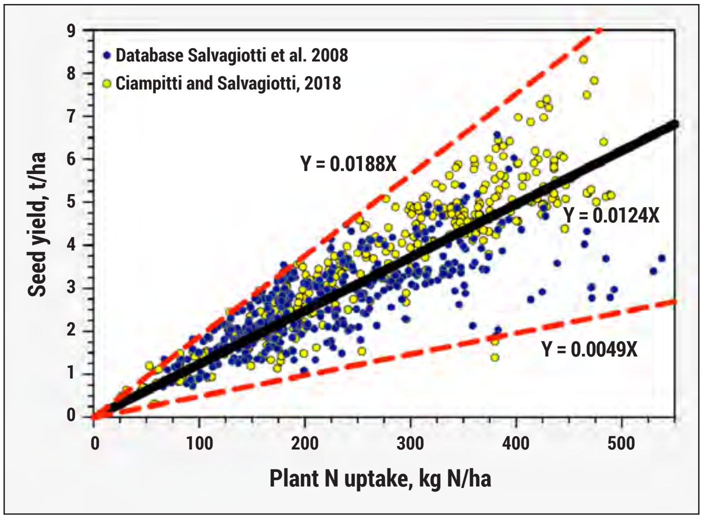


Figure 1. Soybean seed yield versus plant N uptake in studies conducted from 1955 to 2017. Blue circles correspond to the database collected in the previous review paper from Salvagiotti et al. (2008), and the yellow circles refer to the new database gathered by Ciampitti and Salvagiotti (2018).

variation in the N requirement per t of yield produced—from maximum N dilution (upper boundary line) close to 53 kg N/t to maximum N accumulation (lower boundary line) of 204 kg N/t.

Overall mean N_2 fixation was 137 kg N/ha, and the maximum value was 372 kg N/ha (**Figure 2**). The relative contribution of N_2 fixation to plant N uptake (BNF%) was 56%, with 50% of the data concentrated between 44 to 72%.

Seed yield and N_2 fixation were linearly related to BNF% (**Figure 2**). For the low BNF% group (green circles; less than 44% BNF), lower yield was associated with low BNF%. This group represents soybean systems more dependent on soil (or fertilizer) N in order to satisfy plant N demand. The high BNF% group (blue circles; above 72% BNF) fixed 59 kg N/t yield, or about twice the amount compared to the low

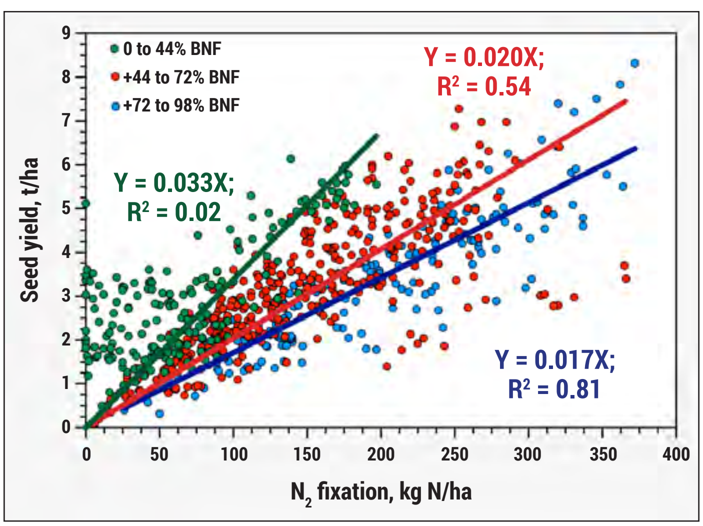


Figure 2. Soybean seed yield versus plant N_2 fixation in studies conducted from 1955 to 2017. Green circles referred to data points with a BNF contribution to plant N uptake (BNF%) ranging from 0 to 44%, red circles from 44 to 72%, and blue circles above 72%.

BNF% group, while still showing a maximum yield above 7 t/ha and N_2 fixation above 300 kg N/ha.

N_2 Fixation and Plant N Demand: The "N-gap"

This study of the relationship between N_2 fixation and plant N uptake was used to quantify the so-called "N-gap", which is understood to be the soybean N demand not supplied by BNF. Overall, median N_2 fixation represented by the 50% quantile line in **Figure 3** shows a N-gap that increases linearly as plant N demand rises. Maximum BNF capacity is displayed as the frontier (99%) quantile line, which represents the maximum N_2 fixation achieved at each plant N uptake level. This quadratic model reflects that the

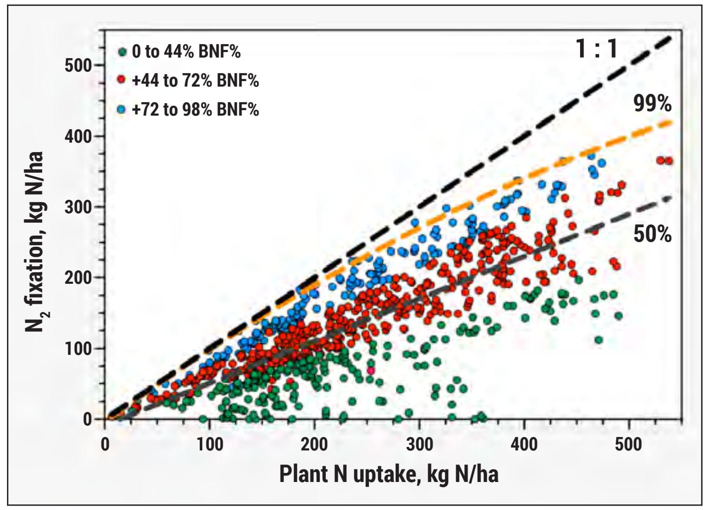


Figure 3. Relationship between the contribution of N_2 fixation and plant N uptake in soybeans, N-gap expressed as the plant N uptake minus fixed N, for BNF% groups ranging from 0 to 44%, red circles for BNF% from 44 to 72%, and blue circles for BNF% above 72%.

maximum BNF capacity to supply N to soybeans decreases more than proportionally as plant N demand increases. Reasonable synchrony between N supply and demand is achieved until 200 kg N/ha, with the N-gap for the maximum values for the plant N uptake-N_2 fixation relationship increasing at a similar rate until 370 kg N/ha, after which the N-gap becomes quite large. For example, when plant N uptake was 330 kg N/ha the N-gap was 38 kg N/ha, but it went up to 60 kg N/ha as plant N uptake reached 400 kg N/ha (**Figure 3**). These results suggest that a larger plant N uptake may tap into N sources other than BNF in high-yielding environments.

Partial N Balance and the Soybean "N-credit"

The partial N balance (excluding BNF contribution from roots) presented an overall mean of -47 kg N/ha, with 50% of the data points concentrated between -75 to -11 kg N/ha. The partial N balance for the low BNF% group averaged -100 kg N/ha, with an overall yield of 2.9 t/ha, and N_2 fixation of 62.5 kg N/ha. The high BNF% group had an average partial N balance of -3.4 kg N/ha, with an overall yield of 3.6 t/ha, and N_2 fixation of 202 kg N/ha.

Cumulative frequencies for the partial N balances (**Figure 4**) indicate that only 3% of the data (n = 4) had positive balances for the low BNF% group, while oppositely, for the high BNF% group, 40% of the data had positive balances (n = 41).

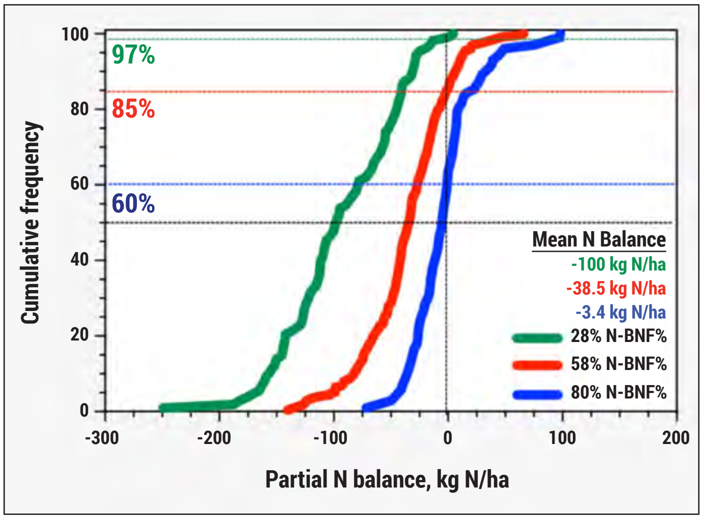


Figure 4. Cumulative distribution for partial N balance in soybean systems. Green, red, and blue lines depict the 0 to 44%, 44 to 72%, and 72 to 98% BNF groups, respectively.

In the future, partial N balance calculations should account for potential N loss via leaf drop and the contribution of roots, as well as a retrieval of in-field N rhizodeposition from thinner roots. It is evident that after considering this current review, more efforts should be focused on collecting data concerning the contribution of roots to obtain a more precise quantification of BNF impact on the partial N balance.

Lastly, the soybean N-credit or "soybean rotation effect", commonly used to make N-fertilizer recommendations in U.S. maize-soybean systems, is entirely dependent on soil N mineralization of soybean residues with low C:N ratios (Bundy et al., 1993; Gentry et al, 2001; 2013). From this review, it seems likely that there can be a net gain in the partial N balance from BNF, but it likely occurs with more frequency when BNF is above 70%, exceeding the N removal from soybean seed harvest. However, it is also likely that there is no soybean N-credit when BNF is below 42%.

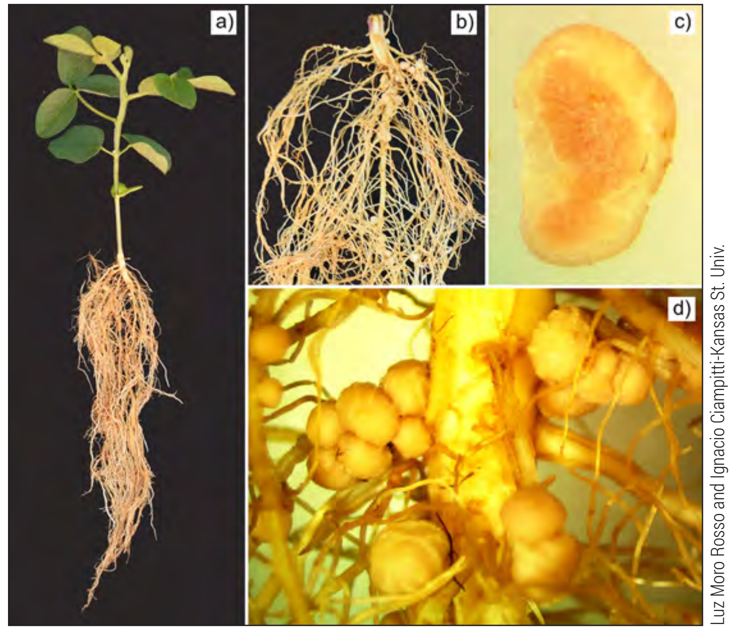
Conclusion

The overall contribution of BNF in soybean systems is between 50 to 60% with maximum BNF satisfying plant N demand until 200 kg N/ha. The N-gap (plant N uptake minus fixed N) widens after 370 kg N/ha, which suggests a need for additional N due to high crop yield potential. Partial N balances, excluding root N contribution, showed negative values across varying levels of BNF, but they become closer to neutral as BNF contribution increased above 70% relative to the plant N uptake.

Future BNF improvements should attempt to identify highly efficient *Rhizobium* strains adapted to environments with high plant N demand and/or reducing the negative impact of soil nitrate concentration on BNF. The priority for research is to improve the understanding of the contribution of roots, the impact of N mineralization, and the plant N processes that have the biggest effects on BNF in high-yielding soybean systems (>7 t/ha) around the world. **BC**

TAKE IT TO THE FIELD

The quantity of BNF from low and medium BNF% groups (<72%) should not be relied upon as a N credit in a maize-soybean cropping rotation.



Soybean plant at V3 (three-leaf) stage growing without inorganic N supply under greenhouse conditions. The seed was inoculated with an inoculant containing Bradyrhizobium japonicum strain. b) and d) show roots (and nodules). c) shows the nodule starting its activity, based on its internal coloration.

Acknowledgment

This article is an excerpt from a research paper entitled *New Insights into Soybean Biological Nitrogen Fixation*, published by Ciampitti, I.A. and F. Salvagiotti in the July/August 2018 issue of Agronomy Journal. doi:10.2134/agronj2017.06.0348.

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References

Alves, B.J.R., et al. 2003. Plant Soil 252:1. doi:10.1023/A:1024191913296.
Balboa, G.R., et al. 2018. Crop Sci. 0. doi:10.2135/cropsci2017.06.0349.
Bundy, L.G., et al. 1993. Agron. J. 85:1061-1067. doi:10.2134/agronj1993.00021962008500050020x.
Collino, D.J., et al. 2015. Plant Soil 392:239-252. doi:10.1007/s11104-015-2459-8.
Gentry L.E., et al. 2001. Plant Soil 236:175-184.
Gentry, L.E., et al. 2013. Agron. J. 105:1658-1664.
Salvagiotti, F., et al. 2008. F. Crop. Res. 108:1-13. doi:10.1016/j.fcr.2008.03.001.

V. Nosov/IPNI

Adapting Fertilization Strategies for High Soybean Productivity in Southern Russia

By Vladimir Nosov, Nikolay Tishkov, and Vasiliy Makhonin

Krasnodar Krai is a top soybean-producing region for Southern Russia that lies within the Southern Federal District of Russia. The district, which is located within the 43° and 51° N latitude, plants 200,000 ha of soybean annually, or about 8% of Russia's total area (ROSSTAT, 2018), however only 27% of this soybean area receives fertilizer. Based on the last five years (2013-2017), average nutrient application rates are estimated at 24-27-9 kg N-P_2O_5-K_2O/ha, respectively. Soybean crops largely depend on residual nutrients from fertilizers applied to other crops grown in rotation.

Recent soybean fertility research in Krasnodar Krai had settled on agronomic optimum rates of 40-80-40 kg N-P_2O_5-K_2O/ha for the crop (Onishchenko, 2015). If grown after winter wheat, soybean has shown a slight response to even higher rates (i.e., 60-120-60 kg N-P_2O_5-K_2O/ha). Research with foliar products has shown promise as highest increases in seed and protein yield of soybean are achieved when ammonium molybdate and soluble complex fertilizer containing chelated forms of Fe, Mn, Zn, Cu, Ca; and inorganic forms of B and Mo are applied at R1 stage (beginning bloom) (Tishkov and Dryakhlov, 2016).

In the neighboring region of Rostov Oblast, the highest yield of soybean has been obtained with application of 30-45-30 kg N-P_2O_5-K_2O/ha. This has resulted in up to 25% more yield over the average grower practice of applying 9-40 kg N-P_2O_5/ha (Nosov et al., 2014). This research reports that yield responses to the additional N were not signif-

SUMMARY

Soybean field experiments conducted in Southern Russia found an advantage for short duration varieties over intermediate duration varieties in years with midseason crop stress caused by drought and high temperatures. Short duration varieties were found highly responsive to both starter and foliar fertilizers.

KEYWORDS:

seed yield; starter fertilizer; foliar fertilizer.

ABBREVIATIONS AND NOTES:

N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; B = boron; Cu = copper; Fe = iron; Mn = manganese; Zn = zinc; KCl = potassium chloride; MAP = monoammonium phosphate; ppm = parts per million; RM = Relative Maturity; US$1 = 62.85 RUB.

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Table 1. Initial soil characteristics (0 to 20 cm) at the experimental sites, Krasnodar Krai.

Soil type	Location (years)	OM, %	pH	NO_3-N	Olsen P	Available P†	Available K†
				ppm			
Ordinary Chernozem	Korenovsk Distr. (2014-2016)	3.2-3.4	6.8-7.2	13-29	15-18	11-15	292-358
Leached Chernozem	Krasnodar (2014-2016)	2.9-3.5	5.4-6.6	12-28	16-17	11-13	328-383
Meadow Chernozem	Abinsk Distr. (2014)	3.6	7.0	5	26	21	197

Soils are defined as Voronic Chernozems Pachic (WRB, 2006).
†1% $(NH_4)_2CO_3$ extractable.

icant during three seasons of study, but higher seed protein contents were obtained. Under irrigation, in soils with high concentrations of available K and medium concentrations of available P, it has been recommended to apply 60-45 kg N-P_2O_5/ha plus 30 to 60 kg K_2O/ha before a preplant cultivation (Guzhvin, 2003).

Besides the general need to improve in-crop nutrition, the region's changing climate has become a major influence on soybean agronomy. In recent years, increasing drought and high temperatures have often coincided with the critical seed-filling stage of varieties that have an intermediate relative maturity (RM). The higher yield potential that is associated with these longer season soybean crops has been difficult to obtain under such adverse weather conditions.

This article outlines three successive years of adaptive research designed to validate and improve fertilizer recommendations for soybean in Krasnodar Krai.

Study Description

Field experiments were conducted in the western, central, and northern environmental zones of Krasnodar Krai. Locations and initial soil characteristics for each site are given in **Table 1**. Soils had comparatively low OM; pH varied from slightly acid in the leached Chernozem to neutral in the other soils. Available P and K ranged from medium to high using routine soil tests.

Winter wheat and rice preceded soybean in the northern/central and western environmental zones, respectively. Intermediate maturing var. Vilana (RM = 115 to 118 days) was grown in 2014; var. Vilana and var. Slaviya (early RM = 105 to 112 days) in 2015; and var. Lira (ultra-early RM = 90 to 100 days) in 2016. Seed inoculation was done immediately before sowing. The inoculant was a peat-based seed coating that included a liquid adjuvant and ammonium molybdate used at 50 g $(NH_4)_6Mo_7O_{24} \cdot 4H_2O$/t seed. Soybean was grown in a wide row spacing of 70 cm with crop management recommended by the Russian Research Institute for Oil Crops. Plots, arranged within a systematic experimental design with four replications, varied from 56 to 112 m^2 depending on the location. Plots were harvested by specialized combines.

2014

The experimental design in 2014 consisted of six treatments (**Table 2**). Growing season conditions were unfavorable for the intermediate RM variety that was selected. Precipitation was 25% below normal and not well distributed within the growing season. Temperatures also exceeded the long-term average and extremely hot and dry weather occurred between mid-July at pod development and seed filling stages and continued through August.

Soybean productivity was generally low and the highest seed yield was 1.98 t/ha. Soybean did not respond significantly to fertilizer application at any of the three sites. Potassium chloride (KCl) application resulted in a yield decrease at two sites when 18-78 kg N-P_2O_5/ha were applied. The spring preplant application of KCl accompanied by higher rates of N and P fertilizer at planting likely created high salt concentrations in the overly dry soil.

Table 2. Seed yield for intermediate maturing (RM) soybean variety in 2014.

Treatment	Fertilizer sources, timing, and placement	Ordinary Chernozem	Leached Chernozem	Meadow Chernozem
		var. Vilana (RM = 115 to 118 days)		
		t/ha		
Control	-	1.44	1.43	1.86
N_{18}	Urea at planting	1.43	1.52	1.96
N_9P_{39}	MAP at planting	1.44	1.32	1.91
$N_9P_{39}K_{60}$	KCl in spring before planting, MAP at planting	1.37	1.32	1.86
$N_{18}P_{78}$	MAP at planting	1.44	1.46	1.98
$N_{18}P_{78}K_{60}$	KCl in spring before planting, MAP at planting	1.27	1.40	1.71
	LSD (0.05)	0.12	0.16	0.24

Inoculation was done with adjuvant and ammonium molybdate.
Fertilizer bands were placed 2 cm below and 2 cm to the side of the seed.
Seed moisture content = 14%.

2015

Nutrient application rates for NP and NPK treatments were adjusted to be slightly lower in 2015, and all treatments were applied as a starter at planting (**Table 3**). Growing season precipitation was close to normal at the ordinary Chernozem location; however, conditions of hot weather with little rainfall prevailed for the last 10-days of July until August 20th. Growing season precipitation at the leached Chernozem site was above normal, but July, August, and the first 10 days of September were also hotter than average. Flowering and seed filling for the intermediate RM variety occurred under both severe rainfall deficiency and high air temperatures.

Treatment responses were generally low across both maturity groups in 2015, but the early RM variety showed higher productivity. The early RM variety yielded highest at 2.06 t/ha due to the starter NPK application, which was significantly higher than the control. The highest yield for the intermediate RM variety was 1.66 t/ha, which was obtained with starter application of N_6P_{26}. Potassium application had no effect on seed yield in both trials.

Table 3. Seed yield for early and intermediate maturing (RM) soybean varieties in 2015.

Treatment	Fertilizer sources, timing, and placement	Ordinary Chernozem var. Slaviya (RM = 105 to 112 days)	Leached Chernozem var. Vilana (RM = 115 to 118 days)
		------------- t/ha	-------------
Control	-	1.93	1.58
N_{18}	Urea at planting	2.02	1.64
N_6P_{26}	MAP at planting	2.02	1.66
$N_6P_{26}K_{18}$	MAP + KCl at planting	2.06	1.66
$N_{12}P_{52}$	MAP at planting	2.03	1.65
$N_{12}P_{52}K_{18}$	MAP + KCl at planting	2.03	1.65
	LSD (0.05)	0.09	0.08

Inoculation was done with adjuvant and ammonium molybdate.
Fertilizer bands were placed 2 cm below and 2 cm to the side of the seed.
Seed moisture content = 14%.

2016

The experimental design was modified once more in 2016 to study the impact of starter plus foliar fertilization (**Table 4**). The foliar applications were done at R1 stage using a 0.53% solution at 200 L/ha. For the ordinary Chernozem site, growing season precipitation was about twice the normal amount, while temperatures between June and August were noticeably higher than the long-term averages. The leached Chernozem site had growing season rainfall that was about one-third above normal, but dry weather lasted from seed-filling stage during the second 10-days of July until the end of August.

Table 4. Seed yield for ultra-early maturing (RM) soybean variety in 2016.

Treatment	Fertilizer sources, timing, and placement	Ordinary Chernozem	Leached Chernozem
		var. Lira (RM = 90 to 100 days)	
		------ t/ha	------
Control	-	2.47	2.35
Foliar fertilizer	R1 stage	2.63	2.50
N_6P_{26} + Foliar fertilizer	MAP at planting, foliar fertilizer at R1 stage	2.77	2.63
$N_6P_{26}K_{18}$ + Foliar fertilizer	MAP + KCl at planting, foliar fertilizer at R1 stage	2.88	2.68
$N_{12}P_{52}$ + Foliar fertilizer	MAP at planting, foliar fertilizer at R1 stage	2.85	2.68
$N_{12}P_{52}K_{18}$ + Foliar fertilizer	MAP + KCl at planting, foliar fertilizer at R1 stage	2.87	2.67
	LSD (0.05)	0.06	0.07

Inoculation was done with adjuvant and ammonium molybdate.
Fertilizer bands were placed 2 cm below and 2 cm to the side of the seed.
Foliar fertilizer was a soluble complex fertilizer (18-18-18+Mg+S+micronutrients) applied at R1 stage using a 0.53% solution.
Seed moisture content = 14%.

The ultra-early RM variety performed well during the growing season and was highly responsive to the fertilizer treatments at both sites (**Table 4**). Foliar fertilizer applied alone resulted in a 6% yield increase compared to the control. This is significant yield improvement from a relatively small amount of soluble fertilizer (~1.0 kg/ha). Under the current economic conditions, this response generates an additional net economic return of 3,000 to 3,200 RUB/ha. However, the combined use of starter + foliar fertilizer produced the highest yields, which were 14 to 17% above the control. The high yields attained at both sites (i.e., 2.68 and 2.88 t/ha) are very close to genetic potential for this shortest duration variety.

Potassium application resulted in a significant but relatively low yield increase at one location. The starter application of MAP at 50 kg/ha (N_6P_{26}) combined with the foliar spray delivers an additional net economic return of 4,400 to 4,900 RUB/ha. Research activities need to be continued to develop final recommendations for these short duration soybean varieties.

Taking into consideration that weather predictions cannot be precisely done for the whole growing season it seems reasonable to use fertilizers mainly for short duration soybean varieties that could move yields higher. Short duration soybean varieties planted at the same dates at research farms of the Institute for Oil Crops were generally more productive compared to long duration varieties during the same years. Three years of study conducted under various environmental conditions allow the following preliminary conclusions:

- Due to the prevailing conditions of inadequate precipitation and high temperatures between late July and mid August, the genetic potential may be best realized for shorter duration soybean varieties, which still prove to be highly responsive to fertilizer application.
- Starter P fertilizer appears an agronomically and economically sound choice when growing short duration varieties on soils with medium concentrations of available P.
- Short duration soybean responded significantly to foliar fertilization applied at R1 stage, but further yield increases may be achieved by combining both starter and foliar fertilizer. **BC**

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References

Guzhvin, S.A. 2003. Soybean Fertilization System on Ordinary Chernozem in Rostov Oblast, Ph.D. Dissertation, Persianovskiy, Russia, 200 p. (In Russian).
Nosov, V.V. et al. 2014. Better Crops 93(3):10-12.
Onishchenko, L.M. 2015. Agrochemical Basics for Building Soil Fertility of Leached Chernozem in Western Ciscaucasia and Increasing Crop Productivity, Doctorate Dissertation, Krasnodar, Russia, 668 p. (In Russian).
ROSSTAT, 2018. http://www.gks.ru
Tishkov, N.M. and A.A. Dryakhlov 2016. Oil Crops. Scientific-Technical Bulletin of Russian Research Institute for Oil Crops, 1 (165):81-87. (In Russian).
WRB, 2006. http://www.fao.org/soils-portal/soil-survey/soil-classification/world-reference-base

V. Nosov/IPNI

Soybean plants and pods taken from (left to right) the control, foliar, and starter (N_6P_{26})+foliar treatments (July 21, 2016).

Dr. Ping He examines maize plants within a field experiment testing fertilizer application rates derived from different recommendation systems.

Field-Specific Fertilizer Recommendations for Better Nitrogen Use in Maize

By Jiajia Zhang and Ping He

Our shared food security goal of producing more food per hectare of land requires sustainable intensification of crop production systems (Cui et al., 2010). Maize plays a significant role in securing food and feed production in China. But in many places in China, excessive or imbalanced fertilization has become a common challenge in the pursuit of higher production. High fertilizer input, especially N fertilizer, is the primary reason for stagnant yields and low NUE. Imbalanced fertilization can cause harmful impacts on the environment, such as GHG emission, water pollution, and nutrient leaching (Zhao et al., 2016).

Nutrient Expert® (NE) for Hybrid Maize is a fertilizer decision support tool developed by the International Plant Nutrient Institute (IPNI). The tool uses the site-specific nutrient management (SSNM) principles and the QUantitative Evaluation of the Fertility of Tropical Soils (QUEFTS) model to develop field-specific fertilizer recommendation. It fits in with the 4R Nutrient Stewardship strategy, which is an approach to managing the right source, rate, timing, and placement of fertilizer nutrients in a cropping system aimed at environmental, economic,

SUMMARY

China is emphasizing a need to optimize nutrient management for maize to secure high yields without jeopardizing the environment. Nutrient Expert (NE)-based fertilizer management in summer maize production systems in north-central China significantly increased grain yield and nitrogen use efficiency, and lowered greenhouse gas emissions.

KEYWORDS:

Nutrient Expert; nitrogen use efficiency; agronomic efficiency; recovery efficiency; greenhouse gas

ABBREVIATIONS AND NOTES:

N = Nitrogen; P = phosphorus; K = potassium; NUE = nitrogen use efficiency; GHG = greenhouse gas.

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and social benefits to the society. The NE tool can work with or without soil testing, and provides an alternative to smallholders when soil testing is not affordable, unavailable or not timely. Nutrient Expert has been used to more closely match nutrient supply and demand within a specific field in a particular cropping system, and has improved crop yield and increased NUE (Chuan et al., 2013a, 2013b; Xu et al., 2014a, 2014b).

Study Description

To date, a medium-term evaluation of NE-based recommendations on yield, NUE, and environmental benefits has been lacking for summer maize crops in north-central China. In this five-year study, an on-farm research approach was used to assess the continued performance of NE for hybrid maize across four major provinces.

The experiments were conducted in farmers' fields from 2010 to 2014 in Hebei (111 fields), Henan (130 fields), Shandong (81 fields), and Shanxi (67 fields). Here summer maize is grown in sequence with winter wheat. The treatments included NE-based fertilizer recommendations, farmers' fertilizer practice (FP), and fertilizer recommendations based on soil testing (ST). The per ha nutrient application rates ranged between 105 to 231 kg N, 37 to 89 kg P_2O_5, and 44 to 105 kg K_2O for NE; 48 to 460 kg N, 0 to 252 kg P_2O_5, and 0 to 158 kg K_2O for FP; and 105 to 330 kg N, 0 to 98 kg P_2O_5, and 25 to 120 kg K_2O for ST.

Total GHG emission, expressed as kg CO_2 eq/ha, was estimated to evaluate an environmental effect of the different fertilizer application methods. The total N_2O emission in each treatment was expressed as kg N_2O/ha, and included direct and indirect N_2O emissions related to the N fertilizer rate. The calculation method for estimation of direct and indirect N_2O emissions (Cui et al., 2013), including ammonia (NH_3) volatilization and nitrate (NO_3^-) leaching for spring maize, is provided below (Klein et al., 2006):

$$\text{Direct } N_2O \text{ emission} = 0.576 \times e^{(0.0049 \times \text{N rate})} \quad (1)$$
$$NH_3 \text{ volatilization} = 0.24 \times \text{N rate} + 1.30 \quad (2)$$
$$\text{N leaching} = 4.46 \times e^{(0.0094 \times \text{N rate})} \quad (3)$$

Indirect N_2O emission was estimated as 1% and 0.75% of NH_3 volatilization and N leaching, respectively.

Total GHG emissions during the entire life cycle of maize production, including CO_2, CH_4, and N_2O (CH_4 emission could be ignored in agro-ecosystems), consisted of three components shown in the equation below (Zhang et al., 2013):

$$GHG = (GHG_m + GHG_t) \times \text{N rate} + \text{total } N_2O \times 44/28 \times 298 + GHG_{others} \quad (4)$$

where GHG (kg CO_2 eq/ha) is the total GHG emission and GHG_m is the GHG emission originating from fossil fuel consumption for the industry's energy source to N product manufacturing. The GHG_t is the N fertilizer transportation emission factor. The GHG_m and GHG_t were 8.21 and 0.09 kg CO_2 eq/kg fertilizer N. N rate is the N fertilizer application rate (kg N/ha). The GHG_{others} represents GHG emission of P (0.73 and 0.06 kg CO_2 eq/kg fertilizer P_2O_5) and K (0.5 and 0.05 kg CO_2 eq/kg fertilizer K_2O) for fertilizer production and transportation, respectively.

Table 1. Comparison of grain yield and economic benefit amongst Nutrient Expert (NE), Farmers' Practice (FP), and Soil Testing (ST) in four provinces in China.

	Grain yield*, t/ha			Gross return above fertilizer cost, $/ha		
Site	NE	FP	ST	NE	FP	ST
Hebei	8.9 a**	8.7 b	8.9 a	2,486 a	2,422 b	2,483 a
Henan	10.0 b	9.9 c	10.2 a	2,845 a	2,765 b	2,867 a
Shandong	8.4 ab	8.4 ab	8.5 a	2,634 a	2,557 b	2,581 b
Shanxi	10.1 a	10.0 b	10.2 a	3,090 a	3,045 b	3,070 ab
Average	9.4 b	9.3 c	9.5 a	2,741 a	2,672 b	2,733 a

*The values for each province are the average across five years of all experiments, and the average values are data from all sites and years.
**Values followed by different letters for different treatments are significantly different ($p < 0.05$).

Yield and Economic Benefits

The NE recommendations increased grain yields compared to FP in all provinces except for Shandong where yields were the same (8.4 t/ha) for NE and FP (**Table 1**). Across all sites, the average increase in gross return above fertilizer cost (GRF) for NE versus FP was US$69/ha.

Nitrogen Use Efficiency

In these small-scale production systems, achieving synchrony between N supply and crop demand without an excess or deficiency is the key factor while optimizing tradeoffs between yield, NUE, and environmental quality. In this study, NUE was assessed as the agronomic efficiency (AE), recovery efficiency (RE), and partial factor productivity (PFP) of applied N, which are terms outlined in the box provided below. In the majority cases, NUE values achieved

Table 2. Comparison of nitrogen use efficiency amongst Nutrient Expert (NE), Farmers' Practice (FP), and Soil Testing (ST) in four provinces in China.

	AE_N, kg/kg			RE_N, %			PFP_N, kg/kg		
Site	NE	FP	ST	NE	FP	ST	NE	FP	ST
Hebei	6.5 a*	3.4 b	6.1 a	22.3 a	10.2 b	22.0 a	55.9 a	34.6 b	55.6 a
Henan	13.8 a	10.3 b	11.2 b	35.3 a	24.0 c	28.0 b	64.4 a	52.2 b	47.8 c
Shandong	8.6 a	6.0 b	8.5 a	21.4 a	12.4 c	18.3 b	56.6 a	35.3 c	43.1 b
Shanxi	8.3 a	5.1 c	7.0 b	25.9 a	17.0 c	23.8 b	66.5 a	43.8 c	54.3 b
Average	9.5 a	6.3 c	8.1 b	27.0 a	16.1 c	23.3 b	60.7 a	42.2 c	50.1 b

*Values followed by different letters for different treatments are significantly different ($p < 0.05$).

with NE were significantly higher than with FP or ST (**Table 2**). On average, NE increased AE_N by 51% and 17%, RE_N by 68% and 16%, and PFP_N by 44% and 21% compared to FP and ST, respectively.

Selected definitions of nutrient use efficiency (NUE).	
Term	**Calculation**
PFP - Partial factor productivity of applied nutrient	Y/F
AE - Agronomic efficiency of applied nutrient	$(Y-Y_0)/F$
RE - Apparent crop recovery efficiency of applied nutrient	$(U-U_0)/F$

F = amount of fertilizer nutrient applied
Y = crop yield with applied nutrient
Y0 = crop yield in control with no applied Nlete
U = total nutrient uptake in aboveground crop biomass with fertilizer applied
U_0 = total nutrient uptake in aboveground crop biomass with no fertilizer applied

Estimated GHG Emission

The GHG emission in this study was estimated from a calculation based on fertilizer production and transportation related to N, P, and K rates (Zhao et al., 2016). Average N_2O and GHG emissions under NE were significantly lower than that for the FP and ST treatments (**Table 3**). The total N_2O and GHG emission were 35.1% and 17.5% and 35.2% and 18.4% lower in the NE treatment when compared with FP and ST, respectively. The GHG emission in this study is presumed higher than other places in the world since China mainly uses coal for its fertilizer production rather than natural gas.

Summary

Compared with FP or ST, the NE treatment maintained higher yields, profitability, and N use efficiency parameters while lowering GHG emission. The advantage of NE over ST and FP lies in the balancing of crop nutrients and adoption of 4R Nutrient Stewardship, which strives for better synchrony between crop nutrient demand and supply through the site-specific application of right nutrient source, rate, timing, and placement combinations. Nutrient Expert is an easy-to-use tool that can help local extension personnel to provide farm-specific fertilizer recommendation to large number of farmers even when soil testing is not available. Large-scale on-farm application of NE-based fertilizer recommendations can help smallholder farmers increase and sustain high yields and NUE, and reduce environmental impact of N fertilizer use in the summer maize production systems of north-central China. **BC**

Table 3. Estimated total N_2O and GHG emission amongst Nutrient Expert (NE), Farmers' Practice (FP), and Soil Testing (ST) in four provinces in China.

Site	Treatment	N_2O emission, kg N_2O/ha	GHG emission, kg CO_2 eq/ha
Hebei	NE	2.8	2,240
	FP	5.0	3,760
	ST	2.8	2,240
Henan	NE	2.8	2,230
	FP	3.8	2,980
	ST	3.8	3,020
Shandong	NE	2.7	2,070
	FP	4.6	3,480
	ST	3.6	2,860
Shanxi	NE	2.7	2,200
	FP	4.6	3,470
	ST	3.3	2,620
Average	NE	2.7	2,200
	FP	4.2	3,390
	ST	3.3	2,690

Acknowledgement

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References

Cui, Z.L. et al. 2013. Environ. Sci. Technol. 47:6015-6022.
Chuan, L.M. et al. 2013a. Field Crops Res. 140:1-8.
Chuan, L.M. et al. 2013b. Field Crops Res. 146:96-104.
Klein, C.D. et al. 2006. *In*, Chapter 11, IPCC Guidelines for National Greenhouse Gas Inventories (S. Eggleston et al., eds.), Intergovernmental Panel on Climate Change. p.5-54. http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_11_Ch11_N2O&CO2.pdf
Xu, X.P. et al. 2014a. Field Crops Res. 163:10-17.
Xu, X.P. et al. 2014b. Field Crops Res. 157:27-34.
Zhao, R.R. et al. 2016. Agric. Ecosyst. Environ. 224:123-130.
Zhang, W.F. et al. 2013. Proc. Natl. Acad. Sci. USA. 110:8375-8380.

PART 2: Effects of 4R Management, Climate, and Soil Variables on Nitrogen Losses

By Tai McClellan Maaz and Alison Eagle


iStock image

Nitrogen (N) fertilizer is critical for meeting yield and crop quality goals. However, N management also has multiple environmental impacts. Unrecovered N may be emitted to the atmosphere through volatilization, nitrification, and denitrification processes, while nitrate (NO_3^-) can travel to surface and groundwater through runoff and leaching pathways. These losses can have unintended consequences. For example, even though <3% of fertilizer N is typically emitted to the atmosphere as nitrous oxide (N_2O), this trace gas has 265 times the global warming potential of carbon dioxide and depletes stratospheric ozone. Nitrate in groundwater and surface waters can impair drinking water or lead to eutrophication in water bodies important to recreation, lake- and ocean-shore residents, and the fishing industry.

Farm managers face the major challenge of maintaining or increasing yields while reducing N losses. Fertilizer management can be fine-tuned to minimize N losses by supplying enough of the appropriate source of N when and where the crop demands it. However, climate and soil factors also affect crop performance and the biological processes that regulate N losses. Optimizing N inputs is further complicated by the existence of multiple pathways through which fer-

SUMMARY
Climate, soil, and 4R Nitrogen (N) management impact N losses in measurable ways. However, nitrous oxide (N_2O) emissions and nitrate (NO_3^-) leaching respond differently to changes in fertilizer management and environmental conditions. Strategies that target multiple pathways may be necessary to combat N losses.

KEYWORDS:
nitrification inhibitors; side-dress nitrogen; nitrous oxide losses; nitrate leaching; soil carbon.

ABBREVIATIONS AND NOTES:
N = nitrogen; NO_3^- = nitrate; N_2O = nitrous oxide.

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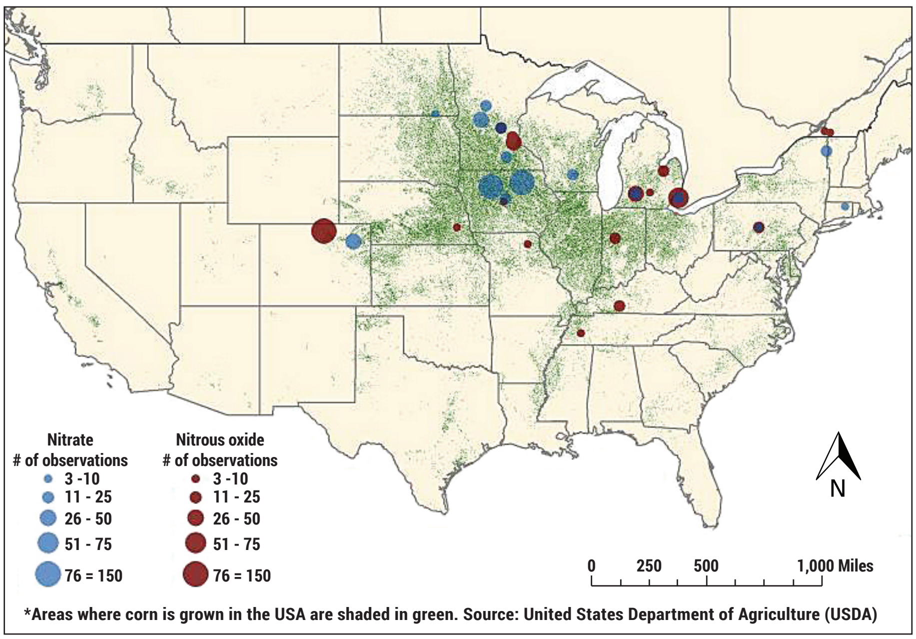
Table 1. Mitigation of N_2O emissions and NO_3^- leaching through 4R nutrient management and influence of climate and soil factors.

	Management change	N_2O emissions	NO_3^- leaching
Fertilizer management			
Rate	Reducing 180 kg N/ha by 10 kg N/ha	-4%	-3%
Timing	Side-dressing	-20 to -39%	No response[1]
Place	Broadcast	-25%	Limited data
Source	Nitrification inhibitor	-31%	No response[1]
Soil factors			
Soil carbon content	Increase in soil carbon content by 1%	+24%	-31%
Climatic factors			
July temperature	Increase by 1°C	+18%	No response[1]
Annual precipitation	Increase by 100 mm	No response[1]	+27%
Irrigation	Application of 200 mm	No response[1]	+27%

[1] The lack of effect may be due to limited data. Experiments were often not set up to test these treatments, and when combining across studies, the differences due to location and year can mask effects of the management differences.



Geographic distribution of agricultural N loss dataset. Eagle et al. 2017.
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tilizer N may be lost from the plant-soil system. Therefore, the effectiveness of different fertilizer management practices to combat N losses likely depends on site-specific conditions.

In 2017, Eagle et al. published a study examining the impact of 4R management, climate, and soil factors on two loss pathways: N_2O emissions and NO_3^- leaching. The authors asked the following research questions:

1. How do fertilizer N source, rate, timing, and placement affect N_2O emissions and NO_3^- leaching?
2. How do such fertilizer management effects compare to and depend on climate and soil factors?
3. Do N_2O emissions and NO_3^- leaching respond similarly to management, climate, and soil conditions?

The authors focused their research on North American corn systems, which produce 37% of the world's supply, and in the USA demand 40% of all N fertilizer consumed. These researchers conducted a systematic review and identified 237 articles that studied fertilizer N management in corn production in North America. Of these, a total of 51 field studies met the following criteria: corn yields were reported, N_2O and/or NO_3^- losses were measured over at least 55 days in the growing season, and at least one of the 4Rs (source, rate, time, place) for N fertilizer management was compared between treatments. They built the final database from studies conducted in the USA and Canada, including 417 observations of N_2O losses (27 studies at 19 locations) and 388 observations for NO_3^- leaching (25 studies at 16 locations). One of these studies, with 16 observations, reported both types of N loss. The articles, and in some cases the field researchers themselves, also contributed other data, including irrigation, tillage, cover crop, 4R management, N uptake, residual soil N, inhibitors, soil texture, drainage classes, surface soil organic carbon, long-term average precipitation, and July temperature, as well as annual precipitation for each study.

Using the database, Eagle et al. (2017) tested the effects of 4R management and environmental factors on N losses. First, they modeled the relationship of N rate and N losses for different site-year combinations using linear and non-linear regressions. Secondly, they used a standard meta-analysis approach to make paired comparisons to determine the effect on N losses from alternative N fertilizer timings, sources, and placements. Finally, they evaluated the entire dataset with a multi-level regression model that could determine the influence of 4R management and environmental factors. This third analysis handled complex data when paired comparisons were not available and could compare

Interactive Chart
Explore the modeled effect of 4R N management on N_2O emissions

TAKE IT TO THE FIELD

Optimizing rate, source, timing, and placement of N fertilizer reduces N_2O emissions. Climate and soil factors affect N_2O emissions and nitrate leaching losses, but sometimes in contrasting ways.

across sites and years that had different management, soil, or weather conditions.

How Do 4R Nutrient Management, Soil, and Climatic Factors Affect Nitrogen Losses?

Nitrous oxide emissions were influenced by 4R N management, including rate, timing, source, and placement. Specifically, N_2O emissions declined due to a reduction in N rate, the application of nitrification inhibitors, side-dressing fertilizer when the crop was growing compared to when all was applied pre-plant, or when N was broadcast rather then banded (**Table 1**). For example, a nitrification inhibitor, broadcast placement, or a side-dress application at least three weeks after planting reduced emissions by a similar magnitude as reducing N rate by 100 kg N/ha. Climate and soil factors also affected N_2O emissions. Specifically, N_2O fluxes tended to increase with higher soil carbon and higher July temperatures. The effect of climate was also comparable to a large reduction in fertilizer rate, where a 1°C increase in July temperature had an equivalent effect on increased N_2O emissions as applying 100 kg N/ha more fertilizer.

In comparison, NO_3^- leaching responded significantly to N rate, but not to source, placement, or timing (**Table 1**). There was some evidence that leaching losses were lower with banded urea and greater with aqueous ammonia, but these data came from single studies. Nitrate leaching increased with precipitation and decreased with soil carbon content, but did not respond to nitrification inhibitors or timing. However, with most studies designed to test management other than the 4Rs, the lack of response may be largely a result of limited data. An increase in precipitation by 100 mm/yr enhanced NO_3^- leaching by a similar magnitude as increasing fertilizer N rate by 100 kg N/ha.

Do We Need to Consider Management Effects on Multiple Loss Pathways?

In general, Eagle et al. (2017) found that practices that reduced N_2O emissions also reduced NO_3^- leaching or had a limited effect. However, a particular management strategy that reduces N_2O emissions may not be effective at reducing NO_3^- leaching, and vice versa. For instance, although both N_2O emissions and NO_3^- leaching increased with N rate, the nature of the relationship was not the same. For N_2O emissions, the relationship was exponential; whereas, for NO_3^- leaching, the relationship was linear. Nitrous oxide emissions were also more dependent on source and timing than were NO_3^- leaching losses.

Climate and soil conditions, on the other hand, could sometimes have contrasting effects on N_2O emissions and NO_3^- leaching. Soil carbon content, for example, was positively correlated with N_2O emissions, but negatively correlated with NO_3^- leaching.

The findings of Eagle et al. (2017) provide valuable insight into mitigating N losses through 4R practices. One important take-away from the article is that simultaneously assessing multiple loss pathways is necessary when tailoring N management to specific soil and climatic conditions. Yet, weighing the potential trade-offs among management decisions is challenged by the lack of scientific studies that measure N losses through more than one pathway. Additionally, N_2O and NO_3^- leaching are not the only two loss pathways, and other losses, such as ammonia volatilization, should also be considered, especially if broadcasting urea without a urease inhibitor. (In fact, lower N_2O losses from broadcast fertilizer could happen if a large portion of the N fertilizer volatilized as ammonia soon after application.) And so, as we continue to conduct the research to fill these knowledge gaps (see http://research.ipni.net/project/IPNI-2017-USA-4RF01), crop advisers must utilize their knowledge to select practices that minimize N losses through the pathways important to their particular systems or site-specific conditions. **BC**

Acknowledgement

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Part 1 of this series, *Can Lower Nitrogen Balances and Greater Recovery by Corn Reduce N_2O Emissions?* is available at https://doi.org/10.24047/BC102227

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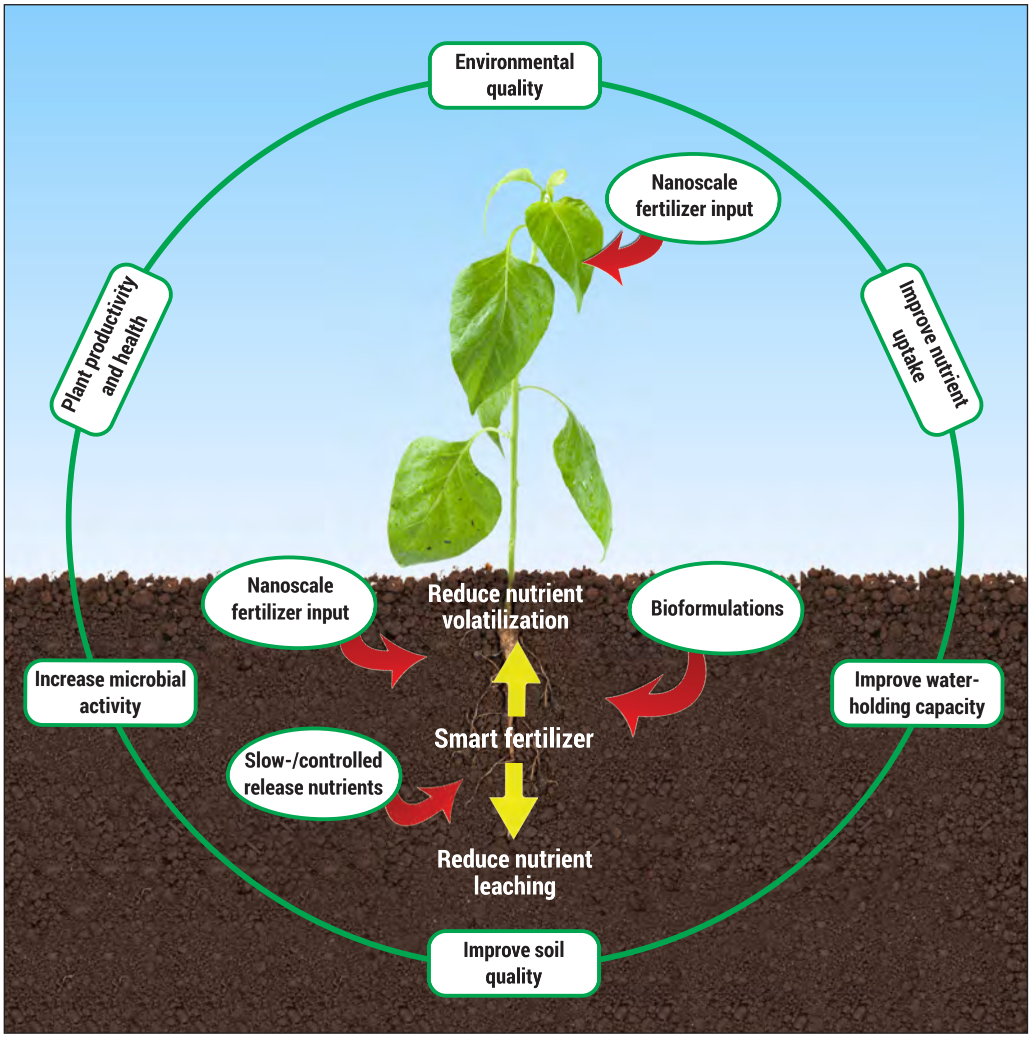
Nanofertilizer and Nanotechnology: A quick look

By Robert Mikkelsen

The word "Nano" means one-billionth, so nanotechnology refers to materials that are measured in a billionth of a meter (nm). A nanometer is so small that the width of a human hair is 80,000 nanometers. The field of nanotechnology has resulted from advances in chemistry, physics, pharmaceuticals, engineering, and biology. The size of a nanomaterial is typically about 1 to 100 nanometers. They can be naturally occurring or engineered. Due to their extremely minute size, they have many unique properties that are now being explored for new opportunities in agriculture.

There are naturally occurring nanoparticles that have been previously proposed for agricultural use, such as zeolite minerals. However, engineered nanomaterials can now be synthesized with a range of desired chemical and physical properties to meet various applications.



Schematic diagram of potential smart fertilizer effects in the soil-plant system. Adapted from Calabi-Floody et al. 2017.

Nanofertilizers are being studied as a way to increase nutrient efficiency and improve plant nutrition, compared with traditional fertilizers. A nanofertilizer is any product that is made with nanoparticles or uses nanotechnology to improve nutrient efficiency.

Three classes of nanofertilizers have been proposed:

1. nanoscale fertilizer (nanoparticles which contain nutrients),
2. nanoscale additives (traditional fertilizers with nanoscale additives), and
3. nanoscale coating (traditional fertilizers coated or loaded with nanoparticles)

Nanomaterial coatings (such as a nanomembrane) may slow the release of nutrients or a porous nanofertilizer may include a network of channels that retard nutrient solubility. The use of nanotechnology for fertilizers is still in its infancy but is already adopted for medical and engineering applications.

Another promising application of nanotechnology is the encapsulation of beneficial microorganisms that can improve plant root health. These could include various bacteria or fungi that enhance the availability of nitrogen, phosphorus, and potassium in the root zone. The development of nanobiosensors to react with specific root exudates is also being explored.

SUMMARY
There is more talk and publications about nanofertilizers in recent years, but these materials are still new for many agronomists. Because these fertilizers are still in the early stage of development, a brief review of their potential is useful.

KEYWORDS:
fertilizer technology; nutrient use efficiency.

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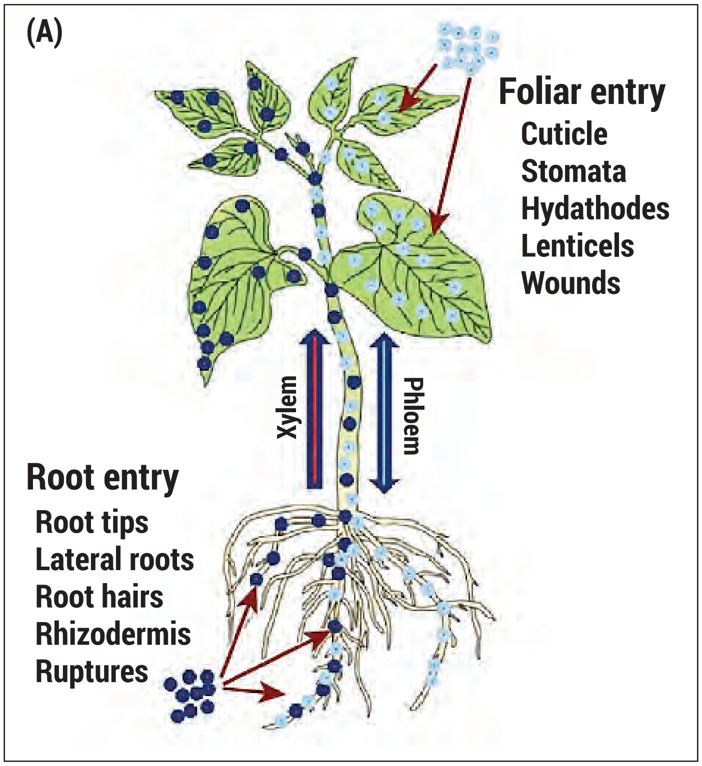
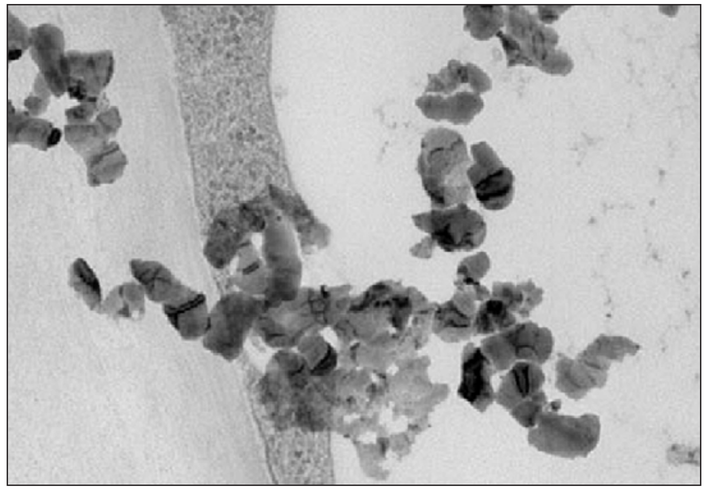


Potential entry points of nanoparticles into plants. Wang et al. 2016.



A corn root surrounded with copper oxide nanoparticles that are penetrating through the cell wall. Tapan et al. 2016.

Examples of potential nanofertilizer designs (adapted from Manjunatha et al., 2016)

Slow release: the nanocapsule slowly releases nutrients over a specified period of time.

Quick release: the nanoparticle shell breaks upon contact with a surface (such as striking a leaf).

Specific release: the shell breaks open when it encounters a specific chemical or enzyme.

Moisture release: the nanoparticle degrades and releases nutrients in the presence of water.

Heat release: the nanoparticle releases nutrients when the temperature exceeds a set point.

pH release: the nanoparticle only degrades in specified acid or alkaline conditions.

Ultrasound release: the nanoparticle is ruptured by an external ultrasound frequency.

Magnetic release: a magnetic nanoparticle ruptures when exposed to a magnetic field.

Many of these nanotechnologies are still in the early development stage for both medical and agricultural uses. However, the next time you hear about nanofertilizers, you will have a better idea of where this field is headed. **BC**

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Additional Reading

Calabi-Floody, M. et al. 2017. Adv. Agron. 147:119-157.
Fraceto, L.F. et al. 2016. Front. Environ Sci. 22 March 2016. https://doi.org/10.3389/fenvs.2016.00020
Manjunatha, S.B. et al. 2016. J. Farm Sci. 29:1-13.
Tapan, A. et al. 2016. J. Plant Nutri. 39:99-115, https://doi.org/doi.org/10.1080/01904167.2015.1044012
Wang, P. et al. 2016. Trends Plant Sci. 21(8) https://doi.org/10.1016/j.tplants.2016.04.005

Crop Nutrition for Vietnamese Robusta Coffee

By Tassilo Tiemann, Tin Maung Aye, Nguyen Duc Dung, Tran Minh Tien, Myles Fisher, Ezio Nalin de Paulo, and Thomas Oberthür

Tin Maung Aye

Dr. Tin Maung Aye (left) and Dr. Tran Minh Tien (right) inspecting a coffee field in Vietnam.

Vietnam is the world's second largest coffee producer, mostly growing Robusta coffee. About 86% of the country's coffee is produced in the Central Highlands. The total production of 28 to 30 million (M) 60 kg bags is similar to that of the state of Minas Gerais, Brazil's largest producer. Coffee covers 582,500 ha of the Central Highlands, which is only about 10% of the area. It is the most intensive and concentrated area of coffee production in the world (Baker, 2016).

Production of Robusta coffee at this intensity exports substantial amounts of nutrients from the field in the green coffee beans and associated pulp and parchment (**Table 1**, summary by Harding, not dated). There is little information on either nutrient recommendations or actual nutrient use in Robusta coffee in Vietnam. We reviewed the in-country literature available on Robusta coffee nutrition in the Central Highlands over the past 25 years. We also met with farmer focus groups in eight villages in two provinces of the Central Highlands. Our objective was to learn what their current fertilizer practices are and their understanding of nutrient management of the crop.

Table 1. Nutrient withdrawals (kg) for each 1 t of harvested green beans, pulp, parchment, and skin.

	N	P	K	Mg	Ca
Literature average	33	2.3	36	2.4	3.4
Estimated removal by					
2 t	66	4.6	72	4.9	6.8
3 t	98	7.0	108	7.3	10
4 t	131	9.3	144	9.8	14
5 t	164	12	180	12	17

Data are averages of values from sources provided by Harding, not dated), and correspond to the amounts removed for 2, 3, 4, and 5 t of green coffee beans.

SUMMARY

Coffee remains one of the most significant sources of income for many farmers in the Central Highlands of Vietnam, but at the same time, yields have been declining or stagnant. Field insights indicate that farmers attempt to counter this trend by experimenting with varying, often increasing amounts of currently available fertilizers. These changes have not worked but have increased production costs markedly. Not to mention that imbalanced fertilizer dressings cause collateral effects of increased contamination of offsite water resources. Robusta coffee systems in the Central Highlands of Vietnam have potential for improvement that can be realized by closing knowledge gaps on balanced crop nutrition, and at the same time, extending access to appropriate nutrients.

KEYWORDS:

Robusta coffee, Central Highlands, Vietnam, fertilizer use, nutrient imbalances.

ABBREVIATIONS AND NOTES:

N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; S = sulfur; B = boron; Zn = zinc; TE = trace elements; ROI = return on investment.

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Farming Systems in the Central Highlands of Vietnam

The Highland region has two main soils, reddish-yellow Acrisols derived from acidic granites and the less common reddish-brown Ferralsols derived from basic and neutral basalts (Tien, 2015). Coffee is mostly grown on Ferralsols (3,500 km^2, 69%) with pH 4.5 to 5.3. The remaining 1,600 km^2 are on Acrisols (Nguyen and Tran, 2017).

Smallholders produce about 1.06 M t of Robusta coffee annually with an average yield of 2.2 t/ha dry beans. Of the farmers we interviewed, 74% generate 20 to 50% of their income off-farm. Farms are typically 1 to 2 ha, 95% in diversified systems that include black pepper, fruits, nuts, and livestock. Coffee is often planted with black pepper in the same farm, at a density of 850 to 1,200 coffee trees/ha and 1,000 to 2,500 black pepper plants. Major production expenses are fertilizers (40%), pruning (25%), and harvesting (20%). Of all the crops they grow, coffee requires the most labor input.

The region has a tropical savanna climate with a warm wet season between April/May and October/November, and a cool dry season from December to March. Annual rainfall varies between 1,200 to 2,000 mm. Growers commonly irrigate coffee during the dry season mostly by pumping from sub-surface wells (Amarasinghe et al., 2015). Growers harvest the crop and apply some crop management in the dry season but do most crop management in the wet season. They prune the plants in January after harvest, in May and in July/August, each time returning pruned material to the field. Farmers apply fertilizer during the rainy season (April, June, and July/August), while some apply additional dressings during the late rainy season or the dry season. Many growers irrigate 3 to 4 times during the dry season at 20 to 25-day intervals by sprinkler or basin irrigation.

Nematodes and mealybug are main pests and coffee rust is the main disease, especially mealybug and rust in the wettest period during June/July. Growers perceive weather and the cost and availability of fertilizer as their biggest constraints. There is also no diversified market with quality-based pricing, and most farmers sell their beans at a moisture content of 15%.

Coffee production in Vietnam became popular more than 20 years ago when smallholders planted large areas of it. About 60% of all coffee trees are now more than 15 years old and will soon come to the end of their productive cycle. They will need to be replaced over the next few years. Moreover, most of the current varieties are not well adapted to diseases and, as well, climate change will reduce their productivity (D'haeze et al. 2017). Farmers might be able to change to better-adapted varieties when they replant.

Table 2. Existing fertilizer recommendation for Robusta coffee in Vietnam (kg/ha/yr).

	Urea	Ammonium sulfate	Fused Ca/Mg phosphate	Potassium chloride	NPK
Growth stage					Equivalent amounts of straight fertilizers
Planting	130 to 150	-	550	70	
Year 2	200	100	550	150	
Year 3	250	150	550	200	
Productive stage					
Bazan red soils (> 3 t dry beans/ha)	400 to 450	220 to 250	450 to 550	350 to 400	
Other soils (> 2 t dry beans/ha)	350 to 400	220 to 250	550 to 750	300 to 350	
Supplemental application*	150		100	120	

*If yields in the productive stage exceed the above average levels by 1 t/ha or more, additional fertilizer should be applied accordingly.

TAKE IT TO THE FIELD

Fertilizer applications are unbalanced. The motivation of farmers to apply in this manner was not fully explained by field interviews, but it is likely related to limited options within the portfolio of fertilizers available, incomplete understanding of farm economics, and the effort to reduce labor. Any future field trials and nutrient management campaigns need to address these interrelated issues.

Current Nutrient Removal and Fertilizer Management

The data in the few studies on nutrient removal that we found for Robusta coffee vary widely so that the following are only rough estimates. Using the mean of several indicative data sources that Harding (not dated, **Table 1**) cites, the average yield of 2.2 t/ha on the Central Highlands withdraws N: P: K of about 72.1: 5.1: 79.4 kg, ignoring vegetative growth, and nutrient losses to leaching and erosion. These figures indicate the minimum requirements that soil and fertilizer must provide to balance the amounts lost in the harvested beans. Farmers in the survey reported yields almost 5 t/ha of green beans in good years, which accordingly will remove 164: 11.5: 180.5 kg/ha N: P: K. At the same time, we also expect the harvest to export 12 kg Mg/ha, which farmers in the Central Highlands apply only rarely, and 17 kg Ca/ha.

Current government guidelines for coffee include recommendations for nutrient management, which we used as the reference base (**Tables 2** and **3**). These recommendations, however, are based on a relatively small number of research studies, mainly on rates of NPK fertilizers. The rates

Table 3. Approximate amount of nutrients recommended for Robusta coffee in the Central Highlands of Vietnam (kg/ha/yr).

	N	P	K	S	Mg	NPK
Growth stage						Equivalent amounts of straight fertilizers
Planting	60 to 70	110	35	-	65	
Year 2	90 + 20	110	80	25	65	
Year 3	115 + 30	110	105	35	65	
Productive stage						
Ferralsols (red) (> 3 t dry beans/ha)	185 to 210 + 45 to 55	90 to 110	180 to 210	50 to 60	55 to 65	
Acrisol (grey) (> 2 t dry beans/ha)	160 to 185 + 45 to 55	110 to 150	155 to 180	50 to 60	65 to 90	
Supplemental application*	70	20	60		12	

*If yields in the productive stage exceed the above average levels by 1 t/ha or more, the additional amount of fertilizer indicated after "+" should be applied accordingly.

are largely deduced from yield-based estimates of nutrients in the harvested beans while nutrient use efficiencies are unknown. There is little information on the best application schedules, or nutrient sources. Furthermore, growers do not use nutrients such as Mg, Zn, and B. There are therefore important knowledge gaps in applying the 4R concept of the right source, rate, time, and place for managing fertilizer for coffee in the Central Highlands.

Experiments showed that combined application of fused magnesium phosphate (for base application) and diammonium phosphate (for topdressing) gave large and sustainable coffee yields. Diammonium phosphate alone was less suitable as a P source due to its fast release peak of 30 days. Fused magnesium phosphate and diammonium phosphate gave good results in early years, however, single superphosphate was better in mature stands.

Farmers apply NPK and NPK+S mostly using a range of low density compound fertilizers because they require less labor. They rarely apply single nutrient fertilizers and seem to have little information about the characteristics of different NPK formulations. Most farmers lack clarity about nutrient requirements and the role of balanced nutrient supply. Rates and ratios of applied nutrients vary widely (**Tables 4** and **5**). In general, farmers apply nutrients in excess, sometimes by as much as four times the recommended rates. Official recommendations, which aim to provide a balanced supply of nutrients, are seldom followed.

Table 4. Amount of applied nutrients (kg/ha/yr), assuming 1,100 plants/ha.

	% of groups	Minimum	Maximum	Average	Recommended
N	100%	201	817	445	205 to 330
P	100%	23	516	236	90 to 170
K	100%	168	721	321	155 to 270
S	75%	43	279	158	50 to 60
Mg	19%	12	119	60	55 to 100

Table 5. Nutrient ratios applied by farmers based on Table 4.

	Minimum	Maximum	Average	Recommended
N:P ratio	1.1	36	1.7 (3.8)*	
N:K ratio	1.0	2.3	1.4	1.2 to 1.3
P:K ratio	0.03	1.6	0.8	0.6
N:S ratio	1.1	15	5.4**	4.0 to 5.5

*If eliminating the most unbalanced value of 36, the average ratio is 1.7.
**Eight groups apply ratios between 1 and 4, three groups have ratios above 10.

Farmers apply fertilizer 3 to 5 times each year, but the rates vary across times. Rates of N and S are more or less constant at 120 kg N/ha and 70 to 80 kg S/ha. Farmers apply P mainly in the rainy season at about 80 kg/ha. Mg, if applied at all, is given in April/May, at the onset of the rainy season. Farmers apply K starting with 25 kg/ha in the dry season (February) and increasing it to about 140 kg/ha in July to October. Although these are the averages across all the farmers that we interviewed, they show that most of them apply fertilizer during the wet season.

Soils in the Central Highlands are rather infertile, with low cation exchange capacity, which limits their ability to store and provide nutrients (Tien et al., 2015). Applied nutrients leach readily during the rainy season, so that it is advisable to limit fertilizer applications during this season. It might be efficient to apply more fertilizer during the dry season using frequent, careful irrigation. Some nutrients are rarely applied and twenty years of intensive production of Robusta coffee may have mined soil nutrients not supplied by external sources. A sustainable production system must replace nutrient losses in addition to those removed with the crop. Recommendations to farmers must address these requirements and consider also the crop's nutrient use efficiency (NUE).

Understanding the Potential Return on Investment from Fertilizer

We compared the farmers' relative income, fertilizer allocation, and production costs (**Figure 1**), and found a picture of lost opportunity. Relative production costs of coffee are generally higher than the relative contribution of coffee to overall farm income (**Figure 1A**). This indicates that the ROI is currently lower for coffee than for other farm activities. At the same time, the relative amount of fertilizer applied to coffee is much larger than coffee's relative con-

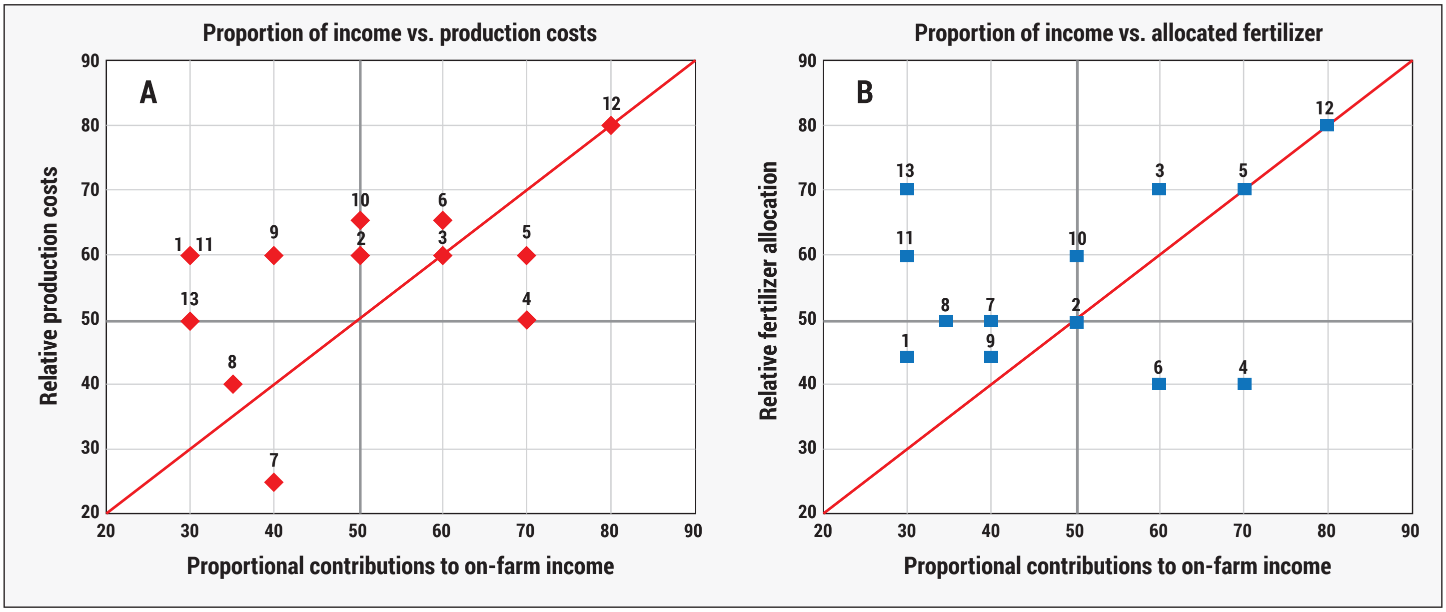

Figure 1. Return on investments to fertilizer use. A) income from coffee versus production costs of coffee, relative to other crops; B) relative income from coffee versus fertilizer allocation to coffee, relative to other crops. Numbers next to each point identify the farmer group that was interviewed.

tribution to household income (**Figure 1B**). This is in line with the perception of farmers that fertilizer application is the most resource intensive amongst the agronomic practices deployed to coffee. Hence, there is potential for large improvement in economic efficiency. The low production cost/high income (lower right) quadrant of **Figure 1A**, which contains no data points, confirms this conclusion.

How Can Improved Economic Efficiency Be Achieved?

It is not entirely clear why growers apply large amounts of fertilizer in an unbalanced manner. Field insights indicate that yields are highly variable, declining or stagnant in recent years, and farmers may attempt to counter this trend by experimenting with varying, often increasing amounts of currently available fertilizers. Some of the decline is likely not even related to nutrient management, but due to trees nearing the end of their production cycle, possibly worsened by increasing pest and disease pressure. These changes in nutrient management have not worked, but increased production costs markedly. Nutrient imbalance is a likely contributor to stagnating variable yields, with sub-optimal Mg, Ca, and micronutrients strong candidates. Farmers do not seem to have access to sufficient fertilizer formulations addressing this. Not to mention that imbalanced fertilizer dressings cause collateral effects of increased contamination of offsite water resources.

We conclude that Robusta coffee systems in the Central Highlands of Vietnam have large potential for improvement. Nutrient management may provide multiple opportunities for change by contributing to stabilized yields (reducing the good - bad year variability), improved crop quality, reduced environmental impacts, and increased climate resistance. Key to success is likely addressing imbalanced nutrition and introducing nutrients into the system that are currently lacking. Additional research is required to generate the knowledge needed to realize this potential. **BC**

Acknowledgement

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Drs. Tiemann (e-mail: Tassilo.Tiemann@gmx.de), Aye and Fisher are advisors to IPNI Southeast Asia program, Dr. Dung and Dr. Tien work for the Soils and Fertilizers Research Institute, Vietnam, Mr. de Paulo is head of agronomic services for K+S Asia Pacific, and Dr. Oberthür is the director of IPNI Southeast Asia based in Penang, Malaysia.

References

Amarasinghe, U.A. et al. 2015. Agricultural Systems 136: 96-105.

Baker, P.S. 2016. Coffee and climate change in the Central Highlands of Vietnam.

Bui, H.H. et al. 2005. The effect of meso and micro fertilizer on robusta coffee in dak lak (Research summary No. Volume 4), Result of Scientific Research. Soils and Fertilizer Research Institute, Hanoi.

D'haeze, D. et al. 2017. Vietnam's central highlands' upland agriculture under pressure because of the looming effects of climate change – focus on Robusta coffee. Conference: Buon Ma Thuot Coffee Festival, March 2017.

Ho, C.T. et al. 2005. Based on the study of nutrient balance to determine fertilizer level for robusta coffee grown on basaltic soil of central highland (Research summary No. Volume 4), Result of Scientific Research. Soils and Fertilizer Research Institute, Hanoi.

Nguyen, T.T. 2005. Some measures to increase in effect of potassium fertilizer on coffee robusta (Re-search summary No. Volume 4), Result of Scientific Research. Soils and Fertilizer Research Institute, Hanoi.

Nguyen, X.L. and M.T. Tran. 2017. Central Highland coffee land; Soil properties in Central High-lands

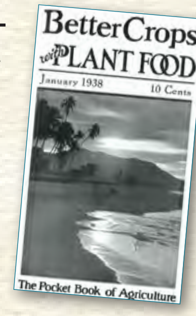
Harding, P. (not dated). IFA Fact Sheet: Coffee [Coffea arabica L. (Arabica coffee); Coffea canephora Pierre ex Froehner (Robusta coffee); Coffea liberica Bull ex Hiern. (Liberica coffee); Coffea excelsa Chev. (Excelsa coffee)]. www.fertilizer.org.

Tien, T.M. 2015. Effects of Annual Potassium Dosage on the Yield and Quality of Coffea robusta in Vietnam (Research Findings No. 41), e-ifc. International Potash Institute, Switzerland.

Tien, T.M. et al. 2015. Potassium Application and Uptake in Coffee (Coffea robusta) plantations in Vietnam (Research Findings No. 42), e-ifc. International Potash Institute, Switzerland.

Better Crops with Plant Food **has a long history of highlighting innovations in nutrient management. It is well worth the effort to occasionally reach back into our archive spanning over 90 years to rediscover what was once discovered. It might be surprising what you find!**

This is a summary of the original article published in January 1938 in *Better Crops with Plant Food* Vol. 22(1): p.21. The article describes field research testing the benefits of banded fertilizer placement over current practice in potato ...the accumulation of positive results were hard to ignore both by growers and farm equipment manufacturers.



Fertilizer Placement Influences Profit: A look back to 1938

By Lewis P. Watson, North Carolina College of Agriculture, Raleigh, North Carolina, USA.

North Carolina County Agent inspects the demonstration plot on the farm of one of his growers. The potatoes in front of him were fertilized according to the "old method", while those behind him by the new band method.

The six demonstrations were located in Beaufort, Camden, Currituck, and Pitt Counties and were under the supervision of the agricultural agent for each county. The plots were an acre in size, and the grower applied the fertilizer to the check plot according to his own practice. This was done by putting the fertilizer out in the drill with a distributor and then mixing it with a plow, followed by bedding. On the demonstration plots, the implement planted the seed, placed the fertilizer, and threw up the bed on the demonstration plot in one operation. The same machine was used to plant the seed on the check plot so that the quantity of seed and the depth of planting would be uniform on the two plots. The fertilizer distributor was disconnected for this operation on the check plot.

The accompanying chart illustrates the results of each demonstration. The average yield of No.1's on all the check plots was 58.2 barrels (1 barrel = 165 lbs). On the demon-

SUMMARY

Six fertilizer placement demonstrations with potatoes in eastern North Carolina in 1937 proved that fertilizer placed to not injure seedlings, yet within ready access to feeder roots, will result in better crop stands and yields. The improved practice placed fertilizer in a band method to each side and slightly below the seed-piece level. The average yield increase was 15.2 barrels of No.1 grade potatoes per acre over the check plot, which was fertilized by the old method of placing the fertilizer in the drill and mixing it with the soil before planting the seed.

KEYWORDS:

potato; side-banding

ABBREVIATIONS AND NOTES:

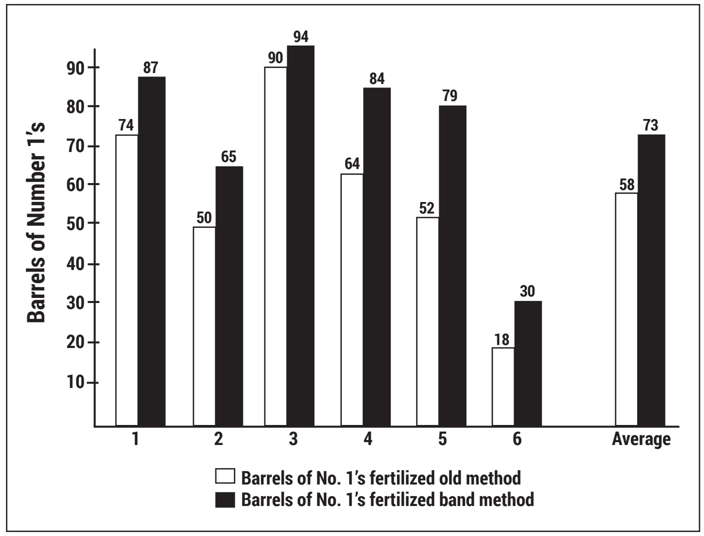
N = nitrogen; P = phosphorus; K = potassium; 1 barrel = 165 lbs.

https://doi.org/10.24047/BC102324

stration plots the average yield was 73.4. The average increase of 15.2 barrels of No.1 potatoes was characterized as an exceptional increase. In Camden County, where the highest yield was made, 2,200 lbs/A of 7-5-5 (N-P_2O_5-K_2O) was applied and planted in 3-ft rows. In Pitt County, where the most significant increase was made, the grower used 2,000 lbs/A of 5-7-5 and also planted in 3-ft rows. Demonstration plots used the same row spacings that were used in the grower's check plot, but applied the same amount of fertilizer in 2-inch bands, 2 inches to each side and slightly below the seed piece.

At the time, results in a number of crops from other States were coming to the same conclusion that yields can be increased by proper placement of fertilizer. In some instances, the efficiency of the fertilizer could be doubled if it is applied below and to the side of the seed-piece level.

Growers' increased interest in crop-specific fertilizer placement aroused considerable concern amongst farm implement manufacturers. The number of new machines permitting the control of the placement of the fertilizer in reference to the seed had begun to increase. Transplanting machines were also being equipped so that the fertilizer can be placed to the side of the plant and not directly under the plant, as has been the custom. In quite a few cases these machines were constructed to provide for planting the seed and distributing the fertilizer at one operation. In this type of operation, a more definite control of the placement could be obtained. **BC**



Banded fertilizer generated higher Irish potato yields at each of the demonstration trials conducted in North Carolina.

Dr. James Mutegi Named Deputy Director for IPNI Sub-Saharan Africa Program

Dr. James Mutegi

Dr. James Mutegi has been appointed program deputy director for Sub-Saharan Africa by the International Plant Nutrition Institute (IPNI) effective August 1, 2018.

Dr. Mutegi has been working as a Soil Scientist and Farming System Analyst in the Sub-Saharan Africa Program. He, amongst other responsibilities, coordinated the Soil Health Consortia and the Fertilizer Stakeholder Forum spanning across eight countries in Eastern and Southern Africa for five years.

James holds a Ph.D. in Soil Fertility and Climate Change from the University of Aarhus, Denmark, a M.Sc. in Environmental Science (soil nutrients and water dynamics) from Kenyatta University, and a B.Sc. in Dryland Management from the University of Nairobi, Kenya. He has over 10 years of experience as a scientist and a consultant with national and international institutions in Africa.

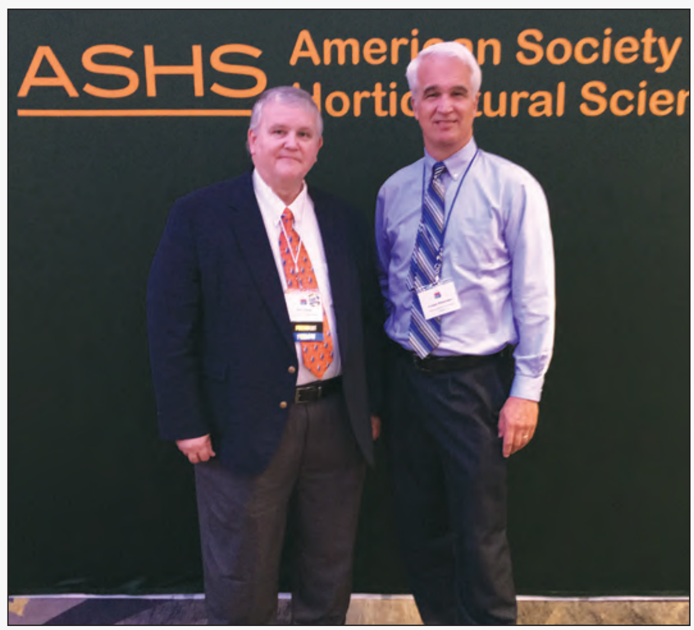
"We are pleased to be able to announce Dr. Mutegi's appointment to our Sub-Saharan program," said Dr. Terry Roberts, IPNI president. "Funding for this position was made possible by a special project grant from OCP S.A. Since its establishment in 2010, our (Sub-saharan) program has made great strides under the leadership of its director, Dr. Shamie Zingore. James brings a wealth of in-the-field experience and his deputy directorship will well position IPNI so that it can accomplish our future goals for research and education throughout South and Eastern Africa," Roberts added.

Dr. Mutegi will be based out of the Sub-Saharan Africa program office in Nairobi, Kenya. **BC**

This story and more news from IPNI is available at: http://www.ipni.net/news

IPNI Staff Honored by the American Society for Horticultural Science

Dr. Rob Mikkelsen was presented with the Outstanding Industry Scientist Award at the American Society for Horticultural Science (ASHS) Annual Meeting held in Washington D.C. Dr. Mikkelsen serves as the IPNI Vice President for Communications. This recognition is given to a horticultural crop scientist working in the private sector who has made outstanding and valuable contributions to horticultural science, the horticultural industry, and the horticultural profession. The ASHS is recognized around the world as one of the most respected and influential professional societies for horticultural scientists promoting scientific research and education in all branches of horticulture. **BC**



Dr. Mikkelsen (on right) with Dr. Carl Sams, ASHA President

48th North Central Extension-Industry SOIL FERTILITY CONFERENCE

The **International Plant Nutrition Institute** (**IPNI**) would like to invite you to attend the North Central Extension-Industry Soil Fertility Conference being held on **November 14-15,** at the **Holiday Inn Airport** in **Des Moines, Iowa.**

Oral and poster presentations will highlight ongoing soil fertility research at universities in the North Central U.S. region (i.e., IL, IN, IA, KS, KY, MI, MN, MO, NE, ND, OH, ON, PA, SD, and WI). The Conference is attended by university extension soil fertility and crop production specialists, industry agronomists, crop advisers, and agency personnel, with representation from states encompassing the North Central region of the US as well as Ontario, Canada. The goal of the conference is to facilitate sharing of new soil fertility and nutrient management research information and fertilizer industry developments.

REGISTRATION OPENS ON SEPTEMBER 5TH

Visit **https://conference.ipni.net** for all registration details, information on speakers, oral and poster sessions, hotel accommodations, and past conference proceedings.

After years of success in the US, the International Plant Nutrition Institute is partnering with New Ag International to take **The InfoAg Conference** to Europe!

This will be a premier event for discussion and advancement of precision agriculture looking at field-centric monitoring with imagery and sensors, seamless connectivity with IoT, data analytics and prediction modeling, variable rate technology, prescription platforms and digitalization.

KEY TOPICS COVERED:

• Sensors • Imagery • Weather Apps • Scouting Apps • Soil Health Monitoring • Data Connectivity • Data Management and Analysis • Nutrition & Irrigation Management • Robotics & AI • Ensuring ROI

Join us in Dublin to meet with the leaders of the Precision and Digital Agriculture World.

Conference Website: https://lifesciences.knect365.com/infoag-international-conference-exhibition/ **BC**

20 Years is Just a Beginning

There is a famous tango song that says *"Feeling life is a blow, that twenty years is nothing …"*. Our IPNI Latin America-Southern Cone program (formerly PPI/PPIC LASC) is celebrating 20 years in 2018. Sometimes it can look like 20 years is nothing since time flies; however, these last 20 years has been quite a ride. In fact, it feels like a celebration of life, not just a rapid wind blowing past us.

In figures, these 20 years went from 1 million t of fertilizer consumption to 3.7 million t, but the years represent much more than figures. These 20 years brought many encounters, discussions, visits, activities, and meetings with fellow farmers, colleagues, researchers, industry staff … lots of friends, emotions, fields, crops, landscapes, adventures, travels, joy, passion, blessings …

Many times, we are asked, what does IPNI do? Lots!! But I feel that we are just the glue that puts together a farmer with a colleague, and a scientist, and an agricultural industry staff; the glue that joins an idea with a project and then with a test, and then with crop production; all together in pursuing the paradigm of agriculture, converting solar energy into dry matter as food and many other products.

We are blessed daily for working with people and nature, in nurturing crops and soils, in looking for new days with new challenges, in helping farmers in doing a better job, for themselves, for their families, for us, for society …

It has been quite a ride, and despite my love for tango I should say that *Feeling life is a blow, that twenty years is just a beginning!!!*

Fernando García
Director, IPNI Latin America Southern Cone Program

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